705.00 REINFORCEMENT (*SSHC Section 707*)

705.01 DESCRIPTION

A. The reinforcement of concrete for structures consists of furnishing and placing deformed metal reinforcing bars or welded-wire fabric in the concrete as required by the plans and specifications.

705.02 MATERIAL REQUIREMENTS (*SSHC Subsection 707.02*)

A. Samples of reinforcing steel and welded-wire fabric are required by the Central Laboratory unless these materials are shipped from tested stock. Generally reinforcing steel has been sampled and tested before shipment to the project, and will arrive with acceptance tags attached. At the time this steel is placed in the work, the structure inspector should collect, record in field book, and submit the tags to the Project Manager. Steel arriving untagged should not be incorporated in the work until approved by the Materials Engineer. See the "*Materials Sampling Guide*".

B. The Materials and Research Division requires that two 6 ft (2.0 m) sample lengths of epoxy-coated reinforcing steel be submitted for testing purposes, and a special provision to that effect will be included in future contracts.

C. Similarly, the *Materials Sampling Guide* requires two 6 ft (2.0 m) sample lengths for uncoated reinforcement bars be provided (unless shipped from tested and approved stock). Enter the date resteel is verified on-site in SiteManager.

705.03 CONSTRUCTION METHODS (*SSHC Subsection 707.03*)

A. Placement and Checking (Bridge Deck)

1. Bridge plans specify nominal slab thickness and nominal clearance of reinforcing bars from face of the concrete. This section will establish acceptable deviations from nominal plan dimensions.

2. Four dimensions must be given special attention when checking placement of bridge slab reinforcing:

   (a) Slab thickness.

   (b) Clearance of bottom reinforcement from bottom of slab.

   (c) Distance from bottom of slab to top of top mat of reinforcement.

   (d) Cover over top mat of reinforcement

B. Slab Thickness

1. This shall be the nominal slab thickness shown on the plans with a tolerance of minus zero and plus ½ inch (13 mm).

C. Clearance of Slab Reinforcement

1. The reinforcing steel shall be placed to monitor the nominal clearances shown in the plans ± ¼ inch (5 mm). Contractors must provide an adequate number of bolsters and/or bar chairs of suitable height and strength to maintain clearance within this range.

2. Contractors must provide an adequate (sag shall be minimal, see *SSHC Figure 707.01*) number of bar chairs of suitable height and strength to maintain the distance within this range of tolerance.

D. Protection of Material (*SSHC Subsection 707.03*)

1. The Specifications provide that steel reinforcement shall be protected at all times from damage. When placed in the work, it shall be free of dirt, loose scale, detrimental rust, paint, oil or any foreign material. Detrimental rust is defined as heavy reddish coating formed on iron or steel when chemically attached by moist air. This must be removed by wire brushing. However, a light layer of rust or mill scale that is not readily removed with a wire brush is acceptable.

E. Placing and Fastening (*SSHC Subsection 707.03*)

1. Positioning - It is essential that inspectors give special attention to the placement of reinforcing steel in all structures. Reinforcement shall be placed in the exact position shown in the plans and held securely in that position to preclude movement or shifting during placement of the concrete. On a 7 inch (175 mm) thick bridge floor, designed with the top steel 1 ¾ inch (45 mm) below the surface, a sag or displacement in the top steel of only ½ inch (13 mm) will reduce the strength of the floor 19 percent. The reduction in strength of thinner sections such as culvert slabs and walls is even more critical.

2. Present policy is to tie all bar intersections except when the bar spacing is less than 12 inches (300 mm) in both directions in which case alternate intersections may be tied. This requirement is enforceable through *SSHC Subsection 707.03* in that it specifically defines the frequency of tieing. The Project Manager should thoroughly study the project documents in order to be aware of this requirement as well as any change which might occur in this revision.

3. Horizontal reinforcement in slabs shall be spaced vertically by means of approved metal chairs. The type and adequacy of bar support systems which includes the spacing of bar supports shall be in accordance with the Concrete Reinforcing Steel Institute's "Manual of Standard Practice", unless other stipulations are provided in the contract provisions. A copy of this manual may be obtained from the District Construction Engineer. Bar supports which are located at exposed concrete surfaces shall be galvanized, plastic coated or stainless steel to a depth of ½ inch (13 mm) minimum from the concrete surface. Chairs may also be used to keep vertical columns and wall steel from contacting the form.

4. Field welding will be permitted only when shown on the plans or with written permission of the Construction Engineer. Reinforcement can best be checked as the work progresses rather than waiting until the contractor has enclosed the reinforcement with forms. In the case of walls and columns it is virtually impossible to do the checking after the forms are in place. When bent bars are used, a check should be made that there are no cracks or splits at the bends. Stirrup hooks should be rotated to different positions in order that the hooks do not fall in the same location when a series of stirrups are used in beams or columns.

5. No welding will be allowed on the main vertical steel of high mast lighting tower foundations except at the very top and bottom where the end loops may be tack welded. If a more rigid cage is desired, additional vertical steel will be required to act as the frame and lifting points for the cage. The required loops may be tack welded to this additional vertical steel. The required vertical steel will then need to be wire tied to the tack welded loops.

6. Welding of all loops, other than the top and bottom loop, to the required vertical steel will not be allowed. Additional bracing may be tack welded to the added vertical bars, if required. The added vertical bars should be sized to support the required load.

7. *SSHC Subsection 704.03* requires the contractor to give the Project Manager sufficient advance notice before starting concrete operations in any unit of a structure, to permit the inspection of forms and reinforcing bars. The Project Manager shall require all reinforcing steel to be accurately placed and firmly held in position.

F. Special Attention Areas

1. Tie-Downs and Supports

   a. *SSHC Subsection 707.03* require that the top mat of reinforcing steel is to be tied down at not greater than 4 feet (1.2 m) spacing measured in each direction. This requirement can partially be met by wiring the top mat down to shear lugs at 4 feet (1.2 m) spacing along the beam. Regardless of beam spacing, the top mat must be tied to the forms or the bottom reinforcing mat at 4 feet (1.2 m) spacing. Likewise, the top reinforcing mat is to be tied to the bottom reinforcing mat on a 4 feet (1.2 m) grid in floors of concrete slab bridges. Tying should include bars near the ends of the bridge and bars near the curbs. **At least 50 percent of the bar contacts must be tied unless the spacing is more than 1 ft (300 mm) and then every bar contact must be tied.**

2. Epoxy Coated Bar

   a. Epoxy coated reinforcing steel requires the use of epoxy or plastic coated bar supports and tie wires (*SSHC Subsection 707.03*). Epoxy coated tie wires may tend to slide or break. If this occurs, they should be double tied or stronger ties used.

3. Clearance Check

   b. The specified clear distance from surface to reinforcing steel must be maintained. To check this, a clearance guide ¼ inch (5 mm) less in thickness than the specified clearance to top steel should be temporarily fastened to the bottom of the finishing machine screed. The finishing machine should then be operated along the bridge to insure that proper clearance is obtained. It will be necessary to bend all tie wire loops down to permit the clearance gauge to pass. Any steel not properly placed must be corrected.

4. Checks During Placement

   a. Checks of slab thickness and cover over top reinforcement must be made in the finished concrete directly behind the finish machine. A thickness and cover check should be made at the same location of an approximate grid of 10 ft (3 m) transverse and 20 ft (6 m) longitudinal. These checks must be documented in the field book. When the slab is of deficient thickness or cover checks indicate incorrect rebar placement corrections must be made immediately.

5. Cleaning Forms and Steel

   a. Mud and other foreign material must be removed from the steel and forms prior to placement. Remove any trapped/ponded water before placing the concrete.

G. Epoxy-Coated Reinforcement (*SSHC Section 1021*)

1. Epoxy coatings are applied to reinforcing bars by a fusion-bonded process. This means the coating achieves adhesion to the bar as a result of a heat-catalyzed reaction. Besides chemical adhesion, there is also physical adhesion of the coating to the bar.

H. Care and Handling

1. Epoxy coated bars are subjected to many quality control tests and inspections prior to leaving the supplier's facility. However, from that point forward, careless handling and construction practices can cause excessive coating damage. Contractors should be strongly encouraged to exercise care in handling, storage, and placing of epoxy coated bars. If problems are noted after delivery, the inspector is to contact the Materials and Research Division.

2. Handling

   a. During unloading epoxy coated bars from the truck, care must be exercised to minimize scraping of the bundles or bar-to-bar abrasion from sags in the bundles. Skidding bundles from the truck onto the ground should not be allowed. Use of power hoisting equipment for unloading and handling is strongly encouraged. Further, equipment for handling the bars should have

protective contact areas. Specifically, nylon slings or padded wire rope slings should be used and bundles should be lifted at multiple pick-points.

3. Storage

a. Epoxy coated bars should be stored on timbers or other suitable protective cribbing. All types of reinforcing bars should be stored off the ground as close as possible to the area where they will be used. The following storage practices are suggested to prevent damage:

b. Store bars above the ground on timbers, cribbing, or dunnage placed close enough together to prevent sags in the bundles.

c. If a large quantity of bars has to be stored in a small area, bundles can be stacked if adequate blocking is placed between the layers.

d. While fading of the coating's color is not specifically detrimental, it should be avoided to the fullest extent possible. One recommended method is to cover exposed bundles with burlap or dark plastic.

NOTE: If plastic or other nonporous material is used for covering, the ends must be left open to allow air movement. Without this, condensation under the cover could cause damage.

e. Long-term site storage (from one year to the next) of epoxy coated bars is not recommended.

4. Placing

a. Placing of epoxy coated bars is done similar to uncoated bars. The KEY exception is that coated bars require more careful handling and placing. Once bundles have been opened, dragging one bar over another or over any abrasive surface MUST be avoided.

b. After epoxy coated bars are placed, walking on the bars by construction personnel should be held to a minimum. Bars in high traffic areas or runways for concrete placement should be protected with plywood or other suitable material. Concrete placement equipment shall not be placed on, or supported by, any reinforcing steel.

c. Bar supports and tie wires for epoxy coated reinforcement shall be coated with epoxy, nylon, or plastic.

l. Field Inspection

1. Epoxy coated bars should be inspected for damaged coating:

a. when received at the job site, and

b. after they are placed in the structure.

2. Damage Evaluation and Repair

a. Damaged coating shall be evaluated as outlined below. The "holiday detector" should be used to determine coating flaws.

b. Bent Bars

(1) Examination of physical coating condition on the outside radii of hooks and other bends might reveal cracks in the coating. When cracking of the coating is evident, the contractor must remove loose coating, clean the area, and repair.

c. Fading of Color

(1) When epoxy coated bars are exposed to sunlight over a period of time, fading of the color may occur. Since discoloration does not harm the coating nor affect its corrosion protection properties, such fading will not be cause for rejection.

d. Damaged Ends

(1) Damage to ends because of field shearing, dragging or whatever must be repaired in the field.

J. Repair of Damaged Coating

1. When a damaged coating must be repaired, the patching or touch-up material should be applied in strict accordance with the instructions furnished by the manufacturer. Generally, surface preparation consists of a **THOROUGH** manual cleaning of damaged areas, including complete removal of: (1) unbonded epoxy and (2) all rust. Cleaning is usually accomplished with a power driven wire brush, hand steel brush, and/or emery paper. Care should be exercised during preparation so that excessive sound epoxy is not damaged. Acceptance criteria for epoxy repair and touchup materials is in accordance with the original epoxy resin manufacturer's recommendations.

2. Epoxy coated reinforcing steel is used in concrete bridge decks to prevent spalling of the concrete which is, in turn, caused by the corrosion of the reinforcing steel. The epoxy coating prevents the corrosion of the reinforcing steel. Two factors influence the capability of the coating to prevent corrosion. One of these factors is the thickness of the coating. The other factor is the integrity of the coating, i.e., the absence or presence of defects in the coating which would allow moisture and de-icing chemicals to reach the metal itself.

3. The epoxy coating on the rebars may have three types of defects when the bars arrive at the site. One of these is defined in the Specifications as a "holiday." A holiday is a small hole in the coating which is not visible to the naked eye. This type of defect is the result of some inadequacy in the application process. Holidays can be detected only with an electronic detector and the Specifications permit two holidays per 1 foot (300 mm).

4. The second type of defect, which may be present in the epoxy coating when the bar arrives at the site, is defined as handling damage. Handling damage may take the form of scuffs, scars, scratches or any other wound to the coating caused by rough handling. The Specifications permit a "reasonable" amount of handling damage. Handling damage is generally visible to the naked eye since rust will form over the damaged spot after a sufficient amount of time passes. A fresh cut or scar in the coating would probably be difficult to locate visually, but would be readily picked up with an electronic detector.

5. The third type of defect, which may be present in the epoxy coating when the bar arrives at the site, is due to what may be considered as an "uncoatable" bar. During the rolling process, some bars are formed with very sharp edges on the deformations and ribs.

6. These edges are very difficult to coat adequately, and coating applicators usually avoid coating bars so formed. The defect in coating on these edges may or may not be visible to the naked eye. This particular defect can be detected with an electronic detector. When this defect is present, the detector will indicate this flaw by a constant 'beeping' when run along a rib. In most instances, the thickness of the epoxy coating will be very low in these areas or there may be no coating at all where the sharp edges are present.

7. Materials and Research Division personnel will inspect epoxy coated rebars at the coating applicator's plant in some, but not, all cases. In cases where inspection is made at the applicator's plant, the bars will have a maximum of two holidays per meter, plus handling damage, is allowed, when they arrive at the site. In addition, the coating thickness, on bars inspected at the applicator's plant, must meet the specification requirements for thickness of coating. Bars not so inspected at the applicator's plant will have an unknown number of holidays and possibly uncoated sharp edges plus handling damage when they arrive at the site and, in addition, the coating thickness will not have been checked. Bars that contain rolling defects or have uncoated sharp edges that are found during the inspection shall be rejected.

8. The basis for acceptance will be the total of defects per 1 foot (300 mm) of bar, i.e., holidays plus handling defects as located with the electronic detector.

9. A total of six defects in any 1 foot (300 mm) of the bar will be permitted. As an example, in a bar of given length, if any 1 foot (300 mm) section of that bar has no more than the two allowable holidays and four handling defects, the bar is acceptable, providing none of the four handling defects has an area greater than 0.0025 $ft.^2$ (225 mm^2). [A square measuring 0.05 ft x 0.05 ft (15 mm x 15 mm) has an area of 0.0025 $ft.^2$ (225 mm^2)]. All handling defects having an area greater than 225 mm^2 must be repaired.

10. The following points may be helpful in the inspection and repair of epoxy coated rebars in the field.

    a. Inspect bars for coating defects, using the electronic detector, as they come out of the bundle.

b. It may not be necessary to check all bars in each bundle, but enough bars out of each bundle should be checked in order to determine the quality of coating on all bars in the bundle.

c. When the number of defects per 1 foot (300 mm) section exceeds six, only the number of defects necessary to bring the bar into compliance need be repaired. Only exception is that all defects greater than .00005 in^2 (.035 mm^2) must be repaired.

d. Repair of defects is accomplished with an approved two component epoxy compound supplied by the coating manufacturer.

e. Epoxy compounds used for repair have a minimum temperature at which they may be used and a limited pot life, as recommended by the manufacturer.

f. Any rust showing through the defect must be removed before applying the epoxy compound. A file or grinding wheel may be used provided no substantial reduction in the area of the bar occurs.

g. Coating thickness of the painted repair area must be as specified for the factory applied coating.

h. Coating on bars may be damaged during placement at the site. Such damage to the bars must be repaired when the bars are in place, if the six defects per 1 foot (300 mm) section limitation is exceeded.

i. Check coating thickness if bars were not inspected at the coating applicator's plant. This should be done as they come out of the bundle. Coating thickness is checked with a magnetic thickness gage.

j. To obtain a holiday detector, contact the nearest branch laboratory or the Construction Division. "Electometer" magnetic thickness gages may be obtained by requisition from the Engineering Equipment Section, "Inspector" or "Microtest" thickness gages which are used for checking paint film thickness cannot be used for checking epoxy coating thickness on reinforcing steel.

11. For situations where there is no information available as to what type of touch-up material should be used, 3M Corporation has two products available:

a. SCOTCHKOTE 213 is often used to repair minor nicks and gouges.

b. SCOTCHKOTE 312 is a two component epoxy that has been used to repair both small and large areas of damage.

NOTE: Repaired areas do not have as much corrosion or abrasion resistance as factory-applied coatings.

K. Bar Designation System

1. You must be very careful when you review a bar list. Currently, steel bar in the USA is usually measured in English units. Do not assume anything; measure to be sure you are getting the correct size. In general, the mark number for reinforcing bars as shown in the plans generally uses the following designation system. The first letter or letters identify the general location of the bar such as abutment, pier, or slab bar.

Location	Code
Abutment	A
Pier	P
Slab	S

2. The first number or numbers indicate the size of the bar and the last two numbers indicate whether the bar is bent or straight. (Even numbers are straight bars and odd numbers are bent bars.)

3. For example, P1002 would be a straight No. 10 bar located in the pier; A415 would be a bent No. 4 bar located in the abutment. The last two numbers also indicate the approximate length of the bar. The lower the number the longer the bar; for example, a S602 bar would indicate the longest, straight, No. 6 bar used in the slab, whereas a S612 bar would indicate that there are five groups of straight, No. 6 bars that are longer than the S612 in the slab. The reinforcing steel table in *Appendix 4* lists pertinent information concerning the standard bar designation system.

L. Splicing

1. All reinforcement shall be furnished in the full lengths indicated in the plans. Splices, not shown in the plan, shall not be allowed without approval of the Project Manager. Welding shall be allowed only if shown in the plans or authorized by the Construction Engineer in writing.

2. When splices are required, they should be staggered as far as possible in order that a plane of weakness is not caused in the member. The laps should be at least as long as is shown in the plans and if no lap is shown, the bars should be lapped as required in *SSHC Subsection 707.03*. Splices should preferably be made in areas of low stress concentration. The bars in the top of a slab or beam should be spliced in a positive moment section (bottom of slab or beam in tension) and the bars in the bottom of a slab or beam should be spliced in a negative moment section (top of slab or beam in tension). For example, the longitudinal bars in the top of a slab should be spliced near the center of the span rather than over a pier and the longitudinal bars in the bottom of the slab should be spliced near the pier rather than in the middle of a span. Following is a tabulation of 24 and 36 diameter lap requirements for the various sizes of rebars.

ASTM Standard Reinforcing Bars				
		Nominal Dimensions - Round Sections		
Bar Size Designation	Weight Pounds per Foot	Diameter Inches	Cross-Sectional Area - Sq. Inches	Perimeter Inches
#3	.376	.375	.11	1.178
#4	.668	.500	.20	1.571
#5	1.043	.625	.31	1.963
#6	1.502	.750	.44	2.356
#7	2.044	.875	.60	2.749
#8	2.670	1.000	.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	7.650	1.693	2.25	5.320
#18	13.600	2.257	4.00	7.090

LAP REQUIREMENTS			
Metric Bar Size	English Bar Size	24 Diameter Lap Grade 40 Steel	36 Diameter Lap Grade 60 Steel
10	2	6 in (150 mm)	9 in (225 mm)
10	3	9 in (225 mm)	14 in (350 mm)
10	4	12 in (300 mm)	18 in (450 mm)
15	5	15 in (375 mm)	23 in (575 mm)
15	6	18 in (450 mm)	27 in (675 mm)
25	7	21 in (525 mm)	32 in (800 mm)
25	8	24 in (600 mm)	36 in (900 mm)
30	9	27 in (675 mm)	41 in (1025 mm)
30	10	30 in (750 mm)	44 in (1100 mm)
35	11	33 in (825 mm)	49 in (1225 mm)

3. There are times when splicing of rebar in a manner other than lapping is necessary. Examples include:

   a. Complicated placement where the cage could be tied off site, in sections, and set in place.

   b. Reinforcement cages for drilled shafts.

   c. Situations where an existing rebar is not long enough to develop strengths by lapping.

4. Example: During removal of an existing curb on a bridge deck widening project existing rebar is either cut with the saw or broken during concrete demolition. In this case additional demolition is needed to provide a lap development length.

5. Mechanical splices are only authorized where shown in the plans and materials must be in the NDR Approved Products List. Currently, several couplers are manufactured which can be used to mechanically splice rebar. Mechanical splices, for field approval, shall develop 125% of the rebar's yield strength. Consideration for splice usage must be initiated by the contractor. The Project Manager is to forward that request to the Construction Division for review.

705.04 METHOD OF MEASUREMENT (*SSHC Subsection 707.04*)

A. Reinforcing steel for concrete structures is measured by the pound. Quantities to be paid for are computed from the theoretical mass of bars and wire mesh. The mass of steel reinforcement required for structures of varying sizes is usually given in tables on standard and special plans. The quantities contained therein may be used for computing final payment for structures except bridges. Plan quantity may be used for final quantity reinforcing steel for bridges.