## Ulimate-Construction Series


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## CARPENTRY

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Before the carpenter can begin his work, hemust have a complete set of construction drawings or prints. He must befamiliar with how the drawings are prepared. Heshould also know how to read the drawings so that he will understand what he must do to comply with their requirements. This chapter will help the carpenter to reach that understanding

## ARCHITECTURAL SYMBOLS. LINE CONVENTIONS, AND MATERIAL CONVENTIONS

The plan for a building must give all the details necessary to construct the building. Therefore, it usually consists of a collection of sheets, called a set of plans. E ach sheet shows the details of a different phase or part of the construction. Several of the sheets will be devoted to floor plans. Other sheets in the set will show construction details (such as wiring, plumbing, and air-conditioning details and types and quantities of materials). Refer to Appendix A for conversion tables.

Architectural symbols on construction drawings show the type and location of windows (Figure 1-1), doors (Figure 1-2), and other features. They show the general shape of an actual architectural feature and show any motion that is supposed to occur.



Figure 1-2. Door symbols

Figure 1-1. Window symbols

Line conventions are different types and weights of lines used to represent the features of an object. The meaning of a line with certain characteristics has been standardized and will be the same on any drawing. These line conventions must be understood in order to read drawings. The line conventions most often encountered in construction prints are shown and described in Figure 1-3.

Material conventions are symbols that show the type of material used in the structure. The symbol selected normally represents the material in some way; for example, the symbol for wood shows the grain in the wood. (However, it is not always possible to use a common characteristic of the material for the symbol.) (Appendix B gives the symbols for the most common types of materials.)

Figure 1-4, page 1-4, shows typical exterior and interior wall symbols. (Note how the material conventions are used in the makeup of the symbols for masonry, brick, and concrete walls.)

| NAME | CONVENT. ION | DESCRIPTION AND APPLICATION | EXAMPLE |
| :---: | :---: | :---: | :---: |
| VISIBLE LINES |  | HEAVY, UNBROKEN LINES. <br> USED TO INDICATE <br> VISIBLE EDGES OF AN OBJECT. |  |
| HIDDEN LINES |  | MEDIUM LINES WITH SHORT, EVENLY SPACED DASHES. USED TO INDICATE CONCEALED EDBES. |  |
| CENTER LINES |  | THIN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH. USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS |  |
| DIMENSION LINES |  | THIN LINES TERMINATED WITH ARROWHEADS AT EACH END USEO TO INDICATE DISTANCE MEASURED. |  |
| EXTENSION LINES |  | THIN, UNBROKEN LINE. USED TO INDICATE EXTENT OF DIMENSIONS. |  |
| LEADER |  | THIN LINE TEPMINATED WITH ARFOWHEAD OR DOT AT ONE END. USED TO INDICATE A PART, DIMENSION, OR OTHER REFERENCE. |  |

Figure 1-3. Line conventions

The carpenter should know all of the symbols for materials to help him read a construction drawing. A symbol on a drawing should always be checked if there is any doubt about its meaning. Refer to Appendix B for common abbreviations and symbols.

## WORKING DRAWINGS

Working drawings and specifications are the main sources of information for supervisors and technicians responsible for the actual construction. The construction working drawing gives a complete graphic description of the structure to be erected and the construction method to be followed.

A set of working drawings includes both general and detail drawings. General drawings consist of plans and elevations; detail drawings consist of sections and detail views.

## SITE PLANS

A site plan (also called a plot plan) shows-

- Property lines and locations.
- Contours and profiles.
- Building lines.
- Locations of structures to be built.
- Existing structures.
- Approaches.
- Finished grades.
- Existing and new utilities (such as sewer, water, and gas).

Figure 1-5, page 1-5, shows a typical site plan. Appropriate outlines show the location of each building. The new facility can be located by referring to the schedule of facilities on the plan. The site plan has a north-pointing arrow to indicate site north-not magnetic north. Each facility has a number (or code letter) to identify it in the schedule of facilities. The contour lines

| NAME <br> CON. <br> VENT <br> ION | DESCRIPTION AND <br> APPLICATION |
| :--- | :--- | :--- | :--- |
| PHANTOM <br> OR | MEDIUM SERIES OF ONE LONG <br> DATUM LINE <br> DASH AND TWO SHORT DASHES <br> EVENLY SPACED ENDING WITH <br> LONG DASH. USED TO INDICATE: <br> ALTERNATE POSITION OF PARTS, <br> REPEATED DETAIL, OR A DATUM <br> PLANE. |
| STITCH |  |
| LINE |  |

Figure 1-3. Line conventions (continued) show the elevation of the earth surfaces. (All points on a contour have the same elevation.)

Distances are given between principal details and reference lines. (The coordinate reference lines on the figure are centerlines of the roads surrounding the area.) All distances in a plan view simply give the horizontal measurement between two points; they do not show terrain irregularities. (The sizes of proposed facilities are given in the schedule of facilities.)

Examine the site plan shown in Figure 1-5 to see what information can be obtained from it. For example, the contour lines show that the ground surface of the site area slopes. The location and identification of each facility are given. Most of the facilities are spaced at least 60 feet apart, but the library (facility No. 3) and the recreation building (facility No. 4) are only 15 feet apart. The library is the smallest of the four buildings and is closest to the road- the east wall of the library is 20 feet from the centerline of the road, while the other buildings are 30 or 60 feet from the centerline.

## ELEVATIONS

Elevations are drawings that show the front, rear, or side view of a building or structure. Sample elevation views are given in Figure 1-6, page 1-6. Construction materials may be shown on the elevation. The ground level (called the grade) surrounding the structure may also be shown. When more than one view is shown on a drawing sheet, each view is given a title. If any view has a scale different from that shown in the title block, the scale is given beneath the title of that view.

The centerline symbol of alternate long and short dashes shows finished floor lines The hidden line symbol of short, evenly spaced dashes shows foundations below the grade line. Note that Figure 1-6 shows the footings are below grade.


Figure 1-4. Typical wall symbols

Elevations show the locations and types of doors and windows. Each different type of window shown in the elevations is marked; the three types of windows shown here are marked $\mathrm{W}-1, \mathrm{~W}-2$, and W-3. These identifying marks refer to a particular size of window whose dimensions are given in a table known as the window schedule. In some cases, rough opening dimensions of windows are given on the drawing. Note that the building shown here has two double doors on each side and a double door at each end. The elevation also shows that at the end of the building with the loading platform, the door is at the level of the stage floor; all the other doors are at grade level.

## FLOOR PLANS

A floor plan is a cross-sectional view of a building. The horizontal cut crosses all openings regardless of their height from the floor. The development of a floor plan is shown in Figure 1-7, page 1-7.

A floor plan may show, among other things, the outside shape of the building; the arrangement, size, and shape of the rooms; the type of material and the length, thickness, and character of the building walls at a particular floor; the type, width, and location of the doors and windows; the types and locations of utility installations; and the location of stairways. A typical floor plan is shown in Figure 1-8, pages 1-8 and 1-9.

As you read the floor plan in Figure 1-8, note the features of the recreation building. The lines with small circles show wiring for electrical outlets; appropriate symbols show the plumbing fixtures. These features are important to the carpenter from the standpoint of coordination. He


Figure 1-5. Typical site plan
may have to make special provisions, at various stages of construction, for the placement of electrical or plumbing fixtures. Installation of these fixtures should be coordinated at the appropriate time with the electrician, plumber, and foreman.

As you examine the floor plan, note that the interior of the building will consist of an auditorium, a lobby with a post exchange (PX) counter, a men's toilet, a women's toilet, a projection room on a second level above the lobby, two dressing rooms, and a stage. The stage may not be apparent but,
by noting the steps adjacent to each dressing room, it can be seen that there is a change in elevation. (The elevation view, shown in Figure 1-6 shows the stage and its elevation.)

Note that on the floor plan (Figure 1-8, pages 1-8 and 1-9) all building entrance and exit doors are the same type (1D) and all windows are the double-hung type. All interior single doors are the same (2D), and two double doors (3D) open into the lobby from the auditorium. The projection room will be reached via a 15 -riser stairway located in a 12-x 18-foot room. Entrance to this room will be from the auditorium through a single door opening into the room. At the top of the stairway, a single door opens into the projection room. The wall of the projection room that faces the stage (inside wall) has three openings. N ote that no windows are shown for the side of the building at the second level where the projection room is located, but windows are shown at the main level.

## DETAIL DRAWINGS

Detail drawings are more specific than other types of construction plans. They are generally drawn on a larger scale and show features that do not appear on other plans.

## SECTIONS

Sections are drawn to a large scale showing details of a particular construction feature that cannot be given in a general drawing. They show-

- Height.
- Materials.
- Fastening and support systems.
- Any conceal ed features.


Figure 1-6. Elevation views

A typical wall section, with parts identified by name and/or size, is illustrated in Figure 1-9, page 1-10. This figure shows how a structure looks when cut vertically by a cutting plane.

Wall sections are very important to construction supervisors and to the craftsmen who do the actual building. They show the construction of the wall, as well as the way in which structural members and other features are joined to it. Wall sections extend vertically from the foundation bed to the roof. Sections are classified as typical and specific.

## Typical Sections



Figure 1-7. Floor-plan development

Typical sections are
used to show construction features that are repeated many times throughout a structure.

## Specific Sections

When a particular construction feature occurs only once and is not shown clearly in the general drawing, a cutting plane is passed through that portion.

## DETAILS

Details are large-scale drawings which show features that do not appear (or appear on too small a scale) on the plans, elevations, and sections. Sections show the builder how various parts are connected and placed. Details do not have a cutting-plane indication, but are simply noted by a code. The construction of doors, windows, and eaves is usually shown in detail drawings. Figure 1-10 shows some typical door framing details, window wood-framing details, and an eave detail for a simple type of cornice. Other details which are customarily shown are sills, girder and joint connections, and stairways.

Figure 1-11, page 1-12, shows how a stairway is drawn in a plan and how riser-tread information is given. F or example, on the plan, DOVVN 17 RISERS followed by an arrow means that there are 17 risers in the run of stairs going to the firs floor from the floor above, in the direction indicated by the arrow. The riser-tread diagram provides height and width information. The standard for the riser, or height from the bottom of the tread to the bottom of the next tread, ranges from $61 / 2$ to $71 / 2$ inches.

The tread width is usually such that the sum of riser and tread is about 18 inches (a 7 -inch riser and 11 -inch tread is standard). On the plan, the distance between the riser lines is the width of the tread.

## WOOD FRAMING DRAWI NGS

Framing plans show the size, number, and location of the structural members constituting the building framework. Separate framing plans may be drawn for the floors, walls, and roof. The floor framing plan must specify the sizes and spacing of joists, girders, and columns used to support the floor. Detail drawings are added, if necessary, to show the methods of anchoring joists and girders to the columns


Figure 1-8. Typical
and foundation walls or footings. Wall framing plans show the location and method of framing openings and ceiling heights so that studs and posts can be cut. Roof framing plans show the construction of the rafters used to span the building and support the roof. Size, spacing, roof slope, and all necessary details are shown. Working prints for TO buildings usually show details of all framing.

floor plan

## LIGHT WOOD FRAMING

Light framing is used in barracks, bathhouses, administration buildings, light shops, hospitals, and similar structures.

Detailed drawings of foundation walls, footings, posts, and girder details normally used in standard TO construction are shown in Figure 1-12.

The various details for overall framing of a 20-footwide building (including ground level, window openings, braces, splices, and nomenclature of framing) are shown in Figure 1-13, page 1-14.

Figure 1-14, page 1-15, shows floor framing details showing footings, posts, girders, joists, reinforced sections of floor for heavy loads, section views covering makeup of certain sections, scabs for joint girders to posts, and post-bracing details as placed for cross sections and Iongitudinal sections. On a construction drawing, the type of footings and the size of the various members are shown. In some cases the lengths are given, while in others the BOM that accompanies the print specifies the required lengths of the various members.

Wall framing for end panels is shown in view $A$ in Figure 1-15, page 1-16. Wall framing plans are detail drawings showing the locations of studs, plates, sills, and bracing. They show one wall at a time. The height for panels is usually shown. From this height, the length of wall studs is determined by deducting the thickness of the top or rafter plate and the bottom plate. Studs placed next to window openings may be placed either on edge or flat, depending upon the type of windows used. Details for side panels (view B of Figure 1-15, page 1-16) cover the same type of information as listed for end panels.

Chapter 6 covers the details of wall framing. The space between studs is given in the wall framing detail drawing, as well as the height of the girt from the bottom plate, and the types of door and window openings, if any. F or window openings, the details specify whether the window is hinged to swing in or out, or whether it is to be a sliding panel.

Examples of drawings showing the makeup of various


Figure 1-9. Typical wall section trussed rafters are given in Figure 1-16, page 1-18. A 40foot trussed rafter showing a partition bearing in the center is shown in view A. The drawing shows the splices required, bracing details, the stud and top plate at one end of the rafter, and the size of the members.

A typical detail drawing of a 20-foot trussed rafter is shown in view B of Figure 1-16. Filler blocks are used to keep the brace members in a vertical plane, since the rafter and bottom chord are nailed together rather than spliced.. The drawing shows placement of the rafter tie on the
opposite side from the vertical brace. Usually the splice plate for the bottom chord (if one is needed) is placed on the side where the rafters are to be nailed so that it can serve also as a filler block.

A modified trussed rafter, shown in view C of Figure 1-16, page 1-18, is used only when specified in plans for certain construction. It will not be used in areas subject to high wind velocities or moderate to heavy snowfall. In this type of trussed rafter, the bottom chord is placed on the rafters above the top plate.


Figure 1-10. Typical eave, door, and window details

The construction plans will specify the best type of trussed rafter for the purpose. The drawings must show, in detail, the construction features of the rafter selected.

Another type of truss is the W-truss, shown in Figure 1-17, page 1-19. It may be used in either TO or residential construction, time permitting.

## HEAVY WOOD FRAMING

Heavy wood framing consists of framing members (timber construction) at least 6 inches in dimension (for example, $2 \times 6$ inches or $4 \times 12$ inches). Examples of this type of framing can be found in heavy roof trusses, timber-trestle bridges, and wharves.

The major differences between light and heavy framing are the size of timber used and the types of fasteners used. Fasteners for both light and heavy framing will be covered in Chapter 2.

Note the similarities, as well as the differences, between the drawings for light and heavy wood framing. Figure 1-18, page 1-20, is a typical example of a drawing showing framing details for light and heavy roof trusses. Drawings for other types of heavy wood framing will similarly illustrate the kinds of material to be used and the way in which it is joined.


Figure 1-11. Stairway and steps


Figure 1-12. Typical foundation wall, post, footing, and girder details

Figure 1-13. Light framing details (20-foot-wide bullding)

Figure 1-14. Floor framing details (20-foot-wide building)


Figure 1-15. Typical wall-panel framing details


Figure 1-16. Trussed-rafter details


Figure 1-17. W-truss


Figure 1-18. Roof trusses

Successful construction in the military TO demands a thorough familiarity with the materials used and the planning required to assemble these materials into a building-a building that is most suitable for the requirements, while most effectively fitting within the constraints imposed by the locality. This chapter acquaints the carpenter with those materials and with planning techniques.

## PLANNING

The importance of properly planning construction cannot be overemphasized. Construction planning allows an orderly series of operations and prevents duplication of effort and waste of materials. The major considerations in planning are-

- The construction-plant layout.
- The distribution of materials.
- The number of skilled and semiskilled men available.
- The number and type of units to be constructed.

From a list of the operations required, an estimate is made of the total number of man-hours needed. This estimate forms the basis for determining the number and type of men needed and for organizing the erection crew(s). (Refer to Appendix C.) Arrangements for assembling the necessary materials at the job site and for the preliminary cutting and assembly are made in advance.

The method of erecting buildings directly influences the amount of time, labor, and materials needed. The methods may be divided into two types: the built-in-place method and the panel, or preassembly (prefabricated), method. Working parties for both methods should be set up as follows:

- The layout party.
- The cutting party.
- The assembling party (built-in-place method only).
- The carrying party.
- The erecting party for sidewalls.
- The erecting party for rafters.
- The sheathing party (built-in-place method only).
- The roofing party.
- The door-and-window party.
- The finishing party.

In this method, each piece is separately erected in its proper place. When using the built-in-place method, the noncommissioned officer in charge (NCOIC) of construction divides the men into working parties, whose duties may be as follows:

- Laying out the foundation.
- Grading and excavating.
- Laying out and cutting various sizes of material.
- Carrying material to the cutting and erecting parties.

If a party finishes its task before the building is completed, it is assigned a new task. For example, if the party laying out the foundation completes its work before erection of the building has begun, it is assigned a new duty (such as cutting rafters).

Parts of the building are built in the following order: footings, posts, sills, joists, floor, soles, studs, plates, girts, rafters, bracing, siding, sheathing, roofing, doors, windows, steps, and inside finish (if used).


## PANEL METHOD

In this method (also called preassembly (prefabricated)), a complete section is built as a unit and then set in the building in its proper place. It is used extensively because it makes for greater speed, better control over working parties, and better use of manpower. For example, it allows the use of a standard list of sizes for each similar section. Standard plans shown in Technical Manuals (TMs) 5-02-1 and 5-302-2 further simplify construction. The panel method requires careful planning before the actual construction. Before measuring and cutting lumber, the number and size of sections that are alike should be determined from the construction drawing. This ensures availability of the correct numbers of each piece.

The carpenter assigns a crew to cut and assemble one section. (Several cutting and assembling parties may be used at one time on different types of sections.)

In most cases, a template (Figure 2-1) is built as a guide for assembling the section. The template should be built square and should be correct in size.

The number and size of each piece in a section are given to the man in charge of the cutting party. The cutting party cuts the timber to the correct length with a handsaw or power saw. The length is measured with a square and a tape. After one piece has been cut, it may be used as a pattern for marking the remaining pieces (Figure 2-2). The pattern is set up by nailing two blocks to the piece of correct size, one near each end, as shown in the figure. These blocks act as stops to hold the pattern in place on the timber to be marked.

The plate and sole are placed in the template with the studs and girts between them; then the door and window posts, if any, are placed as shown in Figure 2-1. The girts, sole, and plate are nailed to the studs with 16 d or 20 d nails. If insulation board is used, it and the wall sheathing are put on the section before it is taken out of the template. Applying the wall finish before raising the section makes the use of scaffolds or ladders unnecessary.


The erecting party sets the sections into place, braces them temporarily, and nails them together. The end section should be first; it may be erected on graded earth. The sidewall sections are next; they should be erected so as to keep the two walls even. The rafter party can then place the rafters on the walls.

The panel method of erection may be used for all types of small buildings and large warehouses. When this method is used for large buildings, cranes are used to place sections too heavy to be handled by hand.

## WARNING <br> When machinery is used, use caution in fastening the lifting cable or rope to avoid damaging the section.

## MATERIALS

The primary components used in frame construction are lumber and hardware. This section includes information on the types and sizes of lumber as well as a description of various metal fasteners.

## LUMBER

Lumber varies greatly in structural characteristics. A carpenter must learn about lumber so that he can choose the most suitable material for each job. This section covers the types, standard sizes, and uses of lumber for construction carpentry. It also covers the methods of measuring lumber quantities in terms of board feet, which is the unit by which it is ordered.

## Grades

Lumber, as it comes from the sawmill, is divided into three main classes: yard lumber, structural material, and factory and shop lumber. However, only yard lumber will be considered here. It is classified on the basis of quality. The carpenter must choose a quality that is suitable for the intended purpose. At the same time, he must exercise economy by not choosing a better (and therefore more expensive) grade than is required. Lumber is subdivided into classifications of select lumber and common lumber.

Select Lumber. Select lumber is of good appearance and finishing. It is identified by the following grade names for comparison of quality:

- Grade $A$ is suitable for natural finishes and is practically clear.
- Grade $B$ is suitable for natural finishes, is of high quality, and is generally clear.
- Grade $C$ is suitable for high-quality paint finishes.
- Grade $D$ is suitable for paint finishes between high-finishing grades and common grades and has somewhat the nature of both.

Common Lumber. Common lumber is suitable for general construction and utility purposes. It is identified by the following grade names for comparison of quality:

- No. 1 common is suitable for use without waste, it is sound and tight knotted, and it may be considered watertight lumber.
- No. 2 common is less restricted in quality than No. 1, but of the same general quality. It is used for framing, sheathing, and other structural forms where the stress or strain is not too great.
- No. 3 common permits some waste, and it is lower in quality than No. 2. It is used for such rough work as footing, guardrails, and rough flooring.
- No. 4 common permits waste, is of low quality, and may have coarse features such as decay and holes. It is used for sheathing, subfloors, and roof boards in the cheaper types of construction, but its most important industrial outlet is for boxes and crates.
- No. 5 common is not produced in some kinds of lumber. It is used for boxes, crates, and dunnage, for which the quality requirement is very low.


## Uses

In frame construction, lumber is used primarily for the frame and walls.
Frames. Building frames are the wood forms constructed to support the finished members of a structure. These include posts, girders (beams), scabs, joists, subfloors, sole plates, girts, knee braces, top plates, and rafters. Softwoods are usually used for wood framing and all other construction carpentry covered in this manual.

No. 2 common lumber is used for framing. Heavy frame components, such as beams and girders, are made by combining several pieces of framing material.

Walls. The exterior wall of a frame structure usually has three layers: sheathing, building paper, and siding.

Sheathing and siding lumber are normally grade No. 2 common softwood, which is with solid knots, no voids.

Siding is either vertically or horizontally applied. Theater construction may limit available material to lap siding for both horizontal and vertical surfaces. F or local procurement, there are several types of drop and bevel siding, which is applied horizontally. (See page 6-32, siding.)

## Sizes

Lumber is usually sawed into standard dimensions (length, width, and thickness). This allows uniformity in planning structures and in ordering materials. Table 2-1 lists the common widths and thicknesses of wood in rough and in dressed dimensions in the US. Standards have been established for dimension differences between the quoted size of lumber and its standard sizes when dressed. Quoted size refers to dimensions prior to surfacing. These dimension differences must be taken into consideration. A good example of the dimension difference is the common $2 \times 4$. As shown in Table 2-1, the familiar quoted size $2 \times 4$ is the rough or nominal dimension, but the actual dressed size is $11 / 2 \times 31 / 2$ inches. Lumber is sawn in standard sizes used for light framing

- Thickness: 1,2 , and 4 inches.
- Width: $2,4,6,8,10$, and 12 inches.
- Length: $8,10,12,14,16,18$, and 20 feet.

The actual dimensions of dressed lumber are less than the sawn dimensions because of drying and planing (or finishing). For the relative difference between swan (standard or nominal) dimensions and actual sizes of construction lumber, see Table 2-1.

Table 2-1. Nominal and dressed sizes of lumber

| Nominal Size <br> (In Inches) | Dressed Size <br> (In Inches) |
| :---: | :---: |
| $1 \times 3$ | $3 / 4 \times 21 / 2$ |
| $1 \times 4$ | $3 / 4 \times 31 / 2$ |
| $1 \times 6$ | $3 / 4 \times 51 / 2$ |
| $1 \times 8$ | $3 / 4 \times 71 / 4$ |
| $1 \times 10$ | $3 / 4 \times 91 / 4$ |
| $1 \times 12$ | $3 / 4 \times 111 / 4$ |
| $2 \times 4$ | $11 / 2 \times 31 / 2$ |
| $2 \times 6$ | $11 / 2 \times 51 / 2$ |
| $2 \times 8$ | $11 / 2 \times 71 / 4$ |
| $2 \times 10$ | $11 / 2 \times 91 / 4$ |
| $2 \times 12$ | $11 / 2 \times 111 / 4$ |
| $3 \times 8$ | $21 / 2 \times 71 / 4$ |
| $3 \times 12$ | $21 / 2 \times 111 / 4$ |
| $4 \times 12$ | $31 / 2 \times 111 / 4$ |
| $4 \times 16$ | $31 / 2 \times 151 / 4$ |
| $6 \times 12$ | $51 / 2 \times 111 / 2$ |
| $6 \times 16$ | $51 / 2 \times 151 / 2$ |
| $6 \times 18$ | $51 / 2 \times 171 / 2$ |
| $8 \times 16$ | $71 / 2 \times 151 / 2$ |
| $8 \times 20$ | $71 / 2 \times 191 / 2$ |
| $8 \times 24$ | $71 / 2 \times 231 / 2$ |

Plywood is usually $4 \times 8$ feet and varies from $1 / 8$ to 1 inch in thickness.
The amount of lumber required is measured in board feet. A board foot is a unit measure representing an area of 1 foot by 1 foot, 1 inch thick. Thus, a board that is 1 inch thick, 1 foot wide, and 1 foot long measures 1 board foot. A board that is 1 inch thick, 1 foot wide, and 12 feet long measures 12 board feet.

To determine the number of board feet in one or more pieces of lumber, use the following formula:

Board feet $=\frac{N \times T(\text { in }) \times W(\text { in }) \times L(f t)}{12}$ or $\frac{N \times T(\text { in }) \times W(\text { in }) \times L(\text { in })}{144}$
where-
$N=$ number of lumber pieces
$T=$ thickness
$W=$ width
$L=$ length
Examples of board feet computations are shown in Figure 2-3.

## HARDWARE

A wide variety of fasteners are used for frame construction in the TO. These fasteners are all made of metal. They are classified as nails, screws, bolts, driftpins, corrugated fasteners, and timber connectors.


## Nails

Nails, the most common type of metal fasteners, are available in a wide range of types and sizes.

Some basic nail types are shown in Figure 2-4, page 2-6. The common nail is designed for rough framing. The box nail is used for toenailing and light work in frame construction. The casing nail is used in finished carpentry work to fasten doors and window casings and other wood trim. The finishing nail and brad are used for light, wood-trim material and are easy to drive below the surface of lumber with a nail set.

The size of a nail is measured in a unit known as a penny. Penny is abbreviated with the lowercase letter $d$. It indicates the length of the nail. A 6 d nail is 2 inches long; a 10 d nail is 3 inches long
(Figure 2-5, page 2-6). These measurements apply to common, box, casing, and finish nails only. Brads and small box nails are identified by their actual length and gauge number.

A nail, whatever the type, should be at least three times as long as the thickness of the wood it is intended to hold. Two thirds of the length of the nail is driven into the other piece of wood for proper anchorage. The other one-third of the length provides the necessary anchorage of the piece being fastened. Protruding nails should be bent over to prevent damage to materials and injury to personnel.

There are a few general rules to be followed in the use of nails in building. Nails should be driven at an angle slightly toward each other to improve their holding power. You should be careful in placing nails to provide the greatest holding power. Nails driven with the grain do not hold as well as nails driven across
the grain. A few nails of proper type and size, properly placed an properly driven, will hold better than a great many driven close together. Nails are generally considered the cheapest and easiest fasteners to be applied.

Figure 2-6 shows a few of the many specialized nails. Some nails are specially coated with zinc, cement, or resin materials. Some have threading for increased holding power. Nails are made from many materials, such as iron, steel, copper, bronze, aluminum,
 and stainless steel.

Annular and spiral nails are threaded for greater holding power. They are good for fastening paneling or plywood flooring. The drywall nail is used for hanging drywall and has a special coating to prevent rust. Roofing nails are not specified by the penny system;

Table 2-2. Sizes, types, and uses of nails

| SIZE | LGTH(IN) | DIAM(IN) | REMARKS | WHERE USED |
| :---: | :---: | :---: | :---: | :---: |
| 2 d | 1 | . 072 | Small head | Finish work, shop work |
| 2 d | 1 | . 072 | Large flathead | Small timber, wood shingles, lathes |
| 3d | $11 / 4$ | . 08 | Small head | Finish work, shop work |
| 3d | $11 / 4$ | . 08 | Large flathead | Small timber, wood shingles, lathes |
| 4d | $11 / 2$ | . 098 | Small head | Finish work, shop work |
| 4d | $11 / 2$ | . 098 | Large flathead | Small timber, lathes, shop work |
| 5d | $13 / 4$ | . 098 | Small head | Finish work, shop work |
| 5d | $13 / 4$ | . 098 | Large flathead | Small timber, lathes, shop work |
| 6 d | 13/4 | . 113 | Small head | Finish work, casing, stops, and so forth, shop work |
| 6 d | 2 | . 113 | Large flathead | Small timber, siding, sheathing, and so forth, shop work |
| 7d | ${ }^{21 / 4}$ | . 113 | Small head | Casing, base, ceiling, stops, and so forth |
| 7d | 21/4 | . 113 | Large flathead | Sheathing, siding, subflooring, light framing |
| 8 d | $21 / 4$ | . 131 | Small head | Casing, base, ceiling, wainscot, and so forth, shop work |
| 8 d | $21 / 2$ | . 131 | Large flathead | Sheathing, siding, subflooring, light framing, shop work |
| 8 d | 21/2 | . 131 | Extra-large flathead | Roll roofing, composition shingles |
| 9 d | $11 / 4$ | . 131 | Small head | Casing, base, ceiling, and so forth |
| 9 d | $23 / 4$ | . 131 | Large flathead | Sheathing, siding, subflooring, framing, shop work |
| 10d | $23 / 4$ | . 148 | Small head | Casing, base, ceiling, and so forth, shop work |
| 10 d 12 d | 3 | .148 .148 | Large flathead | Sheathing, siding, subflooring, framing, shop work |
| 12 d | 3 | .148 .162 | Large flathead | Sheathing, subfiooring, framing |
| 20d | $31 / 4$ | . 162 | Large flathead | Framing, bridges, and so forth |
| 30 d | $31 / 2$ | .192 .207 | Large flathead | Framing, bridges, and so forth Heavy framing, bridges, and so forth |
| 40d | 4 | 225 | Large flathead | Heavy framing, bridges, and so forth |
| 50 d | $41 / 2$ | . 244 | Large flathead | Extra-heavy framing, bridges, and so forth |
| 60d | $\begin{gathered} 5 \\ 51 / 2 \\ 6 \end{gathered}$ | . 262 | Large flathead | Extra-heavy framing, bridges, and so forth |

they are referred to by length. They are available in lengths from $3 / 4$ to 2 inches and have large heads. The double-headed nail, or duplex-head nail, is used for temporary construction, such as form work or scaffolding. The double head on this nail makes it easy to pull out when forms or scaffolding are torn down. Nails for power nailing come in rolls or clips for easy loading into a nailer. They are coated for easier driving and greater holding power. Table 2-2 gives the general sizes and types of nails preferred for specific applications.

## Screws

Screws are more expensive than nails in both time and money, but are sometimes required for superior results. They provide more holding power than nails and can be easily tightened to draw material securely together. Screws are neater in appearance and may be withdrawn without damaging the material. The common wood screw is usually made of unhardened steel, stainless steel, aluminum, or brass. The steel may be bright-finished or blue, or it may be zinc, cadmium, or chromeplated. Wood screws are threaded for approximately $2 / 3$ of the length of the screw from a gimlet point and have a slotted head.

Screws vary in length and size of shaft. Each length is made in a number of shaft sizes identified by a number that shows relative differences in the diameter of the screws. Proper screw size number indicates the wire gauge of the body, the drill or bit size for the body hold, and the drill or bit size for the starter hole. Table 2-3 shows screw sizes and dimensions. Table 2-4 shows applicable drill and auger bit sizes for screws.


Both slotted and Phillips (cross-slotted) flathead and oval-head screws are countersunk enough to allow a covering material to be used. Slotted roundhead and Phillips roundhead screws are not countersunk, but are driven firmly flush with the surface.
 discussed in the following paragraphs.

Wood Screws. Wood screws are designated according to head style. The most common types are flathead, oval head, and roundhead (Figure 2-7) with either slotted or Phillips heads. Their sizes vary from $1 / 4$ to 6 inches. Screw sizes up to 1 inch increase by eighths, screws from 1 to 3 inches increase by quarters, and screws from 3 to 6 inches increase by half inches.


To prepare wood for receiving the screws (Figure 2-8), a pilot hole the diameter of the screw is bored into the piece of wood to be fastened. A smaller starter hole is then bored into the piece of wood that is to act as anchor or to hold the threads of the screws. The starter hole has a
diameter less than that of the screw threads and is drilled to a depth of $1 / 2$ or $2 / 3$ the length of the threads to be anchored. This method assures accuracy in placing the screws, reduces the possibility of splitting the wood, and reduces the time required.

Lag Screws. The Army name for lag screws (Figure 2-9) is lag bolt, wood-screw type. They are longer and heavier than the common wood screw and have coarser threads, which extend from a cone or gimlet point slightly more than half the length of the screw. Square-head and hexagon-head lag screws are usually placed with a wrench. They are used when ordinary wood screws would be too short or too light and spikes would not be strong enough. Lag screw sizes are given in Table 2-5, page 2-10. Combined with expansion anchors, lag screws are used to frame timbers to existing masonry.

Sheet-Metal Screws. Sheet-metal screws are used for the assembly of metal parts. These screws are steel or brass with four types of heads: flat, round, oval, and McAllister, as shown in Figure 2-10, page 2-10.

## Bolts

Bolts are used when great strength is required or when the work must be disassembled frequently. Nuts are usually used for fastening bolts. The use of washers between the nut and wood surfaces, or between both the nut and the head and their
 opposing surfaces, will avoid marring the surfaces and will permit additional torque in tightening. Bolts are selected by length, diameter, threads, style of head, and type.

Carriage Bolts. Carriage bolts come in three types: square neck, finned neck, and ribbed neck, as shown in Figure 2-11.

In each type of carriage bolt, the part of the shank immediately below the head grips the materials into which the bolt is inserted. This keeps the bolt from turning when a nut is tightened down on it or removed. The finned carriage bolt has two or more fins extending from the head to the shank. The ribbed type has longitudinal ribs, splines, or serrations on all or part of a shoulder, located immediately beneath the head.

Holes bored to receive carriage bolts are bored to a tight fit for the body of the bolt and counterbored to permit the head of the bolt to fit flush with or below the surface of the material being fastened. The bolt is then driven into the hole with a hammer.

| LENGTHS (INCHES) | DIAMETERS (INCHES) |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | 1/4 | 3/6, 7/16, 1/2 | 5/8, 3/4 | 7/8, 1 |
| 1 $1 / 2$ $2,21 / 2,3,31 / 2$, so forth, $71 / 2,8$ to 10 11 to 12 13 to 16 | $\begin{aligned} & x \\ & x \\ & x \\ & x \end{aligned}$ | $\begin{aligned} & x \\ & x \\ & x \\ & x \\ & x \end{aligned}$ | $\begin{aligned} & x \\ & x \\ & x \\ & x \\ & x \end{aligned}$ | $\begin{aligned} & x \\ & x \\ & x \\ & \hline \end{aligned}$ |

Carriage bolts are chiefly for wood-to-wood use, but may also be used for wood-to-metal. If used for wood-to-metal application, the bolt head should be fitted to the wood item. Metal surfaces are sometimes predrilled and countersunk to allow the use of carriage bolts for metal-to-metal fastening. Carriage bolts can be


Figure 2-12. Machine bolts obtained from $1 / 4$ to 1 inch in diameter and from $3 / 4$ to 20 inches long. (Table 2-6 lists carriage-bolt sizes.) A common flat washer should be used between the nut and the wood surface with carriage bolts.

## Machine Bolts.

Machine bolts (or cap are made with cut national coarse extend from twice the plus $1 / 4$ inch (for bolts length) to twice the plus $1 / 2$ inch (for bolts

screws) (Figure 2-12) national fine or threads. These threads diameter of the bolt less than 6 inches in diameter of the bolt over 6 inches in length). Machine bolts are precision made and generally applied metal to metal where close tolerance is needed. The head may be square, hexagon, double hexagon, rounded, or flat countersunk. The nut usually corresponds in shape to the head of the bolt with which it is used. (Machine bolts are externally driven only.)

A machine bolt is selected on the basis of head style, length, diameter, and type of thread. The hole through which the bolt is to pass is bored to the same diameter as the bolt. Machine bolts are made in diameters from $1 / 4$ to 3 inches and may be obtained in any length desired. (Table 2-7 lists machine-bolt sizes.)


Stove Bolts. Stove bolts (Figure 2-13) are less precisely made than machine bolts. They have either flat or round slotted heads and have threads extending almost the full length of the body. Stove bolts are generally used with square nuts and may be applied metal to metal, wood to wood, or wood to metal. If

flatheaded, they are countersunk; if roundheaded, they are used flush with the surface.

Expansion Bolts. An expansion bolt is a bolt used together with
an expansion shield (Figure 2-14), which is usually made of lead or plastic, to provide anchorage in substances in which a threaded fastener is useless. The shield (or expansion anchor) is inserted in a predrilled hole and expands when the bolt is driven into it. Wedged firmly in the hole, the shield provides a secure base for the grip of the fastener.

The expansion shield can be used with a nail, screw, or bolt. The shield may be obtained separately or may include the nail, screw, or bolt.


## Driftpins

Driftpins (called driftbolts for supply purposes) (Figure 2-15) are long, heavy, threadless bolts used to hold heavy pieces of timber together. Driftpins have heads, and they vary in diameter from


Figure 2-16. Corrugated fasteners $1 / 2$ to 1 inch, and in length from 18 to 26 inches.

To use the driftpin, make a hole in the timber slightly smaller than the diameter of the pin. Drive the pin into the hole. It is held in place by the compression action of the wood.

## Corrugated Fasteners

Corrugated fasteners are used to fasten joints and splices in small boards, particularly in miter joints and butt joints. Corrugated fasteners are made of 18- to 22-gauge sheet metal with alternate ridges and grooves; the ridges vary from $3 / 16$ to $5 / 16$ inch, center to center. One end is cut square; the other end is sharpened, with beveled edges.

There are two types of corrugated fasteners: one with ridges running parallel, the other with ridges running at a slight angle to one another (Figure 2-16). The latter type tends to compress the material, since the ridges and grooves are closer at the top than at the bottom. Corrugated fasteners vary from 5/8 to $11 / 8$ inches wide and from $1 / 4$ to $3 / 4$ inch long. Ridges on the fasteners range from three to six ridges per fastener.

Corrugated fasteners are a great advantage when used to fasten parallel boards together (as in fastening tabletops), to make any type of joint, and to substitute for nails where nails may split the lumber. The fasteners have a greater holding power in small lumber than nails do. The proper method of using the fasteners is shown in Figure 2-17.


Figure 2-17. Proper use of corrugated fasteners

## Timber Connectors

Timber connectors are metal devices for increasing the joint
strength in timber structures. Efficient connections for either timber-to-timber joints or timber-to-steel joints are provided by the several types of timber connectors. The right type is determined by the kind of joint to be made and the load to be carried. The connectors-

- Eliminate much of the complicated framing of joints.


Figure 2-18. Split-ring installation

- Simplify the design of heavy construction.
- Provide greater efficiency in the use of material.
- Reduce the amount of timber and hardware used.
- Save time and

Split rings (Figure 2carbon steel and Winch diameters. between two timber construction. They are cut half the depth of the timber faces. made with a special electric, air, or hand
 and-groove split in
labor.

$$
.
$$ ring to bear equally against the cone wall and the outer wall of the groove into which it is placed. The inside bevel and mill edge make installation into, and removal from, the groove easier.

Toothed rings (Figure 2-19) are corrugated and toothed and are made from 16-gauge plate, low-carbon steel. They are used between two timber frames for comparatively light construction and are embedded into the contact faces of the joint members by pressure.

A BOM is a list of all materials needed to complete a structure It is based on takeoffs and estimates of the materials needed. It includes item number (parts and materials), name, description, unit of measure, quantity and, where called for, the stock size and number, and sometimes the weight. The carpenter uses it when ordering materials.

A BOM is usually made up by the draftsman when the original drawings are prepared. However, when no BOM accompanies field prints, it must be devel oped up by the construction crew. For this reason, a carpenter should be ableto devel op a BOM, as well as work with one Accuracy can best be obtained by having a separate bill prepared by at least two estimators. The bills may then be compared and one copy corrected or both used to make up a final BOM.

Before a BOM can be prepared, a materials takeoff list and a materials estimatelist are prepared.

## MATERIALS TAKEOFF LIST

The first step leading to preparation of a BOM is a materials takeoff list. This is a list of all parts of the building, taken from the plans, usually by tallying and checking off the items indicated on the drawings and specifications. Both architectural and engineering plans provide the names and sizes of the items that are to be listed.

F or example, Figure 3-1 (page 3-2) shows a plan for the substructure of a $20-\times 40$-foot TO building. Table 3-1, page 3-3, is the materials takeoff list for this building. This list identifies all parts of the building, starting with its base and working upward. The following paragraphs are an example of computing the materials needed for the footers.

Look at the first and second columns of the materials takeoff list. The first column gives the item (footers); the next column gives the number of pieces (46) needed to make up the item.

The 20-x 40-foot building shown on the plan requires 15 foundation posts. Since three pieces are needed for each footer, a total of 45 pieces is needed.

The length in place ( 1 foot 5 inches) is the actual length of the member after it has been cut and is ready to be nailed in place. The size $(2 \times 6)$ refers to the nominal size of the lumber. The length refers to the standard lengths available from the lumberyard or depot, such as 8 -, 10-, and 12 -foot pieces of stock.


Figure 3-1. 20- $\times 40$-foot TO building substructure

Table 3-1. Materials takeoff list for a 20-x 40-foot building

| ITEM NAME OR USE OF PIECE | NO. OF <br> PIECES | UNIT | LENGTH <br> IN PLACE | SIZE | LENGTH | NO. PER <br> LENGTH | QUANTITY |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1. Footers | 45 | PC | $1^{\prime}-5^{*}$ | $2 \times 6$ | $10^{\prime}$ | 7 | 7 |
| 2. Spreaders | 30 | PC | $1^{\prime}-4^{*}$ | $2 \times 6$ | $8^{\prime}$ | 6 | 5 |
| 3. Foundation Post | 15 | PC | $3^{\prime}-0^{*}$ | $6 \times 6$ | $12^{\prime}$ | 4 | 4 |
| 4. Scabs | 20 | PC | $1^{\prime}-0^{*}$ | $1 \times 6$ | $8^{\prime}$ | 8 | 3 |
| 5. Girders | 36 | PC | $10^{\prime}-0^{*}$ | $2 \times 6$ | $10^{\prime}$ | 1 | 36 |
| 6. Joists | 46 | PC | $10^{\prime}-0^{*}$ | $2 \times 6$ | 10 | 1 | 46 |
| 7. Joist Splices | 21 | PC | $2^{\prime}-0^{\prime \prime}$ | $1 \times 6$ | $8^{\prime}$ | 4 | 6 |
| 8. Block Bridging | 40 | PC | $1^{\prime}-10^{3} 8^{*}$ | $2 \times 6$ | $8^{\prime}$ | 4 | 10 |
| 9. Closers | 12 | PC | $10^{\prime}-0^{\prime \prime}$ | $1 \times 8$ | $10^{\prime}$ | 1 | 12 |
| 10. Flooring | 800 | BF | RL | $1 \times 6$ | RL | - | - |

Select the most economical length for the 15 footers. Convert the required length to available lengths for economical use. Seven 1 -foot 5 -inch-long pieces are cut from each 10-foot piece of stock; 451 -foot 5 -inch pieces require seven $2 \times 6 \times 10$ pieces. Leftover material can be used for bridging.

Table 3-2. Materials estimate list

| ITEM |  <br> LENGTH | UNIT | TAKEOFF <br> QUANTITY | WASTE <br> ALLOWANCE | ADDITIONAL <br> REQUIREMENTS | TOTAL <br> QUANTITY | BD FT <br> MEASURE |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1. | $6 \times 6 \times 12$ | PC | 4 | 1 | None | 5 | 180 |
| 2. | $2 \times 6 \times 10$ | PC | 89 | 9 | None | 98 | 980 |
| 3. | $2 \times 6 \times 8$ | PC | 15 | 2 | 3 For Temporary <br> Bracing | 20 | 160 |
| 4. | $1 \times 8 \times 10$ | PC | 12 | 2 | None | 14 | 91 |
| 5. | $1 \times 6 \times 8$ | PC | 9 | 2 | 2 For Batter Boards | 13 | 52 |
| 6. | $1 \times 6 \times$ RL | BF | 800 | 160 | None | 960 | 960 |
| 7. | 16 d | LB | - | - | 36 Nails, Framing | 36 | - |
| 8. | 8 d | LB | - | - | 23 Nails, Flooring | 23 | - |

MATERIALS ESTIMATE LIST
The materials estimate list puts materials takeoff list information into a shorter form, adds an allowance for waste and breakage, and makes an estimate of required quantities of material. These materials include nails, cement, concrete form lumber, tie wire, and temporary bracing or scaffold lumber. (Table 3-2 is a sample materials estimate list.)

The first step in preparing this list is to group (from the takeoff list) all pieces of the same size and length. For example, start with the largest size lumber that can be found on the materials takeoff list. Group all the pieces of that same size and length that appear on the list. This groups the total number of each size and length that will be needed. Continue in this way with each size of lumber, working down to the smallest size and length of material.

The sizes and pounds of nails needed should also he added to the list. Two formulas used for estimating the number of pounds of nails needed are shown below:

## Estimating quantity of nails required

- For flooring, sheathing, and other 1 -inch material, use the following formula:

Number of pounds ( 2 penny through 8 penny) -

$$
\frac{\text { penny }}{4} \times \frac{\text { board measure }}{100}
$$

- For framing materials that are 2 inches or more, use the following formula:

Number of pounds (10 penny through 60 penny ) $\frac{\text { penny }}{6} \times \frac{\text { board measure }}{100}$

F or each material size, a waste factor must be added. F or flooring, sheathing, and other 1-inch material, add a waste allowance of 2 percent; for all other materials 2 inches and larger, add 10 percent to the total number.

Next, estimate the amount of additional requirements for materials (such as bracing) that are not shown on the plans. Add the total quantity for each size and length of material. If it is used for siding, sheathing, or flooring, convert it to board feet using the method given in Chapter 2 (page 25).

## BILL OF MATERIALS FORMAT

The information for the BOM (DA Form 2702) is taken from the materials estimate list. The BOM is used to requisition these materials. The materials estimate list contains information on materials needed for a project, but it also contains much information on materials needed for a project, but it also contains much information of little interest to depot personnel. Therefore, use the simplified BOM (DA Form 2702, Figure 3-2) to requisition materials.

The rest of the building would be analyzed in the same way.


Figure 3-2. Sample DA Form 2702

The details of layout and planning are essential to proper construction of a building. Layout prepares the sit $\epsilon$ for the foundation which must be planned and completed for each building being constructed. This chapter introduces the carpenter to the tools, materials, and techniques used in the effective accomplishment of these vital layout and planning functions.

## LAYOUT

Layout techniques are described in the following paragraphs. The following are the most commonly used layout tools and materials:

- A string line is used to distinguish the dimensions of the building layout.
- A sledgehammer is used to sink corner stakes or batter boards and posts.
- A posthole auger is used to dig the holes required to set posts properly in some soils.
- A handsaw is used to cut batter boards and posts.
- An ax or a hatchet is used to sharpen batter-board posts and stakes.
- A hammer is used for building batter boards.
- A chalk line is used to deposit chalk on the surface in order to make a straight guideline.
- A 100-foot/30-meter tape is used for measuring diagonally (usually in a 100 foot length) and for laying or excavation or foundation lines.
- Tracing tape is used for laying out excavation or foundation lines. The tape is made of cotton cloth approximately 1 inch wide. It usually comes in a 200 foot length.
- A carpenter's level is used to level a surface and to sight level lines. It may be used directly on the surface or with a straightedge.
- A line level has a spirit bubble to show levelness. The level is hung from a taut line. It gives the greatest accuracy when it is placed halfway between the points to be leveled.
- An automatic level measures approximate differences in elevation and can establish grades over limited distances. The landscape, level bubble, and index line are seen in the tube.
- $8 d$ nails are used to secure string line to batter boards.
- A plumbing bob is used to locate the corners of the building dimensions.
- A framing square is used to check the squareness of lines.


## LAYING OUT A RECTANGULAR BUILDING SITE

Working from an established line, such as a road or a property line (line AB in Figure 4-1) that is parallel to construction, establish the maximum outer perimeter ( $\mathrm{AB}, \mathrm{CD}, \mathrm{AC}, \mathrm{BD}$ ) of the building area.

Measure away from the front line ( AB ) along the side lines ( AC and BD ) the distances ( AO and BO ) desired to the dimension of the project that is to run parallel to the front line.

Stretch a line tightly from point O to O . This line will mark the project's frontage.

Measure in from lines AC and BD along line OO one-half the difference between the length of line OO and the desired length of the project. The points ( X and X ) will constitute the front corners of the project.


The two distances OX and XO establish the distances E and F. Extend lines from the two front corners, X and X , parallel to AC and BD at the distances established as E and F for the required depth of the project. This provides the side lines of the project (XG and XH ).

Joining the extreme ends of side 111
XH will provide the rear line $(\mathrm{GH})$ of the project.
After the four corners (X, X, G. and H) have been located, drive stakes at each corner. Batter boards may be erected at these points either after the stakes have been set or while they are being set. Dimensions are determined accurately during each step.

## LAYING OUT AN IRREGULAR BUILDING SITE

Where the outline of the building is other than a rectangle, the procedure in establishing each point is the sam as described for laying out a simple rectangle. However, more points have to be located, and the final proving of the work is more likely to reveal a small error. When the building is an irregular shape, it is advisable to first lay out a large rectangle which will comprise the entire building or the greater part of it. This is shown in Figure 4-2 as HOPQ When this is established, the remaining portion of the


Figure 4-2. Laying out irregular projects layout will consist of small rectangles, each of which can be laid out and proved separately. These rectangles are shown as LMNP ABCQ, DEFG, and IJKO in Figure 4-2.

## SETTING BATTER BOARDS

Batter boards are a temporary framework used to assist in locating corners when laying out a foundation. Batter-board posts are made from $2 \times 4$ or $4 \times 4$ material; corner stakes are made from $2 \times 2 \mathrm{~s}$. Batter boards a made from $1 \times 4$ or $1 \times 6$ pieces.

## Staking Procedures

Corner stakes are driven to mark the exact corners of the project. Excavating for a foundation will disturb the stakes, so batter boards are set up outside the boundary established by the stakes to preserve definite and accurate building lines. Heavy cord or fine wire is stretched from one batter board to another to mark these lines.

## Location of Batter Boards

Figure 4-3 shows how to locate batter boards. Right-angle batter boards are erected 3 or 4 feet outside of each corner stake. Straight batter boards are erected 3 or 4 feet outside of the line stakes.

## Construction of Batter Boards

Right-angle batter boards should be fastened to the posts after the posts are sunk. Since the boards should be at the exact height of the top of the foundation, it may be desirable to adjust the height by nailing the boards to the stakes after the stakes have been sunk. Right-angle batter boards may be nailed close to perpendicular by using a framing square and should be leveled by means of a carpenter's level before they are secured. Then, angle saw cuts may be made or nails driven into the tops of the boards to hold the lines in place. Separate cuts or nails may be used for the building line, the foundation line, the footing line, and excavation lines. These grooves


BATTER BOARDS

Figure 4-3. Locating batter
boards permit the removal and replacement of the lines in the correct position.

## EXTENDING LINES

The following procedure applies to a simple layout as shown in Figure 4-4, page 4-4, and must be amended to apply to different or more complex layout problems:

Step 1. After locating and sinking stakes A and B. erect batter boards $1,2,3$, and 4 . Extend a chalk line ( X ) from batter board 1 to batter board 3, over stakes A and B.

Step 2. After locating and sinking stake C, erect batter boards 5 and 6. Extend chalk line Y from batter board 2 over stakes A and C to batter board 6 .

Step 3. After locating and sinking stake D, erect batter boards 7 and 8. Extend chalk line Z from batter board 5 to batter board 7, over stakes C and D.

Step 4. Extend line O from batter board 8 to batter board 4, over stakes D and B.
Where foundation walls are wide at the bottom and extend beyond the outside dimensions of the building, ths excavation must be larger than the laid-out size. To lay out dimensions of this excavation, measure out as far as required from the building line on each batter board and stretch lines between these points, outside the firs layout.


Figure 4-4. Laying out building lines from batter boards

The lines may be at a right angle where they cross the corner layout stakes, found by holding a plumb bob ovi the corner layout stakes and adjusting the lines until they touch the plumb-bob line. All lines should be checked with a line level or a carpenter's level.

## SQUARING LINES

The two methods commonly used for squaring extended lines are the 6-8-10 method and the diagonal methoc
The 6-8-10 Method
After extended lines are in place, measure line EF for a distance of 6 feet (Figure 4-4). Measure line EG for a distance of 8 feet. Adjust the lines ( Y and X ) until FG equals 10 feet. Multiples of 6-8-10 may be used for large layouts; for example, 12-16-20 for a layout 50 feet by 100 feet. For accuracy, never start with a measurement of less than 6 feet.

## The Diagonal Method

If the layout is rectangular, lines H and I, cutting the rectangle from opposing corners, will form two triangles as shown in Figure 4-4. If the rectangle is perfect, these lines will be equal in length and the corners perfectly square. If lines H and I are not equal in length, adjust the corners by moving the lines right or left until H and are equal.

## FOUNDATIONS

Foundations vary according to their use, the soil-bearing capacity, and the type of material available. The material may be cut stone, rock, brick, concrete, tile, or wood, depending on the weight the foundation is to support. Foundations may be classified as wall or column (pier) foundations.

## WALL FOUNDATIONS

Wall foundations (Figure 4-5) are solid their total length and are usually used when heavy loads are to be carried or where the earth has low supporting strength. These walls may be made of concrete, rock, brick, or cut stone, with a footing at the bottom. Because of the time, labor, and material required to build it, this type ${ }^{\prime}$ wall will be used in the TO only when other types cannot be used. Steel-rod reinforcements should be used ir all concrete walls.

Rubble stone masonry is used for walls both above and below ground and for bridge abutments. In military construction, it is used when form lumber for masonry units is not available. Rubble masonry may be laid up with or without mortar; if strength and stability are desired, mortar must be used.

Coursed rubble is assembled of roughly squared stones in such a manner as to produce approximately continuous horizontal bed joints.

Random rubble is the crudest of all types of stonework. Little attention is paid to laying the stone in courses. Each layer must contain bonding stones that extend through the wall. This produces a wall that is well tied together.


## COLUMN OR POST FOUNDATIONS

The use of column or post foundations constructed from masonry or wood saves time and labor. The posts or columns are spaced according to the weight to be carried. In most cases, the spacing is 6 to 10 feet apart. The sketches in Figure 4-6 show the different types of posts with appropriate types of footing. Wood posts are generally used, since they are installed with the least time and labor. When wood posts extend 3 feet or more above the ground, braces are necessary (Figure 4-7).


Figure 4-7. Posts with braces

Forms play a major rolein concrete construction. They give the plastic concrete its shape and hold it until it hardens. Forms protect the concrete, assist in curing it, and support any reinforcing rods or conduits embedded in the concrete. This chapter familiarizes the carpenter with the design and construction of various types of forms.

## FORM DESIGN

Forms for concrete must be tight, rigid, and strong. If forms are not tight, loss of concrete may cause a honeycomb effect, or loss of water may cause sandstreaking. The forms must be braced enough to stay in alignment. Special care is needed when bracing and tying down forms used in applications such as retainer walls, where the mass of concrete is large at the bottom and tapers toward the top. In this type of construction and in the first pour for walls and columns, the concrete tends to lift the form above its proper elevation. (Field Manual 5-742 gives formulas and tables for designing forms of proper strength.)

## FORM CONSTRUCTION

Although forms are generally constructed from wood, fiber, earth, or metal, the TO carpenter usually constructs wood or fiber forms.

Wood forms are the most common in building construction. They are economical, easy to handle, and easy to produce, and they adapt to many shapes. Form lumber can be reused for roofing, bracing, or similar purposes.

Lumber should be straight, strong, and only partially seasoned. Kiln-dried lumber tends to swell when soaked with water. Swelling may cause bulging and distortion. If green lumber is used, allow for shrinkage, or keep it wet until the concrete is in place. Softwoods (pine, fir, and spruce) are the most economical; they are light,
easy to work with, and generally available.
Wood coming in contact with concrete should be surfaced (smooth) on the side towards the concrete and on both edges. The edges may be square, shiplap, or tongue-and-groove. Tongue-and-groove lumber makes a more watertight joint, which reduces warping.

Plywood is economical to use for wall and floor forms; however, plywood used for this purpose should be made with waterproof glue and marked for use in concrete forms. Plywood is warp-resistant and can be used more often than other lumber.

An advantage of using plywood for forms is the great number of sizes available. It is made in thicknesses

## CAUTION

[^0]of $1 / 4,3 / 8,1 / 2,5 / 8$, and $3 / 4$ inch, and in widths up to 48 inches. The 8 -foot lengths are most commonly used. The $6 / 8$ - and $3 / 4$-inch thicknesses are most economical. Thinner plywood requires solid backing to prevent deflection. The 1/4-inch thickness is useful for curved surfaces.

Waterproof cardboard and other fiber materials are used for round concrete columns and other preformed shapes. Forms are made by gluing layers of fiber together and molding them to the right shape. The advantage is that fabrication at the job site is not necessary.

## FOUNDATION AND FOOTING FORMS

When possible, earth is excavated to form a mold for concrete-wall footings. If wood forms are needed, the four sides are built in panels.

Panels for two opposite sides are made at exact footing width; the other pair has two end cleats on the inside spaced the length of the footing plus twice the sheathing thickness. One-inch-thick sheathing is nailed to vertical cleats spaced on 2foot centers. Two-inch dressed lumber should be used for the cleats.

## NOTE : Panels are held in place with form nails until the tie wire is installed. Nails should be driven only part way from the outside so that they can be easily removed.

Tie wires are wrapped around the center cleats. Wire holes on each side of the cleat should be less than 1 inch in diameter to prevent mortar leaks. Reinforcing bars must be placed before the wire is installed.

For forms 4 feet square or larger, stakes are driven as shown in Figure 5-1. These stakes, and $1 \times 6$ boards nailed across the top of the form, prevent spreading. Panels may be higher than the required depth of footing, since they can be marked on the inside to show the top of the footing. If the footings are less than 1 foot deep and 2 feet square, forms can be constructed of 1 -inch sheathing without
cleats (Figure 5-2).
When placing a footing and a small pier at the same time, the form is built as shown in Figure 5-3. To ensure that support for the upper form does not interfere with the placement of concrete in the lower form, $2 \times 4$ or $4 \times 4$ pieces


Figure 5-1. Typical large footing form


Figure 5-2. Typical small footing form
are nailed to the top of the lower form (as shown). The top form is then nailed to these pieces.

Construction and bracing of forms for wall footings are shown in Figure 5-4. The sides are 2-inch lumber held in place by stakes and held apart by spreaders. The short brace shown at
each stake holds the form in line.

## WALL FORMS

Wall forms are made of wall "panels" and other parts shown in Figure 5-5 page 5-4. These Darts are described as follows:


Figure 5-3. Footing and pier form

## Wall Panels

Wall panels are made by nailing the sheathing to the studs and can be built in place or prefabricated elsewhere. Prefabricated wall panels should be no more than 10 feet long so that they can be easily handled. Figure 5-6, page 5-4, shows how wall panels are connected and how wall corners are constructed.

## Sheathing

Sheathing forms the surface of the concrete. It should be smooth, especially if the finished surface is to be exposed. It is normally 1 -inch (3/4-inch dressed) tongue and-groove lumber or $3 / 4$-inch plywood. Concrete is plastic when placed in the form, so sheathing should be watertight. tongue-and-groove lumber or plywood gives a watertight surface. Reinforce sheathing to prevent bulging from the weight of the concrete.

## Studs

Vertical studs make the sheathing rigid. These studs are generally made from $2 \times 4$ lumber. Studs also require reinforcing when they extend more than 4 feet.

## Wales

Double wales reinforce the wall form. They also tie wall panels together and keep them in a straight line. They run horizontally and are lapped at the corners.


Figure 5-5. Concrete wall form


Figure 5-6. Constructing wall panels

## Braces

Braces give the forms stability. The most common brace uses a horizontal member and a diagonal member nailed to a stake and to the stud or wale. The diagonal member of the brace should make a $30^{\circ}$ angle with the horizontal member. Additional bracing may be provided by strongbacks (vertical members) behind the wales or in the corner formed by intersecting wales. (Braces are not part of the form design and are not considered as providing additional strength.)

## Shoe Plates

Shoe plates are nailed into the foundation or footing and must be carefully placed to maintain the wall dimensions and alignment. Studs are tied into the shoe plate.

## Spreaders

Spreaders must be placed near each tie wire Spreaders are cut to the same length as the thickness of the wall and placed between the two sheathing surfaces of the forms. They are not nailed, but are held in place by friction.

Spreaders are removed as the forms are filled (Figure 5-7), so that they will not become embedded as the concrete hardens. A wire is attached to the spreaders to allow them to be pulled out of the form after the concrete has put enough pressure on the walls to allow easy removal. The wire fastened to the bottom spreader passes through a hole drilled off center in each spreader above it.

Pulling on the wire will remove the spreaders one after another as the concrete level rises in the forms.

## Tie Wires

Tie wires hold the forms secure against the lateral pressures of unhardened concrete. Double strands are always used. Ties keep wall forms together as the concrete is positioned; Figure 5-8 shows two ways of doing this. The wire should be No. 8 or 9 gauge, black, annealed iron wire. Barbed wire may be used in an emergency. Tie spacing should be the same as the stud placing, but never more than 3 feet. E ach tie is formed by looping the wire around a wale, bringing it through the form, and looping it around the wale on the opposite side. The tie wire is made taut by twisting it with a smooth metal rod or a spike.

NOTE: Wire ties should be used only for low walls or when tie rods are not available.

## Tie Rods

An alternate to tie wires and spreaders, the tie rod and spreader combination is shown in Figure 5-9, page 5-6. After the form is removed, each rod is broken off at the notch. If appearance is important, the holes should be filled with a mortar mix.

The use of a wood strip as a wedge when curtain walls and columns are placed at the same time is shown in Figure 5-10, page 5-6. In removing the forms, the wedge is removed first.


Figure 5-7. Removing wood spreaders


Figure 5-8. Wire ties for form walls

whether the bottom is to be left until the concrete is strong enough for shoring to be removed. Beam forms receive little bursting pressure but must be shored at close intervals to prevent sagging.

The bottom of the form is the same width as the beam; it is in one piece for its full width. Form sides are 1inch tongue-and-groove material; they lap over the bottom (as shown). The

## COLUMN FORMS

Sheathing runs vertically in column forms to save saw cuts. Corner joints are firmly nailed to ensure watertight construction. Battens or narrow strips of boards (cleats) are placed directly over the joints to fasten the several pieces of vertical sheathing together.

A column and footing form is shown in Figure 5-11. The column form is erected after the steel reinforcement is assembled and is tied to dowels in the footing. The form should have a cleanout hole in the bottom to help remove debris. The lumber removed to make the cleanout holes should be nailed to the form so that it can be replaced before the concrete is positioned.

## BEAM AND GIRDER FORMS

Figure $5-12$ shows both beam and girder forms. The type of construction of these forms depends on whether the form is to be removed in one piece or
sheath is nailed to $2 \times 4$ struts placed on 3 -foot centers. A $1 \times 4$ piece is nailed along the struts to support the joists for the floor panel. The sides of the form are not nailed to the bottom but are held in position by continuous strips. Crosspieces nailed on top serve as spreaders. After erection, the slab panel joints hold the beam in place.

A beam and girder assembly is shown in Figure 5-13, page 5-8. The beam bottom butts tightly against the side of the girder and rests on a $2 \times 4$ nailed to the girder side. Details in Figure 5-13 show the clearances for stripping and the allowances for movement caused by the concrete's weight. The $4 \times 4$ posts are spaced to support the concrete and are wedged at the bottom or top for easy removal.

## FLOOR FORMS

Floor panels are built as shown in Figure 5-14, page $5-9$. The 1 -inch tongue-and-groove sheathing or 3/4inch plywood is nailed to $1 \times 4$ cleats


Figure 5-10. Wall form for curtain walls

on 3 -foot centers. These panels are supported by $2 \times 6$ joists. Spacing of joists depends on the thickness of the concrete slab and the span of the beams. If the slab spans the distance between two walls, the panels are used in the same manner as when beams support the floor slab.

## STAIR FORMS

A method for building stair forms up to 3 feet in width is shown in Figure 5-15, page 5-9. The underside of the steps should be 1 -inch tongue-and-groove sheathing. This platform should extend 12 inches beyond each side of the stairs to support stringer bracing blocks. The back of the panel is shored with $4 x$ 4 pieces (as shown). The $2 \times 6$ cleats nailed to the shoring should rest on wedges to make both adjustments and removal of the posts easy. The side stringers are $2 \times 12$ pieces cut as required for the treads and risers. The face of the riser should be 2-inch material, beveled (as shown).

## FORMREMOVAL

Forms should be built to allow easy removal without danger to the concrete. Before concrete is placed, forms are treated with oil or other coating material to prevent the concrete from sticking. The oil should penetrate the wood to prevent water absorption. A light


Figure 5-12. Beam and girder forms


Figure 5-13. Beam, column and floor form
bodied petroleum oil will do. On plywood, shellac is more effective than oil. If forms are to be reused, painting helps preserve the wood.

If form oil is not available, wetting with water may be substituted in an emergency to prevent sticking.

Wood wedges should be used to wedge forms against concrete, rather than a pinchbar or other metal tool. To avoid breaking the edges of concrete, forms should not be jerked off after wedging has been started at one end. F orms to be reused should be cleaned and oiled immediately. Nails should be removed as forms are stripped.

## CAUTION

-Permit only workmen doing the stripping in the immediate area. --Do not remove forms until the concrete has set.
-Pile stripped forms immediately to avoid congestion, exposed nails, and other hazards.


Figure 5-14. Floor slab form


Figure 5-15. Stainway slab form

After the foundation is built and the batter boards are removed, the carpenter builds the framework. Theframework consists of beams, trusses, walls and partitions, flooring, ceilings, sheathing and siding, stairways, roof framing and coverings (Chapter 7), and doors and windows (Chapter 8). This chapter familiarizes the carpenter with materials, tools, and techniques used to build the framework.

## TYPES OF FRAMING

Framing consists of light, heavy, and expedient framing.

## LIGHT FRAMING

There are three principal types of framing for light structures: western, balloon, and braced. Figure 6-1, page 6-2, illustrates these types of framing and specifies the nomenclature and location of the various members.

Light framing is used in barracks, bathhouses, and administration buildings. Figure 6-2, page $6-3$, shows some details of a 20 -foot wide building (such as ground level, window openings, braces, and splices) and labels the framing parts.

Much of light framing can be done in staging areas while staking out, squaring, and floor framing is being done. Subflooring can begin when a portion of the floor joists has been laid. The better-skilled men should construct the frame, and with good coordination, a large force of men can be kept busy during framing.

## Western Frame

The western or platform frame (Figure 6-1, 1) is used extensively in military construction. It is similar to the braced frame, but has boxed-sill construction at each floor line. Also note that cross bridging is used between the joists and bridging is used between the studs. The platform frame is preferred for one-story structures since it permits both the bearing and nonbearing walls (which are supported by the joist) to settle uniformly.

## Balloon Frame

The balloon frame (Figure 6-1, 2) is a widely used type of light framing. The major difference between balloon and braced framing in a multistory building is that in balloon framing the studs run the full length, from sill to rafters. It is customary for second-floor joists to rest on a 1-x 4-inch ribbon that has been set into the studs. The balloon frame is less rigid than a braced frame.


NOTE: STANDARD SPACING FOR STUDS SHOULD BE 16 NCHES CENTER TO CENTER TO RECEIVE STANDARDSIZE SHEETS OF PLASTERBOARD, SHEETROCK, PLYWOOD. AND SO ON. JOISTS ARE ORDINARILY SPACED SIMILARLY UNLESS STRAPPING OR FURRING STRIPS ARE USED. ROUIG FLOORS, WHERE LAID DIAGONALLY, GIVE ADDITIONAL STRENGTH TO THE STRUCTURE; HOWEVER, WHERE LAID HORIZONTALLY, ECONOMY OF MATERIAL IS OBTANED. EXTERIOR WALLS SHOULD BE BRACED WTH DIAGONAL BRACES FOR STIFFENING PURPOSES WHEN HORIZONTAL. SHEATHING IS USED.

1. WESTERN- (OR PLATFORM-) FRAME CONSTRUCTION


Figure 6-1. Framing for light structures


Figure 6-2. Light-framing details

## Braced Frame

A braced frame (Figure 6-1, 3) is much more rigid than a balloon frame. Exterior studs extend only between floors and are topped by girts that form a sill for the joists of the succeeding floor. Girts are usually $4 \times 6$ inches. With the exception of studs, braced frame members are heavier than those in balloon framing. Sills and corner posts are customarily $4 \times 6$ inches. Unlike the studs, corner posts extend from sill to plate. Knee braces, usually $2 \times 4$ inches, are placed diagonally against each side of the corner posts. Interior studding for braced frames is the same as for balloon-frame construction.

## HEAVY FRAMING

Heavy-frame buildings are more permanent, and are normally used for warehouses and shops. Heavy framing is seldom used in TO construction. Figure 6-3, page 6-4, shows the details of heavy framing. Heavy framing consists of framing members at least 6 inches in dimension (timber construction). Long, unsupported areas between walls are spanned by built-up roof trusses.


Figure 6-3. Heavy-framing details

## EXPEDIENT FRAMING

Some field conditions require expedient framing techniques. For example-

- Light siding. Chicken wire and water-resistant bituminous paper can be sandwiched to provide adequate temporary framing in temperate climates.
- Salvaged framing. Salvaged sheet metal, such as corrugated material or gasoline cans, can be used as siding in the construction of emergency housing.
- Local timber. Poles trimmed from saplings or bamboo can be constructed into reasonably sound framing and may be secured with native vines if necessary.
- Wood-substitute framing. Adobe (soil, straw, and water-mixed until spreadable) can be used to form walls, floors, and foundations. A similar mixture may be used to form sundried bricks.
- Excavations. Proper excavation and simple log cribbing may also be covered with sod and carefully drained to give adequate shelter.


## CONNECTIONS

Weak points in a structure usually occur at the connections (joints and splices) between pieces of lumber. However, these connections can be structurally sound if done correctly. Such weak points are usually a sign of poor workmanship.

## J OINTS

J oints are connections between two pieces of timber that come together at an angle. The types of joints most commonly used in carpentry are butt joints and lap joints.

## Butt J oints

A butt joint is formed by placing the end of one board against another board so that the boards are at an angle (usually a right angle), forming a corner. The types of butt joints are shown in Figure 6-4 and are described below.

Straight Butt J oint. This joint is formed by placing the square-cut end of one board against the square face of another. The butt end of one board should be square and the face of the other board smooth so that they fit perpendicular to each other. Select the right type of nails or screws to hold such a joint securely. F or framing, butt joints are secured by 8d or 10d nails that are toenailed to strengthen the joint. The end grain is the weakest part of a piece of wood when used in joints. A butt joint is made at either one or two endgrain parts. It will be no stronger than the quality of those
 parts. A butt joint is, therefore, the weakest type of joint. This is especially true if the joint is made of two pieces of wood only.

Oblique Butt J oint. This joint is formed by butting the mitered end of one board against the face of another board. Bracing is typically made with this joint. It should not be used where great strength is required. The strength of the oblique butt joint depends upon the nailing. The nail size



MITER BUTT JOINT


Figure 6-5. Lap joints
depends upon the timber size. Nails should be toenailed to strengthen the joint; not too many nails should be used.

Miter Butt J oint. This joint is formed by bringing the mitered ends of two boards together to form the desired angle. This joint is normally used at corners where a straight butt joint would not be satisfactory. To form a right-angle miter joint (the most commonly used), cut each piece at a $45^{\circ}$ angle so that when the pieces are joined they will form a $90^{\circ}$ angle. The miter joint is used mostly in framing. However, it is a very weak joint and should not be used wherestrength is important.

## Lap J oints

The lap joint is the strongest joint. Lap joints (Figure 6-5) are formed in one of two ways: a plain lap joint or a half-lap splice joint.

Plain Lap J oint. This joint is formed by laying one board over another and fastening the two with screws or nails. This is the simplest and most often used method of joining. This joint is as strong as the fasteners and material used.

Half-Lap Splice J oint. This joint is formed by cutting away equal-length portions (usually half) from the thickness of two boards. The two are then joined so that they overlap and form a corner. Overlapping surfaces must fit snugly and smoothly. Overlaps should be sawed on the waste side of the gauge line, to avoid cutting laps oversize by the thickness of the cut. This joint is relatively strong and easy to make.

## NOTE: Some useful variations of the half-lap joint are the cross-lap, the middle-lap, and the mitered half-lap joints.

## SPLICES

Splices connect two or more pieces of material that extend in the same line. The joint will be as strong as the unjoined portions. The type of splice used depends on the type of stress and strain that the spliced timber must withstand.

- Vertical supports (longitudinal stress) require splices that resist compression.
- Trusses, braces, and joists (transverse and angular stress) require splices that resist tension.
- Horizontal supports, such as girders or beams, require splices that resist bending tension and compression.

For example, splices for resisting compression are usually worthless for resisting tension or bending. Figure 6-6 shows splice types; Figure 6-7 shows splice stresses.

## Compression-Resistant

Splices. Compression-resistant splices support weight or exert pressure and will resist compression stress only. The most common types of compressionresistant splices are the butt splice and the halved splice


Figure 6-7. Splice stresses

Butt Splice. This splice is constructed by butting the squared ends of two pieces of timber together and securing them in this position with two wood or metal pieces fastened on opposite sides of the timber. The two short supporting pieces keep the splice straight and prevent buckling. Metal plates used as supports in a butt splice are called fishplates. Wood plates are called scabs and are fastened in place with bolts or screws. Bolts, nails, or corrugated fasteners may be used to secure scabs. If nails are used with scabs, they are staggered and driven at an angle away from the splice. Too many nails, or nails that are too large, will weaken a splice.

Halved Splice. This splice is made by cutting away half the thickness of equal lengths from the ends of two pieces of timber, then fitting the tongues (laps) together. The laps should be long enough to provide adequate bearing surfaces. Nails or bolts may be used to fasten the hal ved splice. Note: To give the halved splice resistance to tension as well as compression, fishplates or scabs may be used.

## Tension-Resistant Splices

In members such as trusses, braces, and joists, the joint undergoes stress in more than one direction; this creates tension, buckling the member in a predictable direction. Tensionresistant splices provide the greatest practical number of bearing surfaces and shoulders within the splice.

Square Splice. This splice is a modification of the compression halved splice. Notches are cut in the tongues or laps to provide an additional locking shoulder. The square splice may be fastened with nails or bolts. Note: It may be greatly strengthened by using fishplates or scabs.

Long, Plain Splice. This splice is a hasty substitute for the square splice. A long overlap of two pieces is desirable to provide adequate bearing surface and enough room for fasteners to make up for the lack of shoulder lock.

## Bend-Resistant Splices

Horizontal timbers supporting weight undergo stress at a splice that results in compression of the upper part; this has a tendency to crush the fibers. Tension of the lower part also tends to
pull the fibers apart. Bend-resistant splices resist both compression and tension. Make a bendresistant splice as follows:

Step 1. Cut oblique, complementary laps in the end of two pieces of timber.
Step 2. Square the upper lap (bearing surface) to butt it against the square of the other lap. This offers maximum resistance to crushing.

Step 3. Bevel the lower tongue.
Step 4. F asten a scab or fishplate along the bottom of the splice to prevent separation of the pieces.

## NOTE: When this splice cannot be done, a butt joint, halved splice, or square splice secured by fishplates or scabs may be used.

## SILLS

There are four types of wood sill construction: platform construction, balloon-framed construction, braced-framed construction, and the builtup sill. The sill is the foundation that supports a building and is the first part of a building to be set in place. It rests directly on the foundation posts or on the ground and is joined at the corners and spliced when necessary. Figure 6-8, page 6-8, shows the most common sills. The type of sill used depends on the type of construction used in the frame. To prevent air from entering into the building, spread a thin bed of mortar on top of the foundation wall. This also provides a solid base for the sill. Another technique is to use a sill sealer made of fiberglass. Place insulation material and a termite shield under the sill if desired.

## PLATFORM CONSTRUCTION

Box sills are commonly used with platform framing, which is the most common type of framing. These may be used with or without the sill plate.

The sill or sill plate is anchored to the foundation wall for supporting and fastening joists with a header at the end of the joists resting on the foundation wall. In this type of sill, the sill is laid edgewise on the outside edge of the sill plate.

## BALLOON-FRAMED CONSTRUCTION

" $T$ " sills are usually used in balloon framing. There are two types of T-sills: one for dry, warm climates and one for colder climates. They are made the same, except that in the latter case the joists are nailed directly to the studs and sills and headers are used between the floor joists.

## BRACED-FRAMING SILLS

Braced-framing sills (Figure 6-8) are usually used in braced-framing construction. The floor joists are notched and nailed directly to the sill and studs.


Figure 6-8. Types of sills

## BUILT-UP SILLS

If posts are used in the foundation, use either sills made of heavy, single timbers or built-up sills. Built-up sills are made with two or more light timbers, such as $2 \times 4 \mathrm{~s}$. A built-up sill is used when heavy, single timbers are not available and lighter lumber (such as a $2 \times 4$ ) alone would not support the building load. Figure 6-9 shows how to make a corner joint for a builtup sill.

Whether heavy timber or built-up sills are used, the joints should be over posts. The size of the sill depends on the load to be carried and the spacing of the posts. The sill plates are laid directly on the post or, in expedient framing, directly on graded earth. When earth floors are used, nail the studs directly to the sill.

## GIRDERS

The distance between two outside walls is usually too great to be spanned by a single joist. A girder is used for intermediate support when two or more joists are needed to cover the span. A girder is a large beam that supports other smaller beams or joists. A girder may be made of timber, steel, reinforced concrete, or a combination of these materials.

Wooden girders are more common than steel in light-frame


Figure 6-9. Corner joint of a built-up sill buildings. Built-up and solid
girders should be of seasoned wood. Common types of wood girders include solid, built-up, hollow, and glue-laminated. Hollow beams resemble a box made of $2 \times 4 \mathrm{~s}$, with plywood webs. They are often called box beams. Built-up girders are usually made of several pieces of framing lumber (Figure 6-10). Built-up girders warp less easily than solid wooden girders and are less likely to decay in the center.

Girders carry a large part of the building weight. They must be rigid and properly supported at the foundation walls and on the columns. They must be installed properly to support joists. The ends of wood girders should bear at least 4 inches on posts.

## CAUTION Precautions must be taken to avoid or counteract any future settling or shrinking, which would cause distortion of the building.

A girder with a ledger board is used where vertical space is limited. This provides more headroom in basements and crawl spaces. A girder with joist hangers is used where there is little headroom or where the joists must carry an extremely heavy load. These girders are shown in Figure 6-11, page 6-10.

## SIZE REQUIREMENTS

Carpenters should understand the effect of length, width, and depth on the strength of wood girders before attempting to determine their size.

Principles that govern the size of a girder are the -

- Distance between girder posts.
- Girder load area.
- Total floor load on the girder per square foot.
- Load on the girder per linear foot.
- Total load on the girder.
- Material to be used.
- Wood moisture content and types of wood used, since some woods are stronger than others.



## Legend

$\mathrm{A}=$ Outside masonry walls
$B=$ Bulitup girders
$\mathrm{C}=$ Joists
$D=$ Columns that support girders

Figure 6-10. Built-up girder details


Figure 6-11. Joist-to-girder attachment
A girder should be just large enough to support an ordinary load. Any size larger than that wastes material. F or greater carrying capacity, it is better to increase a girder's depth (within limits) than its width. When the depth of a girder is doubled (the width of lumber, such as $2 \times \underline{8}$ or $2 \times \underline{6}$ ), the safe load increases four times. For example, a girder 3 inches wide and 12 inches deep will carry four times as much weight as a girder 3 inches wide and 6 inches deep. Table 61 gives the sizes of built up wood girders for various loads and spans.

## LOAD AREA

A building load is carried by foundation walls and the girder. Because the ends of each joist rest on the girder, there is more weight on the girder than on any of the walls. Before considering the load on the girder, it may be well to consider a single joist.

Example 1. Suppose a 10 -foot plank weighing 5 pounds per foot is lifted by two men. If the men were at opposite ends of the plank, they would each support 25 pounds.

Now assume that one of these men lifts the end of another 10 -foot plank of the same weight as the first one. A third man lifts the opposite end of that plank. The two men on the outside are each now supporting one-half of the weight of one plank ( 25 pounds apiece), but the man in the center is supporting one-half of each of the two planks ( 50 pounds).

The two men on the outside represent the foundation walls. The center man represents the girder. The girder carries onehalf of the weight, and the other half is equally divided between the outside walls. However, the girder may not always be located halfway between the outer walls.

Example 2. Imagine the same three men lifting two planks that weigh 5 pounds per foot. One of the planks is 8 feet long and the other is 12 feet long. The total length of these two planks is the same as before. The weight per foot is the same, so the total weight in both cases is 100 pounds.

One of the outside men is supporting one-half of the 8foot plank) or 20 pounds. The man on the opposite outside end is supporting one-half of the 12-foot plank, or 30 pounds. The man in the center is supporting one-half of each plank (50 pounds). This is the same total weight he was lifting before.

> NOTE: To determine the girder load area: a girder will carry the weight of the floor on each side to the midpoint of the joists that rest upon it.

## FLOOR LOAD

After the girder load area is known, the total floor load per square foot must be determined, for safety purposes. Both dead and live loads must be considered.

## Dead Load

The dead load consists of all building structure weight. The dead load per square foot of floor area is carried directly or indirectly to the girder by bearing partitions. The dead load varies according to the construction method and building height. The structural parts in the dead load are-

Table 6-1. Sizes of built-up wood girders

| (Based on Douglas fir 4-equare guideline framing; deffection not over $1 / 360$ of span; allowable fiber strese $1,600 \mathrm{lb}_{\mathrm{ln}}{ }^{2}$ ) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| LOAD P | LENGTH OF SPAN (FEET) |  |  |  |  |
| LINEAR | 6 | 7 | 8 | 9 | 10 |
| GIRDER | NOMINAL SIZE OF GIRDER REQUIRED (INCHES) |  |  |  |  |
| 750 | $6 \times 8$ | $6 \times 8$ | $6 \times 8$ | $6 \times 10$ | $6 \times 10$ |
| 900 | $6 \times 8$ | $6 \times 8$ | $6 \times 10$ | $6 \times 10$ | $8 \times 10$ |
| 1050 | $6 \times 8$ | $6 \times 10$ | $8 \times 10$ | $8 \times 10$ | $8 \times 12$ |
| 1200 | $6 \times 10$ | $8 \times 10$ | $8 \times 10$ | $8 \times 10$ | $8 \times 12$ |
| 1350 | $6 \times 10$ | $8 \times 10$ | $8 \times 10$ | $8 \times 12$ | $10 \times 12$ |
| 1500 | $8 \times 10$ | $8 \times 10$ | $8 \times 12$ | $10 \times 12$ | $10 \times 12$ |
| 1650 | $8 \times 10$ | $8 \times 12$ | $10 \times 12$ | $10 \times 12$ | $10 \times 14$ |
| 1800 | $8 \times 10$ | $8 \times 12$ | $10 \times 12$ | $10 \times 12$ | $10 \times 14$ |
| 1950 | $8 \times 12$ | $10 \times 12$ | $10 \times 12$ | $10 \times 14$ | $12 \times 14$ |
| 2100 | $8 \times 12$ | $10 \times 12$ | $10 \times 14$ | $12 \times 14$ | $12 \times 14$ |
| 2250 | $10 \times 12$ | $10 \times 12$ | $10 \times 14$ | $12 \times 14$ |  |
| 2400 | $10 \times 12$ | $10 \times 14$ | $10 \times 14$ | $12 \times 14$ |  |
| 2550 | $10 \times 12$ | $10 \times 14$ | $12 \times 14$ |  |  |
| 2700 | $10 \times 12$ | $10 \times 14$ | $12 \times 14$ |  |  |
| 2850 | $10 \times 14$ | $12 \times 14$ | $12 \times 14$ |  |  |
| 3000 | $10 \times 14$ | $12 \times 14$ |  |  |  |
| 3150 | $10 \times 14$ | $12 \times 14$ |  |  |  |
| 3300 | $12 \times 14$ | $12 \times 14$ |  |  |  |
| NOTES: <br> 1. The $6^{\prime \prime}$ girder is figured as being made with three pleces $2^{\prime \prime}$ dressed to $13 / 4^{-}$ thickness, <br> 2. The $8^{\prime \prime}$ girder is flgured as being made with four pleces $2^{\prime \prime}$ dressed to $13 / \mathbf{4}^{\prime \prime}$ thickness. <br> 3. The $10^{\prime \prime}$ girder is figured as being made with five pieces $2^{\prime \prime}$ drossed to $13 / 4^{\prime \prime}$ thickness. <br> 4. The $12^{*}$ girder is figured as being made with six pieces $2^{*}$ dressed to $13 / 4^{*}$ thickness. <br> 5. For solid girdera, multiply the above loads by 1.130 when a $6^{\circ}$ girder is used; 1.150 when an $8^{\prime \prime}$ girder is used; 1.170 when a $10^{\circ}$ girder is used; and 1.180 when a $12^{\prime \prime}$ girder is usod. |  |  |  |  |  |
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|  |  |  |  |  |  |
|  |  |  |  |  |  |

- Floor joists for all floor levels.
- Flooring materials, including the attic if it is floored.
- Bearing partitions.
- Attic partitions.
- Attic joists for the top floor.
- Ceiling laths and plaster, including the basement ceiling if it is plastered.

The total dead load for a light-frame building similar to an ordinary frame house is the deadload allowance per square foot of all structural parts added together.

- The allowance for an average subfloor, finish floor, and joists without basement plaster should be 10 pounds per square foot.
- If the basement ceiling is plastered, allow an additional 10 pounds per square foot.
- If the attic is unfloored, make a load allowance of 20 pounds for ceiling plaster and joists when girders or bearing partitions support the first-floor partition.
- If the attic is floored and used for storage, allow an additional 10 pounds per square foot.


## Live Load

The live load is the weight of furniture, persons, and other movable loads, not actually a part of the building but still carried by the girder. The live load per square foot will vary according to the building use and local weather conditions. Snow on the roof is also a part of the live load.

- Allowance for the live load on floors used for living purposes is 30 pounds per square foot.
- If the attic is floored and used for light storage, allow an additional 20 pounds per square foot.
- The allowance per square foot for live loads is usually governed by local building specifications and regulations.

The load per linear foot on the girder is easily figured when the total load per square foot of floor area is known.

Example Assume that the girder load area of the building shown in Figure 6-12 is sliced into 1-foot lengths across the girder. Each slice represents the weight supported by 1 foot of the girder. If the slice is divided into 1 -foot units, each unit will represent 1 square foot of the total floor area. To determine the load per linear foot of girder, multiply the number of units by the total load per square foot.

Note in Figure 6-12 that the girder is off-center. Remember that half of the load is supported by the girder and half by the foundation walls. Therefore, the joist length to be supported on one side of the girder is $\mathbf{7}$ feet (one half of 14 feet) and the other side is 5 feet (one half of 10 feet), for a total distance of $\mathbf{1 2}$ feet across the load area. Since each slice is $\mathbf{1}$ foot wide, it has a total floor area of 12 square feet.

Assume that the total floor load for each square foot is 70 pounds. Multiply the length times the width to get the total square feet supported by the girder ( 7 feot x 12 feet $=84$ square feet).

84 squarefeet $x 70$ pounds per squarefeet (live and dead load) $=5,880$ pounds total load on the girder

## BUILT-UP GIRDERS

Figure 6-10, page 6-9, shows a built-up girder. Notice that the joists rest on top of the girder. This type of girder is commonly used in frame building construction. To make a built-up girder, select lumber that is as free from knots and other defects as possible.

Built-up girders are usually made of three pieces of framing lumber nailed together. (The pieces must be nailed securely to prevent individual buckling.) For proper arrangement of the pieces of lumber, the end grains should match the example in Figure 613. The nailing pattern should be square across the ends of the board ( $11 / 2$ inches from each end) and then diagonal every 16 inches as shown in Figure 6-13. This


Figure 6-12. Girder load area pattern increases the strength of the girder. A typical two- or threepiece girder of 2-inch lumber should be nailed on both sides with 16d common nails.

## SPLICING

Methods for splicing girders differ according to whether the girder is built-up or solid-beam.

## Built-Up Girders

The lumber for a built-up girder should be long enough so that no more than one joint will occur over the span between footings. The joints in the beam should be staggered, and the planks must be squared at each joint and butted tightly together.

## Solid-Beam Girders

To splice solid beams, use halflap joints or butt joints (Figure 614.) See Splices on page 6-6.

Half-Lap. Sometimes a half-lap


Figure 6-13. Built-up girder lumber arrangement joint is used to join sol id beams (Figure 6-14). This is done by performing the fol lowing steps:

Step 1. Place the beam on one edge so that the annual rings run from top to bottom.
Step 2. Lay out the lines for the half-lap joint as shown in Figure 6-14.
Step 3. Make cuts along these lines, then check with a steel square to ensure a matching joint.
Step 4. Repeat the process on the other beam.
Step 5. Nail a temporary strap across the joint to hold it tightly together.

Step 6. Drill a hole through the joint with a drill bit about $1 / 16$ inch larger than the bolt to be used, and fasten the joint with a bolt, a washer, and a nut.

Butt J oints. When a strapped butt joint is used to join solid beams (Figure 6-14, page 6-13), the ends of the beams should be cut square. The straps, which are generally 18 inches long, are bolted to each side of the beams.


Figure 6-14. Butt and half-lap joints

## GIRDER SUPPORTS

When building a small frame building, the carpenter should know how to determine the proper size of girder supports (called columns or posts).

A column or post is a vertical member that supports the live and dead loads placed upon it. It may be made of wood, metal, or masonry.

- Wooden columns may be solid timbers or several pieces of framing lumber nailed together with 16d or 20d common nails.
- Metal columns are made of heavy pipe, large steel angles, or I-beams.

A column must have a bearing plate at the top and bottom which distributes the load evenly


Figure 6-15. Use of metal cap and masonry footing
across the column. Basement posts that support girders should be set on masonry footings. Columns should be securely fastened at the top to the load-bearing member and at the bottom to the footing on which they rest.


Figure 6-16. Column spacing

Figure 6-15 shows a solid wooden column with a metal bearing cap drilled to permit fastening it to the girder. The bottom of this type of column may be fastened to the masonry footing by a metal dowel. The dowel should be inserted in a hole drilled in the bottom of the column and in the masonry footing. The base is coated with asphalt at the drilling point to prevent rust or rot.

A good arrangement of a girder and supporting columns for a $24-\times 40$-foot building is shown in Figure 6-16.

- Column B will support one-half of the girder load between wall A and column C.
- Column C will support one-half of the girder load between columns B and D.
- Column D will share equally the girder loads with column C and wall E.


## GIRDER FORMS

F orms for making concrete girders and beams are made from 2-inch-thick material dressed on all sides. The bottom piece of material should be constructed in one piece to avoid using cleats. The temporary cleats shown in Figure 6-17 are nailed on to prevent the form from collapsing when handled.

## FLOORING

After the foundation and deck framing of a building are completed, the floor is built.

## FLOOR J OISTS

J oists are the wooden members, usually 2 or 3 inches thick, that make up the body of the floor frame (Figure 6-18, page 6-16). The flooring or subflooring is nailed to the joists. J oists as small

NOTE: The bottom piece of the form should never overlap the side pieces. the side pleces must always overlep the bottom.


Figure 6-17. Girder and beam form
as $2 \times 6$ are sometimes used in light frame buildings. These are too small for floors with spans over 10 feet, but are frequently used for ceiling joists.

J oists usually carry a uniform load of materials and personnel; these are live loads. The weight of joists and floors is a dead load. The joists carry the flooring load directly on ends nearest the sills, girders, bearing partitions, or bearing walls. J oists are spaced 16 or 24 inches apart, center to center. Sometimes the spacing is 12 inches, but where such spacing is made necessary by the load, heavier joists should be used.

To support heavily concentrated loads or a partition wall, you may need to double the joist or place two joists together. Two typical reinforced joists are shown in Figure 6-19.

In joining joists to sills, be sure


Figure 6-18. Floor joists that the connection can hold the load that the joist will carry. The joist-connecting method in Figure 6-20, A, is used most often because it provides the strongest joint. The methods shown in Figure 6-20, B and C, are used when it is not desirable to use joists on top of the sill. The ledger plate should be securely fastened. If the joist must be notched, it should not be notched to the sill and girder over onethird of its depth to prevent splitting (Figure 6-20, D).

J oists must be level when framed to girders. If the girder is not the same height as the sill, the joist must be notched as shown in Figure 6-20, C. If the girder and sill are the same height, the joists must be framed to keep the joist level. The joist is always placed crown up. This counteracts the weight on the joists. In most cases there will be no sag below a straight line.

The simplest way to carry joists on steel girders is to rest them on top (as shown in Figure 6-20, E), provided headroom is not restricted. If there is a lack of headroom, use straps or hangers (iron stirrups) as shown in Figure 6-20, $F$. These art among the strongest joist supports.

In connecting joists to girders and sills where posts are used, a $2 \times 4$ is nailed to the face of the sill or girder, flush with the bottom edge. This is called a ledger. These pieces should be nailed securely with 20d nails spaced 12 inches apart. When $2 \times 6$ or $2 \times 8$ joists are used, it is better to use $2 \times 4$ ledgers. This prevents joists from splitting at the notch.

When joists are 10 inches or more deep, $2 \times 4 \mathrm{~s}$ may be used as ledgers without reducing the strength of the joists. If a notch is used, joist ties may be used to overcome this loss of strength. These ties are short $1 \times 4$ boards nailed across the joists. Board ends are flush with the top and bottom edges of the joists.


Figure 6-19. Reinforced joists

Overhead joists are joined to plates as shown in Figure
$6-21, A$ and $B$. The inner end of the joist rests on the partition wall plates. If a joist is to rest on plates or girders, the joist is cut long enough to extend the full width of the plate or girder. Alternatively, the joists are cut to meet in the center of the plate or girder and connected with


Figure 6-20. Sill and joist connections
a scab. When the ends of two joists lie side by side on the plate, they should be nailed together. J oists may also be joined to girders with ledgers (Figure 6-21, C and D).

## FLOOR JOISTS FOR PLATFORM CONSTRUCTION

Check the plans to determine the size and direction of the joists. If the sizes for joists are not specified on the plans, consult Tables 6-2 and 6-3 to determine the appropriate size.

## FLOOR BRIDGING

J oists tend to twist from side to side, especially when used over a


Figure 6-21. Top plates and ledgers long span. Floor frames are bridged for stiffening and to prevent unequal deflection of the joists. This stiffening al so enables an overloaded joist to receive some help from the joists on either side of it. A pattern for the bridging stock is obtained by placing a piece of material between the joists, then marking and sawing it. When sawed, the cut will form the correct angle.

Table 6-2. Allowable spans for floor joists using nonstress-graded lumber

| Size of Floor Jolsts (Inches) | Spacing of Floor Joists (Inches) | Maximum Allowable Span (Feet and Inches) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Group 1 |  | Group II |  | Group III |  | Group IV |  |
|  |  | Plastered Celling Below | Without Plastered Ceiling Below | Plastered Ceiling Below | Without Plastered Celling Below | Plastered Ceiling Below | Without Plastered Ceilling Below | Plastered Coiling Below | Without Plastered Ceilling Below |
| $2 \times 6$ | $\begin{aligned} & 12 \\ & 16 \\ & 24 \end{aligned}$ | $\begin{gathered} 10-6 \\ 9-6 \\ 7-6 \end{gathered}$ | $\begin{gathered} 11-6 \\ 10-0 \\ 8.0 \end{gathered}$ | $\begin{aligned} & 9-0 \\ & 8-0 \\ & 6.6 \end{aligned}$ | $\begin{gathered} 10-0 \\ 8-6 \\ 7-0 \end{gathered}$ | $\begin{aligned} & 7-6 \\ & 6-6 \\ & 5-6 \end{aligned}$ | $\begin{aligned} & 8-0 \\ & 7-0 \\ & 6-0 \end{aligned}$ | $\begin{aligned} & 5-6 \\ & 5.0 \\ & 4.0 \end{aligned}$ | $\begin{aligned} & 6-0 \\ & 5-0 \\ & 4-0 \end{aligned}$ |
| $2 \times 8$ | $\begin{aligned} & 12 \\ & 16 \\ & 24 \\ & \hline \end{aligned}$ | $\begin{aligned} & 14-0 \\ & 12.6 \\ & 10-0 \end{aligned}$ | $\begin{aligned} & 15-0 \\ & 13-6 \\ & 11-0 \end{aligned}$ | $\begin{gathered} 12-6 \\ 11-0 \\ 9-0 \\ \hline \end{gathered}$ | $\begin{aligned} & 13-6 \\ & 11-6 \\ & 9-6 \end{aligned}$ | $\begin{gathered} 10.6 \\ 9.0 \\ 7.6 \end{gathered}$ | $\begin{gathered} 11-6 \\ 10.0 \\ 8-0 \end{gathered}$ | $\begin{aligned} & 8-0 \\ & 7.0 \\ & 6-0 \end{aligned}$ | $\begin{aligned} & \text { B-6 } \\ & 7-6 \\ & 6-6 \end{aligned}$ |
| $2 \times 10$ | $\begin{aligned} & 12 \\ & 16 \\ & 24 \end{aligned}$ | $\begin{aligned} & 17-6 \\ & 15-6 \\ & 13-0 \end{aligned}$ | $\begin{aligned} & 19-0 \\ & 16-6 \\ & 14-0 \end{aligned}$ | $\begin{aligned} & 16.6 \\ & 14.6 \\ & 12.0 \end{aligned}$ | $\begin{aligned} & 17-6 \\ & 15-6 \\ & 13-0 \end{aligned}$ | $\begin{aligned} & 13.6 \\ & 12.0 \\ & 10.0 \end{aligned}$ | $\begin{aligned} & 14-6 \\ & 13-0 \\ & 10-6 \end{aligned}$ | $\begin{gathered} 10.6 \\ 9-6 \\ 7-6 \end{gathered}$ | $\begin{gathered} 11-6 \\ 10-0 \\ 8.6 \end{gathered}$ |
| $2 \times 12$ | $\begin{aligned} & 12 \\ & 16 \\ & 24 \end{aligned}$ | $\begin{aligned} & 21-0 \\ & 18-0 \\ & 15-0 \end{aligned}$ | $\begin{aligned} & 23-0 \\ & 20-0 \\ & 16-6 \end{aligned}$ | $\begin{aligned} & 21-0 \\ & 18-0 \\ & 15-0 \end{aligned}$ | $\begin{aligned} & 21-6 \\ & 19-6 \\ & 16-6 \end{aligned}$ | $\begin{aligned} & 17-6 \\ & 15-6 \\ & 12-6 \end{aligned}$ | $\begin{aligned} & 19-6 \\ & 16-6 \\ & 13-6 \end{aligned}$ | $\begin{aligned} & 13-0 \\ & 12-0 \\ & 10-0 \end{aligned}$ | $\begin{aligned} & 14-6 \\ & 13-0 \\ & 10-6 \end{aligned}$ |

Note: The group classifications in this table refer to the species and minimum grades of nonstress-graded lumber. See Table 6-3.

The three kinds of bridging are: solid (horizontal) bridging, cross bridging, and compression bridging (Figure 6-22, page 620). Cross bridging is used most often. It is very effective and requires less time than horizontal bridging. Cross bridging looks like a cross and is made of pieces of lumber, usually diagonally cut $1 \times 3$ or 2 $\times 3$ between the floor joists. Each piece is nailed to the top of each joist and forms a cross (x) between the joists. Cross bridging should be made so that the two pieces of the cross are against each other.
Compression is metal bridging between joists.

Bridging should be nailed at the tops with 8 d or 11 Id nails,


Figure 6-22. Type of bridging and the bottoms should be left free until the subfloor is laid. This allows the joists to adjust to their final position and keeps the bridging from pushing up the joists and causing unevenness in the floor. The bottom ends of the bridging may then be nailed, forming a continuous truss across the floor. This prevents overl oaded joists from sagging.

Cutting and fitting the bridging by hand is a slow process. A power saw should be used if it is available. One line of bridging should be placed on joists more than 8 feet long. On joists more than 16 feet long, two lines should be used.

## Table 6 3. Group classification-nonstress-graded lumber

## Species

Minimum Grade

## Group I

Douglas Fir and Larch

## Construction

## Group II

Bald Cypress
Douglas Fir (South)
Fir, White
Hemlock, Eastern
Hemlock, West Coast and Western
Pine, Red (Norway Pine)
Redwood, California
Spruce, E astern
Spruce, Sitka
Spruce, White and Western White

No. 2
Construction Construction No. 1
Construction
No. 1
Select Heart
No. 1
Construction
Construction

| Group III |  |
| :--- | ---: |
| Cedar, Western | Construction, West Coast Studs |
| Cedar, Western Red and Incense | Construction |
| Douglas Fir and Larch | Standard, West Coast Studs |
| Douglas Fir (South) | Standard |
| Fir, Balsam | No. 1, Standard |
| Fir, White | West Coast Studs |
| Hemlock, Eastern | No. 2, Standard |
| Hemlock, West Coast and Western | West Coast Studs |
| Pine, Ponderosa, Lodgepole, Sugar, and Idaho White | Construction |
| Redwood, California | Construction |
| Redwood, California (studs only) | Two Star |
| Spruce, Engelmann | Construction, Standard |
| Spruce, Sitka | West Coast Studs |
| Spruce, White and Western White | Standard |
|  |  |
| Group IV |  |
| Cedar, Western | Utility |
| Cedar, Western Red and Incense | Utility |
| Douglas Fir and Larch | Utility |
| Douglas Fir (South) | Utility |
| Fir, White | Utility |
| Hemlock, West Coast and Western | Utility |
| Pine, Ponderosa, Lodgepole, Sugar, and Idaho White | Utility |
| Redwood, California | Merchantable |
| Redwood, California (studs only) | One Star |
| Spruce, Engelmann | Utility |
| Spruce, Sitka | Utility |
| Spruce, White and Western White | Utility |

## FLOOR OPENINGS

Floor openings for stairwells, ventilators, and chimneys are framed by a combination of headers and trimmers. Headers run at right angles to the direction of the joists and are doubled. Trimmers run parallel to the joists and are actually doubled joists. The joists are framed at right angles to the headers of the opening frame. These shorter joists, framed to headers, are called tail beams, tail joists, or header joists. The number of headers and trimmers needed at any opening depends upon-

- The shape of the opening-whether it is a simple rectangle or contains additional angles.
- The direction in which the opening runs, in relation to the joist direction.
- The position of the opening, in relation to partitions or walls.

Figure 6-23, page 6-20, shows examples of openings. One runs parallel to the joist and requires two headers and one trimmer. The other runs at right angles to the joists and requires one header and two trimmers. The openings shown in Figure 6-24, page 6-21, are constructed with corner angles supported in different ways. The cantilever method (shown on the right of Figure $6-24$ ) requires that the angle be fairly close to a supporting partition with joists from an adjacent span that run to the header.

To frame openings of the type shown in Figure 6-25-
Step 1. Headers 1 and 2 are nailed to trimmers $A$ and $C$ with three $20 d$ nails.
Step 2. Headers 1 and 2 are nailed to short joists $X$ and $Y$ with three 20d nails.

Step 3. Headers 3 and 4 are nailed to headers 1 and 2 with 16 d nails spaced 6 inches apart.

Step 4. Trimmers A and C are nailed to headers 3 and 4 with three 20d nails.

Step 5. Trimmers B and D are nailed to trimmers $A$ and $C$ with 16 d nails spaced 12 inches apart.

## SUBFLOORS

The subfloor (Figure 6-26, page 6-22), if included in the plans, is laid diagonally on the joist framework and nailed with 8 d to 10 d nails.


Figure 6-23. Floor openings

Subflooring boards 8 inches
wide or more should have at least three nails per joist. Where the subfloor is more than 1 inch thick, larger nails should be used. The subfloor is normally laid before the walls are framed so that it can be walked on while walls are being framed.


Figure 6-24. Double headers and trimmers

## FINISH FLOORS

A finish floor in the TO is normally of 3/4-inch material, square-edged or tongue-and-groove (Figure 6-27, page 6-22). Finish flooring varies from $31 / 2$ to $71 / 2$ inches wide. It is laid directly
on floor joists or on a subfloor and nailed with 8d common nails in every joist. When a subfloor exists, building paper is used between it and the finish floor to keep out dampness and insects.

In warehouses, where heavy loads are to be carried on the floor, 2-inch material should be used for the finish floor. Such flooring is also face-nailed with 16d or 20d nails. It is not tongue-and-groove, and it ranges in width from 4 to 12 inches. The joints are made on the center of the joist.


Figure 6-25. Floor-opening construction

## Wood Floors

Wood floors must be strong enough to carry the load. The type of building and its intended use determine the arrangement of the floor system, the thickness of the sheathing, and the approximate spacing of the joists.

## Concrete Floors

Concrete floors may be constructed for shops where earthen or wood floors are not suitable. These include aircraft repair and assembly shops, shops for heavy equipment, and certain kinds of warehouses.

After the earth has been graded and compacted, concrete is placed on the ground. The floor should be reinforced with steel or wire mesh. The foundation wall may be placed first and the concrete floor placed after the building is completed. This gives protection to the concrete floor while it sets.

Drainage is provided for the floor area around the footing and the area near the floor, to prevent flooding after heavy


Figure 6-26. Subfloor
rains. A concrete floor is likely to be damp unless it is protected.

## Miscellaneous Floors

These types of floors include earth, adobe brick, duckboard, or rushes. Miscellaneous flooring is used when conventional materials are unavailable or where there is a need to save time or labor. Such floors may be used if facilities are temporary or if required by the special nature of a structure. Selection of material is usually determined by availability.

Duckboard is widely used for shower flooring. Earthen floors are common; they conserve both materials and labor if the ground site is even without extensive grading. Rush or thatch floors are primarily an insulating measure and must be replaced frequently.

## WALLS AND PARTITIONS

Once the floor is in place, it is used to support the wall frame. Wall framing (Figure 6-28) consists of studs, diagonal bracing, cripples, trimmers; headers, and fire blocks. It is supported by the floor sole plate. The vertical members of the wall framing are the studs. They support the top plates and the upper part of the building, or everything above the top plate line. Studs support the lath, plaster, and insulation on the inside and wall sheathing on the outside.

Walls and partitions, which are classed as framed constructions, are composed of studs. Studs are usually closely spaced, slender, $2 \times 4$ vertical members. They are arranged in a row with their ends bearing on a long horizontal member called a bottom plate or sole plate, and their tops are capped with another plate, called a top plate. Double top plates are used to tie walls and partitions together. The bearing strength of stud walls is determined by the strength of the studs. Figure 6-29, page 6-24, shows a typical wall construction.

Partition walls divide the inside space of a building. In most cases, these walls are framed as part of the building. Where floors are to be installed, the partition walls are left unframed.


Figure 6-27. Square-edged and tongue-and-groove finish flooring


Figure 6-28. Typical wall-frame details

The two types of partition walls are bearing and nonbearing. The bearing type supports ceiling joists; the nonbearing type supports only itself, and may be put in at any time after the other framework is installed. Only one cap or plate is used. A sole plate should be used in every case, as it helps distribute the load over a larger area.

Partition walls are framed the same as outside walls; door openings are framed as outside openings. Where there are corners or where one partition wall joins another, corner posts or Tposts are used as in the outside walls. These posts provide nailing surfaces for the inside wall finish. Partition walls in a TO one-story building may or may not extend to the roof. The top of the studs has a plate when the wall does not extend to the roof. If the wall extends to the roof, the studs are joined to the rafters.

## CORNER POSTS

A corner post forms an inside corner and an outside corner which provides a good nailing base for inside wall coverings. Figures $6-30$, page $6-24$, and $6-31$, page $6-25$, show two of the most common types of corner posts as they would appear constructed. The studs used at the corners of frame construction are usually built up from three or more ordinary studs to provide greater strength. These built-up assemblies are called corner posts. They are set up, plumbed, and temporarily braced. Corner posts may also be made in any of the following ways (Figure 6-32):

- A $4 x 6$ with a $2 \times 4$ nailed on the board side, flush with one edge (Figure $6-32$, A). This type of corner is for a 4 -inch wall. Where walls are thicker, heavier timber is used.
- A $4 \times 4$ with a $2 \times 4$ nailed to each of two adjoining sides (Figure 6-32, B).
- Two $2 \times 4$ s nailed together with blocks between them and a $2 \times 4$ flush with one edge (Figure 6-32, C). This is the most common method.
- A $2 \times 4$ nailed to the edge of another $2 \times 4$, the edge of one flush with the side of the other (Figure 6-32, D). This type is used extensively in the TO where no inside finish is needed.


Figure 6-29. Typical wall construction

## PARTITION POSTS

There are two types of partition posts-T-posts and doubleTposts.

## T-Posts

Whenever a partition meets another wall, a stud wide enough to extend beyond the partition on both sides is used. This provides a solid nailing base for the inside wall finish. This type of stud is called a T-


Figure 6-30. Corner-post construction using ordinary $2 \times 4$ studs
post and is made in any of the following ways (Figure 6-33):

- A $2 \times 4$ may be nailed and centered on the face side of a $4 \times 6$ (Figure 6-33, A).
- A $2 \times 4$ may be nailed and centered on two $4 \times 4 \mathrm{~s}$ nailed together (Figure 6-33, B).
- Two $2 \times 4$ s may be nailed together with a block between them and a $2 \times 4$ centered on the wide side (Figure 6-33, C).
- A $2 \times 4$ may be nailed and centered on the face side of a $2 \times 6$, with a horizontal bridging nailed behind them to give support and stiffness (Figure 6-33, D).


## Double T-Posts

When a partition is finished on one side only, the partition post used is a simple stud, set in the outside wall, in line with the side of the partition wall, and finished as shown in Figure 6-34, page 6-26. These posts are nailed in place along with the corner posts. The exact position of the partition walls must be determined before the posts are placed. When walls are more than 4 inches thick, wider timber is used.

In special cases (for example, where partition walls cross), a double T-post is used. It is made as described above, and by nailing another $2 \times 4$ to the opposite wide side, as shown in Figure $6-34, A, B$, and C (C is the most common).

## STUDS

After the sills, plates, and braces are in place and the window and door openings are laid out, the studs are placed and nailed with two 16d or 20d nails through the plates. The remaining studs are laid out on the sills or soles by measuring, from one corner, the distances the studs are to be set apart. Studs are normally spaced 12, 16, or 24 inches on center, depending upon the outside and


Figure 6-32. Corner-post construction using both 2-inch and 4-inch lumber inside finish material. If vertical
siding is used, studs are set wider apart since the horizontal girts between them provide a nailing surface.

To double the post of the door opening, the outside studs are first placed into position and nailed securely. Then short studs (or trimmers) the size of the vertical opening are cut and nailed to the inside face of the outside studs as shown in Figure 6-35 on the sole plate.

The sill of a window opening must be framed. This sill is specified single or double. When it is double, the top header is nailed to the opening studs at the correct height and the trimmer next. The sill headers are toenailed to the trimmer. The door header is framed as shown in Figure 6-35. The jack stud rests on the sole plate.

## GIRTS

Girts are always the same width as the studs and are flush with the face of the stud, both outside and inside. They are used in hasty construction when the outside walls are covered with vertical siding. Studs are placed from 2 to 10 feet apart, with girts spaced about 4 feet apart, running horizontally between them. The vertical siding acts in the same way as the studs and helps carry the weight of the roof. This type of construction is used extensively in the TO.

## TOP PLATE AND SOLE PLATE

The top plateties the studding together at the top and forms a finish for the walls. It supports the lower ends of the roof rafters. The top plates serve as connecting links between the wall and the roof, just as the sills and girders are connecting links between the floors and the walls. The plate is made up of one or two pieces of framing lumber the same size as the studs.

If the studs at the end of the building extend to the rafters, no plate is used at the end of the building. When used on top of partition walls, the plate is sometimes called the cap. Where the plate is doubled, the first plate or bottom section is nailed with 16d or 20d nails to the top of the corner posts and to the studs. The connection at the corner is made as shown in Figure 636. After the single plate is nailed securely and the corner braces are nailed into place, the top part of the plate is nailed to the bottom section with 10d nails. The plate may be nailed over each stud or spaced with two nails every 2 feet. Care must be taken to make sure all joints are staggered. The edges of the top section and the corner joints are lapped.

All partition walls and outside walls are finished either with a $2 \times 4$ or with a piece of lumber the same thickness as the wall. This lumber is laid horizontally on the floor or joists. It carries the bottom end of the studs, and is called the sole or sole plate The sole should be nailed with two 16d or 20d nails at each joist it crosses. If it is laid lengthwise on top of a girder or joist, it should be nailed with two nails every 2 feet.

## BRIDGING

Frame walls are bridged, in most cases, to make them more sturdy. There are two methods of bridging-horizontal or diagonal (Figure 6-37).

Horizontal bridging is nailed between the studs horizontally and halfway between the sole and top plates. This bridging is cut to lengths that correspond to the distance between the studs at the bottom. Such bridging not only stiffens the wall but also helps straighten studs.

## Diagonal

Diagonal bridging is nailed between the studs at an angle. It is more effective than the horizontal type since it forms a continuous truss and keeps the walls from sagging. Whenever possible, interior partitions and exterior walls should be bridged alike.

## PLUMBED POSTS AND STRAIGHTENED WALLS

After the corner post, T-post, and intermediate wall studs have been nailed to the plates or girts, the walls must be plumbed and straightened so that permanent braces and rafters may be installed. This is done by using a level or plumb bob and a chalk line.


Figure 6-34. Partition posts

Plumbing Posts

There are two methods for plumbing posts.
Method 1. To plumb a corner with a plumb bob-
Step 1. Attach a string to the bob. The string should be long enough to extend to or below the bottom of the post.

Step 2. Lay a rule on top of the post so that 2 inches of the rule extend over the post on the side to be plumbed.

Step 3. Hang the bob line over the rule so that the line is 2 inches from the post and extends to the bottom of it, as shown in Figure 6-38.

Step 4. With another rule, measure the distance from the post to the center of the line at the bottom of the post. If it does not measure 2 inches, the post is not plumb.

Step 5. Move the post inward or outward until the distance from the post to the center of the line is exactly 2 inches, then nail the temporary brace in place.

Step 6. Repeat this procedure from the other outside face of the post. The post is then plumb.

## NOTE: This process is carried out for each corner post of the building. If a plumb bob or level is not available, use a rock, half-brick, or small piece of metal.

Method 2. An alternative method of plumbing a post is shown in the inset in Figure 6-38. 1b use this method-

Step 1. Attach the plumb-bob string securely to the top of the post to be plumbed. Be sure that the string is long enough to allow the plumb bob to hang near the bottom of the post.

Step 2. Use two blocks of wood, identical in thickness, as gauge blocks.

Step 3. Tack one block near the top of the post between the plumb-bob string and the post


Figure 6-36. Top-plate and sole-plate construction
(gauge block 1).
Step 4. Insert the second block between the plumb-bob string and the bottom of the post (gauge block 2).

Step 5. If the entire face of the second block makes contact with the string, the post is plumb.

## Straightening Walls

The following procedure is carried out for the entire perimeter of the building. Inside partition walls should be straightened the same way (Figure 6-39).

Step 1. Plumb one corner post with a level or a plumb bob. Nail temporary braces to hold the post in place. Repeat this procedure for all corner posts.

Step 2. Fasten a chalk line to the outside of one corner post at the top and stretch the line to the corner post at the opposite end of the building. Then fasten the line to this post.

Step 3. Place a 3/4-inch block under each end of the line for clearance.

Step 4. Place temporary braces at intervals small enough to hold the wall straight.


Figure 6-37. Types of wall bridging

Step 5. Nail the brace when the wall is far enough away from the line to permit a 3/4-inch block to slide between the line and the plate.

## BRACING

Bracing is used to stiffen framed construction and make it rigid. Bracing may be used to resist winds, storms, twists, or strains. Good bracing keeps corners square and plumb. Bracing prevents warping, sagging, and shifting that could otherwise distort the frame and cause badly fitting doors and windows and cracked plaster. The three methods commonly used to brace frame structures are letin, cut-in, and diagonal-


Figure 6-38. Plumbing a post
sheathing bracings (Figure 640).

## Let-In Bracing

Let-in bracing is set into the edges of studs, flush with the surface. The studs are always cut to let in the braces; the braces are never cut. Usually 1 $x 4$ or $1 \times 6$ s are used, set diagonally from top plates to sole plates, or between top or sole plates and framing studs.

## Cut-In Bracing

Cut-in bracing is toenailed between studs. It usually consists of $2 \times 4 \mathrm{~s}$ cut at an angle to permit toenailing. They are inserted in diagonal progression between studs running up and down from corner posts to the sill or plates.


Figure 6-39. Straightening a wall

## Diagonal-Sheathing Bracing

The strongest type of bracing is diagonal sheathing. Each board braces the wall. If plywood sheathing $5 / 8$ inch thick or more is used, other methods of bracing may be omitted.

## EXTERIOR WALLS

The exterior surfaces of a building usually consist of vertical, horizontal, or diagonal sheathing and composition, sheet metal, or corrugated roofing. However, in TOs, those materials are not always available and substitutes must be provided. Concrete blocks, brick, stone rubble, metal, or earth may be substituted for wood in treeless regions. In the tropics, improvised siding and roofs can be made from bamboo and grasses. Roofing felt, sandwiched between two layers of light wire mesh, may serve for wall and roof materials where the climate is suitable. Refer to TMs 5-302-1 and 5-302-2 for details on substitute, expedient, and improvised construction.

The following paragraphs cover the types of sheathing, siding, and building paper that may be used.

## Sheathing

Sheathing is nailed directly onto the framework of the building. It is used to strengthen the building; provide a base wall onto which the finish siding can be nailed; act as insulation; and, in some cases, be a base for further insulation. Some of the common types of sheathing are-

- Wood, 1 inch thick by $6,8,10$, or 12 inches wide of No. 1 common square or matched-edge material.
- Gypsum board, $1 / 2$ inch thick by 4 feet wide and 8 feet long.
- Fiberboard, $25 / 32$ inch thick by 2 or 4 feet wide and $8,9,10$, or 12 feet long.
- Plywood, $1 / 4,3 / 8,1 / 2$, or $5 / 8$ inches thick by 4 feet wide and $8,9,10$, or 12 feet long.


Figure 6-40. Three methods of bracing

Wood. Wood wall sheathing comes in almost all widths, lengths, and grades. However, it is normally 6 to 12 inches wide and $3 / 4$ inch thick. Lengths are selected for economical use and the sheathing is either square- or matched-edge. Sheathing 6 or 8 inches wide should be nailed with two 8d nails at each stud crossing. Wider boards should be nailed with three 8d nails. It is laid on tight, with all joints made over the studs. It may be nailed on horizontally or diagonally (Figure 6-41); however, diagonal application adds much greater strength to the structure. If the sheathing is to be put on horizontally, start at the foundation and work toward the top. If it is to be put on diagonally, start at a bottom corner of the building and work toward the opposite wall.

Gypsum Board. This type of sheathing is made by casting a gypsum core into a heavy, waterresistant, fibrous envel ope. The long edges of the $4 \times 8$ boards are tongue and grooved. Each board is $1 / 2$ inch thick. Gypsum board is generally used with wood siding. Gypsum board should be nailed with 13/4- or 2-inch galvanized roofing nails spaced 7 inches on center. Gypsum board can be nailed (together with the wood siding) directly to the studs (Figure 6-42). Gypsum sheathing is fireproof, water resistant, and windproof. It does not warp or absorb water and does not require the use of building paper.


Figure 6-41. Horizontal and diagonal sheathing

Plywood. Plywood is highly recommended for wall sheathing (Figure 6-42). It adds a lot more strength to the frame than using diagonally applied wood boards. When this sheathing is used, corner bracing can be omitted. For this reason and because of their large size, weight, and stability, plywood panels are faster and easier to apply. Plywood provides a tight, draftfree installation of high insulation value.

The minimum thickness of plywood wall sheathing should be $1 / 4$ inch for 16 -inch stud spacing, and $3 / 8$ inch for 24 -inch stud spacing. The panels should be installed with the face grain parallel to the studs. A little more stiffness can be gained by

installing them across the studs, but this requires more cutting and fitting. Use 6d common nails for $1 / 4-$, $3 / 8$-, and $1 / 2$-inch panels. At the edges of the panels, space the nails not more than 6 inches on center; elsewhere, not more than 12 inches on center.

## Siding

The siding for exterior walls should be decay-resistant, hold tight at the joints, and take and hold paint well.

Wood Siding. Wood siding should be decay-resistant, well-seasoned lumber. It should hold tight at the joints and take and hold paint well. It ranges from $1 / 2$ to $3 / 4$ inch thick by 12 inches wide.

Vertical Wood Siding. Vertical wood siding (Figure 6-43) is nailed securely to girts with 8d or 10d nails. The cracks are covered with wood strips called battens. To make this type of wall more weatherproof, some type of tar paper or light roll roofing may be applied between the siding and the sheathing.

Horizontal Wood Siding Horizontal wood siding (Figure 6-43) is cut to various patterns and sizes to be used as the finished outside surface of a structure. There are two types bevel ed siding and drop siding (Figure 6-43).

Beveled. Beveled siding is made with beveled boards, thin at the top edge and thick at the butt. It is the most common form of wood siding. It comes in 1 inch for narrow widths, and 2 inches and over for wide types. Beveled siding is usually nailed at the butt edge, through the top edge of the board below. Very narrow siding is quite often nailed near its thin edge, like shingles. It is nailed to solid sheathing over which building paper has been attached. Window and door casings are first framed. The siding butts are put against the edges of these frames. Corners may be mitered, or the corner boards may first be nailed to the sheathing. Siding is then fitted against the edges.

Drop. Drop siding is used as a combination of sheathing and siding or with separate sheathing. It comes in a wide variety of face profiles and is either shiplapped or tongue and grooved. If used as a combined sheathing and siding material, tongue-and-groove lumber is nailed directly to the studs with the tongue up. When sheathing is not used, the door and window casings are set after the siding is up. If sheathing is first used and then building paper is added, drop siding is applied with beveled siding, after the window and door casings are in place.

Corrugated-Metal Siding. Corrugated metal is often used as wall cover since it requires little framing, time, and labor. It is applied vertically and nailed to girts. Nails are placed in the ridges. Sheathing can be used behind the iron with or without building paper. Sincetar paper used behind metal will cause the metal to rust, a resin-sized paper should be used.


Figure 6-43. Vertical and horizontal wood siding

Vinyl and Aluminum Siding. Vinyl and aluminum sidings are popular, low-maintenance, low-cost wall covering. They can be backed with polystyrene or other board reinforcement, both to give the siding a strong base and an insulating R factor value.

Figure 6-44, page 6-34, shows the most common vinyl and aluminum sidings and installation accessories. Some variations exist between manufacturers, but the basic rules for installation are universal. They are-

- Nail in the center of slots.
- Do not nail tightly, leave loose for contracting and expanding.
- Leave at least $1 / 4$-inch clearance at all stops.
- Do not stretch tight.
- Strap and shim all uneven walls.

Step 1. Place outside and inside corners with the bottom of the trim even with the area to weatherproof. Use a level or transit to maintain a constant horizontal line.

Step 2. Using a level, transit, or chalk line, place the bottom of the starter strip level with the bottom of the corner trim. The starter strip will butt the edge of the trim.

Step 3. Snap the bottom of the siding onto the starter strip and slide it tight into the corner trim, then out $1 / 4$ inch to allow for expansion and contraction of materials in changing temperatures. Nail with roofing nails, 16 inches on center, in the center of the slot, without driving the nails home (leaving approximately $1 / 16$ of an inch between the nail head and the wall sheathing).

Step 4. Attach additional pieces of siding in a like manner, except the additional pieces will be placed on top of earlier placed pieces (as top end and bottom ends, like male and female ends in tongue-and-groove materials). Lap tight, then pull away $1 / 4$ inch.


Figure 6-44. Vinyl and aluminum sidings

## NOTE: When ending a 'run" into a corner or a J -channel, cut so that installation is $1 / 4$ inch from butt to trim.

Step 5. Install J -channels on surfaces where the siding run breaks (as in a window or door). TheJ -channel provides a weatherproof surface.

On vertical breaks, butt the siding as described in the previous paragraph. On horizontal breaks, install the undersill trim inside the J -channel. The undersill trim is a fastening device. On surfaces such as the top of the door or window trim, this channel will hold pieces of siding that were cut (removing the part of siding that "snaps" onto the top of previous pieces) tight, keeping them from flapping in the breeze. On surfaces such as where the siding butts into the soffit or below windows, a slotting tool is used to pierce the part of the siding that slides into the undersill trim. This pierce pushes out part of the siding and forms a catch. This is used when siding is pushed into the undersill trim, providing fastening for the top of a section of siding where nailing is not possible.

## Building Paper

Building paper comes in several types. The most common type is resin-sized. It is generally red or buff in color (sometimes black). It comes in rolls, usually 36 inches wide; each roll containing 500 square feet and weighing 18 to 50 pounds. Normally, this building paper is not waterproof.

Another type is heavy paper saturated with a coal-tar product, sometimes called sheathing paper. This type is waterproof and insulates against heat and cold. In wood-frame buildings to
be covered with siding, shingles, or iron, building paper is used to protect against heat, cold, or dampness. Building paper is applied horizontally from the bottom of the wall, and nailed with roofing nails at the laps. Overlapping the paper helps water runoff. Care must be taken not to tear the paper. The waterproof paper is also used in the built-up roof when the roof is nearly flat. Several layers are used, with tar between the layers.

## CEILINGS

Ceiling joists form the framework of the ceiling of the room. They are usually lighter than floor joists but must be large enough and strong enough to resist bending and buckling.

Ceiling joists are usually installed 16 inches or 24 inches on center, starting at one side of the building and continuing across, parallel to the rafters (Figures 6-45 and 6-46). Extra joists, if needed, may be placed without affecting the spacing


Figure 6-46. One method of bracing attic plate of the prime joists.

Selecting and installing the ceiling joists are much the same as for floor joists. Ceiling joists are nailed to both the plates and the rafters, if possible, and lapped and nailed over bearing partitions. J oists that lie beside rafters on a plate are cut at the same pitch as the rafter, flush with the top of the rafter. J oists are installed crown or camber up.

## WALL OPENINGS

In addition to doors and windows (Chapter 8), other wall openings are needed.

## STOVEPIPES

Stovepipes may extend outside a building through a side wall to eliminate the need for flashing and waterproofing around the pipe (Figures 6-47 and $6-48)$. The opening should be cut in an area selected to avoid cutting studs, braces, plates, or other structural members. Sheathing must be cut back in a radius 6 inches greater than that of the pipe. Safety thimbles or other insulation must be used on the inside and outside of the


Figure 6-45. Built-up plate supporting joist and roof rafters
sheathing. Sheet metal insulation may be constructed and used as a single insulator on the outside.

Make the opening for the stovepipe as follows:
Step 1. Cut a hole through the sheet metal where the stovepipe will penetrate.
Step 2. Mark a circle on the metal $1 / 2$ inch larger in diameter than the pipe. Then make another circle within this circle, with a diameter 2 inches less than the diameter of the first.

Step 3. With a straightedge, draw lines through the center of the circle from the circumference. These marks should be from $1 / 2$ to $3 / 4$ inch apart al ong the outer circumference.

Step 4. Cut out the center circle, then cut to the outside of the circle along the lines drawn.
Step 5. After the lines have been cut, bend the metal strips outward at a $45^{\circ}$ angle.


Figure 6-47. Framing for stovepipe

Step 6. F orce the pipe through the hole to the desired position.

## NOTE: Very little water will leak around this joint.

## VENTILATORS

Ventilation is necessary to prevent condensation in buildings. Condensation may occur in the walls, in the crawl space under the structure, in the basement, on windows, and in many other places. Condensation is most likely to occur during the first six to eight months after a building is built and in extreme cold weather when interior humidity


Figure 6-48. Installing stovepipe
is high. Proper ventilation under the roof allows moisture-laden air to escape during the winter heating season and allows the hot, dry air of the summer season to escape. The upper areas of a structure are usually ventilated by louvers or ventilators. (Types of ventilators are shown in Figure 6-49.)

## Upper Structure

One of the most common methods of ventilating is to use wood or metal louver frames. There are many types, sizes, and shapes of louvers.

Determine the size and number of ventilators by the size of the area to be ventilated. One square foot of vent should be placed for each 150 square feet of floor space without soffit vents and for each 300 square feet of floor space with soffit vents. The minimum net open area should be $1 / 4$ square inch per square foot of ceiling area.

Louver frames are usually 5 inches wide. The back edge of the frame should be rabbeted out for a screen, a door, or both. Louvers have $3 / 4$ - inch slats, which are spaced about $13 / 4$ inches apart. The slats should have sufficient slant or slope to prevent rain from driving in. For the best results, upper-structure louvers should be placed as near to the top of the gable as possible.


Figure 6-49. Types of ventilators

## Crawl Spaces

Crawl spaces under foundations (of structures without basements) should be well ventilated. Air circulation under the flooring prevents excessive condensation which causes warping, swelling, twisting, and rotting of the lumber. The crawl space ventilators are usually called foundation louvers. They are set into the foundation as it is built. A good foundation vent should be equipped with a copper or bronze screen and adjustable shutters for opening and closing the louver. Louver sizes should be figured on the same basis as upper-structure louvers $1 / 4$ square inch for each square foot of under-floor space.

## STAIRWAYS

Stair work is made up of the framing on the sides, known as stringers (or carriages), and the steps known as treads. Sometimes risers are framed into the stairs at the back of the treads. The stringers (or carriages) are 2 to 3 inches thick and 8 or more inches wide. They are cut to form the step of the stairs.

There are usually three stringers to a stair if stairs are more than 36 inches wide-one at each of the two outer edges and one at the center. Floor joists must be properly framed around the stairwell (or well hole) to have enough space for the stair framing and the finished trim.

Step stringers are fastened at the top and bottom as shown in Figures $6-50$ and $6-51$. These figures al so show the foundation and give the sizes of the step treads, as well as installation methods and post construction. The types of steps shown are the most common in field construction.


Figure 6-50. Typical stairway

## STAIRWAY FRAMING

To frame simple, straight, string stairs (Figure 6-52, ) -
Step 1. Take a narrow piece of straight stock, called a story pole, and mark on it the distance from the lower-floor to the upper-floor level. This is the lower-room height, plus the thickness of the floor joists and the rough and finished flooring. It is also the total rise of the stairs. Keep in mind that a flight of stairs forms a right triangle. The rise is the height of the triangle, the run is the base, and the length of the stringers is the hypotenuse.


Figure 6-51. Step construction
Step 2. Set dividers at 7 inches, the average distance from one step to another.
Step 3. Step off this distance on the story pole.

Step 4. Adjust the divider span slightly if this distance will not divide evenly into the length of the story pole. Step off this distance again.

Step 5. Continue this adjusting and stepping off until the story pole is marked off evenly. 1he span of the dividers must be near 7 inches. This represents the rise of each step.

Step 6. Count the number of spaces stepped off evenly by the dividers on the story pole. This will be the total number of risers on the stairs.

Step 7. M easure the length of the stairwell opening for the length of the run of the stairs. This length may also be obtained from the plans. The stairwell-opening length forms the base of a right triangle. The height and base of the


Figure 6-52. Complete stairway detail

## RISERS AND TREADS

To determine the width of each tread, divide the number of risers less one - since there is always one more riser than tread-into the run of the stairs. This number is used on the steel square in laying off the run and rise of each tread and riser on the stringer stock. These figures will be about 7 and 10 inches, respectively, since the ideal run and rise totals 17 inches. Lay off the run and rise of each step on the stringer stock equal to the number of risers previously determined by dividing the story pole into equal spaces. The height, base, and hypotenuse of the right triangle are now complete.

The following are two rules of thumb that may be used to check the dimensions of risers and treads:

- Riser height + tread width = between 17 and 19 inches.
- Riser height $x$ tread width $=$ between 70 and 75 inches.

If the sum of the height of the riser and the width of the tread falls between 17 and 19 inches and the product of the height of the riser and the width of the tread equals between 70 and 75 inches, the design is satisfactory

The roof's main purpose is to keep out the rain, cold, or heat. It must be strong enough to with stand high winds; sloped to shed water; and, in areas of heavy snow, it must be constructed morerigidly to bear the extra weight. This chapter will familiarize carpenters with the most common types of roof construction and materials. This chapter al so covers reroofing.

## ROOF FRAMING

Roofs for TOs are chosen to suit the building; the climate; the estimated length of time the building will be used; and the material, time, and skill required for construction. TO constraints dictate simple design as shown in Figure 7-1.


Figure 7-1. Types of roofs

## ROOFING TERMS

When framing a roof (Figure 72), carpenters must be familiar with commonly used roofing terms (Figures 7-3 and 7-4).

RAFTERS
Rafters make up the main framework of all roofs. They are inclined members spaced from 16 to 48 inches apart. They vary in size, depending on length and spacing. The tops of inclined


Figure 7-2. Framing a roof rafters are fastened to the ridge or another rafter, depending on the type of roof. Rafters rest on the top wall plate.

Rafters are nailed to the plate, not framed into it. Some are cut to fit the plate, while in hasty construction they are merely laid on top of the plate and nailed in place. They may extend a short distance beyond the wall to form the eaves and protect the sides of the building.

## Types of Rafters

Examples of most types of rafters are shown in Figure 7-3. The four types are -
Common Rafters. These are framing members that extend at right angles from the plate line to the roof ridge. They are called common rafters because they are common to all types of roofs and are used as the basis for laying out other types of rafters.

Hip Rafters. These are roof members that extend diagonally from the corner of the plate to the ridge.


Figure 7-3. Common roof-framing terms

Basic Triangle. The basic triangle is the most elementary tool used in roof framing. When framing a roof, the basic right triangle is formed by the horizontal lines (or run), the rise (or altitude), and the length of the rafter (the hypotenuse). Any part of the triangle can be computed if the other two parts are known. Use the following equation:

The square of the hypotenuse of a right triangle is equal to the sum of the squares of the two sides. In roofing terms-

$$
\text { Rafter length }{ }^{2}=\text { run }^{2}+\text { rise }^{2}
$$

Rise. The rise of a rafter is the vertical (or plumb) distance that a rafter extends upward from the plate.

Span of a Roof. The span of any roof is the shortest distance between the two opposite rafters' seats.
Cut of a Roof. The cut of a roof is the rise over the run (such as $4 / 12$ roof) or the pitch of the roof.
Horizontal Line. A horizontal line is one level with the building foundation,
Line Length. In roof framing, line length is the hypotenuse of a triangle whose base is the run and whose altitude is the total rise.

Total Rise. The total rise is the vertical distance from the wall plate to the top of the ridge.
Run. Run always refers to the level distance any rafter covers-normally, one-half the span.
Unit of Run (or unit of measurement). Unit of measurement, 1 foot (or 12 inches), is the same for the roof as for any other part of the building. Using this common unit of measurement, the framing square is used in laying out large roofs (Figure 7-5, page 7-4).

Pitch. Pitch signifies the amount that a roof slants and the ratio of rise (in inches) to run (inches). Using this method, 4,6 , or 8 inches rise per foot of run would give a pitch of $4-12,6-12$, or $8-12$. (Figure 7-6, page 7-4, shows how to determine roof pitch.)

Plumb Line. The line formed by the cord on which the plumb bob is hung.
Bird's Mouth. A cutout, near the bottom of a rafter, that fits over the top plate. The cut that fits the top of the plate is called the seat; the cut for the side of the plate is called the heel.

Overhang. The part of a rafter that extends past the outside edge of the walls of a building. When laying out a rafter, this portion is in addition to the length of a rafter and is figured separately. The overhang is often referred to as the tailpiece.

Plate. The wall-framing member that rests on the top of the wall studs.
Ridge. The highest horizontal roof member. It ties the rafters together at the upper end.

Figure 7-4. Roofing terms
Valley Rafters. These rafters extend from the plate to the ridge al ong the lines where two roofs intersect.

J ack Rafters. These are a common rafter. The three kinds of jack rafters are the -

- Hip jack, which extends from the plate to the hip rafter.
- Valley jack, which extends from the ridge of the valley rafter.
- Cripplejack, which is placed between a hip rafter and a valley rafter. The cripple jack rafter is also part of a common rafter, but it touches neither the ridge of the roof nor the rafter plate.


## Collar Tie and Beam

A collar tie or beam (Figure 7-7) is a piece of stock (usually $1 \times 4,1 \times 6, I \times 8$, or $2 \times 4$ ) fastened in a horizontal position to a pair of rafters between the plate and the ridge of the roof. This type of beam keeps the building from spreading. Most codes and specifications require them to be 5 feet apart or every third rafter, whichever is less. Collar ties are nailed to common rafters with four 8d nails to each end of a 1-inch tie. If 2-inch material is used for the tie, they are nailed with three $16 d$ nails at each end. This type of bracing is used on small roofs where no ceiling joists are used


Figure 7-5. Use of framing square
and the building is not wide enough to require a truss.
In small roofs that cover only narrow buildings in which the rafters are short, there is no need for interior support or bracing. In long spans, the roof would sag in the middle if it were not strengthened in some way. To support long rafters, braces or other types of supports must be installed.

## Rafter Layout

Rafters must be laid out and cut with slope, length, and overhang exactly right so that they will fit when placed in the roof.

## Scale or Measurement

Method. The carpenter should first determine the length of the rafter and the length of the lumber from which the rafter may be cut.


Figure 7-6. Determining roof pitch If he is working from a roof plan, he learns the rafter lengths and the width of the building from the plan. If no plans are available, the width of the building must be measured.

Step 1. To determine the rafter length, first find one-half of the horizontal distance (total run) of the rafter. The amount of rise per foot will not be considered yet. (For example, if the building is 20 feet wide, half of the span will be 10 feet. See the example below.)

Step 2. After the length has been determined, lay the timber on sawhorses (saw


Figure 7-7. Collar tie or beam benches), with the crown or bow (if it has any) as the top side of the rafter. If possible, select a straight piece for the pattern rafter. If a straight piece is not available, have the crown away from the person laying out the rafter.

Step 3. Hold the square with the tongue in your left hand, the blade in your right, and the heel toward your body. Place the square as near the upper end of the rafter as possible. (For example, in Figure 7-8, page 7-6 (step 1) the figures 8 on the tongue and 12 on the blade are placed along the timber edge that is to be the top edge of the rafter.)

Step 4. Mark along the outside tongue edge of the square, which will be the plumb cut at the ridge.
Step 5. Since the length of the rafter is known to be 12 feet and $1 / 6$ inch, measure the distance from the top of the plumb cut and mark it on the timber. Hold the square in the same manner with the 8 mark on the tongue directly over the 12 -foot $1 / 6$-inch mark. Mark along the tongue of the square to give the plumb cut for the seat (Figure 7-8, step 2).

Step 6. Measure off, perpendicular to this mark, the length of overhang along the timber. Make a plumb-cut mark in the same way, keeping the square on the same edge of the timber (Figure 7-8, step 3). This will be the tail cut of the rafter. Often, the tail cut is made square across the timber.

Step 7. The level cut or width of the seat is the width of the plate measured perpendicular to the plumb cut, as shown in Figure 78 , step 4 . Using a try square, square the lines down on the sides from all level and plumbcut lines. Now the rafter is ready


Figure 7-8. Scale or measurement method to be cut (Figure 7-8, step 5).

EXAMPLE - Rafter layout, step 1: determine rafter length
As an example, use a rise per foot of 8 inches. To determine the approximate overall length of the rafter, measure on a steel carpenter square the distance between 8 on the tongue and 12 on the blade, because 8 is the rise and 12 is the unit of run. This distance is $145 / 12$ inches. This represents the line length of a rafter with a total run of 1 foot and a rise of 8 inches. Since the run of the rafter is 10 feet, multiply 10 by the line length for 1 foot. The answer is $1442 / 12$ inches, or 12 feet and $1 / 6$ inch. The amount of overhang (normally 1 foot) must be added if an overhang is to be used. This makes a total of 13 feet, which is an odd length for timber. Use a 14 -foot timber.

Rafter length $=$ total run $\times$ line length + overhang
$10 \times 145 / 12$ inches $=1442 / 12$ inches $=12$ feet +1 foot $=13$ feet

Step-Off Method. The rafter length of any building may be determined by "stepping it off by successive steps with the square, as follows:

Step 1. Step off the same number of steps as there are feet in the run. For example, if a building is 20 feet 8 inches wide, the run of the rafter would be 4 inches over 10 feet.

Step 2. This 4 inches is taken care of in the same manner as the full-foot run; that is, with the square at the last step position, make a mark on the rafters at the 4-inch mark (Figure 7-9, step 1).

Step 3. With the square held for the same cut as before, make a mark along the tongue. This is the line length of the rafter. The seat cut and hangover are made as described above and shown in Figure 7-9, steps 2, 3, and 4.

NOTE: When laying off rafters by any method, be


Figure 7-9. Step-off method sure to recheck the work carefully. When two rafters have been cut, it is best to put them in place to see if they fit. Minor adjustments may be made at this time without serious damage or waste of material.

Table Method. The framing square may have one or two types of rafter tables on the blade. One type gives both the line length of any pitch of rafter per foot of run and the line length of any hip or valley rafter per foot of run. The difference in length of the jack rafter, spaced 16 or 24 inches (on center), is also shown in the table. Where the jack, hip, or valley rafter needs side cuts, the cut is given in the table. The other type of table gives the actual length of a rafter for a given pitch and span.

Rafter Table, Type 1. Type 1 (Figure 7-10) appears on the face of the blade. This type is used to determine the length of the common, valley, hip, and jack rafters and the angles at which they
must be cut to fit at the ridge and plate.
To use the table, the carpenter must first know what each figure represents.

- The row of figures in the first line represents the length of common rafters per foot of run, as the title at the left-hand end of the blade indicates.
- Each set of figures under each inch division mark represents the length of rafter per foot of run, with a rise corresponding to the number of inches over the number. (F or example, under the 16 -inch mark appears the number 20.00 inches. This number equals the length of a rafter with a run of 12 inches and a rise of 16 inches. Under the 13 -inch mark appears the number 17.69 inches, which is the rafter length for a 12-inch run and a 13-inch rise.) See the Type 1 layout example below.


## NOTE: The other five lines of figures in the table will not be discussed, as they are seldom used in the $T O$.

The remaining procedure for laying out the rafters after the length has been determined is as described previously.

## EXAMPLE - Rafter layout, table method, Type 1

NOTE: To use the table for laying out rafters, the width of the building must first be known.
Suppose the building is 20 feet 8 inches wide and the rise of the rafters is to be 13 inches per foot of nun. The total run of the rafter will be 10 feet 4 inches (or $101 / 3$ feet). Look at the first line of Figure 7-10. Under the 13-inch mark appears the number 17.69, which is the length (in inches) of a rafter with a run of 1 foot and a rise of 13 inches. To find the length of this rafter, use the following formula:

Rafter length $=$ total run $x$ length of common rafter per ft of run +12
$101 / 3 \times 17.69$ inches $=182.79$ inches
182.79 inches $+12=153 / 12$ feet


Figure 7-10. Rafter table, Type I

Rafter Table, Type 2. Type 2 (Figure 7-11, page 7-8) appears on the back of the blade of some squares. This shows the run, rise, and pitch of rafters of the seven most common pitches of roof.


Figure 7-11. Rafter table, Type 2

The figures are based on the horizontal measurement of the building from the center to the outside.

The rafter table and the outside edge of the back of the square, both the body and tongue, are in twelfths. (The inch marks may represent twelfths of an inch or twelfths of a foot.) This table is used in connection with the marks and figures on the outside edge of the square. At the left end of the table are figures representing the run, the rise, and the pitch:

- In the first column, the figures are all 12 (12 inches or 12 feet). They represent the run of 12 .
- The second column of figures represents various rises.
- The third column of figures (in fractions) represents the various pitches.

These three columns of figures show that a rafter with a run of 12 and a rise of 4 has a $1 / 6$ pitch, 12 and 6 has a $1 / 4$ pitch, and 12 and 12 has a $1 / 2$ pitch. For example, use this scale for -

- A roof with a $1 / 6$ pitch (or the rise of $1 / 6$ the width of the building) and a run of 12 feet. Find $1 / 6$ in the table, then follow the same line of figures to the right until directly beneath the figure 12. Here appear the numbers $12,7,10$, which is the rafter length required and which represents 12 feet 7 inches, and 10/12 of an inch. They are written as follows: 12 feet 7 10/12 inches.
- A roof with a $1 / 2$ pitch (or a rise of $1 / 2$ the width of the building) and a run of 12 feet. The rafter length is $16,11,6$, or 16 feet $116 / 12$ inches.
- A roof with a run of more than 23 feet. F or example, if the run is 27 feet, find the length for 23 feet, then find the length for 4 feet and add the two. The run for 23 feet with a pitch of $1 / 4$ is 25 feet $85 / 12$ inches. F or 4 feet, the run is 4 feet $58 / 12$ inches. The total run for 27 feet is 30 feet $21 / 12$ inches.


## NOTE: When the run is in inches, the rafter table reads inches and twelfths instead of feet and inches.

See the Type 2 rafter table layout example at the top of the next page.
After the length of the rafter has been found, the rafter is laid out as explained previously.

EXAMPLE - Rafter layout, table method, Type 2

If the pitch is $1 / 2$ and the run is 12 feet 4 inches, add the rafter length of a 12 -foot run to that of a rafter length of a 4 -inch run, as follows:

- For a run of 12 feet and $1 / 2$ pitch, the length is 16 feet $116 / 12$ inches.
- For a run of 4 inches and $1 / 2$ pitch, the length is $5,7,11$. In this case, the 5 is inches, the 7 is twelfths, and the 11 is $11 / 12$ of $1 / 12$, which is nearly $1 / 12$.
- Add it to the 7 to make it 8 , making a total of $58 / 12$ inches, then add the two lengths together.
- This sum is 17 feet $52 / 12$ inches.

Rafter lengths are given in the table. The overhang must be added. NOTE: When the roof has an overhang, the rafter is usually cut square to save time. When the roof has no overhang, the rafter cut is plumb, but no notch is cut in the rafter for a seat. The level cut is made long enough to extend across the plate and the wall sheathing. This type of rafter saves material, although little protection is given to the side wall.

## TRUSSES

A truss is a framed or jointed structure composed of straight members connected only at their intersections in such a way that if loads are applied at these intersections, the stress in each member is in the direction of its length. Straight, sound timber should be used in trusses. The types of trusses used in building construction are shown in Figure 7-12. (The Howe and Fink trusses are most commonly used.) Truss terms are listed in Figure 7-13, page 7-10.

Trusses are used for large spans to give wide, unobstructed floor space for such large buildings as shops and hangars. Sometimes small buildings are trussed to save material. These small trusses act as rafters and give the roof rigidity.

The web members of a truss divide it into triangles. The members indicated by heavy lines normally carry tensile stresses for vertical loads. Sometimes the top chords of these trusses slope slightly in one or two directions for roof drainage, but this does not change the type of truss. The necessary number of subdivisions, or panels, depends upon the length of the span and the type of construction.

## Truss Supports

Trusses are supported by bearing walls, posts, or other trusses. To brace a truss to a wall or post, knee braces are used as shown in Figure 7-14. These braces tend to make a truss of the entire building by tying the wall to the roof.

## Purlins

Purlins are used in roof construction to support corrugated sheet metal if it is used, or to support the sheathing of roofs framed with trusses.

- In small roofs, purlins are inserted between the rafters and nailed through the rafters.
- In large buildings where heavy trusses are used, the purlins are continuous members that rest
on the trusses and support the sheathing.
- In small buildings,
and small warehouses, $2 \times 4$ s are used for


Figure 7-12. Types of trusses
purling, with the narrow side up.

## Truss Layout

To lay out a truss, use Figure 7-15 and the following steps:
Step 1. Get the material to a level spot of ground where work benches will be almost level.
Step 2. Obtain from the blueprints the measurement of all pieces to be used in the truss.
Step 3. Lay out the length on the different sizes of timber and cut them accurately.
Step 4. After all lengths are cut, lay them in their correct position to form a truss.
Step 5. Nail them together temporarily.
Step 6. Lay out the location of all holes to be bored. Recheck the measurements for accuracy.
Step 7. Bore holes to the size called for on the print. Use a brace and bit or the woodborer that accompanies the air compressor. Bore holes perpendicular to the face of the timber.

Bottom Chord. A member that forms the lower boundary of the truss.
Top Chord. A member that forms the upper boundary of the truss,
Chord Member. A member that forms part of either the top or bottom chord.
Member. The component that lies between any adjacent joints of a truss; it can be of one or more pieces of structural material.

Web Member: A member that lies between the top and bottom chords.
Joint. Any point in a truss where two or more members meet; sometimes called a panel point.
Panel Length. The distance between any two consecutive joint centers in either the top or bottom chords.

Pitch. The ratio of the height of truss to the span length.
Height of Truss. The vertical distance at midspan from the joint center at the ridge of a pitched truss, or from the centerline of the top chord of a flat truss, to the centerline of the bottom chord.

Span Length. The horizontal distance between the centers of the two joints located at the extreme ends of the truss.

Figure 7-13. Truss terms
Step 8. After the holes have been bored, dismantle the truss and withdraw the nails.

## Truss Assembly

Assembling a truss after it has been cut and bored is simple (Figure 7-16). In most cases, timber connectors are used where different members of the truss join. Straight, sound timber should be used in trusses.

- Assemble the truss with the timber connectors in place.
- Place the bolts in the holes and tighten them.
- Place washers at the head and nut ends of each bolt.

Rafters are usually made into trusses, as shown in Figure 717. Two rafters are connected at the top, using a collar tie well nailed into both rafters. Before any ties or chords are nailed, the rafters should be spread at the lower end to


Figure 7-14. Knee braces
building. This is done by using a template or by measuring the distance between the seat cuts with a tape.

A $1 \times 6$ or $2 \times 4$ chord is nailed across the rafters at the seat cut to tie them together. This chord forms a truss with the two rafters. A hanger or vertical member of $1 \times 6$ is nailed to the rafter joint and extends to the chord at midpoint, tying the rafter to the chord.

In wide buildings where the joists or chords must be spliced and there is no support underneath, the rafter and joists support one another as shown in Figure 718.

If no additional bracing is needed, the truss is set in place on the plates. If additional bracing is needed, a knee brace is nailed to the chord. The knee brace forms a $45^{\circ}$ angle with the wall stud. For easier erection, the knee brace may be omitted until the rafter truss is set in place.

Rafter framing without the use of ridgeboards may be done rapidly by using a truss assembly jig or template. The template is laid out to form a


Figure 7-15. Truss layout


Figure 7-16. Truss assembly


Figure 7-17. Assembling a typical truss pattern conforming to the exact exterior dimensions of the truss.

Layout. Lay out a template as shown in Figure 7-19 and as follows:
Step 1. Measure and mark a straight line on any selected surface. Mark the exact length of the joists that will form the truss chord. This is baseline A.

Step 2. From the center of the baseline and at right angles to it, lay out a centerline (C) to form the leg of a right triangle, the base of which is half the length of the baseline (A), and the hypotenuse
of which (B) is the length of the rafter measured as indicated.
Step 3. Nail $2 \times 4 \times 8$ blocks flush with the ends of baseline $A$ and centerline $C$ as shown in Figure 7-19. Mark the centerline on the center jig blocks.

Assembly. Assemble with a template as shown in Figure 7-19 and as follows:
Step 1. Start the assembly by setting a rafter in the jig with the plate cut fitted over the jig block at one end of the baseline. The peak is flush with the centerline on the peak jig block. Nail a holding block outside the rafter at point D.

Step 2. Lay one $2 \times 4$ joist or chord in place across the base blocks.
Step 3. Lay two $2 \times 4$ rafters in place over the joist.
Step 4. Center one end of a $1 \times 6$ hanger under the rafter peak. Center the rafters against the peak block.

Step 5. Nail through the rafters into the hanger using six 8d nails.
Step 6. Line up one end of the chord.
Step 7. Nail through the rafter with $16 d$ nails.
Step 8. Line up the other end of the chord.
Step 9. Nail as above.
Step 10. Center the bottom of the hangers on top of the chord and nail with 8d nails.

## Installation of Trusses

After the rafters are assembled into trusses, they must be placed on the building (Figure 7-20, page 714). Assemble the first set of rafters either in the end section of the building or at the center. Raise rafter trusses into position (by hand) and nail them into place with 16d nails. (Temporary workbenches may be built for the workers to stand on while erecting trusses.) These trusses must be temporarily braced at the end section of the building until the sheathing is applied. K nee braces are not used on


Figure 7-18. Truss- or rafter-support detail every rafter truss unless
needed. Install trusses as follows:
Step 1. Mark the proper positions of all truss assemblies on the top plate. The marks must show the exact position on the face of all rafters (such as south or north).

Step 2. Rest one end of a truss assembly, peak down, on an appropriate mark on the top plate on one side of the structure.

Step 3. Rest the other end of the truss on the corresponding mark of the top plate on the other side of the structure.

Step 4. Rotate the assembly into position using a pole or rope.
Step 5. Line up and secure the rafter faces flush against the marks.
Step 6. Raise, align, and nail the three assemblies into position. Nail temporary $1 \times 6$ braces across these three assemblies. Repeat with the other assemblies as they are brought into position. Check the rafter spacing at the peaks as the braces are nailed on.

Step 7. Braces may be used as a platform when raising those trusses for which there is not enough room for rotation (Figure 7-21).


Figure 7-19. Laying out and assembling with a template

## ROOF OPENINGS

Major roof openings are those that interrupt the normal run of rafters or other roof framing. Such openings may be for ventilators, chimneys, trap-door passages, or skylight or dormer windows. Figure 7-22 shows roof-opening construction.

Roof openings are framed by headers and trimmers. Double headers are used at right angles to the rafters, which are set into the headers in the same way as joists in floor-opening construction. Trimmers are actually double rafter construction in roof openings. Nailing strips may be added if needed.

## ROOF DECKING

Procedures for installing plywood sheathing is similar to installing wall sheathing except it is laid perpendicular to the rafters and trusses.

## ROOF COVERINGS

Asphalt and asbestos-cement roof coverings are most frequently used on pitched-roof structures. Built-up roofing is used mainly on flat or nearly flat roofs.

## ASPHALT AND ASBE STOS-CEME NT ROOFING

Asphalt roofing comes in rolls (usually 3 feet wide) called rolled roofing, in rolled strips (usually 15 inches wide and 3 feet long), and as individual shingles. The type most commonly used is the flat strip, often called a strip shingle.

A $1 \times 3$ square-butt shingle is shown in Figure 7-23. This shingle should be laid 5 inches to the weather, meaning that 7 inches of each course should be overlapped by the next higher course. The lower, exposed end of a shingle is called the butt. The shingle shown in Figure 7-23 has a square butt divided into three tabs. Various other butt shapes are manufactured. Asbestos-cement roofing usually consists of individual shingles.

## Laying Asphalt Roofing

The first step in covering a roof is to erect a scaffold to a height which will bring the eaves about waist-high to a man standing on the scaffold.

Before any roof covering is applied, the roof sheathing must be swept clean and carefully inspected for irregularities, cracks, holes, or other defects. No roofing should be applied unless


Figure 7-21. Temporary bracing the sheathing boards are
absolutely dry.
An underlay of roofing felt is first applied to the sheathing. Roofing felt usually comes in 3 -foot-wide rolls and should be laid with a 2inch top lap and a 4-inch side lap.

Bundles of shingles should be distributed along the scaffold before work begins. There are 27 strips in a bundle of $1 \times 3$ asphalt strip shingles. Three bundles will cover 100 square feet.

After the first course at the eaves (the starter course) is laid by inverting the first course of shingles or the starter strip of mineral-surfaced roll roofing, each course that follows is begun by stretching a guideline or by snapping a chalk line from edge to edge. This positions the course.


Figure 7-22. Roof-opening construction

Figure 7-24 shows the method of laying a $1 \times 3$ asphalt strip-shingle roof. Strip shingles should be nailed with 1-inch copper or hot-dipped, galvanized roofing nails, two to each tab; this means six nails to each full strip. Nails should be placed about $61 / 2$ inches from the butt edges to ensure that each nail will be covered by the next course (blind-nailing) and driven through two courses.

An asbestos-cement roof is laid in about the same way as the asphalt strip shingles.

## Applying Shingles at Hips and Valleys

One side of a hip or valley shingle must be cut at an angle to obtain an edge line that will match the line of the hip or valley rafter. One way to cut these shingles is to use a pattern made as follows:

Select a piece of $1 \times 6$ material about 3 feet long. Determine the unit length of a common rafter in the roof. Set the framing square back up on the piece to the unit run of a common rafter on the tongue and the unit length of a common rafter on the blade, as shown in Figure 7-25, A. Draw a line along the tongue. Saw the piece along this line and use it as a pattern to cut the shingles as


Figure 7-23. Square-butt asphalt strip shingle

## Installing Flashing

Places especially susceptible to leakage in roofs and outside walls are made watertight by the installation of flashing. Flashing is sheets or strips of a watertight, rustproof material (such as galvanized sheet or sheet copper alloy for valleys and felt for hips). Flashing deflects water from places that are susceptible to leakage. The places in a roof most subject to leakage are the lines along which adjoining roof surfaces intersect (such as the lines followed by ridges, hips, and valleys) and the lines of intersection between roof surfaces and the walls of dormers, chimneys, skylights, and the like.

Ridge lines and hip lines naturally tend to shed water; therefore, they are only moderately subject to leakage. A strip of felt paper usually makes a satisfactory ridge or hip flashing. The ridge or hip is then finished as shown in Figure 7-26. Squares are made by cutting shingles into thirds. The squares are then blind-nailed to the ridge or hip as shown in


Figure 7-24. Laying an asphalt-shingle roof
Figure 7-26.


Figure 7-25. Laying out a pattern

Since water gathers in the roof valleys, they are more subject to leakage. Valley flashing varies with the manner in which the valley is to be finished. There are two common types of valley finish: the open valley and the dosed valley.

Figure 7-27 shows part of an open valley. The roof covering does not extend across the valley. The flashing consists of a prefabricated piece of galvanized iron, copper, zinc, or similar metal, with a splash rib or ridge down the center and a small crimp at the edges. The flashing is nailed down to the valley, with nails driven in the edges (outside the crimps), as shown in Figure 7-27.


Figure 7-26. Hip or ridge flashing Care must be taken not to drive nails through the flashing inside the crimps, to avoid leakage. Figure 7-28, page 7-18, shows an open valley using rolled roofing.

In the closed valley, the roof covering extends across the valley. Sheet metal flashing is cut into small sheets measuring about $18 \times 10$ inches, called shingletins. This flashing is laid under each course of shingles, along the valley, as the course is laid. After the first course of the double course at the eaves is laid, the first sheet of flashing is placed on top of it. The second course is laid over this one so that the metal is partly covered by the next course. This procedure is continued all


Figure 7-27. Open-valley flashing


Figure 7-28. Open-valley flashing details using roll roofing

## BUILT-UP ROOFING MATERIAL

The following building papers are used on a built-up roof. Their purpose is to prevent the seepage of bitumen through roof sheathing on which a built-up roof has been applied.

- Rosin paper is a felt paper, usually pale red, filled with rosin compound.
- Kraft paper is a light brown paper that is usually glazed.
- Sisal kraft consists of two layers of glazed kraft paper with a center section of sisal embedded in a black bituminous compound and laminated by heat and pressure.
- Roofing felt is a felt paper that has been saturated with a bituminous compound (heavy pitch or asphalt oils). The basic
ingredients are usually either asbestos or rag felts. The roll may vary from 32 to 36 inches wide. Weights for built-up roofing vary from 15 to 65 pounds per square. The 15pound felt is most commonly used because of its light weight.

A binder is used to bond the roofing felt together and form a watertight seal. Asphalt and coal tar are the two main types of bituminous binders used.


Figure 7-29. Vertical wall flashing Drying out of the binder causes deterioration of built-up roofs. If this did not happen, a built-up roof would last indefinitely. Asphalt is the preferred binder. It is used on roofs sloping up to 6 inches per foot ( $1 / 4$ pitch). Asphalt has a melting point of 350 to $410^{\circ}$. A roof covered with asphalt should be protected with a covering of slag, gravel, or other protective material. Tar has a lower melting point ( $300^{\circ}$ to $350^{\circ} \mathrm{F}$ ) than asphalt, so it will move more easily; therefore, it is not recommended for roofs having a slope of more than 3 inches per foot ( $1 / 8$ pitch).

Aggregate, crushed stone, or gravel from $1 / 4$ to $5 / 8$ inch in diameter is embedded in a coat of asphalt or tar to hold the roof covering down. It also prevents the binding from disintegrating because of the weather.

Gravel stops on slag or gravel-surfaced roofs, and metal-edge strips on smooth-surfaced built-up roofs are used to finish all exposed edges and eaves to prevent wind from getting under the edges and causing blowoffs. The gravel stop also prevents the loss of gravel or slag off the edge of the roof. The flashing flange of the gravel stop or edge strip is placed over the last ply of felt. It should be nailed securely to the roof deck and double felt stripped. Then the finished coat of bitumen and surfacing or cap sheet should be applied. The lip of the gravel stop should extend a minimum of $3 / 4$ inch above the roof deck. The lip of the edge strip should be a maximum of $1 / 2$ inch above the deck. Both should be securely fastened to the fascia board.

## RE ROOFING

This section provides information on reroofing for the following types of roofs: asphalt-shingle roofs, asphalt-prepared roll roofings, built-up roofs, slate roofs, tile roofs, asbestos-cement roofs, metal roofs, and wood-shingle roofs.

## ASPHALT-SHINGLE ROOFS

The following types of asphalt strip shingles are used for reroofing hospitals and mobilization-type buildings with pitched roofs. These shingles are applied directly over the existing roll roofings.

Standard-weight shingles should be four-tab, $10 \times 36$ inches, and intended for a 4 -inch maximum exposure. Weight per square ( 100 square feet) applied should be approximately 210 pounds. Shingles are fastened with 1 1/4- or 1 1/2-inch nails with heads having a minimum diameter of 3/8 inch. Zinc-coated nails are best.

Thick-butt shingles should be three-tab, $1 \times 3$ feet, and intended for a 5-inch maximum exposure. The entire surface of the shingles should be covered with mineral granules. The bottom part of each shingle, including the part intended to be exposed and a section at least 1 inch above the cutout sections, should be thicker than the remainder of the shingle. Weight per square applied should be approximately 210 pounds. Shingles are fastened with 1 1/2- or 1 3/4-inch nails with heads having a minimum diameter of 3/8 inch. Zinc-coated nails are best.

## Preparation of R oof Decks

The following steps assume that the roof decks are covered with smooth or mineralsurfaced, asphalt-prepared roofing and that the shingles will be applied directly over the existing roofing.

Step 1. Drive in all loose and protruding nails flush with the existing roll roofing.
Step 2. Cut out all vertical and horizontal buckles and wrinkles in the existing roofing. Nail down the edges of the cuts with $3 / 4$-inch or 1 -inch roofing nails so that the entire roof deck is smooth.

Step 3. If shingles are applied over smooth-surfaced roofing or over mineral-surfaced roofing which does not match the shingles, apply an 18-inch starting strip of mineral-surfaced roll roofing at the eaves. Use roofing surfaced with granules of the same type and color as the shingles.

Step 4. Before the strips are applied, unroll them carefully and lay them on a smooth, flat surface until they lie perfectly flat.

Step 5. Nail starter strips at the top at about 18-inch intervals. The lower edge, bent down and nailed to the edge of the sheathing board, should extend about $3 / 4$ inch beyond the edge of the board to form a drip edge. Space the nails in the edge of the sheathing board 6 inches apart.

A starter strip need not be used if the shingles are the same color as the existing roofing and the existing roofing is not buckled. Figure 7-30, page 7-20, shows an example of roof replacement.

## Application of Shingles

Shingles are attached in different ways, depending on the type.

Standard-Weight, Four-Tab, 10- x 36-I nch Shingles. Start the first course with a full shingle placed so that one edge, cut off flush with the tab, is also flush with the side of the roof. The bottoms of the tabs are placed flush with the eaves. Place nails about $3 / 4$ inch above each cutout


Figure 7-30. Roof replacement
section and in the same relative position at each end of the shingle. Use two nails at every cutout. Nail at the center first, then above the cutout sections nearest the center, and finally at the ends. Nailing may start at one end and proceed regularly to the other. Complete the first course with full-width shingles applied so that the ends barely touch each other.

Start the second course with a shingle from which half a tab has been cut. Place it so that the bottoms of the tabs are flush with the tops of the cutout sections of the shingle in the first course. Complete this course with full-width shingles.

Start the third course with a shingle from which one tab has been cut; the fourth with one from which one and one-half tabs have been cut; and so on, until eventually a full shingle is used again.

Thick-Butt, Three-Tab Shingles. F ollow the same method described for standard shingles. Always nail these shingles through the thick part, about $3 / 4$ inch above the cutout sections. The importance of nailing through the thick part of asphalt shingles cannot be emphasized too strongly. Practically all difficulties experienced with asphalt shingles on Army buildings have resulted from nailing the shingles too high.

Hips and Ridges. Finish hips and ridges with individual shingles furnished especially by the manufacturer or with shingles cut from strip shingles. Hips and ridges may al so be finished with a strip of mineral-surfaced roofing 9 inches wide, bent equally on each side and nailed on 2-inch centers $3 / 4$ inch from the edges.

Open Valleys. Open valleys may be flashed with 90 -pound, 18 -inch-wide mineral-surfaced asphalt roll roofing (Figure 7-31) placed over the valley underlayment. It is centered in the valley with the surfaced side down and the lower edge cut flush with the eaves flashing. When it is necessary to splice the material, the ends of the upper segments are laid to overlap the lower segments 12 inches and are secured with asphalt plastic cement. A 36-inch-wide strip is placed over the first strip, centered in the valley with the surfaced side up and secured with nails.

Before shingles are applied, a chalk line is snapped on each side of the valley for its full length. The lines should start 3 inches from the valley on both sides. The chalk lines serve as a guide in trimming the shingle units to fit the valley. The upper corner of


Figure 7-31. Open-valley flashing each end shingle is clipped to direct water into the valley (Figure 7-31). Each shingle is cemented to the valley lining with asphalt cement to ensure a tight seal. No exposed nails should appear along the valley flashing.

Closed Valleys. Closed valleys can be used only with strip shingles (Figure 7-32). This method has the advantage of doubling the coverage of the shingles throughout the length of the valley. A valley lining made from a 36 -inch-wide strip of 55 -pound (or heavier) roll roofing is placed over the valley underlayment and centered in the valley (Figure 7-32).

Valley shingles are laid over the lining by either of two methods:

- Applying both roof surfaces at the same time, with each course in turn woven over the valley.
- Covering each surface to the point approximately 36 inches from the center of the valley and the valley shingles woven in place later.

Either way, the first course at the valley is laid along the eaves of one surface over the valley lining and extended along the adjoining roof surface for at least 12 inches. The first course of the adjoining roof surface is then carried over the valley on top of the previously applied shingle. Each course thereafter is laid alternately, weaving the valley shingles over each other.

The shingles are pressed tightly into the valley and nailed in the usual manner except that no nail should be located closer than 6 inches to the valley centerline and two nails are used at the end of each terminal strip (Figure 7-32).


Figure 7-32. Closed-valley flashing using woven strip shingles

## ASPHALT-PREPARED ROLL ROOFINGS

There are two types of asphalt-prepared roll roofing: mineral-surfaced and smooth-surfaced.

## Mineral-Surfaced Roll Roofing

Mineral-surfaced, asphalt-prepared, two-ply roofing should consist of a layer of 15 -pound asphaltsaturated felt and two plies of roll roofing, cemented together with hot asphalt. Cut roll-roofing material into lengths of 18 or 20 feet, stacked free from wrinkles and buckles in protected piles. Maintain the roofing material at a temperature of at least $50^{\circ} \mathrm{F}$ for 24 hours before laying.

First, cover the roof areas with a layer of 15-pound asphalt-saturated felt, with all joints lapped 2 inches. Nail as required to prevent blowing off during the application of roofing. Next, lay either plain, dry unsurfaced roofing or dry mineral-surfaced roofing as a starter sheet. Lay this upside down parallel to and flush with the eaves. Nail through tin or fiber disks on 12-inch staggered centers; that is, with one row of nails on 12-inch centers placed not more than 2 inches from the lower edge, and with a second row on 12-inch centers staggered with respect to the first and about 8 inches above the first.

Over the lower half of this sheet, apply a uniform coating of hot asphalt at the rate of 30 pounds per 100 square feet. Place the first sheet of roll roofing in the asphalt. Cover the entire roof area, lapping each successive sheet, to obtain a two-ply roofing with a 2-inch head lap. Cement the lower or mineral-surfaced portion of each sheet with hot asphalt to the preceding sheet. Nail the edge through tin or fiber disks on 12-inch staggered centers. Use two rows of nails. Place the first row on 12-inch centers not more than 2 inches above the mineral surfacing and the second row on 12inch centers staggered with respect to the first and about 8 inches above the first.

Perform the work in such a way that no fastenings or asphalt will show on the finished surface. Apply the asphalt immediately before unrolling the sheet of roofing. Do not apply the asphalt more than 3 feet ahead of the roll. Step the edge of each sheet into the asphalt so that all laps are securely sealed. Place the end laps 6 inches in width with the underlying edges nailed on 6-inch centers, asphalt-cement the overlying edges, and step down firmly. Place one ply of roofing at eaves and edges, turn down neatly, and secure it with a wood member nailed on 8 -inch centers.

## Smooth-Surfaced Roll Roofing

Before laying the roll-roofing material, cut it into 18-or 20-foot lengths. Stack them free of wrinkles and buckles in protected piles, and maintain them at a temperature of at least $50^{\circ} \mathrm{F}$ for 24 hours.

F or TO construction, apply single-ply roll roofing horizontally with at least 4-inch side laps and 6inch end laps. Nail the underlying edges of laps through tin or fiber disks on 6-inch centers. Cement overlying laps with hot asphalt or an approved col d-applied sealing compound. Step down firmly on the edges to provide proper adhesion. Double the roofing over the ridge with at least 4inch laps. Turn roofing down neatly at eaves and edges. Nail the roofing in place on 6 -inch centers. Figure 7-33 shows an example.

## BUILT-UP ROOFS

Buildings with roofs of relatively low pitch (less than 2 inches per foot), originally roofed with asphalt-prepared roll roofings, should be reroofed with smooth-surfaced asphalt built-up roof1ng or
with coal-tar-pitch built-up roofing.
Use smooth-surfaced asphalt built-up roofing on buildings with original smooth-surfaced roll roofing.

Use asphalt built-up roofing or coal-tar-pitch built-up roofing on mobilization-type buildings with roofs of relatively low pitch (usually $1 / 2$ inch per foot), originally roofed with wide-selvage, mineralsurfaced roll roofing. If the roof is nearly flat so water collects and stands, the latter type of roofing is best. Asphalt roofs may be smooth- or mineral-surfaced. Coal-tar-pitch roofs must be mineralsurfaced.

## Asphalt Built-Up Roofs



Figure 7-33. Smooth-surfaced roll roofing
buckles and wrinkles. Then apply a three-ply, smooth-surfaced asphalt built-up roof as follows:

Step 1. Lay one layer of 15 -pound asphalt-saturated felt over the entire surface. Lap each sheet 3 inches horizontally and vertically and nail the laps on 12 -inch centers. Also nail through the center of each sheet on 12 -inch centers staggered with respect to the nails at the horizontal laps. Use nails long enough to penetrate into the sheathing at least $3 / 4 \mathrm{inch}$. They should be driven through tin or hard fiber disks.

Step 2. Mop the entire surface with a uniform coating of hot asphalt, using 25 pounds per 100 square feet.

Step 3. Over this coating of asphalt, lay two additional layers of 15 -pound, 36 -inch, asphaltsaturated felt. Lap each sheet 19 inches, and lap the sheet ends not less than 6 inches. Nail these felts through tin or hard fiber disks 1 inch from the back edge on 12 -inch centers. Use nails long enough to penetrate into the wood sheathing at least $3 / 4 \mathrm{inch}$.

Step 4. Mop each of these sheets the full width of the lap with hot asphalt, using 25 pounds per 100 square feet.

Step 5. Apply a uniform mopping of hot asphalt over the entire surface, using 30 pounds per 100 square feet of roof surface.

## NOTE: Do not heat asphalt above $400^{\circ}$. Lay the felt while the asphalt is hot, taking care to keep the surface free from wrinkles or buckles.

The materials needed per 100 square feet of roof surface for the threeply, smooth-surfaced asphalt built-up roof are-

- Asphalt: 80 pounds.
- Asphalt-saturated felt: 45 pounds.

If the existing roofing is so rough that it is impossible to obtain a smooth surface by the method described above, remove the original roofing and apply a three-ply, smooth-surfaced, asphalt built-up roof. Substitute 30 -pound asphalt-saturated felt for the 15 -pound felt originally specified.

If a slag or gravel-surfaced roof is desired for mobilization-type buildings, at step 5 above, apply 45 pounds of hot asphalt instead of 30 pounds per 100 square feet. Into this hot coating, place 300 pounds of roofing slag or 400 pounds of roofing gravel per 100 square feet of roof surface.

## Coal-Tar-Pitch Built-Up Roofs

Prepare the roof surface as previously described, then apply a three-ply, coal-tar-pitch built-up roof as follows:

Step 1. Apply one layer of 15 -pound coal-tar-saturated felt over the entire roof surface. Prepare it as described in step 1 of "Asphalt Built-Up Roofs."

Step 2. Mop the entire surface with a uniform coating of hot coal-tar pitch, using 30 pounds per 100 square feet.

Step 3. Over this coating of coal-tar pitch, lay two additional layers of 15 -pound coal-tar-saturated felt 36 inches wide. Lap each sheet 19 inches over the preceding sheet. If 32 -inch felt is used, lap each sheet 17 inches. Nail the felt 1 inch from the back edge on 12 -inch centers through tin or hard fiber disks. Use nails long enough to penetrate into the wood sheathing at least 3/4 inch. Lap the ends of the sheets at least 6 inches.

Step 4. M op each sheet the full width of the lap with hot coal-tar pitch, using 25 pounds per 100 square feet.

Step 5. Apply a uniform pouring of hot coal-tar pitch over the entire surface. Use 55 pounds per 100 square feet. While the pitch is hot, place over it 300 pounds of roofing slag or 400 pounds of roofing gravel per 100 square feet.

The materials required per 100 square feet of roof surface are-

- Coal-tar pitch: 110 pounds.
- Coal-tar-saturated felt: 45 pounds.
- Roofing slag: 300 pounds.
or
- Roofing gravel: 400 pounds.


## NOTE: Do not heat the coal-tar pitch above $375^{\circ}$ F. Lay the felt while the coal-tar pitch is still hot, taking care to keep the surface free from wrinkles or buckles.

## SLATE ROOFS

Very old slate roofs sometimes suffer failure because of the nails used to fasten the slates. In such cases, remove and replace the entire roof, including the felt underlay materials. Remove or drive in any protruding nails. Make every effort to obtain a smooth, even deck similar to the original one. Apply 30-pound asphalt-saturated felt horizontally over the entire roof deck. Lap the sheets not less than 3 inches. Turn them up 6 inches or more on vertical surfaces and over 12 inches or more on ridges and hips. Secure the sheets along laps and exposed edges with large-head roofing nails spaced about 6 inches apart.

Re-lay all original slates that are in good condition. Replace defective slates with new slates of the same size, matching the original color and texture as nearly as possible.

Recommended slate sizes for large new buildings are 20 or 22 inches long; for small new buildings, 16 or 18 inches long. Use slates of uniform length, in random widths, and punched for a head lap of not less than 3 inches.

Lay roof slates with a 3-inch head lap. Fasten each slate with two large-head slating nails and drive them so that their heads just touch the slate. Do not drive the nails "home." The opposite is true of wood shingles; therefore, workmen accustomed to laying wood shingles must nail slate carefully.

Bed all slates in an approved elastic cement on each side of hips and ridges within 1 foot of the top and along gable rakes within 1 foot of the edge. Match slate courses on dormer roofs with those on the main roof. Lay slate with open valleys.

## TILE ROOFS

Before reroofing with tiles, restore the roof deck as nearly as possible to its original condition. Replace defective boards and apply asphalt-saturated felt (30-pound type) or prepared roofing. Lap the sheets not less than 3 inches. Turn them up on vertical surfaces for at least 6 inches and over ridges and hips for at least 12 inches. Secure the sheets along laps and exposed edges with largehead roofing nails spaced about 6 inches apart.

Tiles must be free from fire cracks or other defects that will impair the durability, appearance, or weather tightness of the finished roof. Special shapes are provided for eaves starters, hips, ridges, top fixtures, gable rakes, and finials. Special shapes for field tile at hips and valleys may be factory-mol ded or may be job cut from whole tile and rubbed down to clean, sharp lines. Roof tiles for use on Army buildings are generally furnished in one or more of the following types:

- Mission tiles are straight-barrel-type, molded to a true arc and machine-punched for one nail and a 3-inch head lap. Use regular cover tile for ridges and hips. Finish with plain mission finials. Eaves closures and hip starters are available. Approved sizes are generally 8 inches wide by 14 to 18 inches long.
- Spanish tiles are S-shaped and machine-punched for two nails and a 3-inch head Iap. Eaves closures and hip starters are available. Use mission-type cover tiles for hips and ridges. Approved sizes are generally $91 / 2$ to 12 inches wide by 12 to 18 inches long.
- Slab-shingletiles are the flat, noninterlocking type, punched for two nails and a 2-inch head lap. Approved sizes are 6 to 10 inches wide, 15 inches long, and 1/2 inch thick.


## Mission and Spanish Tiles

Before starting to lay tiles, mop the wood nailing strips with hot asphalt. Fill the spaces in back of the cant strips with asphalt cement. Lay tiles with open valleys. Set eaves closures back 3 inches from the lower edge of eaves tiles. Lay pan tiles with uniform exposure to the weather. Lay cover tiles in a uniform pattern, except where otherwise necessary to match existing roofs. Give all tiles a minimum lap of 3 inches and extend pan tiles 1 inch over the rear edge of the gutter.

Cut the tiles so that they meet projections with finished joints and point them up with roofer's cement. Waterproof the spaces between field tiles and wood nailing strips at ridges and hips with a fill of roofer's cement. Fit all tiles properly and then secure them with nails long enough to penetrate at least 1 inch into the wood base.

Fill spaces between pan and cover tiles in the first row at the eaves with solid cement mortar made of one part Portland cement, three parts fine sand, and enough clean water to form a plastic mix. Wet all tiles before applying mortar, then press them firmly into the mortar bed. Match the tile courses on dormer roofs with those on the main roof. Cut surplus mortar off neatly. Point up all open joints. Remove loose mortar from exposed surfaces.

Where hurricane winds can be expected, consider reinforcing tile roofs by laying all field tiles in Portland cement mortar. To do this, fill the ends of tiles at eaves, hips, ridges, rakes, and spaces beneath ridges solid with cement mortar. Fill the full width of laps between the tiles, both parallel and perpendicular to the eaves, with cement mortar.

## Slab-Shingle Tiles

Lay slab-shingle tiles with a 2 -inch head lap. Secure each tile with two large-head roofing nails. Double the tiles at eaves and project them 1 inch over the rear edge of gutters. Lay all tiles within 1 foot of hips, ridges, and abutting vertical surfaces in roofer's cement. Lay 10- or 12inch tiles with 1 -inch head lap on the sides of dormers. Match the tile courses on dormer roofs with those on the main roof. Lay tile roofs with open valleys.

## ASBESTOS-CEMENT ROOFS

Before reroofing with asbestos-cement shingles, restore the roof deck as nearly as possible to its original condition. Replace defective boards, and apply new 30-pound asphalt-saturated felt or prepared roofing in horizontal courses. Lap the sheets not less than 3 inches. Turn them up at least 6 inches on vertical surfaces and over at least 12 inches on ridges and hips. Secure the sheets along laps and exposed edges with large-head roofing nails spaced about 6 inches apart.

Re lay all asbestos-cement shingles that are in good condition. Replace defective shingles with new shingles of the same size, matching the originals as nearly as possible in col or and texture.

Lay each shingle with a 2 -inch head lap and secure it with two large-head slating nails. Drive the nails so that their heads just touch the shingles. Do not drive the nails "home" as in laying wood shingles. Bed all shingles on each side of hips and ridges within 1 foot of the edge in an approved elastic slater's cement. Project the shingles 1 inch over the rear edges of gutters. Lay shingles with a 1-inch head lap on sides of dormers. Match the shingle courses on dormer roofs with those on the main roof. Lay shingles with open valleys.

## METAL ROOFS

To conserve critical materials, replace metal roofs with nonmetallic roofing materials.

## WOOD-SHINGLE ROOFS

When old roofing is removed-

- Restore the roof deck as nearly as possible to its original condition. Replace rotted boards and pull out or drive down all protruding nails.
- Install flashings and apply new shingles.

If the existing shingle roofs can be made smooth and can be nailed properly, apply new wood shingles directly over weathered wood-shingle roofs. Reroof over existing wood shingles as follows:

Step 1. Nail down or cut off curled and warped shingles. Nail loose shingles securely, and remove or drive down protruding nails.

Step 2. Cut off the old first-course shingles at the eaves just below the butts of the second course. Replace them with a $1 \times 3$ or $1 \times 4$ strip nailed flush with the eaves line.

Step 3. Cut back the shingles at the gable ends about 3 inches. Replace them with a $1 \times 2,1 \times 3$, or $1 \times 4$ strip nailed flush with the gable end.

Step 4. Remove weathered shingles at the ridge. Replace them with a strip of beveled siding, thin edge down, to provide a solid base for nailing the ridge shingles. Treat the hip the same as the ridges.

Step 5. Fill open valleys with wooden strips level with the old shingle surface or with a narrow strip placed across the 'V' of the valley to act as a support for new flashings.

Step 6. Inspect flashings carefully. Replace terne and galvanized flashings. Reuse old flashings if they are in good condition.

Step 7. Use the following nails in applying shingles over an existing roof:

- 5d box or special overroofing nails, 14-gauge, and $13 / 4$ inches long for 16 - and 18 -inch shingles.
- 6d nails, 13-gauge, and 2 inches long for 24 -inch shingles.

One square of roofing will need about 3 1/2 pounds of nails.
Step 8. Apply new shingles as recommended by their manufacturer.

This chapter covers the rough framing and finish carpentry for doors and windows. Beforeputting the exterior covering on theoutside walls of a building, prepare the door and window openings for the frames.

## DOORS

Before the exterior covering is put on the outside walls, the door openings are prepared for the frames. Square off uneven pieces of sheathing and wrap heavy building paper around the sides and top of the door opening. Since the sill must be worked into a portion of the rough flooring, no paper is put on the floor. Position the paper at a point even with the inside portion of the stud to a point about 6 inches on the sheathed walls, and tack it down with small nails.

NOTE: Rough openings are usually made $21 / 2$ inches larger each way than the size of the door to be hung. (For example, a 2-foot 8-inch by 6-foot 8-inch door would need a rough opening of 2 feet $101 / 2$ space allows for the jambs, the wedging, and the clearance space for the door to swing.

## TYPES OF DOORS

Doors, both exterior and interior, are classified as job-built or mill-built. This classification is further broken down as batten, panel, and flush doors (Figure 8-1).

NOTE: No hinged
interior door should open or swing against a natural entry, swing into hallways, or be obstructed by other swinging doors.

## J ob-Built Doors



Figure 8-1. Types of doors

The batten door is the most commonly used and most easily constructed type of job-built door. It can be constructed in several ways, such as-

- Using diagonal boards nailed together in two layers, at right angles to each other. This type of door is often used as the core for metal-sheathed fire doors.
- Using vertical boards that are tongue-and-grooved or shiplapped. The door is held rigid by two to four cross pieces, called ledgers, which may or may not be diagonally braced. If two additional pieces forming the sides of the door and corresponding to the ledgers are used, these are called frames.

In hasty construction (on-site prefabrication), the carpenter makes a batten door from several $2 \times 6$ boards with ledgers and braces, as follows:

- Nail the ledgers with their edges 6 inches from the ends of the door boards.
- Place a diagonal board between the ledgers. It begins at the top-ledger end, opposite the hinge side of the door, and runs to the lower ledger, diagonally across the door. On an outside door, use roofing felt on the weather side to cover the boards.
- Nail wooden laths around the edges and across the middle of the door to hold the roofing felt in place.


## NOTE: When these doors are hung, 1/4 inch of clearance should be left around the door to allow for expansion.

- Fasten T-strap hinges to the door ledgers and the hinge blocks on the door casing or post.


## Mill-Built Doors

The usual exterior door is the panel type (Figure 8-2). It consists of stiles, rails, and filler panels. Two frequently used interior doors are the flush and the panel types (Figure 8-2).

Panel Doors. Panel doors consist of vertical members called stiles and horizontal members called rails. Stiles and rails form the framework into which panels are inserted. Additional vertical and horizontal members called muntins are used to divide the door into any number of panels. Panels may be solid wood, plywood, particleboard or louvered or have glass inserts.

Flush Doors. Flush doors have flat surfaces on both sides and consist of a wood frame with thin sheets of material (plywood veneer, plastic laminates, hardboard, or metal) applied to both faces. Flush doors have either a solid or hollow core.

- Solid-core doors have a solid particle board or woodblock core which is covered with layers of veneer. They are usually used as exterior doors. Solid-core doors provide better sound insulation and have less tendency to warp.
- Hollow-coredoors have a lightweight core made of various materials that are covered with layers of veneer. They are usually used as interior doors and are less expensive to produce.


Figure 8-2. Mill-built doors

## Specialty Doors

Specialty doors include double doors, sliding doors, and folding doors.

Door frames are made of the following parts: the head casing, the jambs (head and two sides), and the sill (on exterior doors only). (The principal parts of a door frame are shown in Figure 8-3.) Doors and frames may be fabricated in the shop and installed separately; they may also be Remanufactured (prehung), purchased ready for installation.


Door-frame layout calculations begin with the size of the door (height, width, and thickness), as given on the door schedule. Construction information for door frames is usually given in detail drawings like those shown in Figure 84. In the type of frame shown in Figure 8-4, the door jambs (linings of the framing of door opening are rabbeted to depths of $1 / 2$ inch. The rabbet prevents the door from swinging through the frames. A strip of wood may be used instead a rabbet. The door stop also serves to weather proof the door. Most project drawings call for rabbeted exterior door jambs.


Figure 8-5. Single outside door

## Exterior Door Frames

Exterior door frames are made up of two side jambs, a head jamb, a sill, and a stop. They are constructed in several ways. In hasty construction (on-site prefabrication), the frames will be as shown in Figure 8-5. This type requires no frame construction because the studs on each side of the opening act as a frame. Studs are normally placed 16 inches apart on center. Extra studs are added at the sides of door and window openings. Headers are usually used at the top and bottom of such openings.

The siding is applied to the outside wall before exterior doors are hung. The casing is then nailed to the sides of the opening. It is set back the width of the stud. A $3 / 4-\times 3 / 4-$ inch piece is nailed over the door but set back the width of the stud; it supports the drip cap. Hinge blocks are nailed to the casing where the hinges are to be placed. The door frame is now ready for the door to be hung.

On an outside door, the outside casings and the sill are considered parts of the door frame. A prefabricated outside door frame-delivered to the site assembled-looks like the righthand view of Figure 8-3, page 8-3. It usually has the door installed, and the entire unit slides between studs.

## Interior Door Frames

Interior door frames, like outside frames, are constructed in several ways. In hasty construction (on-site prefabrication), the type shown in Figure 8-6 is used. Interior door frames are made up of two side jambs, a head jamb, and stop moldings which the door closes against. Interior door frames have no sill and no casing, otherwise they are the same as the exterior frames. Figure 8-6 shows the elevation of a single inside door.

## NOTE: Both outside and inside door frames may be modified to suit climatic conditions.

Door J ambs


Figure 8-6. Single inside door

Door jambs (Figure 8-7) are the linings of the framing in door openings. The casing and stops are nailed to the door jambs, and the door is hung from them. Door openings should allow $1 / 2$ inch between the frame and the jamb (Figure 8-8, page 8-6) to permit plumbing and leveling of jambs. Inside jambs are made of 3/4-inch stock; outside jambs are made of $13 / 8$-inch stock. The width of the stock varies with the thickness of the walls. Inside jambs are built up with 3/8-x $13 / 8$-inch stops nailed to the jamb. Outside jambs are usually rabbeted to receive the door.

J ambs are made and set as follows:
Step 1. Cut the side jambs of an entrance door to the height of the door, less the depth of the head jamb rabbet (if any), plus the-

- Diagonal thickness of the sill, plus the sill bevel allowance.
- Thickness of the threshold, if any.
- Thickness of the head jamb.
- Height of the side-jamb lugs.

Step 2. Cut the head jamb to the width of the door, less the combined depths of the side-jamb rabbets (if any), plus the combined depths of the head-jamb dadoes (grooves).


Figure 8-7. Door jambs

## NOTE: Regardless of how carefully rough openings are made, be sure to plumb the jambs and level the heads when jambs are set.

Step 3. Level the floor across the opening to determine any variation in floor heights at the point where the jambs rest on the floor.

Step 4. Cut the head jamb with both ends square. Allow the width of the door plus the depth of both dadoes and a 3/16-inch door clearance.

Step 5. From the lower edge of the dado, measure a distance equal to the height of the door plus the dearance required under it. Mark it and cut it square. On the opposite jamb, do the same. Make additions or subtractions on this side for floor variations, if any.

Step 6. Nail the side jambs and jamb heads together with 8d common nails, through the dado into the head jamb.


Figure 8-8. Jam allowances

Step 7. Set the jambs into the opening. Place small blocks on the subfloor under each jamb. Blocks should be as thick as the finished floor will be. This allows room for the finished floor to go under the door.

Step 8. Plumb the jambs and level the jamb head. Wedge the sides with shingles between the jambs and the studs, to align them. Nail them securely in place. Take care not to wedge the jamb unevenly. Use a straightedge 5 or 6 feet long inside the jambs to help prevent uneven wedging.

Step 9. Check the jambs and the head carefully. J ambs placed out of plumb will tend to swing the door open or shut, depending on the direction in which the jamb is out of plumb.

## SWING

The hand of a door describes the direction in which a door is to swing and from which side it is hinged. The hand is determined from the outside of the door. A standard door has the hinges on the right or left and swings away from you. A reverse door has the hinges on the right or left and swings toward you.

## DOOR HARDWARE

Most doors are hung with the loose-pin butt hinge. The pin may be removed and as a result, the door can be removed without the hinges being unscrewed. Doors should be hinged so that they open in the direction of the natural entry, open out in public buildings, and swing against a blank wall whenever possible and never into a hallway. Exterior doors use three hinges to reduce warpage caused by the difference in exposure on opposite sides and to support wider and heavier exterior doors. Interior doors use two hinges.

When installing hinges, the gain is the cutout or mortise made to receive a leaf of the hinge. The depth is determined by the hinge's thickness, and the width is determined by the hinge's size. Setback is the distance that the hinge is placed away from the side of the door, usually $3 / 16$ inch.

The door closer is a device that closes a door and controls the speed and closing action of the door. Install the door closer according to the manufacturer's instructions.

## DOOR INSTALLATION

Doors, both mill-built and job-built, are installed in the finished door frames as described in the following steps (Figure 8-9):

Step 1. Cut off the stile extensions, if any.
Step 2. Plane the edges of the stiles until the door fits tightly against the hinge side and clears the lock side of the jamb by about $1 / 16$ inch. Be sure that the top fits squarely to the rabbeted recess and that the bottom swings free of the finished floor by about $1 / 2$ inch. The lock stile of the door must be beveled slightly so that the edge of the stile will not strike the edge of the door jamb.

Step 3. After proper clearances have been made, tack the door in position in the frame and wedge it at the bottom.

Step 4. Mark hinge positions with a sharp-pointed knife on the stile and the jamb. Hinge positions on the stile must be placed slightly higher than the lower door rail and slightly lower than the upper door rail to avoid cutting out part of the door-rail tenons that are housed in the stile. Three measurements must be marked:

- The location of the butt on the jamb.
- The location of the butt on the door.
- The thickness of the butt on both the iamb and the door.

Step 5. Door butts (or hinges) (Figure 8-10) are mortised into the door frames as shown in Figure 811, page 8-8. Use three butt hinges on all full-length exterior doors to prevent warping and sagging. Place the butts and mortise them with the utmost accuracy so that the door will open and close properly, and so that the door, when open, will not strike the casing. The butt pin must project more than half its thickness from the casing.

Step 6. Using the butt as a pattern, mark the butt dimension on the door edge and face of the jamb.

Step 7. Cut the marked areas, called gains, on the door jambs and door to fit the butts. Use a 1inch chisel and mallet.

Step 8. Test the gains. The butts must fit snugly and exactly flush with the edge of the door and the face of the jamb.

Step 9. Screw half of each of the butt joints on the door and the other three parts on the jamb. Place the butts so that the pins are inserted from the top when the door is hung.

Step 10. Set the door against the frame so that the two halves of the top butt engage. Insert the top pin. Engage and insert pins in the bottom and center butts.


Figure 8-9. Hanging a door


Figure 8-10. Door butt (hinge)

Door Stops
When fitting doors, the stops are usually nailed in place temporarily until the door has been hung. Stops for doors in single-piece jambs are generally $1 / 2$ inch thick and 2 inches wide. They are installed with a butt joint at the junction of the side and head jambs. A $45^{\circ}$ bevel cut at the bottom of the stop, about 1 to $11 / 2$ inches above the finish floor, will eliminate a dirt pocket and make cleaning or refinishing the floor easier.


Figure 8-11. Installing door butts (hinges)

## Finish Door Trim

Door trim is nailed onto the jambs to provide a finish between the jambs and the wall to cover wedging and spaces between the frame and studs. This trim is called casing. Sizes vary from $1 / 2$ to $3 / 4$ inch thick and from $21 / 2$ to 6 inches wide. Most trim has a concave back to fit over uneven plaster. The casing layout depends on the way the side and head casings are to be joined at the corners. The casings are usually set back about $1 / 4$ inch from the faces of the jambs. Care must be taken to make miter joints fit properly. If trim is to be mitered at the top corners, a miter box, a miter square, a hammer, a nail set, and a block plane will be needed. (Door trim and stop are shown in Figure 8-12.)

Door openings are cased up as follows:
Step 1. Leave a margin of $1 / 4$ inch from the edge of the jamb to the casing, all around. Cut one (hinge-side first) of the side casings square and even with the bottom of the jamb. Cut the top or mitered end next, allowing a 1/4-inch margin at the top.

Step 2. Nail the casing onto the jamb, even with the $1 / 4$-inch margin line. Start at the top and work toward the bottom. Use 4d finishing nails along the jamb side and 6d or 8d case nails along the outer edge of the casings.


Figure 8-12. Door trim and stop The nails along the outer edge will need to be long enough to go through the casing and into the studs. Set all nailheads about 1/8 inch below the surface of the wood with a nail set.

Step 3. Apply the casing for the other side and then the head casing.

## LOCK INSTALLATION

Two types of locks used in TO construction are the cylinder and tubular locks. Cylinder locks are sturdy, heavy-duty locks designed for installation in exterior doors. They provide high security. globular locks are light-duty locks. They are used for interior doors on bathrooms, bedrooms, passages, and closets. Since door locks differ, use lock-set installation instructions, or perform the following steps:

Step 1. After placing the hinges in position, mark off the position of the lock on the lock stile, 36 inches from the floor level.

Step 2. Hold the case of the mortised lock on the face of the lock stile. With a sharp knife, mark off the area to be removed from the edge of the stile that is to house the entire case.

Step 3. Mark the position of the door-knob hub and the position of the key.
Step 4. Mark the position of the strike plate on the jamb.
Step 5. Bore out the wood to house the lock and the strike plate and mortises. (Figure 8-13, page 810, shows the installation of the lock and the strike plate.)

Step 6. Clean and install the lock set. The strike plate should be flush or slightly below the face of the door jamb.

Panic hardware is another type of lock. It is also known as a paretic bar or fireexit bolt. It is often installed on the exit doors of public buildings. Slight pressure on the touch bar will retract the latch bolts at the top and bottom. Install panic hardware according to the manufacturer's instructions.

## WINDOWS

The most common types of windows are doublehung and hinged (or casement) windows (Figure 814, page 8-11). All windows consist of two parts, the frame and the sash.

The double-hung window (Figure 8-14) is made of upper and lower sashes that slide vertically past one another. Screens can be located on the outside of a double-hung window without interfering with its operation. Ventilators and window air conditioners may be placed with the window nearly closed. However, for full ventilation of a room, only one-half of the area of the window can be used. Any current of air passing across its face is lost to the room. Its frame construction and operation are more involved than that of casement windows.

Casement windows (out-swinging or in-swinging) may be hinged at the sides, top, or bottom.
Casements have the advantage of catching a parallel breeze and slanting it into a room.

- Out-swinging. The casement window that opens out requires the window screen to be located on the inside with a device cut into its frame to operate the casement.
- In-swinging. In-swinging casements, like double-hung windows, are clear of screens, but they are extremely difficult to make watertight, particularly against a driving rainstorm.


## WINDOW FRAMES

Window frames are made of four basic parts: the head, the jambs (two), and the sill. (The sash is the framework that holds the glass in the window.) Where openings are provided, cut away the
studs and for equivalent strength, double the studs on each side of the opening to form trimmers. I nsert a header at the top. If the opening is wide, the header should also be doubled and trussed. At the bottom of the opening, insert the rough sill.


Figure 8-13. Installing lock and strike plate

In hasty construction, millwork window frames are seldom used. Instead, simple openings are left in the walls with the stops all nailed to the stud. The sash may be hinged to the inside or outside of the wall or may be constructed to slide. The sliding sash with overlapping panes is most common in Army construction because it requires little installation time.

Sills have a usual slope of 1 to 5 inches so that they shed water quickly. They are wider than frames, usually extending about $11 / 2$ inches beyond the sheathing. They also form a base for the outside finished casing.

## WINDOW SASHES

A window is normally composed of an upper and a lower sash. There are two ordinary types of wood sashes: fixed or movable. Fixed sashes are removable only with the aid of a carpenter. Movable sashes may slide up and down in channels in the frame (double-hung), or they may swing in or out and be hinged at the side (casement type).

Sliding sashes are counterbalanced by sash weights that weigh half as much as the sash. Sashes are classified as single or divided, according to the number of pieces of glass (or lights).

A sash may be made of $1 \times 3$ material with reinforced, rolled plastic material, which can be cut to any desired size. For hasty construction of window sashes, perform the following steps:

Step 1. Make two frames with the glass substitute installed on one.
Step 2. Nail the frames together. When the two frames are nailed together, they should be turned so that the joints are not over each other. This staggers the joints and strengthens the sash. Do not make the window sash larger than the available glass substitute. If the sash is too large for the glass substitute to cover, a muntin may be placed in the sash to hold the glass substitute; this should be fastened with corrugated metal fasteners. Where long sashes are made, a muntin should be placed in the center for added strength. Figure 8-15, page 8-12, shows the window frame and sash details.

Step 3. Cut the side pieces to a length equal to the height of the sash, less the width of one piece of material.

Step 4. Cut the top and bottom pieces the same length as the window, less the width of the material.

Step 5. Fasten at the joints with corrugated metal fasteners.


Figure 8-14. Types of windows

## ACCESSORIES

The following are a few items that can be added to a structure to enhance efficiency:

## WINDOW SCREENS

Screen sash is usually 3/4-inch stock; however, for large windows and doors 1 1/8-inch material is frequently used or 3/4-inch lumber is braced with a horizontal member.


Figure 8-15. Window frame and sash details

## Construction

Window screen sash is usually 13/4 or $21 / 4$ inches wide. Screen may be attached by stapling or tacking. Cut the screen 1 inch wider and longer than the opening. Cover the edges with molding. Next, rabbet the inside edges about $3 / 4 \times 1 / 2$ inch. Attach the screen in the rabbet, and nail $3 / 8-x$ $1 / 2$-inch molding flush with the sash face.

## J oints

Window sashes may be made with open mortise, four tenons, and with rails tenoned into stiles; with half-lap corners; or with butt joints or corrugated fasteners. In either of the first two cases, the joints may be nailed or glued.

## Attaching Screen Material

When attaching screen material, start at one end and tack or staple it with copper staples, holding the screen tightly. Next, hand-stretch the screen along the side, working toward the other end. Attach it, making sure the weave is parallel to the ends and sides. Tack the sides and apply the mol ding. Copper staples should be used for bronze or copper screen and cadmium staples for aluminum screens.

## DOOR SCREENS

Door screens are made as shown in Figure 8-16. Two separate frames are made of $1 \times 4$ material for the sides and top; $1 \times 6$ material is used for the bottom and middle pieces. (Figure 8 - 17 shows door screen sizes.) The first frame is made of two side pieces as long as the door. The crosspieces are as wide as the door, less the width of the two side pieces. This frame is put together with corrugated metal fasteners or triangular corner splices; then, the screen wire is applied. The second frame is made with the crosspiece as wide as the door. The side pieces are cut to correspond with the distance between the cross-pieces. The second frame is placed over the first frame and
nailed securely. F or push-and-pull plates, two short $1 \times 4$ braces are nailed to the side opposite the hinge side.


Figure 8-16. Door screen construction

## HOODS OR CANOPIES

Hoods or canopies are used in tropical climates to protect the screened opening at the ends of the buildings. They are framed to the end walls with short rafters, which are nailed to the building with knee braces. The rafters are nailed to the wall, their bottom edge flush with the bottom of the end plate. The rafters and braces are made of $2 \times 4 \mathrm{~s}$ nailed with 8 d or 10 d nails. The sheathing is of the same material as the roof sheathing and is covered with roll roofing. The hood should extend about $21 / 2$ or 3 feet from the building. Figure 8-18, page R-14. shows hood or canopy details.


Figure 8-17. Door screen sizes


Figure 8-18. Hood or canopy details

After the rough framing is complete and a building is weather-tight, carpenters begin the inside finish carpentry. However, finish carpentry may be optional for TO construction. This chapter covers the fol lowing interior wall, partition, and ceiling coverings: gypsum board (or sheetrock/ wallboard), plywood, and fiberboard (or chipboard). It al so covers interior wall and ceiling moldings. (Doors and windows are covered in Chapter 8 and general information, such as floor and wall tile, suspended ceilings, and painting, is covered in Appendix D.)

Over time, "sheetrock" has become the most common term for gypsum board. Also, the term "drywall " is often loosel y used to mean gypsum board / sheetrock / wall board. In this manual we will use ,'sheetrock."

## INTERIOR WALL AND PARTITION COVERINGS

In current construction, sheetrock, plywood, and fiberboard are used instead of laths and plaster to cover walls. Sheetrock is normally applied in single (sometimes double) thickness as shown in Figure 9-1, page 9-2.

NOTE: When covering walls and ceilings, always start with the ceiling. After the ceiling is started, begin covering the wall in one corner and work around the room. Make sure that joints break at the center line of a stud or ceiling joist.

## PLYWOOD AND FIBERBOARD

Plywood and fiberboard can be used for interior wall coverings; however, plywood is most commonly used. It comes in 4 -feet-wide and 5 -to 8 -feet-long sheets, $1 / 4$ to $3 / 4$ inch thick. It is usually applied vertically from the floor to the ceiling. When plywood is correctly applied (with flush joints), the joints do not need to be concealed. However, to improve wall appearance, joints may be covered with moldings. These may be battens fastened over the joints or applied as splines between the panels. Less expensive plywood can be covered with paint or covered in the same way as plastered surfaces. To hang plywood (or fiberboard), see Figure 9-1. Figure 9-2, page 9-3, shows how to fit sheetrock on rough or uneven walls.

## SHEETROCK

Sheetrock saves time in construction and has a short drying time as compared to plaster. It is also fire-resistant. It requires moderately low moisture content of framing members. The dry. ing of members will result in "nail pops," which cause the nailhead to form small humps on the surface. Misaligning sheetrock on the studs may cause a wavy, uneven appearance. Wood sheathing will correct misaligned studs on exterior walls.

WHERE WALLS ARE NOT MORE THAN 8 FEET HIGH


First layer parallet to squds.


Second layer or tace at right angies to studs

WHERE WALLS ARE MORE THAN B FEET HIGH


First layer horizontal joints staggered; use 12-foot boards


Face layer parallei to studs. use fullilength boards from floor to the ceiling

The sketch at the night shows the proper cutting and fitting of the face layer where doors and windows are in the wall. Wherever practical. vertical end joints on side walls should be placed above door and window openings to reduce the joint treatment to a minimum.


Figure 9.1 Hanging sheetrock and wood panels

## Types of Sheetrock

The following are some of the different types of sheetrock used in construction:

- Gypsum board is the most commonly used wall and ceiling covering in construction today.
- Grenboard or blueboard is moisture resistant and is used in bathrooms, Iaundries, and similar areas.
- Sound-deadening board is a sublayer used with other layers of sheetrock (usually type X).
- Backing board has gray paper lining both sides. It is used as a base sheet on multilayer applications and is not suitable for finishing and decorating.
- Foil-backed board serves as a vapor barrier on exterior walls.
- Vinyl-surfaced board is available in a variety of colors. It is attached with special sheetrock finishing nails, screws, or channels and is left exposed with no joint treatment
- Plasterboard or gypsum lath is used for a plaster base. It is not compatible with Portland cement plaster.


## Sheetrock Dimensions

Sheetrock usually comes in sheets that are $4 \times 8,4 \times 9,4$ $\times 10,4 \times 14$, and $4 \times 16$ feet. Its thickness is $1 / 4,3 / 8,1 / 2$, or 5/8 inch.

- $1 / 4$ or $3 / 8$ inch is used effectively in renovations to cover existing finish walls with minor irregularities. This thickness is not adequate for single-layer application.
- $1 / 2$ inch is most commonly used. It is adequate for studs or ceiling joists spaced 16 or 24 inches on center.
- $5 / 8$ inch is widely used in multiple, fire-resistant combinations. It is recommended for singlelayer walls.


## Sheetrock Edges

Sheetrock edges are tapered 1/16 inch thinner than the body of the sheet about 1 1/4 inch on each sheet edge. The shallow channel formed will


1. Place a piece of scrap material in the angle and scribe (mark) it to indicate the surface peculiarities.
2. Saw the scrap material along the scribed line.
3. Place the scribed strip on the wall panel material to be used. Keep the straight edge of the scrap material parallel with the edge of the panel. Scribe the good sheet of paneling.
4. Saw the sheet along the scribed line.

NOTE: This method can also be used for sheetrock; however, it would be easier to just fill the gaps caused by uneven walls with joint compound.

Figure 9-2. Fitting wall panels to uneven walls
be brought level with tape and joint compound.

## Sheetrock Application

Sheets may be applied either horizontally or vertically; specifications may indicate which method should be used.

## Sheetrock Fasteners

Nails used are specially designed with oversized heads for greater holding power and treated to prevent rust and stains. The most common is the annular-ring nail. Other types of nails include the smooth-shank, the diamond-head (used to attach two layers of sheetrock or to attach sheetrock over existing materials), and the predecorated. The predecorated nails have smaller heads, are left exposed, and are colored to match the sheetrock.

Nails. If the sheetrock is single nailed, the nails should be spaced 6 to 7 inches apart on the ceilings and 6 to 8 inches apart on the walls (Figure 9-3). If the sheetrock is double nailed, the centers of the nail pairs are approxi mately 12 inches apart, with each pair 2 to $21 / 2$ inches apart and the outer edges 7 inches on center (Figure 9-4). The distance from the edge should be $3 / 8$ to $1 / 2$ inch. Do not double nail around the perimeter of a sheet.

Drive each nail slightly below the surface, forming a "dimple." Be sure not to break the paper when driving nails. The dimple creates a pocket which is filled with joint compound. Screws are made of high-quality steel; use a power screw gun or an electric drill to drive them in just below the surface without breaking the paper.

Adhesives. Adhesives are used to bond single-ply sheetrock directly to the framing members, furring strips, masonry surfaces, insulation board, or other sheetrock. It must be used with nails or screws.

J oint Compound. J oint compound is used to apply tape over joints, to cover nailheads, and to smooth and level the surface. The powdered form is mixed with water to a desired consistency. It is also available ready mixed. This is the most common form and the easiest to work with.


Figure 9-3. Sheetrock applied vertically


Figure 9-4. The double-nalling system for installing sheetrock

J oint Tape. J oint tape is applied with the first coat of joint compound. It reinforces joints and reduces cracking. The paper type may or may not be perforated. Perforated tape is easier to bed and cover than nonperforated tape. Fiber-mesh tape is self-sticking, which eliminates the need for the first coat of bedding joint compound.

Metal Accessories. Metal accessories include the corner bead and the casing bead. The corner bead is used on all exposed (outside) corners to ensure a clean finish and to protect the outside corners of sheetrock from edge damage It is nailed or screwed 6 inches on center to en sure that it is plumb.

The casing (stop) bead is used where sheetrock sheets butt at wall intersections or wall and exposed ceiling intersections or where otherwise specified. It is matched to the thickness of the sheetrock.

## Sheetrock Tools

The following are tools used in the application of sheetrock:

- The sheetrock hammer is used for hammering nails.
- The sheetrock carrier (lifter) is used for carrying or lifting sheetrock.
- Sheetrock knives are used to apply and finish joint


Figure 9-5. Cutting sheetrock
compound. The 4-inch knife is used to bed the tape in the first layer of joint compound and for filling the dimples, the 6 -inch knife is used for feathering out the second coat, and the 12 -inch knife is used for the third/finish coat.

- The corner trowel flexes from $90^{\circ}$ to $103^{\circ}$. It is used to apply joint compound in interior corners.
- The mud pan is used to hold and carry joint compound.
- The corner-bead crimper is used to fasten the corner bead by crimping.
- TheT-square is used to lay out and guide a $90^{\circ}$ cut on sheetrock.
- The utility knife is used to score or cut the sheetrock (Figure 9-5).
- The keyhole saw is used for cutting out irregular shapes and openings (such as outlet-box openings).
- Surform is used to smooth sheetrock edges after cutting.
- The tape banjo is used to apply tape (dry) or joint compound and tape (wet).
- Sandpaper and sponges are used for feathering or smoothing dried joint compound.
- A chalk line is used to facilitate layout.
- A 16 -foot measuring tape is used for measuring the sheetrock.
- A 4-foot hand level is used to plumb.
- Saw horses are used for placing sheetrock on to make cuts.


## Sheetrock Installation

There are three steps to installing sheetrock - hanging, finishing, and patching.

## Hanging Sheetrock. Apply sheetrock as follows:

Step 1. Install sheetrock on the ceiling first. Measure the distance from the inside edge of the top plate to the outside edge of the second ceiling joist. Measure and cut a piece 48 inches long and to the width measured above. Install and secure the sheet to the ceiling with sheetrock nails. Nail spacing on ceilings is 5 to 7 inches on center.

Step 2. Determine the starting point of the wall. Using a measuring tape, locate a section where the studs are $\sim$ foot on center and where a full sheet could be laid horizontally. Check the layout to ensure that there will be no joints above or below the door or window openings. Sheets will be installed from the ceiling down to the floor, starting at the ceiling.

Step 3. Install the first sheet. With the help of another person, place a sheet of sheetrock in position so that the edges fall on the center of the studs. Place the sheet snug against the ceiling, using a hand level to ensure that it is level. Secure the sheet with sheetrock nails 6 to 8 inches on center, $3 / 8$ inch from the edge. Install succeeding sheets on the top half of the wall against installed sheets, ensuring that joints fall on the center of the studs and proper nail spacing is maintained. Using a utility knife or sheetrock saw, cut out openings for doors and windows.

Step 4. Lay out the receptacles. Measure the distances from an inside corner to both sides of the receptacle box and record them. Measure the distance from the installed sheetrock to the top and bottom of the receptacle box, and record them. Measure and mark these dimensions for the receptacle cutout, allowing 1/16-inch clearance all around.

Step 5. Cut out the opening for the receptacle. With a utility knife, drive a hole within the opening. Using a keyhole saw, cut out the opening. Use a slight undercut bevel so that the back opening is larger than the front opening.

Step 6. Install the prepared sheet. Place the prepared sheet in position, ensuring that the receptacle fits in the opening without breaking the paper. Make adjustments to the opening if necessary. Secure the sheet to the studs with sheetrock nails. Using a Surform, smooth the rough edges of the openings as necessary.

Step 7. Lay out and cut sheets for corner posts. Measure and cut the required number and sizes of sheets to cover corner posts. Scrap pieces of material may be used.

Step 8. Install the corner bead. Using a corner-bead crimper, install the corner bead on the exterior corners of corner posts. Nails may be used if necessary.

Finishing Sheetrock The finishing process consists of covering nailheads and covering seams (covering seams is also referred to as finishing joints). Finish sheetrock as follows:

Step 1. Check for improperly recessed nails by running the edge of a sheetrock knife over the nailheads. A clicking sound indicates a nail needing to be recessed.

Step 2. Use a 4-inch knife and mud pan with joint compound to apply a smooth coat of joint compound over the nails. Remove any excess compound.

Step 3. Use the knife and mud pan to apply a heavy coat of joint compound over a sheetrock joint, horizontal or vertical. A heavy coat is enough to ensure a good bond between the tape and sheetrock and to fill in tapered edges. Measure and cut the tape to the length required for a joint. Keeping the tape centered over the joint, start at one end of the joint and work toward the opposite end. Using the knife, press the tape into the compound, removing all excess compound. Work off all excess joint compound, being careful not to wrinkle the tape or leave air bubbles. Continue to tape all the joints in the same manner.

Step 4. Use a 4-inch knife to apply a heavy coat of joint compound over the sheetrock at the inside corner. Measure and cut the tape to the length required for the joint. Fold the tape in half lengthwise, keeping both edges even. Use a corner tape creaser if necessary. Apply the tape at the top and work downward, running the edge of your hand at the center of the tape to ensure that it is in the corner. Using the inside corner tool, press the tape into the compound, working off all excess compound and being careful not to wrinkle the tape or leave air bubbles.

Step 5. Apply the first coat of joint compound over the tape then apply a medium coat of joint compound. Feather the compound with the 6 -inch knife to about 2 to 3 inches on each side of the joint. A good job of feathering and smoothing will minimize sanding later.

Step 6. Apply the second coat of joint compound over the tape and nail coverings. The joint compound previously applied must be completely dry. Use the 4-inch knife to apply a thin coat of compound over the nails, removing any excess compound. Using the steps above, apply the second coating to the joints using the 6 -inch knife and feathering out 6 to 8 inches on each side of the joint.

Step 7. Apply the third coat of joint compound. The joint compound previously applied must be completely dry. Using the step above, apply the third coat using the 10 -inch knife and feathering out 10 to 12 on each side of the joint. Nails should not require a third coat, but it may be applied if necessary.

Step 8. Using a damp sponge or fine sandpaper, sand the surface to a smooth finish, ensuring that there are no voids and that the surface is ready to receive paint.

Patching Sheetrock. There are several different methods of patching sheetrock, depending on the size of the hole.

F or small holes, apply fiber-mesh tape directly over the hole. Cut the tape with joint compound and feather the edges. Sand or sponge the area smooth after it has dried.

For fist-size holes, cut out a rectangle around the hole with a keyhole saw. Cut a piece of backing ( $1 \times 2$ or $1 \times 3$ ) slightly larger than the opening itself. Glue or screw the backing into place. Cut a patch and glue it to the backing using either wallboard adhesive or mastic. Apply tape and coat it with compound. Feather the edges. Sand or sponge the area smooth after it has dried.

For large holes, mark and cut a rectangular section around the damaged area, reaching from the centers of the nearest studs. Cut a patch and screw or nail it to the studs. Apply tape and coat it with compound. Feather the edges. Sand or sponge the area smooth after it has dried.

## BASE MOLDING

The interior trim of a building should match or complement the design of the doors, the windows, and the building. Base molding is the trim between the finished wall and the floor. It is available in several widths and forms. Figure 9-6, page 9-8, shows the types of base molding.

Squareedge (or two-piece) baseboard consists of a square-edged baseboard topped with a small base cap. When the wall covering is not straight and true, small base molding will conform more closely to the variations than will a one-piece base al one. This type of baseboard is usually $5 / 8 \times 31 / 4$ inches or wider. Installation of square-edged baseboard is shown in Figure 9-7.


Figure 9-6. Types of base molding

Narrow- and wideranch base (one-piece baseboard) are $3 / 4 \times 31 / 4$ inches or wider and vary from $1 / 2 \times$ $21 / 4$ inches to $1 / 2 \times 31 / 4$ inches or wider.

A wood member at the junction of the wall and carpeting serves as a protective bumper; however, wood trim is sometimes eliminated. Most baseboards are finished with a 1/2-x 3/4inch base shoe. A single-base molding without the shoe is sometimes placed at the wallfloor junction, especially where carpeting might be used.

Baseboard should be installed with a butt joint at the inside corners and a mitered joint at the outside corners. (The baseboard installation in Figure 9-7 is done


Figure 9-7. Insfalling base molding with square-edge baseboard.) It should be nailed to each stud with two 8d finishing nails. Base molding should have a coped joint at inside corners and a mitered joint at outside corners. A coped joint is one in which the first piece is square cut against the plaster or base and the second molding is coped. This is done by sawing a $46^{\circ}$ miter along the inner line of the miter. The base shoe should be nailed into the subfloor with long, slender nails, but not into the baseboard itself. Then, if there is a small amount of movement in the floor, no opening will occur under the shoe. When several pieces of molding are needed, they should be joined with a lap miter (Figure 9-8). When the face of the base shoe projects beyond the face of the molding, it abuts (Figure 9-9).


Figure 9-8. Trim lap-miter joint

## CEILING COVERINGS

In current construction, sheetrock, plywood, and fiberboard are used instead of Iaths and plaster to cover ceilings.

## SHEETROCK

Cut the panels and treat the joints the same as for walls and partitions, making sure that joints break
on the centers of ceiling joists.

A brace may be constructed and used to raise and hold a sheet in place when fitting and nailing the sheet to the ceiling joists. Nail sheets with the lengths going across ceiling joists to prevent sagging (F igure 9-10, page 910).

## PLYWOOD

Plywood is hung the same on ceilings as on walls and partitions.


Figure 9-9. Base-shoe trimming

## FIBERBOARD

Fiberboard sheets are $1 / 2$ to 2 inches thick. For a smooth cut on these sheets, use a utility knife. Fiberboard sheets are attached directly to the joists. To improve ceiling appearance, cover the joints between the sheets with batten strips of wood or fiberboard. Smaller pieces of fiberboard (tiles) require furring strips (wooden strips nailed across joints) (Figure 9-11, page 9-10).

Fiberboard sheets also come in small (rectangular or square) pieces called tiles, which are often used for covering ceilings They may be made with a lap joint, which permits blind-nailing or stapling through the edge. They may also be tongue-and-grooved, fastened with 2d box nails driven through special metal clips.

F or fiberboard tiles that need solid backing, place furring strips at right angles across the bottom of the joists. Place short furring pieces along the joists between the furring strips. Nail metal channels to furring strips and slide the tiles horizontally into them. In lowering ceilings (usually in older buildings), metal channels are suspended on wire. Some large ( $2 \times 4$ foot) tile panels are installed in individual frames.

## CEILING MOLDINGS

Ceiling moldings are sometimes used at the junction of the wall and the ceiling to finish the sheetrock paneling (sheetrock or wood). Inside corners should be coped joints. This ensures a tight joint even if minor moisture changes occur. Figure $9-12$ shows ceiling molding.

For sheetrock walls, a small, simple molding might be best. For large moldings, finish nails should be driven into the


Figure 9-10. Brace for holding ceiling panels
upper wallplates and al so into the ceiling joist, when possible. (For plastered ceilings, a cutback edge at the outside of the molding will partially conceal any unevenness of the plaster and make painting easier where there are color changes.)


Figure 9-11. Furring strips on ceiling joists


Figure 9-12. Celling moiding

## CHAPTER

A bridge is a structurethat carries a roadway over a depression or an obstacle. Bridges may be classified in different ways. Two general classifications, for example, arehighway and railroad bridges. One of the bridges most commonly found in theTO is the nonstandard fixed bridge This chapter discusses the construction of both the substructureand the superstructure of this important military bridge.

## BRIDGE CLASSIFICATION

A bridge completely supported by its two end supports (abutments) is called a singlespan bridge. A bridge having one or more intermediate supports between the abutments is a multispan bridge. All supports of a fixed bridge transmit the load directly to the ground.

A nonstandard fixed highway bridge (Figure 10-1) is a semi permanent bridge constructed from local materials or Class IV materials drawn from a depot. It differs from standard bridges, which are prefabricated bridges assembled at the site. The most common nonstandard fixed highway bridges are the simple, stringer-type (the stringers being logs) and those made of structural grade timber or structural steel.


Figure 10-1. Nonstandard fixed highway bridge

## SUBSTRUCTURE

The substructure of a bridge supports the superstructure. The substructure consists of

## ABUTME NTS

There are two types of end supports or abutments: footing and pile

## Footing

The footing abutment consists of-

- Footings. F ootings transmit the load to the ground. They receive the load from the sill and distribute it over a sufficient area to keep the support from sinking into the ground.
- Sill. The abutment sill (Figure 10-2) receives the load from the stringers and transmits it to the footings.
- End dam. The end dam (or bulkhead) is a wall of planks at the end of the bridge to keep the approach road backfill from caving in between the stringers.


## Pile

The pile abutment (Figure 10-3) has three main parts:

- Piles driven into the ground, transmitting the load to the soil.
- A cap on top of the piles to receive the load from the stringers.
- Sheeting fastened to the piles to hold the backfill in place.


Figure 10-2. Timber sill abutment

INTERMEDIATE SUPPORTS
The following are some of the different types of intermediate supports.

## Pile Bent

The pile bent (Figure 10-4) consists of the bent cap, which provides a bearing surface for the stringers and transmits the load to the piles; and the piles, which transmit the load to the soil.


Figure 10-3. Pile abutment and retaining wall

The support for the loads may come either from column action, when the tip of the pile bears on a firm stratum such as rock or hard clay, or from friction between the pile and the soil into which it is driven. In both cases, earth pressure must give some lateral support; transverse bracing is also often used for this purpose.

The pile bent is used for highway bridges only. It is designed to carry both vertical and lateral loads and can be used for spans of up to 50 feet. Its ground-to-ground height is a function of its unbraced length.

## Trestle Bent

The trestle bent (Figure 10-4) is like the pile bent except that posts take the place of piles. The posts transmit the load from the cap to the sill, the sill transmits the load to the footings, and the footings transmit the load to the soil. The length of the posts varies according to the height of the bridge above the gap to be spanned. Transverse bracing like that used with the pile bent is provided.

The trestle bent is used for highway bridges only; however, unlike the pile bent, it is designed to carry vertical loads only. It can be used for spans of up to 30 feet and for ground-to-grade heights of up to 12 feet.


Figure 10-4. Pile bent and trestle bent

## Pile-Bent Pier

The pilebent pier (Figure 10-5, page 10-4) is composed of two or more pile bents with a common cap. The cap transmits the load to the corbels (short, stringer-like members) that, in turn, transmit the load to the individual bent caps and then to the piles and to the soil. Piers usually have cross bracing which ties the bents together, giving them longitudinal rigidity.

The use of multiple bents gives the pile-bent pier great strength. As a result, the pile-bent
pier can be used for both highway and railroad bridges. It will carry both vertical and lateral loads, can be used for spans of up to 200 feet, and its ground-to-grade height is governed by its unbraced length.


Figure 10-5. Pile-bent pier

## Trestle-Bent Pier

The trestle-bent pier (timber-trestle pier) (Figure 10-6, page 10-4) is the same as the pile-bent pier, except that it has sills and footings which transmit the load to the soil.

The trestle-bent pier is used for highway bridges only. It is designed to carry vertical loads only and can be used for spans of up to 60 feet and for ground-to-grade heights of up to 18 feet.

## Crib Pier

The crib pier (Figure 10-7, page 10-5) is quite different from pile and trestle piers. It is composed of logs or dimensioned timber fitted together in log-cabin style and is usually filled with rock or other stable fill material. The crib pier should be made so that it needs no exterior bracing. As an expedient, crib piers may be built to the height of the stringers, eliminating the trestle bents.

The crib pier is used for highway bridges only. It is for vertical loads only and can be used for a span of up to 50 feet and a ground-to-grade height of up to 12 feet.

Bracing consists of longitudinal bracing, transverse bracing, and diaphragms.
Longitudinal bracing (Figure 10-8) is used to stabilize the bridge centerline.
Transverse bracing (Figure 10-8) provides stability at right angles to the centerline. It is sometimes called sway or lateral bracing.


Figure 10-6. Trestle-bent pier

Diaphragms are braces between stringers to prevent them from deflecting laterally (buckling) under load. In spacing these diaphragms, the ratio of distance between diaphragms to the width of the top of stringer (L/b ratio) should not exceed 30 for timber.

L = distance between diaphragms $b=$ width of top of stringer

Example If the stringer is 6 inches wide-


Figure 10-7. Crib pier
$L=30 L=180$ inches ( 15 feet)
In this example, diaphragms should be used every 15 feet between stringers 6 inches wide.

## CONSTRUCTION PROCEDURES

The following paragraphs contain construction procedures for a trestle-bent bridge. This includes laying out the centerline and constructing abutments, retaining walls, and trestle bents.

## Layout of Centerline

The first task in constructing a trestle-bent bridge is laying out the centerline (Figure 10-9, page 10-6):

Step 1. Stretch a line or tape representing the centerline across the stream or ravine.


Figure 10-8, Bracing

Step 2. Attach the line to stakes driven into the ground at least 15 feet behind the proposed location of the abutment sills. F or defiles wider than 100 feet, use intermediate stakes as needed to prevent sag.

Step 3. Place the line at the level of the intended top of the flooring or at some known distance above or below it.

## Construction of Abutments

Saving time in abutment construction is especially important on short bridges. Abutment and approach preparation often requires as much time as the rest of the bridge. Use the simplest abutment possible; often a timber sill with timber footings is adequate (page 10-2).

The end dam is installed after the stringers and planks.

After the centerline is fixed-
Step 1. Place the abutment sill at approximately its correct location under the tape. See that it is at right angles to the centerline by using a line from the centerline stake 15 feet behind the sill to each end of the sill. Both distances must be the same.

Step 2. Once the sill is properly


Figure 10-9. Laying out a centerline
located, mark its position and remove it to construct the foundation.

- Remove the earth as needed to provide a level surface for footings. The sill must be level and supported equally by each footing when installed. Make sure that the surface supporting the footings is about 2 inches higher than its final position to allow for settling. Do not dig too deeply. If this is done by mistake, do not backfill with earth. Instead, raise the level with planking.
- Place the two outside footings so that their outer edges are under the ends of the sill. Place the long dimension of the footings parallel to the bridge centerline.
- Place the remaining footings, equally spaced, between and in line with the outside footings.
- Place the sill on the footing centerline so that the load is in the middle of each footing. Place the sill with the largest dimension vertical.
- Provide for drainage of the abutment area.


## Construction of Retaining Walls

Retaining walls and revetments, when needed, are part of the abutment construction. The simplest type of retaining wall is built of planks or logs supported by piles or posts. (Figure 10-10 shows an abutment and retaining wall; Figure 10-11 shows retaining-wall details.)


Figure 10-10. Abutment and retaining wall

- Use wing walls to prevent the earth from washing out behind the retaining wall.
- Drive piles or posts 4 feet into the ground.
- Fasten anchor cables from the top of the piles to a deadman behind the retaining wall or to the wing-wall end. These deadmen and anchors can be eliminated if two or three rows of piles, driven as far as they will go, are used.
- For long spans and heavy loads, the abutment and retaining wall are often constructed as a unit. This may also be necessary where steep banks and poor soil conditions exist.


## Construction of Trestle Bents

After the position of the near-shore abutment sill is established, locate the position of the first trestle bent:

Step 1. Measure the length of the first span from the abutment sill along the centerline (Figure 1012).

Step 2. Drive a small stake under the centerline where the center of the trestle bent is to be. Use a plumb bob if necessary.

Step 3. Continue this procedure until all trestle bents and the far-shore abutment sill are located.
Step 4. Excavate and place footings under the trestle bent the same as for the abutment (page 10-
5). Outside footings under the trestle sill are centered under the outside posts of the bent.

- Measure the vertical distance from the centerline down to the top of the footings.
- If the centerline was placed at the intended top of the flooring, this distance minus the thickness of the tread, deck, and stringers gives the height of the trestle bent.
- If steel stringers are to be used, allow also for the thickness of the nailing strips.


Figure 10-11. Retaining-wall detalls

Step 5. To obtain the correct height of the trestle-bent posts, subtract the thickness of the cap and sill from the height of the trestle bent.

## Additional Construction Procedures

There are some additional procedures that should be followed when constructing a substructure.

- Make the length of the cap and sill equal to the roadway width plus 2 feet.
- Center the outside posts under the roadway


Figure 10-12. Determining trestle-bent height edges 1 foot from the ends of the cap and sill. Space other posts evenly between the outside posts.

- Use driftpins or bolts to fasten the sill and cap to the posts. Use scabbing instead of driftpins for fast erection.
- Nail transverse bracing across both sides of the bent. Usually 3-x 12-inch planks are used. F asten the bracing to each post that it passes over. Cut the bracing so that the ends extend beyond where they are nailed, to prevent splitting.
- Put the bent into position, using a plumb bob to ensure that it is straight. H old it in place with temporary braces nailed to stakes driven into the ground. Use these temporary braces until the permanent longitudinal bracing can be nailed to the outside posts of adjacent trestle bents.


## SUPERSTRUCTURE

The superstructure is the spanning structure consisting of stringers, flooring (decking and tread), and other features such as curbs, handrails, sidewalks, and end dams.

## STRINGERS

When wood stringers are used, they are usually long enough to extend across the abutment sills and trestle caps on which they rest. Stringers of one span are lapped with those of the next span.

## Placing Stringers

After the abutment and trestle bents are in place, the stringers are installed (Figure 10-13).
When stringers are lapped, place one outside stringer so that its inside face is under the inside face of one curb. Place the other outside stringer so that its outside face is under the inside face of the other curb. Stringers can then be lapped with a similar spacing on the next span. The remaining stringers are usually spaced evenly between the outside
stringers. On some narrow one-lane bridges, stringers may be grouped closer together under the vehide tracks.

When stringers are butted, or continuous across the span, place the outside faces of both outside stringers under the inside faces of the curbs.

## Fastening Stringers

F asten stringers (Figure 1014) as follows:

Wood Stringers. F asten wood stringers by driving nails diagonally through the side of the stringer into the cap or by driftbolts. When


Figure 10-13. Stringer placement using driftbolts, bore a hole, smaller in diameter and 3 inches shorter than the driftbolt, through the stringer and into the cap.

Steel Stringers. Fasten steel stringers by-

- Driving railroad spikes into the cap beside the flange.
- Driving 60d nails partially into the cap and bending them over the bottom flange.
- Driving nails or driftbolts through prebored holes in the bottom flange.


## NOTE: When steel stringers are not fastened through their flanges, frequent inspection is necessary to be sure the stringers have not shifted. Fasten wood nail strips to the top flange of steel stringers to provide a means of fastening the flooring.

When a laminated deck (planks placed on edge) is to be installed, the planks may be fastened to steel stringers either by using metal clips provided for the purpose or by driving nails partially into the deck and bending them around the stringer flange (Figure 10-15).

## FLOORING

The flooring system of a typical timber-stringer trestle bridge consists of two main parts: the decking and the


Figure 10-14. Fastening stringers
tread.

## Decking

The decking is the part of the structure that is laid on the stringers to form the roadway across the trestle bridge. Decking may be laminated or solid plank.

Laminated. Laminated decks may be solid or open with uniform spacing between members.

- For an open laminated deck (Figure 10-16) where the planks are long enough to reach completely across the width, use two spacing blocks between laminations. Place spacers on the stringer nearest onethird the length of the lamination. Where the laminations are not long enough (usually true for two-lane bridges), lap the laminations on a central stringer. Put a spacer block at each outside stringer.
- For a solid laminated deck, place laminations solidly against one another.

Solid Plank. For a solid-plank deck (Figure 10-17), lay planks horizontally, at right angles to the stringers. Leave a $1 / 4$-inch space between planks to allow for swelling when wet.

Extend the decking about 2 feet at approximately 5-foot intervals to support the handrail posts (Figure 10-18, page 10-12).

## Tread

The tread consists of planks placed over the decking and between (but not under) the curbs. The planks are usually 2 or 3 inches thick, of varying lengths, and are laid parallel to the direction of traffic. On one-lane bridges, the tread is limited to the path of the wheels or track. TwoIane bridges are fully covered with tread. (Figure 10-19, page 10-12 shows tread placement.)

## CURBS

A curb system on a timber-trestle bridge is used to guide traffic on


Figure 10-16. Open laminated deck
the bridge. When assorted sizes of lumber are available, make curbs of 6 - x 6 -inch timber supported on $6-\times 12-\times 30$-inch curb risers, spaced on about 5foot centers. The curb is usually bolted to the decking with 1/2inch bolts, two per curb riser.

## HANDRAILS

Handrails (Figure $10-20$, page $10-$ 12) mark the bridge route and provide safety for pedestrians crossing the bridge. Make handrails of 2-x 4-inch or larger material, if available. Over a laminated deck, make handrail posts and knee braces of the same material as the deck so that


Figure 10-17. Solid-plank deck they can be fastened snugly between the laminations, which are extended to receive them.

For solid-plank decks, toenail $4 \times 4$ posts, or two $2 \times 4$ s nailed together, to the extended planks. Make the posts 42 inches high and space them on 5 -foot centers. Place the posts so that the distance from the inside face of the curb to the inside face of the handrail is at least 10 inches.

## SIDE WALKS

If sidewalks are necessary, form them by extending the decking an additional 36 inches. Place stiffening members underneath the outside edge. Support them with braces attached to the stringers, where necessary.

## END DAM

The end dam is the wall that withstands the earth pressure of the abutment of a bridge (see Figure 10-1, page 10-1). After the stringers and flooring are in place, construct an end dam of flooring planks across the end of the stringers. The end dam should extend across the roadway from the top of the footing to the top of the tread. After placement of the end dam, complete the approach up to the top of the bridge deck. Post the traffic-control and classification signs. The bridge is now ready for traffic.


Figure 10-18. Extended deck for handrail support


Figure 10-19. Tread placement


Figure 10-20. Standard curb and handrail

## timber-PILE WHARVES

Wharves are used for loading and unloading ships. This chapter describes how a carpenter constructs a timber-pile wharf. The topics covered include-

- Layout and installation of piles for pilewharf construction.
- Construction of a wharf superstructure.
- Installation of docking hardware
(F or more detailed information on timber-pile wharves, see FM 5-480.)


## TYPES OF WHARVES

Wharf is an overall term that applies to any waterfront structure designed to make it possible for vessels to lie al ongside the shore for loading and unloading. The term wharf is confined in practice to the T- and U-type marginal wharves (Figure 11-1, page 11-2). A marginal wharf usually consists of a timber or steel superstructure supported by a series of timber, steel, or concrete pile bents.

The other structures shown in Figure 11-1 are called piers, except the quay. A quay is a reinforced landing place made toward the sea or at the side of a harbor. All structures shown in Figure 11-1 may consist of fill supported by bulkheads.

## TYPES OF PILES

To protect a wharf against normal wear and tear, three types of piles are used: bearing, fender, and mooring piles. The types of piles are discussed in the following paragraphs:

## BEARING PILES

Bearing piles support the wharf or pier framework and decking. The piles should be straight and measure at least 6 inches across the top, 18 inches across the butt (bottom), and from 60 to 80 feet in length. Pile length varies according to the depth of the water and condition of the bottom.
Bearing piles should be spaced from center to center 6 to 10 feet apart in one direction and 5 feet apart in the other direction.

## FENDER PILES

The force of a moving ship coming in direct contact with bearing piles is enough to collapse an unprotected wharf. To protect and absorb the initial shock, fender piles are placed about $21 / 4$ feet out from the centerline of the outside row of bearing piles. These piles are placed about 18 feet
apart and al ong the sides where ships dock.


Figure 11-1. Common wharves

## MOORING PILES

Mooring piles are aligned with the outside row of bearing piles and are spaced about 30 feet apart. This type of pile is braced along the outside row of bearing piles and usually extends to about 4 feet above the floor (or deck) of the platform. The 4 -foot extension provides ample space to secure mooring lines.

NOTE: Timber piling must be treated with creosote or some other preservative Compound to protect it from fungi and marine borer attacks.

## INSTALLATION OF PILES

Pile-driving equipment and the methods of driving and pulling piles are covered in FM 5-480. The equipment is operated by a special crew, but the carpenter is present during the pile driving to direct the alignment of the piles.

## USING SPECIAL TOOLS

timbers used to build waterfront structures cannot be manhandled, special tools, known as logger's tools (Figure 11-2), are used to move and place these timbers. They consist of-

- Peavy and cant hooks. Lever-type tools, used mainly to roll timbers.
- Timber carriers. Two-man tools, used mainly to pick up and carry timbers.
- Pike poles. Used to hold or steady timbers while they are being placed.
- Cranes. Normally, two men are assigned to a crane: the operator and the helper. The helper drives the crane carrier (truck) and hooks and unhooks loads. Using standard signals, the hel per tells the operator when to lift and lower the load and where to position it. After the heavy timbers have been moved and placed, the carpenter's level is used to level them properly.


## NOTE: Although the crane cannot be considered a special tool, it is mentioned here because of its use to raise and lower heavy timber.

## STRAIGHTENING PILES

Piles should be straightened as soon as any misalignment is noticed. The desired accuracy of alignment varies with each job; however, if a pile is more than a few inches out of plumb, it should be set true. The greater the penetration along the wrong line, the more difficult to get the pile back into plumb. To realign piles, use one of the following:

- A block and tackle (Figure 11-3), with the impact of the hammer jarring the pile back into line.
- A jet (Figure 11-4, page 114), either alone or in conjunction with a block and tackle.
- A block and tackle and an alignment frame (Figure 11-5, page 11-4) to pull the piles In a bent into proper spacing and to align them after they have been driven.

When a floating pile driver is used, a frame (template) for positioning piles may be fastened to the hull. A floating


Figure 11-3. Realigning with a block and tackle


Figure 11-4. Realigning with a jet
template (Figure 11-6, page 11-6) is sometimes used to position the piles in each bent. The spacing of battens is such that the centerline between them is on the pile line desired. Battens are placed far enough apart so that, as the pile is driven, the larger diameter butt end will not bind on the template and carry it underwater.

A chain or collar allows the template to rise and fall with the tide. If the ends of the battens are hinged and brought up vertically, the template may be


Figure 11-5. Realigning with a frame withdrawn from between the bents and floated into position for the next bent. Several templates may be used for a bent; or a single template is moved, if the pile spacing is uniform. The position of the piles is controlled as follows:

Step 1. After each bent has been driven, a line is run back from each pile in the outer bent to the corresponding pile in each of the next several bents shoreward.

Step 2. The alignment and longitudinal spacing of the outshore bent are verified.
Step 3. Any deviation in position of previously driven piles is made up when the template is positioned for the next bent. Piles that are slightly out of position may later be pulled into place as described previously in the first paragraph.

## CUTTING PILES

The lengths of pile selected for a structure should be such that the butts are 2 or 3 feet higher than the desired finished elevation after driving to the desired penetration. Since the pile capping should bear


Figure 11-6. Floating template
evenly on every pile in the bent, trimming should be carried out accurately by nailing saw guides across all piles in the bent. Figure 11-7 shows cutting piles.

## CAPPING TIMBER PILES

Caps are large timbers placed on top of the timber-bearing piles to support the superstructure. The pile capping is fastened as shown in Figure 11-8, page 11-6, and as follows:

Step 1. After the piles have been cut, the cap is put in place; a hole for a driftpin is bored through the cap into the top of each pile; and the driftpins are driven into the holes.

Step 2. At a joint between pile cap timbers, a splice scab is bolted across the joint to each side of the pile cap.

Step 3. The working platform, aligning cables, or spacing frame may then be removed, since the driftpins will hold the piles in the proper position.

## BRACING PILES

Bents are braced as shown in Figure 11-8 and as follows:
Step 1. Bolt diagonal timbers to each pile with the bracing running in one diagonal direction on one side of the bent and in the opposite diagonal direction on the other side.

Step 2. If the piles in a bent differ a lot in diameter at the point of bracing, make one of the following corrections:

- Large piles may be flattened down with an ax (hewed or dapped).
- Small piles may be blocked out with filler pieces.
- The flexibility of the braces may be used to pull them tight against the piles.
(Figure 11-9, page 11-6, shows transverse bracing.)


Figure 11-7. Cutting piles

## WHARF SUPERSTRUCTURE

After the timber pile bents have been aligned, braced, and capped, the construction of the wharf superstructure is begun. Building the superstructure consists of installation of the stringers, the decking, and the curbs or stringpieces; and erection of the fender systems.
Figure 11-10 shows stringers and decking in place.

## STRINGERS

Stringer positions are


Figure 11-8. Capping and bracing piles measured from the centerline of the wharf. The stringers are toenailed to the pile caps with two $3 / 8-\times 10$-inch spikes at each bearing point. The ends of the stringers overlap to provide complete bearing on the pile caps. Spacer blocks are toenailed between stringers with two 60d nails.

## DECKING

Standard decking consists of $4-\mathrm{x} 8$-inch planks, which are spiked to each stringer with two $5 / 16-\mathrm{x}$ 7 -inch spikes, and set with $1 / 4$-inch spacing. Openings greater than $1 / 4$ inch may be used between planks in areas that are subject to heavy rains.

## STRINGPIECES

The stringpiece (or curb) is placed on 2-x 10-inch blocking, 24 inches long, spaced on 48 -inch centers along the edge of the deck. Stringpiece bolts are countersunk and the hole is seated with bituminous material. (Figure 11-11 shows a wharf-edge cross-section of a timberpile wharf.)

- When the stringpieces are


Figure 11-9. Transverse bracing for different size piles
parallel to the direction of the wharf stringers, the stringpieces are bolted through the blocking, the decking, and the stringer end pieces.

- When the stringpieces are perpendicular to the direction of the stringer, they are bolted through the blocking, the decking, alternate stringers, and the pile cap.


## FENDER PILES AND <br> CHOCKS

Timber is the most suitable material for wharf fenders in TO construction. Fender piles


Figure 11-10. Stringers and decking in place serve the following purposes:

- They cushion a wharf from the impact of ships and protect the outer row of bearing piles from damage.
- They protect the hulls of craft from undue abrasion.

The 3- or 4-foot extension of a fender pile above the deck level of a wharf supplements wharfmooring hardware, but is not used for warping a ship into or out of the berth.

Since fender piles are not part of the structural support of the wharf, they are easier to replace than bearing piles.

## Protection of Fender Piles

Protective devices that lengthen the life of fender piles are-

- A heavy timber wearing ribbon, which may easily be replaced. It is sometimes installed al ong a line of fender piles at the elevation receiving the heaviest abrasion.
- Floating logs or camels (floating fenders).
- Rope wrappings, particularly on corner fenders.


## Fender Piles for Quays

Structures that are almost completely rigid, such as solid-fill quays, sometimes have fender piles backed up with heavy springs to give a combination of yield and resistance.

## Installation of Fender Piles

Fender piles are driven at a slight batter (angle). Usually 1 to 12 fender piles are used along the outside edge of all rows of bearing piles, except on the extreme inshore wharf sections. Every third
fender pile may extend 3 to 4 feet above the curb. The others are cut off flush with the top of the curb.

## Chocks and Wales

Chocks are timber braces placed between fender piles at the level of the stringpiece or pile cap to hold them in position and give them lateral stability. Chock ends should be firmly seated against the piles.

- On timber-pile wharves, each chock is fastened with two bolts through the stringer endpiece or pilecap.
- On steel-pilewharves, each chock is bolted by 12-x 12-inch blocks driftpinned to the ends of the stringers or bolted to the ends of the wharf pile cap.

Wales (horizontal beams) are used at mean low water elevation when tidal currents are swift or tidal variations are great. Wales add rigidity to fender piles. A 12-x 12-inch continuous longitudinal timber wale is bolted to the back fender of each pile. Timber chocks are placed between fender piles and bolted to the line wales.

## PILE CLUSTERS AND CORNER FENDERS

Pile clusters, whether at the faces or corners of wharves or acting as dolphins (isolated pile clusters), must combine beam strength, rigidity, and stability against horizontal stresses. Therefore, the individual piles that make up the cluster must be joined so that the cluster will act as a unit.

## Mooring Piles

Clusters of three or more piles are used to supplement or replace wharf-mooring hardware. The top of the cluster is lashed together.

Mooring piles are placed at intervals al ong the wharf face when bollards and other mooring hardware are not avail able. A maximum of three piles of each cluster extends 3 feet or more above the wharf deck.

## Corner Fenders

Piles clustered at exposed corners of the wharf, bolted


Figure 11-11. Wharf-edge cross-section of a timber-pile wharf and lashed together, are provided so that a ship may
use the corner to pivot when warping in and out of the berth. The wharf is strongly reinforced at the corners with layers of diagonal planking laid one across the other. This reinforcing is backed up with diagonal batter piles.

The standard corner-fender cluster is made up of 10 piles battered for adequate spacing at the points. Timber connectors may be used in conjunction with the bolts to tie the piles more firmly into a single rigid member. To avoid undue abrasion to ship hulls and to outside pile surfaces, heavy rope mats may be lashed to the clusters at the level of contact. To supplement mooring hardware, the corner piles extend 3 to 4 feet above deck level.

Deck Reinforcing on Wood-Pile Wharves. Before stringers are set, wooden piles battered inward are driven to support a cap, set diagonally across each corner, and bolted to the bottom face of the other caps. Another piece of cap timber is set to act as a strut between the fender cluster and the diagonal cap.

The space between the cluster and the diagonal cap is then floored over with two layers of plank each 6 inches thick, laid diagonally (and transversely to each other) to fill the thickness between the cap timbers. To complete the reinforcement, stringers are set close and spiked together over the outer half of each corner panel.

Deck Reinforcing on Steel-Pile Wharves. In steel-pile marginal wharves and piers with corner fenders, the deck in each corner panel is similarly reinforced with timber. Wood piles battered inward carry a diagonal cap timber bolted to the bottom flanges of the steel-pile caps. The diagonal cap is strutted against the fender cluster, the diagonal layers of plank are applied, and the stringers are set close and spiked together, as described above for wood-pile wharves.

## FLOATING LOG FENDERS (CAMELS)

F loating logs are used to absorb part of the impact shock when a ship is berthed. They protect the surface of fender piles while a ship is tied up. The simplest type of fender is a single line of floating logs, each secured by two or more lengths of $1 / 2$-inch galvanized chain fastened to $3 / 4$-inch eyebolts in the fender $\log$ and the wharf pile. Some arrangement, such as loose steel collars around the wharf piles, is provided to allow the logs to rise and fall with the tide.

Floating clusters of logs or strongly constructed rafts are called camels. In addition to absorbing impact shock and protecting fender piles from the sliding friction of a ship moving in the berth, camels may be required to breast a ship off the face of the wharf into deeper water.

PILE-MOORING DOLPHINS


Figure 11-12. Typical pile dolphin

Dolphins (Figure 11-12 and Figure 11-13, page 11-10) are isolated clusters of piles to which a ship may be moored. The center of the cluster, called a king pile, may be a single pile or a cluster driven vertically and wrapped to act as a unit. The other piles are driven in one or more concentric rings around the king pile, each battered towards the center. The king pile is normally left somewhat longer than the others for use as a mooring post.

When composed of a cluster, the king pile is wrapped with at least six turns of 1inch diameter galvanized wire rope, stapled to each pile at every turn.

Two wrappings of the type described above are used for the pile cluster. One wrapping is located near the top of the cluster and the second about 2/3 the


Figure 11-13. Typical dolphin plan views distance above mean low water.

To further ensure that the cluster will act as a unit, the piles are chocked and bolted together approximately 2 feet above mean low water.

## DOCKING HARDWARE

Ships tie up to wharves with lines fastened to mooring fittings such as bollards, corner mooring posts, cleats, chocks, and pad eyes (Figure 11-14).

- Bollards, single- or double-bitt, are steel or cast-i ron posts to which large ships are tied. They prevent ships' lines from riding up off the post. Bollards may have waist diameters smaller than ton diameters and may have caps, or projecting, rounded horns. Double-bitt bollards are also known as double bitts or double steamship bitts. Bollard bodies may be hollow for filling with concrete after installation They are usually designed to take line pulls of about 35 tons.
- Corner mooring posts are usually designed to take pulls of up to 60 tons.
- Cleats are generally cast iron, with arms extending horizontally from a relatively low body. The base may be open or closed. Cleats are used for securing smaller ships, tugs, and workboats.
- Open or closed chocks, generally made of cast iron, are used for directing and snubbing lines when working a ship into or out of its berth. A closed chock must be used when there is a change in both vertical and horizontal directions of a line.
- Pad eyes are metal rings mounted vertically on a plate and intended to receive a ship's line spliced with thimble and shackle. They are used only for securing small craft.


Figure 11-14. Mooring hardware

## HARDWARE INSTALLATION

Proper installation requires that the vertical and horizontal stress on any structural unit on which mooring hardware is attached be partially transferred to the wharf structure. This is done by increasing the number and size of stringers under the hardware installation, and by providing anchorage for mooring hardware bolts that will transfer the stress through the pile cap of one or more bents to several piles.

## Stringer Reinforcement

The number and size of stringers are increased at the location of major hardware items. When base widths of hardware are greater than 12 inches, but less than 24 inches, at least two 12- x 12inch stringers are needed. F or base widths greater than 24 inches, but less than 36 inches, three $12 \times 12$-inch stringers are needed; and so forth. Stringers are laid close together and are spiked to each other and at each bearing point. Mooring hardware bolts pass through stringers, filler blocks, and anchorage timbers.

## Standard Installation

Standard wharf structures use the following mooring hardware:

- Pier, $90 \times 500$ feet-six large double-bitt bollards on each side on 100 -foot centers and five 42 inch cleats on each side centered between bollards.
- Offshore marginal wharf, $60 \times 500$ feet- six large double-bitt bollards and five 42 -inch cleats spaced as above on the outshore side only.
- Lighterage quay $35 \times 500$ feet—eleven 42 -inch cleats on 50 -foot centers.

For nonstandard wharf structures, mooring hardware should be installed in numbers, types, and spacing approximately that of standard wharves.

When cleats and pad eyes are not available, every third fender pile must be extended 3 to 4 feet above the wharf deck. Fender-pile extensions may be used to steady a ship in the berth, but not to winch a ship into position.

On berths located near enough to the shore, bollards or mooring posts may be located onshore.

## Location

Bollards and other mooring hardware are placed dear of cranes and traffic and as close to the curb as possible. Onshore mooring anchors should be located so that the lines will not have to be moved for traffic.

## ANCHORAGES FOR HARDWARE

The following paragraphs explain the different types of hardware and their uses:

## Location Between Pile Bents

To provide anchorage for heavy items of mooring hardware located between pile bents, a grillwork of $12 \times 12$ timbers is bolted underneath the pile cap (Figure 11-15). Each of the four piles directly affected by the upward pull on the grillwork is strapped to the pile cap with $3-\times 3 / 8$-inch steel strapping. The straps are spiked to piles and pile caps. Filler blocks of $12 \times 12$ timbers are centered to receive the mooring hardware bolts.

## Location on Pile Bents

Mooring hardware is also located directly over the outside bearing pile of a bent as shown in Figure 11-16. M ooring hardware with 22 - to 26 -inch bolt centers is anchored as follows:

- Two $12 \times 12$ by approximately 20 -footlong timbers are bolted under the pile cap over which the hardware is located and to both sides of three piles of the bent.
- $12 \times 12$-inch filler timbers approximately 4 feet long are bolted to the wharf pile cap under the hardware bolt location.
- Each of the three piles directly affected by the upward pull on the


Figure 11-15. Timber grillwork
grillwork is strapped to the pile cap with steel strappings as described above (see Figure 1115).

Items of mooring hardware with bolt centers greater than 26 inches require using timber wider than 12 inches or doubling the number of timbers, or locating the hardware between bents using the timber grillwork anchorage described previously.

## Bracing

The wharf structure is longitudinally braced at the location of bollard installations. Diagonal bracing is done from just below the pile caps to about low-water level at the location of each bollard. The cross bracing is bolted to each pile.

## Installation of Light Items

Light items of mooring hardware with bolt centers less than 8 inches, such as cleats, chocks, and pad eyes, are bolted through the stringpiece, blocking, decking, and stringer end piece.


Finyra 11-1R Moarina harduraro muor hoorina nilla

| Metric to US | US to Metric |
| :---: | :---: |
| LENGTH |  |
| $\begin{aligned} & 1 \mathrm{~mm}=0.04 \text { in }(0.03937 \mathrm{in}) \\ & 1 \mathrm{~cm}=0.3937 \text { in } \\ & 1 \mathrm{~m}=3.281 \mathrm{ft} \text { or } 1.094 \mathrm{yd}=39.3707 \mathrm{in} \\ & 1 \mathrm{~km}=0.621 \text { statute-mile } \\ & 1 \mathrm{~km}=0.5399 \text { nautical mile (nmi) } \end{aligned}$ | $1 \mathrm{yd}=91.44 \mathrm{~cm}$ |
|  | $1 \mathrm{ft}=30.48 \mathrm{~cm}$ |
|  | $1 \mathrm{in}=2.54 \mathrm{~cm}$ |
|  | $7 / 8 \mathrm{in}=2.22 \mathrm{~cm}(22.22 \mathrm{~mm})$ |
|  | $3 / 4 \mathrm{in}=1.90 \mathrm{~cm}(19.05 \mathrm{~mm})$ |
|  | $5 / 8 \mathrm{in}=1.59 \mathrm{~cm}(15.88 \mathrm{~mm})$ |
|  | $1 / 2 \mathrm{in}=1.27 \mathrm{~cm}(12.70 \mathrm{~mm})$ |
|  | $3 / 8 \mathrm{in}=0.98 \mathrm{~cm}(9.52 \mathrm{~mm})$ |
|  | $1 / 4 \mathrm{in}=0.64 \mathrm{~cm}(6.35 \mathrm{~mm})$ |
|  | $1 / 8 \mathrm{in}=0.32 \mathrm{~cm}$ (3.18) |
| AREA |  |
| $\begin{aligned} & 1 \mathrm{sq} \mathrm{~cm}=0.155 \mathrm{sq} \text { in } \\ & 1 \mathrm{sq} \mathrm{~m}=10.76 \mathrm{sq} \text { ft or } 1.196 \mathrm{sq} \mathrm{yd} \\ & 1 \mathrm{sq} \mathrm{~km}=0.386 \mathrm{sq} \text { miles } \\ & 1 \text { hectare (ha) }=2.47 \text { acres } \end{aligned}$ | $1 \mathrm{sq} \mathrm{in}=6.45 \mathrm{sq} \mathrm{cm}$ |
|  | $1 \mathrm{sq} \mathrm{ft}=0.0929 \mathrm{sq} \mathrm{m}$ |
|  | $1 \mathrm{sq} \mathrm{yd}=0.836 \mathrm{sq} \mathrm{m}$ |
|  | $1 \mathrm{sq} \mathrm{mi}=2.59 \mathrm{sq} \mathrm{km}$ |
|  | 1 acre $=0.405$ ha |
|  | 1 acre $=43560$ sq ft |
| LINEAR MEASURE |  |
| Metric Denomination Meter | US Equivalent |
| 1 millimeter | $=0.001 \quad=0.0394 \mathrm{in}$ |
| 10 millimeters $\quad=1$ centimeter | $=0.01 \quad=0.3937 \mathrm{in}$ |
| 10 centimeters $=1$ decimeter | $=0.1 \quad=3.937 \mathrm{in}$ |
| 10 decimeters $=1$ meter | $=1 . \quad=39.3707 \mathrm{in}=3.28 \mathrm{ft}$ |
| 10 meters $\quad=1$ dekameter | $=10 . \quad=32.809 \mathrm{ft}$ |
| 10 dekameters $\quad=1$ hectometer | $=100 . \quad=328.09 \mathrm{ft}$ |
| 10 hectometers $=1$ kilometer | $=1,000 . \quad=0.62138 \mathrm{mi}$ |
| 10 kilometers $=1$ myriameter | $=10,000 .=6.2138 \mathrm{mi}$ |

## CARPENTRY ABBREVIATIONS AND SYMBOLS

## ABBREVIATIONS

Carpenters use the following abbreviations in connection with lumber:

| ad | air-dried |
| :--- | :--- |
| al | all length |
| av | average |
| avw | average width |
| avl | average length |
| bd | board |
| bf | board foot |
| bdl | bundle |
| bev | beveled |
| bm | board (foot) measure |
| btr | better |
| clg | ceiling |
| CL | centerline |
| clr | clear |
| CM | center-matched; that is, tongue-and-groove joints are made along the center of the |
|  | edge of the piece. |
| com | common |
| csg | casing |
| ctg | crating |
| cu ft | cubic foot |
| D\&CM | dressed (one or two sides) and center-matched |
| D\&M | dressed and matched; that is, dressed one or two sides and tongue and grooved on |
|  | the edges. The match may be center or standard. |
| ds | drop siding |
| D\&SM | dressed (one or two sides) and standard-matched |
| D2S\&CM | dressed two sides and center-matched |
| D2S\&SM | dressed two sides and standard-matched |
| 0 | diameter |
| dim | dimension |
| e | edge |
| FAS | firsts and seconds, a combined grade of the two upper grades of hardwoods |
| fbk | flat back |
| fbm | feet board measure (board feet) |
| fcty | factory (lumber) |
| fg | flat grain |


| flg | flooring |
| :---: | :---: |
| fok | free of knots |
| frm | framing |
| ft | foot or feet |
| hdl | handle (stock) |
| hdwd | hardwood |
| hrt | heart |
| hrtwd | heartwood |
| in | inch or inches |
| kd | kiln-dried |
| kd | knocked down |
| Ibr | lumber |
| Igr | longer |
| Igth | length |
| lin ft | linear foot; that is, 12 inches |
| Ir | log run |
| Ir mco | log run, mill culls out |
| m | thousand |
| mfbm | thousand (feet) board measure |
| mco | mill culls out |
| merch | merchantable |
| mr | mill run |
| mfsm | thousand (feet) surface measure |
| mw | mixed width |
| no | number |
| $\begin{aligned} & 1 s \& 2 s \\ & \text { ord } \end{aligned}$ | ones and twos, a combined grade of the hardwood grades of firsts and seconds order |
| p | planed |
| pat | pattern |
| pky | pecky |
| pln | plain, as in plain sawed |
| pn | partition |
| qtd | quartered (with reference to hardwoods) |
| rd | round |
| rdm | random |
| res | resawed |
| rfg | roofing |
| rfrs | roofers |
| rip | ripped |
| rl | random length |
| rw | random width |
| S\&E | surfaced one side and one edge |
| S2S\&M | surfaced two sides and standard- or center-matched |
| S2S\&SM | surfaced two sides and standard-matched |
| sap | sapwood |
| S1E | surfaced one edge |
| S1S1E | surfaced one side and one edge |
| S1S2E | surfaced one side and two edges |
| S2E | surfaced two edges |
| S4S | surfaced four sides |
| S\&CM | surfaced one or two sides and center-matched |


| S\&M | surfaced and matched; that is, surfaced one or two sides and tongue and grooved on <br> the edges. The match may be center or standard. |
| :--- | :--- |
| S\&SM | surfaced one or two sides and standard matched |
| S2S\&CM | surfaced two sides and center matched <br> sb |
| standard bead |  |
| sd | seasoned |
| sdg | siding |
| Sel | select |
| sesd | square-edge siding |
| sf | surface foot; that is, an area of 1 square foot |
| sftwd | softwood |
| shd | shipping dry |
| ship | shiplap |
| sm | standard matched |
| snd | sap no defect |
| snd | sound |
| sq | square |
| sq e | square edge |
| sq e\&s | square edge and sound |
| sgrs | squares |
| std | standard |
| stk | stock |
| sw | sound wormy |
| t\&g | tongue and groove |
| tb\&s | top, bottom, and sides |
| TO | theater of operations |
| tbrs | timbers |
| vg | vertical grain |
| wal | wider, all length |
| wdr | wider |
| wt | weight |
| wth | width |

## SYMBOLS

Symbols commonly used in carpentry are given below. For additional information on the various symbols used in construction plans and blueprints,

## Architectural

| Tile | (1])] | Brick | याए] |
| :---: | :---: | :---: | :---: |
| Earth | WTVYIM | Firebrick | 8 8 攵翏 |
| Plaster |  | Concrete | 01\%6: |
| Sheet metal |  | Cast concrete block |  |
| Built-in cabin | $\xrightarrow{\square \rightarrow}$ |  |  |


| Outside door: | Hot-water tank | $\ldots . \underset{H W T}{\bigcirc}$ |
| :---: | :---: | :---: |
| Brick wall | Grease trap | ... ${ }^{\text {d }}$ |
| Frame wall | Hose bibb or sill cock | 以 |
| Inside door: frame wall |  |  |
|  | Lavatories: |  |
| Shingles (siding) ...... | Pedestal |  |
| Wood, rough | Pedestal | PL |
|  | Wall hung | 0 |
| Wood, finished | Corner | WL |
| Cased or arched opening | Toilets: |  |
| Single casement window | Tank | $5$ |
| Double-hung window | Flush valve |  |
| Double casement window | Urinals: |  |
| Insulation: | Stall type | $\bigcirc$ |
| Loose fill | Wall hung | $\bigcirc$ |
| Board or quilts | Laundry tray |  |
| Cut stone | Laundry tray |  |
|  | Built-in shower | 1 |
| Ashlar .... | Shower | $0-1$ |
| Plumbing | Sinks: |  |
| Bathtubs: | Single drain board | ED |
| Corner | Double drain board | E믈 |
| Free standing |  |  |
| Floor drain |  |  |
| Shower drain |  |  |

## Electrical

Pull switch ..... -(5)
Single-pole switch ..... $\mathbf{S}_{1}$
Double-pole switch ..... $S_{2}$
Triple-pole switch ..... $S_{3}$
Buzzer ..... $\square$
Floor outlet ..... (
Bell ..... $\square 0$
Drop cord ..... (
Ceiling outlet ..... $\bigcirc$
Wall bracket ..... -
Single convenience outlet ..... $\theta_{1}$
Double convenience outlet ..... $=\theta_{2}$
Motor ..... (1.)

This chapter contains tables ( $\mathrm{C}-1$ through $\mathrm{C}-14$, All tables presume average working conditions pages C-1 through C-8) which may be used in in terms of weather, skill, crew size, accessibility, preparing manpower estimates for carpentry work. The tables do not include provisions for loading and hauling materials to the job site.

Table C-1. Rough framing

| Work element description Beams (3-2" x $8^{\prime}$ ) | Unit |  | Man-hours/unit <br> 30 |
| :---: | :---: | :---: | :---: |
|  | 1.000-bd-ft | sure |  |
| Floor joists, sills | $1.000-\mathrm{bd}-\mathrm{ft}$ | sure | 25 |
| Bridging | 100 pr |  | 5 |
| Wall frames, plates | 1.000-bd-ft |  | 45 |
| Furring, including plugging | 1,000 lin tt |  | 32 |
| Blocking | 1,000-bd-ft | sure | 20 |
| Grounds for plaster | 1.000 lin ft |  | 48 |
| Door bucks | ea |  | 3 |
| Ceiling joists | 1,000-bd-ft | sure | 25 |
| Ratters | 1,000-bd-ft |  | 45 |
| Trusses (span feet) $\quad$ Each | Man-hours assembly | Man-hours placement |  |
| 20 | 1.5 | 1 |  |
| 30 | 20 | 8 |  |
| 40 | 12.0 | 8 |  |
| 50 | 20.0 | $6{ }^{*}$ |  |
| 60 | 24.0 | 6 |  |
| 80 | 32.0 | $6 *$ |  |

Table C-2. Sheathing and siding

| Work element description | Unit | Man-hours/unit |
| :--- | :---: | :---: |
| Wall sheathing | $1,000 \mathrm{sq} \mathrm{f}$ |  |
| Building paper |  | 8 |
| Tongue and groove |  | 24 |
| Plywood |  | 16 |
| Fiberboard |  | 16 |
|  |  |  |
| Roof decking |  | 32 |
| Tongue and groove | 1,000 sq ft | 20 |
| Plywood |  |  |
| Siding |  | 16 |
| Plywood |  | 32 |
| Corrugated asbestos |  | 32 |
| Drop siding |  | 48 |
| Narrow bevel |  | 40 |
| Shingles |  |  |
|  |  |  |
| Typical crew: 1 leader and 8 workers |  |  |

Table C-3. Insulation

| Work element description | Unit | Man-hours/unit |
| :---: | :---: | :---: |
| Thermal | $1.000 \mathrm{sq} \pi$ |  |
| Board |  |  |
| Floor* |  | 32 |
| Wall |  | 8 |
| Ceiling |  | 24 |
| Roof |  | 24 |
| Rock wool |  |  |
| Loose |  | 16 |
| Batts |  | 12 |
| Foil alone |  | 8 |
| Rigid foam |  | 24 |
| Acoustic | 1.000 sq fi |  |
| Strip |  | 24 |
| Quill |  | 8 |
| Typical crew 1 leader and 4 workers. |  |  |
| *Ingtall vermin shield. |  |  |

## Table C-4. Finish carpentry

| Work element description | Unit | Man-hours/unit |
| :---: | :---: | :---: |
| Walls | 1.000 sq H |  |
| Plywood |  | 32.0 |
| Plasterboard (includes tape) |  | 48.0 |
| Ceilings | 1.000 sq ff |  |
| Wood |  | 48.0 |
| Plasterboard (includes tape*) |  | 64.0 |
| Cemented tile |  | 32.0 |
| Panel with suapension |  | 72.0 |
| Baseboard (2 member) | 1,000 lin ft | 720 |
| Molding (chair) | 1.000 lln ft | 48.0 |
| Door frame, trim | ea | 2.5 |
| Sliding door with pocket | ea | 80 |
| Window frame, trim | ea | 3.0 |
| Installing prefab closets | ea | 16.0 |
| Setting kitchen cabinets | ea | 1.5 |
| Shelving | 1.000 sq ft | 64.0 |
| Chalkboard (complete) | $1,000 \mathrm{sq} \pi$ | 110.0 |
| Stairs |  |  |
| Closed stringer, buit on job | story | 16.0 |
| Closed stringer, prefab | story | 8.0 |
| Open stringer | story | 24.0 |
| Typical crew: 1 leader and 3 to 8 workers. <br> For small rooms, increase time required for wall- and ceiling-board installation by 30 to 50 percent. |  |  |
|  |  |  |
| *includes furring strips when necessary. |  |  |

Table C-5. Door installation

| Work element description | Unit | Man-hours/unit |
| :---: | :---: | :---: |
| WOOD DOORS AND FRAMES |  |  |
| Door trames and trim |  |  |
| Single exterior | ea | 3 |
| Double exterior | ea | 3 |
| Single interior | 8a | 3 |
| Double interior | ¢a | 4 |
| Stiding door frame | өa | 4 |
| Door: it, hang, and lock |  |  |
| Single exterior | ea | 5 |
| Double exterior | ea | 8 |
| Single interior | ea | 5 |
| Double interior | ea | 7 |
| Screen doors | ea | 2 |
| METAL DOORS |  |  |
| Single | ea | 6 |
| Doubie | ea. | 9 |
| MISCELLANEOUS DOORS COMPLETE WITH TRIM AND HARDWARE |  |  |
|  |  |  |
|  |  |  |
| Rolling, manual-operated | ea | 29 |
| Rolling, motor-operated | ea | 36 |
| Stiding, manual-operated | er | 20 |
| Sliding, motor-operated | ea | 25 |
| Sliding, fire | ea | 19 |
| Garage doors |  |  |
| Wood $16 \times 7$ | ea | 8 |
| Aluminurn $16 \times 7$ | ยล | 10 |
| Scutties | ea | 10 |
| CaUlking | 1,000 lin tt | 5 |

Table C-6. Flooring

| Work element description | Unit | Man-hours/unit |
| :---: | :---: | :---: |
| Wood floors | $1,000 \mathrm{sq} \mathrm{th}$ |  |
| Subfloor |  | 24 |
| Tongue and groove | 16 |  |
| Plywood |  | 24 |
| Finish floor |  | 32 |
| Sofwood |  |  |
| Hardwood |  |  |
| Soft tile |  | 24 |
| Cemented |  | 32 |
| Nailed | 1,000 sq tt | 32 |
| Linoleum |  |  |
| Typical flooring crew: 1 leader and 4 workers. |  |  |


| Work element description | Unit | Man-hours/unit |
| :---: | :---: | :---: |
| Wood windows |  |  |
| Double hung | ea | 4 |
| Casement, single | ea | 4 |
| Fixed wood sash | ea | 3 |
| Jalousie | ea | 2 |
| Skylights | ea | 8 |
| Louvers | ea | 5 |
| Screens | ea | 2 |
| Venetian blinds | ea | 2 |
| Metal windows |  |  |
| Double hung | ea | 2 |
| Casement | ea | 2 |
| Commercial projected | ea | 2 |
| Skylights | ea | 9 |
| Weather stripping | ea | 3 |
| Caulking | 1,000 inft | 16 |
| Suggested crew size: 2106 workers, |  |  |
| Installation includes drilling fasteners, expansion sills, installing plugs, toggle blocking. hinges, locks, and other hardware |  |  |
| For special pantic-device doors, add three hours for single doors and four hours for double doors. |  |  |

Table C-8. Built-up roofing, insulation, and flashing

| Work element description | Unit | Man-hours/unit |
| :--- | :---: | :---: |
| Roofing | $1,000 \mathrm{sq} \mathrm{ft}$ |  |
| 2 ply |  | 12 |
| 3 ply | 20 |  |
| 4 ply | 25 |  |
| 5 ply | $1,000 \mathrm{sq} \mathrm{ti}$ | 25 |
| Insulation | $1,000 \mathrm{sq} \mathrm{ft}$ | 60 |
| Flashing |  |  |
| Typical crew: 1 leader and 6 workers. |  |  |

Table C-9. Roll roofing

| Work element description <br> Paper (plain) and fett | Unit | Man-hours/unit |
| :--- | :---: | :---: |
| Asphaltic aluminum (including <br> primer) | $1,000 \mathrm{sq} \mathrm{ft}$ | 7 |
| Canvas (including 2 coats <br> of paint) | $1,000 \mathrm{sq} \mathrm{ft}$ | 18 |
| Typical crew: |  |  |

Table C-10. Shingle roofing

| Work element description | Unit | Man-hours/unit |
| :---: | :---: | :---: |
| Wood | $1,000 \mathrm{sq} \mathrm{ft}$ | 35 |
| Slate | $1,000 \mathrm{sq} \mathrm{ft}$ | 55 |
| Metal | $1,000 \mathrm{sq} \mathrm{ft}$ | 50 |
| Asphatt | $1,000 \mathrm{sq} \mathrm{ft}$ | 30 |
| Typical crew: 1 leader and 4 workers. |  |  |

Table C-11. Metal, asbestos-cement, and tile roofing (pitch at least 3 inches per foot)

| Work element description | Unit | Man-hours/unit |
| :--- | :---: | :---: |
| Metal (corrugated and V-crimp) | 1,000 sq ft |  |
| Wood purlins |  | 18 |
| Metal purlins |  | 36 |
| Sheet (seamed) | 60 |  |
| Asbestos-cement | 1,000 sq ft |  |
| Wood purlins |  | 35 |
| Metal purlins | 1,000 sq ft | 45 |
| Tile |  | 55 |
| Clay |  | 60 |
| Metal |  |  |
|  |  |  |
| Typical crew: 1 leader and 5 workers. |  |  |

Table C-12. Pile bracing and capping

| Work element description | Unit | Man-hours/unit |
| :---: | :---: | :---: |
| Bracing* | ea |  |
| Horizontal |  | 1.0 |
| Diagonal |  | 0.8 |
| Capping | 1,000 lin ft |  |
| Wood |  | 100.0 |
| Steel |  | 150.0 |
| Concrete |  | 200.0 |
| Typical crew. 1 leader and 6 workers. <br> *Table based on 4 -inch $\times 10$-inch $\times 4$-toot bracing members. |  |  |
|  |  |  |
| Table C-13. Pier framing |  |  |
| Work element description | Unit | Man-hours/unit |
| Stringers | 1,000-bd-ft measure | 40 |
| Bridging | 1,000 lin ft | 40 |
| 4-inch deck | $1,000 \mathrm{sq} \mathrm{ft}$ | 20 |
| 2 -inch wearing surface | 1.000 sq ft | 16 |
| Bull rall | 1,000 lin tt | 60 |
| Bumper | 1,000 in ft | 36 |
| Typical crew: 1 leader and 10 workers. |  |  |

Table C-14. Deck hardware

| Work eiement description | Unit | Man-hours/unit |
| :---: | :---: | :---: |
| Bits | ea | 3 |
| Bollards | ea | 4 |
| Chocks | ea | 3 |
| Cleats | ea | 2 |
| Pad eyes | ea | 1 |
| Typical crew: 1 leader and 4 workers. |  |  |

## FLOOR AND WALL TILE

The following paragraphs include information pertaining to the various types of tile and their installation procedures.

The number of tiles needed is calculated by performing the following procedures:

First, calculate the square feet of the area to be tiled. If you are using 12 -inch-square tiles, the total floor area (in square feet) equals the total number of tiles needed, plus an additional 10 percent waste factor. If another size of tiles is being used, multiply the area by 144 to convert to square inches. Then divide that number by the area (square inches) of the tiles to find the required amount (include a 10 percent waste factor).

Example: You are using tiles $9 \times 9$ inches. To tile a floor 12 feet long and 9 feet wide-

Multiply the room dimensions to find the area: 12 feet $\times 9$ feet $=108$ square fect

Multiply the area by 144: $108 \times 144=15,552$ square inches

Calculate the area of the tile: 9 inches $\times 9$ inches $=$ 81 square inches

Divide the room area (square inches) by the tile area (square inches): 15,552 divided by $81=192$ tiles

Add 10 percent waste factor: $192+19=211$ tiles required

## RESILIENT FLOOR TILE

Resilient floor tile is durable, easily maintained,
comfortable and attractive, and low cost. It is made of rubber, vinyl, linoleum, and asphalt. Common sizes of this tile are either $9 \times 9$ inches or $12 \times 12$ inches.

A notched trowel (used for spreading adhesive) and a tile cutter are required for installation. To lay out and install resilient floor tile, perform the following procedures:

Locate the center of the end walls of the room. Establish a main centerline by snapping a chalk line between these two points. Lay out another centerline at right angles to the main centerline. This line may be established using a framing square or the triangulation method. With the centerline established, make a trial layout of the tiles al ong the centerlines. Measure the distance between the wall and the last tile. If this measurement is less than $1 / 2$ tile, move the centerline half the width of the tile closer to the wall. This adjustment will eliminate the need to install border tiles that are too narrow. Since the original centerline is moved exactly half the tile size, the border tile will remain uniform on opposite sides of the room. Check the layout al ong the other centerline in the same way.

Spread adhesive over one quarter of the total area, starting with the quarter farthest from the door and working toward the door. Ensure that the floor surface is clean before you spread the adhesive. Spread up to the chalk lines but do not cover them. Be sure to use a notched trowel with the notch depth recommended by the manufacturer of the adhesive. Allow the adhesive to take an initial set before setting the first tile. The time required will vary, depending on the type of adhesive used.

Start laying the tiles at the center of the room. Make sure the edges of the tiles are aligned with the chalk line. Lay rows by width, stair-stepping additional rows and ensuring that the tiles are tight against one another in a cross-grained pattern unless otherwise specified. After all of the full tiles have been laid, install the border or edge tiles around the room. To lay out a border tile, place a loose tile over the last tile in the outside row with the grains running in opposite directions (if using a cross-grained pattern). Then, take another tile and place it in position against the wall and mark a pencil line on the first tile. Cut the tile al ong the marked line.

After all the tiles have been installed, remove any excess adhesive using a cleaner or solvent and procedures approved by the manufacturer.

## CERAMIC AND OTHER SPECIALTY TILES

This tile is used extensively where sanitation, stain resistance, easy cleaning, and low maintenance are desired. Types of tile include ceramic, mosaic, paver, quarry, brick-veneer, cement-bodied, marble, and other stone tiles. These can be used for both interior and exterior flooring. Tile is used on both walls and floors. Field tile is regular tile placed on all courses in the main field of an installation. Trim tile is a specially shaped tile used to border and complete the main field of tile; it is available in a wide variety of shapes, sizes, and colors to match field tile.

Tiles come with two types of finishes-glazed and unglazed. Glazed tiles are coated with a glaze before firing to give the tile color and to preserve its surface. They may be fired to a smooth or textured finish. Glazed tiles are most commonly used for walls but may also be applied to floors and countertops. They are used mainly for interiors. Unglazed tiles are fired without a glaze coating. They derive their col or from the clay from which they are made. Adhesives used are Thinset or Organic Mastic. Thinset is a powdered cementbased product that is mixed with either water, a latex or acrylic additive, or epoxy. It is very versatile. Organic Mastic is premixed in a solvent or latex base. It may deteriorate if exposed to
heat or water.
Grout is a powder made from sand and cement and is used to seal the cracks between the tiles. It is mixed with either water or, to increase durability, an additive. It is available in a variety of colors.

The following tools and equipment are required for installing ceramic and specialty tiles:

A striking tool is used to compact the grout into the joints.

- A beating block is a board used to even the tile surface after it has been set.
- A square-notched trowel is used to spread adhesive.
- A pointing trowel is used to spread adhesive in tight spots.
- A tile cutter is used to score the tile surface so that it can be snapped by applying pressure to the score.
- A finefile or tile stone is used to smooth rough edges after cutting tile.
- A timenipper is used to clip tile and cut irregular openings.
- A squegee or sponge is used to remove excess grout from the tile surface.
- A sponge float or rubber-faced trowel is used to spread grout over the surface.
- An electric tile saw is similar to a mason saw. It is used to make clean, accurate cuts.

To lay out and install ceramic and specialty tiles, perform the following procedures:

Check the area to be tiled to determine if it is square. If the area is slightly out of square, minor changes in the layout can accommodate
these conditions. If the area is seriously out of square, the process stops for any required structural repairs or surface preparation. If the framing problems are serious, it may not be possible to tile the area.

Draw the layout on paper. Layout depends greatly on the pattern desired and the type, size, and shape of the tile being used. Use as many full tiles and as few cut tiles as possible. Place cut tile away from visual focal points (doorways, thresholds, and so forth); tiles should be set symmetrically for a more attractive finish and appearance.

Place reference lines on the floor or wall. Once the layout has been established on paper, transfer it to the floor or wall. A reference line should be snapped to mark the rows of cut tiles around the perimeter. A grid of reference lines should be snapped to enclose
all full tiles in sections no larger than 3 square feet.
To install tiles, first spread adhesive over a small area or section ( $3 \times 3$ feet), making sure to spread it just up to the lines so that the lines will still be visible. Align the first tile against a $90^{\circ}$ intersection in the grid and press it gently into the adhesive. After each course of tile is applied, use a beating block to level the surface. After all the tiles are set, allow the adhesive to set the required time, according to manufacturer's instructions. Prepare the grout and spread it over the tile surface, ensuring that the joints are filled. When the grout begins to dry, clean the tile with a damp sponge. After the grout has dried, wipe off the haze with a clean rag or towel. After the grout has completely dried and hardened (approximately 72 hours), a grout sealer may be applied.

## SUSPENDED CEILINGS

Suspended ceilings are primarily designed for acoustical control; however, ceilings are also lowered to save on heating and air conditioning expenses; finish off exposed joints; and cover damaged plaster.

## ACOUSTICAL TILE

Acoustical tile absorbs sound, reduces noise, reflects light, and resists flame. Its thickness ranges from 3/16 to 3/4 inch; its width from 12 to 30 inches; and its length from 12 to 60 inches. The most common size panels used are $2 \times 2$ feet and $2 \times 4$ feet.

## GRID-SYSTEM COMPONENTS

The grid-system components used in suspended ceilings include the following: the main tee(12-foot lengths), the cross te ( 2 - and 4 -foot lengths), the wall angle (10-foot lengths), the splice plate (available in aluminum only), suspending devices, and suspending wire.

Suspending devices include screw eyelets; suspending hooks and nails; 8d common nails or larger, driven into wood joists and bent into a U-shape; and an
approved Hilti fastener for concrete or steel.
Suspending wire includes 16-gauge anneal wire placed at 4 -foot intervals and attached to suspending devices at the ceiling and to the main tees in the grid system.

## INSTALLATION

First, lay out the grid pattern. This is based on the ceiling's length and width at the new ceiling height. If the ceiling's length or width is not divisible by 2 feet, increase to the next higher dimension divisible by 2 feet. F or example, if a ceiling measures 12 feet 7 inches $\times 10$ feet 4 inches, the dimensions should be increased to 14 feet $\times 12$ feet for layout purposes. Draw the layout on paper. Make sure that the main tees run perpendicular to the joists. Position the main tees so that the border panels at the room's edges are equal and as large as possible. Draw in cross tees so that the border panels at the room's ends are equal and as large as possible.- Determine the number of pieces of wall angle by dividing the perimeter by 10 and adding 1 additional piece for any
fraction. Determine the number of main tees and cross tees by counting them on the grid pattern layout.

Next, establish the ceiling height. Mark a line around the entire room at the desired height to serve as a reference line. There must be a minimum of 2 inches between the new ceiling and the existing ceiling. Ensure that this line is level and marked continuously so that it meets at intersecting corners. Next, install the wall angle. Secure the wall angle along the reference line, ensuring that it is level.

Install the suspension wire. Suspension wires are required every 4 feet along the main tees and on each side of all splices. Attach the wires to the suspending devices. The wires should be cut at least 2 feet longer than the distance between the old and new ceiling. Now, install the main tees. Main tees need to be laid out from the center to ensure that the slots line up with the cross-tee locations. Cut them where appropriate. Tees 12 feet long or less are
installed by resting the ends on opposite wall angles and inserting the suspension wire. Tees over 12 feet long must be cut to ensure that the cross tees will not intersect the main tee at a splice joint. Rest the cut end on the wall angle and attach suspension wires along the tee. Make necessary splices and continue attaching suspension wires along the tee until the tee rests on the opposite wall angle. Ensure that the main tees are level and secured before continuing.

Install the cross tees. Cut and install border tees on one side of the room. Install the remaining cross tees according to the grid-pattern layout. At opposite wall angles, install the remaining border tiles. Finally, install the acoustical panels. Install the full-size panels first. Handle panels with care and ensure that the surfaces are kept clean from hand prints and smudges. If you are working on a large project, work from several cartons to avoid a noticeable change of uniformity. Cut and install the border panels.

## PAINTING CEILINGS AND WALLS

The following tools and equipment are required for painting:

- Paint brushes, wall, 2 to 4 inches wide.
- Paint roller with cover.
- Paint pan.
- Stepladder.
- Paddle (stir stick).
- Rags.
- Paint, latex, flat.
- Bucket of water.

Prepare the paint for application. Remove the cover from the paint container. Remove any film layer from the top of the paint. Using the paddle (stir stick), mix the paint thoroughly, in a figure-8 motion.

Scrape off and break up any unsettled matter on the bottom or lower sides of the container. Pour the paint into the paint pan until it is $2 / 3$ full.

## CEILING

Brush a narrow strip of paint around the perimeter of the ceiling along the inside edges where the wall and the ceiling meet. Using a roller, paint the remaining portion of the ceiling. Cross roll to ensure complete paint coverage without voids.

## WALLS

Brush a narrow strip of paint along the inside corners of the wall and corner post. Cut in around all trim and baseboards with a trim brush. Using a roller, paint the remaining portion of the wall and corner post. The corner post may be painted with a brush. When the first coat has completely dried, apply a second coat in the same way. Ensure that the entire surface is covered and without voids.

## CLEANUP

Clean paint spots from painted surfaces. Use the appropriate solvent and a clean rag. Repaint spots if necessary. Pour excess paint back into the container. Thoroughly clean brushes and rollers.
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## Ulimate-Construction Series




## CARPENTRY I

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## LESSON 1

CONSTRUCTION PRINTS AND BUILDING MATERIALS

## OVERVIEW

## LESSON DESCRIPTION:

In this lesson you will learn to read construction prints, identify drawing legends and symbols, prepare a bill of materials (BOM), and become familiar with basic building materials.

TERMINAL LEARNING OBJECTIVE:
ACTION: You will learn to read prints; prepare a BOM; and learn the basic types of building materials.

CONDITION: You will be given the material contained in this lesson.

STANDARD: You will correctly answer practice exercise questions at the end of this lesson.

## INTRODUCTION

One of the basic skills in carpentry is the ability to read, understand, and interpret architectural drawings. Architectural drawings consist of a preliminary sketch and construction prints. Carpenter should also know how to prepare a BOMs to requisition materials needed for a construction project. They must also be familiar with basic building materials such as lumber and hardware.

PART A - CONSTRUCTION PRINTS FOR BUILDINGS
A set of construction prints (also called working drawings, or a set of plans) consists of all drawings necessary for the carpenter to construct a building. The set is composed of plan views (called plans), elevation views (called elevations), and
detailed drawings (called sections and details); a schedule of drawings; and notes and information (called specifications). Specifications consist of information such as the quality and quantity of the materials and the construction methods to be used. A well-drawn set of prints and well-written specifications will help prevent disagreements and misunderstandings.

The purpose of construction prints is to be exact about shape and size. They are generally scale-size (with dimensions). It is very important to know how to read and use construction prints.

1-1. Information on Drawings. Drawings contain different lines, scales, and symbols. To read drawings, you must be able to interpret these items. They also include other information in the form of schedules, notes, and tables.
a. Schedule of Drawings. A schedule of drawings lists the drawings by number, title, and sheet number (Table 1-1). It is usually on the first drawing of a set of prints.

Table 1-1. Schedule of drawings

| Drawing <br> Number | Description | Sheet <br> Number |
| :--- | :--- | :--- |
| $13-12$ | Plans | $1-2$ of 2 |
| $13-4$ | Window details | 1 of 1 |
| $99-98$ | Standard details |  |
| $34-19$ | Wood frame construction shop- <br> heavy-duty | 1 of 2 |

b. General Notes. General notes give additional information that is needed (Figure 1-1). For example, item number 3 is for the carpenter.

1. Refer to TM 5-303 or building-shell requirements.
2. For national stock number (NSN) BOM, refer to TM 5-303 by facility number.
3. Wood-frame structures are to be based on standard shop heavy-duty buildings. The column heights are to be reduced so that the clear height is 13 feet ( 3.962 meters) minimum below ductwork fixtures.

Figure 1-1. General notes
c. Graphic and Ratio Scales. Because of the sizes of the objects being represented, different scales are used for drawings (Figure 1-2).


Figure 1-2. Graphic and ratio scales
d. Lines on Drawings (Figure 1-3, page 1-4). Line conventions most often seen on working drawings are-
(1) Visible Lines. A heavyweight unbroken line is used for the primary feature of a drawing. For drawings of objects, this line convention represents the edges, the intersection of two surfaces, or the surface limit that is visible from the viewing angle of the drawing. This lines is often called the outline.
(2) Hidden Lines. A medium weight line of evenly spaced short dashes represents an edge, the intersection of two surfaces, or the surface limit which is not visible from the viewing angle of the drawing.
(3) Center Lines. A thin (light) line composed of alternate long and short dashes of consistent length is called a centerline. It is used to signify the center of a circle or arc and to divide object into equal or symmetrical parts.
(4) Dimension Lines. A solid, continuous line terminating in arrowheads at each end. Dimension lines are broken only to permit writing in dimension. On construction drawings, the dimension lines are unbroken. The points of the arrowheads touch the extension lines which mark the limits of the dimension. The dimension is expressed in feet and inches on architectural drawings and in feet and decimal fractions of a foot on engineering drawings.
(5) Extension lines. An extension line is a thin (light), unbroken line that indicates the extent of the dimension lines. The extension line extends the visible lines of an object when it is not convenient to draw a dimension line directly between the visible lines. There is always a small space between the extension line and the visible line.

| LINE CONVENTIONS |  |  |  |
| :---: | :---: | :---: | :---: |
| NAME | CONVENTION | DESCRIPTION AND APPLICATION | EXAMPLE |
| VISIBLE LINES | 1 | HEAVY, UNBROKEN LINES <br> -USED TO INOICATE VISIBLE EDGES OF AN OBNECT |  |
| MHDDEN <br> LINES | $\begin{aligned} & 1 \\ & i \\ & i \\ & i \\ & i \\ & i \\ & i \end{aligned}$ | MEDIUM LINES WITH SHORT, <br> EVENLY SPACED DASHES <br> USED TO INDICATE CONCEALED EDGES |  |
| CENTER <br> LNES |  | THAN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH <br> USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS |  |
| DIMENSION LINES |  | Thin lines terminated with ARROWHEADS AT EACH END <br> USED TO INDICATE OLSTANCE measuried |  |
| EXTENSION LINES |  | THMN, UNBROKEN LINES <br> USED TO INDICATE EXTENT OF DIMENSIONS |  |

Figure 1-3. Line conventions
e. Architectural Symbols. These symbols are used on drawings to show the type and location of doors, windows, and material conventions. To understand construction drawings, you must be able to recognize and interpret these symbols (Figure 1-4).


Figure 1-4. Architectural symbols


Figure 1-4. Architectural symbols (continued)

1-2. Working Drawings. Working drawings and specifications are the main sources of information for supervisors and technicians responsible for the actual construction. The construction working drawing gives a complete graphic description of the structure to be erected and the construction method to be followed. A set of working drawings includes both general and detail drawings. General drawings consist of plans and elevations; detail drawings consist of sections and detail views.
a. Site Plan. A site plan (also called a plot plan) (Figure 1-5) shows the boundaries of the construction site, the location of the building in relation to the boundaries, the ground contour, and the roads and walks. It may also show utility lines such as sewer, gas, and water. This type of plan is drawn from a survey of the area by locating the corners of the building at specific distances from the established reference points.


Figure 1-5. Site plan
b. Elevations. Elevations are drawings that are commonly used to show exterior views of a structure from the front, rear, left, and right sides (Figure 1-6). They show a picture-like view as it would actually appear on a vertical plane. You must have a good overall idea of the structure before you examine it in detail. Elevations also show the types of doors and windows (drawn to scale) and how they will appear on the finished structure. Ask yourself does the structure have a simple roof? Is the floor level close to ground level (grade)?


Figure 1-6. Elevation views
Elevations are made more lifelike by accenting certain lines and adding straight lines to represent the types of materials used on the exterior (Figure 1-7). Lines that may be accented are window, door, roof, and building outlines. When accenting lines, you must assume that the light is coming from a certain direction and that accented lines represent shaded areas. Using straight lines to suggest the texture of exterior materials is a form of architectural rendering. Rendering, as applied to architectural drawings, is the use of a pencil, ink, watercolors, or a combination of these to depict (paint) a structure and bring out its form or shape.


Figure 1-7. Accent lines
c. Floor Plan. A floor plan is a cross-sectional view of a building. The horizontal cut crosses all openings, regardless of their height from the floor. The development of a floor plan is shown in Figure 1-8, page 1-10. Note that a floor plan shows the outside shape of the building the arrangement, size, and shape of the rooms; the type of materials; and the length, thickness, and character of the building walls at a particular floor. A floor plan also includes the type, width, and location of the doors and windows; the types and locations of utility installations; and the location of stairways. A typical floor plan is shown in Figure 1-9, page 1-11.
(1) Drawings and Specifications. Drawings and specifications inform the contractor, owner, material dealers, and tradespeople of decisions made by the architect and owner of the structure. Floor plans are usually drawn to scale (1/4" = 1' or $3 / 16^{\prime \prime}=1$ ). Symbols are used to Indicate different types o fixtures and materials.

NOTE: Electrical, heating, and plumbing layouts are either on the floor plan or on separate drawings attached to the floor plan.
(2) Floor Plan details. Detailed drawings may appear on the plan or on separate sheets attached to the plan. When detailed drawings are on separate sheets, a reference symbol is drawn on the floor plan. A door and window schedule is presented on the plan (see sample on Table 1-2 on page $1-10$ is a sample showing the information given on the schedule.


Figure 1-8. Floor-plan development

Table 1-2. Door and window schedule

| Door Schedule |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Location | Type | Size | Quantity | Remarks |
| $\begin{gathered} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \end{gathered}$ | $\begin{aligned} & \mathrm{A} \\ & \mathrm{~B} \\ & \mathrm{C} \\ & \mathrm{D} \\ & \mathrm{E} \\ & \mathrm{~F} \\ & \mathrm{G} \\ & \mathrm{H} \\ & \mathrm{I} \\ & \mathrm{~J} \\ & \mathrm{~K} \\ & \mathrm{~L} \end{aligned}$ |  | $\begin{aligned} & 1 \\ & 2 \\ & 1 \\ & 1 \\ & 2 \\ & 3 \\ & 2 \\ & 1 \\ & 1 \\ & 4 \\ & 8 \\ & 2 \end{aligned}$ | Insulated Insulated <br> Louvered Double bifold Double bifold Double bifold Double bifold |
| Window Schedule |  |  |  |  |
| $\begin{aligned} & 1 \\ & 2 \\ & 3 \end{aligned}$ | $\begin{aligned} & \mathrm{A} \\ & \mathrm{~B} \\ & \mathrm{C} \end{aligned}$ | $\begin{aligned} & 4^{\prime}-1^{\prime \prime} \times 2^{\prime}-1^{\prime \prime} \\ & 4^{\prime}-1^{\prime \prime} \times 5^{\prime}-3^{\prime \prime} \\ & 4^{\prime} \times 1^{\prime \prime} \times 4^{\prime} \times 1^{\prime \prime} \end{aligned}$ | $\begin{aligned} & 6 \\ & 6 \\ & 4 \end{aligned}$ | Insulated glass Insulated glass Insulated glass |


d. Detail Drawings (Sections and Details). Detail drawings are drawn to a larger scale than plans and elevations to give more elaborate information, dimensions, and details. For example, they may give the size of materials and show the placement of parts in relation to each other.
(1) Sections. Sections are drawn to a large scale showing details of a particular construction feature that cannot be given in a general drawing. They show-

- Height.
- Materials.
- Fastening and support systems.
- Any concealed features.
(a) Wall section. A typical section, with parts identified by name and/or size, is illustrated in Figure 1-10. This figure shows how a structure looks when cut vertically by a cutting plane. Wall sections are very important to construction supervisors and to the craftsmen who do the actual building. They show the construction of the wall, as well as the way in which structural members and other features are joined to it. Wall sections extend vertically from the foundation bed to the roof. Sections are classified typical and specific. Figure $1-11$ shows a typical window section.
(b) Typical sections. Typical sections are used to show construction features that are repeated many times throughout a structure.
(c) Specific sections. When a particular construction feature occurs only once and is not shown clearly in the general drawing, a cutting plane is passed through that portion.


Figure 1-10. Typical wall section


Figure 1-11. Window section
(2) Details. Details are large-scale drawings which show features that do not appear (or appear on too small a scale) on the plans, elevations, and sections. Sections show the builder how various parts are connected and placed. Details do not have a cutting-plane indication but are simply noted by a code. The construction of doors, windows, and eaves is usually shown in detail drawings. Figure 1-12, page $1-14$, shows some typical door-framing details, window wood-framing details, and an eave detail for a simple type of cornice. Other details that are customarily shown are sills, girder and joint connections, and stairways.

Figure 1-13, page 1-15, shows how a stairway is drawn in a plan and how riser-tread information is given. For example, on the plan, DOWN 17 RISERS followed by an arrow means that there are 17 risers in the run of stairs going from the first floor to the floor below, in the direction indicated by the arrow. The riser-tread diagram provides height and width information. The standard for the riser, or height from the bottom of the tread to the bottom of the next tread, ranges from $61 / 2$ to $71 / 2$ inches. The tread width is usually such that the sum of riser and tread is about 18 inches (a 7 -inch riser and 11 -inch tread is standard). On the plan, the distance between the riser lines is the width of the tread.


Figure 1-12. Typical eave, door, and window details


Figure 1-13. Stairway and steps
e. Wood-Framing Drawing. Framing plans show the size, number, and location of the structural members constituting the building framework. Separate framing plans may be drawn for the floors, walls, and roof. The floor-framing plan must specify the sizes and spacing of joists, girders, and columns used to support the floor. Detail drawings are added, if necessary, to show the methods of anchoring joists and girders to the columns and foundation walls or footings. Wall-framing plans show the location and method of framing openings and ceiling heights so that studs and post can be cut. Roof-framing plans show the construction of the rafters used to span the building and support the roof. Size, spacing, roof slope, and all necessary details are shown. Working prints for theater of operation (TO) buildings usually show details of all framing.
f. Light Wood Framing. Light framing is used in barracks, bathhouses, administration buildings, light shops, hospitals, and similar structures. Detailed drawings of foundation walls, footings, posts, and girder details normally used in standard $T O$ construction are shown in Figure 1-14, page 1-16.


Figure 1-14. Typical foundation wall, post, footing, and girder details

The various details for overall framing of a 20 -foot-wide building (including ground level, window openings, brace, splices, and nomenclature of framing) are shown in Figure 1-15, page 1-17.

A construction drawing shows the type of footings and size of the various members. Some drawings give the various lengths, while others specify the required lengths on the accompanying BOM. Figure 1-16, page $1-18$, shows floor-framing details showing footings, posts, girders, joists, reinforced sections of floor for heavy loads, section views covering makeup of certain sections, scabs for joint girders to posts, and post-bracing details as placed for cross sections and longitudinal sections.


Figure 1-15. Light framing details (20-foot-wide building)


Wall framing for end panels is shown in view A in Figure 1-17. Wallframing plans are detail drawings showing the locations of studs, plates, sills, and bracing. They show one wall at a time. The height for panels is usually shown. From this height, the length of wall studs is determined by deducting the thickness of the top or rafter plate and the bottom plate. Studs placed next to window openings may be placed either on edge or flat, depending on the type of windows used. Details for side panels (view B) cover the same type of information as listed for end panels. The space between studs is given in the wall-framing detail drawing, as well as height of girt from bottom plate and types of door and window openings, if any. For window openings the details specify whether the window is hinged to swing in or out, or whether it is to be a sliding panel.


Figure 1-17. Typical wall-panel framing details

Examples of drawings showing the makeup of various trussed rafters are given in Figure 1-18. A 40-foot trussed rafter showing a partition bearing in the center is shown in view A. The drawing shows the splices required, bracing details, the stud and top plate at one end of the rafter, and the size of the members.


A typical detail drawing of a 20 -foot truss rafter is shown in view B. Use filler blocks to keep the brace members in a vertical plane, since the rafter and bottom chord are nailed together rather than spliced. The drawing shows placement of the rafter tie on the opposite side from the vertical brace. Usually the splice plate for the bottom chord (if one is needed) is placed on the side where the rafters are to be nailed so that it can also serve as a filler block.

Use a modified truss, shown in view C, only when specified in plans for certain construction. It should not be used in areas subject to high wind velocities or moderate to heavy snowfall. In this type of trussed rafter, the bottom chord is placed on the rafters above the top plate. The construction plans specify the best type of trussed rafter for the purpose. The drawings must show, in detail, the construction features of the rafter selected.
g. Heavy Wood Framing. Heavy wood framing consists of framing members (timber construction) at least 6 inches in dimension (for example, 2 by 6 inches or 4 by 12 inches). Examples of this type framing are heavy roof trusses, timber-trestle bridges, and wharves. The major differences between light and heavy framing are the size of timber used and the types of fasteners used.
h. Foundation Plan. Figure 1-19, page 22 shows a foundation plan. The foundation is the starting point of the construction. Detail drawings and specifications for a plan are usually attached on a separate sheet.


## PART B - BILL OF MATERIALS

Before any construction project is started, make out a BOMs to requisition building materials. However, you should first make a materials takeoff list and a materials estimate list, before making out the BOM.

1-3. Materials Takeoff List. This list is the first step leading to preparation of a BOM. It is a listing of all parts of the building, taken off the plan. Table $1-3$ shows a materials takeoff list for the building substructure shown in Figure 1-20, page 1-24.

Table 1-3. Sample materials takeoff list

| Item Name or Use of <br> Piece | No of <br> Pleces | Unit | Length in <br> Place | Size | Length | No Per <br> Length | Quantity |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1. Footers | 45 | pc | $1^{\prime}-5^{\prime \prime}$ | $2 \times 6$ | $10^{\prime}$ | 7 | 7 |
| 2. Spreaders | 30 | pc | $1^{\prime}-4^{\prime \prime}$ | $2 \times 6$ | $8^{\prime}$ | 6 | 5 |
| 3. Foundation post | 15 | pc | $3^{\prime}-0^{\prime \prime}$ | $6 \times 6$ | $12^{\prime}$ | 4 | 4 |
| 4. Scabs | 20 | pc | $1^{\prime}-0^{\prime \prime}$ | $1 \times 6$ | $8^{\prime}$ | 8 | 3 |
| 5. Girders | 36 | pc | $10^{\prime}-0^{\prime \prime}$ | $2 \times 6$ | $10^{\prime}$ | 1 | 36 |
| 6. Joists | 46 | pc | $10^{\prime}-0^{\prime \prime}$ | $2 \times 6$ | $10^{\prime}$ | 1 | 46 |
| 7. Joist splices | 21 | pc | $2^{\prime}-0^{\prime \prime}$ | $1 \times 6$ | $8^{\prime}$ | 4 | 6 |
| 8. Block bridging | 40 | pc | $1^{\prime}-103 / 8^{\prime \prime}$ | $2 \times 6$ | $8^{\prime}$ | 4 | 10 |
| 9. Closers | 12 | pc | $10^{\prime}-0^{\prime \prime}$ | $1 \times 8$ | $10^{\prime}$ | 1 | 12 |
| 10. Flooring | 800 | BF | RL | $1 \times 6$ | RL | - | - |

1-4. Materials Estimate List. A materials estimate list puts materials takeoff list information into a shorter form; adds allowance for waste and breakage; and estimates quantities of materials needed (Table 1-4, page 1-25). The lumber required is listed by board feet (BF).

1-5. BF Compution. A BF is a unit measure representing an area of 1 foot by 1 foot, 1 inch thick. The number of board feet in a piece of lumber can be computed using one of the following methods:
a. Rapid Estimate. You can estimate $B F$ rapidly by using Table 15, page 1-25. For example, reading the table, you can see that if a 2 -inch by 12 -inch board is 16 feet long, your board feet would be 32 .


Figure 1-20. $20 \times 40$-ft-wide building substructure
NOTE: Spreaders and closers are not shown in the drawing but are part of the materials takeoff list.

Table 1-4. Sample materials estimate list

| Item | Size and Length | Unit | Takeoff Quantity | Waste Allowance | Additional Requirements | Total Quantity | BF Measure |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1. | $6 \times 6 \times 12$ | pc | 4 | 1 | None | 5 | 180 |
| 2. | 2×6×10 | pc | 89 | 9 | None | 98 | 980 |
| 3. | $2 \times 6 \times 8$ | pc | 15 | 2 | 3 for temporany bracing | 20 | 160 |
| 4. | $1 \times 8 \times 10$ | pc | 12 | 2 | None | 14 | 91 |
| 5. | $1 \times 6 \times 8$ | pc | 9 | 2 | 2 for batter boards | 13 | 52 |
| 6. | $1 \times 6 \times \mathrm{RL}$ | BF | 800 | 160 | None | 960 | 960 |
| 7. | 16d | lb | - | - | 36 framing nails | 36 | - |
| 8. | 8d | lb | - | - | 23 flooring nails | 23 | - |

Table 1-5. Board feet

| Nominal (standard) Size (in inches) | Length (in feet) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 8 | 10 | 12 | 14 | 16 | 18 |
| $1 \times 3$ | 2 | $21 / 2$ | 3 | $31 / 2$ | 4 | $41 / 2$ |
| $1 \times 4$ | $22 / 3$ | $31 / 3$ | 4 | $42 / 3$ | $51 / 3$ | 6 |
| $1 \times 6$ | 4 | 5 | 6 | 7 |  | 9 |
| $1 \times 8$ | $51 / 3$ | $62 / 3$ | 8 | $91 / 3$ | $102 / 3$ | 12 |
| $1 \times 10$ | $62 / 3$ | $81 / 3$ | 10 | 11 2/3 | $131 / 3$ | 15 |
| $1 \times 12$ | 8 | 10 | 12 | 14 | 16 | 18 |
| $2 \times 4$ | $51 / 3$ | 62/3 | 8 | $91 / 3$ | $102 / 3$ | 12 |
| $2 \times 6$ | 8 | 10 | 12 | 14 | 16 | 18 |
| $2 \times 8$ | $102 / 3$ | $131 / 3$ | 16 | $182 / 3$ | 21 1/3 | 24 |
| $2 \times 10$ | $131 / 3$ | $162 / 3$ | 20 | $231 / 3$ | $262 / 3$ | 30 |
| $2 \times 12$ | 16 | 20 | 24 | 28 | 32 | 36 |
| $4 \times 4$ | $102 / 3$ | $131 / 3$ | 16 | $182 / 3$ | $211 / 3$ | 24 |
| $4 \times 8$ | 21 1/3 | $262 / 3$ | 32 | $371 / 3$ | 42 2/3 | 48 |
| $6 \times 6$ | 24 | 30 | 36 | 42 | 48 | 54 |
| $6 \times 8$ | 32 | 40 | 48 | 56 | 64 | 72 |
| $8 \times 8$ | $422 / 3$ | $531 / 3$ | 64 | 74 2/3 | $851 / 3$ | 96 |
| $8 \times 10$ | $531 / 3$ | $662 / 3$ | 80 | $931 / 3$ | $1062 / 3$ | 120 |
| $10 \times 10$ | $662 / 3$ | $831 / 3$ | 100 | 116 2/3 | $1331 / 3$ | 150 |
| $10 \times 12$ | 80 | 100 | 120 | 140 | 160 | 180 |
| $12 \times 12$ | 96 | 120 | 144 | 168 | 192 | 216 |

b. Arithmetic Method. To determine the number of $B F$ in one or more pieces of lumber use the following formula:

$$
\text { Board feet }=\text { Number } \times \frac{\text { Thickness }(\text { in }) \times \text { Width }(\text { in }) \times \text { Length }(f t)}{12}
$$

NOTE: If the unit of measure for length is in inches, divide by 144 instead of 12.

Board feet $=$ Number $\times \frac{\text { Thickness }(i n) \times \text { Width }(i n) \times \text { Length }(i n)}{144}$

SAMPLE PROBLEM 1: Find the number of $B F$ in a piece of lumber 2 inches thick, 10 inches wide, and 6 feet long (Figure 1-21).

$$
1 \times \frac{2 \times 10 \times 6}{12}=\frac{120}{12}=10 \mathrm{BF}
$$

SAMPLE PROBLEM 2: Find the number of BF in 10 pieces of lumber 2 inches thick, 10 inches wide, and 6 feet long.

$$
10 \times \frac{2 \times 10 \times 6}{12}=\frac{1,200}{12}=100 \mathrm{BF}
$$

SAMPLE PROBLEM 3: Find the number of $B F$ in a piece of lumber 2 inches thick, 10 inches wide, and 18 inches long.

$$
1 \times \frac{2 \times 10 \times 18}{144}=21 / 2 \mathrm{BF}
$$



Figure 1-21. Lumber dimensions
c. Tabular Method. The standard essex board measure table (Figure 1-22) is a quick aid in computing BF. It is located on the back of the blade of the framing square. In using the board measure table, make all computations on the basis of 1-inch thickness. The inch markings along the outer edge of the blade represent the width of a board 1 inch thick. The third dimension (length) is provided in the vertical column of figures under the 12 -inch mark.


Figure 1-22. Essex board measure table
SAMPLE PROBLEM: To compute the number of $B F$ in a piece of lumber that is 8 inches wide, 14 feet long, and 4 inches thick-

1. Find the number 14 in the vertical column under the 12-inch mark.
2. Follow the guideline under number 14 laterally across the blade until it reaches the number on that line that is directly under the inch mark matching the width of the lumber.

Example: Under the 8-inch mark on the guideline, moving left from 14, the numbers 9 and 4 appear ( 9 and 4 should be on the same line as 14). The number to the left of the vertical line represents feet; the number to the right represents inches.
3. The total number is $371 / 3 \mathrm{BF}$. BF will never appear in a decimal form.

Example solution: $1^{\prime \prime} \mathrm{x} 4^{\prime \prime} \mathrm{x} 8^{\prime} \mathrm{x} 14^{\prime}$ Feet Inches

| 9 | 4 |
| :--- | :--- |
| $\frac{4}{36}$ | $\frac{4}{16 / 12}$ |
|  | $14 / 12$ |
|  | $36+11 / 3=371 / 3 \mathrm{BF}$ |

NOTE: $1^{\prime \prime} \times 4^{\prime \prime}=$ Always multiply the number of pieces by the thickness and multiply the feet and inches by the sum of pieces and thickness.

1-6. Estimating the Quantity of Nails Required. The sizes and pounds of nails needed should be added to the list. To estimate number of pounds, use the following formulas:

- For flooring, sheathing, and other 1-inch material:

$$
\text { Number of pounds }=\frac{2 d \text { to } 8 d}{4} \times \frac{B F}{100}
$$

- For framing materials that are 2 inches or more:

$$
\text { Number of pounds }=\frac{10 d \text { to } 60 d}{6} \times \frac{B F}{100}
$$

where-

$$
d=p e n n y
$$

1-7. BOMs. Information for the BOM is taken from the materials estimate list. Department of the Army (DA) Form 2702 (Figure 2-23) is used to requisition these materials. When preparing a BOM, follow the building sequence. For example, on most frame buildings, the first pieces of lumber used would be the footers; next would be floor joists, girders, subflooring, sole plates, and studs.


This part covers basic building materials, which include lumber and hardware. The term hardware is used to identify the metal items used by carpenters. The two general types of hardware are rough and finish. Rough hardware is usually used where extra strength is required. It is not decorative. Finish hardware is used for ornamental purposes, such as hinges, drawer pulls, or other miscellaneous items.

1-8. Lumber. Sizes of softwood or building construction lumber are standardized for convenience in ordering and handling.
a. Lumber is sawn in standard (nominal) sizes:

- Length: 8, 10, 12, 14, 16, 18, and 20 feet.
- Width: 2, 4, 6, 8, 10, and 12 inches.
- Thickness: 1, 2, and 4 inches.

The actual width and thickness of dressed lumber are less than the sawn dimensions because of drying and planing (or finishing). For the relative difference between sawn (rough or nominal) dimensions, and actual sizes of construction lumber, see Table 1-6.
b. Plywood is usually 4 feet by 8 feet and varies in thickness from $1 / 8$ to 1 inch.
c. Stock panels are usually 48 inches wide; lengths vary in multiples of 16 inches (up to 8 feet) because the accepted spacing for studs and joists is 16 inches.

1-9. Nails. Nails are the most commonly used items that are under the classification of rough hardware.
a. Types. Nails come in different sizes and are divided into two general types: wire and cut. Also, special nails are available for some jobs.
(1) Wire Nails. Wire nails are divided into five main types: finishing, casing, box, common, and duplex-head.

Table 1-6. Nominal and dressed sizes of lumber

| Nominal Size (rough) <br> (in inches) | Actual Dressed Size <br> (in inches) |
| :---: | :---: |
| $1 \times 3$ | $3 / 4 \times 21 / 2$ |
| $1 \times 4$ | $3 / 4 \times 31 / 2$ |
| $1 \times 6$ | $3 / 4 \times 51 / 2$ |
| $1 \times 8$ | $3 / 4 \times 71 / 4$ |
| $1 \times 10$ | $3 / 4 \times 111 / 4$ |
| $1 \times 12$ | $11 / 2 \times 31 / 2$ |
| $2 \times 4$ | $11 / 2 \times 51 / 2$ |
| $2 \times 6$ | $11 / 2 \times 71 / 4$ |
| $2 \times 8$ | $11 / 2 \times 91 / 4$ |
| $2 \times 10$ | $11 / 2 \times 111 / 4$ |
| $2 \times 12$ | $21 / 2 \times 71 / 4$ |
| $3 \times 8$ | $21 / 2 \times 111 / 4$ |
| $3 \times 12$ | $31 / 2 \times 111 / 4$ |
| $4 \times 12$ | $31 / 2 \times 151 / 4$ |
| $4 \times 16$ | $51 / 2 \times 111 / 2$ |
| $6 \times 12$ | $51 / 2 \times 171 / 2$ |
| $6 \times 16$ | $71 / 2 \times 151 / 2$ |
| $6 \times 18$ | $71 / 2 \times 191 / 2$ |
| $8 \times 16$ | $71 / 2 \times 231 / 2$ |
| $8 \times 20$ |  |
| $8 \times 24$ |  |

(a) Finishing Nails. Finishing nails (Figure 1-24) and box nails are made of the same diameter wire. The head of a finishing nail is only slightly larger in diameter than the body of the nail so that it can be embedded (set) into the surface of the wood. There is a slight depression on the top of the head to prevent the nail set from slipping off the head. The small hole that is made in the wood is filled with putty or some other type of filler to hide the nail when the surface is finished.
(b) Casing Nails.

Casing nails (Figure 1-25) are similar in appearance to the finishing nail. The head, however, is slightly larger and has no depression in the top. These nails are used to nail doors and window casings in place.
(c) Box Nails. Box nails (Figure 1-26) are used in box construction or whenever there is a possibility of splitting the wood with a common nail. The head of a box nail is somewhat thinner and larger in diameter than the head of $a$ common nail. Box nails are sometimes coated with a special cement to give them better holding quality.
(d) Common Nails. Common nails (Figure 1-27) have a thick flat head. They are used for most phases of building construction.


Figure 1-24. Finishing nail


Figure 1-25. Casing nail


Figure 1-26. Box nail

## П-

Figure 1-27. Common nail
(e) Duplex-Head or

Double-Headed Nails. Duplexhead or double-headed nails (Figure 1-28) are used in temporary construction such as form work and scaffolding. The advantage of using this type of nail is easy removal. It has a collar that keeps the head away from the wood, and the claw of the hammer can easily engage the head for removal.
(2) Cut Nails. Cut nails are wedge-shaped with a head on the large end (Figure 1-29). They are often used to nail flooring because they have good holding power and are made of very hard steel.


Figure 1-28. Duplex-head or double-headed nail


Figure 1-29. Cut nail
(3) Special Nails. Rustproof nails are sometimes used when the head is exposed to the weather. The head often rusts and causes a black streak along the grain of the wood, even though it is painted. Therefore, it is desirable to use a nail that will not rust. Plain wire nails that have a zinc coating are often used where there is a possibility of rusting. These are called galvanized nails (such as a roofing nail).
(4) Drywall Nails. Drywall nails (Figure 1-30) are used for hanging drywall and have a special coating to prevent rust.
(5) Masonry (Concrete)

Nails. Masonry nails (Figure 131) are available in lengths from $1 / 2$ inch to 4 inches, with a single head. These nails are usually hardened steel. Concrete nails are thicker and are used to fasten metal or wood to masonry or concrete.


Figure 1-30. Drywall nail


Figure 1-31. Masonry nail
b. Sizes. Nail sizes are given by penny number from twopenny to sixtypenny (Figure 1-32). A small letter $d$ is the recognized abbreviation for penny. The penny number refers to the length of the nail. Nails are normally packaged in 50-pound boxes. Table 1-7, page 1-34, gives the general sizes and types of nails preferred for specific applications.


Figure 1-32. Nail sizes

Table 1-7. Sizes, types, and uses of nails

| SIIE | LGTH(N) | DIAM(N) | REMARKS | WHERE USED |
| :---: | :---: | :---: | :---: | :---: |
| 2d | 1 | . 072 | Small head | Finish work, shop work |
| 2 d | 1 | . 072 | Large flathead | Small timber, wood shingles, lathes |
| 3d | 11/4 | . 08 | Small head | Finish work, shop work |
| 3 d | 11/4 | . 08 | Large flathead | Small timber, wood shingles, lathes |
| 4d | $11 / 2$ | . 098 | Small head | Finish work, shop work |
| 4d | 11/2 | . 098 | Large flathead | Small timber, lathes, shop work |
| $5 \mathrm{5d}$ | $13 / 4$ | . 098 | Small head | Finish work, shop work |
| 6 cd | 13/4 | . 113 | Small head | Finish work, casing, stops, and so forth, shop work |
| $6 d$ | 2 | . 113 | Large flathead | Smaill timber, siding, sheathing, and so forth, shop work |
| 7 d | 2 | . 113 | Small head | Casing, base, ceiling, stops, and so forth |
| 7d | 21/4 | . 113 | Large flathead | Sheathing, siding, subfiooring, light framing |
| 8 d | 21/4 | . 131 | Small head | Casing, base, ceiling, wainscot, and so forth, shop work |
| 8d | 21/2 | . 131 | Large flathead | Sheathing, siding, subflooring, light framing, shop work |
| 8 d | 21/2 | . 131 | Extra-large flathead | Roll roofing, composition shingles |
| 9 d | $11 / 4$ | . 131 | Small head | Casing, base, ceiling, and so forth |
| 9d | 23/4 | . 131 | Large flathead | Sheathing, siding, subilooring, framing, shop work |
| 10 d 10 d | $23 / 4$ | . 148 | Small head <br> Large flathead | Casing, base, ceiling, and so forth, shop work Sheathing, siding, subflooring, framing, shop work |
| 12 d | 3 | . 148 | Large flathead | Sheathing, subflooring, framing |
| 16 d | 3 | . 162 | Large flathead | Framing, bridges, and so forth |
| 200 | $31 / 4$ | . 192 | Large flathead | Framing, bridges, and so forth |
| 30d | $31 / 2$ | . 207 | Large flathead | Heavy framing, bridges, and so forth |
| 40d | 4 | . 225 | Large flathead | Heavy framing, bridges, and so forth |
| 50d | 41/2 | . 244 | Large flathead | Extra-heavy framing, bridges, and so forth |
| 60d | $\begin{gathered} 5 \\ 51 / 2 \end{gathered}$ | . 262 | Large flathead | Extra-heavy framing, bridges, and so forth |

1-10. Screws. Screws are another means of fastening one member to another. Screws have some advantages over nails. They have greater holding power, present a neater appearance, and have more decorative possibilities than nails. They also have the advantage of being easily removed or tightened.
a. Phillips Head. Screws are usually either slotted-head or Phillips head (Figure 1-33). Phillips head screws require a special screwdriver for driving them. Some advantages of Phillips head screws are that the screwdriver does not slip out easily and that the head is not as apt to break as that of a conventional type screw.


Figure 1-33. Slotted and Phillips head
b. Wood Screws. Wood screws are made of iron, bronze, brass, copper, or other metals; however, some are coated with nickel or chrome to match special-finish hardware. The main types of wood screws are roundhead, oval head, and flathead, which can be either slotted or Phillips head.
(1) Roundhead Screws. Roundhead screws (Figure 1-34) are usually used on a surface where the heads will show. The head is not countersunk, and for this reason it should have a pleasing finish-either blued or polished. If slotted-head, the screw slot should always be left in a parallel position to the grain of the wood.
(2) Oval-head Screws. Ovalhead screws (Figure 1-35) are used to fasten hinges or other finish hardware to wood. If slotted-head, the screw slots of these screws should be parallel to each other for better appearance.
(3) Flathead Screws. Flathead screws (Figure 1-36) are used where the head will not show. The head should be countersunk until it is level with or slightly below the finished surface. If flathead screws are used on an exposed area, they should be countersunk in a hole that can be plugged.


Figure 1-34. Roundhead screw


Figure 1-35. Ovalhead screw


Figure 1-36. Flathead screw
(4) Other Screws.
(a) Lag Screws. Lag screws are longer and heavier than the common wood screw and have coarser threads. They have square and hexagon heads (Figure 1-37). They are used when ordinary wood screws would be too short or too light and spikes would not be strong enough.


Figure 1-37. Lag screws
(b) Drive Screws. Special screws, made to be driven with a hammer, are called drive screws (Figure 1-38). They may have a roundhead but are usually made with a flathead, and they may have no slot for a screwdriver. (They also come in larger sizes with square or round heads.) The threads are far apart. Drive screws are available in the same size as wood screws.
(c) Special Screws. Many special hanging and fastening devices have a screw-type body (Figure 1-39). The screw eye is often used on picture frames, screen doors, and many other items. The curved screw hook and square screw hooks are mainly used for hanging articles. The curved screw hook is usually used in the ceiling, while the square screw hook is more often used on vertical walls.


Figure 1-39. Special screws
c. Sheet-Metal Screws.

Like wood screws, sheet-metal screws can also be slotted or Phillips head. They are used for the assembly of metal parts. They are steel or brass with four types of heads: flat, round, oval, and fillister, as shown in Figure 1-40.


Figure 1-40. Sheet metal screws
d. Pilot and Starter Holes. Prepare the wood for receiving a screw by baring a pilot hole (the size of the diameter of the screw) into the piece of wood. A smaller, starter hole is then bored into the piece of wood that is to act as anchor or hold the threads of the screw. The starter hole has a diameter less than that of the screw threads and is drilled to a depth $1 / 2$ or $2 / 3$ the length of the threads to be anchored. This method (shown in Figure 14-1) assures accuracy in placing the screws and reduces the possibility of splitting the wood.


Figure 1-41. Sinking a wood screw
e. Covering Material. Both slotted and Phillips flathead screws are countersunk enough that a covering material can be used (Figure 1-42).


Figure 1-42. Screw-covering material

1-11. Anchors. Fastening wood or other materials to concrete or other materials has always been a task for carpenter's. Anchors (fasteners) for such work can be divided into three general categories. The first group includes anchors installed during the initial construction. The second group includes anchors installed in solid concrete or masonry after construction is completed. The third group includes anchors installed in masonry, plastic, or drywall that has a hollow space behind it.
a. Anchor Bolts. Anchor bolts (Figure 1-43) a used to fasten sills to masonry foundations. These bolts are used to fasten the sill to the footers. Anchor bolts are installed when placing the footer while the concrete is still wet.


Figure 1-43. Anchor bolt installation
b. Expansion Anchor Bolts. Lead screws, plastic anchors, and lag expansion shields all work with the same basic idea. Drill a proper size hole and insert the expansion shield into the hole. The insertion of the screw or lag bolt expands the fastener to provide a secure hold. Figure $1-44$ shows how expansion anchors work.


Figure 1-44. Expansion anchor bolt
c. Molly Universal-Screw Anchors. Molly fasteners (Figure 1-45) provide a solid means of attaching fixtures to interior walls. A hole is drilled the same size as that of the outside diameter of the fastener. These fasteners are designed to expand behind the wall covering.


Figure 1-45. Molly universal screw anchors
1-12. Bolts. Bolts are made of steel with either round, square, or octagon heads and threaded shanks. The threads may run the full length of the bolt, or they may stop a certain distance from the head, leaving a smooth upper shank. Bolts are used to fasten timber, steel, or other materials. They range in diameter from 3/16 to 1 1/2 inches, and in lengths from $3 / 4$ to 30 inches. They are available in three main styles: stove bolts, machine bolts, and carriage bolts.
1-39
a. Stove Bolts. Stove bolts are used mostly with small items of hardware. Roundhead or flathead stove bolts (Figure 1-46) range in length from $3 / 8$ to 6 inches. They are used in light construction.


Figure 1-46. Stove bolts
b. Machine Bolts. Machine bolts (Figure 1-47) are used in woodwork. They usually have square heads and square nuts. A metal washer is usually used under both the head and the nut. These washers prevent the head from embedding into the wood and keep the nut from tearing the wood fibers as it is turned. Two wrenches are required when tightening machine bolts.


HEXAGON HEAD AND NUT


SQUARE HEAD AND NUT

Figure 1-47. Machine bolts
c. Carriage Bolts. Carriage bolts are like machine bolts except for the heads, which are round (Figure 1-48). The shank of the carriage bolt has a square portion, which
is drawn into the wood to prevent the bolt from turning as the nut is tightened. A washer is used under the nut, but not under the head of this bolt.


Figure 1-48. Carriage bolts
d. Toggle Bolts. Toggle bolts are used to fasten fixtures to hollow walls. The two types of toggle bolts are the pivot type and the spring-wing type. Both types have heads similar to those of ordinary wood screws. Both come in various sizes.
(1) Pivot-Type. The pivot-type has a bent-steel channel with the nut slightly off-center so that one end of the channel is heavier than the other (Figure 1-49). A hole is drilled into the hollow wall or block. The heavy end of the nut drops down at a right angle to the bolt when it is inserted into the hole. The nut will pull up tight against the drywall or block as the bolt is tightened.


Figure 1-49. Pivot-type toggle bolt
(2) Spring-Wing Type. Spring-wing type toggle bolts are made like the pivot type except that the wing is hinged in the center. It is held open with a small spring and
is closed while inserting it into the hole. It snaps open when it enters the hollow cavity of the wall, as seen in Figure 1-50.


Figure 1-50. Spring-wing toggle bolts
1-13. Hinges. All hinges are used to make a movable joint between two pieces of material. A hinge consists primarily of a pin and two plates. There are three most commonly used hinges: full-mortise, half-surface, and full-surface. Figure $1-51$ shows the basic design of a common door hinge.


Figure 1-51. Common door hinge
a. Full-Mortise. The fullmortise binge (Figure 1-52) is cut or mortised (gained) into both the doorjamb and the door. The leaves of a full-mortise hinge are completely hidden, leaving only the barrel exposed when the door is closed.
b. Full-Surface. The fullsurface hinge (Figure 1-53) is fastened directly to the door and jamb, and no mortise is required. Note that the edges of the full-mortise are beveled. The surface of the frame and door must be flush when full-surface hinges are used.
c. Half-Surface. As shown in Figure 1-54, the half-surface butttype hinge is like the other hinges, except that one leaf is fastened on the surface of the door and the other leaf fits into a grain in the frame.


Figure 1-53. Full-surface hinge


Figure 1-54. Half-surface hinge
d. Cabinet Hinges. Hinges come in many styles and finishes for every type of cabinet. Either full-mortise, full-surface, or halfsurface hinges are used for cabinet work. A few of the designs of cabinet hinges are shown in Figure 1-55.


Figure 1-55. Cabinet hinges
e. Special Hinges. Many other types of hinges are available. Several are shown in Figure 1-56.


Figure 1-56. Special hinges
1-14. Hinge Hasps. Hinge hasps are like hinges, except for the leaves (Figure 1-57). One leaf has screw holes for fastening the hasp in place. The other leaf is longer with a slot cut near the outer end. A metal loop, riveted to a square metal base, is used with the hinge hasp. The base of the loop is fastened in place with four screws. The slot in the long leaf of the hasp fits over the loop. A hinge hasp is used with a padlock as a locking device. The long leaf of the safety hasp covers the heads of all screws when it is in the locked position.


Figure 1-57. Hinge hasps

1-15. Locks and Striker Plates. The three general types of door locks are: the tubular, the cylindrical, and the mortise lock. Dead-bolt and rim locks can be installed to provide additional security.
a. Tubular Locks. Tubular locks have all the advantages of mortise locks, but are much easier to install because they only need bored holes. They are used mainly for interior doors for bedrooms, bathrooms, passages, and closets. They are available with a key tumbler lock in the knob on the outside of the door or with a turn button or push button on the inside. Figure 1-58 shows a tubular lock set.


Figure 1-58. Tubular lock
b. Cylindrical Locks. Cylindrical locks (Figure 1-59) are basically the same as the tubular type. The cylindrical lock is a sturdy, heavy-duty, and stronger lock, which is used on exterior doors for maximum security.


Figure 1-59. Cylindrical lock
c. Mortise Locks. Mortise locks (Figure 1-60) are used mainly on front or outside doors for high security. The present trend is away from using mortise locks because of the difficulty and time required to install them.


Figure 1-60. Mortise lock
d. Dead Bolts. Dead Bolts are used where added security is needed. They are constructed of very hard steel. Figure 1-61 shows a combination dead bolt and combination dead bolt and latch.


Figure 1-61. Dead bolt locks
e. Rim Locks. Rim locks (Figure 1-62) are easier to install because they are normally installed on the inside surface of exterior doors. One bored hole is usually all that is required. On some types, however, a recess must be cut for the lock.


Figure 1-62. Rim lock
f. Striker Plate. A striker plate (Figure 1-63) is usually mortised into the frame of the opening for a lock. It prevents the wood from wearing or splitting and cannot be pried loose easily.


Figure 1-63. Striker plate

## LESSON 1

## PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer to each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part the lesson which contains the portion involved.

1. You need to know where a certain door belongs that was delivered to the construction site. What plan/schedule would you use to find this information?
A. Site plan
B. Plot plan
C. Door schedule
D. Door plan
2. How many $B F$ are there in 36 pieces of lumber in 1 inch by 4 inches by 20 inches long?
A. 20
B. 30
C. 40
D. 50
3. Why does a finish nail have a light depression in the head?
A. Appearance
B. Classification
C. Holding power
D. Nail set
4. Nails are ordered by the penny starting with twopenny through sixtypenny. What letter of the alphabet stands for penny?
A. $a$
B. d
C. f
D. p
5. Why are general notes written on a construction drawing?
A. To give additional information
B. To give architectural information
C. To provide special notes for supervisors
D. To explain the materials list
6. What are the lines on a construction drawing that represent the edges of surfaces and are somewhat heavier called?
A. Center
B. Extension
C. Hidden
D. Visible
7. Refer to Table 1-5, page 1-25. How many $B F$ are there in a 2 inch by 12 -inch board that is 16 feet long?
A. 32
B. 21
C. 18
8. What are the three most commonly used hinges?
A. Full-mortise, cabinet, and hinge harp
B. Full-mortise, spring, and continuous
C. Full-mortise, full-surface, and half-surface
D. Full-mortise, special, double-acting locks, and striker plates
9. Why are screws better to use in wide ranges of construction?
A. They cost less.
B. There are more sizes.
C. They are harder than nails.
D. They have better holding power.
10. What is the first list that you should make before you make out a BOM?
A. The materials takeoff list.
B. The estimating cost list.
C. The building hardware list
D. The estimating lumber list.

## LESSON 1

## PRACTICE EXERCISE

## ANSWER KEY AND FEEDBACK

Item

1. C Door schedule A door and window...(page $1-9$, para $1-2 \mathrm{c}(2)$ and page 1-10, Table 1-2)
2. 
3. 
4. B d
5. 
6. 
7. 
8. 
9. 
10. 

Correct Answer and Feedback

A
20

D Nail set.
There is a slight depression...(page 1-31, para 19a(a))

A small letter $d$ is the recognized... (page 1-32, para 1-9b)

A To give additional information. General notes give additional information that is needed. (page 1-2, para 1-1b)

D Visible
A heavyweight unbroken...(page 1-3, para 1-1d(1))

A
32
(page 1-25, Table 1-5)

C Full-mortise, full-surface, and half-surface. There are three most commonly used... (page $1-42$, para 1-13)

D They have better holding power.
They have greater holding power,...(page 1-34, para 110)

A The materials takeoff list.

However, you should make...; This list is the first... (page 1-23, Part B Introduction and para 1-3)

## LESSON 2

## TOOLS AND EQUIPMENT

## OVERVIEW

## LESSON DESCRIPTION:

At the end of this lesson, you will be able to describe the methods used to maintain tools and equipment.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will perform maintenance on carpentry/masonry tools.

CONDITION: You are given the material contained in this lesson.

STANDARD: You will correctly answer practice exercise questions at the end of this lesson.

REFERENCE: The material contained in this lesson was derived from the following publications: FM 5-426 (to be published within six months) and TM 5-704.

## INTRODUCTION

The quality of a carpenter's work is greatly affected by the tools and machinery he uses and their condition.

## PART A - CARE AND USE OF HAND TOOLS

## 2-1. Boring Tools

a. Types of Boring Tools. All wood-boring augers and drill bits, held by a brace or hand drill, are boring tools.
(1) Auger Bit. Auger bits come in sizes from $1 / 4$ inch to 1 inch. The number on the tang shows the size of the bit in 1/16-inch increments. For example, in Figure 2-1, page 2-2, the number 6 means that it is 6/16 (or 3/8) inch.

The marked part of the bit is used to start the hole. The spur is made like a screw, which pulls the bit into the wood as you turn the bit. The parts marked lip and nib are the cutting parts. The twist portion removes the shavings from the hole. The shank ends in a tang, which fits into the brace.


Figure 2-1. Auger bit
(2) Expansion Auger Bit. An expansion bit (Figure 2-2) is used to bore a hole larger than 1 inch, such as for a door lock. Notice that the cutting bit has a scale for adjusting the size of the hole needed. The screw shown is used to lock the cutting blade into position. The screw must be tightened to keep the blade from moving and changing the size of the hole. This bit also has a tang to fit into the hand brace.


INTERCHANGEABLE CUTTING BLADE FOR EXPANSION BIT

NOTE: Usually, two cuting bits are turnished with each expansion blt.

Figure 2-2. Expansion auger bit
(3) Twist Drill. A twist drill is used to make holes in wood, metal, fiber, plastic, and other materials. Carpenters often drill holes in metal to which some type of wood or fiber will be bolted. This requires the use of a special type of twist drill (Figure 2-3). Twist drill bits are driven by electric or hand drills (Figure 2-4).

sQuare shank (USED in brace)

Figure 2-3. Twist drills


Figure 2-4. Electric and hand drills
(4) Countersink Bit. A countersink bit is used to increase the diameter of the top of a drilled hole to receive the head of a screw (Figure 2-5).


Figure 2-5. Countersink bit
b. Care and Use of Boring Tools. To cut a clean, splinter-free hole, the cutting parts must be kept sharp. The spur must be kept sharp so that it will pull the bit into the wood. The lip must be kept sharp to prevent tearing of the material being bored. Because these are all sharp edges, the lip should be protected from damage through contact with other tools. Bits should be stored a special case, or the point wrapped with a rag to protect the cutting edges.

2-2. Tooth-Cutting Tools. Both manually operated saws and power saws are tooth-cutting tools.
a. Types of Tooth-Cutting Tools. Manually operated saws used by carpenter's are mainly the crosscut saw, ripsaw, compass saw, coping saw, hacksaw, and miter saw.
(1) Crosscut Saw. A crosscut saw (handsaw) (Figure 2-6) is designed to cut across the grain of the wood. Its teeth are sharpened like a knife so they will cut the fibers of the wood on each side of the saw cuts (or kerf). A crosscut saw is 20 to 26 inches long and has 8 to 12 teeth per inch. The number of teeth per inch is stamped on the blade near the handle.


Figure 2-6. Crosscut saw
(2) Ripsaw. This saw is used to cut with (or parallel to) the grain of the wood. The teeth of a ripsaw (Figure 2-7) are a series of little chisels set in two parallel rows. On each full stroke of the saw, the edges chisel off a little from the end of the wood fibers. This cut is also called a kerf.


Figure 2-7. Ripsaw teeth
(3) Compass Saw. The compass saw (Figure 2-8) has 10 points to the inch. It may be equipped with a blade (with 13 points to the inch) for cutting nails. Its main function is cutting holes and openings such as electrical outlets, where a power tool would be too large.


Figure 2-8. Compass saw
(4) Coping Saw. The blade of a coping saw can be turned to change the direction of the cut or to cut sharp angles. This saw is also used for cutting curved surfaces and circles. Coped joints are sometimes used when joining moldings at right angles. One piece of stock is cut away to receive the molded surface of the other piece (Figure 2-9).


Figure 2-9. Coping saw and coped joint
(5) Hacksaw. This saw is 10 to 12 inches long; it has 14 to 32 points per inch (Figure $2-10$ ). It is used to cut metal, such as metal trim or aluminum thresholds. It should not be used to cut wood.

## WARNING

Do not use the hacksaw with heavy pressure for a long period; stop and let the blade cool. If the blade gets too hot, it will break.


Figure 2-10. Hacksaw
(6) Miter Saw. A miter saw is used with a miter box. The saw is held in a horizontal position and can be adjusted to cut various angles. It is used to cut moldings and picture frames to fit. It can be adjusted to cut at right angles for small pieces of wood. To cut a piece of molding to a specified angle: set the saw to the prescribed angle, insert the piece in the proper position against the fence, and move the saw back and forth across the material (Figure 2-11).
b. Care and Use of Cutting Tools. Cutting tools, like boring tools, have sharp edges and points, which need to be sharpened and protected. The term sharpen is used here in a broad sense to include all of the operations required to put a saw in first-class condition. The master carpenter is an expert in using the right tool in the right way.
(1) Jointing. When a saw comes from the factory, the teeth are all uniform in size, length, bevel, pitch, and set. After being used and sharpened a few times, the teeth become distorted. When this occurs, they must be filed to a straight line. This operation is called jointing (Figure 2-12). When you joint a saw, place it in a saw vise with the handle to the left. Starting with the heel end of the saw, lay a flat file on top of the teeth and move it lightly along the top of the teeth. Do not top the file. Continue this operation until all teeth are even, with a slight crown at the top of each tooth. If you find that the teeth are too short, which would make them hard to set, file them to the proper shape before they are set.
(2) Setting. After the teeth are made even by jointing, they must be set. This means that every tooth will be bent a little to give the blade sufficient clearance. For a handsaw, the set should be half the thickness of the blade. This rule applies to both crosscut saws and ripsaws. When using a saw set (Figure 2-13), bend every other tooth (halfway from the point), starting at either end of the saw. Do not attempt to hurry this operation; it takes skill and practice to do it properly.


Figure 2-12. Jointing a saw


Figure 2-13. Saw set
(3) Filing. To file a crosscut saw (Figure 2-14, page 2-8), place the saw securely in a saw vise with the handle to the left. Using a three-cornered file, start filing from the heel end. Place the file between two teeth and incline it toward the small or tapered end of the saw. File both teeth at once, using one or more strokes and putting the same pressure on each stroke. Work down the length of the saw, then turn the saw around so that the handle is to the right. Incline the file to the tapered end, which is now to the left, and again work down the length of the saw.


Figure 2-14. Filing a crosscut saw
(4) Beveling. To file a ripsaw, place the saw securely in a saw vise. File straight across the front of the teeth using a threecornered file. Lower the file handle from 2 to 3 inches. This gives a bevel on the top of each tooth that leans away from you. File down the length of the saw, starting with the heel end and using the same amount of pressure on each stroke (Figure 2-15).


Figure 2-15. Beveling a ripsaw
(5) Side-Dressing. After you file the saw, lay it flat on a board and run the flat side of the file gently along the side of the teeth. Turn the saw over and repeat the operation on the other side. This is called side-dressing. No setting may be needed for the next two or three filings. In this case, side-dress with an oilstone to remove the burrs (Figure 2-16).


Figure 2-16. Side-dressing a saw

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2-3. Sharp-Edged Cutting Tools. Chisels are considered sharp-edged cutting tools. The chisel is an indispensable tool and is often the most abused. It should be used solely for cutting wood surfaces. It should never be used for prying or as a screwdriver. A chisel is a flat piece of steel (of varying thicknesses and widths) with one end ground to an acute bevel to form a cutting edge.
a. Types of Sharp-Edged Cutting Tools.
(1) Paring Chisel. A paring chisel (Figure 2-17) is used for shaping and preparing large surfaces. It is used with a steady sustained pressure of the hand and should never be driven with a mallet.


Figure 2-17. Paring chisel
(2) Firmer Chisel. The firmer chisel (Figure 2-18) is more substantial tool than the paring chisel. It is usually used for routine work, but may be used for paring or light mortising. When paring, drive the chisel by hand pressure. For light mortising, use a mallet.


Figure 2-18. Firmer chisel

## CAUTION

Never use a hammer or metal tool to drive a chisel-use wood to wood. This will help preserve the handles of your chisels.
(3) Framing Chisel. A framing (or mortise) chisel (Figure 219) is a heavy-duty tool, which is used for heavy work. These chisels have an iron ring fitted to the end of the handle to prevent splitting when it is struck with a heavy mallet.


Figure 2-19. Framing chisel
(4) Slick Chisel. Any chisel having a blade wider than 2 inches is called a slick chisel. Regular sizes range from $21 / 2$ to 4 inches. They are used on large surfaces where there is considerable material to be removed or where unusual power is required.
b. Care and Use of Sharp-Edged Cutting Tools. For most effective use, keep all chisels properly ground and sharp. When chisels are not being used, keep them in a toolbox or other approved storage place such as a rack, to prevent dulling or nicking the cutting edges. To prevent rusting during storage, coat the metal portion of the chisel with light oil.
(1) Replacing the Wood Chisel Head. A wood chisel with a mushroomed head (Figure $2-20$ ) should be replaced immediately, because a mallet can glance off its mushroomed surface easily and spoil the work surface or cause injury.

## NOTE: A slightly battered wood handle can be smoothed with a wood rasp and sandpaper.

(2) Whetting the Cutting Edge. The cutting edge of the wood chisel can be kept in shape by whetting it on an oilstone (Figure 221), unless its edge is nicked or the bevel has become too rounded with careless whetting. In this case, the chisel must be ground, taking care the bevel is ground straight. Keep the length of the bevel about two times the thickness of the unbeveled part of the blade.


Figure 2-20. Mushroomed Chisel head


Figure 2-21. Whetting a chisel cutting edge
(3) Grinding a Wood Chisel. To grind a wood chisel, first square the cutting edge. To do this, hold the chisel at a right angle to the grinding wheel with the bevel up and move it from side to side (Figure 2-22). Dip the chisel in water frequently to avoid loss of temper. Check the edge with a small square to be sure the edge is at a right angle to the sides of the blade.


Figure 2-22. Grinding a chisel cutting edge
(4) Restoring the Bevel. To restore the bevel, readjust the grinder tool rest to a position that will give the chisel the correct bevel (usually 30 degrees). Hold the bevel lightly against the wheel (Figure 2-23) and grind with the same side-to-side motion used in squaring the cutting edge. To avoid loss of temper, cool the chisel by dipping it in water during the sharpening process.


Figure 2-23. Restoring a bevel chisel cutting edge
(5) Grinding and Honing. Figure $2-24$ shows a properly ground and properly honed chisel. Remember $X$ should equal twice the width of $Y$.


Figure 2-24. Ground and honed chisel

## 2-4. Smooth Facing Tools.

a. Types. Smooth facing tools called planes, are sharp-edged cutting tools in which the cutting edge is guided by the body of the tool instead of by the hands. The place bit, for example, is positively guided by contact of the body of the tool with the work, giving a smooth cut in contrast to the rough cut made by hand-guided chisels.
(1) Hand Plane. A plane is a finishing tool used for smooth surfaces (Figure 2-25). It consists of a wood or iron stock or a combination of the two, with the cutting edge projecting from a slot on the underside. The cutter inclines backward and has a chip breaker in front to dispense the shavings. The plane is light and easy to use in finishing and bringing wood down to the desired thickness. Hold the plane with both hands and, with long strokes push it away from you.


Figure 2-25. Hand plane
(2) Block Plane. This is the smallest plane (Figure 2-26). It varies in length from $31 / 2$ to $71 / 2$ inches and can be used easily with one hand. Primarily, it is used for planing end grain or across the grain of wood. No chip breaker is needed to break the shavings because there are no shavings when planing across the grain.


Figure 2-26. Block plane
(3) Smoothing Plane. The smoothing plane is a short, finely set plane, which averages 12 inches in length (Figure 2-27). It is used for finishing uneven surfaces.


Figure 2-27. Smoothing plane
(4) Jointer Plane. This plane is the largest of the plane family (Figure 2-28). It varies in length from 20 to 24 inches. The great length of this plane makes it possible to smooth a large surface or to make the edge of a board true so that two such surfaced areas will fit closely together.


Figure 2-28. Jointer plane
b. Care and Use.
(1) Sharpening Plane Bits. The length of the plane determines the straightness of the cut. If you keep your plane bits sharp, they will produce a true and smooth surface. To get the best service from your planes, the bit should be ground and honed properly. When grinding and honing plane bits, the same rules apply as for wood chisels. The cutting edge should be straight on jointer-, smoothing, and block-plane bits and slightly curved on jack-plane bits.
(2) Using and Storing A Plane. Satisfactory results from a plane depend on how it is used. On the forward stroke, hold the plane flat on the surface to be planed. On the return stroke, lift the back of the plane so that the cutting edge does not rub against the blade. When the plane is not in use, place it on its side. For storage, withdraw the blade into the body of the plane. This helps keep the cutting edge sharp.

2-5. Rough Facing Tools. Rough facing tools are called striking tools because the work is done by a series of strokes. The cut made by this method is rough compared to cuts made by other tools.
a. Hand Axe. The hand axe has a curved cutting edge and a long, flat-faced peen. It is sharpened with a bevel on each side of the blade. The broad hatchet and half hatchet are sometimes referred to as hand axes (Figure 2-29).


Figure 2-29. Hand axe
b. Axe. This is similar to the hand axe but larger, with a long handle. As you can see in Figure $2-30$, it is intended for heavy cutting and should be used with both hands. It is sharpened in the same manner as the hatchet.


Figure 2-30. Axe

## 2-6. Driving Tools.

a. Types of Driving Tools. Driving tools include such tools as claw hammers, tack hammers, and mallets, which are designed for specific uses; however, the one most frequently used is the claw hammer.
(1) Claw Hammer. The best claw hammers are made from the best steel, which is carefully forged, hardened, and tempered. Hammers differ in the shape of the claw-curved or straight-and in the shape of the face-flat or rounded. The style of the neck, the weight, and the general finish of claw hammers differ according to the intended use. Figure $2-31$, page $2-16$, shows straight and curved claw hammers. The average weight of claw hammers is 5 to 20 ounces. Good-
2-15
quality or high-grade hammers have hickory handles and are made from well-seasoned, straight-grained stock. Other hammers of good quality have steel handles with shock-absorbing rubber grips.


Figure 2-31. Claw hammers
(2) Mallets. Mallets are, in reality, wooden hammers. Although not considered a driving tool, they are used the same way as hammers. You will use mallets primarily for driving chisels and wedges. Depending on their use, mallets can vary in size from a few ounces to a few pounds. Many woodworkers make their own mallets to suit their personal touch. Figure 2-32 shows three types of mallets.


Figure 2-32. Mallets
b. Care and Use of Driving Tools.
(1) Driving Nails. When you use driving nails with a claw hammer, guide the nail with one hand and grasp the hammer with the other down near the end of the handle. Avoid holding the hammer near the neck. Use a wrist motion, tapping the nail lightly to start it, then use a few sharp blows to finish driving the nail. After the nail has been driven, it can be set below the surface with a nail set. This prevents hammer marks or cat paws from marring the surface of the wood. Nail sets are made in several sizes. Figure 2-33 shows one type of nail set.


Figure 2-33. Nail set
(2) Removing Nails. Use the claw of the hammer to remove nails. To properly pull a nail, place a block under the claw for leverage. If the nail is large, use a nail puller or a wrecking bar (Figure 2-34).


WRONG WAY (mars work surface)

RIGHT WAY (with block for extra leverage)

Figure 2-34. Removing nails
2-6. Fastening Tools. Fastening tools are used to join parts or materials together with screws or bolts. These tools include screwdrivers and wrenches.
a. Screwdrivers. There are many different types, shaped ends, and lengths of screwdrivers. The automatic screwdriver (Figure 2-35, page $2-18$ ) is a labor and time saver, especially where great numbers of screws are to be driven. The bits for this tool come in different sizes for slotted and Phillips-head screws and can be changed to fit the different sizes of screws. The automatic screwdriver has a
ratchet assembly, which you can adjust to drive or remove screws. You can also lock it in position and use it as an ordinary screwdriver.


Figure 2-35. Automatic screwdriver
b. Phillips Screwdrivers. Phillips screwdrivers are used only for driving Phillips screws (Figure 2-36). Phillips screws have a head with two V-slots, which cross at the center. The tip of the Phillips screwdriver blade is shaped like a pointed or beveled cross to fit into these slots. This type of screwdriver cannot slip out of the slot, therefore preventing damage to expensive finishes.


Figure 2-36. Phillips screwdriver

## 2-7. Holding Tools.

a. Supporting Tools. Supporting tools consist of sawhorses or trestles used to support workers and materials. Figure 2-37 shows a pair of sawhorses, which you might use to support a piece of lumber that you are cutting.
b. Retaining Tools. Retaining tools consist of various types of clamps, which fall into the following general categories: C clamp, double-screw clamp, and bar clamp (Figure 2-38).


Figure 2-38. Clamps
c. Vises. Vises can be fitted to the top of a workbench, and some are adapted to slide underneath the top of the workbench. Most vises used by carpenters are fitted with wood between the jaws to protect the work from scars, dents, and scratches (Figure 2-39, page 2-20).


Figure 2-39. Vises

## 2-8. Leveling Tools.

a. Common Level. The common level (Figure 2-40) is used for both guiding and testing when bringing work to a horizontal or vertical position. The level has a long rectangular body of wood or metal, which has a built-in glass spirit tube on its side and near the end. Each tube contains a nonfreezing liquid with a small air bubble free to move within the tube. The side and end tubes are at right angles to each other. When you center the bubble of the side tube with the hairline, the level is horizontal; when you center the bubble of the end tube with the hairline, the level is vertical. By holding the level against a surface to be checked, you can determine whether the surface is truly level (or plumb). Levels should be hung up when not in use.


Figure 2-40. Common level
b. Plumb Bob. A plumb bob is made of metal, usually brass. It usually has a screw-type cap with a hole in the center. A string or plumb line is inserted through the hole and fastened inside. The bottom end has a point in direct line with the hole in the cap (Figure 2-41). The string is absolutely perpendicular to the horizontal when the plumb bob is suspended


Figure 2-41. Plumb bobs on it. It can be used for the same purpose as the plumb glass on a level; however, the plumb bob is not accurate when used in the wind.
c. Chalk Line. This is a strong, lightweight cord used to make a straight line between two widely separated points. To snap a straight line, rub chalk on a cord held taut between two points. Then pull the cord straight up from the center and release it, to allow it to spring back into place. Chalk lines come in metal or plastic cases. Figure 2-42 shows how to snap a chalk line.


Figure 2-42. Snapping a chalk line

2-9. Measuring Tools. The most used and important tools that you must learn to use are those for measuring and layout work. Carpenter's measuring tools include rulers and tapes. Layout tools include various types of squares, dividers, and compasses and a marking gauge. The square is used for drawing angles. Dividers and compasses are used to scribe circles or transfer measurements. The carpenter's scribe is in the same class as a compass; it is used to scribe lines on building material for irregular joints. The marking gauge is used to mark lines parallel to a surface, an edge, or the end of a piece of lumber. Measuring and layout must be accurate; therefore, use a very sharp pencil or a knife blade.

When measuring, lay out your ruler or tape from your starting point and measure the distance called for by your plan. Place a mark opposite the required distance and square or angle the line as required by your layout.
a. Folding Rule. A folding rule is made from boxwood and has a concealed joint or rivet that holds it stiff and rigid when opened. Usually 6 feet in length, it is marked off in feet and inches and graduated in sixteenths of an inch. Figure $2-43$ shows the folding rule most often used by carpenters.


Figure 2-43. Folding rule
b. Steel Tape. In recent years, the flexible steel tape has been replacing the folding rule. It is also marked off in feet and inches and graduated in sixteenths of an inch. The flexible steel tape is housed in a metal casing with a spring attachment, which retracts the tape into the casing when the end is released. This type of rule is best because of its compactness and suitability for taking inside measurements (Figure 2-44).


## Figure 2-44. Steel tape

2-10. Framing Square. Much could be written about the framing square because of its many uses. However, we will cover only the correct nomenclature (names of terms and symbols) of its parts and the tasks for which it can be used.

In construction work, especially in house framing, the framing square is an invaluable tool and has a use that is common to all squaring devices. It is used for checking the squareness of building materials and for the squaring or angling of a mark placed on the building material. One arm of the square is placed against the edge or face of the building material. The other arm, with measuring units on it, is placed next to the desired mark on the building material. A line is then drawn across the material to the desired length or depth. It can also be used as a calculating machine, a means of solving mathematical problems. You will use it for laying out common, valley, hip, jack, and cripple rafters in roof construction and for laying out stringers for steps.

Figure $2-45$, page $3-24$, shows the framing square and its principal parts. The body of the square is the wider and longer member the tongue is the shorter and narrower member. The face is the side visible both on the body and the tongue when the square is held with the tongue in the left hand and the body pointing to the right. The various markings on a square are scales and tables. The square most generally used is one with a 16-inch tongue and a 24 -inch body.


Figure 2-45. Framing square
a. Try Square. The try square (Figure 2-46) is so called because of frequent use as a testing tool when squaring up wood stock. It consists of a steel blade 8 inches long at right angle to the stock, which is usually made of hardwood and faced with brass to preserve the wood from damage. The blade usually has a scale divided into eighths of an inch.


Figure 2-46. Try square
b. Miter Square. The term miter means any angle except a right angle, but as applied to squares mean an angle of 45 degrees (Figure 2-47). It is similar to a try square, but the stock of a miter square has an angle or 45 degree set in the
stock. When using the miter square, the 45 degrees face of the stock is placed against the edge of a board; then the blade will be at a 45 degree angle with the edge of the board. The scale on the blade is divided into eighths of an inch.


## Figure 2-47. Miter square

c. Combination Square. A combination square does the work of a rule, square, depth gauge, and level (Figure $2-48$, page 2-26). The name combination square indicates that you can use it as a try or miter square. It differs from the try and miter squares in appearance, and you can move the head to any desired position on the blade. The head slides in a groove located in the center of the blade. This groove also permits removal of the head so that the blade may be used as a rule or a straightedge. A spirit level is installed in the head, permitting it to be used as a level. A centering head, which can be substituted for the head, is used to locate the center of shafts or other cylindrical pieces. A scriber is also inserted in the head to be used for laying out work. The protractor head is used to set different angles. In the construction of this tool, the blade is hardened to prevent the corners from wearing round and detracting from its value as a measuring instrument.


Figure 2.48. Combination square
2-11. Sharpening and Smoothing Tools. Two main types of tools are used to sharpen and smooth other tools: stones and files.
a. Grindstones. Most bench grinders found in carpentry shops are equipped with two grinding wheels: one of coarse grit and one with fine grit. Grinding wheels are held to the shaft by nuts, which squeeze the wheel between two special side washers. Grinding wheels are also rated by the turning speed they can withstand. Be sure you use stones made to withstand the rated revolutions per minute of the grinder electric motor. A tool rest is attached to the grinder frame and is adjustable for height as well as for distance from the stone. Most grinders are equipped with heavy-duty glass guards to permit watching as you grind. If there is no eye guard, you must wear safety goggles to protect your eyes. It is considered poor practice to use the side of the wheel for grinding. When the surface of the stone becomes irregular or filled with metal particles, use a stone dressing tool (Figure 2-49) to restore a good grinding surface. A water container, attached to the base of the grinder, is used for cooling parts being ground. Always cool the blades of tools you are sharpening to prevent destroying the temper of the metal with the excess heat generated from grinding. Heavy grinding is done on the coarse wheel, and light or finish-type grinding is done on the fine grit stone. Most cutting edges should be finished by hand, using a fine oilstone.


Figure 2-49. Grindstone
b. Oilstones. Oilstones are used after the grinding operation to give a tool the keen, sharp edge required for smooth cutting (Figure 2-50).


Figure 2-50. Oilstone
c. Artificial Stones. These stones have coarse, medium, or fine grades. Coarse stones are used for general work where fast cutting is required. Medium stones are used for sharpening tools that do not require a keen edge. They are recommended for sharpening tools that are used for working softwoods. Fine stones are used where a keen edge is desired. Cabinetmakers whose tools require a very fine, keen edge use the fine type of stone.
d. Files and Rasps. A file is a steel instrument used for cutting and smoothing metal and wood. A rasp is a very coarse file that differs from an ordinary file in teeth size and shape. Figure 2-51 shows the types of files. Wood files are usually tempered to work lead or brass; they should not be used on any harder surface. When using a file, never allow it to drag on the backward stroke; it cuts only on the forward stroke. When using a rasp, fix the work firmly in a vise and grasp the rasp in both hands, with one hand holding and the other applying a light pressure to the rod (Figure 252).


Figure 2-51. Files and rasps


Figure 2-52. Using a rasp

2-12. Pulling Tools. Pulling tools are used for pulling nails, for prying, and for lifting. They are also used extensively for dismantling buildings, crates, boxes, and other wood products. They include nail pullers and wrecking bars.
a. Nail Pullers. Nail pullers (Figure 2-53) are used for removing nails, especially those that are driven flush or below the surface of wood. A nail puller has two jaws that set over the nailhead. Pressure is applied by a series of bows from the sleeve. The sleeve, which fits over the handle and slides up and down, is usually equipped with a guard to protect your hand from the sliding sleeve. The average length of a nail


Figure 2-53. Nail puller puller is 18 inches.
b. Wrecking Bars. Wrecking bars are usually made of forged, tempered steel. They are hexagonal in shape, with a curved, slotted neck for pulling large nails. The average length is 24 to 36 inches. They are used to dismantle and tear down wooden structures. A bar of the same type without a curved neck is called a pinch bar. It use is similar to that of a wrecking bar. Figure 2-54 shows the types of wrecking bars.


Figure 2-54. Wrecking bars

## PART B - CARE AND USE OF POWER MACHINERY

2-13. Portable Power Saws. Electric circular saws are primarily used for crosscutting or ripping and usually come equipped with a combination rip and crosscut blade. Other blades are available for cutting plywood, masonry, and hardboard.
a. Blade Sizes. The most commonly used blades are 7 1/4-inch and 7 1/2-inch blades. The diameter of the saw blade controls the depth of cut that may be made with the saw.
b. Electric Handsaw. Figure $2-55$ shows the parts of the electric handsaw. Learn these parts and become very familiar with the operation of the saw before trying to use it.
c. Circular Saw. The circular saw has a calibrated scale to control the depth of the cut by raising or lowering the base shoe of the saw. The saw may also be tilted to cut up to a 45-degree bevel cut. Figure 2-55 also shows the scale and tilt lock knobs.
d. Safety Guard. The operator is protected by a safety guard (Figure 2-55), which is pushed back by the piece being cut and returns automatically when the saw is removed from the work.

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CAUTION
This safety device is of vital importance in preventing
bodily injuries. Do not be take it off, tie it, or jam it
back.
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e. Ripping Fence. A very important accessory available for the portable power saw is the ripping fence (or guide) (Figure 2-56), which permits ripping of lumber to a predetermined width. It is used to ensure an exact cut of a predetermined distance from the board edge. Many carpenters reverse the hand position shown here in ripping. Use the most comfortable position.


Figure 2-56. Ripping fence
f. Blade Types. The four common types of blades are shown in Figure 2-57, page 2-32. The combination blade is a multipurpose blade that can be used for crosscutting or ripping.

2-14. Radial Saw. A radial saw (Figure 2-58, page 2-32) is a very versatile power tool, that can be used in all types of construction, such as timber construction, house construction, and form construction.


Figure 2-57. Types of blades


Figure 2-58. Radial saw
a. Blade Guard. Over the blade is a guard that protects the operator from an exposed saw blade. It also channels sawdust out through the opening of the guard.

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b. Crosscutting. Crosscutting is done by placing the board flat on the table with one edge against the backrest. The saw blade should be pulled evenly through the material. Lower the saw only enough to cut through the board.
c. Ripsawing. Ripsawing is very similar to the table saw, except that the saw blade is above instead of below the work. When ripping a board, feed it along the table making sure the teeth of the blade revolve toward the operator.
d. Bevels and Angles. Bevels and angles are cut in much the same manner as crosscutting. The head of the saw can be rotated or tilted to various angles. The procedures apply for crosscutting and ripping.

## Ulimate-Construction Series





SUBCOURSE
EN5156

## CARPENTRY II

## EDITION B

Carpentry is the art or science of measuring, cutting, fitting, and assembling wood and other materials to construct buildings or other structures. Many people associate carpenters with wood and other building materials and tools. They assume carpenters build only homes and other relatively small structures. Of course, this is not true. Carpenters work not only with wood but also with metals, plastic, and other synthetic materials. The carpentry trade includes skills required to construct buildings, bridges, docks, and wharf. Work must be accomplished in a manner consistent with environmental laws and regulations

There are no prerequisites for this subcourse.
This subcourse reflects current doctrine when this subcourse was prepared. In your own work, always refer to the latest publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

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## INTRODUCTION

After the foundation is in place, you are ready to start constructing the framework for the floor system.

## PART A - FLOOR FRAMING

1-1. Types of Sills. Sills are the horizontal timbers of a building which either rest up the masonry foundations or, in the absence of such, form the foundations. The sill is the foundation that supports all of the building above it. It is the first part of the building to be set in place and rest directly on the foundation, posts, or the ground. Sills are joined at the corners and spliced when necessary. The type of sill used depends on the type of construction used in the frame.
a. Box Sills. Figure 1-1, page 1-2, shows box sills. Box sills are often used with the common style of platform framing (either with or without a sill plate). With this type of ill, the part that lies on the foundation wall or ground is called the sill plate. The sill is laid edgewise on the outside edge of the sill plate.


Figure 1-1. Box sills
b. T-Sills. There are two types of T-sill construction-sills commonly used in dry, warm climates (see Figure 1-2) and sills used in colder climates (see Figure 1-3). Although these T-sill constructions are similar, notice that in Figure 1-2 the joists are nailed to the studs and sole plates. In Figure 1-3 the joists are nailed to the studs and sills and headers are used between the floor joists.


Figure 1-2. Dry-climate T-sill


Figure 1-3. Cold-climate T-sill
c. Built-Up Sills. Joints are stagger where built-up sills are used. Notice in Figure 1-4 how the built-up sill corner joints are made. Heavier sills are used if posts are used in the foundation. Sills are single heavy timbers or built-up of two or more pieces of timber (see Figure 1-5, page 1-4). Where heavy timbers are used, the joints should be placed over the post (see Figure 1-6, page 1-4).


Figure 1-4. Built-up sills


Figure 1-5. Braced framing sill


Figure 1-6. Heavy timber sill

1-2. Types of Girders. A girder is a large horizontal member used to support joists or beams. A girder is made of several beams nailed together with 16 d (sixteen penny) common nails, solid wood, steel, reinforced concrete, or a combination of these materials. Girders carry a very large proportion of the weight of a building. They must be well-designed, rigid, and properly supported at the foundation walls and on the columns. Girders must be installed so that they support the joists properly. The ends of the wood girders should be at least 4 inches on the posts.
a. Built-up Girder. The built-up girder is commonly used in house construction. It is generally made of three boards nailed together with 16 d common nails. Figure $1-7$ shows a built-up girder, walls, joists, and columns.

- A shows two outside masonry walls.
- B shows the built-up girder.
- C shows the floor joists.
- D shows the support columns that support the girder.


Figure 1-7. Built-up girder
b. Girder with Ledger Board. Use a girder with a ledger board when vertical space is limited and where more headroom is needed (see Figure 1-8).


Figure 1-8. Girder with ledger board
c. Joist Hangers. A girder with joist hangers is used where there is little headroom or where the joists must carry an extremely heavy load (see Figure 1-9).


Figure 1-9. Joist hangers
1-3. Girder Size Requirement. A girder should be large enough to support the load. The carpenter should understand the effect of length, width, and depth of the wood girder. The principles which govern the size of a girder are--

- The distance between girder posts.
- The girder load area.
- The total floor load per square foot on the girder.
- The load per linear foot on the girder.
- The total load on the girder.
- The material to be used.

1-4. Depth. When the depth of a girder is doubled, the safe load is increased four times. For example, a girder that is 3 inches wide and 12 inches deep will carry four times as much weight as a girder 3 inches wide and 6 inches deep. To obtain greater carrying capacity, it is better to increase the depth than to increase the width of the girder. The sizes of built-up wood girders for various loads and spans may be determined by using Table 1-1.

Table 1-1. Sizes of built-up wood girders

| Load Per Linear Foot of Girder | Length of Span (feet) |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | 6 | 7 | 8 | 9 | 10 |
| Nominal Size of Girder Required (inches) |  |  |  |  |  |
| 750 900 1,050 1,200 1,350 1,500 1,650 1,800 1,950 2,100 2,250 2,400 2,550 2,700 2,850 3,000 3,150 3,300 | $\begin{array}{r} 6 \times 8 \\ 6 \times 8 \\ 6 \times 8 \\ 6 \times 10 \\ 6 \times 10 \\ 8 \times 10 \\ 8 \times 10 \\ 8 \times 10 \\ 8 \times 12 \\ 8 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 14 \\ 10 \times 14 \\ 10 \times 14 \\ 12 \times 14 \end{array}$ | $\begin{array}{r} 6 \times 8 \\ 6 \times 8 \\ 6 \times 10 \\ 8 \times 10 \\ 8 \times 10 \\ 8 \times 10 \\ 8 \times 12 \\ 8 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 14 \\ 10 \times 14 \\ 10 \times 14 \\ 12 \times 14 \\ 12 \times 14 \\ 12 \times 14 \\ 12 \times 14 \end{array}$ | $\begin{array}{r} 6 \times 8 \\ 6 \times 8 \\ 8 \times 10 \\ 8 \times 10 \\ 8 \times 10 \\ 8 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 14 \\ 10 \times 14 \\ 10 \times 14 \\ 12 \times 14 \\ 12 \times 14 \\ 12 \times 14 \end{array}$ | $\begin{array}{r} 6 \times 10 \\ 6 \times 10 \\ 8 \times 10 \\ 8 \times 10 \\ 8 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 14 \\ 12 \times 14 \\ 12 \times 14 \\ 12 \times 14 \\ 12 \times 14 \end{array}$ | $\begin{array}{r} 6 \times 10 \\ 8 \times 10 \\ 8 \times 12 \\ 8 \times 12 \\ 10 \times 12 \\ 10 \times 12 \\ 10 \times 14 \\ 10 \times 14 \\ 12 \times 14 \\ 12 \times 14 \\ 12 \times 14 \end{array}$ |
| NOTES: <br> 1. The 6 -inch girder is figured as being made with three pieces 2 -inch dressed to $\mathbf{1} 3 / 4$-inch thickness. <br> 2. The 8 -inch girder is figured as being made with four pieces 2 -inch dressed to $\mathbf{1} 3 / 4$-inch thickness. <br> 3. The $\mathbf{1 0}$-inch girder is figured as being made with five pleces 2 -inch dressed to $\mathbf{1 3 / 4}$-inch thickness. <br> 4. The 12 -inch girder is figured as being made with six pieces 2 -inch dressed to $13 / 4$-inch thickness. <br> 5. For solid girders, multiply the above loads by $\mathbf{1 . 1 3 0}$ when a $\mathbf{6}$-inch girder is used; $\mathbf{1 . 1 5 0}$ when an 8 -inch girder is used; 1.170 when a 10 -inch girder is used; and $\mathbf{1 . 1 8 0}$ when a 12 -inch girder is used. |  |  |  |  |  |

1-5. Load Area. Both the foundation walls and the girder carry the load area of a building. Because the ends of each joist rest on the girder, there is more weight on the girder than on either of the wall.

Example 1. Before considering the load on the girder, consider the weight of a single joist. Suppose that a $10-\mathrm{ft}$ board weighing 5 pounds per foot is led by two men. If the men are at opposite ends of the plank, they would each be supporting 25 pounds (see Figure 10).


Figure 1-10. Example of weight on a single joist
Example 2. Now assume that one of these men lifts the end of another $10-\mathrm{ft}$ board with the same weight as the first one, and a third man lifts the opposite end. The two men on the outside are each supporting half the weight of one plank, or 25 pounds apiece, but the man in the center is supporting one half of each of the two boards, or a total of 50 pounds (see Figure 1-11).


Figure 1-11. Example of weight on a girder
The two men on the outside represent the foundation walls. The center man represents the girder. The girder carries half of the weigh and the other half is equally divided between the outside walls. However the girder may not always be located halfway between the outer walls.

Example 3. Imagine the same three men lifting two planks that weigh 5 pounds per foot. One of the planks is 8 feet long and the other is 12 feet long. The total length of these two planks is the same as before. The weight per foot is the same, so the total weight in both cases is 100 pounds.

One of the outside men is supporting half of the 8 -foot plank, or 20 pounds. The man on the opposite outside end is supporting half of the 12 -foot plank, or 30 pounds. The man in the center is supporting one half of each plank, or a total of 50 pounds. This is the same total weight he was lifting before. It is important to remember that a girder carries the weight of the floor on each side to the midpoint of the joists which rest upon it.

1-6. Floor Load. After the girder load area is known, the total floor load per square foot must be determined for safety purposes. Both dead and live loads must be considered.
a. Dead Load. A buildings structure weight is called the dead load. The dead load per square foot of floor area is carried directly or indirectly to the girder by bearing partitions. Dead load varies according to the method of construction and the building height. The structural parts included in the dead bad are--

- Floor joists for all floor levels.
- Flooring materials, including the attic if it is floored.
- Bearing partitions.
- Attic partitions.
- Attic joists for the top floor.
- Ceiling lath and plaster, including the basement ceiling if it is plastered.
b. Total Dead Load. For a building of light fame construction similar to an ordinary frame house, the dead-load allowance per square foot of all structural parts must be added together to determine the total dead load. The allowance for an average subfloor, finished floor, and joist without basement plaster should be 10 pounds per square foot. If the basement ceiling is plastered, an additional 10 pounds per square foot should be allowed. If the attic is unfloored, a load allowance of 20 pounds must be made for ceiling plaster and joists when girders or bearing partitions support the first-floor partition. If the attic is floored and used for storage, an additional 10 pounds per square foot should be allowed.
c. Live Load. The weight of furniture, persons, and other movable loads, not actually a par of the building but still carried by the girder, is called the live load. The live load per square foot will vary according to the use of the building and local weather conditions. Snow on the roof is considered part of the live load. The allowance for the live load on the floors used for living purposes is usually 30 pounds per square foot. If the attic is floored and used for light storage, an additional 20 pounds per square foot should be allowed. The allowance per square foot for live loads is usually governed by local building specifications and regulations.
d. Load Per Linear Foot. When the total load per square foot of floor area is known, the load per linear foot on the girder can easily be figured. Assume that the girder load area of the building shown in Figure 1-12 is sliced into 1 -foot lengths across the girder. Each slice represents the weight supported by 1 foot of the girder. If the slice is divided into 1 -foot units, each unit will represent 1 square foot of the total floor area. The load per linear foot of a girder is determined by multiplying the number of units, 12, by the total load per square foot, 70 pounds. This gives you 840 pounds per linear foot on the girder ( $12 \times 70=840$ pounds $)$. Now you can take the 840 pounds per load per linear foot of girder and use Table 1-1, page 1-6, to determine the girder size. If your number is not on the table, round up.


Figure 1-12. Girder load per linear foot
e. Total Floor Load. Note in Figure 1-12 that the girder is off center. Remember that half of the load is supported by the girder and half is supported by the foundation walls. Therefore, the joist length to be supported on one side of the girder is 7 feet (half of 14 feet), and the other side is 5 feet (half of 10 feet) for a total distance of 12 feet across the load area. Since each slice is 1 foot wide, it has a total floor area of 12 square feet. Assume that the total floor load for each square foot is 70 pounds. Multiply the length times the width ( 7 feet x 12 feet) to get the total square feet supported by the girder ( 7 feet x 12 feet $=84$ square feet).

1-7. Girder Material. Wooden girders are more common than steel girders in small frame buildings. Solid timbers may be used, or girders may be built up by using two or more 2 -inch planks. Built-up girders warp less easily than solid wooden girders and are less likely to decay in the center.
a. Choice of Material. Regardless of whether the girder is built-up or solid, it should be of well-seasoned material. For a specific total girder load and span, the size of the girder will vary according to the kinds of wood used, since some woods are stronger than others.
b. Use of Nails. When built-up girders are used, the pieces should be securely nailed together to prevent individual bucking. A two-piece girder of 2-inch lumber should be nailed on both sides with 16d common nails. The nails should be located near the bottom, spaced approximately 2 feet apart near the ends and 1 foot apart in the center. A three-piece girder should be nailed in the same way. The nailing pattern should be square across the end of the board ( $11 / 2$ inches from each end) and then diagonal every 16 inches.

1-8. Girder Splices. To make a built-up girder, select straight lumber free from knots and other defects. The stock should be long enough so that no more than one joint will occur over the span between footings. The joints in the beam should be staggered, taking care to square the planks at each joint and butt them tightly together.
a. Half-Lap Joint Sometimes a half-lap joint is used to join solid beams. In this case, place the beam on one edge so the annual rings run from top to bottom, The lines for the half-lap joint are then laid out (see Figure 1-13). Cuts are made along these lines, then checked with a steel square to assure a matching joint. Repeat this process on the other beam.


Figure 1-13. Girder splices
b. Temporary Strap. Tack a temporary strap across the joint to hold it tightly together. Drill a hole the joint with a bit about $1 / 16$ inch larger than the bolt to be used, and fasten the joint with a bolt, a washer, and a nut.
c. Strapped Joint. When a strapped butt joint is used to join solid beams, the ends of the beams should be cut square. The straps, which are generally 18 inches long, are bolted to each side of the beams.

1-9. Girder Supports. When small houses are built without an architect, the carpenter must know the principles that determine the proper size of girder supports.
a. Columns. A vertical member, designed to carry the live and dead loads placed upon it is called a column or a post. It can be made of wood, metal, or masonry. Wooden columns may be solid timbers or several wooden members nailed together with 16 d or 20 d common nails. Metal columns are made of heavy pipe, large steel angles, or I-beams.
b. Column Spacing. A good arrangement of the girder and supporting columns for a 24 -foot by 40 -foot building is shown in Figure 1-14. Column B will support one half of the girder load existing in the part the building lying between wall A and column C . Column C will support half of the girder load between columns B and D. Likewise, column D will share the girder loads equally with column C and wall E.


Figure 1-14. Girder and column spacing
NOTE: When locating columns which must support girders, avoid spans of more than 10 feet between columns. The farther apart columns are spaced, the heavier the girder must be to carry the joist over the span between the columns.
c. Bearing Plates and Footings. Regardless of the material used in a column, it must have some form of a bearing plate at the top and bottom. These plates distribute the load evenly across the column. Basement posts that support girders should be set on masonry footings. Columns should be securely fastened at the top to the load-bearing member and at the bottom to the footing on which they rest.
d. Column Fastening. Figure 1-15 shows a solid wooden column with a metal bearing cap drilled so that it can be fastened to the column and to the girder. The bottom of this type of column may be fastened to the masonry footings by a metal dowel. The dowel should be inserted in a hole drilled in the bottom of the column and in the masonry footing. The base is coated with asphalt at the drilling point to prevent rust or rot.


Figure 1-15. Girder and column fastening

1-10. Floor Joists. Joists are wooden members, usually 2 or 3 inches thick, that make up the body of the floor frame. The flooring or subflooring is nailed to them.
a. Joist Loads. Joists usually carry a uniform load of materials and personnel. These are live loads. The weight of joists and floor is a dead load. Joists are spaced 16 or 24 inches on the center. Sometimes the spacing is 12 inches, but where such spacing is made necessary by the load, heavier joists should be used. In certain parts of the floor frame, to support heavily concentrated loads or a partition wall, it may be necessary to double the joists or to place two joists together (see Figure 1-16).


Figure 1-16. Reinforced joists
b. Joists and Sills. When joining joists to sills, be sure that the connection can hold the load that the jolt will carry. A joist resting on the sill and girder is shown in Figure 1-17. This connection method is most commonly used because it provides the strongest possible joint. The method shown in Figure 1-18, page 1-14, a joist with ledger plates is used when it is not desirable to use joists on top of the sill. The ledger plate should be securely nailed to the sill and girder. If the joist must be notched, it should be securely nailed to the sill and girder. If the joist must be notched, it should not be notched over one third of its depth (to prevent splitting). Joists must be level when framed to girders. If the joist is not the same height as the girder, the joist must be notched (see Figure 1-19, page 1-14).


Figure 1-17. Joist resting on sill


Figure 1-18. Joist with ledger plates


Figure 1-19. Joist connected
to a girder
c. Joist Hangers. When it is desirable to have the joists and girders flush, the ends of the joists can be supported by joist hangers (see Figure 1-20). Joist hangers support joists at the girders. When joists are hung using joist hangers, the maximum headroom is obtained below the girder.


Figure 1-20. Joist hangers

1-11. Bridging. When the joists are used over a long span, they tend to sway from side to side. Therefore, bridging is installed. Floor frames are bridged for stiffening and to prevent unequal deflection of the joists. Bridging enables an overloaded joist to receive some help from the joist on either side of it. A pattern for the bridging stock is obtained by placing a piece of material between the joist, then marking and sawing it. There are three types of bridging: solid, cross, and compression.
a. Solid. To provide maximum rigidity to the joist, use solid bridging. The bridging is offset to permit end nailing where posible (see Figure 1-21).


Figure 1-21. Solid bridging
b. Cross. Wood-cross bridging is used most often. It is cut to ft diagonally between joists (see Figure 1-22). Each piece is nailed to the top of each joist before the subfloor is placed. The bottoms are left free until the subfloor is laid. This permits the joists to adjust themselves to their final positions and keeps the bridging from pushing up the joists and causing an uneven floor.


Figure 1-22. Cross bridging
c. Compression. Use hammer blows to install compression bridging. Where the bridging is drilled, it is nailed in place (see Figure 1-23).


Figure 1-23. Installation of cross bridging

## PART B - SUBFLOORING

1-12. Plywood Subflooring. After the foundation and basic framework for the floor are completed, the subtler can be installed. Material for constructing the subfloor can be either 1-inch or 2-inch material. Plywood is very satisfactory for subflooring because of the large sheets which can be installed rapidly. The thicknesses required are $1 / 2-, 5 / 8$-, or $3 / 4$-inch, depending on the joist spacing and the floor load requirement.

- Lay sheets with the face grain at a right angle to the joist when installing plywood.
- Lay the sheets so that the joists are placed over the joists.
- Arrange plywood so that the joints for the complete floor are staggered (see Figure 1-24).
- Glue and nail the plywood in place.


Figure 1-24. Plywood subflooring

1-13. Diagonal Subflooring. Lay diagonal subflooring on the joist framework and nail it in place (See Figure 1-25, page 1-18). Subfloor material can be either 1-inch or 2 -inch material.

- Lay the subfloor before the walls are framed.
- Square the ends of the boards before nailing when laying the flooring.
- Place the ends of the boards before nailing when laying the flooring.
- Use at least three nails per joist for boards 8 inches wide or more.


Figure 1-25. Diagonal subflooring

## PART C - FINISH FLOORING

1-14. Prepare to Lay a Floor. The finish flooring should be delivered to the job site in sufficient time to allow the carpenter to lay out the floor. This allows the flooring to adjust to the moisture and temperature conditions in the building. Fifteen-pound asphalt felt should be placed over the subfloor before installing the finish flooring. Before laying the floor, check the floor plans to determine which of the rooms is the largest and what its relationship is to the other rooms. If laying strip flooring, see if the flooring will extend from the largest room into the next room. If so, lay the flooring in the longest direction. Check the walls of the largest room to see if the opposite walls are parallel to each other. Snap a chalk line parallel along the longest wall to establish a straight line (called a baseline). This line should extend into the next room so the strip flooring will be continuous.

1-15. Lay the Floor. The following guidelines should be used when laying a floor:
a. Select a long straight piece of flooring for the first board. Place this piece of flooring in position with the grooved edge toward the wall (see Figure 1-26). Allow approximately $1 / 4$ inch along the wall for expansion.


Figure 1-26. Floor plan
b. Face nail the board at A with a finish nail, but do not drive the nail home.
c. Measure the distance X from the face of the fist board to the chalk line L .
d. Transfer this distance to Y and set a nail at B . Now board 1 is parallel to the chalk line L and to the longest wall in the largest room.
e. Use a straightedge to ensure that board 1 is straight. Then face nail the board every 12 inches. Nail as close to the wall as possible.
f. Continue to cut, fit, and nail the flooring until the board marked 2 has been reached.
g. Make sure the board joints are staggered (see Figure 1-27, page 1-20).
h. Blind nail the rest of the tongue-and-groove flooring through the tongue at about 50 degrees to the floor. To draw up the tongue-and-groove flooring for nailing, use a short piece of tongue-andgroove lumber as a straightedge and a hammer to drive the flooring up tight (see Figure 1-28, page 120).


Figure 1-27. Staggered board joints


Figure 1-28. Blind nailing
i. Stand on the board to be nailed when nailing the floor in place. This holds the strips of flooring in place (see Figure 1-29).


Figure 1-29. Nailing floor in place
j. Look at baseline L in Figure 1-30. When the finished floor has been laid up to line 2, the starter board 3 in the largest room should be laid. The front edge of this board should be the same distance from the chalk line L as the front edge of board 2. This ensures that the boards will come out evenly at the door opening, where the flooring passes from room 1 to room 2.


Figure 1-30. Floor plan
k. Continue laying the floor until you are within two or three boards from the opposite wall.

1. Now, cut the last few boards, open up the groove in the boards, place them in position, draw them tightly together, and surface nail them in place.

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## LESSON 1

## PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. When you have completed the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part which contains the portion involved.

1. Which part of the floor system for a frame building rests directly on the masonry foundation?
A. Sills
B. Joists
C. Solid bridging
D. Pier plates
2. What are the three types of sills used to construct a floor system?
A. Built-up, T, and girders
B. T, built-up, and box
C. Box, T, and plate
D. Plate, edge, and T
3. The load area of a building is carried by both the foundation and the--
A. Joists
B. Partitions
C. Joist hangers
D. Girder
4. Suppose you must increase the girder load capacity to four times greater than the existing girder (which is 3 inches wide and 6 inches deep). What size girder (in inches) would you install?
A. $3 \times 8$
B. $3 \times 10$
C. $3 \times 12$
D. $6 \times 12$
5. Refer to Table 1-1, page 1-6. You are required to determine the girder size for a specific building. There are 14 units of floor area, and the total load per square foot is 80 pounds. What size girder (in inches) is required?
A. $6 \times 8$
B. $6 \times 10$
C. $8 \times 10$
D. $8 \times 12$
6. You know that floor joists are wooden members that make up the body of the floor frame and sometimes must be doubled. Why is it necessary to double a floor joist?
A. Because heavily concentrated loads must be supported.
B. Because of the defective lumber you have to work with.
C. Because of the extra long spans between foundation walls.
D. Because of a weak floor.
7. What is the strongest method for installing floor joists?
A. Joists resting upon sills and girders
B. Joists installed with ledger boards
C. Joists installed using metal hangers
D. Joists installed with metal hangers and 16d nails
8. Why is bridging used when constructing the floor system?
A. To strengthen the weak parts of the subfloor.
B. To allow equal weight to be distributed across the girder.
C. To stiffen the floor frame.
D. To add strength to the joist hangers.
9. How is cross bridging installed in a floor system?
A. The top of the cross bridging is nailed to the top of the floor joist before the subfloor is installed. The bottom of the bridging is nailed in place after the subfloor is installed.
B. The bottom of the cross bridging is nailed to the floor joists. Next, the top of the bridging is nailed to the top of the floor joists, then the subfloor is installed.
C. The subfloor is installed. Next, the bridging is measured, marked, cut, and nailed in place from beneath the floor.
D. Before the subfloor is installed, the top and bottom of the bridging is installed.
10. When installing a plywood subfloor, what must you do to the floor end joints?
A. Line them up
B. Center them
C. Sand them smooth
D. Stagger them

## LESSON 1

## PRACTICE EXERCISE

## ANSWER KEY AND FEEDBACK

Item

1. A
2. B T, built-up, and box

Box Sills. (page 1-1, para 1-la); T-Sills. (page 1-2, para 1-1b);
Built-Up Sills. (page 1-3, para 1-1c)
3. D Girder

Both the foundation walls and ... (page 1-7, para 1-5)
4. $\mathrm{C} \quad 3 \times 12$

Table 1-1 (page 1-6, para 1-4)
5. C $8 \times 10$

Table 1-1 (page 1-6, para 1-4)
6. A Because heavily concentrated loads must be supported.

In certain parts . . . (page 1-12, para 1-10a)
7. A Joists resting upon sills and girders.

A joist resting . . (page 1-13, para 1-10b)
8. C To stiffen the floor frame

Floor frames are bridged . . . (page 1-15, para 1-11)
9. A The top of the cross bridging is nailed to the top of the floor joist before the subfloor is installed. The bottom of the bridging is nailed in place after the subfloor is installed. Each piece is nailed $\ldots$ (page $1-15$, para $1-11 b$ )
10. D Stagger them

Arrange plywood . . . (page 1-16, para 1-12)

## LESSON 2

# WALL-SYSTEM AND STAIRWAY CONSTRUCTION 

Critical Tasks: 051-236-1142
051-236-1143
051-236-2109

## OVERVIEW

## LESSON DESCRIPTION:

At the end of this lesson, you will be able to describe the construction of walls and stairs and the installation of doors and windows.

## TERMINAL LEARNING OBJECTIVE:

ACTION: You will describe how to construct a frame wall and how to install doors and windows.

CONDITION: You will be given the material contained in this lesson.
STANDARD: You will correctly answer the practice exercise questions at the end of this lesson.
REFERENCES: The material contained in this lesson was derived from FM 5-426.

## INTRODUCTION

The primary objective of good construction is to erect a building that is structurally sound. The structure should withstand such forces as wind and vertical loads.

## PART A - FRAMING MEMBERS

Wall framing consists of studs, plates, braces, cripples, trimmers, headers, and fire blocks. It is supported by the floor system. Prefabricate the members of the frame wall on the floor of the building. Then raise the members into position and brace, nail, or bolt them in place.

2-1. Studs. Studs are closely spaced vertical members that support the weight of the upper floors. They provide a framework for exterior and interior finishes. Main studs can be spaced at 12, 16, or 24 inches on center. Lay out studs by measuring from one corner the distance the studs are to be spaced. Make a tick mark on the plate at the proper measurement (see Figure 2-1). After the window and door openings are determined, the studs are paced and nailed through the existing plates with 16d or 20d nails.


Figure 2-1. Tick marks on the plate
To gain the proper location and width of window and door openings you will need additional studs. Fasten the new studs to the plates in the same way as the previously installed studs. The new studs are not framed at 12, 16, or 24 inches on center (see Figure 2-2).

2-2. Plates. There are two types of plates--top and bottom (sole). The plates are laid out so the competed frame wall can be lifted easily and directly into place with the least amount of movement of the wall.
a. Top Plates. A horizontal member of a partition or frame wall is called a top plate. It serves as a cap for the studs and a support for the joist, rafters, and studs. Top plates tie the studs together at the top and ensure that the studs are aligned. They provide support for structural members above the plates and also provide a base for the roof rafters which tie the roof and walls together. To be effective, top plates should be doubled at the top of the walls and partitions and should have their joints staggered. (Double top plats are discussed in paragraph 2-9, page 2-12.)


Figure 2-2. Placement of other studs
b. Sole Plates. Use a sole plate (with dimensions not less than the studs) where the walls do not rest on a sill, girder, or beam. Install the studs or corner posts at intervals that are evenly spaced except where partitions or walls are intersected.

2-3. Door and Window Openings. When framing door openings, it is desirable to double the studs. Cut short studs or trimmers the size of the opening and nail them to the inside face of the new studs (see Figure 2-3).


Figure 2-3. Frame for a door opening
a. Headers. Use 2 by 4 or 2 by 6 lumber to make a header. Double the header when this size of lumber is used. The size and the amount of lumber to be used in a header is determined by the width of the opening and the bearing load.
b. Subsill. When making a window opening, install a header over the window in the same way you would install a header over the door. A subsill must be framed between the trimmers and the cripples. The subsill can be either single or double. When doubled, nail the bottom piece to the outside studs at the proper height. Then nail the top piece of the sill to the bottom section (see Figure 2-4).


Figure 2-4. Frame for window opening
c. Cripples. Place the cripple or jack studs under and over the window and over door openings (see Figure 2-5). Cripples are placed at the same intervals as the ordinary studs and are installed after the openings are framed. These serve the same purpose as studs in the rest of the wall.

2-4. Bracing. Bracing is used to stiffen framed construction and make it rigid. Bracing is also used to resist winds, storms, twists, or strains. Good bracing keeps corners square and plumb. Bracing prevents warping, sagging, and shifting that could otherwise distort the frame and cause badly fitting doors and windows. The three methods commonly used to brace frame structures are let-in, cut-in, and diagonal-sheathing bracings. In some cases, temporary bracing may be used instead.


Figure 2-5. Cripples
a. Let-In Bracing. Let-in bracing is set into the edges of studs, flush with the surface. The studs are always cut to let in the braces; the braces are never cut (see Figure 2-6).


Figure 2-6. Let-in bracing
b. Cut-In Bracing. Cut-in bracing is toenailed between studs. They are inserted in diagonal progression between studs running up and down from corner posts to the sole plate, top plate, or sills (see Figure 2-7).


Figure 2-7. Cut-in bracing
c. Diagonal-Sheathing Bracing. The strongest type of bracing is diagonal sheathing (see Figure 2-8). Each board braces the wall. If plywood sheathing $5 / 8$ inch thick or more is used, other methods of bracing may be omitted.


Figure 2-8. Sheathing used as diagonal bracing
d. Temporary Bracing. Temporary bracing is placed at intervals small enough to hold the wall straight (see Figure 2-9). Bracing placed diagonally on the studs running from the sole plate to the top plate will increase the strength of the wall against horizontal stress (se Figure 2-10).


Figure 2-9. Temporary bracing


Figure 2-10. Temporary diagonal bracing

2-5. Fire Blocks. Fire blocks are short pieces of 2 by 4 s cut to fit snugly between the studs. They are placed midway up the wall, between the studs to prevent the spread of fire inside the wall. The use of fire blocks will differ according to local building codes. Figure 2-11 shows the proper placement of fire blocks.


Figure 2-11. Fire block placement
2-6. Post Construction. Where partitions meet other walls and at the corners, the studs are built-up using three or more regular 2 by 4 s to provide greater strength. Corner posts and T-posts are the most frequently used.
a. Corner Post. A corner post forms an inside corner and an outside corner, which provides a good nailing base for inside wall coverings. The studs used at the corners of fame construction are usually built up from three or more ordinary studs to provide greater strength. These built-up assemblies are called corner posts. They are set up, plumbed, and temporarily braced. Corner post may also be made in any of the following ways (see Figure 2-12).

- A 4 by 6 with a 2 by 4 nailed on the board side flush with one edge (see Figure 2-12, A). This type of corner is for a 4 -inch wall. Where walls are thicker, heavier timber is used.
- A 4 by 4 with a 2 by 4 nailed to each of two adjoining ides (see Figure 2-12, B).
- Two 2 by 4 s nailed together with blocks between them and a 2 by 4 flush with one edge (see Figure 2-12, C). This is the most common method.
- A 2 by 4 nailed to the edge of another 2 by 4 , the edge of one flush with the side of the other (see Figure $2-12, \mathrm{D}$ ). This type is used extensively in the theater of operations, where no inside finish is needed.


Figure 2-12. Corner-post construction using both 2-inch and 4-inch lumber
b. T-Posts. Whenever a partition meets another wall, a stud wide enough to extend beyond the partition on both sides is used. This provides a solid nailing base for the inside wall finish. This type of stud is called a $T$-post and is made in any of the following ways (see Figure 2-13, page 2-10):

- A 2 by 4 may be nailed and centered on the face side of a 4 by 6 (see Figure 2-13, A).
- A 2 by 4 may be nailed and centered on two 4 by 4 s nailed together (see Figure 2-13, B).
- Two 2 by 4 s may be nailed together with a block between them and a 2 by 4 centered on the wide side (see Figure 2-13, C).
- A 2 by 4 may be nailed and centered on the face side of a 2 by 6 , with a horizontal bridging nailed behind them to give support and stiffness (see Figure 2-13, D).

2-7. Plumbing Posts. There are two methods for plumbing posts.
a. Method 1. To plumb a corner with a plumb bob--
(1) Attach a string to the bob. The string should be long enough to extend to or below the bottom of the post.
(2) Lay a rule on top of the post so that 2 inches of the rule extend over the post on the side to be plumbed.


Figure 2-13. T-post construction
(3) Hang the bob line over the rule so that the line is 2 inches from the post and extends to the bottom of it. Refer to Figure 2-14.
(4) With another rule, measure the distance from the post to the center of the line at the bottom of the post. If it does not measure 2 inches, the post is not plumb.
(5) Move the post inward or outward until the distance from the post to the center of the line is exactly 2 inches, then nail the temporary brace in place.
(6) Repeat this procedure from the other outside face of the post. The post is then plumb.

NOTE: Follow this process for each corner post of the building. If a plumb bob or level is not available, use a rock, half-brick, or small piece of metal.
b. Method 2. An alternate method of plumbing a post is shown in the inset in Figure 2-14. To use this method--
(1) Attach the plumb-bob string securely to the top of the post to be plumbed. Be sure that the string is long enough to allow the plumb bob to hang near the bottom of the post.
(2) Use two blocks of wood, identical in thickness, as gauge blocks.
(3) Tack one block near the top of the post between the plumb-bob string and the post (guard block 1).
(4) Insert the second block between the plumb-bob string and the bottom of the post (gauge block 2).
(5) If the entire face of the second block makes contact with the string, the post is plumb.


Figure 2-14. Plumbing a post
2-8. Bridging The term bridging is used to refer to a system for bracing joists and studs. Frame walls are bridged in most cases, to make them more sturdy. Two types of bridging are diagonal and horizontal.
a. Diagonal Bridging. Diagonal bridging is nailed at an angle between the studs (see Figure 215, page 2-12). It is more effective than the horizontal type because it forms a continuous truss and keeps the wall from sagging. Whenever possible, both interior partitions and exterior walls should be bridged alike.
b. Horizontal Bridging. Horizontal bridging is nailed between the studs horizontally and halfway between the sole and top plates. This type of bridging is cut to fit between the studs. The measurements should be taken at the sole plate in case the studs are warped. Such bridging not only stiffens the wall but also helps to straighten the studs. Notice that the bridging is staggered in Figure 216, page 2-12.


Figure 2-15. Diagonal bridging


Figure 2-16. Horizontal bridging

2-9. Double Top Plates. After the frame walls are assembled and set in place, they must be tied together. Use a double top plate to interlock exterior walls at the comer and load-beading partition walls. Overlap the double top plates at the corners (see Figure 2-17). Tie load-bearing partition walls into the exterior walls
by leaving an opening in the top plate of the outside wall. This allows the double top plate to Et into place. Or cut out a piece of the double top plate to allow the overlap to fit (see Figure 2-18).


Figure 2-17. Lapped at the corner


Figure 2-18. Lapped at the partition wall

2-10 Hasty Wall Construction. Hasty wall construction is used frequently in the theater of operations. This type of construction uses less material and requires less time. The panels used most are end wall and sidewall.
a. End-Wall Panels. The walls at the end of the building have studs that extend to the rafters and do not require a top plate (see Figure 2-19).


Figure 2-19. End-wall panels
b. Sidewall Panels. Place studs from 2 to 10 feet apart, with girts placed horizontally between the studs to construct sidewalls (see Figure 2-20). Vertical siding is normally used in this type of construction.


Figure 2-20. Sidewall panels

## PART B - WALL SHEATHING

After completing the framework of a building, fasten a covering, known as sheathing, to it. Sheathing includes exterior wall sheathing, finish siding, and interior wall sheathing.

2-11. Exterior Wall Sheathing. Sheathing is nailed directly onto the framework of the building. It is used to strengthen the building; provide a base wall to which finish siding can be nailed; act as insulation; and, in some cases, be a base for further insulation. Some common types of sheathing include wood, gypsum board, and plywood.
a. Wood Sheathing. Wood sheathing may be nailed on horizontally or diagonally (see Figure 2-21) however, diagonal application adds much greater strength to the structure. If the sheathing is to be put on horizontally, start at the foundation and work toward the top. If it is to be put on diagonally, start at the corner of the building and work toward the opposite wall.
b. Gypsum Board. The long edges of the 4 by 8 boards are tongue-and-grooved. Gypsum board can be nailed (together with the wood siding) directly to the studs. Gypsum sheathing is fireproof, water resistant, and windproof. It does not warp or absorb water and does not require the use of building paper (see Figure 2-22).


Figure 2-21. Wood sheathing


Figure 2-22. Gypsum board sheathing
c. Plywood. Plywood is highly recommended for wall sheathing because of its weight, strength, and structural properties. Plywood is most commonly used because it adds a lot more strength to the frame than using diagonally applied wood boards. It comes in 4-feet-wide and 5 - to 8 -feet-long sheets, $1 / 4$ to $3 / 4$-inch thick. Install the sheets with the face grain parallel to the studs (see Figure 2-23, page 2-16). It is usually applied vertically from the floor to the ceiling. When plywood is correctly applied (with flush joints), the joints do not need to be concealed. However, to improve wall appearance, joints may be covered with moldings. These may be battens fastened over the joints or applied as splines between the panels. Less-expensive plywood can be covered with paint or covered in the same way as plastered surfaces. Figure 2-24, page 2-16, shows how to fit plywood on rough or uneven walls.


Figure 2-23. Plywood sheathing


Figure 2-24. Fitting wall panels to uneven wails

2-12. Finish Siding. Finish siding is the outside wood finish of the wall. Only board siding made of long, narrow boards will be covered in this section.
a. Vertical Wood Siding. Vertical wood siding is nailed securely to girts with 8 d or 10 d nails. The cracks are covered with wood strips called battens. To make this type of wall more weatherproof some type of tar paper or light-roll roofing may be applied between the siding and the sheathing. (See Figure 2-25.)


Figure 2-25. Vertical wood siding
b. Horizontal Wood Siding. Horizontal wood siding is cut to various patterns and sizes to be used as the finished outside surface of a structure (see Figure 2-26). It should be well-seasoned lumber. Siding is made in sizes ranging from $1 / 2$ inch to 1 inch by 12 inches. Two types of siding are beveled and drop.


Figure 2-26. Horizontal wood siding
(1) Beveled Siding. Beveled siding is made with beveled boards, thin at the top edge and thick at the butt (see Figure 2-27). It is the most common form of wood siding It comes in 1 inch for narrow widths and 2 inches and over for wide types. It is nailed to solid sheathing, over which building paper has been attached.


Figure 2-27. Beveled siding
(2) Drop Siding. Drop siding is used as a combination of sheathing and siding or with separate sheathing. It comes in a wide variety of face finishes and is either shiplapped or tongue-andgrooved (see Figure 2-28). When sheathing is not used, the door and window casings are set after the siding is up. If sheathing is used and then building paper is added, drop siding is applied with beveled siding, after the window and door casings are in place.


Figure 2-28. Drop siding

2-13. Sheetrock Tools. The following are tools used in the application of sheetrock:
a. The sheetrock hammer is used for hammering nails.
b. The sheetrock carrier (lifter) is used for carrying and lifting sheetrock.
c. Sheetrock knives are used to apply and finish joint compound. The 4-inch knife is used to bed the tape in the first layer of joint compound and for filling the dimples, the 6-inch knife is used for feathering out the second coat, and the 12 -inch knife is used for the third/finish coat.
d. The corner trowel flexes from $90^{\circ}$ to $103^{\circ}$. It is used to apply joint compound in interior corners.
e. The mud pan is used to hold and carry joint compound.
f. The corner-bead crimper is used to fasten the comer bead by crimping.
g. The T-square is used to lay out and guide a $90^{\circ}$ cut on sheetrock.
h. The utility knife is used to score or cut the sheetrock (see Figure 2-29).


Figure 2-29. Cutting sheetrock
i. The keyhole saw is used for cutting irregular shapes and openings (such as outlet-box openings).
j. Surform is used to smooth sheetrock edges after cutting.
k. The tape banjo is used to apply tape (dry) or joint compound and tape (wet).

1. Sandpaper and sponges are used for feathering or smoothing dried joint compound.
m. A chalk line is used to facilitate layout.
n. A 16 -foot measuring tape is used for measuring the sheetrock.
o. A 4-foot hand level is used to plumb.
p. Sawhorses are used for placing sheetrock on to make cut.

2-14. Interior Wail Coverings. Interior wall coverings are divided into two general types: wet wall material (such as plaster) and drywall material (including wood, sheetrock, plywood, and fiberboard). Only drywall will be covered in this subcourse.
a. Drywall. Sheetrock, fiberboard, and plywood usually comes in 4-foot-wide and 5- to 8-footlong sheets, $1 / 4$ to $3 / 4$ inch thick. Drywall is applied in either single or double thicknesses with panels placed as shown in Figure 2-30. When covering both walls and ceilings, always start with the ceilings. Use annular ringed nails when applying finished-joint drywall to reduce nail pops.


Figure 2-30. Drywall placement
b. Drywall (Sheetrock) Installation. The three steps to installing sheetrock are hanging, finishing, and patching.
(1) Hanging Sheetrock. Apply sheetrock as follows:

- Install sheetrock on the ceiling first. Measure the distance from the inside edge of the top plate to the outside edge of the second ceiling joist. Measure and cut a piece 48 inches long to the width measured above. Install and secure the sheet to the ceiling with sheetrock nails. Nail spacing on ceilings is 5 to 7 inches on center.
- Determine the starting point of the wall. Using a measuring tape, locate a section where the studs are 8 foot on center and where a full sheet could be laid horizontally. Check the layout to ensure that there will be no joints above or below the door or window openings. Sheets will be installed from the ceiling down to the floor, starting at the ceiling.
- Install the first sheet. With the help of another person, place a sheet of sheetrock in position so that the edges fall on the center of the studs. Place the sheet snug against the ceiling, using a hand level to ensure that it is level. Secure the sheet with sheetrock nails 6 to 8 inches on center, $3 / 8$ inch from the edge. Install succeeding sheets on the top half of the wall against installed sheets, ensuring that joints fall on the center of the studs and that proper nail spacing is maintained. Using a utility knife or sheetrock saw, cut out openings for doors and windows.
- Lay out the receptacles. Measure the distances from an inside corner to both sides of the receptacle box and record them. Measure the distance from the installed sheetrock to the top and bottom of the receptacle box, and record it. Measure and mark these dimensions for the receptacle cutout, allowing $1 / 16$-inch clearance all around.
- Cut out the opening for the receptacle. With a utility knife, drive a hole within the opening. Using a keyhole saw, cut out the opening. Use a slight undercut bevel so that the back opening is larger than the front opening.
- Install the prepared sheet. Place the prepared sheet in position, ensuring that the receptacle fits in the opening without breaking the paper. Make adjustments to the opening if necessary. Secure the sheet to the studs with sheetrock nails. Using a Surform, smooth the rough edges of the openings as necessary.
- Lay out and cut sheets for corner posts. Measure and cut the required number and sizes of sheets to cover corner posts. Use scrap pieces of material if needed.
- Install the corner bead. Using a corner-bead crimper, install the corner bead on the exterior corners of corner posts. Use nails if necessary.
(2) Finishing Sheetrock The finishing process consists of covering nailheads and covering seams (covering seams is also referred to as finishing joints). Finish sheetrock as follows:
- Check for improperly recessed nails by running the edge of a sheetrock knife over the nailheads. A clicking sound indicates a nail needing to be recessed.
- Use a 4-inch knife and mud pan with joint compound to apply a smooth coat of joint compound over the nails. Remove any excess compound.
- Use the knife and mud pan to apply a heavy coat of joint compound over a sheetrock joint, horizontal or vertical. A heavy coat is enough to ensure a good bond between the tape and sheetrock and to fill in tapered edges. Measure and cut the tape to the length required for a joint (see Figure 2-31). Keeping the tape centered over the joint, start at one end of the joint and work toward the opposite end. Using the knife, press the tape into the compound, removing all excess compound. Work off all excess joint compound, being careful not to wrinkle the tape or leave air bubbles. Continue to tape all the joints in the same manner.


Figure 2-31. Covering joints

- Use a 4-inch knife to apply a heavy coat of joint compound over the sheetrock at the inside corner (see Figure 2-32). Measure and cut the tape to the length required for the joint. Fold the tape in half lengthwise, keeping both edges even. Use a corner tape creaser if necessary. Apply the tape at the top and work downward, running the edge of your hand at the center of the tape to ensure that it is in the corner. Using the inside corner tool, press the tape into the compound, working off all excess compound and being careful not to wrinkle the tape or leave air bubbles.


Figure 2-32. Applying tape at corners

- Apply the first coat of joint compound over the tape then apply a medium coat of joint compound. Feather the compound with the 6 -inch knife to about 2 to 3 inches on each side of the joint. A good job of feathering and smoothing will minimize sanding later.
- Apply the second coat of joint compound over the tape and nail coverings. The joint compound previously applied must be completely dry. Use the 4 -inch knife to apply a thin coat of compound over the nails, removing any excess compound. Using the steps above, apply the second coating to the joints using the 6 -inch knife and feathering out 6 to 8 inches on each side of the joint.
- Apply the third coat of joint compound (see Figure 2-33, page 2-24). The joint compound previously applied must be completely dry. Using the step above, apply the third coat using the 10 -inch knife and feathering out 10 to 12 inches on each side of the joint. Nails should not require a third coat, but it may be applied if necessary.
- Using a damp sponge or fine sandpaper, sand the surface to a smooth finish, ensuring that there are no voids and that the surface is ready to receive paint.


Figure 2-33. Finishing the joints
(3) Patching Sheetrock. There are several different methods of patching sheetrock, depending on the size of the hole.

- For small holes, apply fiber-mesh tape directly over the hole. Cut the tape with joint compound and feather the edges. Sand or sponge the area smooth after it has dried.
- For fist-size holes, cut out a rectangle around the hole with a keyhole saw. Cut a piece of backing ( 1 by 2 or 1 by 3 ) slightly larger than the opening itself. Glue or screw the backing into place. Cut a patch and glue it to the backing using either wallboard adhesive or mastic. Apply tape and coat it with compound. Feather the edges. Sand or sponge the area smooth after it has dried.
- For large holes, mark and cut a rectangular section around the damaged area, reaching from the centers of the nearest studs. Cut a patch and screw or nail it to the studs. Apply tape and coat it with compound. Feather the edges. Sand or sponge the area smooth after it has dried.


## PART C - MOLDINGS

The different trims of a building, which have a definite architectural relationship to the design of the building, are called moldings.

2-15. Base Moldings. The interior trim of a building should match or complement the design of the doors, the windows, and the building. Base molding is the trim between the finished wall and the floor. It is available in several widths and forms. Two-piece base consists of a baseboard topped with a small base cap (see Figure 2-34). The common size for this type baseboard is 1 by 4 inches or wider. Onepiece baseboard varies in size from $1 / 2$ by 3 inches to 1 by 4 inches and wider (see Figure 2-35). Although a wood member is desirable at the junction of the wall and carpeting to serve as a protective bumper, wood trim is sometimes eliminated entirely.


Figure 2-34. Two-piece baseboard


Figure 2-35. One-piece baseboard
a. Square-edged (or two-piece) baseboard consists of a square-edged baseboard topped with a small base cap. When the wall covering is not straight and true, small base molding will conform more closely to the variations than will a one-piece base alone. This type of baseboard is usually $5 / 8$ by $31 / 4$ inches or wider. Install square-edged baseboard with a butt-joint at the inside corners and a mitered joint at the outside corners (see Figure 2-36, page 2-26).


Figure 2-36. Square-edged baseboard
b. Narrow- and wide-ranch base (one-piece baseboard) are $3 / 4$ by $31 / 4$ inches or wider and vary from $1 / 2$ by $21 / 4$ inches to $1 / 2$ by $31 / 4$ inches or wider.
c. A wood member at the junction of the wall and carpeting serves as a protective bumper; however, wood trim is sometimes eliminated. Most baseboards are finished with a $1 / 2$ - by $3 / 4-$ inch base shoe. A single-base molding without the shoe is sometimes placed at the wall-floor junction, especially where carpeting might be used.
d. Baseboard should be installed with a butt joint at the inside corners and a mitered joint at the outside corners. It should be nailed to each stud with two 8d finishing nails. Base molding should have a coped joint at inside corners and a mitered joint at outside corners. A coped joint is one in which the first piece is square cut against the plaster or base and the second molding is coped. This is done by sawing a $45^{\circ}$ miter along the inner line of the miter. The base shoe should be nailed into the subfloor with long, slender nails, but not into the baseboard itself. Then, if there is a small amount of movement in the floor, no opening will occur under the shoe. When several pieces of molding are needed, they should be joined with a lap miter. When the face of the base shoe projects beyond the face of the molding, it abuts.

## PART D - STAIRS

The most critical factor in stair design is the relationship between the rise (riser) and run (tread). A unit rise of 7 inches to $75 / 8$ inches high with an appropriate tread will combine both comfort and safety. Although you will often find service
stairs steeper, the riser should not exceed 8 inches. To make the stairs steeper, increase the rise and shorten the run (see Figure 2-37).


Figure 2-37. Stair design
2-17. Stair Design. Use the following rules when designing stairways:
Rule 1. The sum of 2 risers and 1 tread should equal 25 inches.
Rule 2. The sum of 1 riser and 1 tread should equal 17 to 19 inches.
Rule 3. The height of the riser, multiplied by the width of the tread, should equal approximately 75 inches. According to rule 1, a riser of $71 / 2$ inches would require a tread of 10 inches. A $61 / 2$-inch riser would require a 12 -inch tread.

2-18. Stairway Calculations. To calculate the number and size of risers and treads for a given run, first divide the total rise by 7. If the total rise for a stairway is 7 feet 10 inches or 94 inches, the answer will be 13.43 . Since there must be a whole number for risers, select the one closest to 13.43 (13) and divide it into the total rise.

94 inches divided by $13=7.23$ or $71 / 4$ inches
Number of riser $=13$
Riser height $=71 / 4$ inches

In a given stair run (see Figure 2-38), the number of treads will be one less than the number of risers. A $101 / 2$-inch tread will be correct for the following example, and the total run would be calculated as follows:

Number of treads $=12$
Total run $=101 / 2$ inches $\times 12$ treads $=126$ inches or 10 feet 6 inches
The stairs will have--
13 risers each, $71 / 4$ inches high.
12 treads each, $101 / 2$ inches wide.
A total run of 10 feet and 6 inches.


Figure 2-38. Stair run
2-19. Stairway Frames. To frame simple, straight, string stairs--
a. Take a narrow piece of straight stock, called a story pole, and mark on it the distance from the lower-floor to the upper-floor level. This is the lower-room height, plus the thickness of the floor joists and the rough and finished flooring. It is also the total rise of the stairs. Keep in mind that a flight of stairs forms a right triangle. The rise is the height of the triangle, the run is the base, and the length of the stringers is the hypotenuse.
b. Set dividers at 7 inches, the average distance from one step to another.
c. Step off this distance on the story pole.
d. Adjust the divider span slightly if this distance will not divide evenly into the length of the story pole. Step off this distance again.
e. Continue this adjusting and stepping off until the story pole is marked off evenly. The span of the dividers must be near 7 inches. This represents the rise of each step.
f. Count the number of spaces stepped off evenly by the dividers on the story pole. This will be the total number of risers on the stairs.
g. Measure the length of the stairwell opening for the length of the run of the stairs. Obtain this length from the plans. The stairwell-opening length forms the base of a right triangle. The height and base of the triangle have now been obtained.

2-20. Stairway Dimensions. Standard procedures can be used to determine the height of the rise, the length of the stairway, and the width of tread.
a. Rise Height. In order to determine the height of the risers, use a set of dividers and set them at 7 inches. Now step off the distance on the story pole from one end of the pole to the mark you made on the other end. If the distance will not divide into the length of the story pole evenly, adjust the divider spans slightly and again step off this distance on the story pole. Continue adjusting and stepping off until the story pole is marked off evenly. Now count the number of spaces stepped off. This will be the total number of risers in the stairs.
b. Stairway Length. Measure the length of the stairwell for the length of the run of stairs. The length may also be obtained from the details on the pane.
c. Tread Width. To determine the width of each tread, divide the number risers, less one (remember there is one more riser than thread), into the run stairs. The numbers obtained are to be used on the steel square in laying off the run and rise of each tread and riser on the stringer (see Figure 2-39).


Figure 2-39. Laying off run and rise

- Locate the width of the tread and the height of the riser on the steel framing square.
- Use thee figures to lay off the tread and riser of each step on the stringer equal to the number of risers previously obtained by dividing the story pole into equal spaces. Your stringer is now ready to be cut.


## LESSON 2

## PRACTICE EXERCISE

The following items will test your grasp of the material covered this lesson. There is only one correct answer to each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. When can siding be placed before door and window casings are set in place?
A. On hasty construction
B. When sheathing is not used
C. Only when plywood is used
D. When studs are 24 inches on center
2. Where do you center joints when hanging sheetrock?
A. On girts
B. On joints
C. On studs
D. On T-posts
3. What purpose does molding serve at the junction of a wall and the floor?
A. As a bumper
B. As a decoration
C. As an extension
D. As a support
4. What type of bracing is placed between the studs in short blocks?
A. Corner
B. Cut-in
C. Let-in
D. Diagonal
5. What type of sheathing can be used to omit some types of bracing?
A. Diagonal board
B. Horizontal board
C. Building paper
D. Plywood
6. When using a story pole to design a flight of stairs, step off the pole the average distance of the risers. You find that this distance will not divide into the height of the stairs evenly. What should you do?
A. Adjust the distance slightly
B. Divide again by the same number
C. Measure the pole again
D. Use another story pole
7. What type of joint should a square-edged baseboard have at the outside corners?
A. Dove-tail
B. Rabbet
C. Half-lap
D. Mitered
8. At what point on the wall should you start when nailing diagonal sheathing?
A. The corners
B. The left side
C. The right side
D. The top
9. In relation to the studs, which direction should the face grain run when using plywood sheathing?
A. Horizontal
B. Diagonal
C. Parallel
D. Half-lap
10. What is nailed over the cracks between vertical wood siding?
A. Battens
B. Tar paper
C. Vertical siding
D. Molding

## LESSON 2

## PRACTICE EXERCISE

## ANSWER KEY AND FEEDBACK

Item

1. B When sheathing is not used

When sheathing is not used . . . (page 2-18, para 2-12b(2))
2. C On studs

Install succeeding sheets . . . (page 2-21, para 2-14(1))
3. A Bumper

Although a wood member . . . (page 2-25, para 2-15)
4. B Cut-in

Cut-in bracing . . . (page 2-28, para 2-4b)
5. D Plywood

If plywood sheathing . . . (page 2-6, para 2-4c)
6. A Adjust the distance slightly

Adjust the divider . . . (page 2-28, para 2-19d)
7. D Mitered

Install square-edge baseboard . . . (page 2-25, par 2-15a)
8. A Corners

If it is to be put . . .(page 2-14, para 2-11a)
9. C Parallel

Install the sheets . . . (page 2-15, para 2-11c)
10. A Battens

The cracks are covered... (page 2-17, par 2-12a)

## LESSON 3

## ROOF CONSTRUCTION

Critical Task: 051-236-1144

## OVERVIEW

## LESSON DESCRIPTION:

At the end of this lesson, you will be able to describe the construction of a roof system.

## TERMINAL LEARNING OBJECTIVE:

ACTION: You will describe how to construct a roof system.
CONDITION: You will be given the material contained in this lesson.
STANDARD: You will correctly answer the practice exercise questions at the end of this lesson.
REFERENCES: The material contained in this lesson was derived from FM 5-426 (Chapter 7).

## INTRODUCTION

The roof's main purpose is to keep out the rain, cold, or heat. It must be strong enough to withstand high winds sloped to shed water; and, in areas of heavy snow, it must be constructed more rigidly to bear the extra weight.

## PART A - ROOF TYPES

This part will familiarize carpenters with the most common types of roof construction. Roofs for theater of operations construction are chosen to suit the building; the climate; the estimated length of time the building will be used; and the material, time, and skill require for construction.

3-1. Gable Roof. This roof has two roof slopes that meet at the center (ridge), forming a gable. It is the most common roof because it is simple, economical, and may be used on any type of structure. Refer to Figure 3-1, page 3-2.

3-2. Lean-To or Shed Roof. This roof used where hasty or temporary construction is needed and where sheds or additions to buildings are erected. The pitch of this roof is in one direction only. The roof is held up by the walls or posts on four sides. One wall, or the posts on one side, is higher than those on the opposite side. Refer for Figure 3-2.


Figure 3-1. Gable roof


Figure 3-2. Lean-to or shed roof

3-3. Hip Roof. This roof has four sides or slopes running upward toward the center of the building to create a ridge (or peak). Rafters at the corners run diagonally from the bottom edge to meet at the center (ridge). Other rafters are then framed into them. Refer to Figure 3-3.

3-4. Valley Roof. This roof is framed of two intersection hip or gable roofs. The two roofs meet at a valley. Each roof slants in a different direction. This roof is seldom used, since it is complicated and requires much time and labor. Refer to Figure 3-4.


Figure 3-3. Hip roof


Figure 3-4. Valley roof

## PART B - FRAMING MEMBERS

Joists, rafters, truss, purlins, and braces are considered the main framing members of a roof system.
3-5. Joists. Ceiling joists form the framework of the ceiling of the room. They are usually lighter than floor joists but large enough to remain rigid. Ceiling joists are usually installed 16 or 24 inches on center, with the first ceiling joist placed on the outside edge of the top plate. The second joist is placed 16 inches on center lines from the outside edge of the first joist, and the remaining joists are placed 16 inches on the center lines continuing across the building. Extra joists, if needed, may be paced without affecting the spacing of the prime joists. Joists that lie beside rafters on a plate are cut at the same pitch as the rafter, flush with the top of the rafter (see Figure 3-5). The ceiling joists are nailed to both the top plates and the rafters (see Figure 3-6).


Figure 3-5. Ceiling joists


Figure 3-6. Nailing ceiling joists
3-6. Rafters. Rafters make up the main framework of all roofs. They are inclined members spaced from 16 to 48 inches apart. They vary in size, depending on length and spacing. The tops of inclined rafters are fastened to the ridge or
another rafter, depending on the type of roof. Rafters rest on the top wall plate. Rafters are nailed to the plate, not framed into it. Some are cut to fit the plate, while in hasty construction they are merely laid on top of the plate and nailed in place. They may extend a short distance beyond the wall to form the eaves and protect the sides of the building. Sometimes, metal anchor are used to connect joints and rafters to the top plate (see Figure 3-7). Metal anchors permit rapid installation of joist and rafters, eliminating the need for nailing them. Metal anchors are fastened with $11 / 4$ inch nails.


Figure 3-7. Metal anchors
a. Types. Examples of most types of rafters are shown in Figure 3-8. The four types of rafters used are common, hip, valley, and jack.


Figure 3-8. Roof framing terms
(1) Common rafters. These are framing members that extend at right angles from the plate line to the roof ridge. They are called common rafters because they are common to all types of roofs and are used as the basis for laying out other types of rafters.
(2) Hip rafters. These are roof members that extend diagonally from the corner of the plate to the ridge.
(3) Valley rafters. These rafters extend from the plate to the ridge along the lines where two roofs intersect.
(4) Jack rafters. These are a common rafter. The three kinds of jack rafter are the--

- Hip jack, which extends from the plate to the hip rafter.
- Valley jack, which extends from the ridge of the valley rafter.
- Cripple jack, which is placed between a hip rafter and a valley rafter. The cripple jack rafter is also part of a common rafter, but it touches neither the ridge of the roof nor the rafter plate.
b. Rafter Layout. Rafters must be laid out and cut with the slope, length, and overhang exactly right so that they will fit when placed in the roof.
(1) Scale or Measurement Method. The carpenter should first determine the length of the rafter and the length of the lumber from which the rafter may be cut. If he is working from a roof plan, he learns the rafter lengths and the width of the building from the plan. If no plans are available, the width of the building must be measured.

To determine the rafter length, first find one-half of the distance between the outside plates. (The amount of rise per foot has yet to be considered.) If the building is 20 feet wide, half the span will be 10 feet.

As an example, use a rise per foot of 8 inches. To determine the overall length of a rafter, measure on the steel carpenter's square the distance between 8 on the tongue and 12 on the blade ( 8 is the rise, and 12 is the unit run). This distance is $145 / 12$ inches. This represents the line length of a rafter with a total run of 1 foot and a rise of 8 inches (see Figure 3-9, page 3-6).

Since the run of the rafter is 10 feet, multiply 10 by the line length for 1 foot $(10 \times 145 / 12=1442 / 12)$. The answer is $1442 / 12$ inches or 12 feet $1 / 6$ inch. The amount of overhang, normally 1 foot, must be added if an overhang is to be used. This makes the total length of the rafter 13 feet $1 / 6$ inch. Use a 14 foot timber.


Figure 3-9. Steel carpenter's square
(2) Pattern Rafter Method. After the length has been determined, the timber is laid on sawhorses (saw benches) with the crown or bow (if it has any) as the top side of the rafter. If possible, select a straight piece for the pattern rafter. If a straight piece is not available, have the crown toward the person laying out the rafter. Figure 3-10 illustrates the five steps of the pattern rafter method.

- Hold the square with the tongue in the right hand, the blade in the left, and the heel away from the body. Place the square as near the upper end of the rafter a possible.
- In the example, the figure 8 on the tongue and 12 on the blade are placed along the timber edge, that is to be the top edge of the rafter as shown in step 1. Mark along the tongue edge of the square, which will be the plumb cut at the right.
- Since the length of the rafter is known to be 12 feet $1 / 6$ inch, measure the distance from the top of the plumb cut and mark it on the timber. Hold the square in the same manner with the 8 mark on the tongue directly over the 12 -foot $1 / 6$-inch mark. Mark along the tongue of the square to give the plumb cut for the seat (see step 2).
- Next, measure off perpendicular to this mark, the length of overhang along the timber. Make a plumb-cut mark in the same way, keeping the square on the same edge of the lumber (see step 3). This will be the tail cut of the rafter. Often, the tail cut is made square across the timber.


Figure 3-10. Rafter method

- The level cut or width of the seat is the width of the plate, measured perpendicular to the plumb cut, as shown in step 4 . Using the try square, square the lines down on the sides from all level and plumb-cut lines. Now the rafter is to be cut (see step 5).
(3) Step-Off Method. The rafter length of any building may be determined by "stepping it off" by successive steps with the square, as follows:
- Step off the same number of steps as there are feet in the run. For example, if a building is 20 feet 8 inches wide, the run of the rafter would be 4 inches over 10 feet. Figure 3-11, page 3-8, illustrates the four steps of the step-off method.
- This 4 inches is taken care of in the same manner as the full-foot run; that is, with the square at the last step position, make a mark on the rafters at the 4 -inch mark (see Figure 3-11, step 1).
- With the square held for the same cut as before, make a mark along the tongue. This is the line length of the rafter. The seat cut and hangover are made as described above and shown in Figure 3-11, steps 2, 3, and 4.


Figure 3-11. Step-off Method
NOTE: When laying off rafters by any method, be sure to recheck the work carefully. When two rafters have been cut, it is best to put them in place to see if they fit. Minor adjustments may be made at this time without serious damage or waste of material.
(4) Table Method 1. To use the framing square to lay out rafters, the width of the building must first be known. Suppose the building is 20 feet 8 inches wide, and the rise of the rafters is to be 13 inches per foot of run. The total run of the rafters will be 10 feet 4 inches.

- Look at the first line of figures under the 13-inch mark (see Figure 3-12). You will see the number 17.69. This is the length in inches of a rafter with a run of 1 foot and a rise of 13 inches.


Figure 3-12. Table Method 1

- To find the line length of a rafter with a total run of 10 feet 4 inches, multiply 17.69 inches by $101 / 3$ and divide by 12 to get the answer in feet $(17.69 \times 10.333=182.79)$. The total of 182.79 inches is divided by 12 to equal $153 / 12$ feet. Therefore, 15 feet 3 inches is the line length of the rafter.
(5) Table Method 2. The rafter table is on the back of the blade of some squares. Figure 313 shows the run, rise, and pitch of the rafters of the seven most common roof pitches. The figures are based on the length of the horizontal measurement of the building from the center to the outside (run). The rafter table on the outside edge, on the back of the square, gives both the body and the tongue in twelfths. The inch marks on the square may represent inches or feet, and the twelfth marks may represent twelfths of an inch or twelfths of a foot. The rafter table is used in connection with the marks and figures on the outside edge of the square. You will notice that at the left end of the table there are figures representing the run, rise, and the pitch.


Figure 3-13. Table Method 2

- Run. In the first column, the figures are all 12. These may be used as 12 inches or 12 feet, because they represent the run of 12 inches.
- Rise. The second column of figure represents various rises per foot: $4,6,8,10,12$, 15 , and 18.
- Pitch. The third column of figures, in fractions, represents various pitches: $1 / 6,1 / 4$, $1 / 3,5 / 12,1 / 2,5 / 8$, and $3 / 4$ (see Figure 3-14, page 3-10).


Figure 3-14. Pitch on the rafter table
c. Assembly. Rafters are usually made into trusses. Two rafters are connected at the top, using a collar tie well nailed into both rafters. Before any ties or chords are nailed, the rafters should be spread at the lower end to equal the width of the building. This is done by using a template or by measuring the distance between the seat cuts with a tape (see Figure 3-15).


Figure 3-15. Assembling a truss
(1) Chord. A 1 by 6 or 2 by 4 chord is nailed across the rafters at the seat cut to tie them together. This chord forms a truss with the two rafters. A hanger or vertical member of 1 by 6 is nailed to the rafter joint and extends to the chord at midpoint, tying the rafter to the chord.
(2) Collar Beam. A tie or collar beam is a piece of stock (usually 1 by 4,1 by 6,1 by 8 , or 2 by 4) fastened in a horizontal position to a pair of rafters between the plate and the ridge of the roof This type of beam tends to keep the building from spreading. Most codes and specifications require them to be 5 feet apart or every third rafter, which ever is less. Collar ties are nailed to common rafters with four 8 d nails to each end of a 1 -inch tie. If 2-inch material is used for the tie, they are nailed with three 16 d nails at each end. This type of bracing is used on small roofs where no ceiling joists are used and the building is not wide enough to require a truss. The lower the collar beam or chord, the better it works.
(3) Support. In small roofs that cover only narrow buildings and in which the rafters are short, there is no need for interior support or bracing. In long spans, the roof would sag in the middle if it were not strengthened in some way. To support long rafters, braces or other types of supports must be installed.
(4) Rafter Support. In wide buildings, where the joists or chords must be spliced and there is no support underneath, the rafter and joists support one another (see Figure 3-16).
d. Knee Brace. If no additional bracing is needed, the truss is set in place on the plates. If additional bracing is needed, a knee brace is nailed to the chord. The knee brace forms a $45^{\circ}$ angle with the wall stud. For easier erection, the knee brace may be omitted until the rater truss is set in place (see Figure 3-16).


Figure 3-16. Rafter support detail
3-7. Trusses. A truss is a framed or jointed structure composed of straight members connected only at their intersections in such a way that if loads are
applied at these intersections, the stress in each member is in the direction of it length. Straight, sound timber should be used in trusses. Figure 3-17 shows various types of trusses used in construction. (The Howe and Fink trusses are most commonly used.) Trusses are used for large spans to give wide, unobstructed floor space for such large buildings as shops and hangars. Sometimes small buildings are trussed to save material. These small trusses act as rafters and give the roof rigidity.


Figure 3-17. Types of trusses
a. Placement. After the rafters have been assembled into trusses, they must be placed on the building (see Figure 3-18). Assemble the first set of rafters in the end section of the building or at the center. Raise rafter trusses into position by hand and nail them into place with 16 d nails. (Temporary workbenches may be built for the workers to stand on while erecting trusses.) These trusses must be temporarily braced at the end section of the building until the sheathing is applied. Knee braces are not used on every rafter truss unless needed. Install trusses as follows:


Figure 3-18. Installing trusses
(1) Mark the proper positions of all truss assemblies on the top plate. The marks must show the exact position on the face of all rafters (such as south or north) (see Figure 3-18, A).
(2) Rest one end of a truss assembly, peak down, on an appropriate mark on the top plate on one end of the structure (see Figure 3-18, A).
(3) Rest the other end of the truss on the corresponding mark of the top plate on the other side of the structure (see Figure 3-18, B).
(4) Rotate the assembly into position using a pole or rope (see Figure 3-18, C, page 3-13).
(5) Line up and secure the rafter faces flush against the marks.
(6) Raise, align, and nail the three assemblies into position. Nail temporary $1 \times 6$ braces across these three assemblies. Repeat this procedure with the other assemblies as they are brought into position (see Figure 3-18, D). Check the rafter spacing at the peaks as the braces are nailed on.
(7) Braces may be used as a platform when raising those trusses for which there is not enough room to permit rotation.
b. Web Members. The web members of a truss divide it into triangles. The members indicated by heavy lines normally carry tensile stresses for vertical loads. Sometimes the top chords of these trusses slope slightly in one or two directions for roof drainage, but this does not change the type of truss. The necessary number of subdivisions, or panels, depends on the length of the span and the type of construction.
c. Terms. These terms should be understood before proceeding further with this lesson.
(1) Bottom chord. A member that forms the lower boundary of the truss (see Figure 3-19).


Figure 3-19. Truss
(2) Top chord. A member which forms the upper boundary of the truss.
(3) Chord member. A member that forms part of either the top or the bottom chord.
(4) Member. The component that lies between any adjacent joints of a truss. It can be of one or more pieces of structural material.
(5) Web member. A member that lies between the top and bottom chords.
(6) Joint. Any point in a truss where two or more members meet; sometimes called a panel point
(7) Panel length. The distance between any two consecutive joint centers in either the top or bottom chords.
(8) Pitch. The ratio of the height of the truss to the span's length.
(9) Height of Truss. The vertical distance at midspan from the joint center at the ridge of a pitched truss or from the centerline of the top chord of a flat truss to the centerline of the bottom chord.
(10) Span length. The horizontal distance between the centers of the two joints located at the extreme ends of the truss.
d. Uses. Trusses are used for large spans to give wide, unobstructed floor space for such large building as shops and hangers. The Howe and Fink trusses are most commonly used (see Figure 3-20).


Figure 3-20. Howe and Fink trusses
e. Support. Trusses are supported by bearing walls, posts, or other trusses. To brace a truss to a wall or post, knee braces are used as shown in Figure 3-21. These braces tend to make a truss of the entire building by tying the wall to the roof (see Figure 3-21).


Figure 3-21. Knee braces
f. Layout. Use the following steps to lay out a truss:
(1) Build the truss on workbenches that are paced on a level spot on the ground.
(2) Obtain the measurement of al material from the blueprints.
(3) Lay the pieces in their correct position t form a truss.
(4) Nail them together temporarily (see Figure 3-22).
(5) Lay out the location of all holes to be bored.
(6) Bore the holes to the size called for on the blueprint.
(7) Dismantle the truss and withdraw the nails after the holes have been bored.


Figure 3-22. Truss layout
g. Assembly. Assembling a truss after it has been cut and bored is simple. In most cases, timber connectors are used where different members of the truss join. Assemble the truss with the split rings in place. The bolts are then placed in the holes and tightened. Place washers at the head and nut ends of each bolt. Use straight, sound timber trusses (see Figure 3-23).


Figure 3-23. Split rings on a truss
3-8. Purlins. Purlins are used in roof construction to support corrugated sheet metal if it is used or to support the sheathing of roofs famed with trusses. In small roofs, short purlins are inserted between the rafters and nailed through the rafters. In large buildings where heavy trusses are used, the purlins are continuos members that rest on the trusses and support the sheathing. In small buildings, such as barracks, mess halls, and small warehouses, 2 by 4 s are used for purlins, with the narrow side up (see Figure 3-24, page 3-18).


Figure 3-24. Purlins
3-9. Braces. Bracing is used to stiffen framed construction and make it rigid. Bracing may be used to resist winds, storms, twists, or strains. Good bracing keeps corners square and plumb. Bracing prevents warping, sagging, and shifting that could otherwise distort the frame and cause cracked plaster and badly fitting doors and windows. In small roofs that cover narrow buildings and in which the rafters are short, there is no need for interior support or bracing. In long spans, the roof would sag in the middle if it were not strengthened in some way. To support long rafter, braces or other types of supports must be installed. The three methods commonly used to brace frame structures are let-in, cut-in, and diagonal-sheathing bracings.
a. Let-In Bracing. Let-in bracing is set into the edges of studs, flush with the surface. The studs are always cut to let in the braces; the braces are never cut. Use 1 by 4 s or 1 by 6 s set diagonally from top plates to sole plates, or between top or sole plates and framing studs.
b. Cut-In Bracing. Cut-in bracing is toenailed between studs. It usually consists of 2 x 4 s cut at an angle to permit toenailing. They are inserted in diagonal progression between studs running up and down from corner posts to the sill or plates.
c. Diagonal-Sheathing Bracing. The strongest type of bracing is diagonal sheathing. Each board braces the wall. If plywood sheathing $5 / 8$ inch thick or more is used, other methods of bracing may be omitted.

3-10. Roofing Terms. When framing a root carpenters must be familiar with commonly used roofing terms. The following are the most common of those terms:
a. Basic Triangle. The basic triangle is the most elementary tool used in roof framing (see Figure 3-25). When framing a roof, the basic right triangle is formed by the horizontal lines (or run), the rise (or altitude), and the length of the
rafter (the hypotenuse). Any part of the triangle can be computed if the other two parts are known. Use the following equation:

The square of the hypotenuse of a right triangle is equal to the sum of the squares of the two sides. In roofing terms--

$$
\text { Rafter length }{ }^{2}=\text { run }^{2}+\text { rise }^{2}
$$



Figure 3-25. Basic triangle
b. Bird's Mouth. A bird's mouth is a cutout near the bottom of a rafter, that fits over the top plate. The cut that fits the top of the plate is called the seat; the cut for the side of the plate is called the heel (see Figure 3-26).


Figure 3-26. Bird's mouth
c. Cut of a Roof. The cut of a roof is the rise over the run (such as $4 / 12$ roof) or the pitch of the roof (see Figure 3-27).


Figure 3-27. Roofing terms
d. Span of a Roof. The span of any roof is the shortest distance between the two opposite rafters' seats (see Figure 3-27).
e. Line Length. In roof framing, line length is the hypotenuse of a triangle whose base is the run and whose altitude is the total rise (see Figure 3-27).
f. Horizontal Line. A horizontal line is one level with the building foundation.
g. Overhang. The overhang is that part of a rafter that extends past the outside edge of the walls of a building. When laying out a rafter, this portion is in addition to the length of a rafter and is figured separately. The overhang is often referred to as the tailpiece.
h. Total Rise. The total rise is the vertical distance from the wall plate to the top of the ridge.
i. Run. Run always refers to the level distance any rafter covers--normally, one-half the span.
j. Unit of Run (or unit of measurement). The unit of measurement, 1 foot (or 12 inches), is the same for the roof as for any other part of the building. Using this common unit of measurement, the framing square is used in laying out large roofs.
k. Pitch. Pitch signifies the amount that a roof slants and the ratio of rise (in inches) to run (in inches). Using this method, 4, 6, or 8 inches of rise per foot of
run would give a pitch of $4: 12,6: 12$, or $8: 12$. There are two methods of indicating pith.
(1) Method 1. The pitch is indicated as a ratio of the rise to the span of a roof, stated in fractions ( $3 / 4,5 / 8,1 / 2$, and $5 / 12$ ). The units of span and rise must be the same (inches or feet), and the faction is reduced to its lowest common denominator (see Figure 3-11, page 3-8).

- To obtain the unit rise, multiply the pitch by 24 . For example, if the pitch is given as $1 / 3$, multiply $1 / 3$ by $24(1 / 3 \times 24=8)$. Therefore, the unit rise is 8 inches per foot $(8-12$ pitch).
- If the pitch is given as $5 / 12$, multiply $5 / 12$ by $24(5 / 12 \times 24=10)$. Therefore, the unit rise is 10 inches per foot ( $10-12$ pitch).
(2) Method 2. The pitch is stated as the ratio of rise (in inches) per 1 foot of run ( 12 inches). Using this method, 4,6 , or 8 inches of rise per foot of run would give a pitch of $4-12,6-12$, or $8-12$. A roof with $1 / 2$ pitch can be said to have a $12-12$ pitch. Remember $1 / 2 \times 24=12$.

1. Rise. The rise of a rafter is the vertical (or plumb) distance that a rafter extends upward from the plate.
m . Plumb Line. The line is the line formed by the cord on which the plumb bob is hung (see Figure 3-28).


Figure 3-28. Roof pitch
n. Plate. The plate is the wall-framing member that rests on the top of the wall studs (see Figure 3-8, page 3-4).
o. Ridge. The ridge is the highest horizontal roof member. It ties the rafters together at the upper end (see Figure 3-8).

3-11. Rafter Tables on a Framing Square. The framing square may have one or two types of rafter tables on the blade. One type gives both the line length of any pitch of rafter per foot of run and the line length of any hip or valley rafter per foot of run. The difference in the length of the jack rafter, spaced 16 or 24 inches (on center), is also shown in the table. Where the jack, hip, or valley rafter needs side cuts, the cut is given in the table. The other type of rafter table gives the actual length of a rafter for a given pitch and span.
a. Line length. The rafter table (see Figure 3-29) is used to determine the length of the common, valley, hip, and jack rafters, and the angles at which they must be cut to fit at the ridge and plate. To use the table, the carpenter must know what each figure represents.


Figure 3-29. Line lengths on the rafter table
(1) The row of figures in the first line represents the length of common rafters per foot of run (look at the left end of Figure 3-29), as the title at the left-hand end of the blade indicates.
(2) Each set of figures under each inch division mark represents the length of a rafter per foot of run, with a rise corresponding to the number of inches over the number. For example, under the 16inch mark appears the number 20.00 inches. This number equals the length of a rafter with a run of 12 inches and a rise of 16 inches. Under the 13 -inch mark appears the number 17.69 inches, which is the rafter length for a 12 -inch run and a 13 -inch rise.

## NOTE: The other five lines of figures in the table are seldom used in the theater of operations.

b. Actual Length. At the left end of the table (see Figure 3-30) are figures representing the run, rise, and the pitch of a roof
(1) The figures show that a rafter with a run of 12 and a rise of 4 has $1 / 6$ pitch. A 12 run, 6inch rise has $1 / 4$ pitch. A 12 run, 8 -inch rise has $1 / 3$ pitch.


Figure 3-30. Actual lengths on the rafter table
(2) To use the rafter table to determine the length of a rafter with a $1 / 6$ pitch (or a rise of $1 / 6$ the width of the building) and a run of 12 feet, find the $1 / 6$ in the table, then follow the same line of figures to the right until directly beneath the figure 12. The numbers that appear beneath this figure are 12,7 , and 10 , which show the rafter length required and which represent 12,7 , and 10 mean 12 feet, 7 inches, and $10 / 12$ of an inch. Therefore, the length of the rafter required is 12 feet $710 / 12$ inches long.
(3) Using rafter table method 2 , assume you have a roof with a $1 / 2$ pitch (or a rise of $1 / 2$ the width of the building) and a run of 12 feet (see Figure 3-30). Find $1 / 2$ pitch on the table. Follow the same line of figures to the right until directly beneath the figure 12 . The numbers that appear beneath this figure are 16,11 , and 6 , which represents 16 feet $116 / 12$ inches. The length of the rafter required is 16 feet $116 / 12$ inches long.
(4) When the run is in inches, the rafter table reads inches and twelfths instead of feet and inches. If the pitch is $1 / 2$ and the run is 12 feet 4 inches, add the rafter length of a 12 -foot run to that of a rafter length of 4-inch run (see Figure 3-30). For a run of 12 feet and $1 / 2$ pitch, the length is 16 feet 11 $6 / 12$ inches. For a run of 12 feet and $1 / 2$ pitch, the length is 5,7 , and 11 . In this case, the 5 is inches, the 7 is twelfths, and the 11 is $11 / 12$ of $1 / 12$ (which is nearly $1 / 12$ of an inch). Add the $1 / 12$ to the 7 to make it 8 , making a total of $58 / 12$ inches. Add the two lengths together ( 16 feet $116 / 12$ inches $+58 / 12$ inches $=17$ feet $51 / 12$ inches)
(5) If the run of a building is over 23 feet, the table is used as follows: Using a run of 27 feet, with a $1 / 4$ pitch (the framing square blade is 24 inches long), find the length for 23 feet, then find the length for 4 feet, and add the two. The run for 23 feet with a pitch of $1 / 4$ is 25 feet $85 / 12$ inches. For 4 feet, the run is 4 feet $58 / 12$ inches. The total run for 27 feet is 30 feet $21 / 2$ inches.
(6) The lengths that are given in the rafter table are line lengths. The overhang must be added.
(7) When the roof has an overhang, the rafter is usually cut square to save time. If the roof does not have an overhang, the rafter is cut plumb, but no notch is cut in the rafter seat.
(8) A level cut is made on the rafter long enough to extend across the plate and the wall sheathing. This type of rafter allows very little protection to the sidewalls.

3-12. Template Use. Rafter framing without the use of ridgeboards may be done rapidly by using a truss assembly jig or template. The template is laid out t form a pattern conforming to the exact exterior dimensions of the truss. Lay out a template as follows (see Figure 3-31).


Figure 3-31. Laying out a template
a. Lay Out. Lay out a template as shown in Figure 3-31 and as follows:
(1) Measure and mark a straight line on a selected surface. Have the exact length of the joists that will form the truss chord. This is baseline A (see Figure 3-31).
(2) From the center of the baseline and at right angles to it lay out the centerline (C) to form the leg of a right triangle, the base of which is at half the length of baseline A , and the hypotenuse of which (B) is the length of the rafter measured as indicated (see Figure 3-31).
(3) Nail 2- by 4- by 8 -inch blocks flush with the ends of baseline A and centerline C as shown in Figure 3-31. Mark the centerline on the center jig blocks.
b. Assembly. Assemble with a template as shown in Figure 3-31 and as follows:
(1) Start the assembly by setting a rafter in the jig with the plate cut fitted over the jig block at one end of the baseline. The peak is flush with the centerline on the peak jig block. Nail a holding block outside the rafter at point D as shown in Figure 3-31.
(2) Lay one 2- by 4-inch joist or chord in place across the base blocks.
(3) Lay two 2- by 4-inch rafters in place over the joist.
(4) Center one end of 1 - by 6 -inch hanger under the rafter peak. Center the rafters against the peak block.
(5) Nail through the rafters into the hanger using six 8 d nails.
(6) Line up one end of the chord.
(7) Nail through the rafter with 16d nails.
(8) Line up the other end of the chord.
(9) Nail as above.
(10) Center the bottom of the hangers on top of the chord and nail with 8 d nails.

3-13. Roof Openings. Major roof openings are those that interrupt the normal run of rafters or other roof framing. Such openings may be for ventilation, chimneys, trap-door passage, skylight, or dormer windows. Roof openings are framed by headers and trimmers. Double headers are used at right angles to the rafters, which are set into the headers in the same way as joists in floor-opening construction. Trimmers are actually double rafter construction in roof openings. Nailing steps may be added if needed. Figure 3-32 shows roof-opening construction.


Figure 3-32. Roof opening

## PART C - ROOF-COVERING MATERIAL

Many different kinds of roof-covering materials are available, including tile, built-up roofing, asphalt shingles, mineral fiber (asbestos-cement) shingles, and wood shines. Carpenters mainly work with the last three.

3-14. Roof Sheathing. Plywood or one-by material is satisfactory for sheathing roofs. Plywood is more economical than one-by material, and it can be installed rapidly. The thickness required is $3 / 8$, $1 / 2,5 / 8$, or $3 / 4$ inch depending on the rafter spacing, pitch, and load on the roof. When installing sheathing, be sure that the joints are placed over the rafters. The roof sheathing should be arranged so that the joints for the complete roof are staggered.

3-15. Roof-Covering Terms. These terms should be understood before proceeding with this part.
a. Square. Roofing is estimated and sold by the square. A square is the number of shingles required to cover 100 square feet of roof surfaces.
b. Coverage. Shingles overlap, and depending on the manner in which they are laid, one, two, or three thicknesses cover the roof at any one place. The roofing is termed single coverage, double coverage, and so on.
c. Shingle Butt. The shingle butt is the lower exposed edge of the shingle.
d. Exposure. The exposure is the distance from the butt of one shingle to the butt of the shingle above it. This is the portion of the shingle that is exposed to the weather.
e. Underlayment. The underlayment is the application of saturated felt that is placed over the roof surface to protect the roof sheathing until the shingles are applied.
f. Toplap. The width of the shingles minus the exposure.

3-16. Shingle Roof. An asphalt-shingle roof begins with the application of a drip edge, followed by underlayment (felt) and eave flashing strips. Then, the first full shingle is inverted and nailed in place. Asphalt roofing comes in rolls (usually 3 feet wide), called rolled roofing; in rolled strips (usually 15 inches wide and 3 feet long); and as individual shingles. The type most commonly used is the flat strip, often called a strip shingle. The size of a square-butt strip shingle is 12 by 36 inches. This shingle should be laid 5 inches to the weather, meaning 7 inches of each course should be overlapped by the next higher course. There are various types of shingles. Figure 3-33 shows a butt shingle with three tabs.


Figure 3-33. Butt shingle
3-17. Shingle Installation. The first step in covering a roof is to erect a scaffold to a height that will bring the eaves about waist-high to a man standing on the scaffold. Before any roof covering is applied, the roof sheathing must be swept clean and carefully inspected for irregularities, cracks, holes, or other defects. No roof should be applied unless the sheathing boards are absolutely dry. An underlay of roofing felt is first applied to the sheathing. Roofing felt usually comes in 3-foot-wide rolls and should be laid with a 2 -inch top lap and a 4 -inch side lap (see Figure 3-34). Bundles of shingles should be distributed along the scaffold before work begins. There are 27 strips in a bundle of 1 by 3 asphalt strip shingles. Three bundles will cover 100 square feet.


Figure 3-34. Laying an asphalt shingle roof
a. Install the first course of shingles inverted. This arrangement provides a roofing edge without notches.
b. Nail inverted shingles in place with $3 / 4$-inch over the drip edge on the eaves and the gable ends of the roof (see Figure 3-35, page 3-28).


Figure 3-35. Applying the drip edge
c. Snap chalk lines on the underlayment (felt) to indicate the location of each course (see Figure 3-36).


Figure 3-36. Snapping a chalk line
d. Begin the first course of shingles with a whole strip at one end of the roof (see Figure 3-37).
e. Cut the second course so that the lap occurs at the half-tab point (see Figure 3-37).
f. Use four or six nails in each shingle.
g. Use nails that are $11 / 4$ inches long for new roofs.
h. Place a nail 1 inch from the edge of the shingle.
i. Place one or two nails near the tab slots (depending on the requirement) as shown in Figure 3-37.


Figure 3-37. Laying the shingles
j. Passes each nail through two thicknesses of shingles and is concealed (blind nailed) by the next course of shingles.
k. Finish the ridge of the roof by overlapping the shingles to prevent the roof from leaking.

1. Make three short 12 - by 12 -inch shingles from a 12 - by 36 -inch shingle for the ridge of the roof
m . Lay short shingles with an exposure of 5 inches to the weather.

## Ulimate-Construction Series





## CARPENTRY III

# CARPENTRY III <br> (SPECIALIZED CARPENTRY) 

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## CHAPTER 1

## Cabinetwork

IN YOUR JOB AS A carpenter, you will build many cabinets. Cabinet building is a precision job that is performed inside a shop, although much of the work is done at the location where the cabinets are to be installed. The cabinets should be well designed, structurally sound, and appealing in appearance. Look at some of the cabinetwork around you or try to recall the appearance of some kitchen cabinets that you have seen. Do they make good use of the available space? Do the doors fit and latch tightly? Are the shelves strong and the joints tight? Do the cabinets look like they were done by a craftsman?
2. This chapter is devoted to the materials used and methods applied to achieve these goals. We will cover the types and characteristics of wood used in cabinetwork. Some of the softwoods are white pine, fir, cedar, and redwood; some of the hardwoods are walnut, mahogany, and oak. Of course, grades and standards of hardwood and plywood will also be covered here.
3. We will discuss some of the joints used in cabinetwork, such as parallel grain joints, right-angle grain joints, grooved joints, miter joints, mortise and tenon joints, dovetail joints, and butt joints. Remember, a good joint is one that is well made and fits properly. The type of cabinet that you will make will be one of three types: frame, stool, or box. A step-by-step procedure will be given in the construction of each of these items.
4. Study each section carefully and try to apply what you learn to all of your cabinetmaking projects.

## 1. Cabinet Woods

1-1. In cabinetmaking, those characteristics of wood with which we are concerned differ somewhat from those characteristics of wood with which we are concerned when we are dealing with frame construction. For example, in cabinetmaking, beauty and finishing qualities are the determining factors rather than strength.

Many beautiful hardwoods are strong. Being strong and naturally beautiful, they are favored for cabinetwork.
$1-2$. It is almost impossible to discuss in detail all the woods used in cabinet construction; however, we are primarily concerned with those woods which are in common use.

1-3. In this section we will discuss the types of wood used in cabinetwork and the characteristics of each type. After studying these characteristics, you should be able to identify and select the proper wood for a particular job.
$1-4$. The most desirable woods for cabinetwork should:
a. Have the ability to keep their shape without shrinking, warping, or swelling.
b. Be easily workable with tools and machinery without causing rough surfaces.
c. Be strong, with suitable grain characteristics that are pleasing to the eye.
1-5. Softwoods. Many softwoods are used in cabinetmaking. Among these, white pine is one of the most useful of all. It is also easy to work, because it has a uniform grain and holds its shape well. White pine is soft, light, and of medium strength. It splits easily but holds nails fairly well. It also takes glue well. The grain is not prominent; therefore, it has no particular beauty. For this reason, coupled with its ability to hold paint, it is most often painted.

1-6. Fir comes in three well-known species: Douglas fir, yellow fir, and red fir. Fir is difficult to work with hand tools, because it splits easily. It glues well but will not hold paint; therefore, it is usually treated with a preservative. It is used extensively for making plywoods and in millwork, boatbuilding, and shingle manufacturing.

1-7. Cedar comes in a variety of species; this makes it difficult to, cover each in detail; however, we will discuss some of its general characteristics. The sapwood is generally white, with the heartwood being a reddish brown to
dull brown and sometimes turning to a lavender tinge. Cedar is known for its pungent odor and spicy bitter taste. It is a light, soft wood of low strength and does not bend easily. However, it works well, finishes smoothly, takes paint, and glues well, although it will split easily. Cedar has a high resistance to decay, is uniform in texture, and is very knotty. After it is seasoned, it will keep its shape well. It is used as a liner for closets, cedar chests, etc., because of its moth-repellent action. It is also used for millwork, novelties, and furniture.
$1-8$. Redwood is a soft, odorless, straight, evengrained softwood, coarse in texture and light in weight. It works well with tools and holds glue and paint exceptionally well. Redwood shrinks very little and keeps its shape well after it is seasoned. It resembles cedar in color but has a much coarser texture. It is used for building construction, millwork, garden furniture, novelties, and shingles.

1-9. Hardwoods. Hardwoods are used extensively for fine furniture and cabinets. Their strength, plus beauty and ability to take clear finishes (varnish and lacquer), makes them ideal for the finest products of the cabinetmaker. There are many types of hardwoods; however, we will cover only the principal ones.
$1-10$. Walnut is one of the finest of cabinet woods, because the grain is porous and varies from straight to irregular. Walnut works well with tools, finishes smoothly, and holds glue and stain well. It is a hard, strong wood and is easily identified by its dark heartwood. It is used extensively for plywoods, veneers, furniture, and millwork.

1-11. Mahogany is not a native wood; therefore, all species are imported. Most varieties come from Central America, Africa, and India. It is a hard, strong wood; however, the hardness can vary with the species. Color can vary in shade, but generally speaking, it is reddish brown. Mahogany has a close, varying grain, causing a pleasing reflection of light. It is used chiefly for fine furniture, plywood panels, veneers, and interior finishes.
$1-12$. Oak is a very hard, strong wood with two main species: white and red. Unless it is carefully seasoned, it will warp and check; however, once it is worked to a finish it is without rival for strength and beauty. Oak bends excellently, holds nails well, finishes smoothly, and holds glue satisfactorily. The grain is coarse and porous; and when quartersawed, the medullary rays are broad and numerous, making pleasing patterns. It takes stain very well, making beautiful grain contrasts, and is used for interior finishes, flooring, plywood panels, veneers, and
furniture. Oak sometimes is used in boatbuilding where strength is required.

1-13. Hardwood Grades and Standards. Because hardwood grading standards are of particular importance in cabinetmaking, we will emphasize this importance by discussing such standards under a separate special heading. These standards are based on the amount of clear, usable lumber in each piece. Material commonly called clear-cutting must have one clear side and the reverse side sound. This means that there must be no rot, shakes, or other features present which might impair the strength of the wood.
1-14. The highest grade of hardwood is termed "first" and the next grade "second." The third grade is termed "select," followed by No. 1, No. 2, and No. 3 common. These grading rules are by no means complete. There are numerous details and special rules for certain species. However, if you keep those specifications mentioned above in your mind. your problems in selecting general hardwoods will be made easier.

1-15. Plywood. Today plywood is used for thousands of products, and the average person comes into contact with it every day. It, too, is used extensively in cabinetwork.
1-16. Modern plywood consists of veneers that are fabricated with glues. In simple terms, it consists of three or more layers of thin wood firmly glued together, with the grain direction of the middle layer at right angles to the outer layers. By this means of fabrication, swelling and shrinking is reduced and stability and strength are added, qualities which would not be found in the original material.
1-17. Wood used in cabinetwork consists of a variety of hardwoods, softwoods, and plywood. When selecting materials for cabinets, you should select the type best suited for the job you are doing. That is, don't use the highest grade of lumber or the best grade of plywood to construct a cabinet that is to be used for storage.

1-18. Now that we have discussed some of the woods used in cabinetwork and their characteristics, let's take a look at some of the joints used when constructing a cabinet.

## 2. Joints Used in Cabinetmaking

2-1. Wood surfaces that are to be glued must be smooth and rue; therefore, when you glue wood surfaces, be sure that there are no machine marks, chipped or loosened grain, or other surface irregularities and that you follow the instructions on the glue container. Another important point for you to remember is that a strong joint is a joint where the glue and wood are in
contact over the entire area and that there are no air bubbles or foreign particles between the wood layers.

2-2. A product of the cabinetmaker is no stronger than its weakest joint. However it is well to remember that you need not be a skilled perfectionist to produce a good joint. If you pan your work, visualize the various steps in their proper sequence, and perform these steps to the best of your ability, you can succeed in making joints that fit well and serve their purpose. A strong joint is one that is well fitted.

2-3. Many types of joints are used in woodworking; however, in this section we will discuss only the following classifications pertaining to cabinetmaking:

- Parallel grain joints.
- Right-angle grain joints.
- Lap joints.
- Grooved joints.
- Miter joints.
- Mortise and tenon joints.
- Dovetail joints.
- Butt joints.
$2-4$. This section will acquaint you with these classifications, the types of joints covered by each, and where they are used, rather than with any detailed descriptions of bow each kind of joint is laid out and constructed.
$2-5$. The selection of a specific type of joint is determined by the following factors:
a. Working qualities and strength of the material to be used.
b. Whether the work is on the exterior or on the interior and whether it is a movable or a stationary project.
c. How the project will be fastened, such a nailed, screwed, glued, or a combination of these.
d. Whether the grain is parallel or at right right angles where the joint is fastened.
e. Whether the fasteners are to be visible or concealed.

2-6. Classification by Grain Direction. In our study of joints, let's first consider their classification pertaining to grain direction. By this we mean the length, face, edge, and end of a board.

2-7. Parallel grain joints. Parallel grain joints are those in which the grain in the jointed pieces runs in the same direction. There are two types of such joints: (1) Parallel edge grain joints, which are used in joining wood edgewise; and (2) parallel right-angle joints, which are used in joining pieces of wood so that their faces are at right angles and their grain parallel.

2-8. Right-angle joints. Right-angle joints are those in which the grain of the woods meet at right angle when they are joined. There are three types of right-angle grain joints: (1) end-to-edge joints, in which the end of one member is fitted to the edge of the other member (see fig. 1, A); (2) oblique joints, where the graining of both members is fitted end to end; and (3) end-to-face joints, where the end gain of one member is joined to the face of the other member (see fig. 1, C). The pain miter joint shown in figure $1, \mathrm{~B}$, is a good example of an oblique right-angle joint.

2-9. Classification by Construction Detail. We have described the main classes into which all woodworking joints fall. Now let's study joint classification with regard to construction detail.

2-10. Lap joints. The lap joint a simple lap, or halved, joint made by cutting out equal half sections from both members which are to be jointed. There are several variations of the lap joint. When the half sections are cut from the end of the members to be jointed and cross each other at right angles, the joint is known as an end lap joint as shown in figure $2, \mathrm{~A}$. If the members cross each other at right angles in the center, the joint is called a cross lap joint, as


Figure 1. End-to-edge joints.


Figure 2. Lap joints.
illustrated in figure 2, B. If one end of a lap joint joins the other in the center, as shown in figure $2, \mathrm{C}$, the joint is known as a middle lap joint.
2-11. Lap joints are used by the carpenter in framing timbers for sills and girders. Cabinetmakers use lap joints for connecting crossrails to the side of cabinets and for many other types of frames.
2-12. Grooved joints. Grooved joints are those which have a groove, or recess, cut into one member, either with the grain or across the grain, into which the edge or end of the other member is fitted. The grooved joint is a familiar joint to the cabinetmaker and has many variations.
$2-13$. Dado joints are actually grooved joints with the groove running across the grain of the wood. They are used extensively in cabinetwork drawer construction. The dado is a housing, or groove, cut into one member with the other member fitting into this groove. A plain dado is one which extends completely across the board. (See fig. 3, A.) When the groove, or dado, is not extended completely across, as illustrated in figure $3, \mathrm{~B}$, it is known as a stopped, or blind, dado. A shouldered dado (see fig. 3, C) differs from the


Figure 3. Dado joints.


Figure 4. Grooved joints.
plain dado in regard to the horizontal member, which is rabbeted to fit the dado. To counteract strain, a dado joint can be dovetailed, as shown in figure 3, D. Dovetailed dado joints can be constructed in the blind, or stopped, dado style.
$2-14$. Grooved joints have the groove, or plow as it is sometimes called, running with the grain of the wood. They are used extensively in panel construction. Figure 4 illustrates three methods in which a member can be inserted and fitted into a groove. Grooved joints can be plain or cut with a rabbet or tongue and can be joined with either glue or nails. However, when a panel is inserted and surrounded by a frame, the panel is made to fit snug but is not glued or nailed. This allows the panel to swell or shrink without breaking the frame. Grooved joints can be cut with the circular saw, using a dado head.
2-15. Miter joints. Miter joints are diagonal joints used extensively for frames and moldings. Shown in figure 5 , A , is a plain miter joint, which can be fastened with glue, dowels, wood screws, nails, or corrugated fasteners.
2-16. The mitered half lap joint (see fig. 5, B) is similar to the end lap joint and can be mitered to any desired angle. This type of joint can be fastened with, glue, nails, wood screws, or a combination of glue and metal fasteners. The splined miter is a method used to reinforce


Figure 5. Miter joints.


Figure 6. Open mortise and tenon joints.
a plain miter joint. Shown in figure 5, C, is one way of inserting a spline in a miter joint. A miter joint with a spline is usually fastened only with glue. Joints of this type, if made with hand tools, must have each piece marked. However, if power machinery is used, then only one layout is necessary to set up the machine.
2-17. Mortise and tenon joints. The mortise and tenon joint is one of the oldest and most used joints in cabinet construction. The numerous variations of this type of joint provide ample choices for framing doors, panels, tables, chairs, and cabinets. Of these variations, we will discuss four: open, through, blind, and haunched mortise and tenon joints.
a. Open mortise and tenon joints. These joints are sometimes called slip joints, as illustrated in figure 6. As you can see, the mortise is cut completely through the end of one piece, which is open on three sides, and the tenon is slipped into this open mortise. It is a strong joint and can be used on various types of frames. This type of mortise and tenon joint can be nailed, screwed, pegged, or glued for added strength. Another version of this type of joint is the bridle joint, illustrated in figure 7. However, in this version one member is joined in the center.
$b$. Through mortise and tenon joints. These


Figure 7. Bridle mortise and tenon joints.


Figure 8. Through mortise and tenon joints.
joints are those in which the mortise extends completely through one member. (See fig. 8.) When wedges are driven into the end of the tenon, it is called a wedged mortise and tenon joint, as illustrated in figure 9. For rough knockdown or outside furniture, the tenon can be cut longer than the depth of the mortise, with a hole drilled into the protruding part of the tenon and a wedge driven close to the outer face of the member which has the mortise cut into it. (See fig. 10.) When this is done, it is called a keyed mortise and tenon joint.
c. Blind mortise and tenon joints. These joints are those in which the mortise and tenon do not go completely through the mortise member, as shown in figure 11. They are used for doors, table legs, rails, and panels when it is desired that no part of the mortise or tenon be seen after the work is assembled.
d. Haunched mortise and tenon joints. These joints are used when a groove is cut into the framing where the mortise and tenon will fit. Figure 12 illustrates how the tenon is cut to fit into the groove after the tenon is inserted into the mortise. These are used often for framework where grooves are cut for panels.
2-18. When making a mortise and tenon joint, make sure the tenon has at least one shoulder where the greatest stress is anticipated. For additional strength on wide stock, provide a double


Figure 9. Wedged mortise and tenon joints.


Figure 10. Keyed mortise and tenon joints.
mortise and tenon. This eliminates a springy tenon and gives more shoulders which can rest against the sides which have the greatest stress. Before starting any mortise and tenon joints, be sure the stock is squared. To determine the proper thickness of a tenon, compare a with the member of which it is a part. The thickness should be approximately one-third the thickness of the member. The tenon should fit snugly but not bulge the sides of the mortise or have to be driven into it.
2-19. Dovetail joints. One of the strongest and neatest of all joints used in cabinetwork is the dovetail joint. For a corner joint, the dovetail is considered a mark of good workmanship, and a good fit can only be achieved by accurate and painstaking labor:
a. Single dovetail joints, like the one shown in figure 13, are used for drawing boards, tabletops. drawers, etc.
b. Finger, or box, dovetail joints are those which have square fingers and tails, as shown in


Figure 11. Blind mortise and tenon joints.


Figure 12. Haunched mortise and tenon joints.
figure 14. They are used primarily for corners of small boxes.
2-20. There are a few good rules to follow when making dovetail joints. In softwood, the tails should be wider than they are deep. For hardwood, the face (widest part) of the pins, or fingers, should be at least threefourths of the thickness of the wood.
2-21. It is not feasible to try to explain each step in laying out the fingers and tails of each type of dovetail joint, but it does take experience and patience to make them.
2-22. Dowel joints. Similar to the one shown in figure 15 , dowel joints are used extensively to reinforce boards that are glued edge to edge or otherwise butted together. The dowels are made of birch and the standard diameter sizes range from three-sixteenths to one inch. When you bore holes for the dowels, use a bit the same size as the dowel. The size of the dowel should be large enough to support the intended job but not so large as to weaken the work rather than strengthen it. The diameter should be approximately one-third to one-half the thickness of the stock on which it is being used, and all holes must be bored straight so that the dowel will not be forced into a bent position. It is good practice to


Figure 13. Single dovetail joints.


Figure 14. Finger or box dovetail joints.
cut the dowels one-eighth inch shorter than the combined depths of the holes and to point the end with coarse sandpaper or a knife. Dowel joints are always glued and are often used as a substitute for mortise and tenon joints. To allow air and excess glue to escape, cut a channel, or spiral, the full length of each dowel.
2-23. Corner joints. Corner joints, other than the mitered, butted, doweled, or dovetailed types, are used extensively in the construction of drawers for furniture and cabinets. A corner joint is shown figure 16. A. One member of the joint is rabbeted, with the other member fitted into the rabbet and fastened with glue, nails, screws, or a combination of glue and a metal fastener. The box corner joint, shown in figure 16 . B. consists of two members, one dadoed and the other rabbeted to fit the dado. This corner joint is pri-


Figure 15. Doweled joints.
marily used for the rear corners of drawers. The milled corner joint, shown in figure 16, C, consists of two members with milled grooves that are fisted together. This joint is used for the front corners of drawers, because it will resist the pull exerted on the front of the drawer.
$2-24$. By now you should have a good idea of both the wood used and the types of joints required to construct an article. With this information firmly in mind, let's take a look at the recommended procedures for constructing a wooden article.
2-25. Butt joints. The butt joint consists of two members that are fastened together end to end without overlap. This joint is often strengthened with a strap or straps.

## 3. Constructing Wooden Articles

3-1. You can probably remember the furniture in your grandmother's home when you were a youngster. Today, your grandmother's furniture would be considered as old fashioned as that


Figure 16. Corner joints.
of her grandparents, because designs and styles continue to change. Modern-day furniture designers try to create furniture that will give us convenience, comfort, and beauty.

3-2. Along with the many style changes, mass production methods and new materials have changed cabinet construction procedures. However, the basic forms of construction remain relatively the same as they were when our so-called antiques were made. Today, however, there are more "built-ins" in the form of cabinets, dressing tables, and workcounters.

3-3. This section will provide you with the knowledge you will require to construct and repair cabinets; it will also cover types of construction, which include frame, stool, and box. The procedure used in the selection of materials for the items covered in this section are also extremely important and should be followed as closely as possible.

3-4. The last two major topics in this section are the assembling of parts into complete units


Figure 17. Frame construction.
and final inspection of your finished work. Obviously, knowledge of construction fundamentals and of which materials should be selected-and how-is useless to you if you do not put your piece of work together adequately and carefully check your completed article.

3-5. You may have the opportunity to construct new cabinets, or your work may consist only of rebuilding damaged ones. Remember to apply what you have learned. By doing so, you will produce an article out of wood that will make you proud to say, "I made it."

3-6. Constructing Cabinets. Before you start constructing a cabinet, become familiar with all of the building details and prepare a bill of materials. As you study your drawing, you will find that the article to be constructed can be classified in one of three forms of cabinet construction. Regardless of the cabinets you make, use one of the three general forms (frame, stool, or box) or a combination of them. These three forms are the basis for all cabinet construction and can be adapted to fit any design; however. special methods must be used where intricate shape are desired.


Figure 18. Stool construction.

3-7. Frame construction. Frame construction consists of a grooved frame and a panel which fits into the groove. The framework adds strength because the grain of the wood runs lengthwise in both length and width. Frame construction is highly desirable, because it overcomes shrinkage and swelling and provides ample strength for the panel. Figure 17 illustrates a simple type of frame construction which is used extensively in cabinet construction. The various joints we have covered can be used to fasten the frame together.

3-8. Stool construction. As shown in figure 18, stool construction may be regarded as four frames put together to form a rectangle or square. It is used for tables, chairs, stands, and many types of cabinets. Mortise and tenon joints and dowel joints work well in stool construction. When fitting this type of construction with a top (for example, a tabletop), do not secure the top with glue, because wood shrinks across its width and the top must be able to give with the shrinking


Figure 19. Securing tops.
and swelling process. Figure 19 illustrates how a tabletop is secured in stool construction. If the rails and top shrink or swell, then the top can move without splitting.

3-9. Box construction. Box construction is used for articles made from solid wood, such as chests of drawers, cupboards, and bookcases. Any item built without a framework comes under the heading "box construction." Figure 20 illustrates one type of box construction. When using the box construction method, use rabbet, butt, mitered, or dovetail joints.

3-10. Selection of Materials. Now that we have discussed the three forms of cabinet construction, let's assume that we have our drawing, have checked all the details, and have made out our bill of materials. After this assumption, select the materials needed. When selecting materials for your project, bear in mind how and where the article will be used. Normally, you would not use the most expensive trade of ma-


Figure 20. Box construction.
terial for a cabinet which would be used for tools. How the article will be finished also has a bearing on the material you will use. If your article is to be painted, use material with minor defects that the paint will cover. If the article is to have a clear finish, then use a better grade of material.
3-11. After the material has been selected, you are ready to mill the stock and form it according to the blueprint or drawing.
3-12. Posts or legs used in stool type construction to support articles such as tables, chairs, and stools are often milled to decorative shapes, using the wood lathe. Refer to your blueprint for the size of the posts, and mill them to these specified sizes and shapes.
3-13. Fasten posts to the rails (see fig. 18) with mortise and tenon or dowel joints. If mortise and tenon joints are used, mortise each a side rail, while the other side receives one tenon of an end rail. If doweled joints are used, drill dowel holes on the sides in place of the mortises. When you make mortises or dowel holes, pair off your posts; in other words, label them left and right. As you do this, keep the best sides for the face sides. The face sides are those which will be seen when the article is assembled.
3-14. Rails, when assembled with posts, form a square or rectangular-shaped frame supported by the posts. Your blueprint will give you the dimensions for the length and width of the rails. The material you selected must be milled to these dimensions, using the jointer, planner, and table and cutoff saws. When you cut the rails to length, add the length of each tenon if mortise and tenon joints are used. Rails that are fitted with a panel, as shown in figure 21 , must have a groove cut on the pane edge of each rail.

3-15. Tops are used in all three forms of construction previously mentioned. Most often, they are large enough to require two or more pieces of stock to be glued together. The pieces can be joined with glue, using various types of joints, such as the tongue and groove. butt, and dowel. When selecting the material to be glued together, make the selection so that each piece has similar grain characteristics, and glue them so that the grain of each piece has some semblance of matching. We repeat, the method used to fasten the top to a cabinet or piece of furniture is an important consideration, because of the swelling and shrinking of the top.

3-16. In your job, you will probably install laminated plastics on some surfaces, especially cabinet tops. These plastics are manufactured in sheets, or rolls, ready for use; therefore, the only thing you have to do is to install them. Laminated plastics also come in different lengths, widths, and thicknesses. When you install this material, select the nearest size sheet, or roll, to the size you need for your particular job. After you select the correct size materials, be sure that both surfaces to be bonded are smooth, clean, and dry. Before you open the contact cement container, read the instructions on the container and follow them religiously, because the contents in the container are extremely flammable and harmful or fatal if swallowed. Shake the contact cement in the container vigorously before you use it. Open the container and, using a short-fibered


Figure 21. Rails fitted with panel.


Figure 22. Dado and mortises for box construction.
paint roller or a wide brush, spread the contact cement on the back of the laminated plastic top and on the surface to which you are going to apply the plastic. One full coat is usually enough on nonporous surfaces (back of laminated
materials or metal). Porous surfaces, such as wood, usually require two coats. When you use more than one coat of contact cement, allow it to dry thoroughly between coats. Be sure that you allow the contact cement to dry before you bond the laminated plastic top. Position the surfaces carefully, because no adjustment is possible after the contact cement films make contact Use scrap plastic, thin wood, metal strips, screen wire, or some other material to separate the contact cement films when you are positioning large pieces of laminated plastics. Apply pressure immediately and firmly with a 3-inch-wide roller or a rubber-faced hammer, working from the center to the edges over the entire surface. Only momentary pressure is needed, but the more pressure you apply within the limits of the bonded material, the stronger the bond will be. Trim and finish the job with a router as soon as you have completed the bonding process. You can knock the sharp edges off with a file if needed.
3-17. Sides, ends, or backs can be constructed with frame, stool, or box type construction or a combination of all three. For a combination of frame and stool construction, the sides would be paneled, as illustrated in figure 21. This requires an upper and lower rail with a groove cut into the rails and the posts. This type of construction is used primarily for desks. The plywood used for the panels should have the best side out for appearance sake. The same applies to the rails and posts. Be sure to cut the panels square and to remove the rough edges from around the panel. Smooth edges will help the panel slide into the groove easily. The groove must be large enough for the panel to slide into without its being driven.
3-18. In box type construction, the sides and ends are usually solid, similar to a top. Articles such as dressers and chests of drawers usually have the pieces which make up the ends and sides glued to make them wide enough. Check your drawing for the correct dimensions and allow a little extra so that you can mill the sides and ends to these dimensions after the pieces have been glued together. In this type of construction, the solid sides or ends are rabbeted on the back edge to receive the back, which is usually a piece of plywood. The rabbet is cut after the stock has been milled to the specified size. The interior side may also need dados or mortises cut to receive drawer rails or shelves, as shown in figure 22. These are cut to the correct size and depth after the milling process.
3-19. Frame type construction for sides, ends, or backs (see fig. 23) is made by assembling the various panels together according to your drawing. When you form the various parts, keep the best sides out for the rails and panels. Cut the


Figure 23. Panels for frame construction.
panels square, remove the rough edges, and be sure that the groove is large enough to receive the panel.
3-20. Doors used on cabinets and furniture can be classified as paneled or flush. Flush doors are usually made solid or with a frame covered with plywood. The frame for panel doors can be mortised and tenoned, doweled, lapped, or mitered. Your drawing will give you these details. The material for the framework is milled to the dimensions specified on your drawing. After the milling process, the rails and stiles are cut to length. The material for the framework is milled to the dimensions specified on your drawing. After the milling process, the rails and stiles are cut to length. The joint to be used is made along with a groove in each rail and stile for the panel. Sometimes a molding is cut on the inside edge of the frame near the panel. (See fig. 24.) Before cutting the molding, select the best side of the frame to show when the doors are closed. If any joint other than a miter joint is used, the molding must be mitered, as shown in figure 24. The hinged side of the door should be planed true with the top and bottom, and the lock side should have a slight angle to provide clearance
for opening. When you fit doors, remove the waste equally from all stiles and rails so that their width will stay balanced.
3-21. Flush doors for most cabinets are solid and are cut to the specified dimensions shown on your drawingmaking sure the tops, bottoms, and hinged sides are true.
$3-22$. Regardless of the type of door, the material selected must be straight and have good grain characteristics. If the material for the doors must be glued, match the grain characteristics. When you mill out material for more than one door-especially for double doors-do it all at one time.

3-23. If the article you make has drawers., there will usually be a detailed drawing of the drawer construction along with your blueprint. Check your plan for the thickness and width of the sides, front, and back of each drawer, and then mill the stock to these dimensions. When you start cutting the joints for a drawer, mark the pieces "sides," "fronts," and "backs," with the side pieces marked "lefts" and "rights." The reason for this is that bottoms of most drawers are inserted into grooves cut on the inside of each side, front, and back piece of drawer. This is clearly illustrated in figure 25. Plywood used for the bottom of the drawers should have the good side up so that it can be seen when the drawer is opened. It is essential to have all material cut square if the drawer is to fit well. Wood used for side and back pieces can have slight defects; however, they must be placed so that they cannot be seen from the inside when the drawer is open. Material for the drawer fronts


Figure 24. Molding on paneled door.


Figure 25. Detail for drawer construction.
should have a pleasing grain, and if more than one drawer is used, the grain characteristics should be similar on each front. This is true for a clear finish but is not important if your articles will be painted. Your drawing may call for a false front on a drawer (see fig. 25); if so, the material should be carefully selected and milled to the dimensions specified.
3-24. We have discussed the various parts you will have to mill in any one of your projects. Before you begin to assemble any of these pans into units, sand each part to remove toolmarks or other blemishes. The greater portion of the sanding should be completed before the parts are assembled, so that after an article is assembled, it needs only touchup sanding to have it ready for finishing.
3-25. Always sand with the grain-never across it-or you will mar the surface of the wood with scratches. Figure 26, A, illustrates the correct direction the sand block should move when you are sanding by hand. The other three parts of figure 26 show incorrect use of the sand
motion when sanding flat surfaces; instead, use long, even strokes.
3-26. If parts of the article you are making have irregular curves, sand them on the spindle part of the disk and spindle sander; however, if a sander is not available and the curves are long, sand by hand with a block. The block guards against rounding the edges. Sand inside curves by hand, using a stick with a rounded surface. (See fig. 27.)
3-27. For all lathe turnings, such as the posts for tables, stools, or the rungs of chairs, make sure each turning is sanded to a smooth surface before you begin any assembly work.


Figure 26. Direction for sand block.


Figure 27. Sanding curves.
3-28. Assuming that all individual parts have been sanded, you are ready to begin the first step in assembling your article into a unit.
3-29. Assembling the Parts into Unit. Assembly of the parts into a unit is done after all pieces have been milled to size, shaped, and sanded. Before you assemble the unit into its final form, make a preassembly check. Make sure that all pieces are ready to be assembled by checking each piece for dimensions, shape, and fit.
3-30. Dimensions are checked first to see that they correspond with those on the drawing. Each dimension must be exactly as long, wide, and thick as the drawing specifies.
3-31. Check shapes with a trysquare or T-bevel, making sure that all angles are correct. A
board may be of the specified dimensions, but if the angles are not properly measured according to the drawing, proper shape cannot be achieved.
3-32. Check your work by actually fitting one piece with its counterpart. After all, a board can be of correct dimensions and shape and still not fit properly. Obviously, then, all three-dimensions, shape, and fit-must be checked in a preassembly. Forming this habit will enable you to eliminate disappointment and save trouble, time, effort, and material.

3-33. Final Inspection. After the article has been assembled and all glue joints have been given time to dry, make a final check before applying the finish. This check will include: (1) all angles for proper cut and fit, (2) all joints for excessive glue, and (3) the entire surface for blemishes.
3-34. So far we have covered some of the woods used in cabinetwork, along with the types of joints used. We have also covered the procedure used to construct a wooden article. However, as a carpentry specialist, you will be required to repair or replace parts or sections of cabinets. If you remember how to select materials for constructing an article, you should not have any trouble selecting materials for the repairing or replacing of sections. Some of the items to check for are the kind of wood and grain characteristics; that is, the piece being replaced should have the same grain texture as the original and the color should be the same. You may also construct models, mockups, and patterns. These items will require a great deal of time and skill to construct. For this reason, detail drawings will be furnished to aid you in the construction. These items are usually fastened together with screws, dowel pins, and glue. The method of fastening these items together will be shown on the particular drawing you will be using.

## CHAPTER 2

## Prefabricated Buildings

TODAY, ARMY installations all over the world are using prefabricated buildings. These buildings are used mostly in localities where materials cannot be purchased locally. To save time and material, as well as to simplify erection, prefabricated buildings are standardized and available for use in Temperate, Tropic and Arctic regions.
2. As a carpentry specialist, you will be erecting prefabricated buildings. Like other structures, they must start with a good foundation. As we follow the procedures for the erection of one of these buildings, you will see that its construction is similar to that of any frame building.
3. Besides constructing buildings, prefabricated or otherwise, much of your time will be spent in keeping the buildings good repair. This is your work in maintenance and repair. Maintenance and repair work will challenge all of your building skill. You will inspect work done by others, some of it done a long time ago. Whether it was poorly done or is just wearing out so that it could require expensive repairs, you will be able to correct the trouble.
4. This chapter discusses erecting, maintaining, and repairing prefabricated buildings. It also discusses the requirements for constructing these buildings in Temperate, Tropic and Arctic regions.

## 4. Prefabricated Wooden Buildings

4-1. A prefabricated (prefab) wooden building is assembled of precut members. The joists, plates, studs, rafters, etc., are ready for assembly when they are delivered to the building site. In some cases the precut pieces may be partially assembled into standard size panels. These pane may be designed for use with a frame or they may be shaped in such a manner that the can be bolted together to form floors, walls, and roofs. Let's look at the construction of each type and the method of making repairs.

4-2. Paneled Prefabricated Buildings. A wood prefab that is assembled of panels will have an
outward appearance similar to the building shown in figure 28. The vertical strips used to cover the joints between the exterior wall panels distinguish this building as a panel type prefab. Look at figure 29 and then compare it with figure 28 . Figure 29 shows a partially assembled panel type prefab building, while figure 28 shows a completed building. Note the distinct lines made by the joints between the panels. Also, note in figure 29 that the framework is a part of the panel and that no separate framing is required.

4-3. Floors. The floor of a panel prefab building consists of flooring, joists, and girders. The boards are fastened to two or three joists to form a panel 4 feet wide and 8 feet long. The panels are placed on girders that are supported by posts or column. The panels are fastened in place with screws, and the joints between the panels are covered with a T-shaped metal strip. When plywood is used for the floor, the edges are protected by an H-shaped metal strip that is inserted between two panels. This strip also prevents dust and small objects from collecting in the joint. The panels are easily removed without damaging the edge or the metal strip. If you remove the end or side panels first.

4-4. Repairs can be made to individual floor panels in the same manner repairs are made to floors in other buildings. Also, the panels are interchangeable. Repaired or weak panels may be moved from the main path of traffic and exchanged with stronger panels located in other parts of the building.
$4-5$. There is a variety of floor panels for this type of building, but only one type should be used on your post. Some panels have a subfloor, insulation, or both. The type you use will depend on the particular use to which panels will be put and the climate in which they will be used. For example, flooring which must have heavy equipment must obviously be much stronger than that which will bear light equipment. Again, panels intended for use in hot, humid climates, such as are common in the Trop-


Figure 28. Prefabricated wooden building.


Figure 29. Prefabricated wooden panel building.
ics, are not, for this reason alone, suitable for use in the cold, low humidity, and dryness of the Arctic regions.

4-6. Walls. The panels used for the exterior walls consist of an exterior covering on a light frame. The covering may be fiberboard, plywood, or siding. The frame may be made of $1 \times 1,1 \times 2,11 / 2 \times 11 / 2-$, or $2 \times 2$-, or $2 \times 3$-inch material. Where insulation is required, a fiberous filler is installed between the exterior and interior coverings.

4-7. Doors and windows are assembled within a standard size $4 \times 6$-or $4 \times 8$-foot panel. The panels are interchangeable so that you can relocate windows, door, and solid sections as desired.
$4-8$. The wall panels are fastened in place with double-head scaffold nails or lag screws (bolts). Bolts are used to fasten two panels together along the vertical edge, as shown in figure 29. The fasteners used in this prefab can be easily removed without damaging the panels.

4-9. Repairs to wall panels usually consist of replacing $1 \times 2$ or $1 \times 4$ strips over the vertical joints and replacing wall coverings. The parts of insulated panels are assembled with glue and cannot be disassembled. You can repair a damaged area on a fiberboard covered panel by installing a fiberboard patch. Make the patch large enough so that you can fasten at least two edges of it to the framing members. Use a waterproof glue to fasten the other two edges. Glue may also be used to fasten small plywood or fiberboard patches if they cannot be fastened to the frame.
$4-10$. Sticking doors and windows are a problem in this type of building when the panels weaken or begin to warp. If normal adjustments do not correct the situation, you may have to strengthen the panel. Replacing the panel covering with new material will give it additional strength. Adding an interior covering on the panel will also help to reduce its flexibility and keep it straight.
$4-11$. The panel type prefab building does not have corner braces. As the building becomes older, it is weakened, and wind pressures may cause the building to lean or shift slightly and the windows and doors to bind. You can use guy wires at each corner to help prevent excessive shifting of the panels. The guy wire should be attached at the top of the corner panel or near the eave of the corner roof panel. The other end of the wire may be fastened to a stake, another prefab building, or a solid structure. These guy wires are a part of the original assembly when the prefab building is used in an area of strong prevailing winds.
4-12. Roof. Roof panels are built according to the climatic conditions that exist where the
building is to be used. A panel that consists of a $2 \times 2$-inch frame and fiberboard covering is sufficient for some areas. Heavier $2 \times 4$ frames are used with one inch decking or plywood where snow loads are expected. Insulated panels are used in both hot and cold climates.
4-13. Roof panels are fastened at the top of the exterior wall panels and at the ridge. A ridge board is placed between the upper end of two roof panels, and bolts are used to hold them together, as shown in figure 29. The side members (rafters) of the panel frame are bolted to adjoining panels.
4-14. Some roof panels have offset edges so that they fit together with a lap joint (see fig. 1 and pars. 2-9 and 2-10 in ch. 1) like shiplap lumber. This joint helps in lining up the panels and also helps in preventing leaks. The joints between the panels are sealed by covering them with a bitumen adhesive and cloth strip. Since expansion, contraction, or any other movement of the panels will damage the joint seal, you will probably have to renew or replace the seal every year or two. When extended usage is planned for the building, it is best to cover the entire roof with a layer of roll roofing. The roofing can be cut at the panel joints when the building is disassembled.
$4-15$. The roof on this panel prefab building is not as strong as standard wood construction. Therefore, you must be careful when you check or repair the roof panels. Make a temporary walkway by using a $1 \times 12$-inch board (with cleats) that will extend from the cave to the ridge. When you replace joint seals, start work at one end of the building and work toward the other to avoid walking on or near the repaired area. Don't walk back across the panels after completing your work. Unnecessary walking on the roof will break the joint seals, and you will have to replace them again.
4-16. Framed Prefabricated Buildings. The framed prefabricated wooden building is also known as a precut or light frame building. The framing is precut and prepared for assembly before it is delivered to the job site. The studs and rafters are widely spaced, as shown in figure 30. Let's take a look at the construction of this building.
4-17. Floors. The floor of the framed prefab building consists of flooring, joists, and girders. A combination subfloor and finish floor is used where a smooth finish or the additional insulating value is required. Girders extend around the perimeter and along the centerline of the building to support the joists. The joists are spaced 24 inches on-center with each length of joist spanning the distance between the girders. The


Figure 30. Prefabricated wooden frame building.
subfloor is laid either diagonally or perpendicular to the joists. The finish floor, if one is used, is laid lengthwise in the building. This type of building may also be used with a concrete slab floor.
4-18. Repairs to the floor consist of replacing individual pieces of flooring. Recovering with a layer of plywood may also be justified if the walls and roof are in good condition and the building can be used for several more years. Use a layer of 15 -pound felt between the layers of flooring to prevent dust from entering through the joints. Tile and linoleum are not used on wood floors if the floor is not reasonably solid and covered with a smooth underlayment.
4-19. Walls. The walls in the framed prefab consist of studs, plates, girts, and braces. The sidewalls have studs spaced 4 feet on-center and the end walls have studs at the corner and beside the door opening. Single top and bottom plates are used on the ends of the studs. The bottom, or sole plate, is placed on top of the subfloor and is fastened to the subfloor and joists as in platform construction. The girt is a horizontal member located at about the center height of the wall. It serves as a fastening surface for exterior wall coverings. Notice the horizontal gins in the end section in figure 30. These girts serve as a fastening surface for $4 \times 8$-foot sheets of plywood that are place horizontally.

The plywood may be placed either horizontally or vertically on the sidewall. Sheets placed horizontally help to brace the corners. Knee braces (see fig. 30) in end sections extend from the top plate at a corner to the bottom plate at the door opening. Set-in bracing (short lengths of $2 \times 4$ 's nailed between the studs at an angle) may be used in the sidewalls. Corner braces (see fig. 30) extend across a corner, from top plate to top plate, to hold the corner square.
$4-20$. The exterior wall covering may be 1 -inch sheathing, fiberboard and insulation panels, or plywood. Rigid insulation boards may be installed as a first covering, followed by a felt membrane, a layer of plywood, and a layer of roofing felt. The roofing felt protects the exterior wall from moisture and eliminates the need for painting. Thin wooden strips or wood lathe are used to hold the roofing felt in place.

4-21. Your work on the exterior walls consists of adding additional bracing, repairing windows and doors, and replacing sheathing and felt. Torn felt should be replaced and fastened with wood strips. Check the wood strips that hold the felt covering in place. Draw loose nails up tight to hold the strips firmly against the felt.
4-22. Roof. The roof consists of precut rafters, ceiling joists, and braces that can be assembled on the job to make a truss. The ceiling joist extends the full width of the building and
is fastened to the lower ends of the rafters. The lower end of the rafter is seated on the top plate of the sidewalls, as shown in figure 30. The joint made by the joist and rafter is very important The joist helps to prevent the lower end of the rafter and the top of the wall from moving outward. Perhaps you have noticed buildings where the sidewalls bowed outward and the ridge sagged in the middle. This is possible when the rafter and top plate pull loose from the ceiling joist. The load on the rafter forces the upper part of the wall outward, and the ridge line becomes lower. This also happens in permanent structures but is most common in light frames, where fewer and lighter ceiling joist are used.
4-23. The rafter spacing is the same as stud spacing, 4 -foot on-center. A knee brace fastened to the rafter, ceiling joist, and wall stud is used every 12 or 16 feet for the length of the building. One-inch sheathing boards are used for the roof deck. Roll roofing is used as the roof covering. There is no roof overhang at the eave or gable, and the roof covering is lapped down the side walls to prevent leaks along the edge of the roof.
4-24. The interior of the light frame prefab is usually open, and leaks are easily located by a visual inspection. When a ceiling and partitions are used in the building, you must locate leaks by entering the attic or going on the roof. Don't walk around on the roof any more than is absolutely necessary. Instead, you should locate the leak by entering the attic and checking for water marks. Then go on the roof and make the repair. Use a $1 \times 12$ for a walkway and avoid walking between the rafters. The wide spacing of the rafters allows the decking to sag when you walk on it Of course, old, brittle roofing may be broken beyond repair, and the only feasible way to fix leaks may be to put on new rolled roofing.
4-25. Most repair work on the framed prefab building is similar to the repair work on a standard frame structure. Just keep in mind that this is a light frame building. Repairs to the frame usually consist of nailing splices beside the faulty member rather than attempting to replace the frame.
4-26. Now that we have discussed wooden prefab buildings, let's see how prefabricated metal buildings are assembled and repaired.

## 5. Prefabricated Metal Buildings

5-1. The prefabricated metal buildings in use on some military installations are constructed of many different types of metal. However, galvanized sheet metal and aluminum are the most common metals used in prefab buildings. Most metal prefabs are referred to as portable buildings, because they are easy to disassemble and
relocate. When they are no longer needed in one area, they can be shipped to an area where they can serve a useful function. We will concentrate our attention upon two metal buildings that are frequently used: the advanced base hut and the light steel frame buildings.

5-2. Advanced Base Hut. The advanced base hut is usually referred to as a "quonset hut". The standard size is 20 by 48 feet. However, you will find that some of them are two or three times as long as this. They are planned so that they can be assembled in sections 8 -foot lengths to make a building $8,16,28$, etc., feet long. They are easily adapted for quarters, office space, workshops, training areas, supply storage, or any other function that can be placed within them. Nails, screws, and bolts used in the assembly of the quonset hut are easily removed when repair or disassembly of the unit is required. The primary parts of this hut are the floor and wall, so let's see how they are put together.

5-3. Floors. The floor of the hut consists of a metal frame with a plywood covering. The main support of the building is provided by five girders that run the length of the building. These I-shaped girders are spaced approximately 5 feet 1 inch on-center to provide support for the floor joists. The girder, as we called it in the wooden building, is referred to as an I-beam (its shape) or joist sill (its function) in metal construction. Joists spaced 2 feet on-center are placed on, and perpendicular to, the joist sills, as shown in figure 31. A U-shaped channel plate fastened to


Figure 31. Sill and joist assembly.


Figure 32. Joint and spline.
the top of the joists borders the floor and serves as a fastening surface for the end wall studs and arch ribs. Figure 32 shows the arch ribs connected to the channel plate. This channel plate is comparable to the bottom plate used in a wood frame building.

5-4. The floor is made of $4 \times 8$-foot sheets of plywood. Twelve sheets of plywood are placed side by side on the joist along each sidewall to cover the length of a 48 -foot building. The two rows of sheets are butted against the channel plates of the side walls. Six sheets of plywood placed end to end fill the remaining 4 feet in the center of the building. The actual floor width between the channel plates is 20 feet 1 inch, or 1 inch more than the 2 lengths and 1 width of the plywood sheets used as the floor covering. This 1 -inch space is divided between the two center joints to allow a $1 / 2$-inch crack between the ends of the side sheets and the edge of the center sheets. These joints are protected by the H -shaped metal floor splines, as shown in figure 33. This spline protects the edge of the plywood, keeps the joint clean, and allows for movement of the plywood sheets. The wide joint and the slip-on spline make it easy for you to remove the center sheets, which are subjected to the most wear. Only 3 or 4 nails are used to fasten a sheet into place. Sixpenny common nails are driven through the plywood and into the groove in the joist. Notice the groove or separation along the top and bottom of the joist shown in figure 31.

5-5. Walls. The end walls of the hut consist of metal studs, channel plate, window and door headers, and corrugated sheet metal siding. The studs set in the channel are fastened into place with roundhead sheet metal screws. One screw is placed through the inside edge of the channel, and another is placed through the outside edge of the channel. There are 4 screw holes in the end of the stud, but it is not necessary to fasten through each of them except to splice two lengths
of channel plate. Alternate holes, inside right and outside left or inside left and outside right, are normally used. To remove a stud, you must gain access to both the inside and outside screws. Figure 34 shows the location of the framing members in an end section. The window and door headers consist of channels that are fastened between the studs. They serve as a fastening point for siding, interior finish, and the window or door frame.

5-6. The sidewalls and roof are framed with arch ribs, purlins, and window headers. The arch ribs are spaced 4 feet on-center and extend from the channel to the ridge or highest point in the building. Two arch ribs are spliced at the peak with splice plates and bolts to form a complete arch. The bottom of each arch rib is fastened in the channel plate with sheet metal screws. Headers for the side windows are fastened between arch ribs. Four purlins are fastened near the top of the arch, as shown in figure 34.

5-7. Corrugated sheet metal is used to cover the arch. It is fastened horizontally on the side of the arch to cover the area from the lowest purlin to the joist sill. The curved sheets that cover the top of the arch are placed across the purlins. Vents and roof jacks are built into the rounded sheets that are used on the purlins. These sheets are the same width and length as the others and are interchangeable with them so you can relocate the vents if necessary.

5-8. Repairs to the exterior walls usually consist of replacing the seals or retightening the fasteners around the doors and windows. Figure 35 shows the shape of a rubber seal that is used to prevent leaks at a joint made by corrugated metal and a flat surface.

5-9. When insulation is used in the walls of the quonset hut, it is fastened to wooden strips that are placed between the arch ribs. The interior covering consists of plywood panels, $1 / 2$-inch thick, that are easily bent to fit the inside surface of the arch rib. An H-shaped spline is used along the sides of the plywood, and a wood strip is used to cover horizontal joints. Figure


Figure 33. Splicing channel plates.


Figure 34. End wall framing.

36 shows the complete assembly as it appears at the bottom of the wall. Be very careful when you remove an inside panel. If you should loosen the adjoining panels, they may spring from the ribs and you will have more than a handful of panels at one time. Always have another worker with you when you remove the panels or corrugated sheet metal, because it is a two-man job.
5-10. Light-Steel Frame Buildings. The light steel frame building is a common building or many bases. It is usually a special-purpose build-

ing that has been put up to support one special function. The light-steel frame building is made in different sizes, with different types of light-steel frames. The frame shown in figure 37 is similar to the frames used for buildings of 20 -to 50 -foot width, with bays 12,16 , or 20 feet long, and exterior walls that are 10,12 , or 14 feet high. A bay is the distance between columns along the side walls. A bay is the basic assembly, and a building consists of one or more bays. There is no limit to the number of bays that can be placed end-to-end to form a building. The frame shown in figure 37 is often referred to as open-bay construction, because the are no supports needed in the bay. The area between the side walls is open, unobstructed space.
5-11. Framing. The end wall frame is assembled of prefabricated parts. Each piece of metal is shaped and drilled for assembly before it leaves the factor. The frame is set up on a concrete foundation or slab. Anchor bolts are placed in the concrete to provide solid fasteners far the columns. Because the column is a vertical member, a channel type base plate is used to secure the column in place. The anchor bolts hold the base plate, and the base plate is bolted to the base of the column

Figure 35. Rubber seal.


Figure 36. Exterior wall assembly.
5-12. Roof beams, extending from the top of the column to the peak of the roof, form the main supports for the roof. The roof beams follow the path of the common rafter and are joined at the ridge with splice plates and bolts. Splice plates are placed on the top. bottom, and sides of the roof beams at the ridge.
$5-13$. End wall posts, or door posts, extend from the foundation to the roof beam and are bolted in place at each end. Door framing is attached to the door posts. The door header is fastened to the door header girt, which extends between the door posts. A girt that extends from column to column across the end of the bay may also be used to secure the door header and tracks when a sliding door is used. A base angle ( $90^{\circ}$ angle) is fastened to the foundation between the columns to provide a fastening surface for the vertical siding. The top of the siding is fastened to an angle that is attached to the roof beam. The eave strut provides a surface for fastening the top of the sidewall panels. The intermediate fastening surfaces are provided by horizontal girts on both end and side walls.
$5-14$. The sag rods, shown in figure 37, are used to prevent the girts from sagging between the columns. Sag rods are also used in the roof frame to help hold the purlins in line. The rods may be thin channels that clip in place and are not adjustable, or they may be threaded rods that can be adjusted. These rods should be kept tight, but overtightening will force the girts out of line and pull the screws loose in the siding.
$5-15$. Angles are installed vertically to frame louvers and windows. The angles for the louver form a frame in the upper part of the gable and provide a fastening surface for the louver frame


Figure 37. Prefabricated steel building.


Figure 38. Deep V-wall panel.
and the siding. Angles also fit between the Z-shaped wall girts to provide a fastening surface for the window frame.
$5-16$. Notice the brace rods in figure 37. These brace rods are used to square the end bays of the building. The brace rods in the wall run diagonally from the top of one column to the bottom of the adjoining column. The rods pass through slots in the columns, and a bevel washer, flat washer, and nut are used on the ends of the rods. Turnbuckles are used at an intermediate point in the rod to provide for adjustment. The turnbuckle has a right-hand thread in one end and a left-hand thread in the other so that it can be tightened or loosened on each section of the rod at the same time. Adjustments may also be made by tightening or loosening the nuts on the end of the rods. When you tighten one rod, you must loosen the one that crosses it to provide for a shift in the framing. The brace rods between the roof beams serve to hold the bay square and must be considered if you adjust the brace rods enough to cause a shift in the frame.
$5-17$. Wall and roof coverings. The metal wall covering may be a panel that contains a
layer of insulation or it may be some other type of material. Figure 38 shows two insulated panels joined together with a vertical joint. With this type of installation, the T-bar is secured to the wall girts, and the metal weather seal is placed over the T-bar to provide a durable, moisture-proof joint. The insulation of the first panel butts against the weather seal, and the metal siding laps over the joint. The next panel has the insulation butted against the weather seal, and the metal siding laps over the previous sheet to form a lap joint of $11 / 2$ laps. A mastic seal is applied to the area of the lap before the second panel is installed. This mastic seal is permanent and should never have to be replaced, except when the panel is replaced or the building in disassembled and relocated.
$5-18$. Another type of ribbed wall panel that has an insulated core is shown in figure 39. This panel has vinyl joint seals inserted along the edges. The vertical edges fit together as do those of tongue and groove boards to make a weatherproof joint.
$5-19$. The lap joint and the vinyl seal joint are the two common methods used to make weatherproof vertical joints in exterior walls. The mastic seal used in the lap joint of insulated panels is also used with sheetmetal siding and roofing. The mastic comes in strips with a moisture-proof paper backing that looks like masking tape. The strips are rolled like tape for easy handling. You unroll the tape and apply the mastic and backing on the joint area. Leave the paper backing on the mastic until you are ready to install the next panel. Just peel the paper off to expose the clean layer of mastic when you are ready to cover the joint. This mastic is also required in the horizontal joints of roof panels to prevent water from being blown under the top panel.
5-20. When horizontal joints are required in


Figure 39. Ribbed wall panel.


Figure 40. End lap of exterior wall panel.
a wall, they are formed by lapping an upper panel over a lower panel, as shown in Figure 40. A Z-shaped bar is used at the girt where the splice is made. The metal covering of the lower panel extends above the Z-bar, and the metal covering of the upper panel laps over the lower panel to form a 6-inch lap joint.
5-21. A solid rubber seal is used to make a waterproof joint where ribbed panels overlap a smooth surface. Figure 41 (A, B, C, and D) shows the shape of the rubber seals used with roof and wall galvanized sheet metal panels (A), aluminum ribbed panels (B), asbestos-cement panels (C), and corrugated glass panels (D). The seals are placed under the panel to prevent moisture from getting between the panel and the smooth surface.
$5-22$. Special rubber seals may also be used at eave struts, as shown in figure 42. Metal closure strips may be needed, in addition to the

rubber seals, to close the space between the ribs of the panel.
5-23. Figure 42 also illustrates the type of information you can get from the master file of drawings in the drafting section. This drawing shows a side view of each part of the eave assembly. Each part is identified by shape, name, size, or type of material. Check the drawing file to locate hidden parts of the building so that you can plan your work accordingly.
5-24. Sheet metal siding is fastened to the girts, base angle, and eave strut or gable angle with self tapping sheetmetal screw. When fastening steel to steel, you can use steel screws or


Figure 42. Eave assembly.
cadmium coated, rust resistant screws. These coated screws are also used to fasten aluminum panels to steel frames.

5-25. When aluminum panels are placed on a steel frame, some type of separator must be used between the different metals. This separator is usually provided by coating the steel (area of contact) with an asphalt paint. You can also use a layer of waterproof paper or asphalt saturated felt as the separator.
5-26. In metal construction, it is frequently impossible to prevent the contact of dissimilar metals. This contact may result in the corrosion of one of the metals and the protection from

Figure 41. Rubber seals.
corrosion of the other metal. This is the so-called galvanic action or electrolysis that occurs when metals of different position in the electromotive series are in direct contact in the presence of an electrolyte. The common metals used in construction are listed in the electromotive series in the following order: 1-aluminum, 2-zinc, 3-iron 4-tin, 5-lead, 6-copper. When any two metals in this list are in contact in the presence of an electrolyte, the one with the lowest number is corroded. Also, the farther the separation in the list, the greater the corrosion will be. Thus with iron and copper contact in the presence of water, the iron would be corroded more than lead in contact with copper under similar any condition. Any means that separates dissimilar metals will protect against this action.
5-27. Perhaps you are beginning to wonder how dissimilar metals can be used in layers as a single sheet of metal. Let's take lead-coated copper as an example. The lead coating on the copper is of a lower number value in the electromotive series and is affected by the corrosion while the copper is being protected from corrosion. Also, the two metals are consecutive (5 and 6) in the series, and a minimum amount of corrosion is anticipated. The purpose of the lead coating is to protect the copper; in this case, it protects it in two ways, physically and chemically.
5-28. Doors and windows. We have discussed the location and fastening of door post and window angles. Now let's look at the main units.
5-29. Metal doors are preferred for prefabricated metal buildings. There are two types of these doors. One type has an angle iron, steel, or aluminum frame and a single metal covering that serves as the exterior surface. The frame is exposed on the inside of the building. The other type of metal door has a metal frame with a metal covering on each side. This door is built


Figure 43. Weatherstrip installation.


Figure 44. Glazing metal sash.
like a flush door and may have either a hollow or insulated core.
5-30. Metal doors seldom need repairing and maintenance usually consists of tightening the bolts that hold the lock in place, or tightening or replacing screws in the hinges and weatherstrip. Occupants usually correct the problem of loose screws and bolts, but you will probably be called on to supply new or larger screws. When retightening of screws is required at frequent intervals, you should substitute a screw that is one size larger than the old one or relocate the hinge and make new screw holes. The weatherstrip on the jamb causes very little trouble, but the strip along the bottom of the door may get damaged or become loose. This threshold strip extends beyond the lower edge of the door and hooks into a groove in the threshold as shown in figure 43. Make sure that the strip is adjusted so that it fits into the groove. This type of threshold and weatherstrip is common in exterior doors that swing over a concrete floor.
5-31. Window maintenance consist of tightening the mounting screws in the frame, side panels, and the U-shaped drip channel (gutter). Replacing glass in a metal sash is a little different than working with a wood sash. When you remove the old putty from the sash, you must locate and save the metal glazing clips. Look at the glazing clip shown in figure 44 . This clip fits between the edge of the glass and the frame. One end of the clip fits into a hole in the frame, and the other end hooks over the edge of the glass. Allow for the thickness of these clips when you cut the new glass. Place a bed of putty on the frame and press the new glass gently against it. Use a screwdriver to install the glazing clips. The clips will hold the glass in place while you are applying the beveled layer of putty around the edge of the glass.

5-32. Any other problems you encounter when repairing prefabricated buildings can be solved by using the information you have learned about other types of buildings. We will therefore move on to the discussion of construction of prefabricated buildings for temperate, tropic, and arctic regions.

## 6. Construction of Prefabricated Buildings for Temperate, Tropic, and Arctic Regions

6-1. Prefabricated buildings are constructed and standardized for use in Temperate, Tropic, and Arctic regions. This is done to save time and material, as well as to simplify erection.

6-2. Construction for Temperate Regions. All of the prefabricated buildings discussed in sections 1 and 2 in this chapter were constructed for use in temperate regions. No special factors are needed for standard prefab buildings for temperate climates. The construction plans for a temperate climate specify minimum requirements. The floors can be earth, wood, or concrete, depending upon the purpose of the building.

6-3. Construction for Tropic Regions. The floor plans for prefabricated buildings for tropical climates are made to provide as much air circulation as possible. Most buildings designed for tropical climates have wood floors, which are
raised above the ground to insure dryness and to prevent mildew and the entrance of insects. The use of continuous screened openings, such as ridge vents and floor level vents, provides as much ventilation as possible consistent with the shelter that is required. Overhanging eaves shield these openings from the direct rays of the sun and afford some protection during rainstorms. For protection against termites, all wood members touching ground surfaces are covered with a metal shield. Standard prefabricated buildings are designed to resist normal wind forces. However, in areas where high wind velocities occur, all buildings should be anchored by cables or guys rather than by modifying the buildings themselves.

6-4. Construction for Arctic Regions. The extremes of Arctic weather will require modification of the standard prefabricated building normally used in a temperate climate. Two major modifications include the use of floors that are of double thickness and of walls and roofs that are insulated. Heat is supplied by individual stoves or heaters. The door and window openings are small-only large enough to provide adequate ventilation and passage. The roof framing is designed for snow loads of 15 pounds per square foot. When it is impossible to clear heavier snow from these roofs, the roof framing must be strengthened.

## CHAPTER 3

## Heavy Timber Construction

THE FOOD YOU EAT in the mess hall, the items you buy at the PX, and the clothes you purchase at the sales store-all these were at one time shipped to and stored in a warehouse. To make the handling of these items by warehouse personnel easier, most warehouses are constructed with loading docks or platforms. It is important that these warehouse loading docks or platforms be well constructed and maintained to prevent their breakdown. You, as an Army carpenter, will be responsible for the maintenance of these facilities, and this chapter will help you do the job.
2. This chapter also deals with waterfront structures. Naturally, we think of the Navy when we think of wharves and piers. Yet there are places where Army personnel maintain such facilities.
3. A good example of this is our port facilities in Vietnam. These facilities were expanded at first but most of them have been completely rebuilt to accommodate all the services. Some of these facilities may be used by the Navy for its tankers and supply ships which bring in fuel, food and other necessary supplies. The facilities engineer, or an engineer unit under Army command, is responsible for all maintenance and repair work to keep facilities in operating condition. This is only one example-there are many others-where you may have the opportunity to work on wharves or piers. Some may be large, like the example just given, or they may be small, only large enough to accommodate small boats. This chapter discusses the fundamental principles of constructing and maintaining warehouse loading docks and waterfront structures.

## 7. Warehouse Loading Docks

7-1. Practically every item we see around us was at one time packed and crated or stored in a warehouse. Some of these items are large, heavy, and very difficult to handle. To make them easier to handle and store, warehouses have been
constructed with heavy-duty loading docks. Some docks are constructed with inclined ramps (see fig. 45) to accommodate small loading and unloading equipment. Others are built upright for direct loading or unloading of trucks and rail cars. No matter what type loading dock is provided, it must be strong enough to withstand the impacts of loaded trucks and movements of loading equipment. To make sure these structures can withstand this abuse, they must be periodically inspected and adequately maintained.

7-2. Construction Features. This section contains information on the construction features, general maintenance problems, and corrective repairs of warehouse loading docks. There are two important factors to consider when planning loading docks: the size of cargo to be handled and the weight to be carried by the platform. For example, if only small, light items of cargo will be stored in the warehouse, the dimension of the loading dock may be small. But if the platform is to carry the weight of cargo and transporting vehicles (forklifts, tugs, and trucks), it must be built much larger and stronger than if it is to


Figure 45. Warehouse loading dock.
carry only the weight of cargo. For this reason, we will discuss the different types of foundations and how they should be constructed to adequately support the intended loads.

7-3. Foundations. Normally, loading dock foundations are constructed of either wood and masonry piers or columns. These columns or piers must be spaced according to the weight they are to carry. In most cases, however, they are spaced from 6 to 10 feet apart.
$7-4$. If the earth on which the foundation is to rest has low supporting strength. of if the loads are expected to be extremely heavy, the foundation should be constructed as a solid, reinforced concrete wall.

7-5. Sills. Sills consist of single heavy timbers or buildups of two or more timbers. Sill sizes will be determined by the intended loads to be carried and the distance between piers. Consequently, sills are used with pier type foundations and are placed directly on the pier. If sills are correctly placed, they will surround the perimeter of the dock. After the sills are tied to the piers, girders (if needed) are placed.

7-6. Girders. Girders are used as interior foundation walls to support the inner ends of floor joists. However, they will not be needed if joists safely span the distance from sill to sill. If girders are not used, joists should be placed directly on the sills.

7-7. Joists. Joists are the lighter pieces which make up the body of the floor fame. We don't mean that they are actually light in weight but that they are light in comparison with the other framing members. Joists are usually 3 inches thick, but thicknesses will vary to suit the construction details. They are usually spaced from 16 to 24 inches on-center. However, if this spacing is too wide to support the intended load.


Figure 46. Joist contruction
you should use a heavier joist rather than narrow the spacing. When joists are being placed, make sure that the greatest bearing surface is used. In other words, place them with the crown edge up.
Placing the crown edge up will tend to counteract the bending force imposed on the joist. After each joist is placed, it should be secured. as indicated in figure 46.

7-8. Bracing. If we expect loading docks to adequately support the loads placed up on them and to withstand the abuse from vehicles, we must reinforce them with some type of bracing.
This bracing must be properly designed and placed to give the support desired.

7-9. If wooden piers are used as a foundation, they should be braced to each other with diagonal braces, as shown 'in figure 45. If wooden girders are used in the platform construction, a truss brace should be placed under each girder. If the platform is to support extremely heavy loads.
bracing should be secured with bolts. On the other hand, light load carrying platform bracing may be secured with spikes. No matter what method you use to secure the bracing, make sure that the materials used have good bearing qualities.
7-10. Decking. Decking. or flooring. used on loading docks should be at least 3 inches thick and laid perpendicular to the joists. All joints must be staggered and joined directly over a joist. After decking has been correctly fitted and placed, it should be secured with large spikes.
7-11. After the platform has been erected and properly floored, it should be protected from unnecessary bumps and scrapes. This protection is supplied by fender boards.
7-12. Fender boards. Fender boards are heavy timbers placed in front of the loading dock to protect it from vehicle contact damage. They are secured to the sills with spikes or bolts, depending upon the size of the timbers. If adequately placed, fender boards form a solid, continuous row of timbers.
7-13. General Maintenance Problems. Your job is not complete when you finish the construction of the warehouse loading dock. There is a continual maintenance problem, and it is your job to perform this maintenance. Aside from original flaws in materials, structural sealing, weathering, and normal wear and tear, deterioration presents our most extensive maintenance problem. Deterioration is cause by decay (fungi action), rust (chemical action), and insects (termites and marine borers).
7-14. Decay and its prevention. Unpainted or untreated wooden members are more subject to decay than any of the other construction materials. Warm, humid climates or seasonal periods
of high humidity (moisture content) provide excellent conditions for the growth of decay-causing fungi. Wooden members which are near, touching or set in damp ground are especially subjected to fungi growth. To prevent or minimize this fungi growth is our job if we expect maximum service from our wooden structures.
7-15. Exposed wooden members should be panted or soaked with creosote Whenever possible, wooden members should be constructed on some type of masonry foundation and above ground level. This holds true for treated as well as untreated timber.
7-16. Rust and its prevention. Iron and steel components will rust after prolonged periods of exposure to rainfall, snow, or moisture-laden air.
This is particularly true If the metals are not painted or otherwise treated against this type of reaction. Paint metals which are not inherently resistant or otherwise protected from rust.
7-17. Insects and their elimination. Where wooden structures are concerned, termites present a major inspection and repair problem. If these insects establish themselves in or beneath a structure, they construct earthlike shelter tubes which lead to the wood portion of the structure. These tubes may enter the wood from below or through cracks between brick or hollow tile.
A well-established termite colony can cause major structural damage in a very short while. For this reason, we must provide an adequate insect control program.
7-18. Some of the basic methods used to discourage termite infiltration are soil treatment, wood treatment, termite shields, not allowing wood to come in contact with the ground, and preservative treatment of supporting wood piles. Special detail in foundation construction will also discourage termite activity. However, if termite colonies do accumulate, consult your entomologist.
7-19. Corrective Repairs. These maintenance problems can and do create serious situations; however, if they are adequately approached and treated, the seriousness will be reduced. Proper inspection and maintenance methods will prolong the useful life of all structures.
7-20. To determine the best repair method depends upon the use of the structure, extent of damage, life expectancy, and its possible future use. These are very important factors, but why repair are needed is also important. The extent of damage will depend upon why or how the structure failed. To determine this we must know the causes for failure.
$7-21$. Premature failure of materials and various components may be caused by one of the following reasons:
a. Defective materials or structural components.
b. Incorrect installation or application.
c. Failure of related, connected, or adjacent component.
d. Faulty design.
e. Unusual or extreme climatic conditions, exceeding the design specifications for which the material or structural part was de.
signed.
f. Use exceeding the limitations of original de sign.
g. Use other than that for which the structure was designed.
7-22. If failures occur during the normal life expectancy of the structure, they should be carefully investigated and the defects corrected before any superficial repair is done. Unless the causes of these failures are identifiable or corrective procedures are standard, the installations engineer should be consulted $r$ adequate corrective measures.

## 8. Waterfront Structures

8-1. The fundamental principles and practices presented here are meant to assist you in the preservation of waterfront structures in the most economical manner. These fundamentals are intended to insure that facilities are maintained in such a condition that they can be used throughout their planned life. These structures would be maintained by an Army carpenter, if that carpenter was assigned to one of the waterfront installations maintained by the Army.

8-2 If a carpenter is expected to maintain waterfront structures, he must know what these structures are, the terms used in working with them, what damages them, the preventive maintenance methods, and the inspection and repair procedures used in conjunction with them. Let's discuss these methods and procedures.

8-3. Generally speaking, waterfront structures include wharves, quays, pier bulkheads, retaining walls, breakwaters, jetties, groins, and other supporting features. However, wharves, quays, piers bulkheads, and retaining walls are the only structure that we will be working with; so we will center our discussions around them. This section covers the construction features, special tools needed, general maintenance problems, corrective repairs, preventive maintenance measures, and safety measures for waterfront structures.

8-4. Wharves and quays are structures constructed parallel or approximately parallel to the shoreline which provide berthing or docking for seagoing vessels. These structures are virtually
the same and, from this point, will be referred to as wharves.

8-5. Piers are structures constructed perpendicular or approximately perpendicular to the shoreline which provide berths and slips to tie up, or moor, vessels on either side.

8-6 Bulkheads and retaining walls are structures constructed approximately parallel to the shore to protect the shore from soil erosion.

8-7. Wharves and pier must be maintained to the extent necessary to insure safe and efficient use for berthing, servicing, repairing, and overhauling seagoing vessels. The principal jobs of maintaining these structures are as follows:
a. Replacement of broken or damaged fender piles.
$b$. Replacement of deteriorated wood decks and stringers and other timbers affected by attacks of marine borers.
c. Replacement of corroded and deteriorated pipe.
d. Removing scale and repainting steel member.
e. Repairs to pavement deck surfacing.
$8-8$. There are several terms specifically applicable to the maintenance and repair of waterfront structures and harbor facilities. Some of these terms and their definitions are as follows:

BITT--A double post to which vessels are moored, or tied.

BOLLARD--A single post to which vessels are moored, or tied.

CHOCK--A block with two horn-shaped converging arms used t guide lines. It is sometimes called a fairlead. A chock is also considered a horizontal timber fitted between two vertical fender or fender piles.

CLEAT--A horizontal device with two diverging arms to which mooring lines from vessels are fastened.

DOCKS--Sheltered basins in which vessels are berthed or docked.

DOLPHIN--Usually a cluster of piles placed in the water for mooring vessels or keeping them away from structures, shoals, or shores.

FENDER--A structural feature used to lessen the shock or minimize the damage when vessels come in contact with shore structures.

MOORING--Facilities to which vessels are safely secured. They include mooring platforms or islands, dolphins, piers, wharves, etc.

PIERHEAD LINE--An established harbor line marking the permissible limit of pier construction. This is usually limited to open type construction.

QUAY WALL--A wall along the shore to retain the soil. It may be used as a wharf: however.
when used as a wharf. it becomes a quay. or marginal wharf.

SEAWALL--A wall along the shore to prevent encroachment (enter by gradual steps) by the sea. But if the wall is used as a wharf, it is not called a seawall.

SLIP-The area between two piers.
8-9. Wharves and piers are constructed from timber. concrete, steel, or a combination of these materials. Usually, timber is the most widely used, because it is more economical, lighter, and easier to work. However, the serviceable life of timber is shorter than the others, because it is subject to decay by fungi action and deterioration by insect infestation. Its life can be extended by protecting it with a preservative. For the most part, creosote treatments are very effective against these actions.
$8-10$. Before any waterfront structure is constructed, there are many factors to be considered. Among these factors are:
a. The sizes of vessels to be accommodated.
$b$. The amount of cargo to be handled.
c. The loads (dead and live) to be carried on the structure.
d. The depth of the water.
$e$. The variations in tide.
8-11. Construction Features. To make sure that our wharf or pier can absorb the abuse, we must use the type of construction components recommended.
$8-12$. Pilings. There are three types of piles used for wharf and pier construction: bearing pile, fender pile, and mooring pile. If timber is used as piling, it must be treated with creosote or some other preservative compound to protect it from fungi and marine borer attacks.
$8-13$. Bearing piles support the wharf or pier framework and decking. The piles should be straight and measure at least 6 inches across the top, 18 inches across the butt (bottom), and from 60 to 80 feet in length. The length varies according to the depth of the water and condition of the bottom. These bearing pies should be spaced from 6 to 10 feet apart, center to center, in one direction and 5 feet apart, center to center, in the other direction.
$8-14$. The force of a moving ship (coming in direct contact with bearing piles) is sufficient to collapse a wharf it the pilings are not protected. To furnish this protection and to absorb the initial shock, fender piles are placed approximately $21 / 4$ feet out from the centerline of the outside row of bearing piles. These piles are placed approximately 18 feet apart and along the sides where the ships dock.


Figure 47. Logger's tools.
8-15. The third type of piles, mooring, is placed in line with the outside row of bearing piles, spaced
approximately 30 feet apart, and braced along the outside row of bearing pies.
These piles usually extend about 4 feet above the floor, or deck, of the platform. The 4 -foot extension provides ample space to secure mooring lines.
8-16. Caps and girders. Caps are large timbers which are placed on top of the bearing piles to support pier girders. They are secured to the piles with driftpins (steel pins which hold timbers together). Pier girders ret on the caps and are secured to the caps with driftpins. Girders for wharf construction, however, may rest directly on the bearing piles. These girder are also secured with driftpins.
8-17. Joists. Joists are smaller timbers (like 8 xl 2 -inch) to which the flooring, or decking, is secured. They rest directly on the girders and are secured to them with driftpins. Joists are very important and should be constructed of well-seasoned well-treated timbers.
8-18. Decking. Decking, or flooring, should be laid perpendicular to the joists and secured with sixty-penny (60d) nails or driftpins. This deck-


Figure 48. Standard crane signals.
ing should be at least 3 inches thick and joined directly over the joist. The joints should be staggered for greater strength and support.
8-19. Special Tools Needed. Since you cannot manhandle all of the heavy timbers you will be using to build waterfront structure, special tool are used to move and place these timbers. They are known as logger's tools and consist of peavys, cant hooks, timber carriers, and pike poles. The peavy and cant hook are lever type tools and are primarily used to roll timbers Timber carriers are considered two-man tools; they are primarily used to pick up and/or carry timbers. Pike pole are used to hold or steady timbers while they are being placed. These tools are shown in figure 47. Although the cane cannot be considered a special tool, we include it here because it is used to raise and lower heavy timbers, such as are used in the building of waterfront structures. Normally, two men are assigned to the crane: the operator, and the helper. The helper drives the crane carrier (truck), hooks and unhooks loads, and signals the operator when to lift and lower the load and where to position the load. Standard signals are used for these purposes. You will not be called upon to operate the crane; but there will be times when the crane helper is not available, and at such times you will probably have to help the crane operator with the signals. You will probably be working with the standard crane signals, illustrated in figure 48. Study and learn the signals thoroughly, because f you give the crane operator an incorrect signal, it could cause an accident that would damage some very expensive equipment. Remember, after the heavy timbers have been moved and placed, they must be leveled properly. The carpenter's level, which you learned about in Memorandum 531, is the tool used for this purpose.
8-20. Let's assume that you are going to remove and replace some damaged wooden pier component. Before you can replace the component, you must prepare them by boring boltholes, notching for special fits, etc. Also, you must know and use certain types of timbers, equipment and specifications. What are some of these things you should know?
8-21. These items of information are called General Notes and are found on the construction plan. They should be used any time you construct a new structure or repair an existing one.
From these notes you will get such information as the size hole to drill for driftpins and bolts, how bolts should be placed, basis of design, type of hardware to use, etc Let's take a look at a sample General Notes legend.

## General Notes

Holes for driftpins (D.P.) shall be $1 / 16$ " smaller than the pin itself.

Holes for through bolts shall be the same diameter as the bolt itself.
No bolthead should project beyond face of timber on outside face of fender system.
All piles must be creosoted if they are to be used where marine borers are active.
All lumber must be rough except 4" plank decking, which shall be finished on wearing side only.

Basis of design:
Live load--500\# per sq. ft.
Pile bearing value--50,000\#
Gantry crane--17-ton capacity.
Extreme fiber stresses--wood, 1800\# per sq. in.
Compression parallel to grain--wood, $1500 \#$ per sq. in.
Compression perpendicular to grain--wood, 450\# per sq. in.
Horizontal shear--wood, 15-\# per sq. in.
Modulus of elasticity--wood, 1,600,00.
Use O.G. cast iron washers with all bolts.
The length of pile as listed in "Bill of Material" assumes a penetration of $15^{\prime}$. The penetration required should be determined by driving tests and the length of piles adjusted accordingly.
Projecting ends of all bolts should be peened after nuts are tightly drawn.

8-22. Let's take a look at some of the problems of general maintenance of waterfront structures with which those, like you, in the specialized carpentry field should be familiar. To begin with, what are the primary causes of pier or wharf construction failures?
8-23. General Maintenance Problems. Chief among the general maintenance problems resulting from pier or wharf construction failure are the same causative factors as those that damage warehouse loading docks. To these can be added storms, collisions, and marine borers.
8-24. Deterioration is also responsible for some pier and wharf failures. This deterioration may be anticipated and corrected as outlined below. It is caused by decay and the action of termites and marine borers. Decay, turn, caused by the action of low parasitic forms of plant life known as fungi. The growth of these fungi depend upon moisture, food, air, and temperature (warmth). Consequently, the absence of any one of these requirements will prevent fungi growth. However, the most general and successful way to stop fungi growth is to poison the food supply We usually poison the food supply by treating the timber itself with creosote.
$8-25$. Termite attacks on structural building timbers are probably the chief causes of insect damage. This is specifically true of timber components which are in direct contact with the earth. Although termite are the chief causes of damage, they are not the only damaging insects.

Marine borers are also responsible for some of the deterioration actions on timbers.
8-26. There are many types of marine borers, but only two general groups (mollusks and crustaceans) are important to us now. Borers belonging to the mollusks group enter the timber, burrow themselves, and honeycomb the interior. On the other hand, the crustaceans operate by forming shallow gullies just under the surface.
8-27. Wharf or pier construction failures are caused either by mechanical factors or by deterioration factors. No matter which is responsible, the damage must be repaired So lets take a look at some of the corrective repairs which can be made and try to determine which method we should use to repair any particular damaged pier.
8-28. Corrective Repairs. Wharves and piers are usually repaired by replacing the damaged part. The replacement part should be of the same type of material as the part it is to replace. But, if failure is due to overloading and if it is believed that overloading will recur, the structure should be reinforced or otherwise strengthened.
8-29. Failures by deterioration are the hardest to detect and correct. Failure to correctly estimate how far repairs should be carried out is one of our biggest errors. This is specifically true if the failure is due to deterioration. From a visual inspection, some timbers look solid and sound; but when removed, they may be found to be hollow shells. This is primarily due to attacks by termites. Similarly, fender pile which are sound above the water line are often damaged near the ground line by marine borers. For these reasons, all timbers must be carefully checked to determine their true condition. Two ways to do this are to hammer on timbers or $t$ drive nail into them to see whether they have become softened by deterioration. If you have doubt as to the soundness of a structure, you should bore holes into the sides of caps and stringers. If you find the timber to be sound, carefully plug and paint the holes to keep out further moisture.
8-30. Generally speaking, the materials used for repairs or replacements should be of the same type and size as those used in the original design. However, no matter what type of materials are used, you must handle them with care if you intend to get maximum service. Also, to stop the entrance of fungi and insect, you must re-treat all low-resistant areas and broken surfaces of treated timbers. If cu are made in the surface of treated timbers, you should paint them with two or more coats of preservative compound. Now, if creosote is used for this
treatment, it must be applied at some temperature between $175^{\circ}$ And $200^{\circ}$ Fahrenheit. Another thing to remember is to avoid the use of timber hooks, cant hooks, or other sharp-pointed tools when you are handing treated timbers.

8 -31. Most of our modern treatment plants precut timbers to size and notch and bore them before treatment. This prevent the need for further treatment if you handle these timbers with care.
$8-32$. So far, we have discussed the construction features of wharves, piers, and quays; the special tools needed for such work; the general maintenance problems involved here; and the corrective repairs necessary. Now let's talk about some of the ways to prevent or minimize damage to these structures and safety measures which you use in such work.
8-33. Preventive Maintenance Measures. To adequately maintain wharves and piers, we must provide and maintain an appropriate preventive maintenance program. This program must outline preventive measures and present specific frequencies for inspections and corrective actions. Therefore, we are going to discuss the methods you should use to maintain these structures. As we have explained above, wharf and per structures are damaged from wear, deterioration, insect infestation, overloading, storm damage, fire, etc However, the damaging effect from these factors can be minimized if we follow the procedures and precautions outlined in the following paragraphs.
8-34. To guard against excessive wear to decking, we must make frequent inspections and keep tracked vehicles or other iron wheeled equipment from traveling over it Post notices of this restriction in conspicuous places. All loose bolts and nuts found during the inspection should be tightened. All decking should be securely nailed at every joist. If decking is 3 inches thick, 60 d nails or 6 -inch spikes should be used. If it is 4 inches thick, 7 -or 8 -inch spikes should be used. All planking used as decking material should be of the same thickness to give a smooth surface.
$8-35$. Fender piles should be removed and replaced before excessive wear occurs. Normally, only hardwoods (such as oak) are used for fender piles; however, if traffic is light, creosoted softwood piles may be used. No matter what type wood is used, make sure that all chocks are tightly fitted between the piles. These chocks help prevent the piles from rolling when rubbed by vessels. If currents are swift, fender log should be used to prevent damage to piles. Also, a thorough check of all timber and hardware should be made and any necessary corrective actions taken.

8-36. If fender piles should break. serious damage can be done to the structure by the impact of vessels; therefore, all fender piles should be replaced at regular intervals.
8-37. The anticipated normal life of fender piles will vary in different localities, depending upon the type of pile, water and soil conditions and other factors. Anticipated normal life can be established with reasonable accuracy after a few years or by observing other similar structures in the vicinity. After the anticipated normal life has been established, every replacement pile should be numbered and a historical record kept on it to make sure that it is replaced before the end of its anticipated life.
8-38. Safety Measures. When any type of work is performed on a wharf or pier structure, the following safety precautions should be observed:

- Make sure all safety provisions arc applied when ladders, runways, platforms, scaffolds, and guardrails are used.
- See that all equipment is inspected by some qualified person and is found in safe operating condition before it is used.
- Don't permit workmen to ride loads, hooks, hammers, material hoists, buckets, or any type of moving equipment.
- Don't allow loads, booms, or buckets to be swung over the heads of workmen.
- Require all workmen to wear life vests when they are working over water, unless proper scaffolds, platforms with guardrails, or safety belts and life lines arc provided.
- Insist that workmen wear protective clothing, goggles, or other safety equipment required by the type of work being done.
- Make sure that all provisions covering storage of materials and disposal of waste are adequately followed.


## CHAPTER 4

## Sawmill Operation

THE NUMBER Of Army people serving in Vietnam has increased tremendously since 1965. As a result, facilities construction--quarters, offices, depot, hangars, etc.-has been a major problem. It is your job to relieve this and similar problems, because as an Army carpenter, you will be building the facilities needed.
2. It take much hard work to build a building when the lumber is available. In your job in the Army, in places like Vietnam, there will probably be times when the lumber is not available. If you run into this situation, your job will be twice as difficult, because you will have to go into the jungle and cut the lumber. For you to be able to do this job, you must know how to erect and operate a sawmill.
3. This chapter discusses erecting sawmill, building log skidways, operating sawmills, and caring for large cutting saws. It also discusses the important rules in sawmill operation.

## 9. Erecting the Sawmill

9-1. Most of your sawmill work in the Army will probably be performed with a portable sawmill. One of the many different types of portable sawmills is shown in figure 49. Usually, a portable sawmill is erected (set up) once a day and it very seldom remains at one setup over 2 days. It is preferable to move the sawmill away from the material accumulated rather than to move the lumber, slabs (the outside pieces, with or without the bark, taken from logs in sawing them into boards), and sawdust. On large setups the sawmill is simply moved ahead progressively to other skidways and away from the accumulated material. After you set up a sawmill two or three times, you should be able to set it up in a short length of time.
9.2. To erect the main frame of the sawmill, place it within a few feet of the location where you intend to operate it. Then you can prepare the exact location and move the mill the few feet into place. If the sawmill is mounted on pneumatic tires, dig a shallow trench in front
of each wheel on level ground. This is done so that when the sawmill is leveled up, some of its weight will be removed from the tires. If this is not done, the sawmill will not sit rigidly enough. Pull the sawmill ahead to fit into the trenches. Be sure that the sawdust conveyor does not rest on the ground when the sawmill is pulled into the trenches. Unhitch the truck or power unit from the sawmill and place it in a relative position to the sawmill that will let you align the drive belt from the power unit to the sawmill.

9-3. Leveling. The sawmill must be leveled properly, If it is not level, the saw will run "in' or "out at the front. A saw that runs "in" at the front will make the last piece of lumber cut (the dog board) thin at the top. A saw that runs "out" at the front will make the dog board thick at the top. In other words, the lumber will not be square. When you level the sawmill, be sure that some material, such as a plank or timber, is placed on the ground underneath each leg to prevent it from settling into the soil as the operations proceed. To level the sawmill properly, you must consult the operator's manual for the particular make and model you are using.

9-4. Bracing. After you have leveled the sawmill correctly, brace it securely to compensate for drive belt tension. Most portable sawmills are braced by securing a brace against the frame of the sawmill and to the ground or power unit. In addition to bracing the sawmill, you must also set up the sawdust conveyor chain and anchor it. On most sawmills, this chain is anchored by driving an iron pipe or strong pole into the ground. To brace the sawmill properly and to anchor the sawdust conveyor chain, you must also consult the operator's manual for the particular make and model you are using.

## 10. Building Log Skidways

10-1. Before you erect the sawmill, you should line up your sawing sites before you start sawing the lumber. This is done to determine the exact


Figure 49. Portable sawmill.
location of the logs, to ascertain the accessibility by truck, and to check the skidway. A skidway is a platform made of skids on which logs are piled for loading. If possible, skidways should be made on a gentle slope where there is enough space to pile lumber, slabs, and sawdust. A skidway is shown in figure 50. Skidways are installed on gentle slopes so that the lumber and slabs are carried downgrade. This procedure decreases the labor involved tremendously. It is also advantageous to have logs piled on one rollway, because most portable sawmill carriages are not equipped to take on logs from two rollways. Logs are usually received on the carriage with the butt-end toward the saw.

10-2. Sometimes a tractor with a fingerlift can be used to great advantage with a portable sawmill. It can be used to load and even turn large logs at the skidway, and load lumber on trucks. In large commercial operations, or where the timber stands are thick and the logs large, portable sawmills can be used in pairs. A tractor with a fingerlift can be kept busy at the skidways, at the slab piles, and loading lumber at the trucks. This is a good method to use when you are short of personnel, because the need for quite a few men can be eliminated by this method.

## 11. Operating the Sawmill

11-1. Now that you have erected the sawmill and have built the log skidway, you are ready to operate the mill. But before you attempt to operate the sawmill, you should acquaint yourself with the operator's or sawyer's position and stance on the carriage. This familiarization will give you the feel of the moving carriage and allow you to make the movements most natural to you.

11-2. You must also acquaint yourself with the relative dimensions of the sawmill carriage. Give special attention to the length and distance between the head blocks (blocks under the head of the log to raise it), because this information will help you position the carriage properly to receive the $\log$ that is approaching on the skidway. This positioning of the log on the carriage cannot be overemphasized. No set rule can be given, because all logs are different, but you should always strive to work with the center of the $\log$ in the center of the carriage. You will feed the saw from the operator's position on the carriage. The carriage moves forward and backward past the
saw. On the forward movement, the log directed into the saw to cut the board from the side of the log.
11-3. As the log is being brought up in readiness to be placed on the carriage, you must consider the presence of extending knots or other obstructions that could prevent the log from lying firmly on the carriage or obstruct it pas age as the carriage is brought forward.
11-4. You must also consider any bends in the log. The tendency for a new operator is to place the bow or "belly" of the log up or down. In fact, many old sawyers want the bow up and slightly out. It has been found by careful check as to the quality of lumber produced, that this procedure b definitely wrong. The correct position is with the bow of the $\log$ on a horizontal plane toward the operator's side to the carriage, and the log resting on all the head blocks over which it extends.

11-5. In this position, the $\log$ can easily be brought out on either end by use of a wedge or pried out with a cant hook so that the line of cut will be equal on each end.
11-6. Logs should be received on the carriage with the butt-ends (large ends) toward the saw, especially long logs, because the heavy butt on the overhanging end will
have a tendency to tip the carriage up. Also, the saw is now apt to run "out", that is, to follow the grain of the wood.
11-7. After the log is received on the carriage, it must be dogged. "Dogging" is the term given to the act of securing the $\log$ on the carriage by hooking the dogs into the log This very important, because improperly dogged logs or cant my result in accidents and usually result in damage to the saw, which in turn means lose of time and manpower.
11-8. The following hand tools are considered essential to the operation of a portable sawmill unit:
a. Axe
b. Shovel
c. Oil can
d. Cant hook
e. Spirit level
f. 8-inch half-round Ale
g. Saw Ale
h. 8-inch adjustable jaw wrench


Figure 50. Skidway.
i. 10-inch adjustable jaw wrench
j. Additional tools for the power unit

## 12. Caring for the Saw

12-1. Your job is not complete when you finish sawing the lumber. You must take care of the saw. It is impossible to place enough emphasis on taking care of the saw. It can truthfully be said that it is the most important part of any type of machine which converts logs into lumber, whether it be a stationary or a portable sawmill. If you do not take care of your saw, it can slash your production, ruin the accuracy of the dimensions if the lumber, and leave you in the depths of despair.

12-2. There is nothing on the sawmill that takes as much abuse as the saw. For instance, should a log come loose from the dogs while this tremendous strain is on the saw, it will very likely kink (bend) it, bringing a halt to operations and resulting in loss of time and manpower. All saws vary considerably and require different methods of handling. This is partly due to the hardness or mildness (softness) of the steel from which they are made.

12-3. Teeth. A new saw will always run well for a few hours. It may make a rather rough cut, but it will always run a few hours if the saw is tensioned for the proper speed and the natural lead is properly set. These facts assure you that, if the teeth can be kept properly sharpened (like new teeth), the saw will continue to run and cut in a true line. Therefore, when you find that it does not do this, the deviation usually indicates that the saw teeth have not been sharpened properly. It has been proven that if an improperly sharpened saw is too long it will lose the proper tension and may cause blisters to develop on the saw blade. If this happens, you will have to have a competent saw expert retension the saw by hammering it. Hammering a saw is an art and should under no circumstances be attempted by anyone with limited experience. When your saw ceases to cut properly, stop your operations and sharpen it.

12-4. Blade. Most of your sawing will be done with a chisel tooth. So let's find out how a chisel tooth saw works. Many saws used to cut wood lengthwise of the grain are swedge-set chisel tooth saws. Many saws used to cut crosswise of the grain are spring-set pointed tooth saws. A spring-set cutoff saw cuts the sides free and tears out the portion between the two edges that are cut free by the sharp points. Therefore, as soon as the point become dull and do not cut the edges free, further sawing is difficult, and the saw is said to be dull. Sharpening the points will correct this situation and you can resume your work. Inasmuch as the center is torn out, any alight increase in the kerf (cut or stroke) will increase the
amount to be torn out and will increase the power accordingly.
12-5. A rip chisel tooth saw cuts across the center and tears out the two corners. For this reason, the width of the cut or stroke does not materially affect the power required The two edges have to be torn free, regardless of how narrow the cut or stroke is, and this is what consumes the power. Notice the chisel tooth shown in figure 51. The corners of the tooth do the tearing. Therefore, the things that lessen the tearing effect of the corners will affect the power consumption immediately and cause a corresponding increase in the power used through each tooth. This can cause much trouble. Therefore, the condition of the corners of the teeth is of great importance.

12-6. In addition, if one corner of the tooth becomes duller than the other, the one causing the greater resistance will have a tendency to force the saw the opposite way, which will cause the side of the saw to rub on the side of the log. If the saw rubs on the side of the log, it will do one of two things: (1) If the log is moving endways slowly, and if the saw is rotating as it rubs the slowly moving log, it will generate heat in the saw which will cause the metal to expand. This, in turn, will cause the saw to lose the stiffness required to run straight The further this condition is allowed to develop, the more difficult it becomes to remedy. (2) On the other hand, if the $\log$ is passing the saw at a higher rate of speed, the saw will have a tendency to cool as it rubs against the log, because the inside of the


Figure 51. Chisel tooth.
$\log$ is cool. This will cause the metal to shrink and stiffen.
12-7. Another factor that will affect the operation of the saw is an improper angle on the front of the tooth. This will us the saw to run "in" or "out." Remember, the cutting edge of the saw should be straight across.
12-8. Speed. Usually, the speed of a portable sawmill is the greatest that can be maintained both in and out of the cut. A usual mistake of operators is to try to operate the saw at too great a speed. A regular uniform speed both in and out of the cut insures more lumber and more accurate lumber. The speed should be governed by the available horsepower, of course, and must be increased as the power to drive the saw is increased.

## 13. Basic Rules In Sawmill Operation

13-1. There are many basic rules that are important in sawmill operation. These rules apply to greasing the saw, handling the saw, and checking the carriage.
13-2. Greasing. While greasing the sawmill, do as follows:
a. Apply heavy oil to the gears of the sawdust conveyor twice daily b. Use soft, light pressure gun grease.
c. Use only pressure gun grease in grease gun.
d. Lubricate the knee slides and gear rack slides and other moving parts frequently with light machine oil. Some sawmill operators make a practice of lubricating the surface of the knees on
which the log rests when they are taking on a large $\log$ because it helps in turning the log. Some operators use powdered graphite on the head block slides instead of oil.
$e$. Remove all bearings on which the carriage slides and wash them out with solvent and repack them with pressure gun grease once a year.
13-3. Saw. In handling the saw, always observe the following rules:
a. Don't ever saw with a "hot" saw.
b. Never saw with dull teeth.
c. Don't allow chips to rub the saw.
d. Keep the saw clean of pitch. (NOTE: Pitch sticks only to a hot saw.)
13-4. Carriage. When checking the carriage, proceed as follows:
a. Be sure that the carriage is level.
$b$. Always check the carriage before you start sawing by running it up and down the track two or three time to determine whether the ropes are in order and the saw is in the clear.
c. Always check the dogs when you are not sawing, especially on the "return" after the last board is cut from the log. Keep the dogs away from the saw.
d. Always keep the saw guides adjusted properly.
$e$. Always lock the carriage when you complete the day's work or whenever the machine is not in operation.
$f$. Always put in the carriage bolt and lockpin and set the hand brake when you are going to move the mill.

## Ulimate-Construction Series

## FRAME STRUCTURES

ENGINEER
SUBCOURSE 69

## LESSON OBJECTIVES

Upon completion of this lesson you should be able to accomplish the following in the indicated topic areas:

1. Prints and drawings. Read and interpret correctly, construction prints and architectural drawings.
2. Lumber. Define the different types of wood, good and bad features of each type, defect,

## ATTACHED MEMORANDUM

## 1-1. TYPES OF BUILDINGS

The basis for classification is as follows:
a. Permanent buildings are those which are laid out and designed to have a degree of structural adequacy, durability, and service-ability to assure a useful life of 25 years or more with low maintenance and service expenditures.
causes of deterioration, standard sizes, grades, and the meaning and method of calculating board feet.
3. Methods of fastening. Describe the different methods commonly used for fastening wood and the circumstances under which each type would be used.
4. Building layout. Supervise the layout of a fame building from the installation of batter boards through laying of the subfloor.
b. Semipermanent buildings are those which by the design, use of materials and equipment, and methods of construction will, with normal maintenance, provide structures with an economic life of less than 25 years and more than 5 years.
c. Temporary buildings are those which by design and the use of minimum-quality materials, equipment, and methods of construction will, with minimum maintenance, provide structures with an economic life of 5 years or less. This group of buildings includes:
(1) Factory-fabricated type buildings which can be readily erected and dismantled.
(2) Emergency construction type buildings.
(3) Buildings constructed for temporary use, to include expedients. The subject matter of this subcourse applies particularly to the frame structures used in a theater of operations (TO). As an engineer officer, you may be expected to take charge of this type of building operation.

## 1-2. ARCHITECTURAL DRAWINGS AND PRINTS

a. Basic to the successful accomplishment of any building construction assignment is the ability to read architectural drawings or prints. It can be extremely difficult for an individual to describe the size and shape of a simple object without a drawing of some kind. For example, if an architect designed a simple structure, it would be difficult to convey his idea to the person who is to fabricate the structure without a drawing to show the shape, size, and spacing of members.
b. Drawing or sketching is the universal language used by engineers, technicians, and skilled craftsmen. Whether this drawing is made freehand or by the use of drawing instruments (mechanical drawing), it is needed to convey all the necessary information to the individual who will fabricate and assemble the object whether it be a building, ship, aircraft, or a mechanical device. If many people are involved in the fabrication of the object, copies will be made of the original drawing or tracing so that all persons involved will have the same information.
c. Drawings are normally classified as original drawings, intermediate or reproducibles, or prints. The original drawing is the one produced by the draftsman. An intermediate is a copy of the original which is used to make prints. An intermediate is used to avoid the risk of damaging the original or because the original is not suitable for the type of reproduction process used for the making of prints. Prints may also be made directly from the original without using an intermediate drawing. A print is a working copy to be used on the job.
d. There are many processes used to make intermediates and prints. They an be classified as either negative or positive contact processes or optical processes. Contact processes require a transparent or translucent original. Optical copies can be made from opaque originals. They are usually more expensive and introduce more distortion.

## (1) Negative contact processes.

(a) Blueprints. A blueprint is made by placing a tracing (transparent or translucent original) in contact with a sensitized paper and exposing the paper through the tracing. When the paper is developed, the unexposed portions where the light is blocked by lines on the original remain white, while the exposed portions turn dark blue. This produces a print with white lines on a blue background. Blueprints, in general, have better contrast than other commonly used processes of comparable cost but the wet developing process causes some distortion, and marking the prints is difficult.
(b) Brownprints. The brownline print process (often called Van Dyke) is similar to the blueprint process except that the paper is transparent and exposed areas turn brown when developed. This yields transparent lines on a brown background. Brownprints are frequently used as inter mediates producing a print which has blue lines on a white background and called whiteprint.

## (2) Positive contact processes.

(a) Ozalid prints. The ozalid process is a contact process like blueprinting but the unexposed areas of the sensitized paper turn blue when developed in ammonia vapor, producing blue lines on a white background. These are called blueprints. Papers are also available which yield black lines (called blackline prints). The development in this process is dry, causing less distortion than the blueprint process, but the contrast is usually not as good. These are normally used for Army prints.

Note: Machines are available which produce ozalid-process prints but which project and reduce the
image optically instead of contactprinting. Prints produced by this process will usually be marked "Reduced Size Print-Do Not Scale."
(b) Brownline prints. Brownline paper has the same function in the ozalid process as the brown papers do in the blueprint process. They produce brown lines on a transparent background and are often used as an intermediate for making blueline prints. Brownline prints are often called sepia intermediates.
(c) Special materials. Materials are available for use with the ozalid process which produce a large variety of results, including many colored lines on white paper or colored lines on a clear plastic background.

## 1-3. LINE CONVENTIONS

Lines are symbols used on prints to show information necessary for construction. Figure 1-1 shows the types of lines commonly used on drawings and prints.
a. Visible lines. A heavy- or mediumweight unbroken line is used for the primary feature of a drawing. For drawings of objects, this line convention represents the edges, the intersection of two surfaces, and the surface limit that is visible from the viewing angle of the drawing. This line is often called the outline.
b. Hidden lines. A medium-weight line of evenly spaced short dashes represents an edge, the intersection of two surfaces, and the surface limit which is not visible from the viewing angle of the drawing.
c. Center lines. A thin (light) line composed of alternate long and short dashes is called a center line. It is used to signify the center of a circle or are and to divide objects into equal or symmetrical parts.
d. Cutting plane lines. A pair of short, heavy lines with arrowheads projected at 900 indicates the cutting plane when a drawing includes a section. Letters (A-A, B-B. etc.) are usually placed at the arrowheads to identify the section. The arrowheads show the viewing direction of the
section. Where necessary, the section lines may be connected by a line of short, heavy dashes indicating the exact path of the cutting plane.
e. Dimension lines. Dimension lines are thin (light) unbroken lines with arrowheads used to indicate the extent of a dimension on a drawing. The dimensions may be placed above the dimension line, on a break in the dimension, or, where space is limited, as close as possible to the end of the dimension line. The extent of the dimension is from arrow head to arrowhead, and is expressed in feet and inches on civil engineering drawings.
f. Extension lines. When it is not convenient to draw a dimension line directly between the visible lines it applies to, the visible line is extended by a thin (light) unbroken extension line which almost touches the end of the visible line. The extension line indicates the extent of the dimension lines which have an arrow touching it.
g. Break lines. The break line indicates that the object has been shortened to save space on the drawing. The true length is indicated by the dimension specified. The long break line is a thin (light) line interrupted by a z-shaped symbol. The short break line convention varies with shape and material, and indicates that part of the object has been cut away to show section detail or hidden features.

## 1-4. SCALES AND SCALING

Measuring dimensions on a print is called scaling. Due to possible distortion of the print, scaling should be avoided as much as possible. When scaling is essential, however, be sure to check for accuracy by applying the scale you are using to one or more of the important dimensions normally shown on a print.

## a. Types of scales

(1) Architects'. Architects' scales (1, fig. 1-2) are divided proportionally into feet and inches and are generally used in scaling drawings for machine and structural work. The triangular architects' scale usually contains 11 scales, each subdivided differently. Six scales read from the left end, while five scales read from the right end. 1, figure 1-2 shows how the $3 / 16$-inch subdivision at the end


FULL LINES


HIDDEN OUTLINES



CENTER LINES


DIMENSION LINES


EXTENSION LINES



LONG BREAK LINES

Figure 1-1. Types of lines and convention breaks.

(1)

ARCHITECTS' SCALE

(2)

ENGINEERS' SCALE

(3)

METRIC SCALE

(4)

## GRAPHIC SCALES

Figure 1-2. Types of scales.
of the scale is further subdivided into 12 equal parts representing 1 inch each and the $3 / 32$-inch subdivision into six equal parts representing 2 inches each.
(2) Engineers'. Engineers' scales (2, fig. 1-2) are divided into decimal graduations ( 10,20 , $30,40,50$, and 60 divisions to the inch). These scales are used for plotting and map drawing and in the graphic solution of problems.
(3) Metric. Metric scales (3, fig. 1-2) are used in conjunction with the drawings, maps, and so forth that are made in countries using the metric system. This system is also being used with increasing frequency in the United States. The scale is divided into centimeters and millimeters. In conversion, 2.54 centimeters ( cm ) are equal to 1 inch.
(4) Graphic. Graphic scales (4, fig. 12) are lines subdivided into distances corresponding to convenient units of length on the ground or of the object represented by the tracing. The graphic scale is placed in or near the title block of the drawing, and the relationship of its length to the scale of the drawing is not affected if the drawing is reproduced
as a reduced or enlarged print. This type of scale is used with standard Army plans for frame structures.
b. Methods of sealing.
(1) Architects' or engineers' scales. The method of scaling using architects' or engineers' scales is as follows:
(a) Determine the SCALE of the print from the notation given such as $1 / 4$ inch $=1$ foot- 0 inches; 1 inch $=20$ feet; $3 / 16$ inch $=1$ foot -0 inches and so forth.
(b) Select the corresponding scale on the architects' or engineers' scale.
(c) Using the proper scale, measure the desired dimensions on the print. Figure 1-3 illustrates the use of an architects' scale. Note that alining the 1 -foot mark with the right hand end of the footing gives a direct reading of 1 foot, 9 inches for the length of the footing.
(2) Graphic scales. The procedure normally used with graphic scales is as follows:


Figure 1-3. Scaling a dimension.
(a) On a slip of paper, mark off the length of the dimension desired.
(b) Place the slip on the graphic scale, reading off the dimension represented by the line length.

## 1-5. VIEWS

An architectural drawing consists of several views, each showing the building or structure in two dimensions. It usually includes elevations of the front, side, and rear; plans of floor and roof; and sectional views of construction details. In addition, detail and three-dimensional (perspective and isometric) drawings of special construction features are sometimes used to supplement two-dimensional views.
a. Elevation. Elevation drawings show the front, sides, and rear of buildings in true proportion. Figure 1-4 illustrates the development of elevations of front and side from a simple block to a small theater-of-operations type building. The sides may be specified as right or left with respect to the front view, or according to the point of the compass from which the view is taken, for example, north elevation. Elevations show floor level, grade lines, window and door heights, and the various materials to be used.
b. Plans. Drawings showing the interior arrangements of a building are called plans. These drawings are made looking down on the building from a point directly above. Horizontal surfaces, such as floors, appear without distortion. Figure 1-4 also shows the plan development of a typical TO building. All vertical surfaces, such as walls, appear as lines. Plans show the following information:
(1) Outside shape of building.
(2) Arrangement of rooms.
(3) Size and shape of rooms.
(4) Type of materials.
(5) Thickness of walls and partitions.
(6) Type, size, and location of doors and windows.
(7) Details of framework and structure.
(8) Type, size, and location of mechanical equipment such as heating plant, radiators, plumbing, and electrical wiring.
(9) Instructions concerning actual construction and installation work.
c. Sections. Sectional views show how a structure looks when cut vertically by a cutting plane. They give details which cannot be shown on elevation or plan views. Figure 1-4 illustrates the development of a sectional view of a typical theater-of-operations type building.
d. Details. A complete set of prints includes large-scale drawings of some parts of the building which cannot be shown clearly on the smaller scale drawings of overall plans and elevations. Details may be shown in elevation, plan, and section.

## 1-6. SYMBOLS AND SPECIFICATIONS

a. Symbols. Architectural drawings are simplified by the use of conventional symbols to represent certain parts of the building, various types of construction materials, and the utilities that are to be installed. Figure $1-5$ shows the symbols recommended by the United States of America Standards Institute for the more common types of building materials. Figure 14 shows the symbols used to represent the doors and windows most commonly found in theater-of-operations type construction.
b. Specifications. Even with the most elementary of structures it is seldom possible to include in the actual drawings of floor plans, elevations, sections, and details, all the information required for construction. Notations on drawings or prints that explain materials or construction methods that cannot be indicated by symbols are called specifications. For example, "40-pound prepared roofing" indicates the material to be used to cover the roof; "notch post for handrail" indicates a construction detail. Those notations must always to read before beginning construction.

## 1-7. NOMENCLATURE

Figure 1-7 illustrates and identifies the principal elements of substructures as used in theater-ofoperations (TO) frame structures.

## 1-8. JOINTS

Joints are connections between two pieces of lumber or timber that come together at an angle. Common types include:


Figure 1-4. Architectural views.


Figure 1-5. Material conventions.

SINGLE DOOR, OPENDNG IN


DOUBLE DOOR. OPENING DN


SINGLE DOOR. OPENENG OUT

SINGLE DOOR, INTERIOR

DOUBLE-ACTING STNGLE DOOR

REFRIGERATOR DCOR


TYPICAL WINDOW SYMBOLS


Figure 1-6. Typical door and window symbols.


Figure 1-7. Substructure nomenclature.
a. Straight butt joint. Thin joint is formed by bringing the square-cut end of one piece against the face of another (1, 2 fig. 1-8). Screws will hold such a joint most securely, but for framing, butt joints are toenailed with or 10-penny nails. Nails should always be slanted because nails driven into wood parallel to the grain have very little holding power.
b. Oblique butt joint. This joint is farmed by bringing the end of one piece, cut on the oblique to form the desired angle, against the face of another piece to which it is to be joined (3, fig. 1-8). Nails should be toenailed and the use of too many or too large nails avoided.
c. Miter butt joint. This joint is formed by bringing the mitered ends of two pieces together. The end of each piece cut to the same angle (4, fig. 18). The miter joint is extensively used in trim work around windows and doors, but its principal use in framing is for rafter junctions at roof peaks.
d. Plain lap joint. This joint is formed by laying one piece over anther and fastening the two together with bolts, screws, or nails (5, fig. 1-8).
e. Half-lap joint. This joint is constructed by cutting away a portion (usually half) from the thickness of each of two pieces and joining them $s$ that the cut-away portions overlap in a complementary manner to form a jot (6, fig. 1-8). Variations of the half lap include cross lap (7, fig. 18 ), middle lap (8, fig. 1-8), and mitered half lap (9, fig. 1-8).
f. Dado and rabbet joints. A dado is a square-bottomed, two-sided groove cut in wood, and a rabbet is a square-bottomed, one-sided groove or lip cut in the end of a piece. Principal joints include dado joint (1, 1-9), rabbet joint (2, fig. 1-9), dadorabbet joint (3, fig. 1-9), and stopped dado (4, fig. 19).

## g. Dovetail and mortise-and-tenon

 joints. These locked joints give added strength but require additional work and greater skill. The most common locked joints are lap dovetail (5, fig. 1-9), through single dovetail (6, fig. 1-9), open mortise-and-tenon (7, fig.

Figure 1-8. Butt and lap joints.


Figure 1-9. Dado, rabbet, dovetail, and mortise-and-tenon-joints.
$1-9$ ), and through mortise-and tenon (8, fig 1-9).

## 1-9. SPLICES

Splices are connections between two pieces that extend in the same line. The type of splice to use depends on the type or types of stress the spliced member must withstand. Members subject to longitudinal stress as vertical supports require splices designed to withstand compression (1, fig. 1-10). Members subject to transverse and angular stresses, such as braces, require splices designed to resist tension (2, fig. 1-10). Members used as horizontal supports, such as joists, require splices designed to resist bending ( 3 , fig. 1-10).
a. Compression-resistant
splices.
Compression splices are designed to support weight or exert pressure. The butt splice and the halved splice are the most common types.
(1) Butt splice. The butt splice is constructed by butting the squared ends of two pieces
together and securing them in this position by means of two wood scabs or metal plates (1, 2, fig. 1-11). Metal plates (fishplates) are fastened in place with bolts or screws. Bolts, screws, nails, or ring connectors may be used to secure scabs. Nails used with scabs should be staggered and driven at an angle. Too many nails or nails that are too large will weaken a splice.
(2) Halved splice. This splice is constructed by cutting away half the thickness for equal distances from the ends of two pieces and fitting the complementary tongues together (3, 1-11). The tongues should be long enough to provide adequate bearing surfaces. To give this splice some resistance to tension, fishplates or wooden scabs may be added as used with the butt splice.
b. Tension-resistant splices. Tension members, such as certain truss elements and braces, undergo stress at the splice that is exerted in more than one direction (2, fig.


Figure 1-10. Splice stresses.
1-10). Tension splices are designed to provide increased bearing surface and additional shoulders within the splice to resist the buckling tension.
(1) Square splice. The square splice is a modification of the compression-resistant halved splice. Complementary notches are cut in the tongues to provide an additional locking shoulder (4, fig. 1-11). It may be greatly strengthened by adding fishplates or scabs.
(2) Plain splice. A hasty substitute for the square splice is the long plain splice (5, fig. 1-11). A long overlap of the two pieces is desirable to provide adequate bearing surfaces and room for enough nails or other fasteners to compensate for the lack of shoulder lock.
c. Bend-resistant splices. Horizontal timbers supporting weight are subject to compression of the upper side that has a tendency to crush the fibers, and to tension along the lower side that tends to pull the fibers apart as shown diagramatically in 3, figure 1-10. The bend-resistant splice designed to meet these conditions is constructed by cutting oblique complementary tongues or laps in the ends of two pieces of timber (6, fig. 1-11). To absorb compression stress, the end of the upper tongue is cut square to butt against a corresponding square step or shoulder at the base of the complementary lower tongue. The end of the lower tongue is


Figure 1-11. Compression, tension, and bending-resistant splices.
beveled or scarped to a thin edge since it will be subject to tension only. A fishplate or scab can be fastened along the bottom of the splice to resist the tendency of the pieces to separate there.

## 1-10. TYPES OF WOOD

A knowledge of the kinds and physical characteristics of wood will aid the engineer officer to correctly use this building material which is the basis of most TO construction. We may classify timber initially in four broad categories according to the nature of growth:

Deciduous - broad-leafed trees which shed leaves seasonally.

Coniferous - needle-leafed trees.
Bamboo.
Palm.
Figure 1-12 presents typical characteristics of wood and its uses.
a. Deciduous and coniferous trees are found in temperate climates and make good construction material. When cut into lumber, deciduous trees produce hardwoods and coniferous trees softwoods. Although no definite degree of hardness divides the two groups, woods in the hardwood category are of higher density than those classified as softwoods. Hardness is measured by the compression which a piece of timber can withstand when a weight is applied to it. Oak, maple, hickory, elm, beech, ash, and locust are representative hardwoods. Some of the more common softwoods are pine, fir, cedar, spruce, hemlock, cypress, larch, and redwood. In TO construction the Army uses mainly softwoods, principally because they are easier to work, lighter in weight per unit volume, less expensive, and, in general, more available.
b. Bamboo and palm trees are found in tropical climates, and in some respects are

## HARDWOODS



STRONG HARD


SOFTWOODS GENERAL MILITARY CONSIRUCTION

YELLOW
PINE
ISHORT LEAF
VARIES

DOUGLAS FIR STRONG


Figure 1-12. Lumber and its uses.
better suited to construction than temperate climate trees. For example, they offer more resistance to insects and decay. Because of its shape - a thin hollow column - bamboo has been called the ideal building material. Lack of a simple method of satisfactorily connecting such members is its major short-coming. Both palm and bamboo have been used extensively by the Army.

## 1-11. SEASONING

Seasoning of lumber is the controlled drying or removal of moisture from wood. Seasoning increases the strength of timber, improves its resistance to decay, and minimizes shrinkage and warping of structural members. Since dry lumber is lighter, the dead weight of a structure is reduced by using seasoned timber. Although seasoned lumber is preferred for construction purposes, "green" timber may be used with good results for almost any TO type building. The only item for which green wood cannot be used satisfactorily in TO construction is sheathing. When green sheathing dries out after being covered with roll roofing, it shrinks and tears holes in the roofing material where the nails are inserted.

## 1-12. DEFECTS

In the growth and life of a tree certain defects occur which weaken timber cut from these trees. The defects are classed as heartshakes, windshakes, starshakes, knots, and checks.
a. Heartshake or heart rot. Heartshake is a defect of .the heartwood found in older trees, especially the hemlock; it is seldom found in saplings. The heartshake is evidenced by a small round cavity at the center of the tree or timber. This cavity is caused by decay and results in cracks which extend outward to the bark (1, fig. 1-13).
b. Windshake. Windshake is the separation of the annual rings (2, fig. 1-13). This defect is most common in pine timber. Windshakes sometimes extend several feet up the trunk of a tree.
c. Starshake. A starshake is much like a heartshake in its effect. The difference between the two is that the starshake has no decay at the center. The cracks extend over the cross section of the log,
are wide in the center, and narrow to nothing near the bark. The wood along these cracks is solid (3, fig. 113).
d. Knots. Knots are irregular growths in the body of a tree which interrupt the smooth curve of the grain. The fibers of the tree are turned from their normal course and grow around the knot at that point of a tree where a limb is being formed. If the knot is large, cross grains are formed which cause the lumber to break easily (4, fig. 1-13).
e. Checks. Checks are splits in the outside part of a piece of timber which are caused by irregular shrinkage. Checks are formed when the circumference shrinks more than the interior section of the $\operatorname{wood}(5,6$, fig. 1-13).


Figure 1-13. Defects in timber.

## 1-13. CAUSES OF DECAY

There are several types of decay which render lumber unserviceable: dry rot, wet rot, and common rot.
a. Dry rot. Dry rot is the most common and the most dangerous. It is a disease which spreads from one part of the wood to another, causing the wood to lose its strength and cohesive power and eventually to decay altogether. Dry rot occurs most often where timber is kept alternately wet and dry, or where there is no ventilation. The rot occurs on the inside of timber and leaves a shell on the outside; the inner part becomes soft and powderlike and is generally invisible due to the outer shell.
b. Wet rot. Wet rot occurs in growing trees and is similar to dry rot. It occurs when the wood becomes saturated with water which it absorbs from a swamp or bog. It may be readily communicated from one piece of wood to another by contact.
c. Common rot. Common rot is manifested by the presence of external yellow spots on the ends of timber or by a yellowish dust in the checks and cracks, especially where the pieces are in contact with one another. This is caused by improper ventilation of wood-storage sheds and lumber piles. It is easily remedied by proper stacking and ventilation.

## 1-14. DESTRUCTION BY INSECTS

Although decay is the principal cause of deterioration, a great deal of damage can be done by certain insects. The most common land varieties of destructive insects are the powder post, the pole borer, and the termite. The most common water type is the marine borer.
a. Powder post. The powder post develops very rapidly. It bores into the wood and transforms it into a fine powder. Since the powder post lodges initially under the bark, all bark should be removed from airdried lumber before it is used in buildings.
b. Pole borer. The pole borer attacks timber that is somewhat damp and transforms it into reddish-brown dust. It will not attack watersoaked timber, but it will attack dry timber, either sound or decayed.
c. Termite. Termites are not true ants although they look much like them and live like them, in large colonies. The winged male and female may be seen "swarming" in the spring or fall on their way to start new colonies. Otherwise they are very seldom seen, as they stay in the earth or in wood. They damage rafters, joists, beams, or other timber of buildings; the inside may be entirely eaten out before the damage is noticed since termites leave an outer shell of wood.

## d. Marine borer.

(1) Timber placed in water is subject to attack by two classes of marine borers, the mollusk and crustacean type.
(2) The destructive mollusk is a worm, sometimes called the navalis, teredo, or shipworm. It has a head equipped with a shell-like substance shaped like an auger by means of which it bores its way into timber. It has been known to grow to sizes of $1 / 4$ to $1 / 2$ inch in diameter and from $11 / 2$ to 3 feet in length. It may ruin timber in less than a year. This marine borer prefers clear salty water. It operates against timber set between the mean tide and low water mark and about a foot above the mud line.
(3) The wood louse is a member of the crustacean family. It grows to the size of a grain of rice and bores into wood by means of sharp jaws. It is active only in clear still water and confines itself to a belt or line around the low water line. Wood lice can destroy piling within a year's time in heavily infested areas.

## 1-15. STANDARD SIZES OF LUMBER

Lumber is usually sawed into standard sizes of length, width, and thickness. This permits uniformity in planning structures and in ordering materials. Table 1-1 list some nominal and minimum-dressed sizes for dry, softwood lumber as set forth in the American Softwood Lumber Standard, Voluntary Product Standard 20-70. Dry lumber, in this instance, is defined as lumber which has been seasoned to a moisture content of 19 percent or less. Lumber having a moisture content in excess of 19 percent is called green lumber and the dressed dimensions may be slightly

TABLE 1-1. Nominal Sizes and Dressed Sizes of Lumber (New Standard)

| Nominal size (in.) | Dressed adre (in.) |
| :---: | :---: |
| $1 \times 3$ | $3 / 4 \times 21 / 2$ |
| $1 \times 4$ | $3 / 4 \times 31 / 2$ |
| $1 \times 6$ | $3 / 4 \times 51 / 2$ |
| $1 \times 8$ | $3 / 4 \times 71 / 4$ |
| $1 \times 10$ | $3 / 4 \times 91 / 4$ |
| $1 \times 12$ | $3 / 4 \times 111 / 4$ |
| $2 \times 4$ | $11 / 2 \times 31 / 2$ |
| $2 \times 6$ | $11 / 2 \times 51 / 2$ |
| $2 \times 8$ | $11 / 2 \times 71 / 4$ |
| $2 \times 10$ | $11 / 2 \times 91 / 4$ |
| $2 \times 12$ | $11 / 2 \times 111 / 4$ |
| $3 \times 8$ | $21 / 2 \times 71 / 4$ |
| $3 \times 10$ | $21 / 2 \times 91 / 4$ |
| $3 \times 12$ | $21 / 2 \times 111 / 4$ |
| $4 \times 12$ | $31 / 2 \times 111 / 4$ |
| $4 \times 16$ | $31 / 2 \times 151 / 4$ |
| $6 \times 12$ | $51 / 2 \times 111 / 2$ |
| $6 \times 16$ | $51 / 2 \times 151 / 2$ |
| $6 \times 18$ | $51 / 2 \times 171 / 2$ |
| $8 \times 16$ | $71 / 2 \times 151 / 2$ |
| $8 \times 20$ | $71 / 2 \times 191 / 2$ |
| $8 \times 24$ | $71 / 2 \times 231 / 2$ |

greater. Table 1-2 gives the nominal and dressed sizes that were in use prior to adoption of the standards indicated in table 1-1. Lumber dressed to the dimensions shown in table 1-2 may still appear in some areas and certainly lumber of both finished dimensions will be used and the dimensions must be given consideration in repair and modification work involving existing framed structures.

## 1-16. GRADES OF LUMBER

Lumber as it comes from the sawmill is divided into three main classes: yard lumber, structural material, and factory and shop lumber. In keeping with the purpose of this subcourse, only yard lumber will be considered. Yard lumber is manufactured and classified, on a quality basis, into those sizes, shapes, and qualities required for ordinary construction and genera building purposes including TO construction. It is subdivided into classifications of select lumber and common lumber.

TABLE 1-2. Nominal Sizes and Dressed Sizes of Lumber (Old Standard)

a. Select lumber. Select lumber is of good appearance and finish, and is identified by the following grades:
(1) Grade A. Grade A is suitable for natural finishes and practically clear.
(2) Grade B. Grade B is suitable for natural finishes, of high quality, and generally clear.
(3) Grade C. Grade C is adapted to high quality paint finishes.
(4) Grade D. Grade D is suitable for paint finishes between higher finishing grades and common grades, and contains somewhat the nature of both.
b. Common lumber. Common lumber is suitable for general construction and utility purposes and is identified by the following grade names:
(1) No. 1 common. No. 1 common is suitable for use without waste; it is sound and tightknotted; and it may be considered watertight lumber.
(2) No. 2 common. No. 2 common is less restricted in quality than No. 1 but of the same general quality. It is used for framing, sheathing, and other structural forms where the stress or strain is not excessive.
(3) No. 3 common. No. 3 common permit some waste with prevailing grade characteristics larger than in No. 2. It is used for such rough work as footings, guardrails, and rough flooring.
(4) No. 4 common. No. 4 common permits waste and is of low quality, admitting the coarsest features, such as decay and holes. It is used for sheathing, subfloors, and roof boards in the cheaper types of construction, but the most important industrial outlet is for boxes and crates.
c. TO construction grades. Most of the softwood lumber purchased by the Army for TO construction is common stock, Nos. 1 or 2.

## 1-17. LENGTHS AND DRESSING

a. Standard lengths of lumber range from 8 to 20 feet by 2 -foot increments.
b. For a list of standard thickness and widths of lumber useful for military construction turn
to tables 1-1 and 1-2. Note that both a nominal and an actual size is given for each item in both tables. The nominal size represents the dimensions of the rough lumber, but the actual size is smaller due to the smoothing or "dressing" of the sides and/or edges. During this surfacing process, from $1 / 4$ to $3 / 4$ inch, depending on the size of the lumber, is removed from the edges and sides. Abbreviations are sometimes used to show how many sides or edges have been surfaced.
c. The following tabulation explains the abbreviations commonly used to indicate the amount of surfacing lumber has received.
S \& E........... side and edge
S1E.............. surfaced one edge
S1S1E.......... surfaced one side and one

| edge |
| :---: |

S1S2E.......... surfaced one side and two
edges

S2E..............surfaced two edges
S4S $\qquad$ surfaced four sides

## 1-18. BOARD MEASURE

a. The unit of measurement of lumber is the board foot. By definition a board foot is the volume of a board 1 inch thick, 1 foot wide, and 1 foot long. BF, bf, BFM, bfm are all commonly employed abbreviations for board foot. M in front of the abbreviation stands for 1000 board feet. Thus, 4 MBF would indicate 4000 board feet.
b. From the definition above the following formulas are derived:

$$
\begin{aligned}
& \mathrm{BF}=\text { thickness in inches } \mathrm{x} \text { width in feet } \mathrm{x} \text { length in feet } \\
& \text { or } \\
& \mathrm{BF}=\frac{\text { thickness in inches } \mathrm{x} \text { width in inches } \mathrm{x} \text { length in feet }}{12} \\
& \mathrm{BF}=\frac{\text { thickness in inches } \mathrm{x} \text { width in inches } \mathrm{x} \text { length in inches }}{144}
\end{aligned}
$$

c. Table 1-3 gives the content in board feet of common sizes and lengths of lumber used in TO construction.

## 1-19. METHODS OF FASTENING

Wood fasteners used in the theater of operations are made of metal. These may be classified as nails, screws, bolts, driftpins, corrugated fasteners, and timber connectors.

## 1-20. NAILS

General. The standard nail used by the Army carpenter is the wire nail, so called because it is made from steel wire. There are many types of nails, all of which are classified

| Size of plece <br> ( In.$)$ | Length of plece <br> (ft) |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| $2 \times 4$ | $51 / 3$ | $62 / 3$ | 8 | $91 / 3$ | $102 / 3$ | 12 | $131 / 3$ | 14 2/3 | 16 |
| $2 \times 6$ | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| $2 \times 8$ | $102 / 3$ | $131 / 3$ | 16 | 18 1/3 | $211 / 3$ | 24 | $2612 / 3$ | $291 / 3$ | 32 |
| $2 \times 10$ | $131 / 3$ | $162 / 3$ | 20 | $231 / 3$ | $262 / 3$ | 30 | $331 / 3$ | 36 2/3 | 40 |
| $2 \times 12$ | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |

according to use and form. The wire nail is roundshafted, straight, pointed, and may vary in size, weight, size and shape of head, type of point, and finish. All normal requirements of construction and framing are filled by one of the nail types described below. There are a few general rules to be followed in the use of nails in carpentry. Nails should be driven at an angle slightly toward each other and should be carefully placed to provide the greatest holding power. Nails driven with the grain do not hold as well as nails driven across the grain. A few nails of proper type and size, properly placed and properly driven, will hold better than a great many driven close together. Nails can generally be considered the cheapest and easiest fasteners to be applied. In terms of holding power alone, nails provide the least, screws of comparable size provide more, and bolts provide the greatest amount.
b. Types of nails.
(1) Common wire nails. Common wire nails and box nails are similar except box nails are sized smaller than common nail. The common wire nail (1, fig. 1-14) is used for housingconstruction framing. The common wire nail and the box nail are generally used for structural carpentry.
(2) Finishing nails (2, fig. 1-14). The finishing nail is made from finer wire and has a smaller head than the common nail. It may be set below the surface of the wood into which it is driven and will leave only a small hole, easily puttied up. It is generally used for interior or exterior finishing work and is used for finished carpentry and cabinet making.
(3) Scaffold or form nails (3, fig. 114). The scaffold, form, or staging nail (as it is sometimes called) is made with what may appear to be two heads. The lower head, or shoulder, is provided so that the nail may be driven securely home to give maximum holding power while the upper head projects above the surface of the wood to make its withdrawal simple. The reason for this design is that the scaffold nail is not meant to be permanent. It is used in the construction of temporary structures such as scaffolding and staging and is classified for temporary construction.
(4) Roofing nails (4, fig. 1-14). Roofing nails are round-shafted, diamond-pointed, galvanized nails of relatively short length and comparatively large heads. They are designed for fastening flexible roofing materials and for resisting continuous exposure to weather. Several general rules apply to the use of roofing nails, especially their use with asphalt shingles. If shingles or roll roofing is being


Figure 1-14. Types of nails.
applied over old roofing, the roofing nails selected must be of sufficient length to go through the old material and secure the new. Asphalt roofing material is fastened with corrosion resistant nails, never with plain nails. Nailing is begun in the center of the shingle, just above the cutouts or slots, to avoid buckling.
c. Sizes and uses of nails. Nail sizes are designated by the use of the term "penny". This term
designates the length of the nail (1-penny, 2-penny, etc.), which is the same for all types. The approximate number of nails per pound varies according to the type and size. The wire gage number varies according to type. Figure 1-15 provides the information implicit in the term "penny" for each of the type of nails referred to in this section. The "d" adjacent to the numbers in the "Size" column is the accepted abbreviation of the


Figure 1-15. Nail lengths.
word "penny". Table 1-4 lists the kinds and quantities of nails required for building frame structures.

## 1-21. SCREWS

The use of screws instead of nails may be dictated by a number of factors, including the type of
material that is to be fastened, the need for greater holding power, the desire for a better finished appearance, and limitations on the number of fasteners that can be used. Screws can also be withdrawn easily without damage to the material. Wood screws are usually made of unhardened steel but some

TABLE 1-4. Wire Nails - Kinds and Quantities Required

| Stzes and kinds of Material | Sizes | Lenath in inches | Approx. no. per lbs. | Pounds Der MBF on center as follows: |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | 12" | $16^{\prime \prime}$ | $36^{\prime \prime}$ | $48^{\circ}$ |
| $1 \times 4$ | Bd comon | $21 / 2$ | 106 | 60 | 68 | 23 | 20 |
| $1 \times 6$ | Bd common | $21 / 2$ | 106 | 40 | 32 | 16 | 18 |
| $1 \times 8$ | Bd comon | $21 / 2$ | 106 | 31 | 27 | 12 | 10 |
| $1 \times 10$ | 8d common | $21 / 2$ | 106 | 25 | 20 | 10 | 8 |
| $1 \times 12$ Ueed equare edge, | Bd comen | $21 / 2$ | 106 | 31 | 24 | 12 | 10 |
| $2 \times 4$ floors, sheathing. | 20d comen | 4 | 29 | 105 | 80 | 60 | 33 |
| $2 \times 6$ or ohiplap. When | $20 d$ comon | 4 | 29 | 70 | 56 | 27 | 22 |
| 2 n 0 usad drassed and | 20 d comen | 4 | 29 | 53 | 40 | 21 | 17 |
| $2=10$ notched, blind | 20 d comen | 4 | 29 | 60 | so | 25 | 20 |
| $2 \times 12$ nalled, only 1/2 quantity nemed required. | 20d comen | 4 | 29 | 52 | 61 | 21 | 17 |
| $3 \times 4$ required. | 60 d common | 6 | 11 | 197 | 150 | 16 | 61 |
| $3=6$ | 60d comen | 6 | 11 | 131 | 97 | 52 | 42 |
| $3 \times 8$ | 60d common | 6 | 11 | 100 | 76 | 18 | 36 |
| $3 \times 10$ | 60 d common | 6 | 12 | 178 | 137 | 70 | 55 |
| $3 \times 12$ | 60 d comen | 6 | 11 | 145 | 115 | 53 | 46 |
| Base, per 100 fe. lin. | Ad tinioh | $21 / 2$ | 189 | -* | 1 | -* | -- |
| Cailing, $3 / 4 \times 4$ | Bd Eintah | $21 / 2$ | 189 | 18 | 14 | -- | -* |
| Celling, 1/2 and 5/8 | 6d Eintah | 2 | 309 | 11 | 8 | -- | -- |
| Finish, 118 | 8d tinish | $21 / 2$ | 189 | 25 | 12 | -- | -- |
| Finish, $11 / 8$ | 10d finish | 3 | 121 | 12 | 10 | -- | ** |
| Flooring, $1 \times 3$ | Bd floor brads | $21 / 2$ | 99 | 42 | 32 | -- | -- |
| Floorins, $1 \times 4$ | 8 floor brada | $21 / 2$ | 99 | 32 | 26 | -- | -- |
| Flooring, $1 \pm 6$ | 8 d floor brada | $21 / 2$ | 99 | 22 | 18 | - | -- |
| Franing, $2 \times 4$ to $2 \times 16$ | 20d comen |  | 29 | 20 | 16 | -- | *- |
| requires 3 or more alsen | 16d comon | ${ }_{3} 1 / 2$ | 46 74 | 10 | 10 | - | -- |
| and vary sreatiy | 100 common |  | 84 | 8 | 6 | - |  |
| $\text { Franing, } 3 \times 4 \text { to } 3 \times 16$ | 60 d comon | $21 / 2$ | 111 | 30 | 25 | -- | -- |
| $\text { sidins, drop, } 1 \times 4$ | Bd caning | $21 / 2$ | 145 | 45 | 35 | $\cdots$ | - |
| siding, drop, $1 \times 6$ | 84 cosing | $21 / 2$ | 145 | 30 | 25 | - | - |
| sidint, drop, 1 k 8 | 8 d casins | $21 / 2$ | 145 | 23 | 18 | - | * |
| S1ding, bevel, $1 / 2 \times 4$ | 6d finish | 2 | 309 | 23 | 18 | -- | -* |
| Sidins, bevel, $1 / 2 \times 6$ | 6d finish | 2 | 309 | 15 | 13 | -- | -* |
| Siding, bevel, $1 / 2 \times 8$ | 6d IInish | 2 | 309 | 12 | 10 | -- | -- |
| Casing, per oponing | 6d and 8d caaing |  |  | Aboust | pound |  |  |
| Floorling, 3/8 $\times 2$ | 3 d brede | $11 / 4$ | 568 | About $(12$ | ounds e.) | -qu |  |
| Lath, 45* | 34 tine | $11 / 8$ | 778 | 6 pou | per 1000 | ( | c.) |
| Ready roofing | Barbed roofing | 718 | 469 | $3 / 4$ | und | uars | o.c.) |
| Ready roofing <br> (5/8 heads) | $\begin{aligned} & \text { deericion felt } \\ & \text { roofing } \end{aligned}$ | 718 | 180 | $11 / 2$ | ds to | re. | c.) |
| shingies* | 34 shingle | $11 / 4$ | 420 | $41 /$ | du; | $118$ | $14$ |
| 3hinglea | $4{ }^{4}$ shingle | $11 / 2$ | 276 | $71 / 2$ |  | $118$ | $\text { h } 4$ |
| 3aingles | $\begin{aligned} & \text { Meerican folt } \\ & \text { roofing } \end{aligned}$ | $7 / 8$ | 180 | 12 lb | $8^{\prime \prime}$ he | 11. | ngle |
| Shinglee | Sarbed roofing | ${ }^{7 / 8}$ |  |  |  |  |  |
| Well, board, around entire edge | 2d Iarbed Ierry, flat heed | 1 | $1150$ |  | $5 / 5^{\circ}$ | $=10$ | are |
| Wall bard, intereediate naflings | 2d casing or floor bred | 1 | 1010 | $21 / 2$ | $5 / 8^{n}$ | $10$ | uare |

*Wood shingles vary in width; asphalt are usually 8 inches wide. Regardless of width 1000 shingles are the equivalent of 1000 pieces 4 inches wide.
special-purpose screws are made of brass aluminum, or stainless steel. Ordinary soft-steel screws may be bright finished or blued or they may be zinc, cadmium, brass, or chrome plated. Wood screws have gimlet points and are threaded for approximately two-thirds of their length.
a. Types of wood screws. Wood screws are designated according to head styles as shown in figure 1-16. The types commonly used in construction are: slotted flathead, oval head, round head, and Phillips head. To prepare wood for screws, as shown in figure 1-17, bore a pilot or body hole the diameter of the screw that is to be used through the piece of wood that is to be fastened on. Then bore a smaller starter or lead hold in the piece that is to be fastened to, to avoid hard turning and the possibility of splitting the wood. If flatheaded screws are to be used the pilot or body hole should be countersunk.


Figure 1-16. Types of wood screws.


Figure 1-17. Method of preparing wood for screws.
b. Screw sizes. Wood screws vary in length from $1 / 4$ inch to 6 inches. Screws up to 1 inch in length increase by eighths of an inch screws from 1 to 3 inches by quarter inches, and screws from 3 to 5 inches by half inches. There are also 6 -inch screws. Each length is made in a number of shaft sizes indicated by an arbitrary number that represents no particular measurement but indicates relative diameters. Tables 1-5 and 1-6 provide size, length, gage, and applicable drill and bit sizes for screws.
c. Lag screws. The proper name for lag screws in the nomenclature of the Army supply system is bolt, lag, wood-screw type. These screws are sometimes required in frame construction. They are longer and much thicker bodied than common wood screws and have coarser threads which extend from a cone or gimlet point slightly more than half the length of the screw. Both square- and hexagonheaded lag screws are usually driven by a wrench. Combined with expansion shields or anchors they are used to attach timbers to existing masonry.
d. Expansion shields. Expansion shields, or anchors as they are sometimes called, are inserted in a predrilled hole. After the expansion shield is inserted, the bolt or occasionally another type of fastener such as a screw or even a nail is driven into the shield, causing it to expand and become firmly wedged in place (fig. 1-18).

## $\mathbf{1 - 2 2}$. BOLTS

a. General. Bolts are used in construction when great strength is required or when the work under construction must be frequently disassembled. Their use usually requires nuts for fastening and washers to protect the surface of the material to be fastened. Bolts are selected according to specific requirements in terms of length, diameter, threads, style of head, and type. Proper selection of head style and type of bolt will result in good appearance as well as good construction. The use of washers underneath the nut or underneath both the nut and the bolt head will avoid marring wood surfaces and permit additional torque in tightening.


TABLE 1-6. Drill and Auger Bit Sizes or Wood Screws

| Screw-size No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Nominal screw body diameter | . 073 | . 086 | . 099 | . 112 | . 125 | . 138 | . 151 | . 164 | . 177 | . 190 | . 216 | . 242 | . 268 | . 294 |
|  | $\frac{5}{64}$ | $\frac{3}{32}$ | $\frac{3}{32}$ | $\frac{7}{64}$ | $\frac{1}{8}$ | $\frac{9}{64}$ | $\frac{5}{32}$ | $\frac{11}{64}$ | $\frac{11}{64}$ | $\frac{3}{16}$ | $\frac{7}{32}$ | $\frac{15}{64}$ | $\frac{17}{64}$ | $\frac{19}{64}$ |
| Body Hole | $\frac{5}{64}$ | $\frac{3}{32}$ | $\frac{7}{64}$ | $\frac{7}{64}$ | $\frac{1}{8}$ | $\frac{9}{64}$ | $\frac{5}{32}$ | $\frac{11}{64}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{7}{32}$ | $\frac{1}{4}$ | $\frac{17}{64}$ | $\frac{19}{64}$ |
|  |  |  |  |  |  |  |  |  |  |  | 4 | 4 | 5 | 5 |
| Starter Drill size Hole <br> Bit size |  | $\frac{1}{16}$ | $\frac{1}{16}$ | $\frac{5}{64}$ | $\frac{5}{64}$ | $\frac{3}{32}$ | $\frac{7}{64}$ | $\frac{7}{64}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{9}{64}$ | $\frac{5}{32}$ | $\frac{3}{16}$ | $\frac{13}{64}$ |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  | 4 |

b. Type of bolts (fig. 1-19).
(1) Carriage bolts. Carriage bolts fall into three categories within the Army supply system: bolt, finned neck; bolt, ribbed neck; and bolt, square neck. These bolts have round heads that are not designed to be wrench driven. They are threaded only part of the way up the shaft; usually the threads
are two to four times the diameter of the bolt in length. In each type of carriage bolt the upper part of the shank, immediately below the head, is designed to grip the material in which the bolt is inserted and keep the bolt from turning when a nut is tightened down on it and/or removed. The finned type is designed with two or more fins extending


Figure 1-18. Bolt with expansion shield.


Figure 1-19. Types of bolts.
from the head to the shank. The ribbed type is designed with longitudinal ribs, splines, or serrations on all or part of a shoulder located immediately beneath the head. The square-neck bolt is designed with a square or rectangular shoulder immediately beneath the head. Holes to receive carriage bolts are bored to a tight fit of the body of the bolt and
counterbored to permit the head of the bolt to fit flush with, or below the surface of, the material being fastened. The bolt is then driven through the hole with a hammer. Carriage bolts are chiefly for wood-to-wood application but may also be used for wood-to-
metal applications. If used for wood to metal application, the head should be fitted to the wood members. Metal surfaces are sometimes predrilled and countersunk to permit the use of carriage bolts metal to metal. Carriage bolts can be obtained from $1 / 4$ inch diameter to 1 inch diameter, and up to 20 inches long. A common flat washer should be used with carriage bolts between the nut and the wood surface.
(2) Machine bolts. Machine bolts are made with cut National Fine or National Coarse threads extending in length from twice the diameter of the bolts plus $1 / 4$ inch (for bolts less than 6 inches in length) to twice the diameter of the bolt plus $1 / 2$ inch (for belts more than 6 inches in length). They are precision made and generally applied metal to metal where close tolerance is desirable. The head may be square, hexagon, double hexagon, rounded, or flat countersunk. The nut usually corresponds in shape to the head of the bolt with which it is used. Machine bolts are not slotted for screwdrivers. Selection of the proper machine bolt is made on the basis of head style, length, diameter, number of threads per inch, and coarseness of thread. The hole through which the bolt is to pass is bored to the same diameter as the bolt and may, in some cases, be slightly larger. Machine bolts are made in diameters from $1 / 4$ inch to 3 inches and may be obtained in any length desired.
(3) Stove bolts. Stove bolts are less precisely made than machine bolts. They are made with either flat or round slotted heads and may heave threads extending over the full length of the body, over part of the body, or over most of the body. They are generally used with square nuts and applied metal to metal, wood to wood, or wood to metal. If flat headed, they are countersunk; if round headed, they are drawn flush to the surface. Either type may be driven with a screwdriver, or may be held with a screwdriver while a wrench is used on the nut.

## 1-23. DRIFTPINS (fig. 1-20)

Driftpins, sometimes called driftbolts, are long, heavy threadless pins used to hold heavy pieces of timber together. Driftpins have heads and vary in


Figure 1-20. Driftpins (driftbolts).
diameter from $1 / 2$ to 1 inch, and in length from 18 to 26 inches. To use a driftpin, a hole slightly smaller than the diameter of the pin is made in the timber. The pin is driven into the hole and held in place by the compressive action of the wood fibers.

## 1-24. CORRUGATED FASTENERS

a. General. Corrugated fasteners are one of the many means by which joints and splices are fastened in small timber and boards. They are used particularly to strengthen miter joints. Corrugated fasteners are normally made of sheet metal of 18 to 22 gage with alternate ridges and grooves. The ridges vary from $3 / 16$ to $5 / 16$ inch, center to center. One end is cut square; the other end is sharpened with beveled edges.
b. Types. There are two types of corrugated fasteners: one with the ridges running parallel (1, fig. 1-21), the other with ridges running at a slight angle to one another (2, fig. 1-21). The latter type has a tendency to compress the material since the ridges and grooves are closer at the top than at the bottom.
c. Size. These fasteners are made in several different lengths and widths. The width varies from $5 / 8$ to $1-1 / 8$ inches, while the length varies from $1 / 4$ to $3 / 4$ inch. The fasteners are also made with different numbers of ridges, ranging from three to six ridges per fastener.
d. Use. Corrugated fasteners are used in a number of ways: to fasten parallel boards together, such as in fashioning table tops; to make any type of joint; and to replace nails when nails might split the timber. The fasteners have a greater holding power than


Figure 1-21. Corrugated fasteners and their uses.
nails in small timber. 3, figure 1-21 shows the proper method of inserting the fasteners.

## 1-25. TIMBER CONNECTORS

a. General. Timber connectors are metal devices used for increasing the joint strength in timber structures. Efficient connections for either timber-to-timber joints or timber-to-steel joints are provided by the several types of timber connectors. The appropriate type for a specific structure is determined primarily by the kind of joint to be made and the load to be carried. These connectors eliminate much complicated framing of joints. Some of the important advantages are that they simplify the design of heavy construction provide greater efficiency of material, reduce the amount of timber and hardware used, and save time and labor. Many types are used; however, the most common are split rings and toothed rings.

## b. Types and uses.

(1) Split rings. Split rings are made of low-carbon steel in sizes of $21 / 2$ - and 4 -inch diameters. They are used between two timber faces for heavy construction. They fit into grooves which are cut half the depth of the ring into each of the
timber faces. (fig. 1-22). The grooves are made with a special bit used in an electric, air, or hand drill. The tongue-and-groove split in the ring permits simultaneous ring bearing against the cone wall and outer wall of the groove into which the ring is placed. The inside bevel and mill edge facilitates installation into and removal from the groove.
(2) Toothed rings. Toothed rings are corrugated and toothed on both edges and are made from 16-gage-plate low-carbon steel (fig. 1-23). They are used between two timber framing members in comparatively light construction and are embedded into the contact faces of the joint members by means of pressure.

## 1-26. EXCAVATIONS

In the theater of operations, there is little excavation for building, but any excavating that is done requires a set procedure. In excavating for a building with earth floors, all that is necessary is a small trench to contain the sill (fig. 1-24). The building may then be constructed and the grading on the inside done later, if necessary. In small buildings where there are no wood floors, the earth should be thrown on the inside to raise the


Figure 1-22. Split ring and its installation.


Figure 1-23. Toothed rings and installation.


Figure 1-24. Excavating for structure with earth floor.
floor level above the outside and to prevent water seepage. Then wood floors are laid on the ground, the excavated earth should be used to raise the floor level. The pick and shovel should be used to dig small foundations; large foundations may be dug either by hand or with machinery.

## 1-27. FOUNDATIONS

Foundations vary according to their use and the type of material available. The material may be cut stone, rock, brick, concrete, tile, or wood, depending upon the weight which the foundation is to support. Foundations may be classified as wall or column (pier) foundations.
a. Wall foundations are built solid, the walls of the building being of continuous heavy construction for their total length. Solid walls are used where there are heavy loads to be carried or where the earth has low supporting strength. These walls are made of concrete, rock, brick, or cut stone, with a footing at the bottom (fig. 1-25). Because of the time, labor, and material required to build it, this type of wall will be used in the theater of operations only when other types cannot be used. Steel-rod reinforcements should be used in all concrete walls and columns.
b. Column or pier foundations save time and labor. They may be constructed from masonry or wood. The piers or columns are


Figure 1-25. Types of foundation walls. spaced according to the weight to be carried. In most cases the spacing is from 6 to 10 feet. Figure 1-26 shows the different types of piers with different types of footings. Wood piers are generally used since they are installed with the least time and labor. Where wood piers are 3 feet or more above the ground, braces are necessary (fig. 1-7).

## 1-28. FRAMING

After the building has been laid out and the batter boards set in place, the carpenter proceeds to construct the framework of the building. Framing is the skeleton upon which the covering is to be placed. Just as the bony skeleton is the basic supporting structure of the body, so the framework of a building contains its fundamental strength. The framework consists of the foundation walls, exterior walls, flooring, roofing, beams, trusses, partitions, and ceiling.
a. Substitute, expedient, and improvised framing. The particular form that substitute, expedient, and improvised buildings may take is usually determined by circumstances. Therefore it depends upon the particular nature of such circumstances as the time and place of building, the existence of an emergency, and the form it takes. The ideas included in (1) through (5) below constitute departures from standard plans and the adaptation of natural materials to some circumstances, and may suggest further expedients that would be adjustable to others. Available material and equipment, labor, climatic conditions, and local requirements must all be considered before plans are substituted or amended, or different materials or equipment substituted for standard or recommended items.
(1) Light siding. Chicken wire and water-resistant bituminous-coated paper can be sandwiched to provide adequate temporary cladding in temperate and tropical climates.
(2) Salvaged material. Salvaged sheet metal such as corrugated material or gasoline cans can be utilized as siding in the construction of emergency housing.
(3) Local timber. Poles trimmed from saplings or bamboo can be constructed into reasonably sound framing. Such materials may also be secured with native vines or grasses as a further expedient.
(4) Wood-substitute framing. Adobe, which is soil, straw, and water, "puddled" to proper consistency can be used to form walls, floors, and foundations. This mixture may be used to form sun-dried bricks and be adaptable to construction requirements. Adobe may be used for walls, floors, and/or roofs with adequate support.
(5) Excavations. Proper excavations and simple log cribbing may be covered with sod and carefully drained to provide adequate shelter. This type of construction should be used only under emergency.
b. Light frame construction. Very little of the material used in light construction needs to be framed. Much of the framing that must be done can be accomplished while the staking out and squaring of the budding are being completed. By use of a "shifting" organization, a large force of men can be kept working systematically without loss of time for completion of framing. When an advance crew has the skeleton of a building far enough along so the sides can be boarded, a crew large enough to keep pace with them can be putting on siding and roofing while others are making doors and so forth. Behind the crew nailing on siding, a gang can be roofing. But it must be remembered that those men erecting the frame should be the best men.

## 1-29. SILLS

a. The work involved in sill construction is very important to the carpenter. The foundation wall is the support upon which all


REINFORED CONCRETE

SQUARE CONCRETE

(4)


ROUND CONCRETE


(3)

ROUND TIMBER

(

Figure 1-26. Types of columns or piers.
superstructure rests. The sill is the foundation on which all framing structure rests, and it is the basic point of departure for actual carpentry and joinery activities. The sills are the first part of the frame to be set in place. They rest either directly on the foundation piers or on the ground, and may extend all around the building. They are joined at the corners and spliced when necessary.
(1) Built-up sills. Where built-up sills are used, the joints are staggered (1, fig. 1-27). The corner joints are made as shown in 2, figure 1-27.
(2) Box sills. Box sills are often used with the very common style of platform framing, either with or without the sill plate. In this type of sill 11, 2, fig. 1-28), the part that lies on the foundation wall or ground is called the sill plate. The sill is laid edgewise on the outside edge of the sill plate.
(3) T-Sills. There are two types of Tsill construction; one commonly used in dry, warm climates (3, fig. 1-28), and one commonly used in moderate climates (4, fig. 1-28). Their construction is similar, except that in the case of the moderateclimate T -sill the joists are nailed directly to the studs, as well as to the sills, and headers are used between the floor joists.
b. If piers are used in the foundation, heavier sills are used. These sills are of single heavy timbers or are built up of two or more pieces of timber. When heavy timbers or built-up type sills are used, the joints should occur over the piers. The size of the sill depends upon the load to be carried and upon the spacing of the piers.

## 1-30. GIRDERS

a. Description. Girders are large beams used to support floor joists and concentrated loads at particular points along their length (fig. 1-7). A girder may be either a single beam or a built-up composite. Girders usually support joists; the girders themselves are supported by piers or bearing walls. When a girder is supported by a foundation wall or pier, it must be remembered that such a girder delivers a large concentrated load to a small section of the pier or, to a lesser extent,


Figure 1-27. Sill fabrication.
to a wall; therefore, care must be taken to see that such a pier or wall is strong enough in its column action to carry the load imposed upon it by the girder. When softwood is used for girders it may be necessary to insert a hardwood bolster between the girder and pier to prevent crushing as illustrated in figure 1-29. Girders are needed to support floor joists wherever the width or length of the structure makes it impossible to use joists over the full span. The full span is considered to be from foundation wall to foundation wall. The size of these girders is determined by the span and the load to be carried. In general, the size of a beam or girder varies directly as the square of the length of the span; thus, if one span is twice as great as another, the girder for the longer span should be four times as strong as the girder for the shorter span. Sizes of girders for various loads and spans, designed for military construction in a theater of operations, are given in table 1-7.
b. Construction. Girders can be built up of wood if select stock is used. Be sure it is


Figure 1-28. Types of sills.


Figure 1-29. Protecting girder with hardwood bolster.
straight and sound. Square off ends of stock, if necessary. If the girder is to be built up of $2 \times 8$ or 2
x 10 stock, place pieces on the saw horses and nail together. Use the piece of stock that has the least amount of wind or warp for the center piece and nail other pieces on sides of center stock. Square off the ends of the girders after the pieces have been nailed together if necessary. If the stock is not long enough to build up the girder the entire length, the pieces must be built up by staggering the joints as in the case of the built-up sills (fig. 1-27). Girders are often built up by placing two or more joists side by side and nailing them together. For a girder of two joists, 16-penny nails should be used; for a girder of three joists, 20-penny nails should be used; and for girders of four or more joists, $20-$ or 30 -penny nails should be used. The nails must be placed about $11 / 2$ inches from the top and bottom edges of the joist, spaced about 24 inches apart, and staggered; they should be driven from both

TABLE 1-7. Sizes of Built-up Wood Girders for Various Loads and Spans (Based on Douglas Fir 4-Square Guideline Framing)

## $x$

sides of the girder alternately. If the girdersupporting pier is to be built up, it is to be done in the same manner as described for the girder.

## 1-31. FLOOR JOISTS

Joists are the pieces which make up the body of the floor frame. The flooring or subflooring is nailed to them. They are usually 2 or 3 inches thick and the depth is varied to suit the conditions. Joists as small as $2 \times 6$ are sometimes used in light buildings, but these are too small for floors with spans more than 10 feet though they are frequently used for ceiling joists.

Joists usually carry a uniform load composed of the weight of the joists themselves, plus superimposed loads of materials and personnel. The latter loads are commonly termed "live loads;" the weight of joists and floors is called "dead load." The joists carry the flooring directly on their upper surface, and firstfloor joists are supported at their ends by sills and by girders (fig. 1-7). Joists in second and subsequent floors are supported by bearing partitions, or bearing walls. They are spaced 16 or 24 inches apart, center to center. If additional strength is necessary, it is normally obtained
through the use of heavier joists rather than by closer spacing. However, in some instances, such as under a safe, it may be desirable to place the joists closer together. Two-inch material should not be used for joists more than 12 inches in depth.

## 1-32. METHOD OF CONNECTING JOISTS TO SILLS AND GIRDERS

a. Connecting to sills. In joining joists to sills, always be sure that the connection is able to hold the load that the joists will carry. 1, figure 1-30 shows the joists resting upon the sill. This method is the most commonly used because it gives the strongest possible joint. The methods shown in 2,3 , figure 1-30 are used where it is not desirable to use joists on top of the sill. The ledger plate should be


Figure 1-30. Sill and joist connections.
securely nailed and the joist should not be notched over one-third of its depth. 4, figure 1-30 shows the result of notching too deeply. There are several other methods, but those mentioned above are more or less standard. In the theater of operations it is up to the officer in charge of the carpenters to determine the method to be used; he must keep in mind that time, labor, and material are of vital importance.
b. Connecting to girders. The framing of the joists to the girders may be accomplished in several ways, depending upon the position of the girder. The placing of the girders is an important factor. The joists must be level; therefore, if the girder is not the same height as the sill, the joist must be notched as shown in 3, figure 1-30. If the girder and sill are of the same Height, the joist still must be connected to the sill and girder to keep the joist level. Joists are connected to girders as shown in figure 130. In placing joists, always have the crown up since this helps counteract the weight on the joist. Overhead joists are joined to plates as shown in 1, figure 1-31. The inner end of the joist rests on the plate of a bearing partition. When a joist is to rest on plates or girders, either the joist is cut long enough to extend the full width of the plate or girder, or it is cut so as to meet another joist in the center of the girder and connected with a scab (fig. 1-7). Where two joist ends lie side by side on a plate or girder, they should be nailed together (1, figure 1-31). In 2, figure 1-31 the end of the joist rests on a wall plate.


Figure 1-31. Joist connections to plate.
c. Use of ledger plates. In connecting joists to girders and sills where piers are used, a narrow piece of 2 -inch lumber is nailed to the face of the sill or girder, flush with the bottom edge; this is called a "ledger plate" (fig. 1-32). These pieces should be nailed securely with 20 -penny nails about 12 inches apart. Where $2 \times 6$ or $2 \times 8$ joists are used, it is better to use $2 \times 2$ 's to prevent the joists from splitting at the notch. When joists are 10 inches deep or deeper, $2 \times 4$ 's may be used without reducing the strength of the joists. If a notch is used, joist ties may be used to overcome this loss of strength, as shown in figure 1-2. These ties are short $1 \times 4$ boards nailed across the joist; the ends of the boards are flush with the top and bottom edges of the joists.


Figure 1-32. Ledger plates (or strips).

## 1-33. BRIDGING

When joists are used over a long span they have a tendency to sway from side to side. Floor frames are bridged in order to stiffen the floor frame, to prevent unequal deflection of the joists, and to enable an overloaded joist to receive some assistance from the joists on either side of it. Bridging is of two kinds horizontal bridging (1, fig. 1-33) and cross bridging (2, fig. 1-33). Cross bridging is the one most generally used; it is more effective and requires less material than horizontal bridging. Cross bridging looks like a cross and consists of pieces of lumber, usually $1 \times 3$ or $2 \times 3$, put in diagonally between the floor


Figure 1-33. Types of bridging.
joists. Each piece is nailed to the top of each joist and forms a cross between the joists. These pieces between joists should be placed as near to each other as possible. Bridging should be nailed with two 8 - or 10 -penny nails at each end. The tops should be nailed and the bottoms left with nails driven through the bridging only until the subfloor or finish floor is laid. This permits the joists to adjust themselves to their final positions. The bottom ends of bridging may then be nailed, forming a continuous truss across the whole length of the floor and preventing any overloaded joist from sagging below the others. Cutting the bridging by hand is a slow process; on large jobs a power saw should be used if it is available. After the joists have once been placed, a pattern may be made and used to speed up the process of cutting. On joists more than 8 feet long, one
line of bridging should be placed, and on joists more than 16 feet long, two lines.

## 1-34. SUBFLOOR

Subfloor, if used, is laid diagonally on the joists and nailed with 8 - or 10 -penny nails, the number of nails depending upon the width of the boards. Boards 8 inches wide or over should have three or more nails per joist. Where the subfloor is more than 1 inch thick, larger nails should be used. By the use of subflooring, floors are made much stronger since weight is distributed over a wider area. Figure 1-7 shows the method of laying a subfloor. It may be laid before or after the walls are framed, preferably before as it can then be used as a floor to work on while framing the walls.

## 1-35. REINFORCED JOISTS

In certain parts of the floor frame, in order to support a bearing partition or some other heavy, concentrated load, it may be necessary to construct reinforced joists (fig. 1-34 (1)). If spacing is required for heat ducts, solid blocking should be used between the joists (fig. 1-34 (2)(A)).

## 1-36. HEADERS AND TRIMMERS

A girder may also be necessary in a floor when
an opening is to be left in the floor for some other structure. The timbers on each side of such an opening are called "trimmers," and these must be made heavier than the ordinary joists. A piece called a "header" must be framed in between them to receive the ends of the short joists as shown in figure 1-35. To frame an opening of thin type, first install joists $A$ and $C$ (fig. 1-35), then cut four pieces of timber that are the same size as the joists with the length corresponding to the distance between the joists A and C at the outside wall. Nail two of these pieces between the joists at the desired distance from the ends of the joists; these pieces are shown as headers Nos. 1 and 2. Install short joists X and Y , as shown. The nails should be 16 - or 20 -penny nails. By omitting headers Nos. 3 and 4 and joists B and D temporarily, the short joists X and Y can be nailed in place through the header and the headers can be nailed through the joists A and C into its end. After the header and short joists have been securely nailed, headers Nos. 3 and 4 are nailed beside Nos. 1 and 2. Then joist B is placed beside joist A and joist D beside joist C , and all are nailed securely.

## 1-37. FOUNDATION LAYOUT

The objectives of surveying for building construction are to lay out the proposed


Figure 1-34. Reinforced joists.


Figure 1-35. Headers and trimmers.
structure according to prepared plans and to mark the controlling points of the structure in the manner that is most useful to the construction force. This marking consists of indicating the corners of the building and other horizontal and vertical positions by means of stakes, batter, boards with string-lines, and cut-and-fill notations.

## 1-38. LAYING OUT A SIMPLE RECTANGLE WITH AN ENGINEER'S TRANSIT OR LEVELING INSTRUMENT

The procedures for a typical simple budding layout are shown in figure 1-36.
a. Establish baseline AB from a reference monument or bench mark, or a fixed line such as a street curb, and then locate point C and D on the baseline by measurement.
b. With the transit at point C , backsight on point B , turn a $90^{\circ}$ angle, and locate and place corner
stakes E and F by measurement and determine their elevation.
c. Move transit to point D , backsight on point A, turn a $90^{\circ}$ angle, and locate and place corner stakes G and H by measurement and determine their elevation.
d. Install batter boards and wire to retain the layout during excavation and construction.
e. Check the squareness of the layout by measuring the length of the diagonals, EH and FG and comparing it with the length computed by $\mathbf{c}=\sqrt{\mathbf{a}^{2}+\boldsymbol{b}^{\mathbf{r}}}$ where $\boldsymbol{c}$ is the computed diagonal length and $\mathbf{a}$ and $\mathbf{b}$ are the lengths of the two sides (see calculation of diagonal, fig. 1-6). The squareness can also be checked by using a 3-4-5 right triangle or carpenter's square to check the 900 angle at the corners. The procedure of laying out a simple rectangle with a measuring tape is the same as with an engineer's


Figure 1-36. Method of laying out a simple rectangular building.
transit except the right angles are established by the we of the measuring tape. A right triangle with sides equal to 3-4-5 or a multiple thereof is formed and is used to lay off the $90^{\circ}$ at the turns.

## 1-39. LAYING OUT AN IRREGULARLY SHAPED PROJECT

When the outline of the building is not a simple rectangle, the procedure in establishing each point is the same as described above, except that more points have to be located and the checking of the work is more likely to reveal a small error. After having established the baseline, it is usually advisable with an irregularly shaped building to lay out first a large rectangle which will comprise the entire building or a greater part of it. This is shown in figure 1-37 as rectangle HQRS. Having once established this accurately, the remaining portion of the layout will consist of small rectangles, each of which can be laid out and checked separately.

## 1-40. BATTER BOARDS

a. Staking procedure. At the points where the corners of the building are located,


Figure 1-37. Layout of an irregularly shaped project.
stakes are driven to mark the exact spots (fig 1-38). If the area must be excavated for foundation, the excavating will disturb the pegs. Batter boards are therefore set up to preserve definite and accurate building lines to work toward or from. This is accomplished by stretching heavy cord or fine wire from one batter board to the other so as to define the lines of excavations.
b. Locating batter boards. Right-angle batter beards are erected 3 or 4 feet outside each corner stake (fig. 1-38), and straight batter boards are erected 3 or 4 feet outside of line stakes set at points provided for the extension of foundation lines which intercept side lines.
c. Construction of batter boards. Batter board stakes may be $2 \times 4,2 \times 6$ or $4 \times 4$. They must be heavy enough to be sturdy when driven and withstand all ordinary working conditions. They are driven far enough apart to straddle the line to be marked. The length of the stakes is determined by the required finished grade line and required height above ground. If the height above ground is more than 3 feet, they should be braced. The $1 \times 6$ crosspiece is cut long enough to join both stakes and is nailed firmly to them after the grade has been established. The top of the crosspiece then becomes the mark from which the grade will be measured. All batter boards for one structure are set to the same grade of level line. It is best to use a transit to locate the building lines. The building lines are marked on the crosspiece with a nail or saw cut. Separate cuts or nails may be used for the building line, foundation line, hooting line, and excavation line. These grooves and nails permit the removal and replacement of the lines or wires in correct position.

## 1-41. PROCEDURE FOR ESTABLISHING LINES FROM BATTER BOARDS

Referring to figure 1-39, the following procedure applies to a simple layout and must be amended to apply to different or more complex layout problems.
a. After locating and sinking corner stakes A and B, erect batter boards 1, 2, 3,


Figure 1-38. Batter boards.


Figure 1-39. Establishing building lines from batter boards.
and 4. Place the wire X from batter board 1 over stakes A and B to batter board 3 .
b. After locating and sinking stake $C$ erect batter boards 5 and 6 . Place the wire Y from batter board 2 over stakes A and C to batter board 6 .
c. After locating and sinking stake D , erect batter boards 7 and 8. Place the wire Z from batter board 5 over stakes C and D to batter board 7 .
d. Place line O over stakes D and B from batter boards 8 and 4 .
e. Since TO buildings are generally built with the top of the subfloor a specified minimum distance off the ground, it will usually be found convenient to mark the height of subfloor above the ground on the batter board post at the "high" corner (the corner where the existing grade is highest). The top of the batter board will be placed at the mark and will represent the top of the subfloor. The first batter board crosspiece is located by placing the top edge crosspiece in line with the mark on the post and leveling the crosspiece with a carpenters level, then fastening the crosspiece to the posts with nails. The same procedure is used for the second batter board crosspiece. Now the problem is to carry this reference level to the other corners, thereby maintaining a truly horizontal plane. This is best done with a transit but it can be accomplished with a line level. With the wire attached to the established batter board, attach a line level at the center of the wire. Move the free end of the wire up and down on the next post until the line is level. Once it is level mark the post and reverse the line level and repeat the process. In many cases, due to variation in position and inaccuracies of the level, the reversal will give a different point on the post, but the variation should not exceed 1 inch. If the variation is greater, repeat the procedure. The point of elevation will be a point
midway between the two marks thus found. Vertical distance can then be measured up or down from the batter board lines.

## 1-42. SQUARING BUILDING LINES

There are two generally accepted methods for squaring building lines commonly used by the carpenter: the diagonal method and the 3-4-5 triangle method.
a. The diagonal method. If all the corners are square, the diagonals will be of equal length. These diagonals are seldom equal on the first trial; therefore, we must adjust the sides so that the building will be square. Referring to figure 1-39, let us assume that when the diagonals were measured BC was shorter than AD . It has already been established that al sides are the correct length and also that side AB is always the base. Therefore, all of the adjustments are made by moving the wires on batter boards 6 and 8 either to the left or the right. In this case, the wire BD should be moved to the right a sufficient distance on batter board 8, and AC a corresponding distance on batter board 6 . The diagonals are then measured. If they are not yet the same length, the process is repeated until the diagonals are equal. When the outline is correct, saw cuts are made in the outside edges of the batter board to mark and hold the correct location of the wires.
b. 3-4-5 method. Referring to figure 139, the distance AF is measured. AF is 3 feet or a multiple thereof such as 6,9 , or 12 . Measure off AG to a distance of 4 feet ( 8 feet if 6 feet was used for $\mathrm{AF}, 12$ feet if 9 feet was used for AF , or 16 feet if 12 feet was used for AF). Adjust the wires until FG equals 5 feet if the other two measurements used were 3 feet and 4 feet ( 10 feet if 6 feet and 8 feet were used, 15 feet if 9 feet and 12 feet were used, and 20 feet if 12 feet and 16 feet were used).

## SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a paragraph containing information related to the question. Write your answer in the space provided below each question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Review the lesson as necessary. Do not send in your solutions to these review exercises.

1. Name the classifications of buildings as authorized by Army regulations and give the expected economic life of each. (Para 1-1)
2. How does the architect who designs a structure convey the information he wishes to the builder? (Para 1-2b)
3. On construction drawings, lines may be light or heavy, solid or broken in several variations, each having a different meaning. What type of line is used to divide objects into equal or symmetrical parts? (Para 1-3c)
4. Although scaling of prints should be avoided as much as possible, when it is essential what scale should be used on drawings of machine work? (Para 1-4a(1))
5. Architectural drawings generally consist of several different views of the structure. What view shows the type, size, and location of plumbing and electrical wiring? (Para 1-5b(8))
6. What type joint is most commonly used for rafter junctions of roof peaks? (Para 1-8c)
7. What is the difference, from the standpoint of use, between a joint and a splice? (Para 1-8, 1-9)
8. There are many types of wood that are suitable for use as building material. What type wood is mostly used by the Army in TO construction? (Para 1-10a)
9. There are several types of decay which render lumber unserviceable for normal TO construction. Which type is the most common and the most dangerous? (Para 1-13a)
10. What classification and grade of lumber is most generally used for the construction of boxes and crates? (Para 1-16b(4))
11. What is meant by the term board foot? (Para 1-18a)
12. Three of the most common types of wood fasteners used in the $T O$ are nails, screws, and bolts. Of these three, which is considered the most economical, and which provides the greatest holding power, sizes being comparable? (Para 1-20a)
13. What devices are used between two timber faces to increase the joint strength in timber structures? (Para 1$25 \mathrm{~b}(1))$
14. Building foundations are either of the wall or column (pier) type. Which is the most commonly used in TO construction and why? (Para 1-27)
15. In the construction of a frame building, what is the function of the sill? (Para 1-29a)
16. If the width of a structure is too great to use floor joists over the full span, what structural feature can be added to reduce the length of the joists? (Para 1-30a)
17. When cross bridging is used to prevent side sway in joists, why is the bottom not nailed to the joists at the same time as the top? (Para 1-33)
18. After the baseline for a building layout has been established, what is usually the first step in laying out an irregularly shaped building? (Para 1-39)
19. Batter boards are constructed outside the corner stakes of structures. If they are over a certain height they must be braced. What is this height in feet? (Para 1-40c)
20. It is best to check the level of a building with a transit. If a transit is not available, what is the next best means of checking a layout of a building to see if it is approximately level? (Para 1-41e)

## LESSON 2

## SUPERSTRUCTURES - FRAMING

## LESSON OBJECTIVES

Upon completion of this lesson you should be able to accomplish the following in the indicated topic areas:

1. Nomenclature and function. Name all the members of the superstructure of a Theater of Operations type framed building, and state its function.
2. Walls and partitions. Supervise the construction of walls and partitions to include
plumbing and bracing, doors, windows, and other details.
3. Roofs. Determine the correct size and length of lumber to use for the different members of a roof truss, and the proper method of construction.
4. Light TO type framing. Plan and supervise construction, when appropriate using the light theater-of-operations type framing.

## ATTACHED MEMORANDUM

## 2-1. WALLS AND PARTITIONS

Walls and partitions are structural elements composed of vertical members called studs, and are usually closely spaced. They are arranged in a row with their lower ends bearing on a long horizontal member, called a bottom plate or sole plate, and with their tops capped with another plate, called a top plate. Double top plates are usually used, especially in bearing walls and bearing partitions. The bearing strength of stud walls is determined by the strength of the studs.
a. Corner posts. The studs used at the corners of fame structures are usually built up from two or more ordinary studs or other dimension stock to provide strength and additional nailing surfaces. After the sill and first-floor joists are in place, the
first floor is roughly covered to give a surface upon which to work. The corner posts are set up plumbed, and temporarily braced. The corner posts may be made up of boards in several different ways (fig. 2$1)$.
(1) A corner post may consist of a $4 \times 6$ with a $2 \times 4$ nailed on the broad side, flush with one edge (1, fig. 2-1). This type of corner is primarily for a 4 -inch wall. Where walls are thicker, heavier timber is used.
(2) A $4 \times 4$ may be used with $2 x 4$ 's nailed to two of the adjoining sides (2, fig. 2-1).
(3) Two $2 \times 4$ 's may be nailed together with blocks between and another $2 \times 4$ nailed flush with one edge (3, fig. 2-1).


Figure 2-1. Corner post construction.
(4) A $2 \times 4$ may be nailed to the edge of another $2 \times 4$, the edge of one flush with the side of the other (4, fig. 2-1). This type is used extensively in TO construction where no inside finish is required.
b. T-posts. In conventional framing, whenever a partition meets an outside wall or another partition, a stud wide enough to extend beyond the partition of both sides is used. This affords a solid nailing base for the inside wall finish. This type of stud is called a "T-post" and is made in several different ways (fig. 2-2).
(1) A $2 \times 4$ may be nailed and centered on the face side of a $4 \times 6$ (1, fig. 2-2).
(2) A $2 \times 4$ may be nailed and centered on two $4 \times 4$ 's nailed together (2, fig. 2-2).
(3) Two $2 x 4$ 's may be nailed together with $2 \times 4$ blocks between them and a $2 \times 4$ centered on the wide side (3, fig. 2-2).


Figure 2-2. T-post construction.
(4) A $2 \times 4$ may be nailed and centered on the face side of a $2 \times 6$, with a horizontal bridging nailed behind them to provide support and stiffness (4, fig. 2-2).
(5) Where a partition is finished on one side only as in most TO construction, the partition post used consists of a simple stud, set in the outside wall, in line with the side of a partition wall, and furnished as stud A in 1, figure 2-3. The exact position of the partition walls must be determined before the posts are placed. Where the walls are more than 4 inches thick, wider timber is used.
c. Double T-posts. In special cases, for example where partition walls cross, a double T-post is used. This is made by using T-post construction (1, 2, or 3, fig. 2-2), modified by nailing another $2 \times 4$ to the opposite wide side, as shown in 2,3 , and 4 , figure 2-3.


Figure 2-3. Partition posts.

## d. Studs.

(1) After the sills, posts, plates, and braces are in place, the studs are placed and nailed with two 16- or 20-penny nails through the top plate. Before the studs are set in place, the window and door openings are laid out. Then the remaining or intermediate studs are laid out on the sills or soles by measuring from one corner the distances the studs are to be set apart. Studs are set from 1 to 12 feet apart, depending upon the type of building, whether girts are used, and the type of outside and inside finish. Where vertical or large-panel siding is used, studs may be set wider apart and horizontal girts provided between them to afford nailing surfaces. For residential work in the United States studs are commonly spaced on 16 -inch centers; in TO construction, if girts are used, studs are usually spaced 4 feet apart.
(2) When it is desirable to double the post of the door opening, fist place the outside studs into position and nail them securely. Then cut short studs, or filler studs, the size of the opening and nail these to the inside face of the outside studs as shown in figure 2-4. In making a window opening, a bottom header must be framed. This header is either single or double. When it is doubled, the bottom piece is nailed to the opening studs at the proper height, and the top piece of the bottom header is nailed into place flush with the bottom section. The door header is framed as shown in figure 2-4. The filler stud rests on the sole at the bottom.

## e. Top plate and sole plate.

(1) Top plate. The top plate serves as a connecting link between the wall and the


Figure 2-4. Door and window framing.
roof, just as the sole plates are connecting links between the floors and the walls. The plate is made up of one or two pieces of timber of the same size as the studs. In cases where the studs at the end of the building extend to the rafters, no plate is used at the end of the budding. When it is used on top of partition walls it is sometimes called the cap. Where the plate is doubled, the first plate or bottom section is nailed with 16 or 20 -penny nails to the top of the corner post and to the studs; the connection at the corner is made as shown in 1, figure 2-5. After the single plate is nailed securely and the corner braces are nailed into place, the top part of the plate is then nailed to the bottom section by means of 16 - or $20-$ penny nails, either placed over each stud or spaced with two nails every 2 feet. The edges of the top section should be flush with the bottom section and the corner joints lapped as shown in 2, figure 2-5. Where only a single plate is used the end studs of two walls forming a corner are spiked together as shown in 4, figure 2-1.
(2) Sole plate. All partition walls and outside walls are finished at the bottom with a piece of timber corresponding to the thickness of the wall. This timber, which is usually a $2 \times 4$, is laid horizontally on the subfloor or, occasionally, on the joists. It carries the bottom end of the studs (1, fig. 23 ). This timber is called the "sole" or "sole plate". The sole should be nailed with two 16- or 20-penny nails at each jolt that R crosses. If it is laid


Figure 2-5. Plate construction.
lengthwise on top of a girder or joist, it should be nailed with two nails every 2 feet.
f. Bridging. Frame walls are bridged, in most cases, to make them more sturdy. There are two methods of bridging:
(1) Diagonal bridging. Diagonal bridging is nailed between the studs at an angle (1, fig. 2-6). It is more effective than the horizontal type since it forms a continuous truss and tends to keep the walls from sagging. Whenever possible, both inside and outside walls should be bridged alike.
(2) Horizontal bridging. Horizontal bridging is nailed between the studs horizontally and halfway between the sole and the plate (2, fig. 2-6). This bridging is cut to lengths which correspond to the distance between the studs at the bottom. Such


Figure 2-6. Types of wall bridging.
bridging not only stiffens the wall but also helps straighten crooked studs.
g. Partitions. Partition walls are any walls that divide the inside space of a building. These walls in most cases are framed as part of the building. In cases where floors are to be installed after the outside of the building is completed, the partition walls are left unframed. There are two types of partition walls: the bearing and the nonbearing types. The bearing type supports ceiling joists. The nonbearing type supports only itself. This type may be put in at any time after the other framework is installed. On nonbearing partitions only one cap or plate need be used. A sole plate should be used in every case, as it helps to distribute the load over a larger area and provides a suitable nailing base. Partition walls are framed in the same manner as outside walls, and door openings are framed the same as outside openings. If there is to be an inside finish, corner posts or T-posts are used where one partition wall joins another as in the outside wails. These posts provide nailing surfaces for the inside wall finish. The top of the studs has a plate or cap when the partition does not extend to the roof; when the partition does extend to the roof, the studs are joined to the rafters.

## 2-2. PLUMBING VERTICAL MEMBERS AND STRAIGHTENING WALLS

After the corner posts, T-posts, and intermediate wall studs have been nailed to the plates and the girts, the walls must be plumbed and straightened so that the permanent braces and rafters may be installed. This is done by using a level or a plumb bob and a chalk line.

## a. Plumbing posts.

(1) To plumb a corner with a plumb bob, first attach to the bob a string long enough to extend to or below the bottom of the post. Lay a rule on top of the post so that 2 inches of the rule extends over the post or the side to be plumbed. Then hang the bob line over the rule so that the line is 2 inches from the post and extends to the bottom of it, as shown in figure 2-7. With another rule,


Figure 2-7. Plumbing posts with a plumb bob.
measure the distance from the post to the center of the line at the bottom of the post; if it does not measure 2 inches, the post is not plumb. Move the post inward or outward until the distance from the post to the center of the line is exactly 2 inches. Then nail the temporary brace in place repeat this procedure for the other outside face of the post. The post is then plumb. This process is carried out for the remaining corner posts of the building. If a plumb bob or level is not available, a rock, a half brick, or some small piece of metal may be used instead.
(2) To plumb a corner with a carpenter's level, place the level against each outer face of the post and adjust the post until the level bubble comes to rest exactly between the two scratch marks on the level glass.
b. Straightening walls (fig. 2-8). Plumb one corner post with the level or plumb bob and nail temporary braces to hold the post in place (a above). Repeat this procedure for all corner posts. Fasten a chalk line to the outside of one post at the top and stretch the line to the post at the opposite end of the


Figure 2-8. Straightening walls.
building, fastening the line to this post in the same manner as for the first post. Place a small 3-4-inch block under each end of the line as shown in figure 2-8 to give clearance. Use enough temporary braces to hold the wall straight. When the wall is far enough away from the line to permit a $3 / 4$-inch block to barely slide between the line and the plate, the brace is then nailed. This procedure is carried out for the entire perimeter of the building. Inside partition walls should be straightened in the same manner.

## 2-3. BRACES

Bracing is used to stiffen framed construction and make it rigid. The purpose of bracing may be to resist winds, storm, twist, or strain stemming from any cause. Good wall bracing keeps corners square and plumb and prevents warping, sagging, and shifts resulting from lateral forces that would otherwise tend to distort the frame and cause badly fitting doors and cracks in the wallboard. There are four commonly used methods of bracing the walls of frame structures:
a. Let-in bracing (1, fig. 2-9). Let-in bracing is set into the edges of studs to be flush with the surface. The studs are always cut to let in the braces; the braces are never cut. Usually $1 \times 4$ 's or 1 x 6's are used, set diagonally from top plates to sole plates.


Figure 2-9. Common types of bracing.
b. Cut-in bracing (2, fig. 2-9). It usually consists of $2 \times 4$ 's cut at an angle to permit toenailing, inserted in diagonal progression between studs and running up and down from corner posts to sills or plates.
c. Diagonal sheathing (3, fig. 2-9). The type of bracing with the highest strength is 1 -inch nominal thickness sheathing applied diagonally. Each board acts as a brace of the wall. Similarly, if plywood sheathing $5 / 8$-inch thick or more and in 4 by 8 -foot panels is used, other methods of permanent bracing may be omitted.
d. Internal diagonal bracing (fig. 2-8). Internal diagonal braces are placed wherever the sills, girts, or plates form an angle with corner or T-posts. Diagonal braces consist of material extending from the sill or sole plate to form angles of approximately $60^{\circ}$ at the sill or sole. This type of bracing is used only in TO type structures that do not have an interior finish.

## 2-4. ROOFS

The primary object of a roof in any climate is to keep out the rain and the cold. With the roof covering normally used by the Army, the roof must be sloped to shed water. Where there are heavy snows for long periods of time, roofs must be constructed more rigidly and/or pitched more steeply. They must also be strong enough to withstand high
winds. The most commonly used types of roof construction include:
a. Gable roof (1, fig. 2-10). The gable roof is the most commonly used of the various types of roofs. It has two roof slopes meeting at the center, or ridge, to form a gable. This form of roof is the one most commonly used by the Army, since it is simple in design and economical to construct and may be used on any type of structure.
b. Lean-to or shed roof (2, fig. 2-10). This roof is used where large buildings are framed under one roof, where hasty or temporary construction is needed, and when sheds or additions to buildings are erected. The pitch of the roof is in one direction only. The roof is held up by the walls or posts on four sides; one wall or the posts on one side are at a higher level than those on the opposite side.
c. Hip roof (3, fig. 2-10). The hip roof consists of four sides or slopes running toward the center of the building. Rafters at the corners extend diagonally to meet at the center, or at the end of a ridge. Into these rafters, other rafters are framed.
d. Gable and valley roof (4, fig. 2-10). This roof is a combination of two gable roofs intersecting each other. The valley occurs where the two roofs meet, each roof slanting


Figure 2-10. Types of roofs.
in a different direction. This type of roof is seldom used in TO construction, since it is complicated and requires much time and labor to construct.
e. Slope or cut. The slope of a roof is the angle which the roof surface makes with a horizontal plane. The surface may vary from absolutely flat to a steep slope. The usual way to express roof slope is by means of numbers; for example, 8 and 12,8 being the rise and 12 the unit of run. Occasionally roof slope is given on plans with some other run than 12, the unit of run. For example, suppose a plan gives the rise as 2 inches per 5 inches of run. In this case the slope can be converted to the standard unit of run by simple proportion:

$$
2 / 5=x / 12 \text { or } 5 x=24 \text { or } x=44 / 5
$$

## f. Terms used in connection with roofs.

(1) Span. The span (1, fig. 2-11) of any roof is the shortest distance between the two opposite rafter seats. Stated in another way, it is the measurement between the outside edges of the outside-wall plates, measured at right angles to the direction of the ridge of the building.
(2) Total rise. The total rise (1, fig. 211, fig. 2-13) is the vertical distance measured from the intersection of the upper edge of the rafter with the building limit line, to the top of the ridge. It is the product of the rise in inches times the total run in feet.
(3) Total run. The term total run (1, fig. 2-11) always refers to the level distance over which any rafter (para 5a) passes. For the ordinary gable-roof rafter, this would be one half the span distance.
(4) Unit of run. The unit of measurement, 1 foot or 12 inches, is the same for the


Figure 2-11. Rafter layout terms.
roof as for any other part of the building. By the use of this common unit of measurement the framing square is employed in laying out large roofs (1, 2, fig. 2-11).
(5) Rise in inches. The rise in inches is the number of inches that a roof rises for every foot of run.
(6) Pitch. Pitch is the term used to describe the ratio of rise to roof span (2, fig. 2-11).
(7) Cut of roof. The cut of a roof is the rise in inches and the unit of run ( 12 inches). See 2, fig. 2-11.
(8) Line length. The term line length as applied to roof framing is the hypotenuse of a triangle whose base is the total run and whose altitude is the total rise (1, fig. 2-11).
(9) Plumb and level lines. These terms have reference to the direction of a line on a rafter and not to any particular rafter cut. Any line that is vertical when the rafter is in its proper position is called a plumb line. Any line that is level when the rafter is in its proper position is called a level line (3, fig. 3.11).

## 2-5. RAFTERS

a. General. The members which make up the main body of the frame work of all roofs are called rafters. They do for the roof what the joists do for the floor and what the studs do for the wall. Rafters are inclined members which vary in size, depending on their length and the distance at which they are spaced. The tops of inclined rafters are fastened in one of the various common ways determined by the type of roof. The bottoms of the rafters rest on the plate member which provides a connecting link between wall and roof and is really a functional part of both. The structural relationship between rafters and wall is the same in all types of roofs. Rafters are not framed into the pate but are simply nailed to it, some being cut to fit the plate while others, in hasty construction, are merely laid on top of the plate and nailed in place. Rafters may extend a short distance beyond the wall to form the eaves and protect the sides of the building.
b. Types of rafters and rafter cuts (fig.

2-12). Since rafters, together with ridge-boards and
plates, are the principal members of roof framing it is important to understand the following terms that apply to them:
(1) Common rafters. The common rafters, AAA, extend from plate to ridge-board at right angles to both (1, fig. 2-12).
(2) Hip rafters. Hip rafters, DD, extend diagonally from the corners formed by intersection plates to the ridgeboard (1, fig. 2-12).
(3) Valley rafters. Valley rafters, CC, extend from the plates to the ridgeboard along the lines where roof slopes intersect (1, fig. 2-12).
(4) Jack rafters. Jack rafters never extend the full distance from plate to ridge-board. Jack rafters, BBB, are shorter than common rafters and their lower ends rest on the plate and their upper ends against the hip rafter (1, fig. 2-12).
(5) Cripple jacks. Cripple jacks, FF, are nailed between hip and valley rafters (1, fig. 212).
(6) Top of plumb cut is the cut made at the end of the rafter to be placed against the ridgeboard or, if the ridgeboard is omitted, against the opposite rafters (2, fig. 2-12).
(7) Seat, bottom, or heel cut is to rest on the plate (2, fig. 2-12).
(8) Side or cheek cut is a bevel cut on the side of a rafter to fit it against another frame member (2, fig. 2-12).
(9) Eave or tail is the overhang of the rafter extending beyond the outer edge of the place (2, fig. 2-12).
(10) Rafter line length is measured along the upper edge of the rafter and is the distance from the ridge line to a point marking the intersection of the upper edge of the rafter with the building limit (fig. 2-13).

## 2-6. RAFTER DESIGN AND LAYOUT

Rafters must be laid out and cut with slope, length, and overhang exactly right so that they will fit when placed in position. If detailed building plans are available this


Figure 2-12. Types of rafters.
information may be obtained from them. If no plans are available, or if verification is desired, the width of the building may be measured and the roof slope determined by type of roof covering, use of building,
or other controlling factors. It is then possible to determine the unit run and unit rise, total run and total rise, and the rafter line length. The
rafter line length may be found either by calculation or by use of the steel square.
a. By calculation. The rafter line length forms the hypotenuse of a right triangle whose other sides are the total rise and the total run (fig. 2-13). It can therefore be determined by the following formula:

$$
\text { Rafter line length }=\sqrt{\text { run }^{2}+\text { rise }^{2}}
$$

As an example, assume that the total run is 10 feet and the total rise is 5 feet. Then the rafter line length $=\sqrt{(10)^{2}+(5)^{2}}=\sqrt{125}=$ 11.18, or 11 feet, $21 / 6$ inches. Dropping the fractional inch and adding one foot for overhang, the total length of the rafter would be 12 feet 2 inches.


Rafter Line Length $=\sqrt{\text { RUN }^{2}+\text { RISE }^{2}}$ Rafter Length $=$ Rafter Line Length + Overhang (if Used)

Figure 2-13. Typical common rafter.

## b. Steel square-scaling method.

(1) It is first necessary to determine the total run and the rise in inches. Assume that you have determined a run of 10 feet and a rise of 8 inches per foot of run. To determine the approximate line length of rafter, measure on the steel carpenter square the distance between 8 on the tongue and 12 on the blade, because 8 is the rise and 12 is the unit of run. This distance is $145 / 12$ inches, and represents the line length of a rafter with a total run of 1 foot and a rise of 8 inches. Since the run of the rafter is 10 feet, multiply 10 by the line length for 1
foot. The answer is $145 / 12$ times $10=1442 / 12$ inches, or 12 feet and $2 / 12$ inches. The amount of overhang must be added if an overhang is to be used (it is often 1 foot). Dropping the fraction, this makes a total of 13 feet for the length of the rafter.
(2) After the length has been determined, the timber is laid on sawhorses, sometimes called "saw benches", with the crown or bow (if any) as the top side of the rafter. Select the straightest piece possible for the pattern rafter. If a straight piece is not available, place the crown toward the person laying off the rafter. Hold the square with the tongue in the right hand, the blade in the left, and the heel away from the body, and place the square as near the upper end of the rafter as possible. In this case, the figures 8 on the tongue and 12 on the blade are placed along the edge of timber which is to be the top edge of the rafter as shown in 1, figure 2-14. Mark along the tongue edge of the square, which will be the plumb cut at the ridge. Since the length of the rafter is known to be 12 feet, measure that distance from the top of the plumb cut and mark it on the timber. Hold the square in the same manner with the 8 mark of the tongue directly over the 12 -foot mark. Mark along the tongue of the square to give the plumb cut for the seat (2, fig. 2-14). Next measure off, perpendicular to this mark, the length of overhang along the timber and mark a plumb-cut mark in the same manner, keeping the square on the same edge of the timer (3, fig. 2-14). This will be the tail cut of the rafter. Sometimes the tail cut is made square across the timber.
(3) The level cut or width of the seat is the width of the plate, measured perpendicular to the plumb cut, as shown in 4, figure 2-14. Using the square, square lines down on the sides from all level and plumb-cut lines. Now the rafter is ready to be cut (5, fig. 2-14).
c. Steel square - step-off method. If a building is 20 feet, 8 inches wide, the run of the rafter would be 10 feet, 4 inches, or half the span. Instead of using the method in a above, the rafter length may be determined by "stepping it off" by successive steps with the square as shown in figure 2-15. Take the


Figure 2-14. Rafter layout, scale method.
same number of steps as there are feet in the run, which leaves 4 inches over a foot. This 4 inches is taken care of in the same manner as the full foot run; that is, with the square at the last step position, make a mark on the rafters at the 4 -inch mark on the blade, then move the square along the rafter until the tongue rests at the 4 -inch mark (1, fig. 2-15). With the square held for the same cut as before, make a mark along the tongue. This is the line length of the rafter. The seat cut and overhang are made as described in a above (2, 3, 4, fig. 2-15). When laying off rafters by any method, be sure to recheck the work carefully. When two rafters have been cut, it is best to put them in place to see if they fit. Minor adjustments may be made at this time without serious damage or waste of material.
d. Steel square-rafter tables. The framing square may have one or two types of rafter tables on the blade. Figures 2-16 and 2-17 are illustrations of the two types. One type gives both the line length of any common rafter per foot of run and the line length of any hip or valley rafter per foot of run. The difference in length of the jack rafter spaced 16 to 24 inches OC (on center) is also shown in


Figure 2-15. Rafter layout, step-off method.
figure 2-16. Where the jack rafter, hip, or valley rafter requires side cuts, the cut is given in the table (fig. 2-16). The other type of table (fig. 2-17) gives the actual length of rafter for a given pitch and span.
(1) The first type of table (fig. 2-16) appears on the face of the blade. It is used to determine the length of the common, valley, hip and jack rafters, and the angles at which they must be cut to fit at ridge and plate. To use the table the carpenter must become familiar with it and know what each figure represents. The row of figures in the first line represents the length of common or main rafters per foot of run, as the title indicates at the lefthand end of the blade. Each set of figures under each inch division mark represents the length of rafter per foot of run with a rise corresponding to the number of inches over the number. For example, under the 16inch mark appears the number 20.00 inches. This number equals the length of a rafter with a run of 12 inches and a rise or 16 inches, or, under the 13 -inch mark appears the number 17.69 inches which is the rafter length for a 12 -inch run and a 13 -inch rise. The other five lines of figures in the table will not be discussed as they are seldom used in the theater of operations.
(2) To use the table for laying out rafters, the width of the building must be


Figure 2-16. Rafter table, blade face.


Figure 2-17. Rafter table, back of blade.
known. Suppose the building is 20 feet, 8 inches wide and the rise of the rafters is to be 13 inches per foot of run. The total run of the rafters will be 10 feet, 4 inches. Look in the fist line of figures; under the 13 -inch mark appears the number 17.69 , which is the length in inches of a rafter with a run of 1 foot and a rise of 13 inches. To find the line length of a rafter with a total run of 10 feet, 4 inches, multiply 17.69 inches by $10 \%$ and divide by 12 to get the answer in feet. The 17.69 inches times $10 \%$ equals 182.79 inches, which, when divided by 12 equals 15 $3 / 12$ feet. Therefore 15 feet 3 inches is the line length of the rafter. The remaining procedure for laying out the rafters after the length has been determined is described in a above.
(3) The second type of rafter table appears on the back of the blades of some squares
(fig. 2-17). This shows the run, rise, and pitch of rafters of the seven most common pitches of roof (fig. 2-17). The figures are based on the length of the horizontal measurement of the building from the center to the outside. The rafter table and the outside edge of the back of the square, both the body and tongue, are in twelfths. The inch marks may represent inches or feet, and the twelfth marks may represent twelfths of an inch or twelfths of a foot. The rafter table is used in connection with the marks and figures on the outside edge of the square. At the left end of the table are figures representing the run, the rise, and the pitch. In the fist column, the figures are all 12. These may be used as 12 inches or 12 feet as they represent the run of 12 . The second column of figures represent various rises. The third column of figures, in fractions, represents the various pitches.
(a) These three columns of figures show that a rafter with a run of 12 and a rise of 4 has one-sixth pitch, 12 and 6 has one-fourth pitch, and 12 and 12 has one-half pitch. To use this scale for a roof with one-sixth pitch (or a rise of one-sixth of the width of the budding) and a run of 12 feet, find $1 / 6$ in the table, follow the same line of figures to the right until directly beneath the figure 12 , which is the run of the rafter. Under the figure 12 appear the numbers 12, 7,10 , which is the rafter length required and which represents 12 feet, 7 inch and 10/12 of an inch. They are written as follows: 12 feet $710 / 12$ inches. For a pitch of one-half (or a rise of one-half the width of the building) and a run of 12 feet, the rafter length is $16,11,6$ or 16 feet, $116 / 12$ inches.
(b) If the run is greater than 23 feet, the table in figure 2-17 is used as follows: Using a run of 27 feet, find the length for a run of 23 feet, then find the length of 4 feet and add the two. The run for 23 feet with a pitch of one-fourth is 25 feet, $85 / 12$ inches. For 4 feet, the run is 4 feet, $58 / 12$ inches. The total run for 27 feet is 30 feet, $21 / 12$ inches. When part of the run is in inches, the rafter table reads inches and twelfths instead of feet and inches. For example, if the pitch is one-half and the run is 12 feet, 4 inches, add the rafter length of a 12 -foot run to that of a rafter length of a 4-inch run, as follows: For a run of 12 feet and one-half pitch, the length is 16 feet, $116 / 12$ inches. For a run of 4 inches and onehalf pitch, the length is $5,7,11$. In this case the 5 is inches, the 7 is twelfths, and the 11 is $11 / 12$ of $1 / 12$, which is nearly $1 / 12$. Add it to the 7 to make it 8 , making a total of $58 / 12$ inches, then add the two lengths together. This sum is 17 feet, $52 / 12$ inches. The lengths that are given in the table are the line lengths; the overhang must be added. After the length of the rafter has been found, the rafter is laid out as explained in a above.
(c) When the roof has an overhang, the rafter is usually cut square to save time. When the roof has no overhang, the rafter cut is plumb, but no notch is cut in the rafter for a seat. The level cut is made long enough to extend across the plate and the wall sheathing. This type of rafter saves material, although little protection is given to the side wall.

## 2-7. COLLAR BEAMS

A collar beam or tie is a piece of stock (usually 1 by 4,1 by 6 , or 1 by 8 ) fastened to a pair of raters in a horizontal position part way between the top plate and the roof ridge as shown in figure 2-18. These beams keep the side walls of the building from spreading. The lower the collar beam or chord, the better it fulfills its purpose. This type of bracing is used in the roofs of small buildings where no ceiling joists are used.


Figure 2-18. Collar beam.

## 2-8. TRUSS TYPE RAFTERS

a. General. Rafters will seldom be put up singly; they are usually assembled into trusses, as shown in figure 2-19. Two rafters are connected at the top by using a rafter or collar tie well nailed into both rafters. Before any ties or chords are nailed, accuracy of the rafter cuts should be checked by spreading the lower ends of the rafters to correspond to the width of the building. This may be accomplished by a template, or by measuring the distance between the seat cuts with a tape.
b. TO type trusses. Trussed rafters for a 20-foot-wide, TO type building are made from the following members (fig. 2-19).


Figure 2-19. Typical rafter truss for a TO type building.
(1) Rafters. The rafters or upper chords are the same as the rafters in the end panel. Their primary function is to carry the roof load to the studs. NOTE: rafters in end panels are an integral part of the panel and are not considered as rafter trusses.
(2) Lower chord. The lower chord or ceiling joist is a $1 \times 6$ member spanning from the lower ends of the two rafters in the truss. When a ceiling is used, these members are increased to $2 \times 6$ 's and the ceiling is attached to them.
(3) Hanger. The hanger is the $1 \times 6$ vertical member in the center of the truss that ties in the peak of the rafters to the center of the lower chord.
(4) Web members. The web members are the diagonal braces which tie in the center of the lower chord with the centers of the rafters. They are cut from $2 \times 4$ 's.
(5) Rafter tie. The rafter tie, normally a piece of $1 \times 8$, connects the two rafters at the peak of the truss as in the end panel.
(6) Knee braces. Knee braces are the members which tie in the roof system with the wall
system. You can see that they are attached to the rafter, to the lower chord, and to the stud in the sidewall panel.
c. Advantages. The principal advantages of a trussed rafter system over a plain rafter system are that smaller size lumber can be used and that the truss can be fabricated as a unit for later erection. This results in economy of labor and material, and saves time except on very small projects.
d. Templates or jigs. Rafter framing constructed without the use of ridgeboards may be rapidly completed by use of a truss assembly jig or template. The template is laid out (1, fig. 2-20) to form a pattern conforming to the exact exterior dimensions of the truss. Templates or jigs must be constructed accurately to assure proper dimensions of the rafter truss. Lay out a jig in the following manner (2, fig 2-20):
(1) Measure and mark a straight line on a selected surface, the exact length of the joists which will form the chord of the truss. This is the base line A.
(2) From the center of the base line and at right angles to it, lay out a line the length required to form the leg of a right


Figure 2-20. Rafter-truss jigs.
triangle, the base of which is half the length of the base line, A, and the hypotenuse, B, which is the length of the rafter measured as indicated. This is the centerline, C .
(3) Nail $2 \times 4$ by 8 -inch blocks flush with the ends of base line $A$ and centerline $C$ as shown. Mark centerline on center jig blocks.
(4) Start assembly by setting a rafter in the jig with plate cut fitted over jig block at one end of base line. Peak is flush with centerline on peak jig block. Nail a holding block outside rafter at point D. Repeat for other rafter at $E$.
(5) Assemble trusses in the following order: Lay one $2 \times 4$ joist or chord in place across base blocks. Lay two $2 \times 4$ rafters in place over joist. Center one end of a $1 \times 6$ hanger under rafter peak. Center rafters against peak block. Nail through rafters into hanger with six 8-penny nails. Line up one end of chord. Nail through rafter with 16-penny
spikes. Line up other end of chord. Nail as above. Center bottom of hanger on top of chord and nail with 8-penny nails.
e. Placement. After the rafters have been assembled into trusses, they must be placed on the building. The first set of rafters may be assembled in the end section of the building or at the center as indicated in figure 2-21. The rafter trusses are raised by hand into position and nailed to the plate with 16or 20-penny nails. These trusses are temporarily braced to the end section of the building, until the sheathing is applied. Building temporary platforms or work-benches for the workers to stand on while erecting these trusses will save time. The knee braces may be applied before or after the sheathing is applied. Knee braces are not used on every rafter truss unless severe wind conditions are anticipated. In fact, as figure 2-19 shows, they may be spaced as widely as 16 feet OC. There are several methods for


Figure 2-21. Erection of rafter trusses.
the actual installation. The following procedures may be used in the actual installation of trusses:
(1) Mark proper positions of all truss assemblies on top plate. The marks will show the exact position of a given face of all rafters (south or north, etc.).
(2) Rest one end of a truss assembly, peak down, on an appropriate mark on top plate on one side of structure (1, fig. 2-21).
(3) Rest other end of truss on opposing mark on top plate on other side of structure (2, fig. 221).
(4) Rotate assembly into position by means of a pole or rope (3, fig. 2-21).
(5) Line up rafter faces flush against marks and secure.
(6) Raise, aline, and nail several truss assemblies into position. Nail temporary $1 \times 6$ braces across these assemblies (4, fig. 2-21) and other assemblies as they are brought into position. Check rafter spacing at peaks as braces are nailed on.
(7) Braces may be used as a platform when raising those trusses when there is too little room to permit rotation.

## 2-9. HEAVY TRUSSES

a. Definition. A heavy truss is a framed or jointed structure composed of straight members connected only at their intersections in such a way that if the loads are applied at these intersections the stress in each member is in the direction of its length.
b. Types. The web members of a truss divide the truss into a number of triangles. It is possible to arrange innumerable types of trusses, but certain types have proved to be more satisfactory than others, and each of these types has its special uses. The various types of trusses used in heavy building construction are illustrated by line diagrams in figure 2-22. The members indicated by heavy lines normally carry compressive stresses, and those indicated by light lines normally carry tensile stresses for vertical loads. In most cases, the compression members are the shortest members in the truss, while the tension members are the longest. This results in a great saving of material, for a compression member requires a greater sectional area for a given stress than does a tension member. Sometimes the top chords of these trusses are slightly sloping in one or two directions for roof drainage, but this does not change the type of truss. The necessary number of subdivisions or panels depends upon the length of the span and the type of construction.
c. Terms used in connection with trusses.
(1) Member is the component which lies between any two adjacent joints of a truss; it can be of one or more pieces of structural material.
(2) Bottom chord is a member which forms the lower boundary of the truss.
(3) Top chord is a member which forms the upper boundary of the truss.


Figure 2-22. Types of trusses.
(4) Chord member is a member which forms part of either the top of bottom chord.
(5) Web member is a member which lies between the top and bottom chords. If it is vertical and at the centerline, it is also called a hanger.
(6) Joint is any point in a truss where two or more members meet and is sometimes called a "panel point."
(7) Panel length is the distance between any two consecutive joint centers in either the top or bottom chords.
(8) Pitch is the ratio of the height of truss to the span length.
(9) Height of truss is the vertical distance at midspan from the joint center at the ridge of a pitched truss, or from the centerline of the top chord of a flat truss to the centerline of the bottom chord.
(10) Span length is the horizontal distance between the joint centers of the two joints located at the extreme ends of the truss.
d. Use. Timber trusses are used for large spans to provide wide unobstructed floor space for such large buildings as shops and hangars. The Howe and Fink trusses are the ones most commonly used.
e. Truss layout and construction (fig. 2-
23). The first task is to get the material to a level spot of ground where workbenches will be approximately level. Obtain from the blueprints the necessary measurements of all pieces that are to be used in the truss. Lay out the length on the different sizes of timber and cut them. Care must be taken that the lengths are cut accurately. After all the lengths of different sizes of material for a truss have been cut, lay the pieces in their correct position to form a truss and nail them together temporarily. After the truss is assembled in this manner, lay out the location of all holes to be bored, then recheck the measurements to be sure that they are correct. After this is done, bore the holes to the size called for on the print. They may be bored with a brace and bit, an electric drill, or with the woodborer which is part of a set which
accompanies the air compressor. They should be bored perpendicular to the face of the timber. After the holes have been bored, the truss is dismantled and the nails with drawn. The assembling of a truss after it has been cut and bored is simple. In most cases, timber connectors are used where the different members of the truss join. The truss is again assembled as it was for boring holes, with the timber connectors in place. The bolts are then placed in the holes and tightened, a washer being placed at the head and nut ends of each bolt. Straight and sound timber should be used in trusses to avoid weak places.

## 2-10. PURLINS

Purlins are roof members that run at right angles to the rafters or rafter trusses. They are used in roof construction where corrugated sheet metal is used without sheathing, or to support the sheathing when roofs are framed with high-capacity trusses set on wide centers. In small roots, short purlins are inserted between the rafters and toenailed through the rafters (fig. 3-2, lesson 3). In small buildings, such as barracks, mess halls, and small warehouses, $2 \times 4$ 's are used for purlins, with the narrow side up. In large-building construction, the purlins are continuous members which rest on the trusses and support the sheathing.

## 2-11. LIGHT THEATER-OF-OPERATIONS TYPE FRAMING

a. Plates, corners, and T-posts. TO type framing is characterized by simplicity and by economy in the use of lumber. Single rather than double top plates are used. Most TO buildings have no inside wall finish, and partitions, when used, are finished on one side only. Consequently, corners are formed by simply nailing end studs together as shown in 4, figure 2-1 and figure 24 . T-posts are omitted as shown in A in 1, figure 2-3.
b. Girts. TO type framing is also characterized by widely spaced studs (spacings as wide as 8 feet OC are common) and the use of girts (fig. 2-24). Girts are horizontal members placed between studs halfway between the


Figure 2-23. Typical heavy roof truss.
sole plate and the top plate to serve a stiffeners and nailing bases for corrugated sheet metal, outdoor plywood, waterproof composition board, and other types of vertical or large-panel siding. Note in 2,
figure 2-24, two studs are set flatwise with their outside faces flush with the outside of the sole and top place to accommodate sliding windows. The girts are notched to take these special studs.


Figure 2-24. TO framing details.

## SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a paragraph containing information related to the question. Write your answer in the space provided below each question. When you have finished answering all the questions for this lesson, compare your answers with those given for this lesson in the back of this booklet. Review the lesson as necessary. Do not send in your solutions to these review exercises.

1. What structural member determines the bearing strength of stud walls? (Para 2-1)
2. Wherever a partition wall meets an outside wall, a special structural member must be used. What is it called and what is its function? (Para 2-lb)
3. For residential construction within the United States, studs are normally placed on 16 -inch centers. In the more temporary TO construction studs may be placed 4 feet apart. What makes this possible? (Para 2-1d(1))
4. At what stage of the wall construction are the vertical members plumbed and the walls straightened? (Para 22)
5. Good diagonal bracing is essential in preventing a wall from getting out of plumb. What type of diagonal bracing is used most in TO construction where no interior finish will be applied? (Para 2-3d)
6. There are several types of roofs that can be constructed. Which type is most commonly used by the Army, and for what reason? (Para 2-4a)
7. The usual way to express roof slope is by inches of rise per 12 inches (or 1 foot) of run. If you determine from a plan or sketch that a certain roof is to rise 3 inches in 9 inches of run, convert this slope to the standard unit of run. (Para 2-4e)
8. The shortest distance between the outside edges of the outside wall plates of the side walls of a structure to receive a gable roof, is 20 feet six inches. What would be the total fun in this situation? (Para 2-4f(1)(3))
9. Name the three principal structural members involved in framing a roof. (Para 2-5b)
10. When preparing to install conventional rafters in a gable roof, it is determined that many rafters have varying amounts of crown or bow. How should these rafters be installed? (Para 2-6b(2))
11. The rafter table on the back of the blade of the carpenters framing square can be used to lay out rafter cuts. Referring to figure 2-17, what is the length of rafter required if the building width is 24 feet, outside to outside, and the run to rise is 12 to 6 ? (Para $2-6 \mathbf{d}(3)$ )
12. When are collar beams used and what is their function? (Para 2-7)
13. Rafters form the upper chord of TO type trusses. What is their primary function? (Para 2-8b(1))
14. Rafters are often assembled into trusses instead of being put up singly. What is the principal advantage of trussed rafters? (Para 2-8c)
15. Trussed rafters eliminate the need for one structural roof member essential when rafters are installed, singly. What is this member called? (Para 2-8d)
16. Knee braces are the structural members that tie the roof system to the wall system. Spacing of knee braces may vary under different conditions. Explain briefly. (Para 2-8e)
17. In a heavy truss why is it generally designed so that compression members are shorter than tension members? (Para 2-9b)
18. In the construction of a heavy truss what actions are taken before the joint holes are bored? (Para 2-9e)
19. What is the difference in the installation of purlins for large roofs and small roofs? (Para 2-10)
20. Simplicity and economy are the key words in TO construction. How is economy in the use of studs frequently accomplished? (Para 2-11b)

## LESSON 3

## ROOFING-FINISHING DETAILS

## LESSON OBJECTIVES

Upon completion of this lesson you should be able to accomplish the following in the indicated topic areas:

1. Roofing. Design and supervise the installation of roofs for any typical theater-ofoperations type building.
2. Finishing details. Plan and supervise the finishing details for both interior and exterior
walls of a structure utilizing the materials most suitable under the prevailing circumstances.
3. Stairs. Design and construct stairs for theater-of-operations type buildings.
4. Fire prevention. Determine appropriate measures to obtain adequate protection against the hazards of fire.

## ATTACHED MEMORANDUM

## 3-1. PLYWOOD

a. Plywood is a timber product frequently used in frame structures. It consists of wood panels, usually made up of three of more thin layers glued together, with the grain of adjacent layers at an angle, usually 90 , to each other. It may be made up of veneer lumber or various combinations of veneer and lumber. Plywood used in TO construction is usually $5 / 16^{\prime \prime}, 3 / 8^{\prime \prime}, 1 / 2^{\prime \prime}$, or $5 / 8^{\prime \prime}$ thick and composed of three or five plies of veneer. Depending upon the type of adhesive used in manufacture, plywood is also rated as nonwater-resistant, water-resistant, or waterproof.
b. Compared with solid wood, plywood has the advantages of approaching equalization of strength along the length and width of the panel, greater resistance to checking and splitting, and less change in dimension with change in moisture
content. Also, since it comes in large panels (usually 4 by 8 feet), it can be installed with less labor and provides more bracing effect than ordinary lumber.

## 3-2. FINISHING MATERIALS

a. Glass (or window pane) in sometimes available for TO construction in either single- or double-strength panes. Since glass is difficult to ship and requires special handling, several substitutes have been developed. One of the most common glass substitutes furnished for TO construction purposes is a clear, flexible, plastic which comes in rolls and is cut to the size required as it is used.
b. Several types of fiberboard and insulation board are manufactured and are used for finishing ceilings and the inside walls of
buildings. These materials are frequently referred to as "wall board." They are normally stocked at depots and are component parts of many of the issue prefabricated buildings.

## 3-3. ROOF SHEATHING

a. All flexible roof coverings such as roll roofing and asphalt shingles require a continuous supporting surface. Rigid, large-panel roofing materials, such as corrugated sheet metal and asbestos boards do not require continuous support except that, in extremely cold climates, solid sheathing is recommended for its insulating value.
b. Wood sheathing should be seasoned wood ranging in nominal size from $1 \times 4$ to $1 \times 8$. If the roof is sheathed solid the sheathing may be square edged, tongued and grooved, or shiplapped. It should be surfaced on both edges and at least one side. It should be nailed with two or more 8-penny nails to studs or rafters. Joints are made on the rafters and are staggered to prevent weak spots in the roof. After the roof has been sheathed, cutting lines are marked by snapping a chalkline. Then the ends of the sheathing are cut off smooth, preferably with a power saw, leaving the correct amount of overhang. If there is no overhang the cut in made flush with the outside edge of the end rafter.
c. Where corrugated sheet metal or other strong, large-panel material is used for roof covering, slatted sheathing may be used as an economy measure if extra insulation in not required and if the rafter spacing is moderate. "One-in-three" spacing, in which the spaces left between the sheathing boards are twice the width of the boards (fig. 3-1), is common practice. Where rafters are very widely spaced ( 2 feet on centers (OC) and wider) the use of $2 \times 4$ purlins set flush with the tops of the rafters and spaced 1 to 3 feet apart (fig. 3-2) is preferable to slatted sheathing for corrugated metal.

## 3-4. TYPES OF ROOFING

Of the many types of roof covering which are used, this subcourse covers only the types used by the Army in the theater of operations;


Figure 3-1. Slatted sheathing.
corrugated sheet metal and prepared roofing.
a. Corrugated sheet-metal roofing. Standard corrugated sheet-metal covering has corrugations $21 / 2$ inches wide and $5 / 8$ inch deep. The sheets are 26 inches wide and vary in length from 6 to 12 feet. If steel they are either painted or galvanized to prevent corrosion. Corrugated aluminum requires no coating.
b. Prepared roofing. There are several brands of prepared roofing, a similar in type. They are composed of either paper, felt, or asbestos paper, and are saturated with different brands of waterproofing compounds. They are assembled at the factory, along with roofing nails and asphalt cement, into strips about 1 yard wide and 12 yards long. The roofings used in TO construction usually have a plain surface treated with sand, mica, or talc to prevent sticking. Other mineral surfacing includes slate and ceramic granules.


Figure 3-2. Purlins.

This type of roofing is furnished in rolls and is sometimes called "roll roofings." TO structures are normally roofed with a paper weighing 40 pounds per roll; for wall coverings a 15 -pound asphalt felt is standard.

## 3-5. ROOFING INSTALLATION

a. Corrugated roofing. Corrugated sheet iron may be nailed to either solid or slatted wood sheathing, or to wood purlins. The sheets are overlapped one or two corrugations on the sides and 6 or 8 inches on the ends, depending upon the slope of the roof. To nail this type of roofing securely, a special type nail should be used, such as lead-headed nail or a galvanized nail with a neoprene washer. Common wire nails may be used but they rust easily and may cause slight leaks. The side laps should be nailed every 2 feet, while the end laps should be nailed every foot. This type of roofing should not be used on roofs with slopes of less than 4 inches per foot.
b. Prepared roofing. Prepared roofing is nailed to solidly sheathed roofs with special nails and asphaltic material that are normally furnished with the roofing. These nails have large, flat heads and are used on edge and end laps 3 inches on centers. All laps are cemented with asphalt or tar before being nailed. Prepared roofing may be laid parallel to the roof slope, but it is somewhat less likely to leak when the strips run parallel to the eaves. In TO construction this type of roofing should be laid with an -inch end lap and with a 4-inch edge or side lap on slopes of more than 2 inches per foot. If used on flatter slopes, at least a 6 -inch edge lap must be used and great care must be taken to have all joints fully cemented. All roof slopes of less than 1 inch per foot are unsuitable for prepared roofing and require multilayer, built-up roofing. Because of the wide laps used by the Army and allowances for jobcut flashings, a 40-pound roll (or "square ") of prepared roofing will cover only 80 square feet in TO construction. Rolls of 15 - and 30 -pound felt cover 320 and- 160 square feet, respectively.

## 3-6. ROOF FLASHINGS

Where two roofs come together at angles, a valley is formed and some type of additional covering must be used along the joint to provide adequate waterproofing. A hasty and yet satisfactory expedient is to use two layers of roll roofing in the valley, one 14 inches and the other 22 inches wide, both cut from a 36 -inch width of material. A strip of sheet metal 22 inches wide may also be used (1 and 2, fig. 3-3;). The metal or roll-roofing material used to cover the joining roofs is cut back from the center of the valley 3 or 4 inches, as shown in 1 and 2, fig. 3-3. The joint formed when a roof butts against a vertical wall is flashed as seen in 3 and 4, fig. 3-3. Metal or roll roofing may be used as the flashing. If the vertical wall is not sheathed, a girt is installed between the studs (4, fig. 3-3), to support the flashing.


Figure 3-3. Flashing details.

## 3-7. HOOD

The hood or canopy is used in tropical climates to afford protection to the screened opening at the ends of the buildings. Hoods are framed to the end walls with short rafters which are nailed to the building with knee braces, as shown in figure 3-4. The rafters


Figure 3-4. Typical hood or canopy.
are nailed to the wall, the bottom edge flush with the bottom of the end plate. The rafter and braces are 2 x 4 's nailed with 8 - or 10 - penny nails. The sheathing is the same material as the roof sheathing and is covered with roll roofing. The hood should extend about 2 / to 3 feet from the building.

## 3-8. ROOF FINISH

a. The lines in which the sloping roof meet the vertical wall are called the eaves. In TO construction, eaves are usually finished as shown in 1 and 2, fig. 3-5. This method is the most efficient and should be used wherever possible. The roof should have an overhang at the eaves. The length of overhang will depend upon the climatic conditions and amount of protection required. The spaces between the rafters on top of the plate should be dosed with boards.
b. Where rafters have no overhang the first piece of sheathing is placed on the rafters so that it hangs over the rafters 3 to 4 inches. A fascia board is placed under the sheathing and nailed to the rafter ends to close the opening between the rafters. This board should be at the minimum a $1 \times 4$.
c. At the ridge of the roof where two slopes meet, provision must be made to finish the covering so that it will not leak. When roll roofing is used, the finish can be made as in 3 and 4, fig. 3-5. This is the simplest


Figure 3-5. Types of eave and ridge finish.
method and promotes efficiency and conserves time. On the ends of the roof ridge the roofing may be rolled around the edge of the sheathing and back on the under side far enough so that a $1 \times 2$ strip can be nailed underneath to hold the roofing, or it may be cut flush with the end of the sheathing and the strip nailed flush with the edge to hold the roofing. When corrugated sheet metal is used, the metal should overhang the sheathing from 1 to 2 inches. The sheathing may overhang on the gable ends as it does on the eaves to provide added protection to the walls.
d. If the sheathing does not overhang the gables, it should end at the rafters edge. The wall sheathing should end at the top edge of the rafter. The roofing is lapped over the end of the rafters by a minimum of 3 inches and fastened by a $1 \times 4$ nailed over the roofing along the gable with the top edge of the board even with the top of the rafter.

## 3-9. EXTERIOR WALL FINISHES

a. General. The exterior surfaces of a building usually consist of vertical or horizontal sheathing and composition or corrugated sheet-metal roofing. However, in TO construction the materials prescribed by typical plans are not always available, and substitutes or improvised materials must be provided from local sources. Concrete block,
rubble stone, metal, or earth may be substituted for wood in treeless regions. In the tropics, improvised siding and roofs can be made from bamboo and grasses. Roofing felt sandwiched between two layers of light wire mesh may serve for wall and roof materials where the climate is suitable.
b. Vertical sheathing. Vertical sheathing consists of 1-inch nominal-thickness boards, usually 6 inches or more in width, nailed with 8 - or 10-penny nails at top and bottom to the plate and sole plate and in the middle to the girts. Vertical sheathing requires less framing lumber than horizontally applied siding since the vertical sheathing helps support the roof load on the top plate. Cracks between the boards may be covered with narrow wooden strips called "battens", or some type of light roll roofing, tar paper, or asphalt felt may be applied over the entire surface and fastened at the seams with roofing nails or with laths or light battens.
c. Siding. Siding may be classified into three types: beveled siding, drop siding, and Shiplap. It is applied horizontally and nailed to studs with two or more 8 - or 10 -penny nails. To make this siding more weatherproof, building paper may be used on the studs and nailed either to the siding, after it has been applied, or between the sheathing and siding if sheathing is also used. The methods of application for the different types are similar. Drop and shiplap siding have a rabbeted edge to give the proper lap. The lap must be measured each time in applying the beveled siding, which requires much time. In TO construction, siding, when used, will normally be applied alone without the back-up layer of wood or other sheathing customarily found in permanent construction.
d. Use of corrugated iron. Corrugated sheet iron is used extensively as wall coverage since little framing, time, and labor are needed to install it. It is applied vertically and nailed to girts, the nails being placed in the ridges. Sheathing may be used behind the sheet iron with or without building paper. Since asphaltic felt or tar paper used behind sheet iron will cause the metal to rust, a resin-seized paper should be used.
e. Other large-panel wall finishes. Other
large-panel, rigid wall finishes that are often applied to framing characterized by widely spaced studs supplemented by girts include exterior grade plywood, tempered hardboard, gypsum board, and treated fiberboard. Characteristics are, briefly, as follows:
(1) Plywood. As stated previously, the standard plywood panel is 4 by 8 feet, but plywood may occasionally be issued in $6-, 9-, 10$-, and 12 -foot lengths.
(2) Hardboard. Hardboard is a very dense, tough, grainless material made from highly compressed wood fibers. It is furnished in "ordinary" which is water-resistant, and "tempered" which is waterproof. It comes in $1 / 8^{\prime \prime}$ and $1 / 4^{\prime \prime}$ thickness and in the same widths and lengths as plywood.
(3) Gypsum board. This is $1 / 2$-inch thick, 24 and 48 inches wide, and $8,9,10$, and 12 feet long. It consists of a gypsum core cast in a heavy water-resistant fiber envelope. The long sides are normally tongued and grooved. It does not warp or absorb water.
(4) Fiberboard. Fiberboard is usually made from sugarcane refuse (bagasse) and treated with asphalt. It comes $25 / 32$-inch thick, 24 and 48 inches wide, and $8,9,10$, and 12 feet long.
f. Building paper. Building paper is of several types, the most common being the nonwaterproof resin-seized papers.
(1) Resin-seized papers are usually red or buff but sometimes blue in color. They are usually put up in rolls 36 inches wide containing 500 square feet and weighing from 18 to 50 pounds per roll. Conventionally, this type of paper is applied between the sheathing and the siding or other external wall finish. In consequence, it is of limited usefulness in TO construction which is characterized, in the main, by single-layer wall construction.
(2) Tar- and asphalt-treated papers are frequently used in temporary TO construction as final protective wall finish. Tar papers are usually furnished in rolls containing 500 square feet; asphalt felts in rolls of 216 or 432
square feet. All are usually 36 inches wide and black in color.

## 3-10. INTERIOR FINISHES

a. Wallboard. Interior walls and ceilings are not normally finished in TO construction. When they are, it is usually done with one of the several types of wallboard that may be carried in depot stock, or furnished with prefabricated buildings. Most common of these wallboards are plywood, plaster board, and fiber board. The most common size for wallboard is 4 feet by 8 feet by $1 / 2$ inch thickness, but some are available in lengths up to 12 feet and in $1 / 4$ to 1 or more inches in thickness. This type of material requires a minimum of labor time and in some cases will provide greater structural strength with less materials, than other types of interior finish materials.
b. Plaster and wood. Other methods of interior finish may be used, depending upon materials and labor available. Wet walls, generally plaster, are normally not used in the TO because of lack of skills and materials and the curing time required. Dimension lumber if available, will provide an excellent finish. Installation of this material, sometimes called ceding lumber, is either horizontal or vertical depending upon framing used in the structure (fig. 3-6).


Figure 3-6. Partition-wall finishes.

## c. Door frames.

(1) Outside door frames are constructed in several ways. In most haste construction the frames will be as shown in figure 37. This type requires no framing because the studs on each side of the opening act as a frame. The outside finish is applied to the wall before the door is hung. The casing is then nailed to the sides of the opening and is set back the width of the stud. A $3 / 4 \times 3 / 4$ piece is nailed over the door to act as a support for the drip cap and is also set back the width of the stud. Hinge blocks are nailed to the casing where the hinges are to be placed. The door frame is now complete and ready for the door to be hung. Figures 3-7 and 3-8 show the elevation and cross section of a single and double outside door frame.
(2) Inside door frames, like outside frames, are constructed in several ways. In most TO construction the type shown in figure 3-9 will be used. The interior type is constructed like the outside type except that no casing is used on inside door frames. Hinge blocks are nailed to the inside wall


Figure 3-7. Single outside door.


Figure 3-8. Double outside door.


Figure 3-9. Single inside door.
finish, where the hinges are to be placed to provide a nailing surface for the hinge flush with the door. Figure 3-9 shows the elevation, section and plan of a
single inside door. Both the outside and inside door frames may be modified to suit climatic conditions.
d. Doors. In TO construction, the carpenter who erects the building usually makes the doors from several boards with battens and braces as shown in figure 3-7. These boards are $1 \times 6$ 's, laid close together and ailed to battens. The battens are placed with their edges 6 inches from the ends of the door boards. A brace is placed between the battens, beginning at the top batten end opposite the hinge side of the door, and running to the lower batten diagonally across the door. These battens and braces are well nailed. If the door is used as an outside door, roofing felt is used to cover the boards on the weather side. The battens and braces are nailed over the felt. Wooden laths are nailed around the edges, top, bottom, and sides, and across the middle of the door to hold the roofing felt in place. The battens and braces on doors are of $1 \times 6$ 's and are nailed securely to the door boards. In hanging these doors, T-strap hinges are used. The hinges are fastened to the battens of the door and to the hinge blocks on the door casing or post. One-quarter of an inch clearance should be left at top, bottom, and latch side of the door to take care of expansion.
e. Window frames. In TO construction, millwork frames are seldom used. The window frames are mere openings left in the walls with the stops all nailed to the stud. The sash may be hinged to the inside or the outside of the wall, or constructed so as to slide. The latter type of frame is the most common in Army construction as it requires little time to install. Figure 3-10 shows the section and plan of a window and window frame of the type used in the field. After the outside walls have been finished, a $1 \times 3$ is nailed on top of the girt at the bottom of the window opening to form a sill. A $1 \times 2$ is nailed to the bottom of the plate on the side studs and acts as a stop for the window sash. A guide is nailed at the bottom of the opening flush with the bottom of the girt, and one nailed to the plate with the top edge flush with the top of the plate. These guides are $1 \times 3$ 's, 8 feet long. Stops are nailed to the bottom girt and plate between the next two studs, to hold the sash in position when open.


Figure 3-10. Detail of wall section with window frame and sash.
f. Window sashes. A sash can be made of $1 \times 3$ material, with glass substitute installed as shown in figure 3-11. Glass substitute is obtained in rolls, like screen wire or roll roofing, and can be cut to any desired size with a sharp-edged tool. Two frames are made with the glass substitute installed on one; the two frames are then nailed together. In making these frames the side pieces are all cut the same length, the length being the height of the sash less the width of one piece of material. The top and bottom pieces are cut the same length as the window, less the width of the material. They are fastened at the joints with corrugated metal fasteners. When the two frames are nailed together, one should be turned end for end so that the joints are not over each other. This staggers the joints and gives the sash more strength. If the sash is too large for the glass substitute to cover, a muntin (wood strip) may


Figure 3-11. Window frame and sash detail (sliding window).
be placed in the sash to hold the glass substitute and should be fastened with corrugated metal fasteners.
g. Window and door details. Door and window details normally show sectional views of the jamb (the side piece or frame of the opening) as well as of the head and sill (the top and bottom portions respectively of the window and door frames). It is also customary to give an elevation view of the doors and window sash.
h. Wainscoting. Wainscoting is installed at the bottom 3 or 4 feet of plaster board, fiber board, or other finish walls which are continuously subject to damage by hard usage. It may be constructed of wood, plywood, or a tempered (hard) fiber board. (fig 3-12)
i. Flooring. A finish floor in the theater of operations, in most cases, is of $3 / 4$-inch material, square edged or tongued and grooved, and varying from $3 / 4$ to $71 / 4$ inches wide. It is laid directly on floor joists or on a subfloor (perpendicular to the joists) and nailed with 8-penny cut nails in every joist. If these nails are not obtainable, 8-penny common nails may be used. When wide flooring is used, it should be face nailed in every joist.


Figure 3-12. Wainscot installation.
When laid on a subfloor, it is best to use building paper between the two floors to keep out dampness and insects. In warehouses, where heavy loads are to be carried on the floor, 2 -inch material should be used. The flooring is face nailed with 16 - or 20 penny nails. It is not tongued and grooved and it ranges in width from 4 to 12 inches. In all cases, unless there is subflooring, the joints are made on the centers of the joists.

## j. Hardware.

(1) The term "hardware" is used to designate locks, hinges, sash cord, weight, pulleys, checks, pulls, fasteners, etc. These items are divided into two classes, rough hardware and finish hardware.
(2) Rough hardware includes such hems as padlocks, used to fasten doors; strap hinges, used to hang doors and other items; sash cord, weights, and pulleys, used for double-hung windows; track assemblies for sliding or rolling doors; and screen wire used for protection against insects. In most cases all these items are easily installed. In the theater of operations, hinges and screen wire are the most common hardware.
(3) Finish hardware includes mortise and rim locks, butt hinges, door checks, and window pulls.
k. Screens. Screens are placed on door and window openings. These screens are made and installed at the jobsite. Door screens are made as shown in figure 3-8. Two separate frames are made of $1 \times 4$ material for the sides and top, and $1 \times 6$ material for the bottom and middle pieces. This frame is put together with corrugated metal fasteners, then the screen wire is applied. The second frame is
made with the crosspiece the full width of the door. The side pieces are cut to correspond with the distance between the crosspieces. The second frame is placed over the first frame and nailed securely. For push-and-pull plates, two short braces of $1 \times 4$ 's are nailed to the side opposite the hinge side.

## 3-11. DESIGN OF THEATER-OFOPERATIONS STAIRS

a. General. In large multistory buildings, stair design becomes an involved problem, but in a single-story TO frame building the problem is simply to get a good stair from the ground to the platform. The platform is usually located outside the exterior door. In the TO stairway the primary structural members are the stair stringers or carriages which are $2 \times 12$ members spaced 2 feet on centers. In properly designed stair stringers a definite relationship exists between the riser, a vertical part of the stairs, and the tread, a horizontal part. One dimension, always known as the total rise, is the vertical height of the flight of stairs or the distance from the top of the platform to the ground. The total stringer rise is always one riser less than the total rise because one riser is provided by the platform framing. The rise of stairs is illustrated in figure 3-13.


Figure 3-13. Rise of stairs.
b. Determining dimensions of risers and
treads. There are two rules of thumb that may be used to determine the dimensions of risers and treads. They are:

$$
\begin{aligned}
& \text { Riser }+ \text { tread }=17 \text { to } 19 \text { inches } \\
& \text { Riser } \mathrm{x} \text { tread }=70 \text { to } 75 \text { inches }
\end{aligned}
$$

If the sum and the product of the riser and tread fall within these limits, the stair design is satisfactory. Riser dimensions usually fall
between $61 / 2$ and $91 / 2$ inches; treads between 8 and 11 inches.
c. Application. To illustrate the application of these rules of thumb, let us take the problem of determining the dimensions and number of risers and treads required for the outside stairs of a TO building with a total rise of 25 inches.
(1) If we assume a $61 / 2$-inch height for the riser, $\frac{25}{6.5}$ or 3.84 risers are required.
Since a whole number of risers must be used, we will use 4. If 4 risers are to be used, each must have a dimension of $\frac{25}{4}$ or $61 / 4$ inches.
(2) Utilizing the first rule of thumb, riser plus tread $=18$ inches, then the tread $=18$ inches minus riser. In this case the tread dimension will be 18 inches less $61 / 4$ inches or $113 / 4$ inches.
(3) Next check the dimensions by the second rule of thumb, riser times tread $=70$ to 75 . In this instance, $6.25 \times 11.75$, or 74.4 . Since this value is between 70 and 75 , the stair design is satisfactory. Figure 3-13 shows the regular progression of steps from ground to platform level in the stairs designed.

## 3-12. STRINGER LAYOUT

a. The framing square is normally used in the layout of stair stringers. To illustrate its use for this purpose let us take the problem to laying out the stringers for the stairs shown in figure 3-13.
b. Figure $3-14$ shows how the completed stringer will look. The stringer itself has only three risers, the fourth riser being provided by the platform framing. The $61 / 4$-inch dimension of the first or bottom riser is measured from the ground to the top of the $1 / 2$-inch-thick tread (actual thickness of $2 \times 4$ stock). Each of the other $61 / 4$-inch dimensions is measured from the top of one tread to the top of the next tread. The first riser in the stringer is therefore 6 $1 / 4$ less $11 / 2$, or $43 / 4$ inches. The other two risers are the full $61 / 4$ inches.


Figure 3-14. Stringer dimensions.
(1) Starting with a 2 x 12 and a framing square, the stringer can be laid out in the same manner as a rafter, by using $61 / 4$ inches as the rise and $113 / 4$ inches as the run. The first mark will be made in the manner shown in figure 3-15. Line A indicates the


Figure 3-15. Vertical or "plumb" cut for stringer.
vertical cut that will be framed against the platform.
(2) The next step is to mark off the top tread. Using again a rise of $61 / 4$ inches but with a run of 2 times $113 / 4$ or $231 / 2$ inches, lay off the top tread as shown in figure 3-16. By drawing line B 11 $3 / 4$ inches long, the top tread has been marked.


Figure 3-16. First tread cut.
(3) To mark the top riser of the stringer and the second tread from the top, use again a $61 / 4-$ inch rise and $113 / 4$-inch run and mark them in the manner shown in figure 3-17. Line C is the riser and D the tread.


Figure 3-17. Riser and tread layout.
(4) The next tread and riser are marked in exactly the same way as C and D. When this is completed, the only marks still to be laid off are the bottom riser and the horizontal cut at the bottom of the stringer. Figure 3-18 illustrates how the bottom riser is marked. It should be noted again that the bottom riser is always shorter than the other risers
by the thickness of a tread - in this case $11 / 2$ inches.


Figure 3-18. Layout of bottom riser.
(5) The final step is to mark the horizontal cut at the lower end of the stringer. It is located by drawing a horizontal line through the lower end of line E. Figure 3-19 shows the placement of the framing square. When this line has been drawn, the layout of the stair stringer is complete. The stringer can then be cut out and used as a pattern for other stringers of the same stairs, either conventional or built-up.


Figure 3-19. Marking the bottom horizontal cut.
c. The triangular blocks cut out in cutting conventional stringers from $2 \times 12$ or similar stock can be used to make built-up stringers. The blocks are toenailed to a piece of $2 \times 4$ stock as shown in figure 3-20. The vertical cut (fig. 3-15) and the bottom cut (fig. 3-19) are obtained by using an already cut conventional stringer as a pattern, adding pairs of scabs if necessary to fill out the
vertical (last) or bottom (first) cut. The triangular blocks can also be cut from $2 \times 6$ or 8 -inch stock.


Figure 3-20. Built-up stair stringer.

## 3-13. ELECTRICAL SYMBOLS

A study of utility installation in TO buildings is beyond the scope of this subcourse. But since the location and type of electrical wiring and fixtures are normally shown on plan views, you should be able to recognize the basic electrical portion of architectural drawings. Some of the most commonly used symbols are shown in figure 3-21.

## 3-14. FIRE PREVENTION

Since fire is always a danger in TO structures, precautions must be taken to reduce this hazard. It is important to know where to insulate against intense heat and how far wood framing must be placed from stoves, stovepipes, flues, and chimneys, in order to prevent fires.
a. Framing around stovepipes is of major importance to the carpenter in the theater of operations since stoves are the usual method of heating buildings. The pipes are carried out of the building by several methods. Figure 3-22 shows how the pipe is carried through the ridge of the roof. Here the sheathing must be cut to form an opening at least 12 inches larger than the pipe. The stove, where possible, should be set so that the rafters need not be cut. The ceiling joists or tie beams must also be considered. Figure 3-22 also presents a detailed
description of the method of framing a pipe through the ridge. Where a roof jack is not used, the sheathing and other wood should be at least 6 inches from the pipe. If some type of insulation board is available, the wood should be covered with this. Figure 3-23 shows the pipe through the roof when the slope is in one direction. The framing is placed as stated above. In many cases stovepipes are carried to the outside of the building through the side wall. This eliminates flashing and waterproofing around the pipe or roof jack (fig. 3-24). Here the sheathing on the side is cut back 6 inches from the pipe and some type of insulating material is used, if possible.
b. (1) Where stovepipes are carried through the roof, roof jacks are used with flashing attached (figs. 3-22 and 3-23). In most cases these are installed over the roof and nailed. Fibered tar cement is used around the edges and over the nail heads, and the roof jack is soldered to the stovepipe, if practicable. If the roof jack is used on a metal roof, it is soldered to the roof if practicable; otherwise, the tar cement is used around the edge after it has been nailed securely (fig. 3-23). Where no roof jack is used, the hole is covered with a piece of sheet metal which has a hole cut to the size of the stovepipe. The sheet metal is placed over the roofing at the bottom edge, and under it at the top edge. Where a metal roof is used, the flashing is soldered to the roof or fastened by means of tar cement. When the stovepipe does not go through the roof but out through the wall, no flashing is required; only one piece of sheet metal slightly larger than the wall opening, with a hole the size of the pipe is necessary. This is nailed over the opening in the wall (fig. 3-24).
(2) Where a stovepipe goes through the sheet metal, a hole must be cut. The best method is to mark a circle on the metal $1 / 2$ inch larger in diameter than the pipe, then make another circle on the inside with a diameter 2 inches less than the diameter of the first. With a straightedge, draw lines through the center of the circle from the outside. These marks should be from $1 / 2$ to $3 / 4$ inch apart along the outer circumference. Cut out the center circle, then cut to the outside

## 1 LIGHTING OUTLETS

a CEILING

b WALL


## 2 SWITCHES

| 0 | SINGLE POLE | S | f | KEY-OPERATED SWITTCH | SK |
| :---: | :---: | :---: | :---: | :---: | :---: |
| b | DOUBLE POLE | 52 |  |  |  |
|  |  |  | © | DOOR SWITCH |  |
| c | THREE-WAY | $S_{3}$ |  |  |  |
| d | SWITCH AND PILOT LAMP | SP | h | TIME SWITCH | $\mathbf{S T}$ |
|  | CEILING PULL SWITCH |  | i | CIRCUIT <br> BREAKER <br> SWTTCH | 8 |

Figure 3-21. Electrical symbols.

## RECEPTACLE OUTLETS

a SINGLE OUTLET
b DUPLEX OUTLET
c QUADRUPLEX OUTLET
d SPECIAL, PURPOSE OUTLET

- 20-AMP. 250-VOLT OUTLET
f SINGLE FLOOR OUTLET (BOX AROUND ANY OF ABOVE INDICATES FLOOR OUTLET OF SAME TYPE)


## 4 MISCELLANEOUS

a WIRING CONCEALED IN CEII.ING OR WALL
b WIRING CONCEALED IN FLOOR

PANET BOARD (NO. OF ARROWS EQUALS NO. OF CIRCUITS DESTGNATION IDENTIFIES DESTINATION AT PANEL)

- THREE OR MORE WIRES (NO. OF CROSS LINES EQUALS NO. OF CONDUCTORS TWO CONDUCTORS INDICATED IF NOT OTHERWISE NOTED)
( INCOMING JERVICE LINES
g CIRCUTT BREAKER-AIR


Figure 3-21. Electrical symbols (continued).
of the circle along the lines drawn. After the lines have been cut, bend the metal strips outward at a $45^{\circ}$ angle and force the pipe through the hole to the desired position. Very little water will leak around this joint (fig. 3-24).


Figure 3-22. Smoke pipe through roof ridge.


Figure 3-23. Smoke pipe through roof slope.


Figure 3-24. Smoke pipe through side wall.

## SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a paragraph containing information related to the question. Write your answers in the space provided below each question. When you have finished answering all the questions for this lesson compare your answer with those given for this lesson in the back of this booklet. Review the lesson as necessary. Do not send in your solutions to these review exercises.

1. Plywood is used frequently as a construction material in framed structures. What advantages are there in using plywood instead of solid wood? (Para 3-1b)
2. In slatted sheathing, what is meant by "one-in-three" spacing, and when is it used? (Para 3-3c)
3. What two types of roofing are used by the Army in TO construction? (Para 3-4)
4. In the design of a gable roof for a small storage building, each rafter will have a horizontal run of 10 feet. If you use corrugated sheet metal roofing, what is the least total rise each rafter must have? (Para 3-5a)
5. How many rolls of 40 -pound prepared roll roofing will you need to cover a gable roof on a building 60 feet long with rafters having a line length of 11 feet 4 inches and a 2 -foot overhang? (Para 3-5b)
6. Corrugated sheet metal roofing cannot be used for slopes less than 4 inches per foot. Prepared roll roofing cannot be used for slopes less than 1 inch per foot. How can you cover a flat roof? (Para 3-5b)
7. A valley is formed where two roofs come together at an angle. What are the two most common methods used in TO construction, to waterproof this valley? (Para 3-6)
8. Sheathing is being applied to the rafters of a building on which 40 -pound prepared roofing is to be installed. The rafters do not overhang. Describe the placement of the first piece of sheathing. (Para 3-8b)
9. When corrugated sheet metal is used as the roof covering, what measure can be taken to provide added protection to the building walls? (Para 3-8c)
10. Why is it that less framing lumber is required in a structure when the sheathing is placed vertically than when it is placed horizontally? (Para 3-9b)
11. Three common types of siding are: beveled siding, drop siding, and shiplap. What disadvantage is there in bevel siding in comparison to the others? (Para 3-9c)
12. Why is it inadvisable to install asphaltic felt or tar paper behind corrugated sheet iron which is being installed as a wall covering? (Para 3-9d)
13. What is the main difference between the construction of an interior door fame and an exterior door frame? (Para 3-10c)
14. T-strap hinges are used to hang batten doors in TO construction. Explain the placement of these hinges. (Para 3-10d)
15. What is the purpose of wainscoting and where is it installed? (Para 3-10h)
16. For a finish flooring, you plan to use $1 \times 4$ tongue-and-groove lumber over a diagonal subfloor. In what direction should these boards run? (Para 3-10i)
17. Determine the rise and tread for the outside stairs of a TO building with a total rise of 38 inches. Check it by the rules given. (Para 3-11b)
18. In constructing steps for a barracks, plans call for the use of $2 \times 12$ lumber for treads. The stair stringers have four 7 -inch risers and a bottom riser. What height cut (in inches) should be made for the bottom riser? (Para 3-12b, (4))
19. When roof jacks are not available a piece of sheet metal can be used to carry a stove pipe through the roof of TO structures. What is the minimum distance in inches that sheathing and other wood may be to the pipe? (Para 3-14a)
20. When a stovepipe goes out through a wall instead of the roof, what is required for fire prevention at that type of installation? (Para 3-14b(1))

## LESSON 4

## MATERIALS ESTIMATING

## LESSON OBJECTIVES

Upon completion of this lesson on materials estimating you should be able to accomplish the following in the indicated topic areas:

1. Importance of estimating. Relate the importance of estimating to the overall planning of a construction project.
2. Qualifications and trailing of estimators. Outline the qualifications a good materials estimator should possess and the training and experience necessary to develop these skills.
3. Prepare a bill of materials. Prepare a bill of materials following the five steps outlined in this lesson.

## ATTACHED MEMORANDUM

## 4-1. TOTAL ESTIMATING

a. Importance of estimating. One of the most important steps in planning a construction project is estimating. It should be considered the first approach in scheduling cost of time and materials. In military construction carelessly made estimates may lead to failure to meet completion dates; may cause uneconomical use of men, materials, and equipment; and may seriously jeopardize a tactical or strategic situation. The military construction manager must have competent estimators in his organization as well as being a good estimator himself.

## b. Steps in overall estimating.

(1) An estimator's first task is to study the plans and specifications from which he computes
the main portion of the estimate. He should compare the specifications with the plans to insure proper application of the specifications. After this, he should visit the work site to become thoroughly familiar with local conditions.
(2) The next step the estimator must do is prepare a checklist of tasks that have to be performed to complete the project. Experience enables the estimator to determine the sequence of the tasks. However, the less experienced estimator can gain some insight into this process by examining the plans and specifications.
(3) The third step in estimating is the preparation of a bill of materials. Information
for preparing the bill of materials is obtained from drawings and specifications.
(4) The fourth step is the preparation of a labor and equipment estimate. This is a listing by type, amount of time, and number of personnel required to complete each task of the project.
(5) The final step is to summarize the amount of materials, equipment, and labor required for each task on the estimate or checklist. The estimator should insure at this point that nothing is omitted or duplicated.
c. Lesson coverage. In this lesson, we will concentrate on and fully discuss step three above, preparation of a bill of materials.

## 4-2. QUALIFICATIONS AND TRAINING OF A MATERIALS ESTIMATOR

a. Qualifications of a materials estimator. A materials estimator is one who prepares materials estimates. He should possess the following qualifications:
(1) Ability to read plans accurately.
(2) A good knowledge of arithmetic.
(3) Ability to compute accurately.
(4) Ability to visualize both the planning steps and the finished product of a construction project.
(5) A knowledge of materials.
(6) Ability to use pertinent Department of the Army publications.
b. Training in materials estimating. A man may be taught methods, calculations involved, items to include, and errors to avoid in materials estimating. However, he cannot be taught the indispensable factors of experience and judgment. These he must acquire over a period of time.

## 4-3. MATERIAL ESTIMATES

a. Sources of information. Plans and specifications for bridges, building, and other vertical structures normally contain bills of materials. When they do, the materials estimator should check the bill against the drawings and specifications for any discrepancies. If alterations or modifications of the
plans are necessary, which is frequently the case for facilities of the Army Facilities Components System (AFCS), the materials estimator will have to make the required additions and deletions to the accompanying bills.
b. Omission of bill of materials. When a bill of materials is not provided with the drawings and specifications for a construction project, the materials estimator must prepare one from the drawings and specifications.

## 4-4. PREPARING A BILL OF MATERIALS

a. Essential elements. The methods discussed in this lesson are representative only. The materials estimator has latitude in preparing his own system. However, listed below are five essential elements of whatever system he uses.
(1) Take-off list.
(2) Consolidation.
(3) Waste allowance.
(4) Nail requirements.
(5) Grouping and arranging.
b. Explanation. The following paragraphs illustrate and explain a recommended method of preparing a bill of materials incorporating these five elements. The additional elements of thoroughness, accuracy, and neatness are stressed here because they are vital to successful material estimating.

## 4-5. TAKE-OFF LIST

a. Definition. A take-off list is a descriptive and individual listing of each part in a structure. It gives the materials estimator the opportunity to determine firsthand the kind and quantities of materials needed. The method discussed below for preparing a materials takeoff is reliable and thorough. It incorporates the principle that the materials estimator, when preparing the takeoff list from a drawing, will work in a systematic manner.
b. Method. In preparing a takeoff list follow the rule "keep it separate." Whenever a part (item) is taken off a drawing or
specification, it is listed separately, described individually, and specifically allocated.
(1) Parts are not combined unless size and nomenclature are identical. A structure may have 20 posts (all same nomenclature) but any one or all of these posts would be listed and described individually if any difference in size existed. Also, a part having the identical size of any other differently named part would be separately itemized and described.
(2) The second step in preparing a take-off list is listing and describing the part in detail. For example, the number of pieces, nominal size, and length in place of wooden pieces would be listed. For parts other than wood, the listing consists of full description by nomenclature, size and/or quantity.
(3) The third phase of a take-off list is indicating the standard lengths of lumber to use for each wooden part listed and described. This requires that the materials estimator know the different sizes of lumber available at the depot and which sizes will produce the most parts with the least waste. This phase includes determining the number of pieces per part each standard length will produce and the number of standard lengths required for the total number of pieces per part.
c. Form. In general the take-off list should contain these important columns: (1) item. (2) part, (3) number of pieces, (4) nominal size, (5) length in place, (6) standard length, (7) number of pieces per standard length, and (8) number of standard lengths.

## 4-6. DEVELOPMENT OF TAKE-OFF LIST

a. Development of a take-off list begins with examination of the plans and follows the method described in paragraph 4-5b, above. For example, let us develop the first five columns of a take-off list for a scrub table shown in figure 4-1.
(1) Starting at the bottom, from the front and end views, note (as visualized through the detail) that the cable has two side rails (bottom) each made up of $2 \times 4$ 's, $4^{\prime}-6^{\prime \prime}$ long. Enter this as item 1
under column 1 and record the remaining information under columns 2 through 5 , as follows:

(2) The second item, from the same front and end view, is the end rail (bottom). Two pieces are also required, each $2 \times 4$. The length in place, $3^{\prime}-0^{\prime \prime}$, is located in the end view. Incorporating this information, as above, the following listing would result;

(3) Working systematically and in a logical sequence, take-off item three (3). Note that it is a pair of top side rails, one rail for each side of the table. Dimensions are $2 \times 4-4^{\prime}-6^{\prime \prime}$. The next item (4) labeled for take-off is the top end rail. Two of them are required, one for each end, in nominal size of $2 \times 4$. The length in place, shown in the side view, is $3^{\prime}-0 \prime$. Here are the entries for items 3 and 4 .

| (1) | $\stackrel{(2)}{P_{\text {Part }}}$ | $\begin{aligned} & \text { (3) } \\ & \text { Number of } \\ & \text { pleces } \end{aligned}$ | $\begin{gathered} \text { (t) } \\ \text { Nominal } \\ \text { slie } \end{gathered}$ | (б) 3.angthe in place |
| :---: | :---: | :---: | :---: | :---: |
| 3 | side rail (top) | 2 | $2 \times 4$ | $4^{\prime}-8{ }^{\prime \prime}$ |
| 4 | end rail (top) | 2 | $2 \times 4$ | $3^{\prime}-0^{\prime \prime}$ |

(4) Next, note item 5, the intermediate rail. Like item 4 , it is a $2 \times 4\left(3^{\prime}-0^{\prime \prime}\right.$ long) member and provides support to the table top. Four legs (item 6) in nominal size of $2 \times 4$ with length in place of $3^{\prime}$ $0^{\prime \prime}$ complete the items on the lower part of the table Take-off items 5 and 6 are listed as follows:


Figure 4-1. Scrub table detail.

(5) The final item to takeoff, item 7, is located in the top view of figure $4-1$. It is the table top, composed of six members with dimensions of 2 x $6,4^{\prime}-6^{\prime \prime}$ long. Here is the entry for top members:

b. Development of the last three columns (6 through 8) of the takeoff list requires some calculations.
(1) For columns 6 and 7, it is necessary to determine the standard length of material from which the items (parts) can be cut and how many can be cut from the length
selected. The shortest standard length (they range from 8 feet to 20 feet in 2-foot increments, paragraph $1-17 \mathbf{a}$, lesson 1) which supplies the most pieces with the least waste is normally chosen, i.e., usually several short pieces (up to 6 feet) can be cut from one standard length whereas pieces measuring more than 6 feet normally require the entire standard length. The selected standard length is entered in column 6. For convenience all measurements should be converted to inches. Footage is converted into inches prior to actual computation. i.e., 8 feet $=96$ inches ( 8 x 12 ), 10 feet = 120 inches ( $10 \times 12$ ), and so on. The entry far column 7 (number per standard length) is developed by dividing the standard length in column 6 by the length in place in column 5 .
(2) The number of standard lengths for column 8 , is then developed by dividing column 3 (number of pieces) by column 7 .
c. Continuing the example of the scrub table (a above) and following the method just described columns 6,7 , and 8 , let us proceed to finalize the takeoff list.
(1) Complete item 1, listed in a(1), above. Note that two pieces, each $4^{\prime}-6^{\prime \prime}$ long, are required. To develop columns 6 and 7 which relate to each other, try a 10 -foot length.

Converting to inches:

$$
\begin{aligned}
& 10^{\prime}-0^{\prime \prime}=10 \times 12=120 \text { inches } \\
& 4^{\prime}-6^{\prime \prime}=(4 \times 12)+6=48+
\end{aligned}
$$

Then:
$6=54$ inches

$$
\frac{120}{54}=54 \sqrt{\frac{2}{120}}
$$

$=2$ pieces $\mathrm{w} / 12$ inches waste

Trying a 12-foot standard length:

$$
\begin{gathered}
12^{\prime}-0^{\prime \prime}=12 \times 12=144 \text { inches } \\
4^{\prime}-6^{\prime \prime}=(4 \times 12)+6=48+ \\
6=54 \text { inches }
\end{gathered}
$$

Then:

$$
\frac{144}{54}=\frac{2}{54 \sqrt{\frac{108}{36}}} \text { (waste) }
$$

$$
=2 \text { lengths } \mathrm{w} / 36 \text { inches waste }
$$

It is apparent the 10 -foot standard length is more economical and should be selected for column 6. Column 7, as a result of this calculation, would list 2 as the number of pieces which can be cut from the length selected. Developing column 8 (number of standard lengths), divide the number of pieces listed in column 3 by column 7 .

$$
\frac{2}{2}=1
$$

Thus columns 6,7 , and 8 for item 1 would be:


Note: In this example, column 4 is omitted since it is not used in the calculations.
(2) Continuing with item 2 (a(2), above), observe that the item requires two pieces, each $3^{\prime}-0^{\prime \prime}$ long. In selecting the standard length (column 6) and the number per standard length (column 7), calculate on the closest standard length by trying an 8 -foot versus a 10 -foot length.
Converting to inches:

$$
\begin{aligned}
& 8^{\prime}-0^{\prime \prime}=8 \times 12=96 \text { inches } \\
& 3^{\prime}-0^{\prime \prime}=3 \times 12=36 \text { inches }
\end{aligned}
$$

Then:

$$
\frac{96}{36}=\frac{2}{3 6 \longdiv { \frac { 9 6 } { \frac { 9 2 } { 2 4 } } } \text { (waste) }}
$$

$=2$ pieces $\mathrm{w} / 24$ inches waste

Similarly for:

$$
\begin{gathered}
10^{\prime}-0^{\prime \prime}=10 \times 12=120 \text { inches } \\
3^{\prime}-0^{\prime \prime}=3 \times 12=36 \text { inches }
\end{gathered}
$$

Then:

$$
\begin{aligned}
\frac{120}{36} & =\frac{3}{36 \sqrt{\frac{108}{120}}} \\
& =3 \text { pieces w} / 12 \text { inches waste }
\end{aligned}
$$

Note: If a 10 -foot length was used there would be 48 inches waste, the unnecessary third length ( 36 inches) plus 12 inches waste.

Thus for column 6, the 8 -foot standard length is chosen as it will supply the two required number of pieces (column 3) with the least waste. Again, for column 8 , divide the number of pieces (column 3 ) by number per standard length (column 7).

$$
\frac{2}{2}=1
$$

Hence, the developed entries for columns 6, 7, and 8 for item 2 would be:


Note: In this example, column 4 is omitted since it is not used in the calculations.
(2) Continuing with item 2 (a(2), above), observe that the item requires two pieces, each $3^{\prime}-0^{\prime \prime}$ long. In selecting the standard length (column 6) and the number per standard length (column 7), calculate on the closest standard length by trying an 8 -foot versus a 10 -foot length.
(3) Note that items 3 and 4 have the same size and number of pieces requirement as items 1 and 2, hence, no additional computations are required. Thus the listings of items for 3 and 4 (for columns 6,7 , and 8 ) are the same as for items 1 and 2 , respectively.

(4) For item 5, use a short standard length of 8 feet since, in this instance, only one piece is required. Item 6 is similar to item 2 and will be listed accordingly; only the number standard lengths in column 8 will be different:

$$
\frac{4}{2}=2
$$

The entries for columns items 5 and 6 are as follows:

(5) Since item 7 is $4^{\prime}-6^{\prime \prime}$ long (same as items 1 and 3 ) select the 10 -foot standard length as it will supply two lengths with least waste. Then to develop column 8 (number of standard lengths) compute:

$$
\frac{6(\text { colm } 3)}{2(\text { colm } 7)}=3
$$

Developed columns for item 7 follow:

d. The completed take-off list for the scrub table is shown in figure 4-2.

| $\begin{aligned} & \text { (1) } \\ & \text { Item } \end{aligned}$ | (2) Part | $\begin{aligned} & \text { (3) } \\ & \text { Number } \\ & \text { of } \\ & \text { Pieces } \end{aligned}$ | $\begin{aligned} & \text { (4) } \\ & \text { Nominal } \\ & \text { Size } \end{aligned}$ | $\begin{aligned} & \text { (5) } \\ & \text { Length } \\ & \text { in } \\ & \text { Place } \end{aligned}$ | $\begin{aligned} & \quad(6) \\ & \text { Standard } \\ & \text { Length } \end{aligned}$ | (7) <br> Number of Pieces per Standard Length | (8) <br> Number of Standard Lengths |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | side rail <br> (bottom) | 2 | $2 \times 4$ | $4^{\prime}-6^{\prime \prime}$ | 10'-0' | 2 | 1 |
| 2 | end rail <br> (bottom) | 2 | $2 \times 4$ | $3^{\prime \prime} 0^{\prime \prime}$ | 8'-0'' | 2 | 1 |
| 3 | $\begin{aligned} & \text { side rail } \\ & \text { (top) } \end{aligned}$ | 2 | $2 \times 4$ | $4^{\prime}-6^{\prime \prime}$ | 10'-0' | 2 | 1 |
| 4 | $\begin{aligned} & \text { end rail } \\ & \text { (top) } \end{aligned}$ | 2 | $2 \times 4$ | 3'-0' | 8'-0'' | 2 | 1 |
| 5 | intermediate rail | 1 | $2 \times 4$ | 3'-0' | 8'-0" | 1 | 1 |
| 6 | legs | 4 | $2 \times 4$ | 3'-0' | 8'-0' | 2 | 2 |
| 7 | top members | 6 | $2 \times 6$ | 4'-6" | 10'-0' | 2 | 3 |

Figure 4-2. Completed take-off list for scrub table.

## 4-7. CONSOLDATION

a. Having completed the take-off list (fig. 4-2), we are ready to consider the development of the consolidation element for a bill of materials (par. 4-4a(2), above). Consolidation on a bill of materials is the process of combining into one listing all identical items, regardless of nomenclature. This process turns the detailed and lengthy take-off list into a concise and easily read list of materials. The method for developing the information on a consolidated list of materials and the takeoff list (pars 4-5 and 4-6, above) is identical with the exception of columns 2 and 3.
(1) Column 2 (part) lists the name of the part or parts consolidated into one entry.
(2) Column 3 (number of pieces) lists the total number of pieces required for all the parts listed in column 2.
b. Continuing with the example of the scrub table, consider consolidation of the take-off list.
(1) Note that items 1 and 3 are identical. Each is made up of $2 \times 4$ 's, 4'-6" long. Enter these as item 1, column 1, and record the remaining information under columns 2 through 8 , as follows:

| (1) Item | (2) Part | (3) <br> Number of pleces | (4) <br> Nominal sive | $\begin{gathered} (5) \\ \text { Length } \\ \text { in } \\ \text { place } \end{gathered}$ | (6) <br> Standard length | (7) <br> Number of pleces per standard length | (8) <br> Number of standard lengths |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | side rail (top and bottom) | 4 | $2 \times 4$ | $4^{\prime \prime-6 \prime \prime}$ | $10^{\prime}-0^{\prime \prime}$ | 2 | 2 |

(2) Further note that items 2, 4, 5, and 6 are identical, each $2 \times 4,3^{\prime}-0^{\prime \prime}$ long. Consolidating these items requires a recalculation of column 6 (standard length). Thus, this information would result in the following entry:

| (1) Item | (2) Part | (3) <br> Number of pieces | (4) <br> Nominal slzo | $\begin{gathered} \text { (5) } \\ \text { Length } \\ \text { in } \\ \text { place } \end{gathered}$ | (6) <br> Standard length | (7) <br> Namber of pieces per standard length | (8) <br> Number of standard lengths |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2 | end rails (bottom and top) intermediate rail, legs | 9 | $2 \times 4$ | $3^{\prime}-0^{\prime \prime}$ | ${ }^{10} 10-0^{\prime \prime}$ | 3 | 3 |

-Select the 10 -foot length now (par. $4-6 \mathrm{c}(2)$, above). For nine pieces, it is more economical.
(3) Note that item 7 is not identical with any other item. Thus, it would be listed as shown below without consolidation:

| (1) <br> Item | (2) <br> Part | (3) <br> Number <br> of <br> pleces | (4) <br> Nominal <br> stze | (5) <br> Length <br> in <br> place | (6) <br> Standard <br> length | Namber of <br> pleces per <br> standard <br> length | (8) <br> Number of <br> standard <br> lengths |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 3 | top <br> members | 6 | $2 \times 6$ | $4^{\prime}-6^{\prime \prime}$ | $10^{\prime}-0^{\prime \prime}$ | 2 | 3 |

c. Figure 4-3 shows the completed consolidated list for the scrub table.
d. Demonstrating another example of consolidation, let us develop the number of board feet (BF) par. 118 and table 1-3, lesson 1) in the standard lengths required for the scrub table.
(1) Noting that items 1 and 2 are identical (fig. 4-3) by size and length of pieces, consolidate the number of standard lengths (column 8$)(2+3=5)$. Using table $1-3$, convert to BF:
( $2 \times 4,10^{\prime}-0^{\prime \prime}$ long $=62 / 3 \mathrm{BF}$ ).
Computing: $6^{2 / 3} \times 5=\frac{20}{3} \times 5=\frac{100}{3} \quad$ or $\quad 33 \mathrm{BF}$
(2) Since item 3 has no identical part, one $2 \times 6,10^{\prime}-0^{\prime \prime}$ long $=10 \mathrm{BF} \times 3$ standard lengths (column 8 ) or 30 BF
(3) Therefore, each scrub table contains a total of $63 \mathrm{BF}(33+30)$.

| $\begin{aligned} & \text { (1) } \\ & \text { Item } \end{aligned}$ | $\begin{aligned} & \text { (2) } \\ & \text { Part } \end{aligned}$ | (3) <br> Number of Pieces | $\quad(4)$ Nominal Size | (5) <br> Length <br> in <br> Place | (6) <br> Standard <br> Length | (7) <br> Number of Pieces per Standard Length | (8) <br> Number of Standard Lengths |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | side rails (top and bottom) | 4 | $2 \times 4$ | 4'-6' | 10'-0' | 2 | 2 |
| 2 | ```end rails, inter- mediate rail, and legs``` | 9 | $2 \times 4$ | $3^{\prime}-0^{\prime \prime}$ | 10'-0' | 3 | 3 |
| 3 | top members | 6 | $2 \times 6$ | $4^{\prime}-6^{\prime \prime}$ | 10'-0' | 2 | 3 |

Figure 4-3. Consolidated list for scrub table.

## 4-8. WASTE ALLOWANCE

Waste allowance, the third essential element (par. 4-4a(3)) of a bill of materials, is important because during construction a certain amount of material is wasted due to cutting, fitting, and handling. For example, lumber comes in standard lengths which seldom can be used without cutting and fitting. Sometimes the piece of lumber cut off is used, but more often it goes into the scrap heap. Another example is mortar sand which is normally stored at the job site. The sand on the bottom of the pile cannot be picked up without some earth getting in it. This generally makes the sand unusable and therefore wasted. Likewise, some electrical items, wire outlets, toggle switches, insulators, and so forth, are wasted due to malfunctioning, wrong size, damage, and so on. Thus, waste allowance must be included in a bill of materials to cover unavoidable losses. Table 4-1 lists the different allowances for waste. Note that the allowance percentages are based on the function of the item. When developing waste allowances, multiply the total quantity of any one particular part

TABLE 4-1. Allowances for Waste

| Itom | Allowance |
| :---: | :---: |
| Dimension lumber - 2 inches or more thick | 10\% |
| Sheathing and flooring - less than 2 inches thick | 20\% |
| Matched boards - 3 inches or more wide $\qquad$ | 33\% |
| Matched boards - less than 3 inches wide $\qquad$ | 50\% |
| Common wire nails | 20\% |
| Other construction material | 5\% - 10\% |

(standard lengths, units, rolls, concrete mixtures, and so forth) by the applicable waste allowance (table 41). Then include the result on the final bill of materials. (In computing waste, count any fraction from .5 up as a whole number; drop anything less.) Ordinarily no waste allowance would be taken on items such as scrub table parts. However, if 100 such tables were to be built, 500 pieces of $2 \times 4{ }^{\prime} \mathrm{s}, 10^{\prime}-0^{\prime \prime}$ long and 300 pieces of $2 \times 6$ 's, $10^{\prime}-0$ " long would be required (results of items 1 and 2 combined and item 3 (fig. 4-3) multiplied by 100). An allowance of 10
percent for waste is made on each item, so 550 pieces and 330 pieces would be listed respectively in the bill of materials.

## 4-9. NAIL REQUIREMENTS

Nail requirements (par. 4-4a(4)) are expressed in pounds of nails. The quantity of nails required can be determined by counting the number of joints in simple structures, by using the formulas for approximate quantities or by using table 1-3 in lesson 1. When the quantity of nails is determined by counting joints, allow two nails per joint for material up to 8 inches wide and three per joint for wider material.
a. Nail requirements can also be estimated by use of the following formulas:
(1) For framing members (dimension lumber), pounds of nails per $\mathrm{MBF}=$ $\frac{\text { Size of nail in pennies } \times 10}{6}$ or pounds of nails per MBF $=1.67 \mathrm{~d}$.
(2) For sheathing and flooring, pounds of nails per MBF $=$ $\frac{\text { Size of nail in pennies } \times 10}{4}$ or pounds of nails per $\mathrm{MBF}=\mathbf{2 . 5 d}$.
b. The nail size should be at least 1.5 to 2 times the thickness of the wood it is intended to hold if it is driven across the grain of the second piece of wood and at least 3 times the thickness of the wood it is intended to hold if it is driven with the grain of the second piece of wood. Table 1-3 gives some recommended nail sizes and the quantities required for various elements of frame structures.
c. For example, let us determine the size and quantity of nails required to finish 100 scrub tables.

The greatest thickness of wood the nail is intended to hold is $11 / 2$ inches. The nails will be driven across the grain of the second piece of wood. Nail lengths should be at least 1.5 or 2 times $11 / 2$ inches. Two times the thickness of a $2 \times 4$ is 3 . Select a 3 -inch length, or 10-penny common nail. Since this is a simple structure, the number of nails
required will be determined by counting the joints. Referring to figure 4-1, there are 30 joints. Only two nails are required per joint because the maximum width is less than 8 inches. Thirty joints per table x 2 nails per joint $=60$ nails/table. The job requirement is for 100 tables,

## 100 tables x 60 nails per table $=6000$ nails

From table 4-1, the allowance for waste for common wire nails is $20 \%$.

$$
6000 \times 1.20=7,200 \text { nails }
$$

The number of 10 d per pound from figure 1-15 or table 1-3 is 74 nails per pound.

## $\frac{7,200 \text { nails }}{74 \text { nails/pound }}=\underset{\substack{\text { pounds of } 10 d \\ \text { nails }}}{97.3 \text { pounds, say } 97} \underset{\text { common }}{97}$

d. In comparison, determine the quantity of nails to construct the 100 scrub tables required by using the formula for framing members:

$$
\begin{aligned}
\text { pounds of nails per MBF }= & 1.67 \mathrm{~d} \\
= & 1.67 \times 10= \\
& 16.7
\end{aligned}
$$

Referring to paragraph 4-7d(3), there are 63 BF per scrub table or 6,300 BF per 100 scrub tables or 6.3 MBF per 100 scrub tables.

Thus the number of pounds of nails required:
16.7 pounds of nails per MBF x $6.3 \mathrm{MBF}=$ 105.21 pounds of nails say $\mathbf{1 0 5}$ pounds of $\mathbf{1 0 d}$ common nails.

For this case, the formula gives a value that is $8.25 \%$ greater than the exact amount plus the standard allowance for waste

$$
\frac{105-97}{97} \times 100=8.25 \%
$$

e. The following example on the use of table 1-3 will illustrate its usefulness: What size, kind, and quantity of nails are required to lay $1 \times 4$ flooring for a room $50 \times 100$, joists spaced 16 inches on centers?

Referring to table 1-3 look in the first column headed "Sizes and Kinds of Materials" and find "Flooring $1 \times 4$." Read horizontally across to the second column headed "sizes" and find the size and kind as 8d floor brads.

Continue horizontally across to the column headed $16^{\prime \prime}$ under "Pounds per MBF on center as follows" and find the quantity 26 pounds.

BF in flooring 1 inch thick $=50 \times 100=5,000=$ 5 MBF

26 pounds of nails x $\mathbf{5} \mathbf{~ M B F}=\mathbf{1 3 0}$ pounds
Thus the required size, kind, and quantity is $\mathbf{1 3 0}$ pounds of 8 floor brads.
f. The following will also be found convenient in estimating the quantity of nails required for building frame structures:
(1) For 1,000 shingles, allow 5 lb 4 penny nails or $31 / 2 \mathrm{lb} 3$-penny.
(2) For 1,000 laths, 7 lb 3 -penny fine, or for 100 sq yd of lathing, 10 lb 3 -penny fine.
(3) For $1,000 \mathrm{sq} \mathrm{ft}$ of beveled siding, 18 lb 6-penny.
(4) For $1,000 \mathrm{sq} \mathrm{ft}$ of sheathing, 20 lb 8 -penny or 25 lb 10 -penny.
(5) For $1,000 \mathrm{sq} \mathrm{ft}$ of flooring, 30 lb 8 penny or 40 lb 10-penny.
(6) For $1,000 \mathrm{sq} \mathrm{ft}$ of studding, 15 lb 10 -penny and 5 lb 20 -penny.
(7) For $1,000 \mathrm{sq} \mathrm{ft}$ of 1 by $21 / 2 \mathrm{in}$. furring, 12 in . centers, 9 lb 8 -penny or 14 lb 10 penny.
(8) For $1,000 \mathrm{sq} \mathrm{ft}$ of 1 by $21 / 2 \mathrm{in}$. furring, 16 in . centers, 7 lb 8 -penny or 10 lb 10 penny.

## 4-10. GROUPING AND ARRANGING

The last and final element in the preparation of a bill of materials is grouping and arranging (par. 4$4 \mathrm{a}(5)$ ). It results in a completed bill of materials which facilitates requisitioning.
a. Items are grouped and arranged by sections. Codes applicable to frame structures are as follows:

| Code number | Deacription |
| :--- | :--- |
| $01-02$ | Frame and Roof |
| 03 | Cladding - - Doors and Windows |
| 04 | Interior Liner |
| 05 | Floor |
| 06 | General Interior Construction |
| 07 | Plumbing |
| 08 | Heating and Ventilation |
| 09 | Interior Electric Wiring |
| 10 | Interior Fire Protection |

These major groupings are then subgrouped according to common items required for the specific work assignment, lumber, nails, hardware, and so forth. Items are arranged within each subgroup by name and size and numbered consecutively. This arrangement may be developed from the consolidated listing.
b. Figure 4-4 shows a finalized bill of materials and illustrates grouping and arranging.



Figure 4-4. Finalized bill of materials.

## SELF TEST

Note: The following exercises comprise a self test. The figures following each question refer to a paragraph containing information related to the question. Write your answer in the space provided below each question. When you have finished answering all the questions of this lesson, compare your answers with those given for this lesson in the back of this booklet. Review the lesson as necessary. Do not send in your solutions to these review exercises.

1. Estimating is one of the most important steps in planning a construction project. In what way does good estimating help insure successful completion of a project? (Para 4-1a)
2. What is the first step an estimator should take when assigned to a new project? (Para 4-1b(1))
3. Where does the estimator obtain the information he needs to prepare the bill of materials? (Para 4-1b(3))
4. Plans and specifications for bridges, buildings, and other vertical structures normally contain bills of materials. What is the function of the material estimator if alterations or modifications of the plans are necessary? (Para 4-3a)
5. List the five essential elements of any bill of materials. (Para 4-4a)
6. In reference to the preparation of a takeoff list, what is the meaning of the rule "keep it separate?" (Para 45b(1))
7. When the materials estimator converts the actual requirements for a certain size of lumber into the number of pieces of standard lengths to be procured, what is his primary consideration? (Para 4-5b(3))

Note: Review exercises 8 through 14 assume a knowledge of the takeoff form described in paragraph 4-5c and your ability to read details from figure 4-5.
8. The wood floor of the tent frame shown in fig. $4-5$ is nailed to 2 " $\times 4$ " sleepers. What entry do you make in columns 3 and 5 on the takeoff form to cover sleepers? (Para 4-5c, 4-6, fig. 4-5)
9. Figure $4-5$ shows skirtboards installed on each side of the tent frame. What is your entry in column 4 for skirt boards? (Para 4-5c, 4-6, fig. 4-5)
10. Bracing must be used to make the frame rigid. What are entries for columns 4 and 5 in regard to bracing? (Para 4-5c, 4-6, fig. 4-5)
11. Most of the common sized lumber is stocked in lengths ranging from 8 to 20 feet in 2 -foot intervals. What is the general rule to observe in selection of standard lengths for column six of the takeoff list? (Para 4-6b(1))
12. What standard length $1 \times 6$ floor material would you enter in column 6 for the tent frame illustrated in figure 4-5? (Para 4-5c, 4-6, fig. 4-5)
13. When constructing an earth floor tent frame the sides are anchored to brace stakes. What standard length should you enter in column 6 for brace stakes? (Para 4-5c, 4-6, fig. 4-5)
14. Having determined in exercise 13 the standard length of $2 \times 4$ material required for brace stakes, what entry do you make in column 7 on the brace stake line? (Para 4-5c, 4-6, fig. 4-5)


Figure 4-5. For use with exercises 8 through 14.
15. Referring to figure $4-2$, how do you arrive at the figure to enter in column 8? (Para 4-6b(2))
16. Consolidation on a bill of materials is the process of combining into one listing all identical items, regardless of nomenclature. Of the seven items listed in figure 4-2, which cannot be consolidated with any of the others? (Para 4-7b(3))
17. In figure $4-2$, items $2,4,5$, and 6 are identical. When they are consolidated, why does the entry in column 6 change? (Para 4-6c(2))
18. How much waste allowance is made for dimension lumber two or more inches thick? (Para 4-8, table 4-1)
19. Nail requirements are expressed in pounds of nails. Using the method outlined in paragraph 4-1, how many pounds of eight-penny nails will be required for 1500 square feet of sheathing? (Para 4-9f)
20. The last element in the preparation of a bill of materials is grouping and arranging. What benefit is to be realized from grouping and arranging? (Para 4-10)

## LESSON 5

CONSTRUCTION METHODS AND STANDARDS
PLANNING ESTIMATES
b. Detailed labor production estimate. Company and battalion progress schedules and output records of comparable work performed under similar conditions are the most reliable bases for estimating labor capabilities. This is one of the major reasons why it is so important that engineer units keep detailed, accurate records of all work accomplished. If such data are not available, the construction handbook and manuals to which you were referred previously contain information on average labor production for various building operations. The engineer must use good judgment and sound knowledge of construction principles in applying these standard estimates to his particular building operations. He should take into account such factors as: experience and training of personnel, availability of special tools and equipment and materials, method of cutting and assembling components, erection procedures, and weather and climate conditions.

## 5-5. INFLUENCE OF CLIMATE ON DESIGN

a. Temperate climate. Unless otherwise indicated, standard plans provide minimum requirements for a temperate climate. No special factors influence this design. Floors are earth, wood, or concrete, as necessary. Heating is by individual stoves and ventilation by adequate doors and windows. Roof framing shown on standard plans is designed for a snow load of 15 pounds per square foot. If heavier loads of snow can be partially removed, stronger original framing is unnecessary. Wet snow approximately 6 inches deep or dry snow approximately 18 inches deep weighs about 15 pounds per square foot. Standard buildings are designed to resist normal wind forces of 10 pounds per square foot. In areas where high wind velocities occur, all buildings should be anchored by guys instead of redesigned as to framing.
b. Frigid climate. The extremes of frigid weather require modification of temperate-climate plans. Floors are laid double thick and walls and roof are insulated. Woodfloor buildings have skirting to the ground. Heating is by individual stoves. Door and window openings are small, sufficient only to provide adequate ventilation. Since standard roof framing is designed for snow loads of only 15 pounds per square foot, roof construction must be strengthened if partial clearing of heavier snow from roofs is impractical. Resistance to high wind velocities should be provided by guy wires, when necessary.
c. Tropical climate. Floor plans for temperate climates are also used in tropical climates, but are modified to provide as much circulation of air as possible. Most buildings have wood floors, raised above ground to insure dryness and to prevent mildew and the entrance of insects. Use of continuous screened openings, ridge vents, and floorlevel vents provides the maximum ventilation possible, consistent with the shelter required. Overhanging eaves exclude the direct rays of the sun and protect openings during rainstorms. To protect the building against termites, all wood members touching the ground should be treated and have metal shields installed to prevent insect infestation. Resistance to high wind velocities should be provided by guy wires, when necessary.

## 5-6. CONCRETE FLOORS

Concrete floors are often used in TO construction, especially for
repair and assembly shops, and certain types of warehouses where earthen or wooden floors are not suitable. These floors are made by placing the concrete on the ground after the earth has been graded and tamped. This type of floor is likely to be damp unless protected. Drainage is provided, both for the floor area and for the area near the floor, to prevent flooding after heavy rains. The floor should be reinforced with steel or wire mesh. Where concrete floors are to be placed, a foundation wall may be placed first and the
floor placed after the superstructure is completed. This provides protection to the concrete floor while it sets and eliminates the waiting period that must otherwise follow before construction of the building can begin.

## 5-7. METHODS OF ERECTION

a. General. The method of erecting buildings directly affects the time, labor, and material needed. The methods may be divided into two types.
(1) Built in place. In this method each piece is separately erected in its proper place.
(2) Panel method. In this method a complete section is built up as a unit and then set in the building in the proper place. It is used extensively because it makes for greater speed, better control over working parties and better use of manpower. It also allows the use of a standard list of sizes for each similar section; standard plans shown in TM 5-302 further simplify construction.
b. Factors considered in selection of method to be used. Construction planning permits an orderly series of operations and prevents duplication of effort and waste of material. Factors considered in planning are construction plant layout, distribution of material, number of skilled and semiskilled men available, and number and type of units to be constructed. From a list of the various separate operations required, an estimate of the total number of man-hours needed is made. This estimate forms the basis for determining the number and type of men needed and for organizing the erection crew or crews. Arrangements for assembling the necessary materials at the job site and for doing the preliminary cutting and assembly are made in advance.
c. Procedures, built-in-place method. When using the built-in-place method, the officer in charge of construction divides the men into working parties, whose duties may be as follows:

## (1) Laying out the foundation. <br> (2) Grading and excavating. <br> (3) Laying out and cutting various sizes of material.

(4) Carrying material to the cutting and erecting parties.

If a party completes its task before the building is completed, it is assigned a new task. For example, if the party laying out the foundation completes its work before erection of the building is begun, it is assigned a new duty such as cutting rafters. Parts are built in the following order: footings, piers, sills, joists, floor, sole, studs, plates, girts, rafters, bracing, siding, sheathing, roofing, doors, windows, steps, and inside finish (if used).
d. Procedures, panel method. The panel method (preassembly method) requires careful planning before the actual construction. Most Army buildings are now built by this method, as follows:
(1) Before measuring and cutting lumber, the number and size of sections that are alike should be determined from the blueprint. This insures the correct numbers of each piece. The carpenter assigns a crew to cut and assemble one section. In most cases, a template is built as a guide for assembling the section. It should be built square, correct in size, and level. Most TO construction now built by the panel method uses the basic 8 foot by 10 foot panel (fig. 51) with special door panels, window panels, and modified panels. Modified panels are smaller by the actual width of a $2 \times 4$ and are used as end panels. Detailed drawings of this type panel construction including roof and gable panel are included in TM 5-302.


Figure 5-1. Basic wall panel.
(2) The number and size of each piece in a section is given to the man in charge of the cutting party. The cutting party cuts the timber to the correct length with a handsaw or power saw. The length is measured by the use of square and tape. After one piece has been cut, it may be used as a pattern for marking the remaining pieces. The pattern is set up by nailing two blocks to the piece of correct size, one near each end, as shown in figure 52. These blocks act as stops to hold the pattern in place on the timber to be marked. Several cutting and assembling parties may be used at one time on different types of sections.


## Figure 5-2. Marking a pattern

(3) The plate and sole are placed in the template with the studs and girts between; then the door and window posts, if any, are placed (fig. 5-3). The girts, sole, and plate are nailed to the studs with 16 - or 20 -penny nails. If insulation board is used, it and the wall sheathing are put on the section before it is taken out of the template. By applying the wall finish before raising the section, no scaffold or ladders need be used.
(4) The erecting party sets the sections into place, braces them temporarily, and nails them together. The end section should be first, and it may be erected on graded earth. The sidewall sections are next and should be erected so as to keep the two walls even. The rafter party can then place the rafters on the walls. Parties should be set up as follows: layout party, cutting party, assembling party, carrying party, erecting party for rafters, sheathing party, roofing party, and door-and-window party.
(5) The preassembly method of erection may be used for all types of small buildings and large warehouses. When this method is used for large buildings, cranes are


Figure 5-3. Template for wall panels.
used to place sections too heavy to be handled by hand. Where machinery is used, caution in fastening the cable or rope avoids damaging the section.

## 5-8. NUCLEAR WEAPONS FACTORS IN THEATER-OF-OPERATIONS CONSTRUCTION

Changes in construction standards resulting from possible increased use of nuclear weapons are governed by Department of the Army policy and will normally be outlined by TO or other appropriate directives. General considerations, as they pertain to this subcourse, involve probable effects on structures and possible precautionary measures to minimize damage.
a. Damage to structures and material in a nuclear explosion is due to blast and shock, and fire. Fires may be started by thermal radiation, but most will be extinguished by the blast. The majority of fires will be from secondary causes as indirect blast effects. Wooden, brick, and light steel frame buildings are highly vulnerable to blast. In open
terrain, high air bursts can be expected to produce severe structural damage at distances ranging from 1300 meters for a 2 kt bomb to 8000 meters for a bomb yielding 500 kt . Underground shock will cause water, sewer, and gas mains to suffer severely, but electric mains will not be greatly affected.
b. Although nuclear weapons possess unprecedented destructive capabilities, it is not to be assumed that defensive measures cannot lessen their effectiveness. Some general precautions are listed below:
(1) Take advantage of natural terrain. A hill mask can reduce structural damage considerably at distances comparatively close to ground zero.
(2) Use glass-substitute material.
(3) Observe minimum-spacing requirements.
(4) In some instances it may be advisable to dig in or to partially bury certain structures.
(5) Provide for an adequate water supply.
(6) If materials are available, use noninflammable exterior finish, and additional bracing at structural joints.

## 5-9. NONSTANDARD CONSTRUCTION

a. Although standard plans are normally used in meeting requirement for new construction in a TO, climate conditions lack of standard materials, transportation shortages, availability of local materials and labor, or other considerations may make it necessary or advisable to modify these
typical designs. Nonstandard construction may be classified generally as follows:
(1) Substitute construction which involves the modification of standard plans or use of substitute materials.
(2) Expedient construction which uses materials of any type. It may not be economical of labor or materials, but its employment is warranted to get the job done.
(3) Improvised construction which is the simplest type suitable for immediate needs.
b. In addition to new construction involving standard or nonstandard structures, a good portion of the engineer effort in some theaters is directed to repairing and adapting existing structures for military usage.

## 5-10. REFERENCES AND TABLES

Although this subcourse aims primarily at covering the fundamentals of standard-type TO construction, you were given in paragraph 5-1 for this lesson a list of reference works which provide information on nonstandard construction and related subjects. It is not possible here to cover in detail the use of these manuals, but it is believed that some of the exercises for this lesson will illustrate how reference materials can be used in solving typical problems which may arise in modifying standard structures, in designing nonstandard buildings, or in repairing existing structures. Tables 5-1, 5-2, 5-3, 54 , and 5-5, and examples of their use (in the self-test) are extracted from FM 5-35, Engineers' Reference and Logistical Data.

TABLE 5-1. Working stresses.

| Allowable working stresses in pounds per square inch for various domestic species of wood, including the unit weight and modulus of elasticity, are as follows: |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Variety and arade of wood | Stress grade ${ }^{3}$ <br> (2) | Average unit weight ${ }^{\text {a }}$ (lb per cu ft) <br> (3) | Allowable working stresses for military use ${ }^{\text {t }}$ (lb per sq in) |  |  |  | Modulus of elasticity(8) |
| Species and grade description <br> (1) |  |  | Extreme fiber stress in bending <br> (4) | Horizontal shear <br> (5) | Compression perpendicular to grain <br> (6) | Compression parallel to grain: <br> (7) |  |
| UNITED STATES SPECIES |  |  |  |  |  |  |  |
| Douglas fir -- |  | 35 |  |  |  |  | 1,600,000 |
| Dense, select structural | 1,800f |  | 2,700 | 180 | 500 | 1,950 |  |
| Select structural | 1,600f |  | 2,400 | 150 | 450 | 1,800 |  |
| Yellow pine (longleaf, or dense shortleaf) | 1,400f | 40 | 2,100 |  | 500 | 1,650 | 1,600,000 |
| Select structural | 2,000f |  | 3,000 | 150 | 500 | 2,200 |  |
| Prime structural | 1,800f |  | 2,700 | 150 | 500 | 1,950 |  |
| Merchantable structural; and structural square edge and sound | 1,600f |  | 2,400 | 150 | 500 | 1,800 |  |
| No. 1 structural | 1,400f |  | 2,100 | 150 | 500 | 1,500 |  |
| Larch |  | 36 |  |  |  |  | 1,300,000 |
| Select structural | 1,800f |  | 2,700 | 200 | 500 | 1,950 |  |
| Structural | 1,600f |  | 2,400 | 150 | 470 | 1,800 |  |
| Common structural | 1,200f |  | 1,800 | 135 | 430 | 1,650 |  |
| Redwood (structural) <br> Dense, select, all heart |  | 30 |  |  |  |  | 1,200,000 |
| Dense, select, all heart Select, all heart | 1,400f |  | 2,100 1,800 | 135 120 | 350 350 | 1,800 1,650 |  |
| Sulkhead and heart | 1,200f |  | 1,800 1,650 | 120 | 350 350 | 1,650 1,500 |  |
| Southern cypress |  | 32 |  |  |  |  | 1,200,000 |
| Select structural | 1,400f |  | 2,100 | 180 | 400 | 1,800 |  |
| Structural <br> Eastern hemlock | 1,100f | 30 | 1,650 | 150 | 400 | 1,500 | 1,100,000 |
| Select structural | 1,100f |  | 1,650 | 105 | 400 | 1,050 |  |

' Reduce all stresses to 70 percent of tabular values for green wood and for design of parts of bridge structure continuously wet. Reduce all stress values to 75 percent of tabular values for design of structures carrying long-continued live load.
: Grade designations of structural timber adopted by United States lumber industry for long-time use. ${ }^{2}$ At about 15 percent moisture conten

- Working stress in tension same as for bending.
"Working stresses for compression parallel to grain apply io posts, columns, and atruts the unsupported length of which does not exceed il times
least dimenaion of cross aection.

TABLE 5-2. Beam Stresses.
flexure controls, the following table is used:

| $\begin{gathered} \text { Span } \\ \text { (ft) } \end{gathered}$ | Safe losis in pounds uniformily distributed for rectangular beams per inch of actual width (For allowable aber stress of 1,000 pal) |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Nominal dopth of beam (Inches) |  |  |  |  |  |  |  |  |  |  |
|  | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 4 | 370 | 880 | 1,580 | 2,510 | 3,670 | 5,060 |  |  |  |  |  |
| 6 | 240 | 590 | 1,040 | 1,670 | 2,450 | 3,380 |  |  |  |  |  |
| 8 | 180 | 440 | 780 | 1,280 | 1,840 | 2,530 |  |  |  |  |  |
| 10 | 150 | 350 | 630 | 1,000 | 1,470 | 2,020 | 2,670 | 3,400 | 4,220 | 5,140 | 6,140 |
| 12 | 120 | 290 | 520 | 840 | 1,220 | 1,680 | 2,220 | 2,840 | 3,520 | 4,280 | 5,110 |
| 14 | 100 | 250 | 450 | 720 | 1,050 | 1,450 | 1,900 | 2,430 | 3,020 | 3,660 | 4,380 |
| 16 | 90 | 220 | 390 | 630 | 920 | 1,260 | 1,670 | 2,120 | 2,640 | 3,220 | 3,840 |
| 18 | 80 | 200 | 350 | 560 | 820 | 1,120 | 1,480 | 1,890 | 2,340 | 2,880 | 3,400 |
| 20 | 70 | 180 | 310 | 500 | 730 | 1,010 | 1,330 | 1,700 | 2,110 | 2,570 | 3,060 |
| 22 |  | 160 | 280 | 460 | 670 | 920 | 1,210 | 1,540 | 1,820 | 2,340 | 2,790 |
| 24 |  | 150 | 260 | 420 | 610 | 840 | 1,110 | 1,420 | 1,760 | 2,140 | 2,560 |
| 26 |  | 140 | 240 | 390 | 560 | 780 | 1,030 | 1,310 | 1,620 | 1,980 | 2,360 |
| 28 |  | 130 | 220 | 360 | 530 | 720 | 950 | 1,210 | 1,510 | 1,830 | 2,190 |
| 30 |  | 120 | 210 | 330 | 490 | 670 | 890 | 1,130 | 1,410 | 1,710 | 2,040 |
| 32 |  | 110 | 200 | 310 | 460 | 630 | 830 | 1,060 | 1,320 | 1,610 | 1,820 |
| 34 | ---- | 100 | 180 | 290 | 430 | 590 | 780 | 1,000 | 1,240 | 1,510 | 1,810 |

Note 1. For aber atrasses other than 1,000 pal, change safe loada proportionately. warehouse floor service in which live loads can be applied over long periods.
Timber beams are designed using the standard beam formulas and the unit stresses in table I. For beams in which

Note 1. For allowable atresces other than 100 pal, change safe loads proportionately.
Note 2. Example. Aesume the $8^{\prime \prime} \times 14^{\prime \prime}$ beam in the axample in note 2, table II, is used on a 10-foot apan. The allowable load due to texure is:
$71 / 2 \times 2,020 \times \frac{1,800}{1,000}=27,270$ pounds
Allowable load due to horisontal shear: streas is aiven as 150 pal in table $I$ $71 / 2 \times 1,800 \times \frac{150}{100}=20,250$ pounds

[^1]TABLE 5-4. Column Design

| Square Columns. $\begin{aligned} & \text { Safe } \\ & \text { (For }\end{aligned}$ | Safe axial load in kips for square timber columns: (For allowable compression parallel to grain of $\mathbf{1 , 1 0 0} \mathrm{psi}$ ) |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Nominal size (inches) | Actual sive (inches) | Area <br> (square Inches) | Length (feet) | Safe load (kips) |
| $6 \times 6$ | $51 / 2 \times 51 / 2$ | 30.3 | $\begin{array}{r} 8 \\ 10 \\ 12 \end{array}$ | $\begin{aligned} & \hline 26.0 \\ & 24.2 \\ & 22.4 \end{aligned}$ |
| $8 \times 8$-------- | $71 / 2 \times 71 / 2$ | 56.3 | $\begin{array}{r} 8 \\ 10 \\ 12 \\ 14 \\ 16 \\ 18 \end{array}$ | $\begin{aligned} & 52.0 \\ & 49.5 \\ & 47.0 \\ & 44.5 \\ & 42.0 \\ & 39.6 \end{aligned}$ |
| $10 \times 10$.---.-- | 9112 $\times 11 / 2$ | 90.2 | 8 10 12 14 16 18 20 | 86.8 83.6 80.1 77.2 74.3 71.0 67.8 |
| $12 \times 12$-------1 | $11112 \times 11112$ | 132.2 | $\begin{array}{r} 8 \\ 10 \\ 12 \\ 14 \\ 16 \\ 18 \\ 20 \end{array}$ | $\begin{aligned} & 130.5 \\ & 127.0 \\ & 123.0 \\ & 119.0 \\ & 115.2 \\ & 111.3 \\ & 109.5 \end{aligned}$ |

Note 1. Safe load on a round column is 0.785 times the safe load on a square column of side equal to dlameter.

## $1 \mathrm{klp}=1000 \mathrm{lb}$.

Note 2. For loada on columns of various grades and apecien, proportion from the loada tabulated above, uaing allowable compresoion stresees parallel to grain from column 7 of table 1 . For example, a eelect structural Douglas-ar column ln warehouse service has an allowable stresa of 75 percent of 1,800 or 1,350 pal.
Such a column $10^{\prime \prime} \times 10^{\prime \prime} \times 12$ carries $80.1 \times \frac{1,350}{1,100}=98.3 \mathrm{kips}$.

TABLE 5-5. Average Construction Rates for Building Parts Installed by Carpenters

| Parts | Dimensions <br> (In) | Amount installed per <br> man per $\mathbf{1 0 - h r}$ day |
| :--- | :---: | :---: |
| Girders | $2 \times 6$ | 350 BF |
| Plates, studs, and girts | $2 \times 4$ | 300 BF |
| Floor joists | $2 \times 6$ | 480 BF |
| Rafters | $2 \times 4$ | 240 BF |
| Flooring | $1 \times 6 \mathrm{S4S}$ | 600 BF |
| Sheathing (wall) | 1 vertical | 480 BF |
| Sheathing (roof) | 1 horizontal | 600 BF |
| Rolled roofing | - | 800 sq ft |


[^0]:    - Watch for protruding nails. They are the principal cause of accidents on form work. - Inspect tools frequently.
    - Place mud sills under shoring that rests on the ground.
    - Protect all men on scaffolds and on the ground.
    - Do not raise large form panels in heavy gusts of wind.
    - Brace all shoring securely to prevent collapse of form work.

[^1]:    (Whon waing table III to calculate horisontal shear uee the full tabular value in column b, table i; make no allowance for long-continued (trove.)

