11.40 REINFORCEMENT

General Placement Guidelines for Bridge Reinforcing Steel

Bridge plans and bridge standards typically provide the following information regarding placement of reinforcing steel: reinforcing bar spacing, reinforcing bar required splice lengths, and reinforcing bar edge and end clearances. The intent is for the reinforcing steel in each of the above cases to be installed as specified. In application, it will be necessary to determine what is considered reasonably acceptable. For reinforcing steel placement in bridges, the following guidelines are recommended:

- Reinforcing bar spacing should be within 13 mm (1/2 inch) of the specified spacing to be considered reasonably acceptable.
- Reinforcing bar required splice lengths are typically represented as minimum splice lengths. Reasonably acceptable splice lengths shall never be less than the minimum specified.
- Reinforcing bar edge and end clearances are typically represented by the plan note "Minimum clear distance from face of concrete to near reinforcing bar is to be 50 mm (2 inches) unless otherwise noted or shown." Reasonably acceptable clearances for bridge structures, other than bridge decks, shall be the clearance specified on the plans with a tolerance of minus zero and plus 13 mm (1/2 inch).
- Specification 2404.03, E requires that all vertical reinforcement shall be positioned using side-form spacers. Side-form spacers are chairing devices (similar to chairs used for support of horizontal reinforcement) used to positively position vertical reinforcing steel at the required clearance from the face of concrete (surface of forms).

  Clearances and respective tolerances for bridge deck reinforcing are defined in *Construction Manual 11.41.*

  Field welding of deformed reinforcing steel is not permitted without the approval of the Construction or Bridge Engineer as stated in *Materials I.M. 558, Field Welding Inspection Manual.*

11.41 PLACEMENT AND CHECKING (BRIDGE FLOORS)

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

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

1. Slab thickness
2. Clearance of bottom reinforcement from bottom of slab
3. Distance from bottom of slab to top of top mat of reinforcement
4. Cover over top mat of reinforcement

Slab Thickness

This shall be the nominal slab thickness shown on the plans with a tolerance of minus zero and plus 19 mm (3/4 inch).

Clearance of Bottom Reinforcement

The clearance of bottom of reinforcement from bottom of slab shall be the nominal clearance shown on the plans with a tolerance of minus 3 mm (1/8 inch) and plus 6 mm (1/4 inch). Contractors must provide an adequate number of bolsters and/or bar chairs of suitable height and strength to maintain clearance within this range.

Clearance of Top Mat Reinforcement
Distance "d" is the slab thickness minus specified concrete cover over the top steel.

When all top reinforcing is of the same diameter, the nominal "d" distance is to be maintained with a tolerance of minus 6 mm (1/4 inch). The nominal "d" distance may be increased as long as the requirements for slab thickness and cover over top reinforcement are met. Contractors must provide an adequate number of bar chairs of suitable height and strength to maintain the distance within this range of tolerance.

When more than one diameter of top reinforcement bar is used, the above described "d" distance shall be maintained for the larger diameter bar. The distance may be decreased for the smaller diameter bar by an amount not to exceed the difference in the bar diameters.

Cover Over Top Mat of Reinforcement
Minimum allowable cover shall be the nominal cover shown on the plans minus 3 mm (1/8 inch). Maximum cover will be controlled by maximum allowable slab thickness.

Slab Bridges
Some slab bridges have the bottom of slab formed in a straight line from edge to edge, while the top of slab is crowned. This results in a variable slab depth of a variable distance from bottom of slab to top of reinforcing. The contractor will have to provide variable height bar chairs to maintain the proper positioning for top reinforcing for these slab bridges.

Special Attention Areas

A. Tie-downs and Supports
Specification 2404.03, E and 2412.03, B require that the top mat of reinforcing steel is to be tied down at not greater than 1.2 m (4 foot) spacing measured in each direction. This requirement can partially be met by wiring the top mat down to shear lugs at 1.2 m (4 foot) spacing along the beam. Regardless of beam spacing, the top mat must be tied to the forms or the bottom reinforcing mat at 1.2 m (4 foot) spacing. Likewise, the top reinforcing mat is to be tied to the bottom reinforcing mat on a 1.2 meter (4 foot) 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% of the bar contacts must be tied. (Refer to *2404.03, D and* 2412.03, B.)

Specification 2404.03, E requires that bottom and top mat reinforcing be independently supported. The support system spacing shall not exceed 4 feet (1.2 m) in each direction for bolsters or continuous high chairs and 3 feet (0.9 m) in each direction for individual high chairs. These supports should also be placed near the ends of the bridge and under bars near the curbs to ensure bar position and clearances are maintained.

B. Epoxy Coated Bar
Epoxy coated reinforcing steel requires the use of epoxy or plastic coated bar supports and tie wires (2404.03, E.) Epoxy coated tie wires may tend to slide or break. If this occurs, they should be double tied or stronger ties used. Note: Approval for support chairs and bolsters is now included in *Materials IM 451.01*.

C. Clearance Check

The specified clear distance from surface to reinforcing steel must be maintained. To check this, a clearance guide 6 mm (1/4 inch) 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.

D. Checks During Placement
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 3 m (10 feet) transverse and 6 m (20 feet) longitudinal. These checks must be documented in the field book.

When the slab is of deficient thickness or cover, corrections must be made immediately. Deficiencies in thickness or cover may be a result of incorrect rebar placement, settling of the finish machine supports, or incorrect/change in the finish machine setting. For deficiencies in thickness or cover that exceed 13 mm (1/2 inch), contact the Office of Construction to discuss need for additional action.

E. Cleaning Forms and Steel
Mud and other foreign material must be removed from the steel and forms prior to placement. If water is used, cleaning shall be completed at least 1 day prior to placing concrete. This is to prevent excess water from being incorporated into the concrete being placed.

11.42 EPOXY COATED REINFORCEMENT

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.

Care and Handling

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 District Materials Office.

By specification, epoxy coated bar is a certified product when delivered to our projects. (EXCEPTION: Epoxy coated deck steel is a certified product, and is accepted on a field assurance/acceptance test.)

A. Handling
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.

B. Storage
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:

1. Store bars above the ground on timbers, cribbing, or dunnage placed close enough together to prevent sags in the bundles. Coated and uncoated steel reinforcing bars shall be stored separately.
2. 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.
3. While fading of the coating's color is not specifically detrimental, it should be avoided to the fullest extent possible. Exposure to sunlight over a period of time can result in coating brittleness and cracking. 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.
4. *Specification 4151.03, G, 2* requires that placed coated bars and/or long term storage of epoxy coated bars (greater than two months) shall be covered with a non-transparent material. Provisions shall be made for adequate ventilation to minimize condensation under the cover.

C. Placing
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.

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.

Bar supports and tie wires for epoxy coated reinforcement shall be coated with epoxy, nylon, or plastic. (Refer to Specification 2404.03, E.) Also refer to *Materials IM 451.01* for approval of chairs and bolsters.)

Field Inspection

There are two aspects to field inspection. **First**, complete the requirements of *Materials I.M. 204* for assurance/acceptance testing. When the largest bar diameter used for deck steel is delivered, contact the District Materials Engineer for sampling and testing. The **Second** aspect is primarily concerned with evaluating the physical condition of all epoxy coating. Epoxy coated bars should be inspected for damaged coating:

- when received at the job site, and
- after they are placed in the structure.

A. Damage Evaluation and Repair
Damaged coating shall be evaluated as outlined in *Specification 4151.03*, F, 5.
NOTE: All visible damage shall be repaired. Bars in which the amount of repaired damaged areas exceeds 2 percent of the total surface area in each 1.0 linear foot (0.3 m) of the bar shall be removed and replaced with an acceptable bar.

B. Bent Bars
Examination of physical coating condition on the outside radii of hooks and other bends might reveal cracks in the coating. If there is a question about acceptable cracking, the inspector needs to contact their District Materials Office for assistance. When disbondment of the coating is evident, the contractor must remove loose coating, clean the area, and repair.

C. Fading of Color
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. However, storage practice should be modified to keep fading to a minimum and reduce the effects that sunlight can have on coating brittleness and cracking.

D. Damaged Ends
Damage because of field sheared ends must be field repaired.

Repair of Damaged Coating

When 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 touch-up materials is in accordance with the original epoxy resin manufacturer's recommendations. [Refer to *Specification 4151.03, F, 2]* Note: Coating patch materials shall be of organic composition and shall be a two-component liquid properly mixed that hardens to a solid form upon curing. Check *Materials IM 451.03B - Appendix B* for approved touch-up materials.

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

11.43 CAGE STEEL (DRILLED SHAFTS)

Drilled shaft foundations are not covered in the Standard Specifications, but are constructed in accordance to a Supplemental Specification (SS) for the particular project. A SS will include items about fabricating and installing steel cages in the shaft.

General items to look for are:

- Typically, cages are assembled horizontally on the ground, then lifted to a vertical position, and placed in the shaft. A multi-pick is required to preclude cage bending during the "righting" process. Check to be sure the cage is not bent and that hoops/spirals are in the proper location prior to setting cage in the hole.

- In almost every case, there are requirements for spacers both along the side as well as the bottom. These spacers assure proper cage location and cover while placing concrete. There are several commonly used side spacers:
  A. Concrete cylinders of proper diameter are cut into a series of circular "wheels," a hole is drilled in the center, and a "wheel/spacer" is placed onto the hoop steel.
  B. There is a plastic spacer wheel specifically manufactured in various diameters for use in drilled shafts. These wheels simply snap onto the hoop steel.
  C. U-shaped bent epoxy coated reinforcing bars wire tied to the drilled shaft vertical bars have also been used to ensure correct side spacing. When this method is proposed by the contractor, the detail for the U-shaped bent bar should be reviewed with Office of Bridge Design.

11.44 SPLICING

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

- Complicated placement where the cage could be tied off site, in sections, and set in place
- Reinforcement cages for drilled shafts
- Situations where an existing rebar is not long enough to develop strengths by lapping

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.

Currently, several couplers are manufacturered which can be used to mechanically splice rebar. Mechanical splicing for the above conditions may be approved unless the plans exclude their usage. 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 engineer is to forward that request to the Office of Construction for review.

Splice Approval

The use of mechanical splices will only be permitted when specified in the plans or approved by Office of Bridge Design. When mechanical splices are permitted *Materials I.M. 451 Appendix E* provides the basis for acceptance and an approved list of mechanical splicers.

When proposed mechanical splices are not on the approved list, the project engineer shall require three sample splices to be made using the same equipment and process proposed for the project. These samples must be at least 450 mm (18 inches) long and have the splice approximately centered in the sample. Samples will be submitted to the Office of Materials for testing prior to field approval. If the samples fail to develop 125% of the rebar's yield:

- Splicing method will be denied.
- Contractor may at this time change splice type, or recalibrate the splicing equipment and resubmit three samples for testing.

Bottom Line is mechanical splicing has been used successfully in many projects from deck widening to drilled shafts to new construction. Mechanical splicing shall be used only if preapproved or detailed on the plans. For mechanical splices not on the approved list, three mock-up splices must be submitted for testing. (The testing is to assure proper field methods have been used to develop a reliable splice.)

Descriptions of currently approved mechanical splices is provided in *Materials I.M. 451 Appendix E.*

11.45 PAYMENT FOR REINFORCING STEEL

Reinforcing steel is paid for by kilograms (pounds) as noted on the plans. For bent bars, dimensions on the plans are given by the tangent distance (out to out). This length is greater than the actual length of bar required to fabricate these bent bars, but the method of dimensioning and calculating their respective lengths and masses (weights) are according to accepted industry standards. (In this case, *ACI Standard 315*.)

Some fabricators have chosen to calculate the bend distance and thereby shorten the length of bar required. If they use this length to calculate the mass (weight), it will be less than plan quantities. So long as this mass (weight) is within 1 percent of the plan quantities, no further documentation is necessary. (Refer to Specification 2404.04, D.