Fundamentals of Concrete and Masonry

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**"Engineering Aide Guide
Ch. 7 – Concrete and Masonry"**

CHAPTER 7

CONCRETE AND MASONRY

This chapter provides information and guidance for the Engineering Aid engaged in or responsible for drawing structural and architectural layouts from existing plans, engineering sketches, or specifications, It includes information on basic materials commonly used in concrete and masonry construction.

Basic principles and procedures associated with the construction of reinforced, precast, and prestressed concrete and tilt-up construction are also discussed in this chapter. Terminology as it applies to masonry units is used to acquaint the Engineering Aid with the various terms used in this type of construction.

CONCRETE

CONCRETE is a synthetic construction material made by mixing CEMENT, FINE AGGREGATE (usually sand), COARSE AGGREGATE (usually gravel or crushed stone), and WATER together in proper proportions; the product is not concrete unless all four of these ingredients are present. A mixture of cement, sand, lime, and water, without coarse aggregate, is NOT concrete, but MORTAR or GROUT.

Mortar is used mainly for bonding masonry units together. The term grout refers to a water-cement mixture (called neat-cement grout) or water-sand-cement mixture (called sand-cement grout) used to plug holes or cracks in concrete, to seal joints, and for similar plugging or sealing purposes.

The fine and coarse aggregates in a concrete mix are called the INERT ingredients; the cement and water are the ACTIVE ingredients. The inert ingredients and the cement are thoroughly mixed together first. As soon as the water is added, a chemical reaction between the water and the cement begins, and it is this reaction (which is called HYDRATION) that causes the concrete to harden.

Always remember that the hardening process is caused by hydration of the cement by the water, not by a DRYING OUT of the mix. Instead of being dried out, the concrete must be kept as moist as possible during the initial hydration process. Drying out would cause a drop in water content below the amount required for satisfactory hydration of the cement.

The fact that the hardening process has nothing whatever to do with a drying out of the concrete is clearly shown by the fact that concrete will harden just as well under water as it will in the air.

Concrete may be cast into bricks, blocks, and other relatively small building units that are used in concrete MASONRY construction.

The proportion of concrete to other materials used in building construction has greatly increased in recent years to the point where large, multistory modern building are constructed entirely of concrete, with concrete footings, foundations, columns, walls, girders, beams, joists, floors, and roofs.

REQUIREMENTS FOR GOOD CONCRETE

The first requirement for good concrete is a supply of good cement of a type suitable for the work at hand. Next is a supply of satisfactory sand, coarse aggregate, and water; all of which must be carefully weighed and measured. Everything else being equal, the mix with the best graded, strongest, best shaped, and cleanest aggregate will make the strongest and most durable concrete.

The best designed, best graded, and highest quality mix in the world will NOT make good concrete if it is not WORKABLE enough to fill the form spaces thoroughly. On the other hand, too much fluidity will result in certain defects. Improper handling during the whole concrete-making process (from the initial aggregate handling to the final placement of the mix) will cause segregation of aggregate particles by sizes, resulting in nonuniform, poor concrete.

Finally, the best designed, best graded, highest quality, and best placed mix in the world will not produce good concrete if it is not properly CURED—meaning, properly protected against loss of moisture during the earlier stages of setting.

As you can see, the important properties of concrete are its strength, durability, and watertightness. These factors are controlled by the WATER-CEMENT RATIO or the proportion of water to cement in the mix.

Strength

The COMPRESSIVE strength of concrete is very high, but its TENSILE strength (meaning its ability to resist stretching, bending, or twisting) is relatively low. Consequently, concrete that must resist a good deal of stretching, bending, or twisting, such as concrete in beams, girders, walls, columns, and the like, must be REINFORCED with steel. Concrete that must resist compression only may not require reinforcement.

Durability

The DURABILITY of concrete means the extent to which the material is capable of resisting the deterioration caused by exposure to service conditions. Ordinary structural concrete that is to be exposed to the elements must be watertight and weather resistant. Concrete that is subject to wear, such as floor slabs and pavements, must be capable of resisting abrasion. It has been found that the major factor controlling durability is strength—in other words, the stronger the concrete is, the more durable it will be. As mentioned previously, the chief factor controlling strength is the water-cement ratio, but the character, size, and grading (distribution of particle sizes between the largest permissible coarse and the smallest permissible fine) of the aggregate also have important effects on both strength and durability. Given a water-cement ratio that will produce maximum strength consistent with workability requirements, maximum strength and durability will still not be attained unless the sand and coarse aggregate consist of well-graded, clean, hard, and durable particles, free from undesirable substances (fig. 7-1).

Watertightness

The ideal concrete mix would be one made with just the amount of water required for complete hydration of the cement. This would be a DRY mix, however, too stiff to pour in the forms. A mix that is fluid enough to be poured into forms always contains a certain amount of water over and above the amount that will combine wit h the cement, and this water will eventually evaporate, leaving voids or pores in the concrete.

Even so, penetration of the concrete by water would still be impossible if these voids were not interconnected. They are interconnected, however, as a result of a slight sinking of solid particles in the mix during the hardening period. As these particles sink, they leave water-filled channels, which become voids when the water evaporates.

The larger and more numerous these voids are, the more the watertightness of the concrete will be impaired. Since the size and number of the voids vary directly with the amount of water used in excess of the amount required to hydrate the cement, it follows that to keep the concrete as watertight as possible, you must not use more water than the minimum amount required to attain the necessary degree of workability.

PLAIN CONCRETE

Plain concrete is defined as concrete with no reinforcement, This type of concrete is most often used where strength is not essential and stresses are minimal, such as sidewalks or driveways and floors where heavy loads are not anticipated.

REINFORCED CONCRETE

Reinforced concrete refers to concrete containing steel (bars, rods, strands, wire, and mesh) as reinforcement and designed to absorb tensile and shearing stresses, Concrete structural members, such as footings, columns and piers, beams, floor slabs, and walls, must be reinforced to attain the necessary strength in tension.

Reinforced Concrete Structural Members

A reinforced concrete structure is made up of many types of reinforced structural members, including footings, columns, beams, slabs, walls, and so forth. Their basic functions are briefly described below.

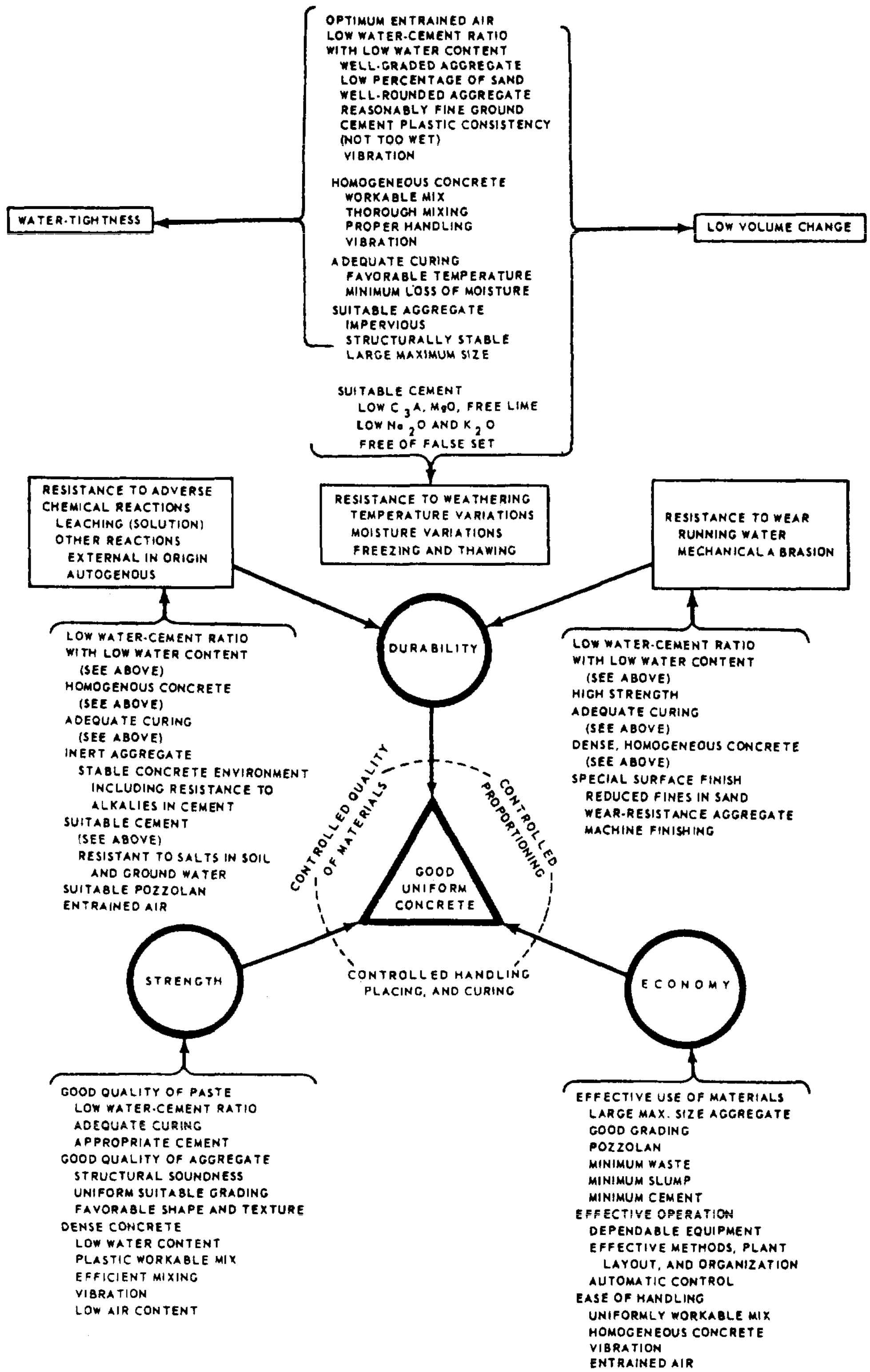

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Figure 7-1.-The principal properties of good concrete.

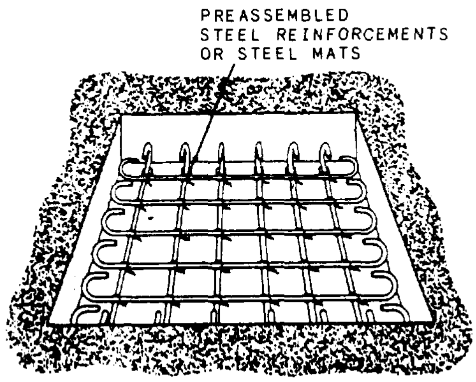


Figure 7-2.-Typical small footing.

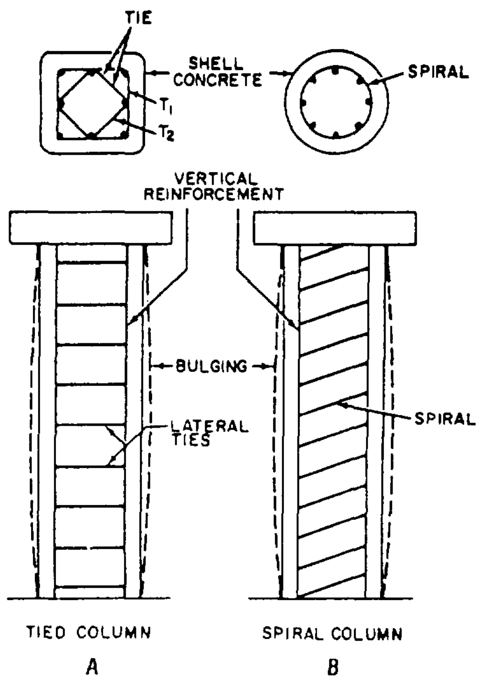


Figure 7-3.-Reinforced concrete columns.

FOOTING AND FOOTING REINFORCEMENT.— Footings support the entire structure and distribute the load to the ground. The size and shape of a footing depend upon the design of the structure. In a small footing (fig. 7-2), "steel mats" or reinforcements are generally preassembled and placed after the forms have been set. In large or continuous footings, such as those found under bearing walls, steel mats are constructed in place.

COLUMN AND COLUMN REINFORCEMENT.— A column is a slender, vertical member that carries a superimposed load. Concrete columns, especially those subjected to bending stresses, must always be reinforced with steel. A PIER or PEDESTAL is a compressive member that is short (usually the height is less than three times the least lateral dimension) in relation to its cross-sectional area and carries no bending stress.

In concrete columns, vertical reinforcement is the principal reinforcement. However, a loaded column shortens vertically and expands laterally; hence, lateral reinforcements in the form of lateral ties are used to restrain the expansion. Columns reinforced in this manner are called tied columns (fig. 7-3, view A). If the restraining reinforcement is a continuous winding spiral that encircles the core and longitudinal steel, the column is called a spiral column (fig, 7-3, view B).

BEAM AND BEAM REINFORCEMENT.— Beams are the principal load-carrying horizontal members. They take the load directly from the floor and carry it to the columns. Concrete beams can either be cast in place or precast and transported to the jobsite. Figure 7-4 shows several common types of beam reinforcing steel shapes. Both straight and bent-up principal

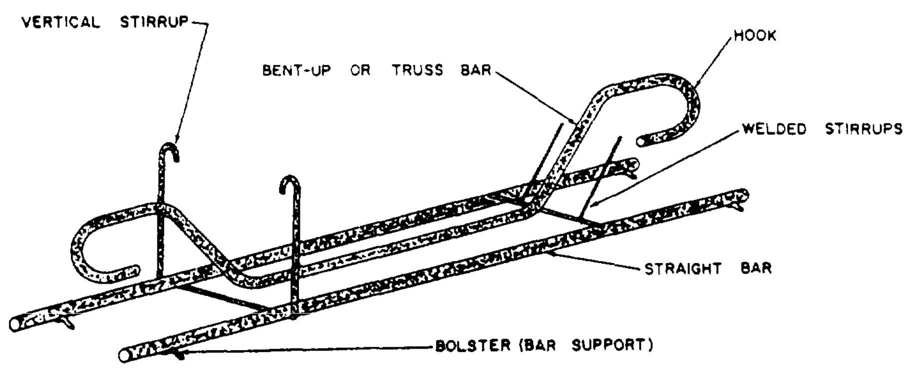


Figure 7-4.-Typical shapes of reinforcing steel.

reinforcing bars are needed to resist the bending tension in the bottom over the central portion of the span. Fewer bars are necessary on the bottom near the ends of the span where the bending moment is small. For this reason, some bars may be bent so that the inclined portion can be used to resist diagonal tension. The reinforcing bars of continuous beams are continued across the supports to resist tension in the top in that area.

SLAB AND SLAB REINFORCEMENT.— Concrete slabs come in a variety of forms depending on their locations. Ground slabs take the load directly to the ground. Plain slabs (similar in shape to ground slabs) take the load directly from the floor and transmit it to the beams. In other cases, joists, poured as part of plain slabs, carry the loads to the beams. Joists are used to strengthen the middle portion of the slab.

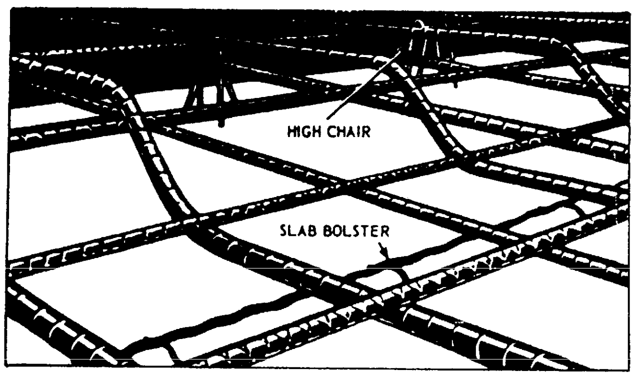


Figure 7-5.—Reinforcing steel for a floor slab.

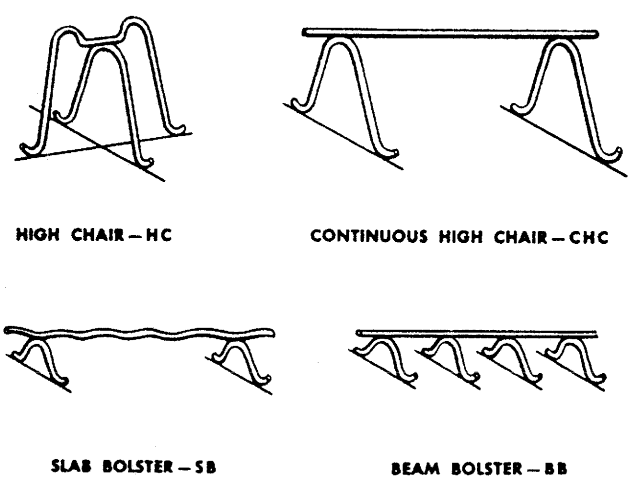


Figure 7-6.—Devices used to support horizontal reinforcing bars.

Concrete slab reinforcements (fig. 7-5) are supported by reinforcing steel in configurations called slab bolster and high chair. Concrete blocks made of sand-cement mortar can be used in place of the slab bolster. The height of the slab bolster is determined by the concrete protective cover required. If the concrete surface is to be in contact with the ground or exposed to the weather after removal of the forms, the protective covering of concrete over the steel should be 2 in. Other devices used to support horizontal reinforcing bars are shown in figures 7-6, 7-7, and 7-8. Wood blocks should be

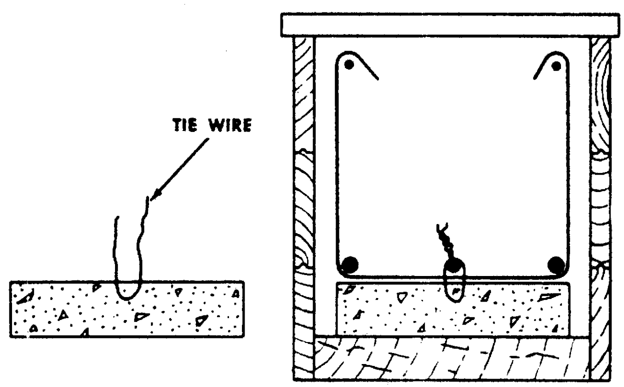


Figure 7-7.—Precast concrete block used for reinforcing steel support.

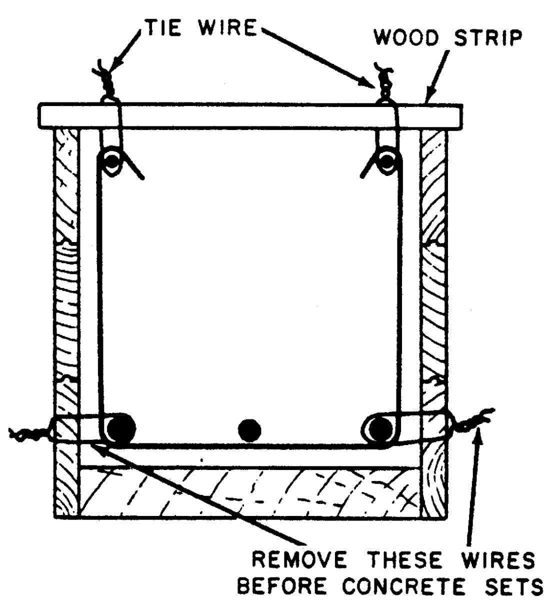


Figure 7-8.—Beam-reinforcing steel hung in place.

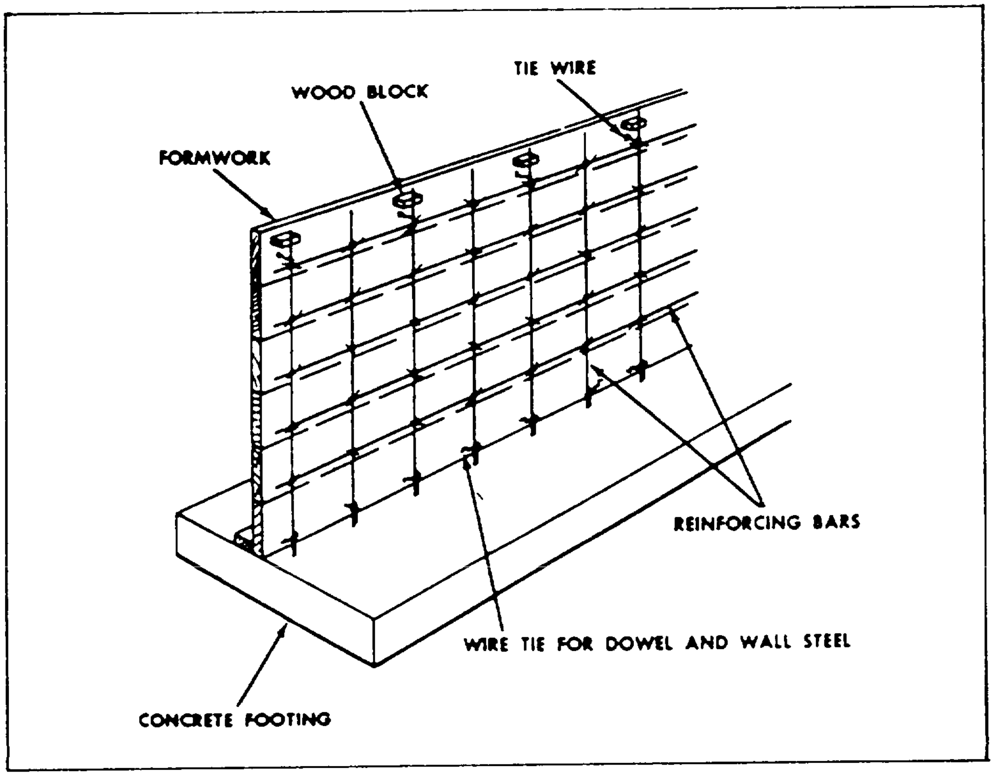


Figure 7-9.-Steel in place in a wall.

substituted for the metal supports only if there is no possibility of the concrete becoming wet or if the construction is known to be temporary.

WALL REINFORCEMENT.— Placement of steel reinforcement in load-bearing walls is the same as for columns except that the steel is erected in place and not preassembled. Horizontal steel is tied to vertical steel at least three times in any bar length. The wood block is removed when the form has been filled up to the level of the block, as shown in figure 7-9.

Reinforcing Steel

Steel is the best material for reinforcing concrete because the coefficients of expansion of the steel and the concrete are considered almost the same; that is, at a normal temperature, they will expand and contract at an almost equal rate. (At very high temperatures, steel will expand more rapidly than the concrete, and the two materials will separate.)

Steel also works well as a reinforcement for concrete because it makes a good bond with the concrete. This bond strength is proportional to the contact area surface of the steel to the concrete. In other words, the greater the surface of steel exposed to the adherence of the concrete, the stronger the bond. A deformed reinforcing bar

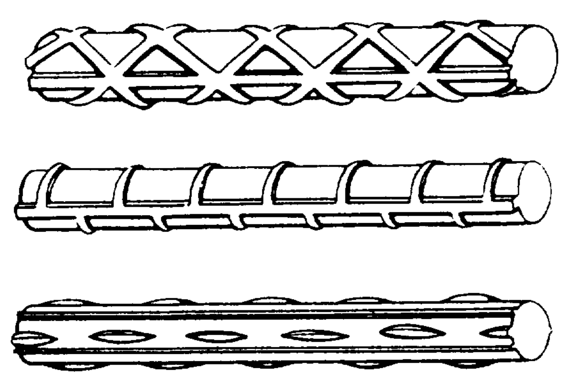


Figure 7- 10.-Types of deformed reinforcing bars.

is better than a plain round or square one. In fact, when plain bars of a given diameter are used instead of deformed bars, approximately 40 percent more plain bars must be used.

The adherence of the concrete depends on the roughness of the steel surface: the rougher the steel, the better the adherence. Thus, steel with alight, firm layer of rust is superior to clean steel, but steel with loose or scaly rust is inferior. Loose or scaly rust may be removed from the steel by rubbing the steel with burlap.

The requirements for reinforcing steel are that it be strong in tension and, at the same time, ductile enough to be shaped or bent cold.

Reinforcing steel may be used in the form of bars or rods that are either PLAIN or DEFORMED or in the form of expanded metal, wire, wire fabric, or sheet metal. Each type is useful for a different purpose, and engineers design structures with these purposes in mind.

Plain reinforcing bars are usually round in cross section. They are used as main tension reinforcement for concrete structures. They are the least used of the rod type of reinforcement because they offer only smooth, even surfaces for the adherence of concrete. Reinforcing bars or rods are commonly referred to as rebars.

Deformed bars are like the plain bars except that they have either indentations in them or ridges on them, or both, in a regular pattern. The twisted bar, for example, is made by twisting a plain square bar cold. The spiral ridges along the surface of the deformed bar increase its bond strength with concrete. Other forms used are the round- and square-corrugate d bars. These bars are formed with projections around the surface that extend into the surrounding concrete and prevent slippage. Another type is formed with longitudinal fins projecting from the surface to prevent twisting. Figure 7-10 shows a few of the various types of deformed bars available. In the United States, deformed bars are used almost exclusively, while in Europe, both deformed and plain bars are used.

There are 11 standard sizes of reinforcing bars. Table 7-1 lists the bar numbers, weight, and nominal diameters of the 11 standard sizes. Bars No. 3 through No. 18, inclusive, are deformed bars. Remember that bar numbers are based on the nearest number of 1/8 in. (3. 175 mm) included in the nominal diameter of the bar. To measure rebar, you must measure across the roundsquare portion where there is no deformation.

Table 7-1.-Standard Reinforcing Bars

BAR NUMBERS	WEIGHT	NOMINAL DIAMETER	
	POUNDS PER FOOT	INCHES	MILLI-METERS
#3	0.376	0.375	9.5
#4	0.668	0.500	12.7
#5	1.043	0.625	15.8
#6	1.502	0.750	19.0
#7	2.044	0.875	22.2
#8	2.670	1.000	25.4
#9	3.400	1.128	28.5
#10	4.303	1.270	31.7
#11	5.313	1.410	35.9
#14	7.650	1.693	43.0
#18	13.600	2.257	57.3

05NP0001

The raised portion of the deformation is not considered in measuring the rebar diameter.

BENDS.— Frequently, it is required that reinforcing bars be bent into various shapes. There are several reasons for this. First, let us go back to the reason for using reinforcing steel in concrete—to increase the tensile and compressive strength of concrete. You might compare the hidden action within abeam from live and dead loads to breaking a stick over your knee. You have seen how the splinters next to your knee push toward the middle of the stick when you apply force, while the splinters from the middle to the opposite side pull away from the middle. This is similar to what happens inside the beam.

For instance, take a simple beam (a beam resting freely on two supports near its ends). The dead load (weight of the beam) causes the beam to bend or sag. Now, from the center of the beam to the bottom, the forces tend to stretch or lengthen the bottom portion of the beam. This part is said to be in tension, and that is where the steel reinforcing bars are needed. As a result of the combination of the concrete and steel, the tensile strength in the beam resists the force of the load and keeps the beam from breaking apart. At the exact center of the beam, between the compressive stress and the tensile stress, there is no stress at all—it is neutral.

In the case of a continuous beam, it is a little different. The top of the beam may be in compression along part of its length and in tension along another part. This is because a continuous beam rests on more than two supports. Thus, the bending of the beam is NOT all in one direction but is reversed as it goes over intermediate supports.

To help the concrete resist these stresses, engineers design the bends of reinforcing steel so that the steel will set into the concrete just where the tensile stresses take place. That is why some reinforcing rods are bent in almost a zigzag pattern. The joining of each bar with the next, the anchoring of the bar ends with concrete, and the anchoring by overlapping two bar ends together are some of the important ways to increase and keep bond strength. Some of the bends you will encounter are shown in figure 7-11.

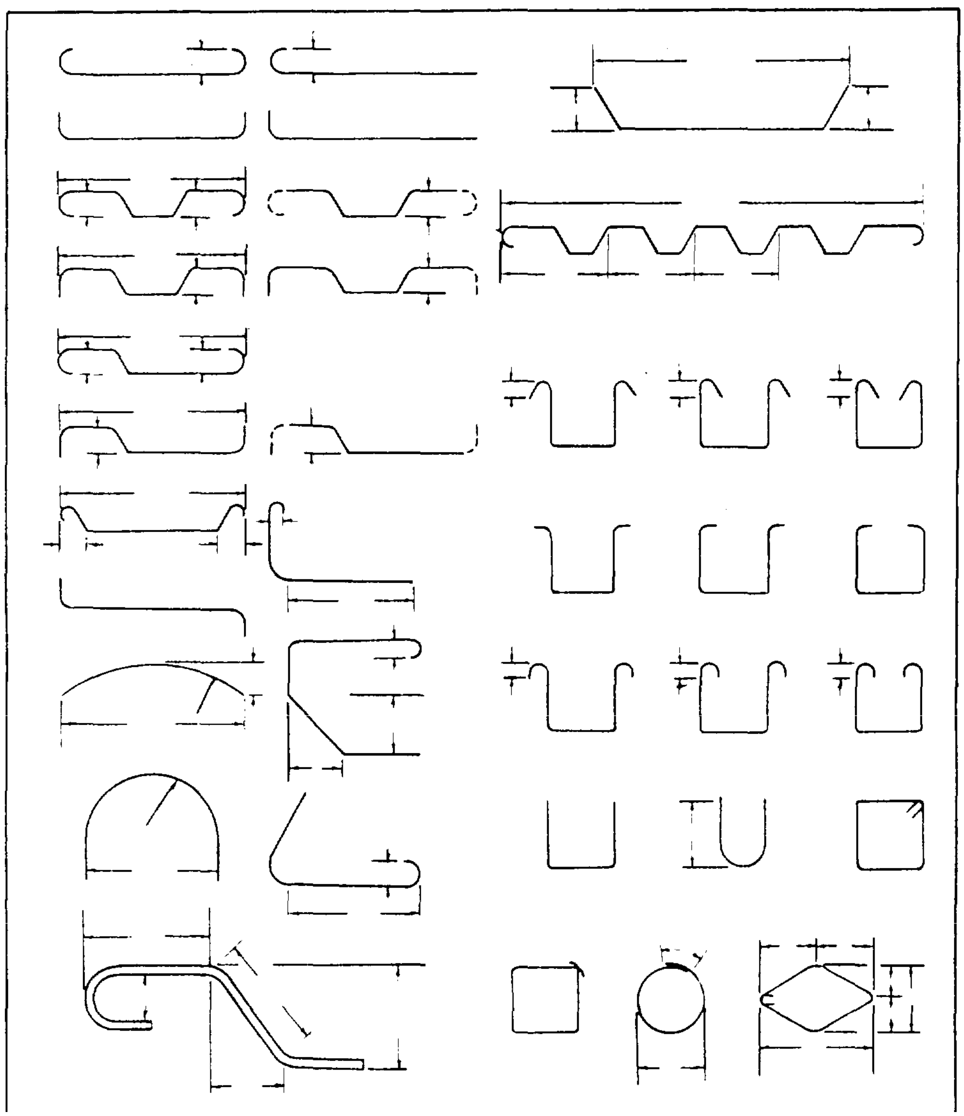
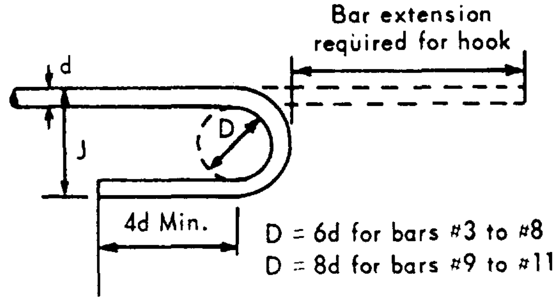


Figure 7-11.-Typical reinforcement bar bends.

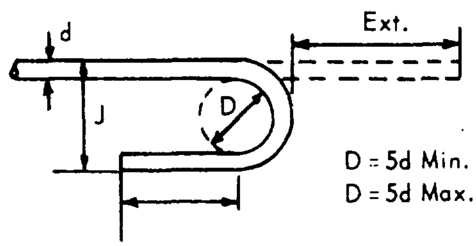
When reinforcing bars are bent, caution must be exercised to ensure the bends are not too sharp. If too sharp a bend is put into the bars, they may crack or be weakened. Therefore, certain minimum bend diameters have been established for the different bar sizes and for the various types of hooks. These bending details are shown in figure 7-12. There are many different types of bends, depending on where the rods are to be placed. For example, there are bends on heavy

Recommended sizes - 180° hook



Bar size d	Bar exten.	J
#2	4	2
3	5	3
4	6	4
5	7	5
6	8	6
7	10	7
8	11	8
9	1-3	11¼
10	1-5	1-0¾
11	1-7	1-2¼

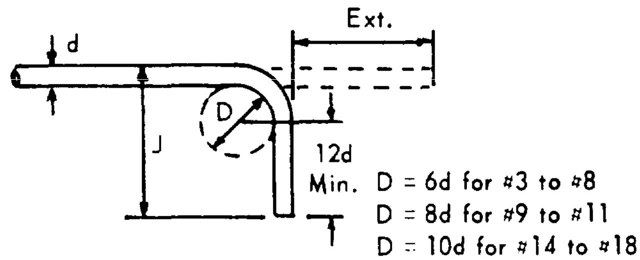
Minimum sizes - 180° hook



Note: Minimum size hooks to be used only for special conditions.

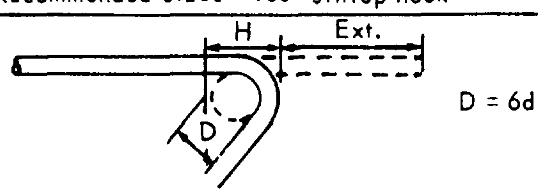
Bar size d	Bar exten.	J
#2	4	1¾
3	5	2¾
4	5	3½
5	6	4¼
6	7	5¼
7	9	6
8	10	7
9	11	8
10	13	9
11	14	10

Recommended minimum sizes - 90° hook



Bar size d	Bar exten.
# 2	3½
3	6
4	8
5	10
6	1-0
7	1-2
8	1-4
9	1-7
10	1-10
11	2-0

Recommended sizes - 135° stirrup hook



Bar size d	Bar exten.
# 2	3½
3	4
4	4½
5	5½

Note: Stirrup hooks may be bent to the diameter of the supporting bars.

Figure 7-12.-Standard hook details.

beam and girder bars, bends for reinforcement of vertical columns at or near floor levels, stirrup and column ties, slab reinforcement, and bars or wire for column spiral reinforcement.

SPLICES.— Where splices in reinforcing steel are not dimensioned on the drawings, the bars should be lapped not less than 30 times the bar diameter, nor less than 12 in. The stress in a tension bar can be transmitted through the concrete and into another adjoining bar by a lap splice of proper length. The "lap" is expressed as the number of bar diameters. If using the No. 2 bar, make the lap at least 12 in.

EXPANDED METAL AND WELDED WIRE FABRIC.— Expanded metal or wire mesh is also used for reinforcing concrete. Expanded metal is made by partly shearing a sheet of steel, as shown in figure 7-13, view A. The sheet steel has been sheared in parallel lines and then pulled out or expanded to form a diamond shape between each parallel cut. Another type is square rather than diamond shaped, as shown in figure 7-13, view B. Expanded metal is frequently used during plastering operations.

Welded wire fabric is available both in rolls (fig. 7-14) for light building construction and sheets for highways and use in buildings when roll sizes will not give ample reinforcement. Wire fabric is furnished in both square and rectangular patterns, welded at each intersection. The rectangular sizes range from 2 by 4 in. to 6 by 12 in. The square patterns are available in 2 by 2 in., 3 by 3 in., 4 by 4 in., and 6 by 6 in. Both are furnished in a wide variety of wire gauges. The square pattern has the same gauge in both directions, while the rectangular type may have the same gauge in both directions or the larger gauge running longitudinally. Specifications and designs are usually used when wire fabric (mesh) is being lapped; however, a minimum of 2 in. between laps is usually sufficient.

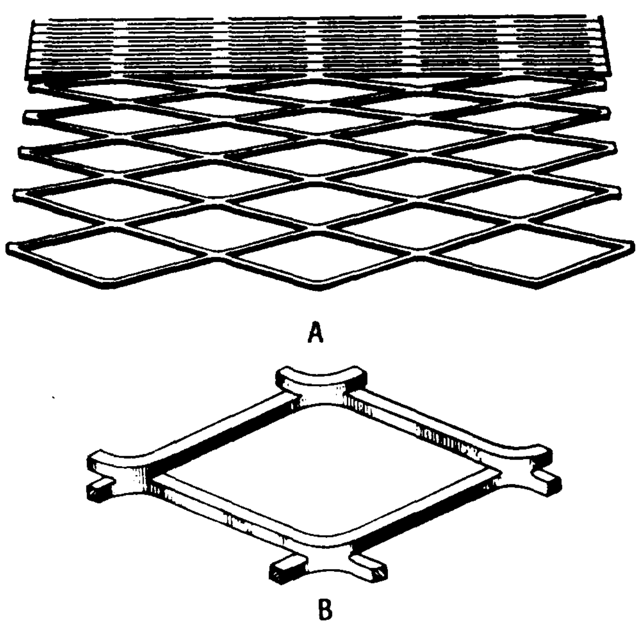


Figure 7-13.-Expanded or diamond mesh steel reinforcement.

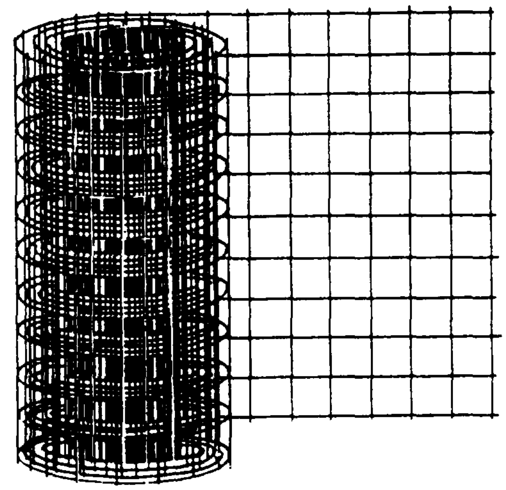


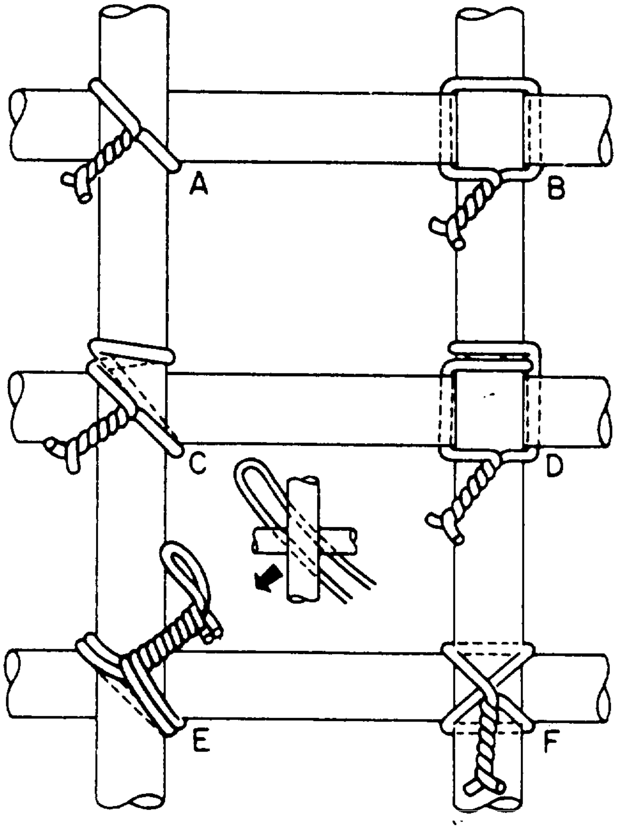
Figure 7-14.-Welded wire fabric.

Reinforcing bars can be joined together by different types of ties. Figure 7-15 shows six types used by the SEABEEs.

PRECAST CONCRETE

Precasting is the fabrication of a structural member at a place other than its final position of use. It can be done anywhere, although this procedure is best adapted to a factory or yard. Jobsite precasting is not uncommon for large projects. Precast concrete can be produced in several different shapes and sizes, including piles, girders, and roof members. Prestressed concrete is especially well adapted to precasting techniques.

Generally, structural members including standard highway girders, poles, electric poles, masts, and building members are precast by factory methods unless the difficulty or



A. Snap or simple tie.
B. Saddle tie.
C. Wall tie.
D. Saddle tie with twist.
E. Double-strand single-tie.
F. Cross tie.

Figure 7-15.-Types of ties.

impracticability of transportation makes jobsite casting more desirable. On the other hand, concrete that is cast in the position that it is to occupy in the finished structure is called cast-in-place concrete.

Precast Concrete Floors, Roof Slabs, Walls, and Partitions

The most commonly used precast slabs or panels for FLOOR and ROOF DECKS are the channel and double-T types (fig. 7-16, views A and B).

The channel slabs vary in size with a depth ranging from 9 to 12 in., width 2 to 5 ft, and a thickness of 1 to 2 in. They have been used in spans up to 50 ft. If desired or needed, the legs of the channels may be extended across the ends

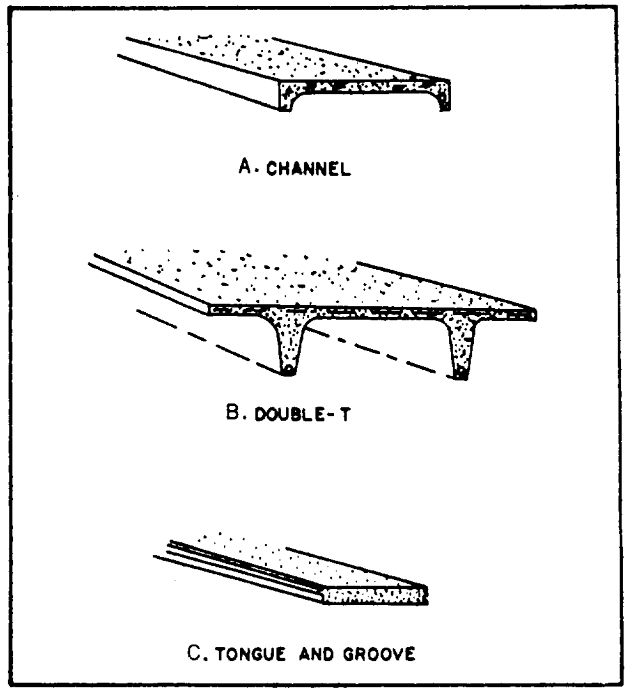


Figure 7-16.-Typical precast panels.

and, if used in combination with the top slabs. may be stiffened with occasional cross ribs. Wire mesh may be used in the top slabs for reinforcement. The longitudinal grooves located along the top of the channel legs may be grouted to form keys between adjacent slabs.

The double-T slabs vary in size from 4 to 6 ft in width and 9 to 16 ft in depth. They have been used in spans as long as 50 ft. When the top-slab size ranges from 1 1/2 to 2 in. in thickness, it should be reinforced with wire mesh.

The tongue-and-groove panel (fig. 7-16, view C) could vary extensively in size, according to the design requirement. They are placed in position much like tongue-and-groove lumber; that is, the tongue of one panel is placed inside the groove of an adjacent panel. They are often used as decking panels in large pier construction.

Matching plates are ordinarily welded and used to connect the supporting members to the floor and roof slabs.

Panels precast in a horizontal position, in a casting yard, or on the floor of the building, are ordinarily used in the makeup of bearing and nonbearing WALLS and PARTITIONS. These panels are placed in their vertical positions by cranes or by the tilt-up procedure, as shown in figures 7-17 and 7-18.

Usually, these panels are solid, reinforced slabs, 5 to 8 in. in thickness, with the length varying according to the distances between columns or other supporting members. When windows and door openings are cast in the slabs, extra reinforcements should be installed around the openings.

A concrete floor slab with a smooth, regular surface can be used as a "casting surface." When this smooth surface is used for casting, it should be covered with some form of liquid or sheet material to prevent bonding between the surface and the wall panel. The upper surface of the panel may be finished as regular concrete is finished by troweling, floating, or brooming.

SANDWICH PANELS are panels that consist of two thin, dense, reinforced concrete-face slabs separated by a core of insulating material, such as lightweight concrete, cellular glass, plastic foam, or some rigid insulating material.

These panels are sometimes used for exterior walls to provide additional heat insulation. The thickness of the sandwich panels varies from 5 to 8 in., and the face slabs are tied together with wire, small rods, or in some other manner. Welded or bolted matching plates are also used to connect the wall panels to the building frame, top and bottom. Caulking on the outside and grouting on the inside should be used to make the points between the wall panels watertight.

Precast Concrete Joists, Beams, Girders, and Columns

Small, closely spaced beams used in floor construction are usually called JOISTS; however, these same beams when used in roof construction

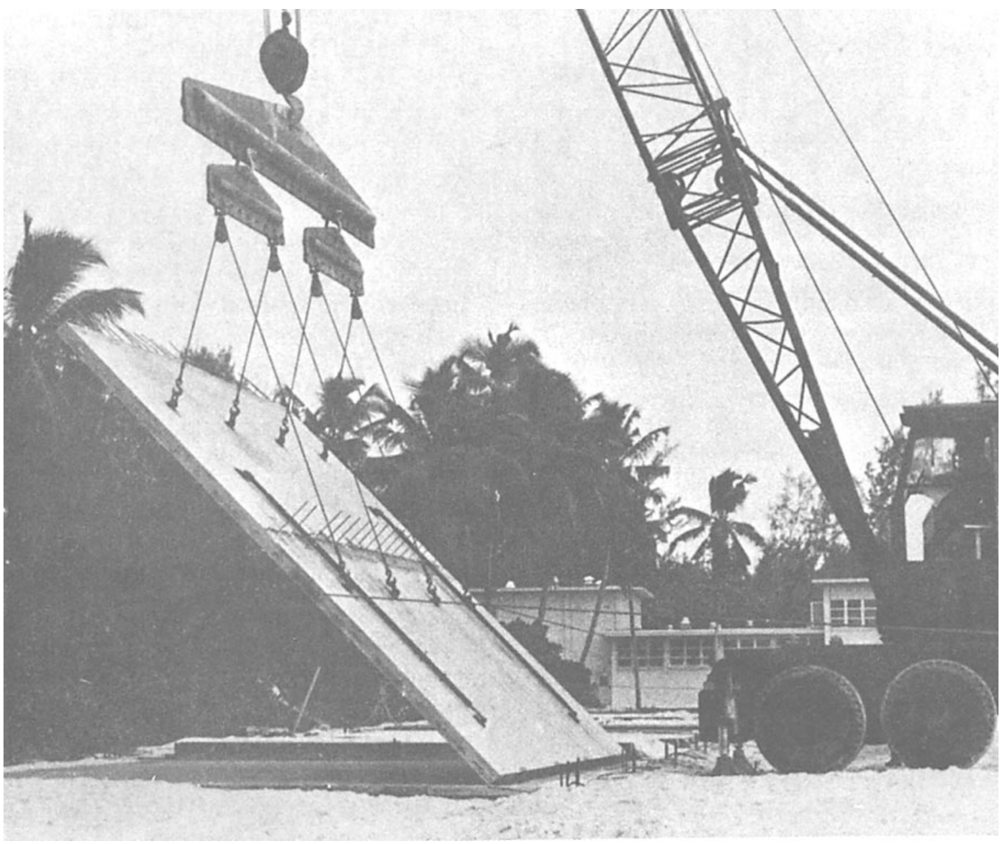


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Figure 7-17.-Precast panels being erected by use of crane and spreader bars.

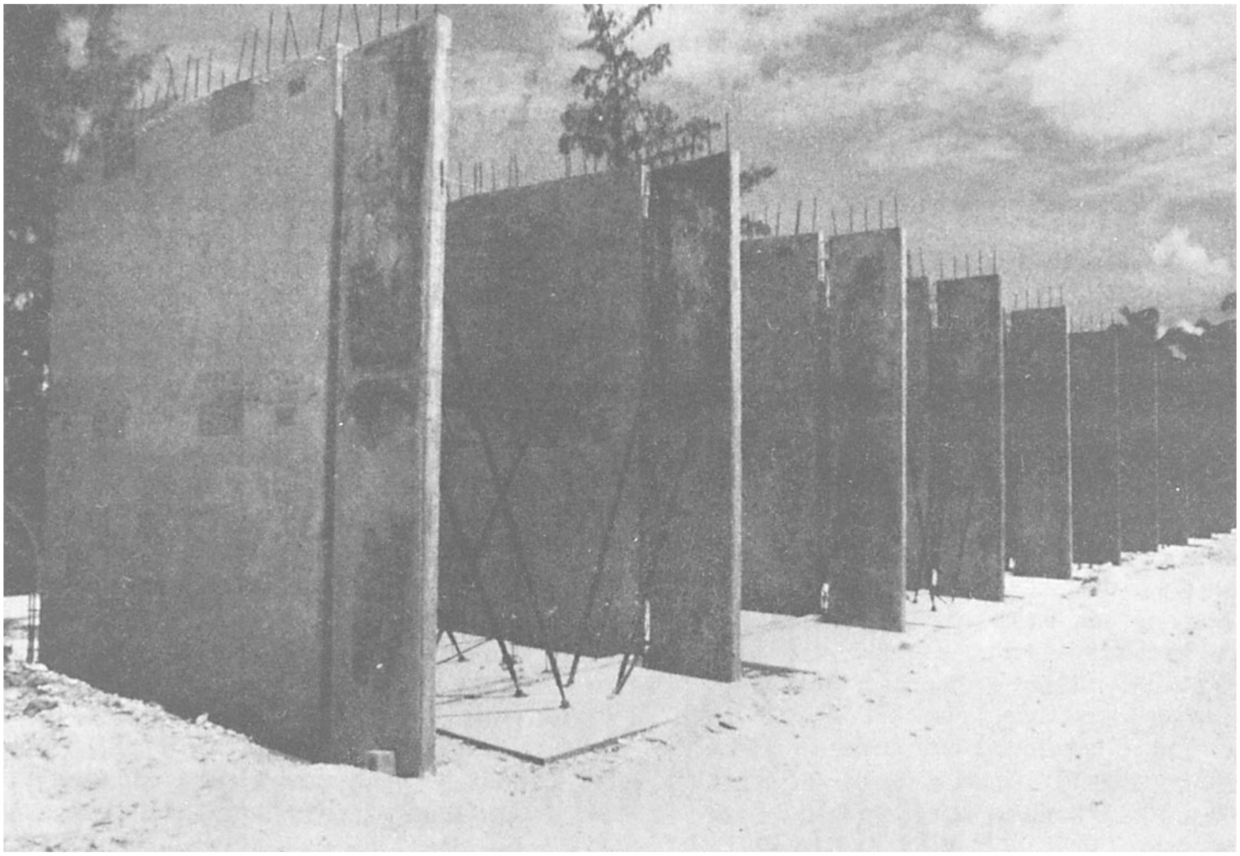

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Figure 7-18.-Precast panels in position.

are called PURLINS. The cross sections of these beams are shaped like a T or an I. The ones with the inverted T-sections are usually used in composite construction where they support cast-in- place floor or roof slabs.

BEAMS and GIRDERS are terms usually applied to the same members, but the one with the longer span should be referred to as the girder. Beams and girders may be conventional precast design or prestressed. Most of the beams will be I-shaped unless the ends are rectangular. The T-shaped ones can also be used.

Precast concrete COLUMNS may be solid or hollow. If the hollow type is desired, heavy card-board tubing should be used to form the core. A looped rod is cast in the column footing and projects upward into the hollow core to help hold the column upright. An opening should be left in the side of the column so that the column core can be filled with grout. This causes the looped rod to become embedded to form an anchor. The opening is dry packed.

Advantages of Precast Concrete

Precast concrete has the greatest advantage when identical members are to be cast because the same forms can be used several times. Some other advantages are listed below.

Control of the quality of concrete.

Smoother surfaces, and plastering is not necessary.

Less storage space is needed.

Concrete member can be cast under all weather conditions.

Better protection for curing.

Weather conditions do not affect erection.

Faster erection time.

PRESTRESSED CONCRETE

A prestressed concrete unit is one in which engineered stresses have been placed before it has been subjected to a load. When PRETENSIONING is used, the reinforcement (high-tensile-strength steel strands) is stretched through the form between the two end abutments or anchors. A predetermined amount of stress is applied to the steel strands. The concrete is then poured, encasing the reinforcement. As the concrete sets, it bonds to the pretensioned steel. When it has reached a specified strength, the tension on the reinforcement is released. This prestresses the concrete, putting it under compression, thus creating a built-in tensile strength.

POST-TENSIONING involves a precast member that contains normal reinforcing in addition to a number of channels through which the prestressing cables or rods maybe passed. The channels are usually formed by suspending inflated tubes through the form and casting the concrete around them. When the concrete has set, the tubes are deflated and removed. Once the concrete has reached a specified strength, prestressing steel strands or TENDONS are pulled into the channels and secured at one end. They are then stressed from the opposite end with a portable hydraulic jack and anchored by one of several automatic gripping devices.

Post-tensioning may be done where the member is poured or at the jobsite. Each member may be tensioned, or two or more members may be tensioned together after erection. In general, post-tensioning is used if the unit is over 45 ft long or over 7 tons in weight. However, some types of pretensioned roof slabs will be considerably longer and heavier than this.

When a beam is prestressed, either by pretensioning or post-tensioning, the tensioned steel produces a high compression in the lower part of the beam. This compression creates an upward bow or camber in the beam (fig. 7-19). When a load is placed on the beam, the camber is forced out, creating a level beam with no deflection.

Those members that are relatively small or that can be readily precast are normally pretensioned. These include precast roof slabs, T-slabs, floor slabs, and roof joists.

SPECIAL TYPES OF CONCRETE

Special types of concrete are essentially those with unique physical properties or those produced with unusual techniques and/or reproduction processes. Many special types of concrete are made with portland cement as a binding medium; some use binders other than portland cement.

Lightweight Concrete

Conventional concrete weighs approximately 150 lb per cubic foot. Lightweight concrete weighs 20 to 130 lb per cubic foot, depending on its intended use. Lightweight concrete can be made by using either gas-generating chemicals or

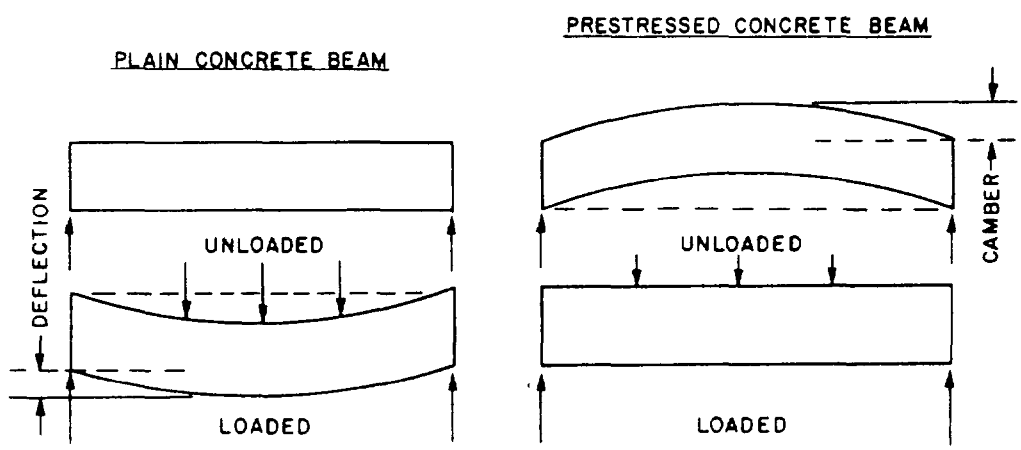

Figure 7-19.-Comparison of plain and prestressed concrete beams.

lightweight aggregates, such as expanded shale, clay, or slag. Concrete containing aggregates like perlite or vermiculite is very light in weight and is primarily used as insulating material. Lightweight concrete is usually classified according to its weight per cubic foot.

Semi-lightweight concrete has a unit weight of 115 to 130 lb per cubic foot and an ultimate compressive strength comparable to normal concrete. Sand of normal weight is substituted partially or completely for the lightweight fine aggregate.

Insulating lightweight concrete has a unit weight ranging from 20 to 70 lb per cubic foot, and its compressive strength seldom exceeds 1,000 psi. This type of concrete is generally used for insulating applications, such as fireproofing.

Structural lightweight concrete has a unit weight up to 115 lb per cubic foot and a 28-day compressive strength in excess of 2,000 psi. This type is used primarily to reduce the dead-load weight in concrete structural members, such as floors, walls, and the roof section in high-rise structures.

Heavyweight Concrete

Heavyweight concrete is produced with special heavy aggregates and has a density of up to 400 lb per cubic foot. This type is used principally for radiation shielding, for counterweights, and for other applications where higher density is desired. Except for density, the physical properties of heavyweight concrete are similar to those of normal- or conventional-weight concrete.

TILT-UP CONSTRUCTION

Tilt-up concrete construction is a special form of precast concrete building. This method consists basically of jobsite prefabrication, in which the walls are cast in a horizontal position, tilted to a vertical position, and then secured in place. Tilt-up construction is best suited for large one-story buildings, but it can be used in multistory structures. Usually, multistory structures are built by setting the walls for the first story, placing the floor above, then repeating the procedure for each succeeding floor. An alternate method is to cast two- to four-story panels.

The wall panels are usually cast on the floor slab of the structure. Care must be exercised to ensure the floor slab is smooth and level and that all openings for pipes and other utilities are temporarily plugged. The casting surface is treated with a good bond-breaking agent to ensure the panel does not adhere when it is lifted.

Reinforcement of Tilt-Up Panels

The steel in a tilt-up panel is set in the same manner as it is in a floor slab. Mats of reinforcement are placed on chairs and tied as needed. Reinforcement should be as near the center of the panel as possible. Reinforcing bars are run through the side forms of the panel. When welded wire fabric or expanded wire mesh is used, dowel bars are used to tie the panels and their vertical supports together. Additional reinforcement is generally needed around openings.

The panel is picked up or tilted by the use of PICKUP INSERTS. These inserts are tied into the reinforcement. As the panel is raised into its vertical position, the maximum stress will occur; therefore, the location and number of pickup inserts is extremely important. Some engineering manuals provide information on inserts, their locations, and capacities.

Tilt-Up Panel Foundations

An economical and widely used method to support tilt-up panels is a simple pad footing. The floor slab, which is constructed first, is NOT poured to the perimeter of the building to permit excavating and pouring the footings. After the panel is placed on the footing, the floor slab is completed. It may be connected directly to the outside wall panel, or a trench may be left to run mechanical, electrical, or plumbing lines.

Another method that is commonly used, as an alternative, is to set the panels on a grade beam or foundation wall at floor level. Regardless of the type of footing, the panel should be set into a mortar bed to ensure a good bond between the foundation wall and the panel.

Panel Connections

The panels may be tied together in a variety of ways. The location and use of the structure will dictate what method can or can NOT be used. The strongest method is a cast-in-place column with the panel-reinforcing steel tied into the column. However, this does NOT allow for expansion and contraction. It may be preferable to tie only the corner panels to the columns and allow the remaining panels to move.

A variety of other methods of connecting the panels are also used. A BUTTED connection, using grout or a gasket, can be used if the wall does NOT contribute any structural strength to the structure. Steel columns are welded to steel angles or plates secured in the wall panel. Precast columns can also be used. Steel angles or plates are secured in both the columns and plate and welded together to secure the panel.

When panel connections that do not actually hold the panels in place are used, the panels are generally welded to the foundation and to the roof by using steel angles or plates. All connections must provide waterproof joints. This is accomplished by the use of expansion joint material.

Finishes

Tilt-up panels may be finished in a variety of ways similar to any other concrete floor or wall. Some finishes may require the panel to be poured face up; others will require face-down pouring. This may affect the manner in which the panels are raised and set.

CONCRETE CONSTRUCTION JOINTS AND CONNECTIONS

Construction joints are divisions between concrete work done at intervals spaced widely enough to allow partial hardening. They are used between the units of structure and placed where they will cause the minimum amount of weakness to the structure. It is safe to assume that construction joints are located where the shearing stresses and bending moments are relatively small or where the joints will be supported by other structural members. For horizontal work, such as floor slabs, construction joints should be in a vertical plane; whereas, for vertical work, such as columns, the joints should lie in a horizontal plane (fig. 7-20).

Foundation walls are bonded to footings with vertical reinforcing steel called "dowels, " which are placed in footings and extend about 3 to 4 ft up into the wall. A wedge-shaped through, called a keyway, is built into the footing to strengthen the bond between footings and walls (fig. 7-21).

Contraction Joints

The purpose of contraction joints is to control cracking caused by temperature changes

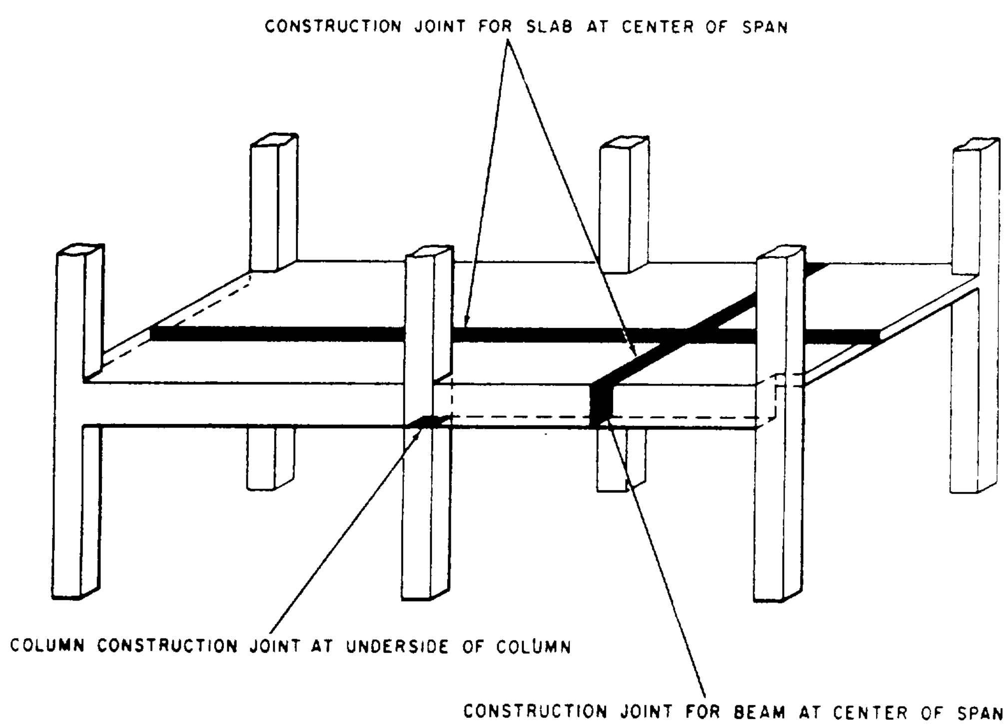

Figure 7-20-Location of construction joints in beams, columns, and floor slabs.

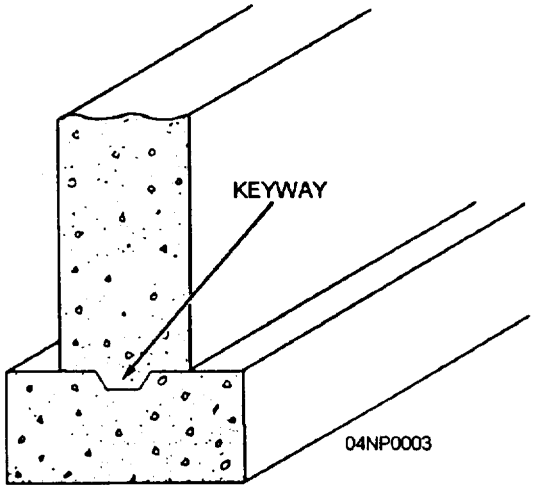

Figure 7-22.-Use of a contraction Joint.

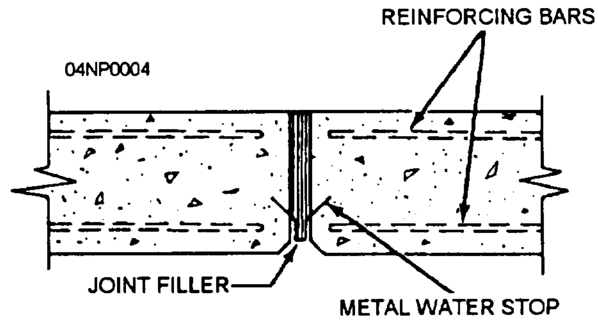

Figure 7-23.-Expansion joint for a wall.

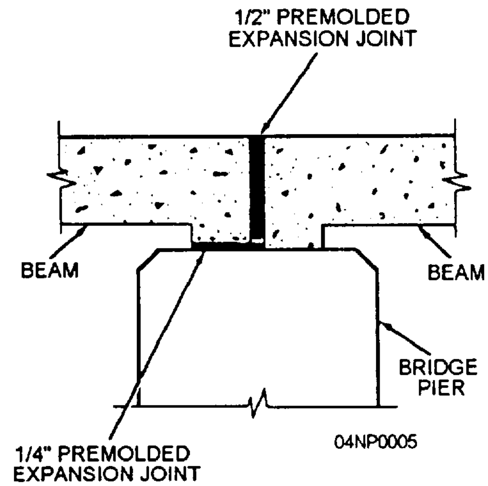

Figure 7-24.-Expansion joint for a bridge.

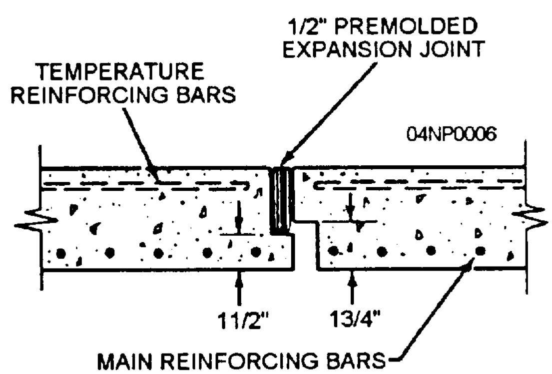

Figure 7-25.-Expansion joint for a floor slab.

incident to shrinkage of the concrete. A typical dummy contraction joint (fig. 7-22) is usually formed by cutting a depth of one third to one fourth the thickness of the section. Some contracting joints are made with no filler or with a thin coat of paraffii or asphalt and/or other materials to break the bond. Depending on the extent of local temperature, joints in reinforced concrete slabs may be placed at 15-to 25-ft intervals in each direction.

Expansion Joints

Wherever expansion might cause a concrete slab to buckle because of temperature change, expansion joints (also called isolation joints) are required. An expansion joint is used with a pre-molded cork or mastic filler to separate sections from each other, thus allowing room for expansion if elongation or closing of the joint is anticipated. Figures 7-23, 7-24, and 7-25 show expansion joints for a variety of locations. Expansion joints may be installed every 20 ft.

CONCRETE FORMS

Most structural concrete is made by placing (also called CASTING) plastic concrete into

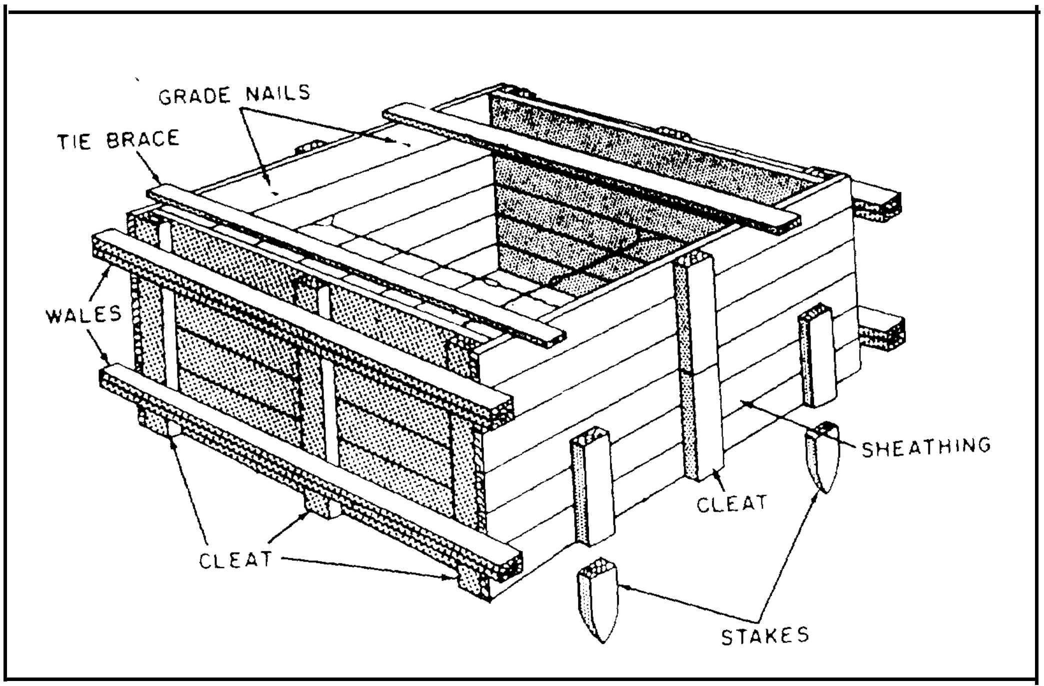

Figure 7-26. Typical large footing form.

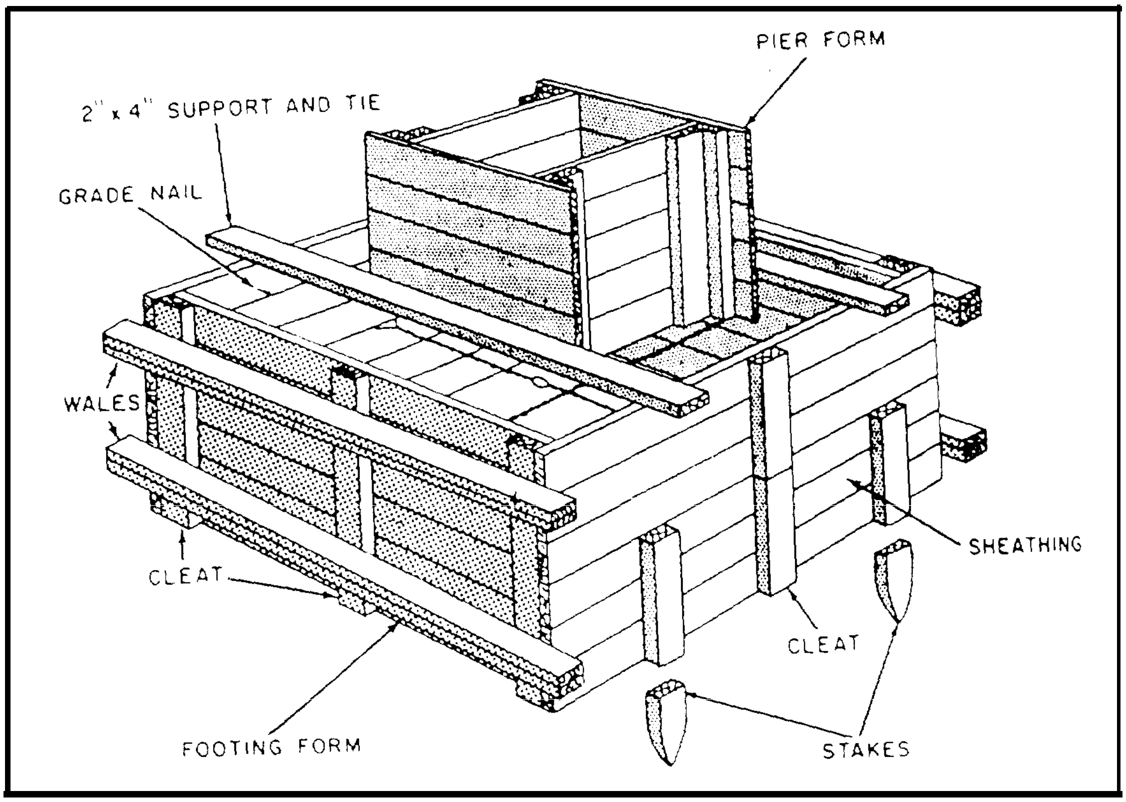

Figure 7-27.-Typical footing and pier form.

spaces enclosed by previously constructed FORMS. These forms are usually removed once the plastic concrete hardens into the shape outlined by the forms.

Forms for concrete structures must be tight, rigid, and strong. If the forms are NOT tight, loss of water and paste may cause sand streaking as well as weakness to the concrete. The forms must be strong enough to resist the high pressure exerted by the concrete.

Form Materials

Undisturbed soil or clay, if sufficiently rigid and excavated to proper dimensions, maybe used as EARTH FORMS. Design, specifications, and construction methods, however, dictate what kind of form materials are to be used on certain structures. Wood, plywood, steel, fiber glass, and other approved materials are commonly used as form materials. Forms for concrete pavement and curves should be metal; surfaces exposed to view in the finished structure and those requiring special finishes should be wood, plywood, or other approved material.

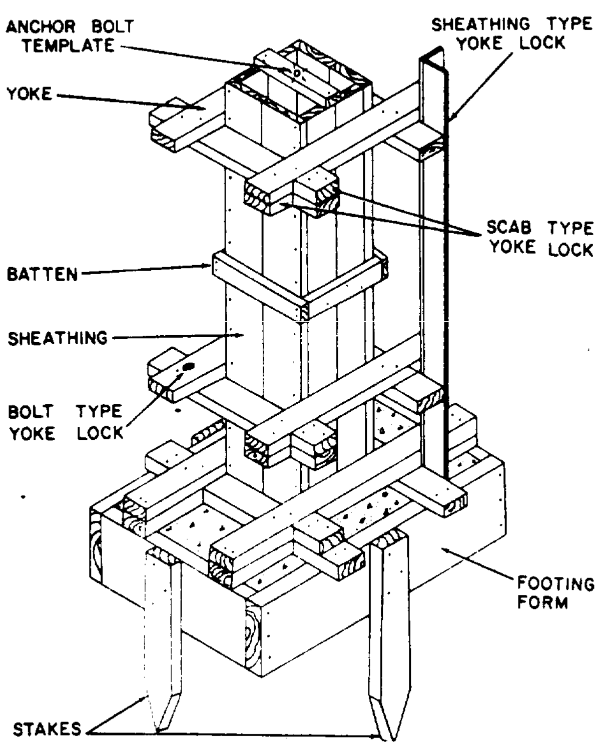

Figure 7-28.-Form for concrete column.

Foundation Forms

Foundation forms may include forms or parts of forms for column footings, pier footings, and wall footings. Whenever possible, the earth should be excavated and the hole used to contain the foundation of footing forms. In most cases, FOOTINGS are cast directly against the earth, and only the sides are molded in forms. In some cases where there is a firm natural earth surface that is capable of supporting and molding the concrete, parts of forms are often omitted. Figure 7-26 shows a typical large footing form. Figures 7-27 and 7-28 show typical footing forms for a concrete pier and a concrete column, respectively.

Wall Forms

Wall forms are made up of five basic parts. They are as follows: (1) sheathing, to shape and retain the concrete until it sets; (2) studs, to form a framework and support the sheathing; (3) wales, to keep the form aligned and support the studs; (4) braces, to hold the forms erect under lateral pressure; and (5) ties and spreaders or tie-spreader units, to hold the sides of the forms at the correct spacing (fig. 7-29).

Wall forms may be built in place or pre-fabricated, depending on the shape and the desirability for reuse.

Wall forms are usually reinforced against displacement by the use of TIES. Two types of

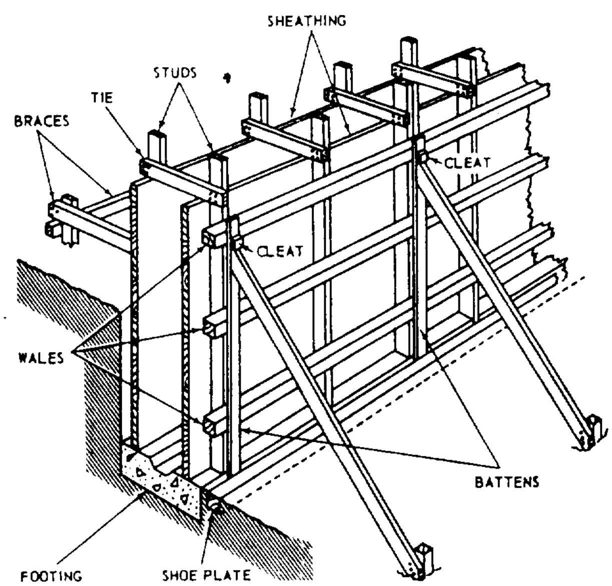

Figure 7-29.-Parts of a typical wall form.

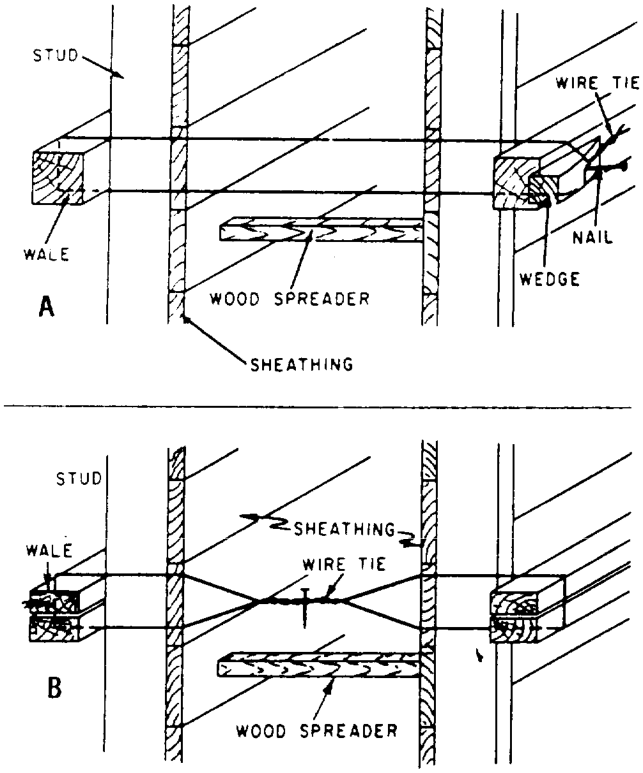

Figure 7-30.-Wire ties for wall forms.

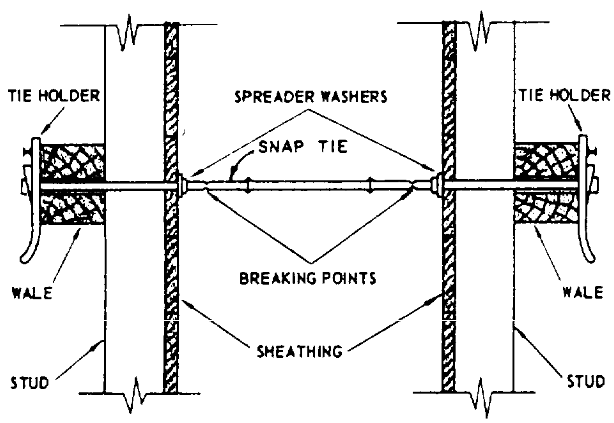

Figure 7-31.-Snap tie.

simple wire ties, used with wood SPREADERS, are shown in figure 7-30. The wire is passed around the studs and wales and through small holes bored in the sheathing. The spreader is placed as close as possible to the studs, and the tie is set taut by the wedge shown in the upper view or by twisting with a small toggle, as shown in the lower view. When the concrete reaches the level of the spreader, the spreader is knocked out and removed. The parts of the wire that are inside the forms remain in the concrete; the outside surplus is cut off after the forms are removed.

Wire ties and wooden spreaders have been largely replaced by various manufactured devices that combine the functions of the tie and spreader. Figure 7-31 shows one of these, called a SNAP TIE. These ties are made in various sizes to fit various wall thicknesses. The tie holders can be removed from the tie rod. The rod goes through small holes bored in the sheathing and also through the wales, which are usually doubled for that purpose. Tapping the tie holders down on the ends of the rod brings the sheathing to bear solidly against the spreader washers. After the concrete has hardened, the tie holders can be detached to strip the forms. After the forms are stripped, a special wrench is used to break off the outer sections of rod; they break off at the breaking points, located about 1 in. inside the surface of the concrete. Small surface holes remain, which can be plugged with grout, if necessary.

Another type of wall form tie is the TIE ROD, as shown in figure 7-32. The rod in this type consists of three sections: an inner section, which is threaded on both ends, and two threaded outer sections. The inner section, with the cones set to the thickness of the wall, is placed between the forms, and the outer sections are passed through the wales and sheathing and threaded into the cone nuts. The clamps are then threaded up on the outer sections to bring the forms to bear against the cone nuts. After the concrete hardens, the clamps are loosened, and the outer sections of rod are removed by threading them out of the cone nuts. After the forms are stripped, the cone nuts are removed from the concrete by threading

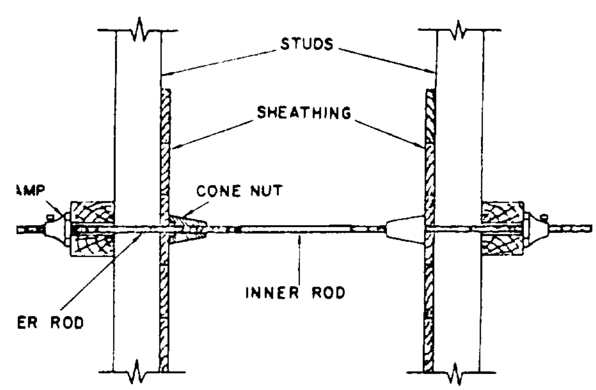

Figure 7-32.-Tie rod.

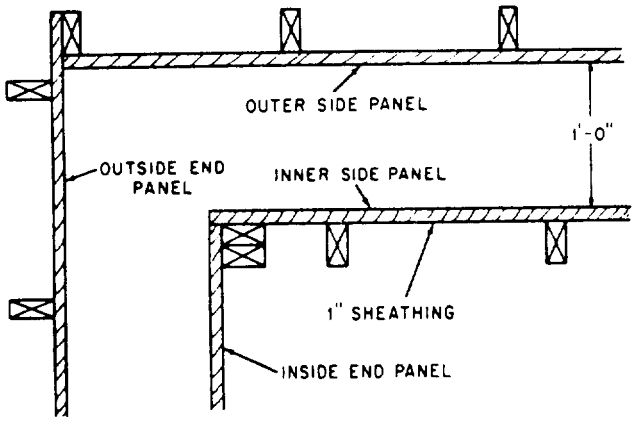

Figure 7-33.-Method of joining wall form panels at a corner.

them off the inner sections of rod with a special wrench leaving the cone-shaped surface holes. The outer sections and the cone nuts may be reused indefinitely.

The use of prefabricated panels for formwork has recently been on the increase. These panels can be reused many times, thus reducing the time and labor required for erecting forms on the site.

Many types of prefabricated form panels are in use. Contractors sometimes build their own panels from wood framing covered with plywood sheathing (fig. 7-33). The standard size is 2 ft by 8 ft, but panels can be sized to suit any particular situation.

Panels made with a metal frame and plywood sheathing are also in common use and are available in a variety of sizes. Special sections are produced to form inside corners, pilasters, and so forth. Panels are held together by patented panel clamps. Flat bar ties, which lock into place between panels, eliminate the need for spreaders. Forms are aligned by using one or more doubled rows of 2 by 4's, secured to the forms by a special device that is attached to the bar ties.

Form panels made completely of steel are also available. The standard size is 24 by 48 in., but various other sizes are also manufactured. Inside and outside corner sections are standard, and insert angles allow odd-sized panels to be made up as desired.

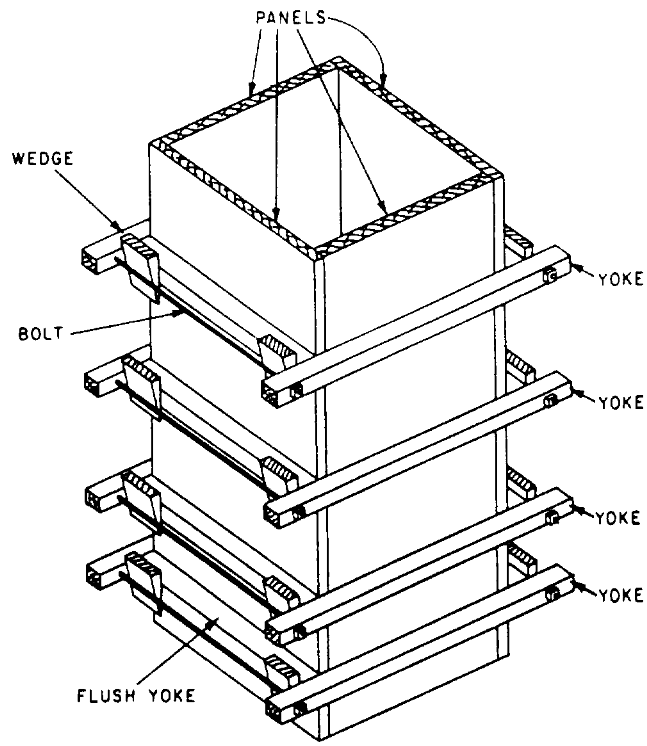

Figure 7-34.-Column form.

Large projects requiring mass concrete placement are often formed by the use of giant panels or ganged, prefabricated forms. Cranes usually raise and place these large sections, so their size is limited only by the available equipment. These large forms are built or assembled on the ground, and their only basic difference from regular forms is the extra bracing required to withstand handling.

Special attention must be given to corners when forms are being erected. These are weak points because the continuity of sheathing and wales is broken. Forms must be pulled tightly together at these points to prevent leakage of concrete.

Column Forms

A typical concrete column form (fig. 7-34) is securely braced by YOKES to hold the sheathing together against the bursting pressure exerted on the form by the plastic concrete. Since the bursting pressure is greater at the bottom than the top, the yokes are placed closer together at the bottom. Notice, in figure 7-34, that on two panels, the

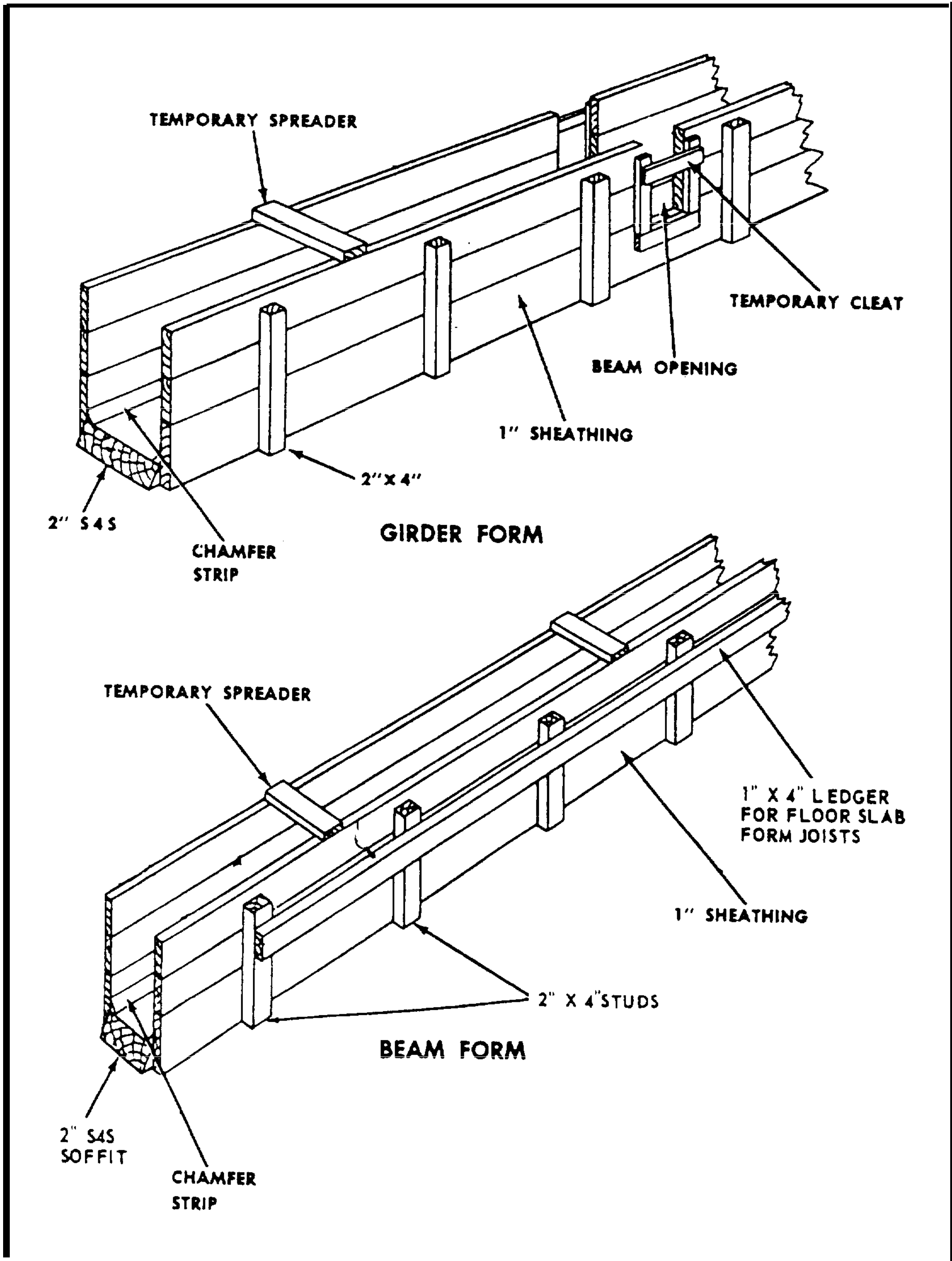

Figure 7-35.-Typical beam and girder forms.

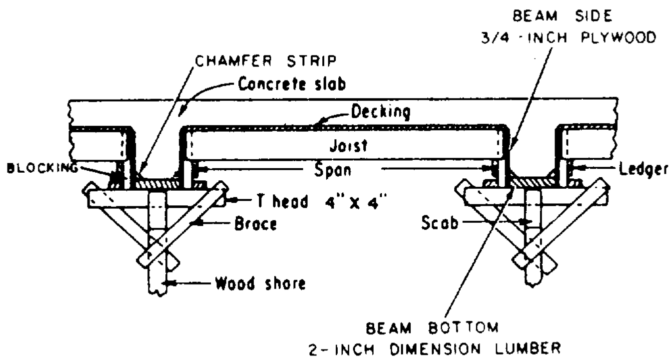

Figure 7-36.-Typical components of beam formwork with slab framing in.

yoke members come flush with the edges of the sheathing; on the other two, they project beyond the edges. Bolt holes are bored in these projections, and bolts are inserted to backup the wedges that are driven to tighten the yokes.

Beam and Girder Forms

The type of construction to be used for beam forms depends upon whether the form is to be removed in one piece or whether the sides are to be stripped and the bottom left in place until such time as the concrete has developed enough strength to permit removal of the shoring. The latter type of beam form is preferred, and details for this type are shown in figure 7-35. Beam forms are subjected to very little bursting pressure but must be shored up at frequent intervals to prevent sagging under the weight of the fresh concrete.

Figure 7-36 shows atypical interior beam form with slab forms supported on the beam sides. This drawing indicates that 3/4-in. plywood serves as the beam sides and that the beam bottom is a solid piece of 2-in. dimensioned lumber supported on the bottom by 4- by 4-in. T-head shores. The vertical side members, referred to in the figure as blocking, are placed to assist in transmitting slab loads to the supporting shores.

MASONRY

MASONRY is that form of construction composed of stone, concrete, brick, gypsum, hollow clay tile, concrete brick, tile, or other similar building units or materials or a combination of these materials, laid up unit by unit and set in mortar. This section will discuss the basic masonry materials commonly used in construction.

CONCRETE MASONRY

Concrete masonry has become increasingly important as a construction material. Important technological developments in the manufacture and utilization of the units have accompanied the rapid increase in the use of concrete masonry. Concrete masonry walls properly designed and constructed will satisfy various building requirements including fire, safety, durability, economy, appearance, utility, comfort, and good acoustics.

The most common concrete masonry unit is the CONCRETE BLOCK. It is manufactured from both normal and lightweight aggregates. There are two types of concrete block: heavyweight and lightweight. The heavyweight block is manufactured from cement, water, and aggregates, such as sand, gravel, and crushed limestone. The lightweight blocks use a combination of cement, water, and a lightweight aggregate. Cinders, pumice, expanded shale, and vermiculite are a few of the aggregates used in lightweight block production. The lightweight units weigh about 30 percent less than the heavyweight units.

Concrete blocks are made to comply with certain requirements, notably compressive strength, absorption, and moisture content. Compressive strength requirements provide a measure of the blocks' ability to carry loads and withstand structural stresses. Absorption requirements provide a measure of the density of the concrete while moisture content requirements indicate if the unit is sufficiently dry for use in wall construction.

Block Sizes and Shapes

Concrete block units are made in sizes and shapes to fit different construction needs. Units are made in full- and half-length sizes, as shown

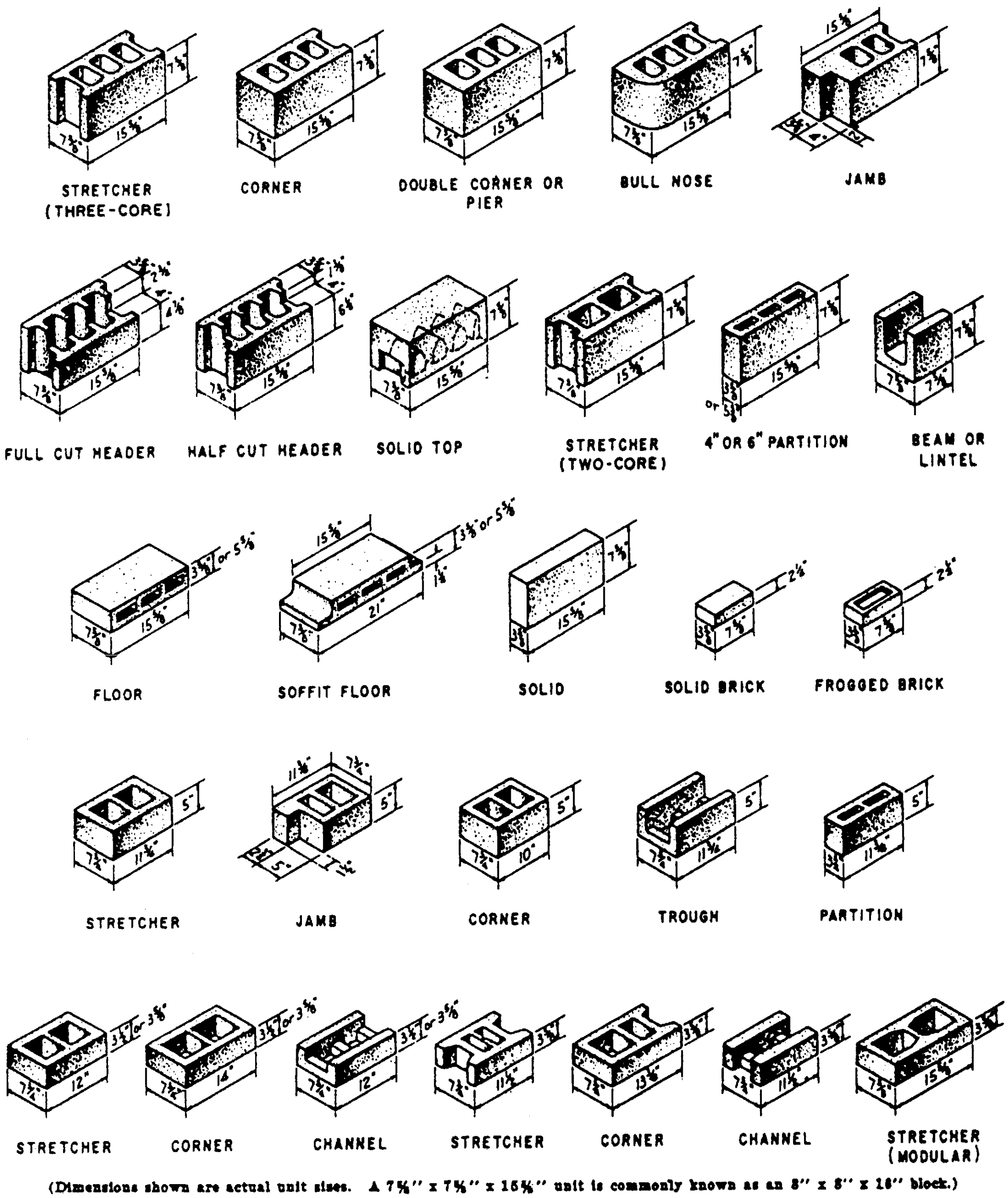

Figure 7-37.—Typical sizes and shapes of concrete masonry units.

in figure 7-37. Concrete unit sizes are usually referred to by their nominal dimensions. A unit measuring 7 5/8 in. wide, 7 5/8 in. high, and 15 5/8 in. long is referred to as an 8- by 8- by 16-in. unit. When it is laid in a wall with 3/8-in. mortar joints, the unit will occupy a space 16 in. long and 8 in. high. Besides the basic 8- by 8- by 16-in. units, the illustration shows a smaller partition unit and other units that are used much as cut brick are in brick masonry.

The corner unit is laid at a corner or at some similar point where a smooth, rather than a recessed, end is required. The header unit is used in a backing course placed behind a brick face tier header course. Part of the block is cut away to admit the brick headers. The uses of the other shapes shown are self-evident. Besides the shapes shown in figure 7-37, a number of smaller shapes for various special purposes are available. Units may be cut to the desired shapes with a bolster or, more conveniently and accurately, with a power-driven masonry saw.

The sides and the recessed ends of a concrete block are called the SHELL (fig. 7-38). The

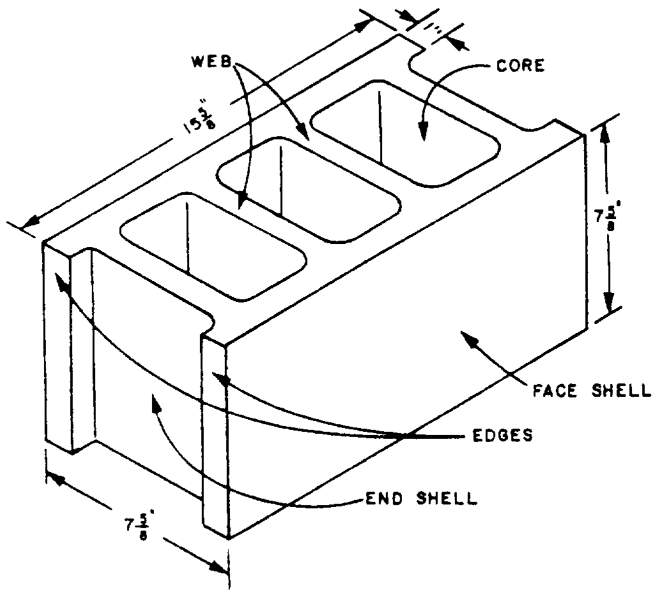

Figure 7-38.-Concrete block.

material that forms the partitions between the cores is called the WEB, and the holes between the webs are called CORES. Each of the long sides of a block is called a FACE SHELL, and each of the recessed ends is called an END SHELL. The vertical ends of the face shells, on either side of the end shells, are called the EDGES.

Wall Patterns

The large number of shapes and sizes of concrete blocks lend themselves to a great many uses. Figure 7-39 shows only a few of the wall patterns that can be developed using various pattern bonds and block sizes. Commercial publications from the Portland Cement Association show many more. Figure 7-40 shows some of the styles of SCREEN BLOCKS (blocks with patterned holes). This type of block is used to

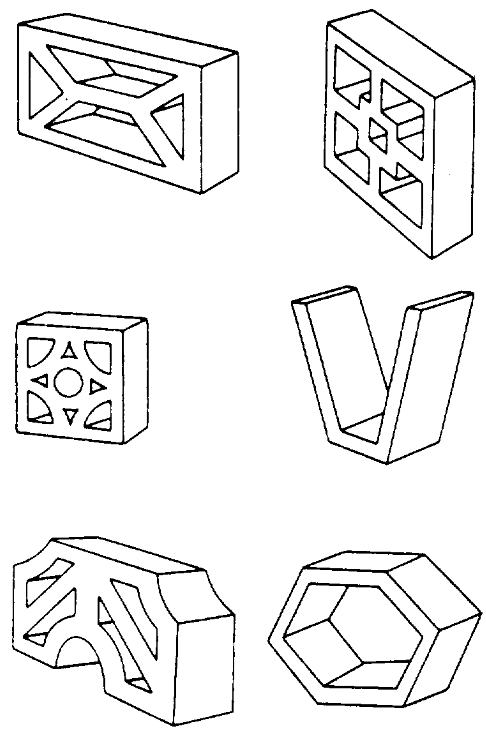

Figure 7-40.-Screen block designs.

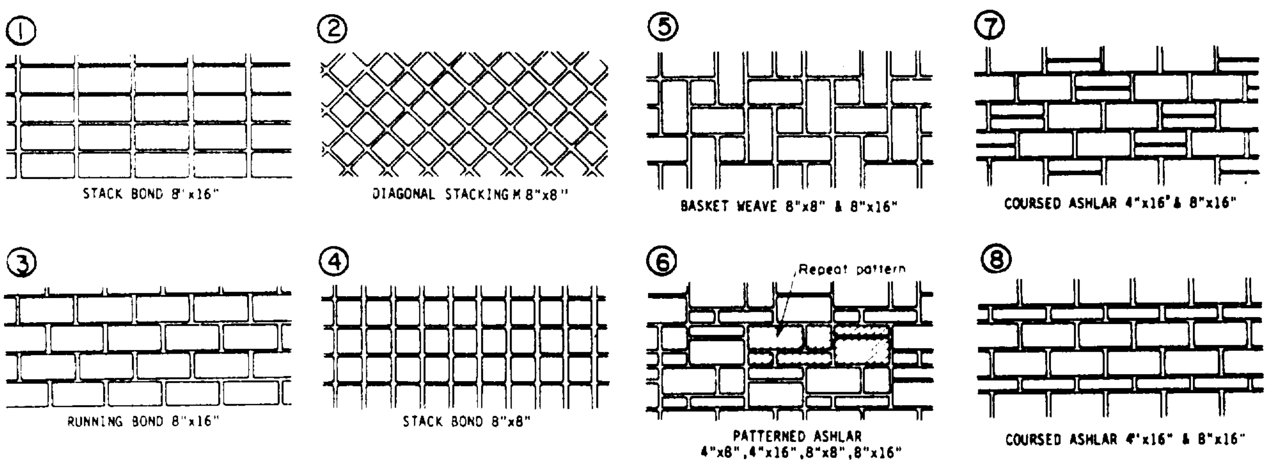

Figure 7-39.-Wall patterns.

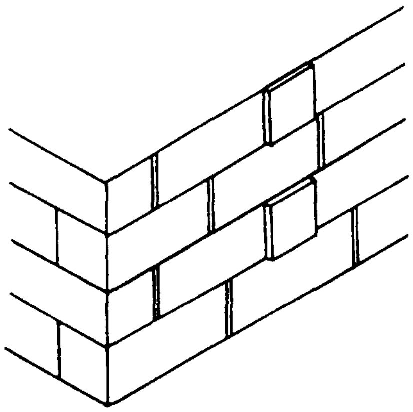

Figure 7-41.-Blocks laid in relief.

make a decorative wall called a PIERCED or SCREEN wall. Other architectural effects can be achieved by laying some block in relief (fig. 7-41) or by varying the type of mortar joint.

Modular Planning

Concrete masonry walls should be laid out to make maximum use of full- and half-length units, thus minimizing cutting and fitting of units on the job. Length and height of walls, width and height of openings, and wall areas between doors, windows, and corners should be planned to use full-size and half-size units, which are usually available (fig. 7-42). This procedure assumes that window frames and doorframes are of modular dimensions that fit modular full- and half-size units. Then, all horizontal dimensions should be in multiples of nominal full-length masonry units, and both horizontal and vertical dimensions should be designed to be in multiples of 8 in. Table 7-2 lists nominal lengths of concrete masonry walls by stretchers, and table 7-3 lists nominal heights of concrete masonry walls by courses. When units 8 by 4 by 16 are used, the horizontal dimension should be planned in multiples of 8 in. (half-length units), and the vertical dimensions, in multiples of 4 in. If the thickness of the wall is greater or less than the length of a half unit, a special length unit is required at each corner in each course.

STRUCTURAL CLAY TILE MASONRY

Hollow masonry units made of burned clay or shale are called, variously, structural tiles,

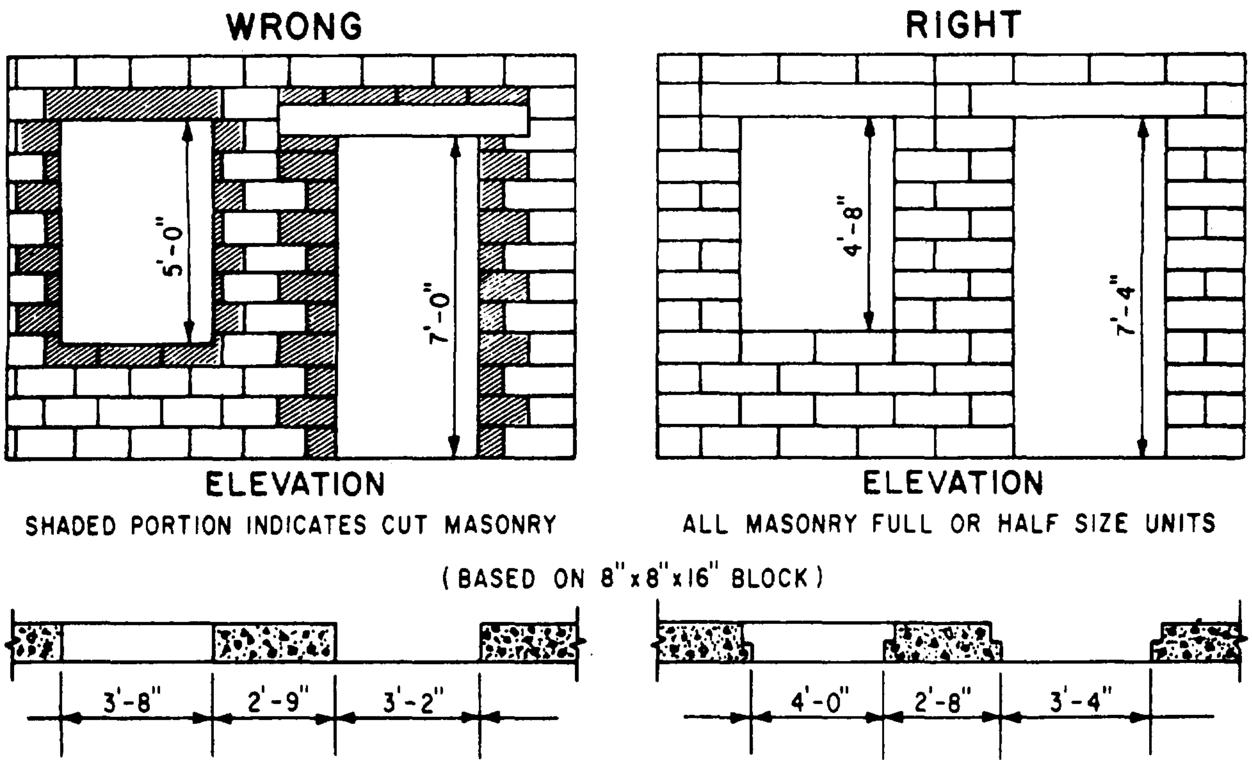

Figure 7-42.-Use of modular dimensions in concrete masonry wall openings.

Table 7-2.-Nominal Length of Concrete Masonry Walls by Stretchers

(**Actual length** of **wall** is measured from outside edge to outside edge of units and is equal to the nominal length **minus** ⅜" (one mortar joint).)

No. of stretchers	Nominal length of concrete masonry walls	
	Units 15⅝" long and half units 7⅝" long with ⅜" thick head joints.	Units 11⅝" long and half units 5⅝" long with ⅜" thick head joints.
1	1' 4"	1' 0".
1½	2' 0"	1' 6".
2	2' 8"	2' 0".
2½	3' 4"	2' 6".
3	4' 0"	3' 0".
3½	4' 8"	3' 6".
4	5' 4"	4' 0".
4½	6' 0"	4' 6".
5	6' 8"	5' 0".
5½	7' 4"	5' 6".
6	8' 0"	6' 0".
6½	8' 8"	6' 6".
7	9' 4"	7' 0".
7½	10' 0"	7' 6".
8	10' 8"	8' 0".
8½	11' 4"	8' 6".
9	12' 0"	9' 0".
9½	12' 8"	9' 6".
10	13' 4"	10' 0".
10½	14' 0"	10' 6".
11	14' 8"	11' 0".
11½	15' 4"	11' 6".
12	16' 0"	12' 0".
12½	16' 8"	12' 6".
13	17' 4"	13' 0".
13½	18' 0"	13' 6".
14	18' 8"	14' 0".
14½	19' 4"	14' 6".
15	20' 0"	15' 0".
20	26' 8"	20' 0".

Table 7-3.-Nominal Height of Concrete Masonry Walls by Courses

(For concrete masonry units 7⅝" and 3⅝" in height laid with ⅜" mortar joints. Height is measured from center to center of mortar joints.)

No. of courses	Nominal height of concrete masonry walls	
	Units 7⅝" high and ⅜" thick bed joint	Units 3⅝" high and ⅜" thick bed joint
1	8"	4".
2	1' 4"	8".
3	2' 0"	1' 0".
4	2' 8"	1' 4".
5	3' 4"	1' 8".
6	4' 0"	2' 0".
7	4' 8"	2' 4".
8	5' 4"	2' 8".
9	6' 0"	3' 0".
10	6' 8"	3' 4".
15	10' 0"	5' 0".
20	13' 4"	6' 8".
25	16' 8"	8' 4".
30	20' 0"	10' 0".
35	23' 4"	11' 8".
40	26' 8"	13' 4".
45	30' 0"	15' 0".
50	33' 4"	16' 8".

hollow tiles, structural clay tiles, structural clay hollow tiles, and structural clay hollow building tiles, but most commonly called building tile. In building tile manufacture, plastic clay is pugged through a die, and the shape that emerges is cut off into units. The units are then burned much as bricks are burned.

The apertures in a building tile, which correspond to the cores in a brick or a concrete block, are called CELLS. The solid sides of a tile are called the SHELL and the perforated material enclosed by the shell is called the WEB. A tile that is laid on one of its shell faces is called a SIDE-CONSTRUCTION tile; one that

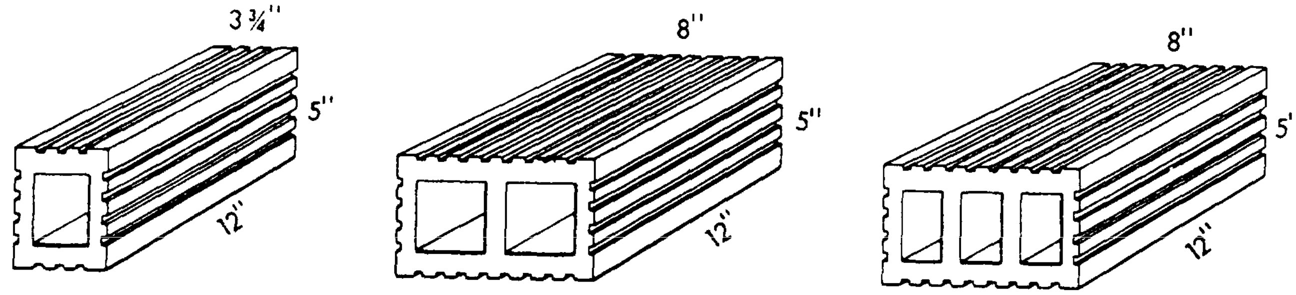

Figure 7-43.-Standard shapes of side-construction building tiles.

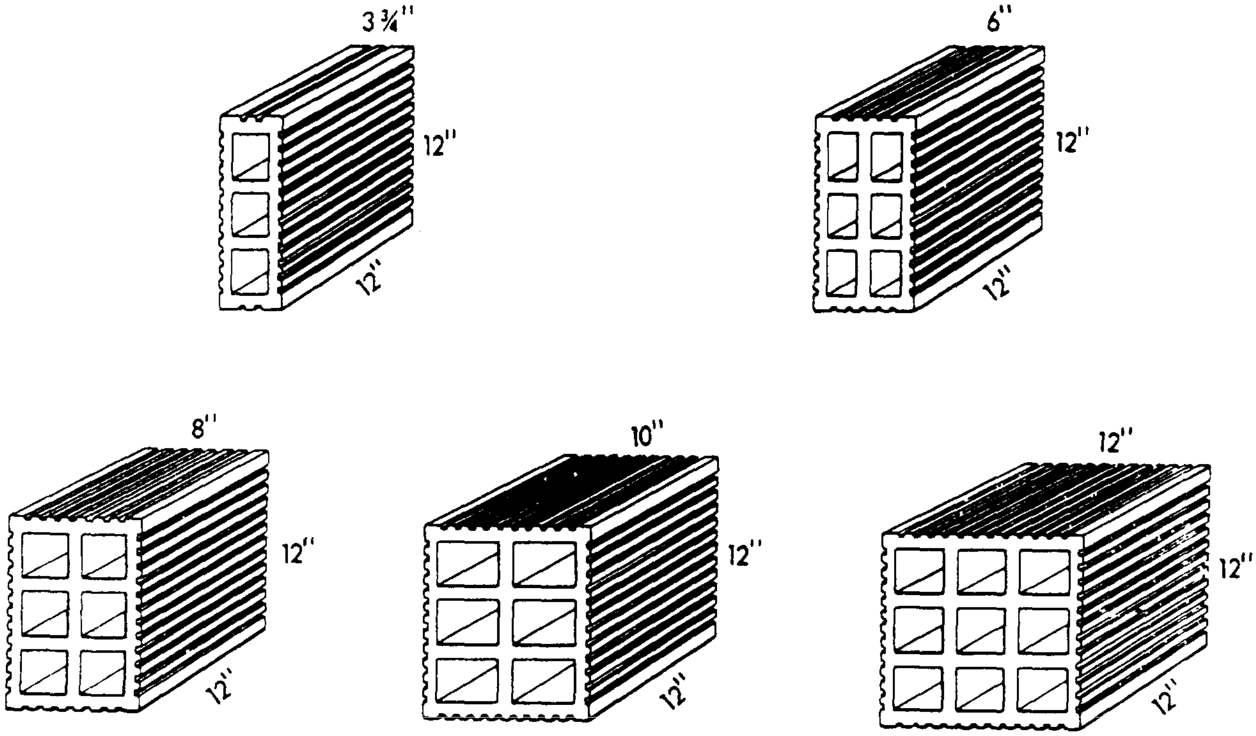

Figure 7-44.-Standard shapes of end-construction building tiles.

is laid on one of its web faces is called an END-CONSTRUCTION tile. Figures 7-43 and 7-44 show the sizes and shapes of basic side- and end-construction building units. Special shapes for use at corners and openings, or for use as closures, are also available.

Physical Characteristics

The compressive strength of the individual tile depends upon the materials used and upon the method of manufacture, in addition to the thickness of the shells and webs. A minimum compressive strength of tile masonry of 300 lb per square in, based on the gross section may be expected. The tensile strength of structural clay tile masonry is small. In most cases, it is less than 10 percent of the compressive strength.

The abrasion resistance of clay tile depends primarily upon its compressive strength. The stronger the tile, the greater its resistance to wearing. The abrasion resistance decreases as the amount of water absorbed increases.

Structural clay facing tile has excellent resistance to weathering. Freezing and thawing action produces almost no deterioration. Tile that will absorb no more than 16 percent of its weight of water have never given unsatisfactory performance in resisting the effect of freezing and thawing action. Only portland cement-lime mortar or mortar prepared from masonry cement should be used if the masonry is exposed to the weather.

Walls containing structural clay tile have better heat-insulating qualities than walls composed of solid units because of the dead air space that exists in tile walls. The resistance to sound penetration of this type of masonry compares favorably with the resistance of solid masonry walls, but it is somewhat less.

The fire resistance of tile walls is considerably less than the fire resistance of solid masonry walls. It can be improved by applying a coat of plaster to the surface of the wall. Partition walls of structural clay tile 6 in, thick will resist a fire for 1 hr provided the fire produces a temperature of not more than 1700°F.

The solid material in structural clay tile weighs about 125 lb per cubic foot. Since the tile contains hollow cells of various sizes, the weight of the tile varies, depending upon the manufacturer and type. A 6-in. tile wall weighs approximately 30 lb per square foot, while a 12-in. tile weighs approximately 45 lb per square foot.

Uses for Structural Clay Tile

Structural clay tile may be used for exterior walls of either the load-bearing or nonload-bearing type. It is suitable for both below-grade and above-grade construction.

Structural load-bearing tile is made from 4- to 12-in. thicknesses with various face dimensions. The use of these tiles is restricted by building codes and specifications, so consult the project specification.

Nonload-bearing partition walls from the 4- to 12-in. thicknesses are frequently made of structural clay tile. These walls are easily built, light in weight, and have good heat- and sound-insulating properties.

Figure 7-45 shows the use of structural clay tile as a back unit for a brick wall.

Figure 7-46 shows the use of 8- by 5- by 12-in. tile in wall construction. Exposure of the open end of the tile can be avoided by the application of a thin tile called a SOAP at the corner.

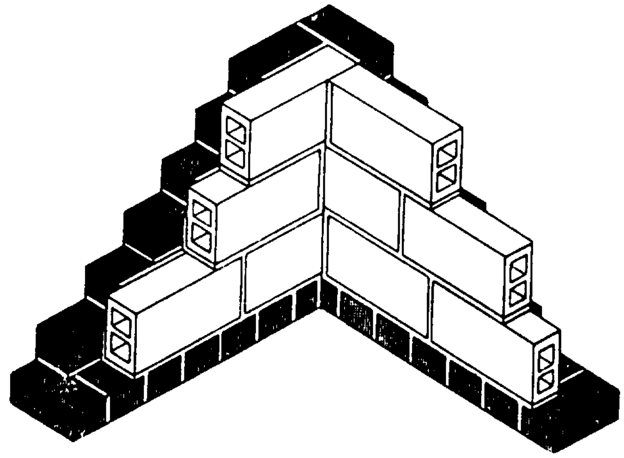

Figure 7-45.-Structural tile used as a backing for bricks.

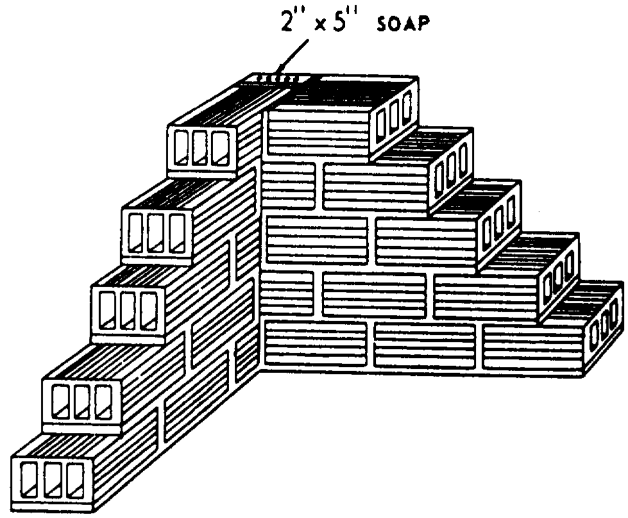

Figure 7-46.-Eight-inch structural clay tile wall.

STONE MASONRY

Stone masonry is masonry is which the units consist of natural stone. In RUBBLE stone masonry, the stones are left in their natural state, without any kind of shaping. In ASHLAR masonry, the faces of stones that are to be placed in surface positions are squared so that the surfaces of the finished structure will be more or less continuous plane surfaces. Both rubble and ashlar work may be either RANDOM or COURSED.

Random rubble is the crudest of all types of stonework. Little attention is paid to laying the

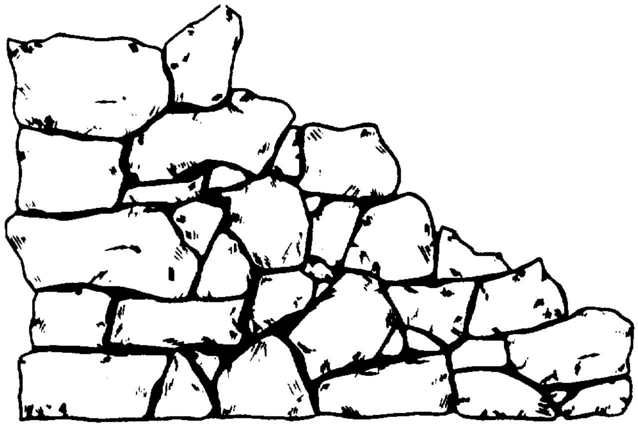

Figure 7-47.-Random rubble stone masonry.

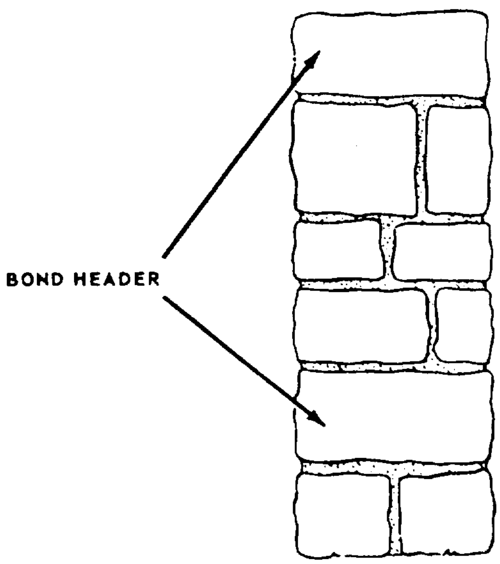

Figure 7-48.-Layers of bond stones in random stone masonry.

stones in courses, as shown in figure 7-47. Each layer must contain bonding stones that extend through the wall, as shown in figure 7-48. This produces a wall that is well tied together. The bed joints should be horizontal for stability, but the "builds" or head joints may run in any direction.

Coursed rubble consists of roughly squared stones assembled in such a manner as to produce approximately continuous horizontal bed joints, as shown in figure 7-49.

The stone for use in stone masonry should be strong, durable, and cheap. Durability and strength depend upon the chemical composition and physical structure of the stone. Some of the

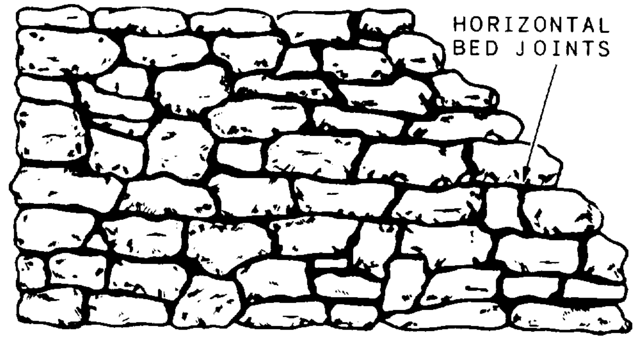

Figure 7-49.-Coursed rubble masonry.

more commonly found stones that are suitable are limestone, sandstone, granite, and slate. Unsquared stones obtained from nearby ledges or quarries or even fieldstone maybe used. The size of the stone should be such that two people can easily handle it. A variety of sizes is necessary to avoid using large quantities of mortar.

The mortar for use in stone masonry may be composed of portland cement and sand in the proportions of one part cement to three parts sand by volume. Such mortar shrinks excessively and does not work well with the trowel. A better mortar to use is portland cement-lime mortar. Mortar made with ordinary portland cement will stain most types of stone. If staining must be prevented, nonstaining white portland cement should be used in making the mortar. Lime does not usually stain the stone.

BRICK MASONRY

In brick masonry construction, units of baked clay or shale of uniform size are laid in courses with mortar joints to form walls of virtually unlimited length and height. These units are small enough to be placed with one hand. Bricks are kiln-baked from various clay and shale mixtures. The chemical and physical characteristics of the ingredients vary considerably; these and the kiln temperatures combine to produce brick in a variety of colors and harnesses. In some regions, pits are opened and found to yield clay or shale that, when ground and moistened, can be formed and baked into durable brick; in other regions, clays or shales from several pits must be mixed.

The dimensions of a U.S. standard building brick are 2 1/4 by 3 3/4 by 8. The actual dimensions of brick may vary a little because of shrinkage during burning.

Brick Nomenclature

Frequently, the Builder must cut the brick into various shapes. The most common shapes are shown in figure 7-50. They are called half or bat, three-quarter closure, quarter closure, king closure, queen closure, and split. They are used to fill in the spaces at corners and such other places where a full brick will not fit.

The six surfaces of a brick are called the cull, the beds, the side, the end, and the face, as shown in figure 7-51.

Brick Classification

A finished brick structure contains FACE brick (brick placed on the exposed face of the structure) and BACKUP brick (brick placed behind the face brick). The face brick is often of higher quality than the backup brick; however, the entire wall may be built of COMMON brick.

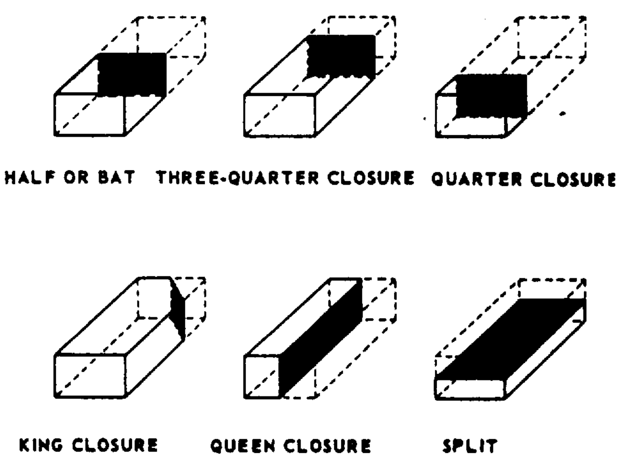

Figure 7-50.-Nomenclature of common shapes of cut brick.

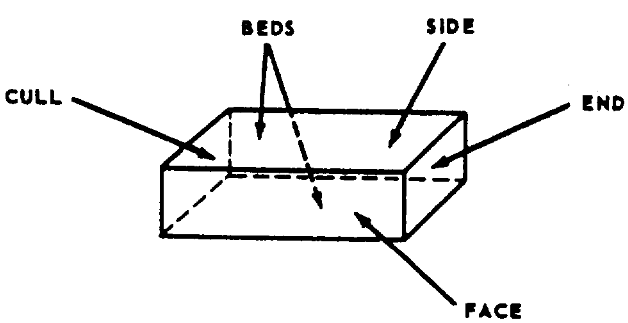

Figure 7-51.-Brick surfaces nomenclature.

Common brick is brick that is made from pit-run clay, with no attempt at color control and no special surface treatment like glazing or enameling. Most common brick is red.

Although any surface brick is a face brick as distinguished from a backup brick, the term *face brick* is also used to distinguish high-quality brick from brick that is of common-brick quality or less. Applying this criterion, face brick is more uniform in color than common brick, and it may be obtained in a variety of colors as well. It may be specifically finished on the surface, and in any case, it has a better surface appearance than common brick. It may also be more durable, as a result of the use of select clay and other materials, or as a result of special manufacturing methods.

Backup brick may consist of brick that is inferior in quality even to common brick. Brick that has been underburned or overburned, or brick made with inferior clay or by inferior methods, is often used for backup brick.

Still another type of classification divides brick into grades according to the probable climatic conditions to which it is to be exposed. These are as follows:

GRADE SW is brick designed to withstand exposure to below-freezing temperatures in a moist climate like that of the northern regions of the United States.

GRADE MW is brick designed to withstand exposure to below-freezing temperatures in a drier climate than that mentioned in the previous paragraph.

GRADE NW is brick primarily intended for interior or backup brick. It maybe used exposed, however, in a region where no frost action occurs, or in a region where frost action occurs, but the annual rainfall is less than 15 in.

Types of Bricks

There are many types of brick. Some are different in formation and composition while others vary according to their use. Some commonly used types of brick are described in the following paragraphs.

COMMON brick is made of ordinary clays or shales and burned in the usual manner in the kilns. These bricks do not have special scorings or markings and are not produced in any special color or surface texture. Common brick is also known as hard- and kiln-run brick. It is used generally for backing courses in solid or cavity brick walls. The harder and more durable kinds are preferred for this purpose.

FACE bricks are used in the exposed face of a wall and are higher quality units than backup brick. They have better durability and appearance. The most common colors of face brick are various shades of brown, red, gray, yellow, and white.

CLINKER bricks are bricks that have been overburned in the kilns. This type of brick is usually hard and durable and may be irregular in shape. Rough hard corresponds to the clinker classification.

PRESS bricks are made by the dry press process. This class of brick has regular smooth faces, sharp edges, and perfectly square corners. Ordinarily, all press brick are used as face brick.

GLAZED bricks have one surface of each brick glazed in white or other colors. The ceramic glazing consists of mineral ingredients that fuse together in a glass-like coating during burning. This type of brick is particularly suited for walls or partitions in hospitals, dairies, laboratories, or other buildings where cleanliness and ease of cleaning are necessary.

FIREBRICK is made of a special type of fire clay that will withstand the high temperatures of fireplaces, boilers, and similar usages without cracking or decomposing. Firebrick is larger than regular structural brick, and often, it is hand molded.

CORED BRICK are made with two rows of five holes extending through their beds to reduce weight. There is no significant difference between

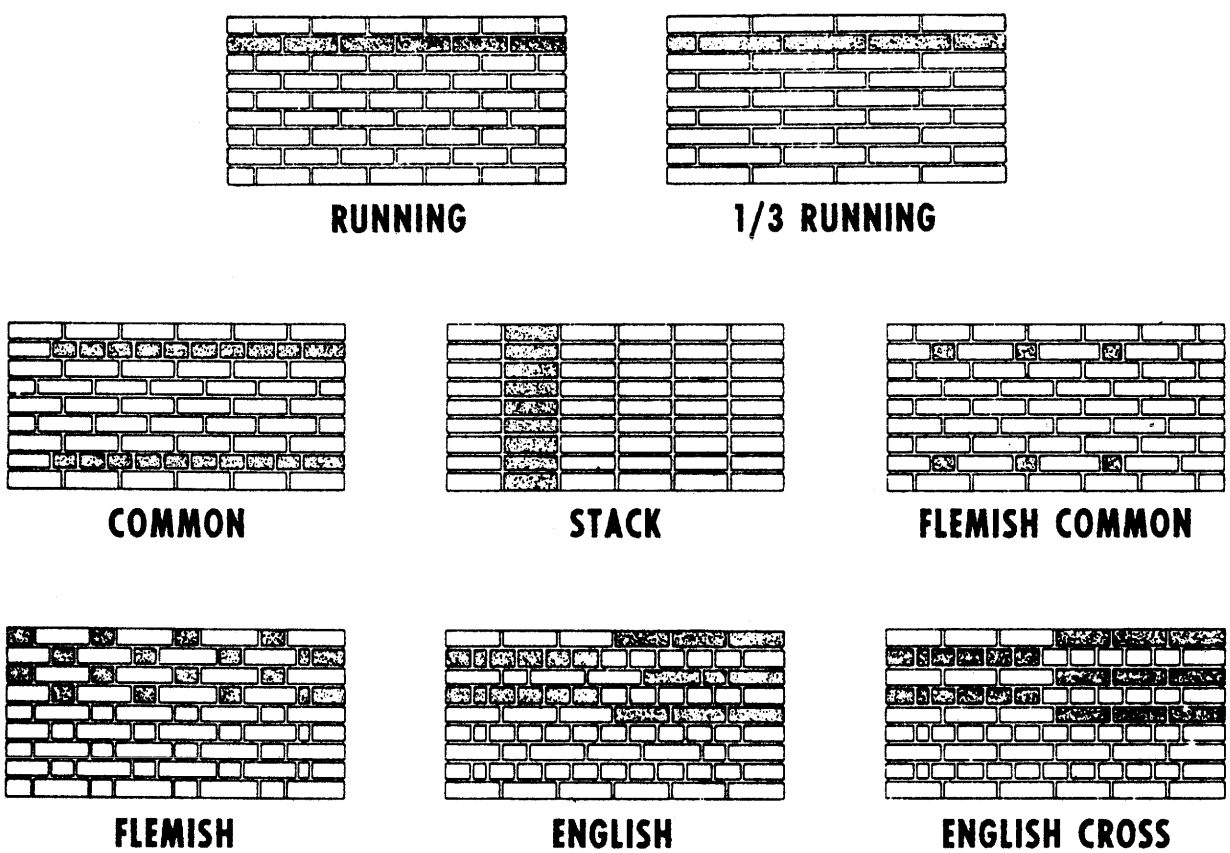

Figure 7-52.—Types of brick masonry bond.

the strength of walls constructed with cored brick and those constructed with solid brick. Resistance to moisture penetration is about the same for both types of walls. The most easily available brick that will meet the requirements should be used whether the brick is cored or solid.

SAND-LIME bricks are made from a lean mixture of slaked lime and fine silicious sand, molded under mechanical pressure and hardened under steam pressure.

Types of Bonds

When the word *bond* is used in reference to masonry, it may have three different meanings:

STRUCTURAL BOND is a method of interlocking or tying individual masonry units together so that the entire assembly acts as a single structural unit. Structural bonding of brick and tile walls may be accomplished in three ways: first, by overlapping (interlocking) the masonry units; second, by the use of metal ties embedded in connecting joints; and third, by the adhesion of grout to adjacent wythes of masonry.

MORTAR BOND is the adhesion of the joint mortar to the masonry units or to the reinforcing steel.

PATTERN BOND is the pattern formed by the masonry units and the mortar joints on the face of a wall. The pattern may result from the type of structural bond used or may be purely a decorative one in no way related to the structural bond. Five basic pattern bonds are in common use today, as shown in figure 7-52. These are running bond, common bond, stack bond, Flemish bond, and English bond.

RUNNING BOND is the simplest of the basic pattern bonds; the running bond consists of all stretchers. Since there are no headers used in this bond, metal ties are usually used. Running bond is used largely in cavity wall construction and veneered walls of brick and often in facing tile walls where the bonding may be accomplished by extra width stretcher tile.

COMMON or AMERICAN BOND is a variation of running bond with a course of full-length headers at regular intervals. These headers provide structural bonding, as well as pattern. Header courses usually appear at every fifth, sixth, or seventh course, depending on the structural bonding requirements. In laying out any bond pattern, it is important that the corners be started correctly. For common bond, a three-quarter brick must start each header course at the corner. Common bond may be varied by using a Flemish header course.

STACK BOND is purely a pattern bond. There is no overlapping of the units, all vertical joints being aligned. Usually, this pattern is bonded to the backing with rigid steel ties, but when 8-in.-thick stretcher units are available, they may be used. In large wall areas and in load-bearing construction, it is advisable to reinforce the wall with steel pencil rods placed in the horizontal mortar joints. The vertical alignment requires dimensionally accurate units, or carefully prematched units, for each vertical joint alignment. Variety in pattern may be achieved by numerous combinations and modifications of the basic patterns shown.

FLEMISH BOND is made up of alternate stretchers and headers, with the headers in alternate courses centered over the stretchers in the intervening courses. Where the headers are not used for structural bonding, they may be obtained by using half brick, called blind-headers. Two methods are used in starting the corners. Figure 7-52 shows the so-called FLEMISH corner in which a three-quarter brick is used to start each course and the ENGLISH corner in which 2-in. or quarter-brick closures must be used.

ENGLISH BOND is composed of alternate courses of headers and stretchers. The headers are centered on the stretchers and joints between stretchers. The vertical (head) joints between stretchers in all courses line up vertically. Blind headers are used in courses that are not structural bonding courses. The English cross bond is a variation of English bond and differs only in that vertical joints between the stretchers in alternate courses do NOT line up vertically. These joints center on the stretchers themselves in the courses above and below.

Masonry Terms

Specific terms are used to describe the various positions of masonry units and mortar

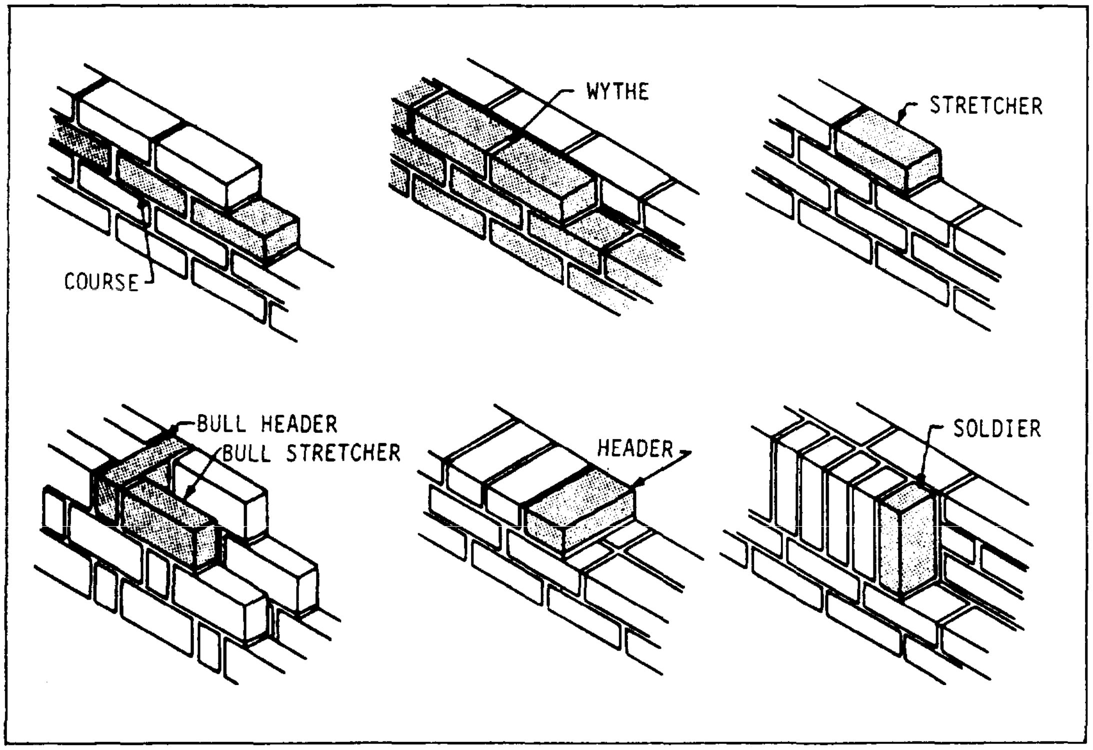

Figure 7-53.-Various positions of wall masonry units and mortar joints.

joints in a wall (fig. 7-53). These are as follows:

Course. One of the continuous horizontal layers (or rows) of masonry that, bonded together, form the masonry structure.

Wythe. A continuous single vertical wall of b r i c k

Stretcher. A masonry unit laid flat with its longest dimension parallel to the face of the wall.

Bull-Stretcher. A rowlock brick laid with its longest dimension parallel to the face of the wall.

Bull-Header. A rowlock brick laid with its longest dimension perpendicular to the face of the wall.

Header. A masonry unit laid flat with its longest dimension perpendicular to the face of the wall. It is generally used to tie two wythes of masonry together.

Rowlock. A brick laid on its edge (face).

Soldier. A brick laid on its end so that its longest dimension is parallel to the vertical axis of the face of the wall.