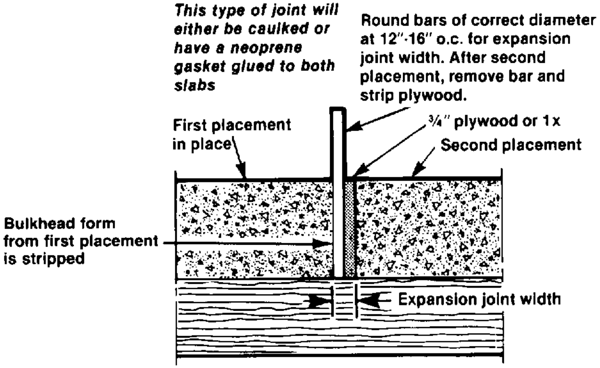

Fig. 7.6f—Forming an expansion joint.

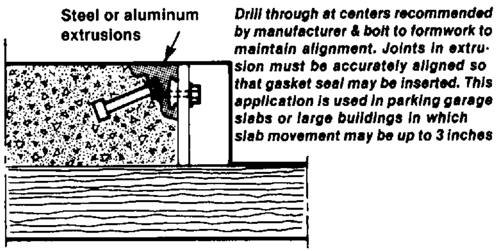

Fig. 7.6g—Embedments at an expansion joint.

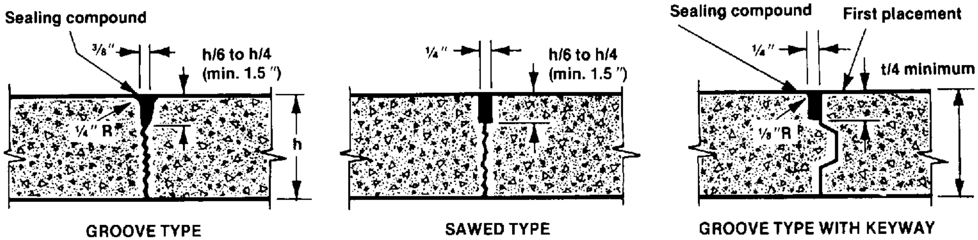

Fig. 7.6h—Contraction joints.

Edge forms

Maintaining the exterior slab line with edge forms is very important. Other exterior building materials may be attached to embedded plates anchored to the slab concrete. An accurate slab edge will simplify and minimize the amount of adjustment for the crew installing the exterior skin. Fig. 7.7 shows a slab edge form.

Occasionally, it may be necessary to cast an upturned curb at the slab edge or on the interior of the slab. Support of this formwork is important and the removal of any supports that penetrate the concrete must be done as soon as possible and the resultant voids filled with additional concrete. Fig. 7.8 shows typical formwork for these conditions.

Waterstops

Fig. 7.9 shows three methods of installing waterstops for vertical joints. Placing the waterstop between split forms is the most common, though the nail-on types are more convenient and economical. The waterstop must be held securely in position, so that it will not be displaced during concreting.

Care is required in placing and consolidating the concrete so that no voids or honeycombing occur adjacent to the waterstops. Contamination of the waterstop surfaces by form coatings, for example, should be avoided. While rubber and polyvinyl chloride waterstops are not susceptible to damage

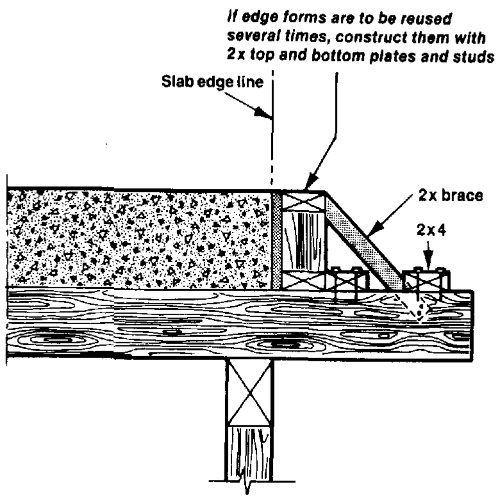

Fig. 7.7—Slab edge forms.

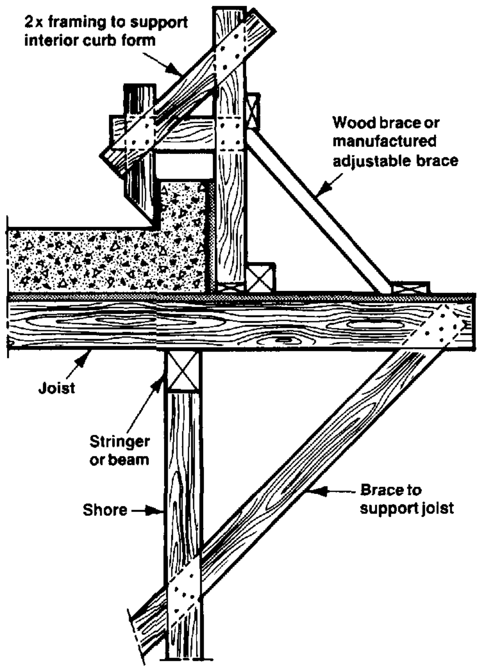

Fig. 7.8a—Forming a curb at slab edge.

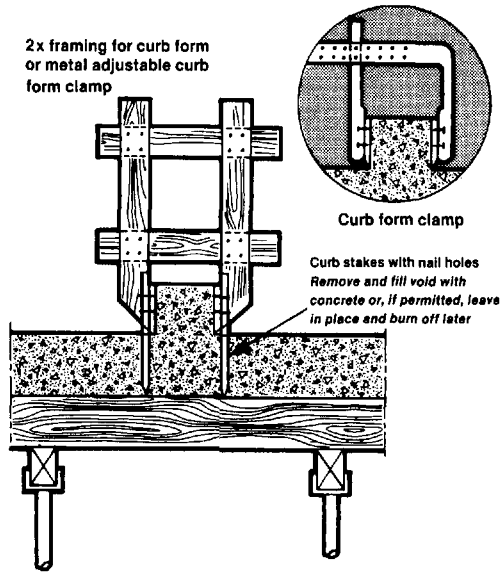

Fig. 7.8b—Forming an interior curb on slab.

during normal handling or concreting operations, thin metal waterstops are easily bent or torn and, therefore, require special care.

Waterstops may need splicing at intersections, abrupt changes of direction, or to form long continuous lengths. Prefabricated junction pieces may be ordered from the manufacturer and joined to the main run by simple butt splices in the field.

Polyvinyl chloride waterstops can be butt-welded by softening the ends with heat and pressing together until cool. Rubber waterstops can be joined by mitering the ends to mate and, after cleaning and roughening, cementing them together.

"Guide to Joint Sealants for Concrete Structures" (ACI 504R) will provide the reader with more information on joints and sealants.

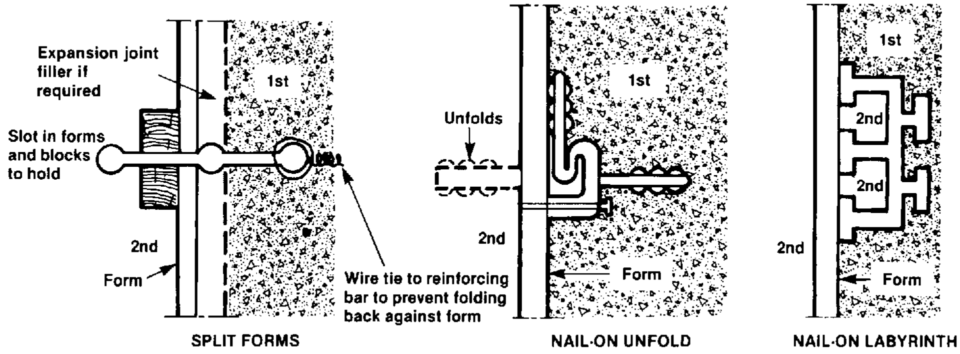

Fig. 7.9—Three methods of installing waterstops.

CHAPTER 8
REINFORCEMENT

General

Plain (unreinforced) concrete is strong in compression and weak in tension. Where concrete structural members must take tension, it is necessary to resist the tensile forces by the use of steel reinforcing bars. These bars are embedded in the concrete and must be properly located to resist tensile forces in the most effective manner. Since there are lugs or ribs projecting from the main section of the bar, these bars are called deformed bars. Standard deformed bars are round and range from approximately 3/8 in. to 2 1/4 inches in diameter. Deformed reinforcing bars are commonly referred to as rebars.

The adhesion of the concrete to the surface of the bars, plus the keying action provided by the deformations or lugs, keeps the bars from slipping through the concrete and makes the two materials act together. This adhesion and keying action of the bars in the concrete is known as bond.

Grades of bars

Reinforcing bars are furnished in several grades which vary in strength (yield and ultimate tensile), other mechanical characteristics, and chemical composition. The particular grade is a very important factor in the design of concrete members. The design engineer will state in the specifications or on the drawings the specific grades he wants furnished for the various parts of the reinforced concrete structure.

To obtain uniformity throughout the United States, ASTM, (formerly the American Society for Testing and Materials) has prepared standard specifications for these steels. It will be helpful for you to know what these standards are since grades will appear on bar bundle tags, in color coding, in rolled-on marking on the bars, or on bills of material. They are:

(a) A 615 Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
 (1) Grade 40 (40,000 psi minimum yield strength).
 (2) Grade 60 (60,000 psi minimum yield strength).

(b) A 616 Standard Specification for Rail-Steel Deformed Bars for Concrete Reinforcement
 (1) Grade 50.
 (2) Grade 60.

(c) A 617 Standard Specification for Axle-Steel Deformed Bars for Concrete Reinforcement
 (1) Grade 40.
 (2) Grade 60.

(d) A 706 Standard Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement
 (1) Grade 60.

The most widely specified grade of steel is the A615, Grade 60. Each mill which rolls deformed bars may have a different pattern of deformation on the bar, but all are rolled to conform to ASTM specifications. Some of the patterns are shown in Fig. 8.1, but the patterns are not restricted to the ones shown.

Bar sizes

Deformed bars are always designated by number. There are eleven standard sizes—#3 to #11 inclusive, #14 and #18. The number denotes approximately the diameter of the bar in eighths of an inch. For example, a #5 bar has an approximate diameter of 5/8 in., a #9 bar, 1 1/8 in. The approximate diameter may be helpful to a worker in identifying a bar size where the tag is missing or the roll marking is not clear. Table 8.1 lists the various bar sizes and physical characteristics.

Bar identification

ASTM specifications require that each bar producer shall roll onto the bar, (a) a letter or symbol to show the producer's mill; (b) a number corresponding to the size number of bar; (c) a symbol or marking to indicate the type of steel; and (d) a marking as shown in Fig. 8.2 to designate Grade 60.

The A615 specification contains a Supplementary Requirement (S1). As shown in Fig. 8.2, reinforcing bars furnished to the supplement must be designated for type of steel by the symbol "S" instead of the traditional "N".

The worker should verify these markings to be sure the correct grades and sizes are placed in the location where they are intended. If there is a doubt, the foreman should be notified.

Lap splices

Limitations on bar lengths must be considered. Long lengths of bars projecting far beyond construction joints are generally undesirable. A normal lap splice at or near the joint is preferable. The Concrete Reinforcing Steel Institute defines a lap splice as: Joining of two reinforcing bars by lapping them side by side; similarly the side and end overlap of sheets or rolls of welded wire fabric.

In design, under the ACI Building Code, the location and length of lap splices are critical. The length of lap will vary with the location of splice, size of bar, concrete strength, grade of steel, bar spacing, amount of stress in the bar, and whether the bar is in tension or compression. As such, one cannot determine by any simple rule the lap splice length or location of splices. These must be dimensioned completely on the contract drawings. The bar fabricator's placing drawings will show the location and type of splices specified. Some typical lapped splice details are shown in Fig. 8.3.

Table 8.1—ASTM standard reinforcing bars

		Nominal Dimensions		
Bar Designation No.	Nominal Weight, lb/ft	Diameter, in.	Cross-Sectional Area, in.	Perimeter, in.
3	0.376	0.375	0.11	1.178
4	0.668	0.500	0.20	1.571
5	1.043	0.625	0.31	1.963
6	1.502	0.750	0.44	2.356
7	2.044	0.875	0.60	2.749
8	2.670	1.000	0.79	3.142
9	3.400	1.128	1.00	3.544
10	4.303	1.270	1.27	3.990
11	5.313	1.410	1.56	4.430
14	7.65	1.693	2.25	5.32
18	13.60	2.257	4.00	7.09

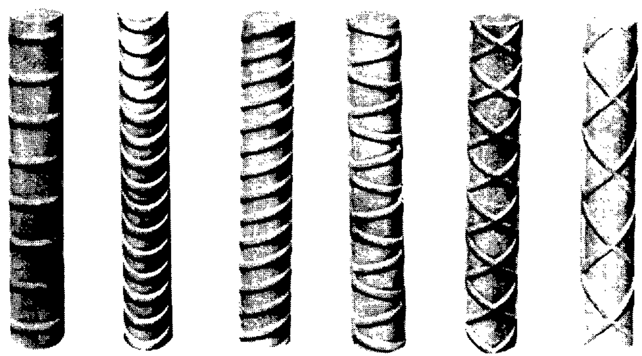

Fig. 8.1—Various types of deformed bars.

In elevated concrete slab construction the reinforcing steel is normally located in the areas where tensile forces exist. If excessive compressive forces are calculated, reinforcement is added to increase the ability of the member to take compression (shortening). An example of tension due to bending of a loaded beam is shown in Figure 8.4.

As a beam is loaded, the bottom of the member "stretches" causing tension cracks to appear at the bottom of the beam. These cracks will continue rapidly upward in an unreinforced concrete beam causing a sudden failure near midspan. Plain concrete in tension is weak and brittle. It will fail suddenly without warning shortly after the first crack appears. Deformed bars are placed inside the beam near the bottom to resist the tensile forces which crack the concrete.

The best example of compression is the force acting on a column. The column is loaded in compression by the downward load of the floors and the upward resistance of the footing. These two forces produce compression, as shown in Fig. 8.5.

A simple beam loaded by its own weight is bent downward in the center. This bending action also causes compression forces to occur in a beam. Fig. 8.6 shows a simple beam resisting bending with reinforcing under tension in the bottom and with compression in the concrete indicated in the upper portion.

Somewhere between these two forces is an area where neither tension nor compression exist. This is called the neutral axis because stress is zero at this point. It is shown in Fig. 8.6 by the broken line. The steel is located as near as possible to the bottom of the concrete, but the bars must be covered with sufficient concrete to assure bond and to protect the steel against corrosion (rust) and fire (heat). This concrete cover should be at least 1 in. thick to the side and bottom of a beam and 3/4 in. for slabs.

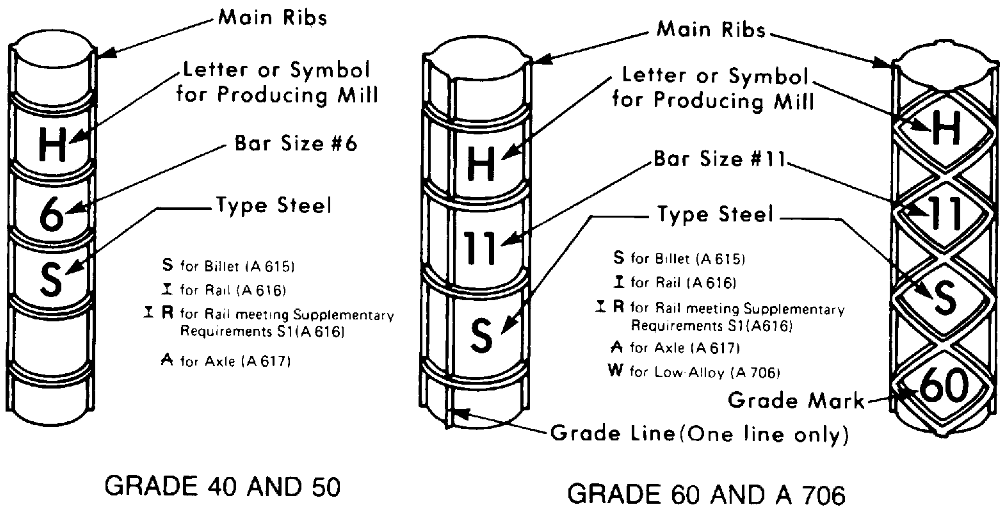

Fig. 8.2—Identification marks for ASTM standard reinforcing bars.

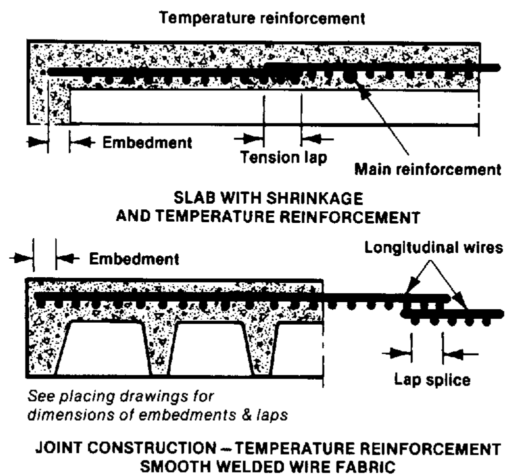

Fig. 8.3—Typical lapped splice details.

Shear is another stress which engineers identify and calculate. It is a more complex force than simple tension or compression. A common example of almost pure shear is illustrated by a bolted lap joint in steel plates, producing what is called single shear. In concrete, this is best illustrated by a loaded column bracket. See Fig. 8.7 and 8.8.

If a set of books was carried horizontally, as shown in Fig. 8.9, they would have to be squeezed tightly together, or they would slip and fall due to what is called vertical shear. In a beam each imaginary vertical slice (as the case of a single book) with a load on top is prevented from slipping down by the shear strength of the concrete (see Fig. 8.10). If several boards are laid flat across two supports and loaded, they will bend downward, but will also slip along each other horizontally (see Fig. 8.11). The horizontal slippage is caused by a force known as horizontal shear.

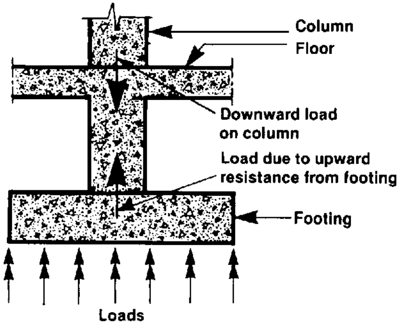

Fig. 8.5—Compression forces acting on a column.

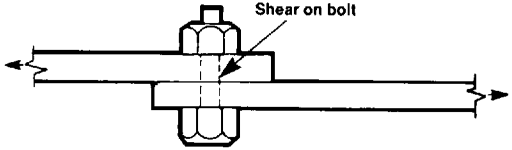

Fig. 8.7—Bolted bracket showing single shear.

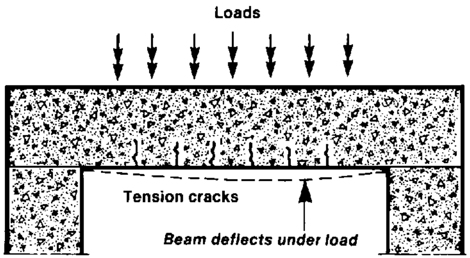

Fig. 8.4—Example of tension due to bending of a loaded beam.

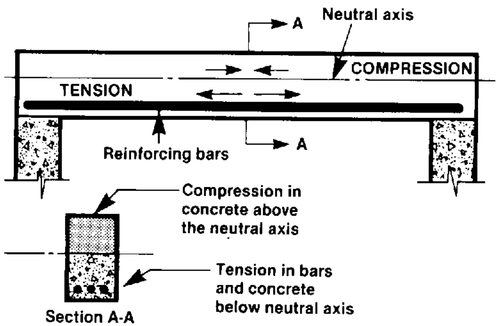

Fig. 8.6—Simple beam resisting bending.

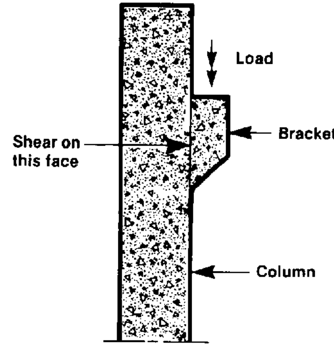

Fig. 8.8—Loaded column bracket develops shear at column face.

In a loaded beam, both vertical and horizontal shear are present, and the net result of the two forces produces what is called diagonal tension (see Fig. 8.12). In a beam which is uniformly loaded throughout its length, these stresses are greatest near the end support and decrease to zero at midspan.

The bottom steel, intended for longitudinal tension, does not provide sufficient resistance to cracking produced by diagonal tension. Additional reinforcement, bent into hoops called stirrups, is placed vertically in the member to resist the diagonal tension.

Another example of shear is that present in a floor slab around a column. The loads transferred from the slab to the column produce what is termed punching shear (see Fig. 8.13).

Loads and general steel location

You will not be expected to decide where or what reinforcement is needed. That is the responsibility of the engineer of record. However, some knowledge of how concrete acts under applied forces and where steel is located to resist these forces will enable you to have a much better understanding of the design details on the structural drawings. This understanding will emphasize the importance of adherence to the plans and specifications.

Individual concrete members

Simple beams. A simple beam is one resting freely on end supports such as brick or concrete block walls (see Fig. 8.6). Since the bottom of the beam is in tension (see Fig. 8.4) and would

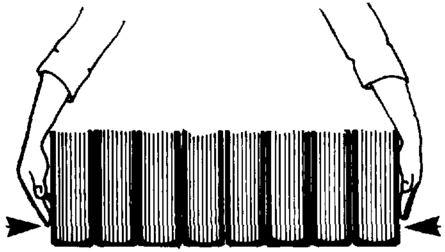

Fig. 8.9—Books demonstrate vertical shear.

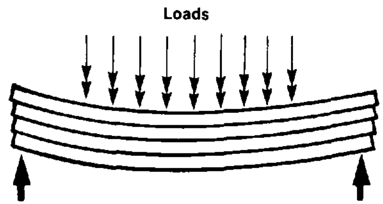

Fig. 8.11—Slippage of individual boards in a stack demonstrate horizontal shear.

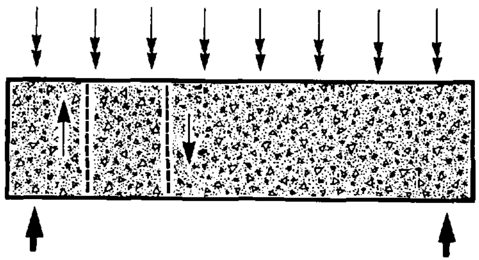

Fig. 8.10—Vertical shear in a concrete beam.

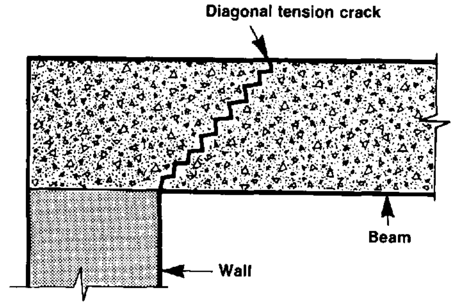

Fig. 8.12—Diagonal tension in a beam at face of wall.

otherwise crack under load, longitudinal bars are required. Shear is also present, resulting in diagonal tension (see Fig. 8.12). Shear is usually at a maximum near the support and decreases toward midspan.

Reinforcement against diagonal tension is called web reinforcement and is provided by vertical bars. U-shaped bars, called stirrups, are used throughout that part of the beam where diagonal cracks would occur. They are more closely spaced near the support and farther apart toward midspan because of the decreasing shear. Stirrups are held by wire ties to the bottom bars with their upper ends tied to stirrup support bars extending from the first to the last stirrup at the end of the beam (see Fig. 8.14).

The purpose of the stirrup support bar is solely to hold the stirrups in place. It is often necessary that bars must be added to properly support the required reinforcement. Normally, these will be indicated on the bar fabricator placing drawings.

There are some circumstances when designing a simple beam where the engineer will call for bars in the top of the member at the supports. This is done by using bottom bars and stirrups, as just described, with the addition of top bars hooked into the support and extending partway across the beam (see Fig. 8.15).

On occasion you may see bottom longitudinal bars that are bent upward, as shown in Fig. 8.16. Since the tensile forces decrease toward the supports, these bars can be bent at a 45 deg. angle; they are called truss bars. Truss bars have lost favor and may soon be eliminated by design engineers. It may

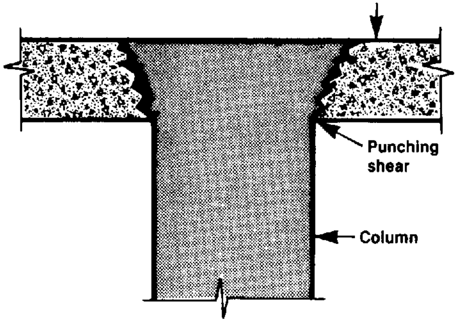

Fig. 8.13—Punching shear in slab at column.

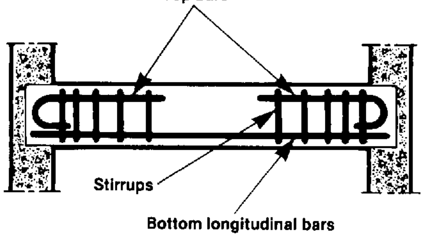

Fig. 8.15—Beam with hooked top bars extending into supports.

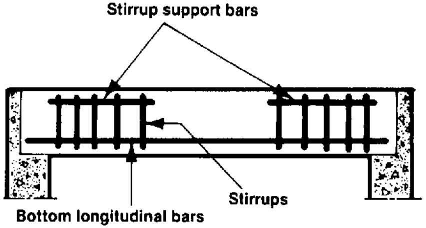

Fig. 8.14—Stirrups to resist diagonal tension.

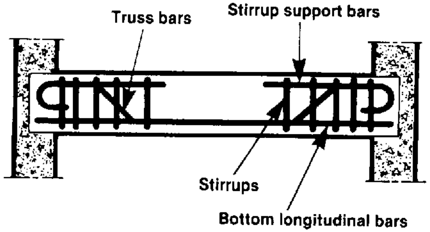

Fig. 8.16—Truss bars bent up from bottom bars.

take a few years for this to happen so you should therefore be aware of truss bars.

Continuous beams. Beams which extend for two or more spans with intermediate supports are called continuous beams. Fig. 8.17 shows the bending action. In this case, the beam ends are fixed (held against turning), instead of resting freely on a support. Note that at the center and end supports the convex surface is at the top, indicating tension in the top at the supports, as well as in the bottom at midspan. This is characteristic of any beam which is fixed at the supports. Fixed supports are those resulting from a beam framing into another beam or girder, or into a concrete wall or column. It is the most common condition encountered in reinforced concrete framing.

Fig. 8.18 shows typical reinforcement required for continuous beams. Hooked top bars are used at exterior supports for proper anchorage. The steel used for tension in the top is called negative steel. At the interior support top bars must extend a sufficient distance into the adjacent span beyond the point where they are needed for tension. The top steel required is provided by straight top bars at the intermediate supports and hooked top bars at end supports.

Compression reinforced beams. Ordinarily, no reinforcement is needed in the compression area of a beam. Most beams are cast together with the slab they support. The beam is then T-shaped, because it includes one-half the slab span between adjoining beams. The slab acts as a flange on the beam

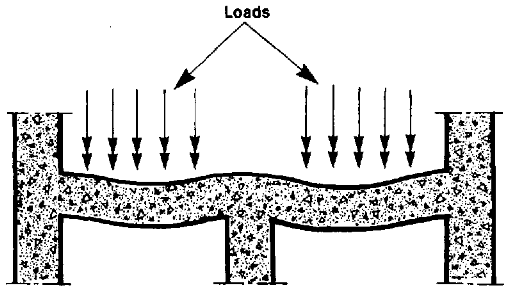

Fig. 8.17—Bending action of a continuous beam over an intermediate support.

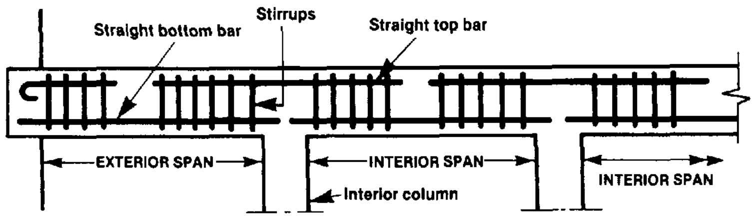

Fig. 8.18—Typical reinforcement for continuous beams.