

# CHAPTER SIX

## Reinforcement

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# 6

## REINFORCEMENT

### TYPES OF REINFORCEMENT

Concrete is a material that is strong when compressed (in compression) but weak when stretched (in tension). Therefore, reinforcing steel is placed in the concrete to increase its ability to resist tension. You will encounter two types of reinforcing steel during your inspection:

- Wire mesh
- Deformed bars

Deformed bars have irregular surfaces so that the concrete will grip and bond with the bars. Bonding enables the concrete to use the strength of the steel. The bars are used either straight or bent to some specific shape. Unless the plans or the Engineer state otherwise, all bending should be cold bending done at the shop prior to delivery. Bars should not be hot bent or straightened, welded, or cut with heat such as a torch, unless it is allowed by the contract documents.

## DELIVERY AND STORAGE OF REINFORCEMENT

Before any reinforcing steel is placed, you must be sure that the proper bars are delivered and that they are stored properly. When reinforcing steel is delivered you must check the following:

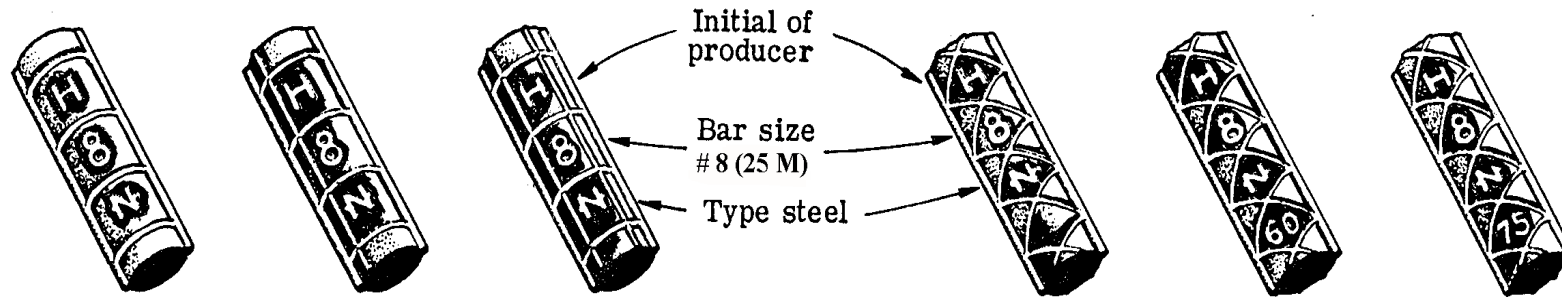
- Check the producer's delivery tickets and heat number tags. These tickets should be compared to the Bill of Reinforcing Steel, in the plans. These tickets should also bear the proper "Buy America" certification.
- Check the bars against the plan requirements for proper grades, lengths, sizes, numbers and bends. An identification tag should be attached to each bundle or group of bars.
- Check all of the bars for corrosion. A thin film of rust or mill scale that cannot be removed by rubbing with burlap does no harm, but any loose rust or scale must be removed before the bars can be used.
- Typically, a 7 foot long random sample of rebar must be taken for every 80 tons delivered to the site and the sample is sent to the State Materials Office in Gainesville. However, the exact rebar sampling requirements of your project must be in accordance with the Material Guide Schedule.

Reinforcing steel bars can be identified according to the designations shown in the plans. In order to do this, you must be able to interpret the manufacturer's markings. Let's take a look at these. Reinforcing steel, by requirement of AASHTO and ASTM specifications, must be identified by sets of marks rolled into the surfaces of the bars. The bar will have three or four marks depending on whether it is grade 40 or 60 and they will be as follows and in the order they will appear on the bar:

### AMERICAN STANDARD BAR MARKS

#### CONTINUOUS LINE SYSTEM

#### NUMBER SYSTEM



ONE VERTICAL LINE

TWO VERTICAL LINES

ENGLISH: Grade 40

Grade 60

Grade 75

Grade 40

Grade 60

Grade 75

METRIC: Grade 300

Grade 400

Grade 500

Grade 300

Grade 400

Grade 500

COMMON GRADES

HIGH-STRENGTH GRADES

COMMON GRADES

HIGH-STRENGTH GRADES

The bar size in English units is roughly its diameter, in eighths of an inch: a #8 bar has a one inch diameter. (This convention begins to break down for bar diameters above #8.) In metric the bar size is approximately its diameter in millimeters: a 25 bar is 25.2 mm in diameter. Most reinforcing bars bearing a Metric diameter mark will not have the "M" designation. You should learn to quickly distinguish between English and Metric bar marks.

After you have checked the bars for certification and markings, the bars can be stored until ready for use. Be sure they are stored above ground -- on platforms, skids, or other supports -- and are protected at all times from damage, corrosion, dirt, scaling, paint, oil or other foreign substances.

Storage is important. As an Inspector, you should be looking for the following:

- Reinforcing steel should be separated and stored according to the part of the structure that the steel will be used in.
- The reinforcing steel that will be used first should be closest to the job site.
- The reinforcing steel should be protected as much as possible from damage or exposure to corrosive conditions. It may be necessary to have protective covers on the steel.
- Reinforcing steel for different structures should be separated.



### **Pre-tied Column Reinforcement**

Notice that the reinforcement is elevated off the ground and is protected from the elements. Also notice the light grey coating from the mill “pickling” process and the light rust present at the bends. These surface conditions are normal and acceptable.

## QUIZ

To verify the quantity, size and shape of reinforcing steel bars, you should consult the \_\_\_\_\_.

In what unit of weight is the quantity of reinforcing bars recorded? \_\_\_\_\_

A bar's size is its \_\_\_\_\_, measured in \_\_\_\_\_ of a an inch.

When reinforcing steel is delivered to your project you will have to check for four things. One of them is a check for corrosion. What are the other three?

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_

To be stored properly, reinforcing steel should:

- A. be separated according to the part of structure.
- B. have protective covers.
- C. be stored above ground.
- D. be separated for different structures.
- E. be stored close to the site, for steel to be used first.

A "60" ("400") marked on a steel bar indicates the bar's \_\_\_\_\_.

## QUIZ, continued

An "8" ("25") marked on a steel bar indicates the bar's \_\_\_\_\_.

What grade of steel bar is indicated by two continuous lines? \_\_\_\_\_

What does the marking "N" mean on a steel bar? \_\_\_\_\_

## PLACEMENT OF REINFORCEMENT

All reinforcing steel must be accurately placed and securely held in position. The Contractor has the option of placing the reinforcing steel either by the piece or in sections. Your job during placement is to see that the correct bars have been installed in the specified locations and that they are firmly held in position during the placing of concrete.

Proper cover -- the distance between the finished surface of the concrete and the nearest surface of the steel -- must be maintained by supporting devices which do not require removal after the concrete is placed, such as stays, spacer blocks or wheels, mortar blocks, ties, hangers, chairs, bolsters. In addition, the bars must be spaced according to the plan requirements.

The concrete cover between the rebar and the outside surface is for corrosion protection. Too little cover means insufficient protection; too much cover can lead to cracking because of shrinkage, temperature or stress. The designer considers all of these issues prior to specifying the cover required in the plans. In practice, however, the exact, planned cover is not always achievable. Consequently, the Specification allows rebars to be slightly out of position which is referred to as a tolerance. Refer to specification Section 415, for the permitted tolerances.

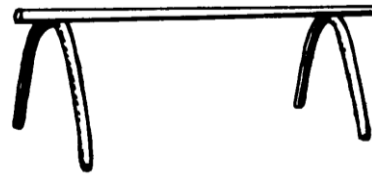
Some of the hardware that may be used to maintain the proper cover and spacing are listed below and on the next few pages.

- Metal chairs are placed under and tied to rebars. They may be in the configuration shown here. Whatever the shape, be sure that the heights of the chairs are correct. Also, the tips of all metal chairs in contact with the outside surface of the concrete must be molded plastic or plastic coated a minimum of 1/2 inch from the outside surface.
- Plastic chairs and bolsters are also permitted.

Low chairs

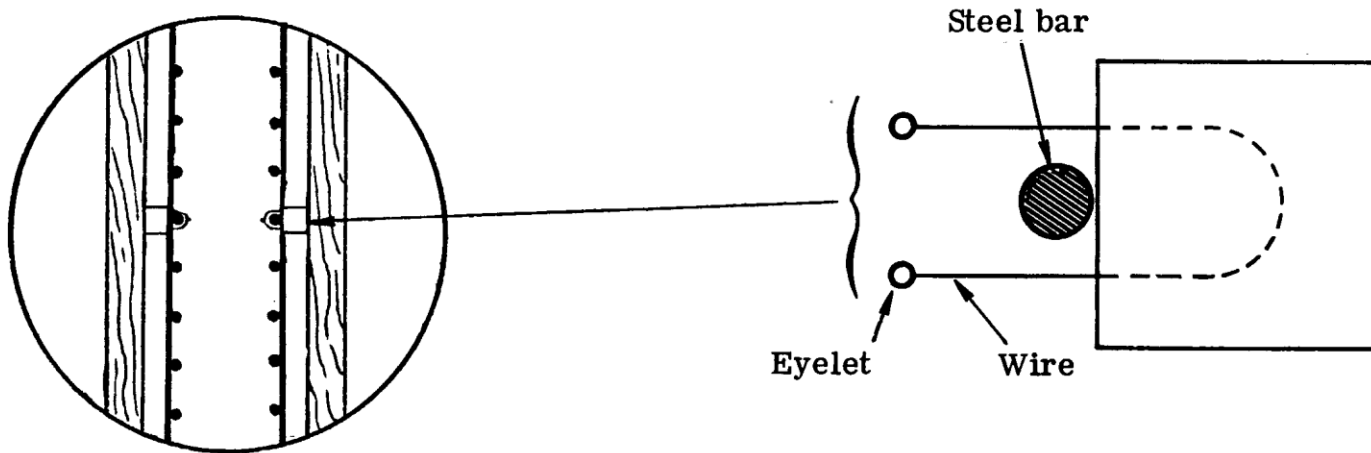


High chairs



Where extensive mats of large diameter bars are used, reinforcing support is especially important. Note the use of mortar blocks to support the bottom mat.

- Precast mortar blocks (sometimes called “hog apples”) with tie wires cast into them also are used for spacing reinforcing steel. The size of the blocks is usually 4 inches by 4 inches by the specified concrete cover. The faces of the blocks should rest on or against the forms to prevent the blocks from being dislodged when the forms are removed. Pebbles, broken stones, metal pipes or wood blocks are not acceptable substitutes for precast mortar blocks.



When the Contractor is making mortar blocks, be sure that the bottom of the loop is satisfactorily anchored in the mortar. Also, when the loops are tied, the wire should be bent in such a way as to be as far as possible from the outside surface of the concrete to provide maximum concrete cover. This is to prevent or minimize corrosion.

- Wire ties are used to hold rebars together where they intersect. You should check Standard Specifications Section 415, to see what type of tie should be used for each structural member (footings, columns, walls, beams, caps, slabs and culverts). Also, since ties are not always required at each intersection, the Standard Specification will delineate which intersections require ties. Several different ties are shown below. The twisted ends of wire ties should project away from exterior surfaces.

Study the ties shown at right:

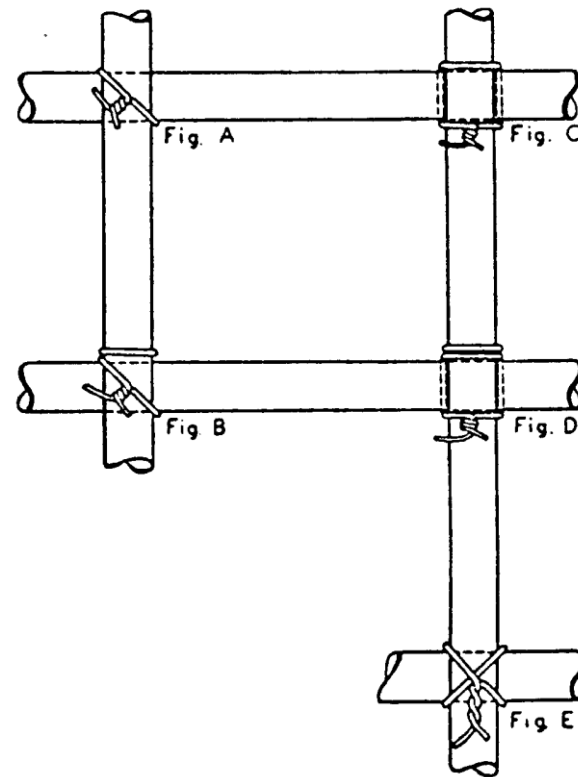
Figure "A" shows a Single or Snap Tie.

Figure "B" shows a Wrap-and-Snap Tie.

Figure "C" shows a Saddle Tie.

Figure "D" shows a Wrap-and-Saddle Tie.

Figure "E" shows a Figure Eight Tie.



As was just mentioned, the Contractor may place reinforcing steel either by the piece or by assembling the steel into mats or cages before placing it in the forms. As an Inspector, your job is to inspect the Contractor's work to verify that it complies with the plans and specifications. Below and on the following pages are items you should check and observe during the placement of reinforcing steel:

- Count the number of bars used. It should exactly equal the number called for in the plans.
- It is critical that the correct rebar, as far as size and length, is placed at the exact location in the structure that the plans indicate. Remember, the size numbers are stamped on all bars. You should check spacing and length with a tape or rule at random points and should check all spacing by eyeballing chalk lines on forms.
- Be sure the bars are secured with the correct ties and in the proper manner, according to the Specifications. The bars, supports and ties must form a rigid cage that will not deform or be displaced by concrete placement, vibration, screeds, finishing equipment or workmen.
- Never allow tack welding instead of tying -- this practice weakens the steel.
- Check splices. Splicing of reinforcing bars is allowed only when shown on the plans. Usually, splices are made in areas that are away from points of maximum stress and are lapped a sufficient distance to transfer the entire capacity of the bars through the splice. The plans will usually specify a minimum distance for the bar laps. Keep in mind that this is a minimum.

- Check the bar laps at splices. Overlap distances should be shown in the plans. If the lap distance does not appear in the plans, ask the Project Administrator what the distance should be. Bar overlap at splices must not be less than 30 bar diameters unless shown otherwise in the plans.

Keep in mind that the splices should be arranged to obtain the specified clearance between the splice and the surface of the completed concrete. The clear distance between adjacent splices must be at least 1 inch.

Also check to be sure that the bars are rigidly clamped and wired at each splice. They must be fastened together tightly. Before any splicing takes place, you must consult your Project Administrator.

- Splicing by welding will be permitted only if indicated in the plans or if authorized by the Engineer in writing. When a weld is specified, consult your Project Administrator as to what is required of the Contractor and as to what you will need to inspect.
- You must verify rebar spacing and location. It is difficult and sometimes impossible to place the bars exactly as shown in the plans. However, the steel should be placed as close to the planned location as possible. Equal distribution of the reinforcing steel is important so that each reinforcing bar carries its proportionate share of the load. Uneven distribution of the steel can cause the concrete to crack. A bar should never be omitted or cut without the approval of the Engineer. Similarly, bars should never be displaced vertically by increasing or decreasing the cover.
- Watch for bent bars. If you find a bar with a major kink or bend that is not called for in the plans, the bar should be rejected. If the bend or kink is minor, it may be straightened with a rebar bending device commonly referred to as a Hickey Bar and which is specifically designed to bend or unbend rebars without damaging them. However, keep in mind that if a bar is repeatedly bent, it will be weakened. When rebars are fabricated they are bent around pins, which eliminate sharp-angle bends.

- Heating reinforcing bars for bending is not allowed, since heating can change the characteristics of the steel and weaken it.
- Check the conditions of the bars. The surfaces should be free of dirt, oil, grease, mortar or any other foreign material which may prevent the steel from bonding with the concrete.

Study your responsibilities again, starting on page 6-11, then try the quiz on the next page.

## QUIZ

Name two ways in which the Contractor can place reinforcing steel.

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Why are steel bars supported by chairs or mortar blocks? \_\_\_\_\_

A mortar block is generally 4 inches by 4 inches by \_\_\_\_\_.

The twisted ends of wire ties should project \_\_\_\_\_ exterior surfaces.

Never allow \_\_\_\_\_ instead of tying reinforcing steel.

Unless shown otherwise on the plans, bar overlap at splices must be at least \_\_\_\_\_ bar diameters.

Splices should be made away from areas of \_\_\_\_\_ stresses.

What may happen to the concrete if the reinforcing steel is unevenly distributed? \_\_\_\_\_

Two #6 (19) bars are spliced. If the plans do not indicate a splice distance, what is the minimum overlap distance that you must measure when you check the splice? \_\_\_\_\_

Are reinforcing steel bars bent by heating? \_\_\_\_\_

Go on to CONTRACTOR NONCOMPLIANCE.

## CONTRACTOR NONCOMPLIANCE

The placement of reinforcement is a critical operation. A poor job of placement, if not corrected, will produce a structure of questionable strength and service life -- or can cause immediate and total failure of the structure. For this reason, the Contractor should take extreme care in this portion of the work.

Improper spacing of bars or missing bars will cause too much stress on properly placed bars, reducing the structural strength. And, it can cause concrete damage.

It has been determined that, in a deck 6 inches thick, a 1/2-inch mistake in the vertical placement of the bars will affect the load-carrying capacity of the deck by as much as 20% -- you can see just how important positioning of steel is.

Too little concrete cover -- a result of improper spacing -- could cause cracking, spalling, reduced strength and, finally, failure. Also, too little cover can expose reinforcing steel, which will corrode, causing further damage.

This can be a serious problem in Florida. In coastal areas, the harsh salt water environment accelerates corrosion which leads to spalling, which leads to further corrosion and -- ultimately -- failure.

- The use of wrong size bars will cause:
  - Reduced strength, if smaller bars are used.
  - Difficulty in concrete consolidation and too little concrete cover -- especially in walls and other confined areas -- if larger bars are used.
  
- The use of dirty or oily reinforcing steel bars will cause:
  - Poor bonding.
  - Reduced structural strength.
  - Possible concrete failure.

In all cases, your response to noncompliance is the same. You should tell the Contractor of your findings and tell him that the situation must be corrected before concrete operations begin. Also, keep your supervisor informed of any problems. If the problems are not corrected within a reasonable amount of time, you should contact the Project Administrator and advise him of the situation. An Inspector should never attempt to suspend operations or shut a Contractor down. This must be done by the Project Administrator.

## COMPENSATION

Reinforcing steel is usually measured and computed for payment by the pound. Payment is based on or computed from the dimensions specified in the plans. Also, the table below should be consulted. Keep in mind that this table may be updated, so consult the latest Standard Specifications or Special Provisions.

The Contractor is responsible for the proper positioning of the bars and will not receive extra compensation for any device used for splicing, clamping, tying or positioning of reinforcement.

Bar Designation English / (Metric)	Weight in lbs./LF	Bar Designation English / (Metric)	Weight in lbs./LF
#4 (13)	0.668	#9 (29)	3.400
#5 (16)	1.043	#10 (32)	4.303
#6 (19)	1.502	#11 (36)	5.313
#7 (22)	2.044	#14 (43)	7.650
#8 (25)	2.670	#18 (57)	13.600

## QUIZ

Match one or more items from the CAUSES column below with each result in the RESULTS column and enter the choice/s in the blank to left of the results item.

### RESULTS

- \_\_\_ 1. Concrete cracking, and accelerated corrosion
- \_\_\_ 2. Too much stress on properly placed bars
- \_\_\_ 3. Reduced strength, if smaller bars are used
- \_\_\_ 4. Exposed reinforcing steel resulting in corrosion
- \_\_\_ 5. Exposed reinforcing steel resulting in corrosion
- \_\_\_ 6. Difficulty in concrete consolidation and too little concrete cover, if larger bars
- \_\_\_ 7. Poor bonding

### CAUSES

- A. Use of wrong size bars
- B. Improper spacing of bars or missing bars
- C. Use of dirty or oily reinforcing steel bars
- D. Too little concrete cover

What should you do if you find one of the "Causes" above before concrete is placed? \_\_\_\_\_

What should you do if you find one or more of the "Results" after concrete is placed? \_\_\_\_\_

Refer to the table on page 6-19. What is the weight of fifteen, 6-foot, #4 (13) bars? \_\_\_\_\_

## ANSWERS TO QUESTIONS

### Page 6-7

- Plans
- Pounds
- diameter, eighths of an inch or millimeters
- 1. Delivery tickets and heat number tags
- 2. Proper grades, lengths, sizes, numbers and bends
- 3. 7 foot long sample per 20 tons delivered
- All of them
- grade

### Page 6-8

- size
- 75
- The type of steel

### Page 6-16

- By the piece, Assembled in Sections
- To maintain proper cover (clearance)
- specified clearance
- away from
- tack welding
- 30
- maximum
- The concrete may crack
- 22.5 inches
- No

### Page 6-20

1. A, B, D
  2. A, B
  3. A
  4. A, B, C, D
  5. D
  6. A, B
  7. C
- Tell the Contractor to correct the situation
  - Inform Contractor and Project Administrator and watch for the cause in the next placement.
  - 60.12 pounds