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Title: **INSTRUCTIONS: DESIGN AND PLACEMENT REVISIONS TO STRUCTURAL CONCRETE BRIDGE DECKS**

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Approved:

J.M. O'Connell
Deputy Chief Engineer (Structures)

6-23-97
Date

EFFECTIVE DATE: These directives shall be implemented in all Department contracts let on or after January 15, 1998. If it can be implemented on projects let before January 15, 1998, it should also be implemented on those projects, provided that existing plans or designs in progress can be modified as necessary in a reasonable and timely manner.

PURPOSE: This instruction provides new directives for the design and detailing of Concrete Bridge Decks, that replace our current practice.

BACKGROUND: The Department is actively engaged in continuous improvement in all its operations. In this vein the Chief Engineer directed that a Task Force be formed to review all aspects of bridge decks with the expressed goal to revise existing and/or develop new policies, standards, and specifications, that reflect the current state-of-the-art. Many of the bridges in the State are deficient by FHWA's definitions solely because of the deck condition. Also, it is the Department's experience that as decks deteriorate the rest of the bridge deteriorates at a faster rate.

The Task Force was composed of Department leaders from the Structures Design and Construction, Technical Services, and Construction Divisions. A work group from these same Divisions and also with Regional representation provided valuable assistance.

The final recommendations were made to the Chief Engineer in a report dated October 31, 1995, and received an emphatic endorsement to proceed with implementation. The recommendations are divided into three areas: design, materials, and construction. The materials recommendations were implemented with EI 96-24, 96-53 and 96-54.

The directives presented here deal with those recommendations that are related to structural design. Additional Task Force recommendations related to structural design are undergoing further study in the Division.

The following three (3) directives apply to all cast-in-place concrete bridge decks supported on steel or concrete stringers, that are designed by or for the Department.

1). ISOTROPIC REINFORCEMENT

Isotropic reinforcement shall be used on all cast-in-place concrete bridge decks supported on steel or concrete stringers meeting the criteria listed in Section 1.1, and shall be designed in accordance with Section 1.2, below. Bridge decks not meeting these criteria shall be designed for flexure by conventional AASHTO methods.

1.1 Selection Criteria for Isotropic Bridge Deck Reinforcement

1.1.1 The maximum center-to-center spacing of stringers is 3.3m.

1.1.2 The minimum center-to-center spacing of stringers is 1.5m.

1.1.3 The minimum overhang is 750 mm. If a concrete barrier composite with the deck is used, the minimum overhang is 600 mm.

1.1.4 There must be 4 or more stringers in the final cross section.

1.2 Design and Detailing Requirements for Isotropic Deck Reinforcement

1.2.1 Reinforcement shall consist of top and bottom mats comprised of No. 13 bars at 200 mm spacing, in the transverse and longitudinal directions.

1.2.2 When construction or other considerations warrant, No. 16 bars at 300 mm spacing is an acceptable, but less desirable, alternative. The need for larger bars should be identified in the design process so that the change may be included in the plans by the designer. If the need for the larger bars is identified after letting, the decision to make the substitution must have the concurrence of the DCE(S). Since the substitution is not equal in every way, (See Commentary 1.2.2) this action should not be taken only for the convenience of the contractor.

1.2.3 Cover shall be as stated in Section 2 of this E.I.

1.2.4 Reinforcement placement shall be as stated in Section 3 of this E.I.

1.2.5 Deck thickness shall be 240 mm minimum. Design depth shall be 200 mm.

1.2.6 The deck shall be fully cast-in-place and water cured, using the Department's current specification for class HP concrete. Only corrugated metal SIP forms and removable forms shall be permitted. The designer shall place a note on the Contract Plans to prohibit the use of prestressed concrete SIP forms.

1.2.7 The deck shall be fully composite in positive moment regions.

1.2.8 In the negative moment regions of continuous structures, as a minimum, pairs of shear connectors at 600 mm spacing shall be provided. For the purposes of computing girder moments, shears, and stresses, the designer shall consider the section composite with the longitudinal reinforcing steel. The designer shall also check for fatigue and ultimate strength in accordance with AASHTO 10.38.2; additional connectors may be required.

1.2.9 Additional reinforcement in negative moment regions as required by AASHTO/NYS Section 10.38.4.3 shall also be provided. The effect of this steel shall be included in the computation of composite section properties for the purposes of determining moments, shears, and stresses in the steel girder.

1.2.10 Fascia overhang reinforcement shall be designed for flexure in accordance with current AASHTO and Division standards. Detailing with No. 13 or 16 bars is preferred.

1.2.11 For skew angles up to 30°, the transverse bars shall be placed parallel to the skew angle, and the rebar spacing, perpendicular to the bar (200 mm or 300 mm), shall be reduced by the cosine-squared of the skew angle. Ex: 22° skew → 200 mm x $\cos^2(22°) = 172$ mm.

1.2.12 For skew angles greater than 30°, the transverse bars shall be placed normal to the stringers.

1.2.13 For skew angles greater than 30°, additional reinforcement shall be placed in the slab end zones, as defined below:

The top and bottom reinforcement spacing shall be reduced by 50% for a longitudinal distance from each end of slab at abutments, equal to the beam spacing; e.g., No. 13 bars at 100 mm, in both directions. (The transverse bars shall not be offset in this zone - see Section 3 of this E.I.)

1.2.14 Lap splices shall be used. Welded splices are not permitted. Mechanical splices are permitted only when stage construction requires their use due to lack of adequate clearance for a lap splice. The preferred location for splices is within a zone between the 1/5 and 1/3 points of the slab span, measured from the girder centerline.

Commentary, General

Isotropic reinforced bridge decks have been constructed widely throughout the United States and Canada during the last 15 years, with the largest supporter and user being the Ontario Highway Ministry (OHM). (The Ontario Highway and Bridge Design Code is internationally known and respected as a "model" code.) New York State has constructed such decks on a limited basis over the past 10 years, and now has at least 35 such decks in service. They have been the focus of an ongoing NYS DOT research project to evaluate their on-site performance (TR&DB RR161). Isotropic reinforcement design has been the topic of research at the national and international level also, with the OHM being the leader in the development of this technology. It is an acceptable method of design that is documented in the AASHTO LRFD code.

The design is based on the acknowledgment of flexural strength enhancement by membrane compressive forces which develop in the slab, referred to as "arching-action". The primary failure mode is punching shear due to concentrated wheel loads. The term "isotropic" relates to equivalence in the orthogonal directions. Hence, the reinforcement layout is identical in both directions (i.e., a mat comprised of the same size bar and uniform spacing in both transverse and longitudinal directions).

Isotropic decks are usually more economical without causing a reduction in durability. Current research and theoretical analysis indicates that the cracking potential and crack densities, both predicted and observed, are roughly equal to the conventional AASHTO deck. However, less steel and smaller bars in the top mat reduces the potential for corrosion induced spalling; and the uniform steel distribution results in uniform ability to control cracking in all directions.

Generally, AASHTO LRFD code requirements were followed in the development of this section, with some modifications to make the criteria more in-line with New York State design and construction practices. The use of LRFD to develop the NYS Design Criteria does not in any way indicate or require LRFD as the general standard or preferred design code. This matter is still under considerable review by the Department. However, should LRFD be adopted as the Department standard design code, our Isotropic Deck Design will already be in-line with the new code requirements.

Commentary on Selection Criteria

1.1.1 LRFD requires that $\frac{\text{EFFECTIVE LENGTH}}{\text{DESIGN DEPTH}} \leq 18$; where EFFECTIVE LENGTH = beam spacing - 1/2 flange width.

Taking the maximum beam spacing = 18 x DESIGN DEPTH is simpler and conservative. This results in 3.75m, however the Department will limit it to 3.3m, which is 16.5 x DD.

1.1.2 LRFD requires $\frac{\text{EFFECTIVE LENGTH}}{\text{DESIGN DEPTH}} \geq 6$. Again, MIN. = 6 x DESIGN DEPTH is simpler.
This equals 1.2m, however the Department will limit this to 1.5m, which is 7.5 x DD.

1.1.3 LRFD requires 5 x DESIGN DEPTH & 3 x DESIGN DEPTH, respectively, however, a smaller overhang will be allowed for decks with bridge railing, based on the Department's performance experience.

1.1.4 LRFD has no such requirement for isotropic decks, but it is already the Department's current practice. This is to insure adequate boundary constraint for arching action of the deck and also insures a redundant superstructure. For temporary stage construction, less than 4 stringers is allowed. If temporary overhang(s) result from the staging sequence, the overhang shall be designed to withstand the temporary live and dead load imposed; additional reinforcement in the overhang area may be required.

Commentary on Design and Detailing Requirements

1.2.1 LRFD requires LESS steel in the top mat than bottom, i.e.:

0.2% in top mat 0.3% in bottom mat

The requirement of No. 13 bars at 200 mm or No. 16 bars at 300 mm, is equivalent to or slightly greater than 0.3%. This is conservative and provides better crack control. The 0.2% is adequate for strength, but does not consider fatigue or long-term serviceability; 0.3% is recommended by NYSDOT Transportation Research and Development Bureau (TR&DB RR161) to account for this.

1.2.2 Research indicates that smaller bars at tighter spacings provides optimal durability. The use of smaller bars at standard spacings, could foster reductions in fabrication/assembly costs, e.g., could automate production of "mats"in the plant which could then be shipped to job site and laid down by crane, with a minimum of labor to place and tie at lap points. However, the option of using larger, "stiffer" mats may prevent some construction problems that are specific to a particular structure or site.

1.2.3 Nothing in LRFD to contradict this. The minimum top cover required by LRFD is 50 mm; bottom is 25 mm. The 75 mm and 35 mm covers required in Section 2 of this EI exceed this for durability reasons.

1.2.4 LRFD calls for transverse bars to be in the outermost layers. However, the placement called for in Section 3 of this EI provides better transverse crack control.

1.2.5 LRFD requires a minimum design slab depth of 180 mm, and a minimum "core-depth" of 100 mm (defined as the distance between extreme points of top and bottom mats). Proposed design requirements result in 200 mm and 130 mm, respectively.

1.2.6 LRFD does not allow concrete SIP forms; states that "...radial confinement around wheel load is weakened by inherent discontinuity of bottom reinforcement at [panel] boundaries..." Corrugated metal SIP forms add additional support and rigidity to the slab, and reduce dead load stresses in the concrete.

1.2.7 Composite anchorage at beam is a necessary requisite for "arching-action" to occur. In the past, we recommended it for most bridges; but now it is required for this type of deck system.

1.2.8 LRFD requires this minimum to satisfy anchorage required for arching action. Structures Division Design Committee has authorized the design of a fully composite section.

1.2.9 Designers shall check stresses at the top-of-slab in negative moment regions at piers considering the slab as acting compositely with the girder. Where slab stresses computed in this fashion are excessive, the designer may want to increase the longitudinal steel above that required in AASHTO 10.38.4.3.

1.2.10 The maximum overhang and overhang reinforcement requirements given in the NYS Standard Details for Highway Bridges manual are not changed by this EI. The maximum overhang is still 4'-6" (1.37m) when using the standard 0.6% reinforcement in the overhang. The general recommendation stated in the manual is that the overhang should not exceed 4'-0" (1.22m). Also, good design practice and economics suggests that the overhang should not exceed ½ the girder spacing. If necessary, overhangs greater than 4'-6" (1.37m) may be used if they are designed for flexure in accordance with appropriate AASHTO requirements.

1.2.11 & 12 This is our usual policy. LRFD also requires, but the skew angle cutoff is 25°.

1.2.13 This is required by LRFD for crack control in the end zones of skewed bridges where high torsional stresses and cracking occur due to differential deflections (OHBDC-1983). A note should be placed on the Plans requiring the contractor to exercise care and use proper equipment to ensure adequate vibration/consolidation of concrete poured in these zones, due to tight clearances between bars.

1.2.14 LRFD prohibits welding due to fatigue potential. Also prohibits mechanical splices, but this would severely impact our ability to employ stage construction.

2). COVER

2.1 Top cover on all cast-in-place concrete bridge decks supported on steel or concrete stringers shall be 75 mm.

2.2 Bottom cover shall be 35 mm.

Commentary

This retains our current 240 mm thick deck standard, while reducing the potential flexural crack width on the top surface, and improving the consolidation and aggregate distribution of concrete placed in the lower portion of the deck; i.e., under the lower reinforcing mat. The 75 mm top cover is in line with current research, which indicates that covers greater than 75 mm are not incrementally more effective. Thicker covers may also accelerate deterioration due to greater shrinkage in the top layer and wider flexural crack widths.

3). REINFORCEMENT PLACEMENT

3.1 For all cast-in-place concrete bridge decks, longitudinal bars shall be placed on top of transverse bars in both the top and bottom mats.

3.2 For isotropic reinforced bridge decks, the top and bottom mats shall be offset by ½ space in each direction, except in the end zones of the deck. (see Section 1.2.13, above.)

Commentary

Transverse cracking is the most prevalent and damaging type, especially on continuous structures over the interior supports. Putting the reinforcement that resists this type of cracking closer to the surface makes it more effective in controlling crack width and density. In some cases transverse overhang reinforcement will have to be increased due to new NYS code requirements.

Offsetting the bars reduces the presence of vertical planes-of-weakness, thus reducing the potential for full-depth cracking.

IMPLEMENTATION:

- This EI modifies existing EI 92-043, until it is reissued, as follows:

  1). Where a reference is made to 3-1/2" top cover, the top cover shall be 3" (75 mm).

  2). Where a reference is made to 1" bottom cover, the bottom cover shall be 1-1/2" (35 mm).

- This EI shall amend the Standard Details for Highway Bridges manual, as follows:

  1). Delete the text of Section 3.1.3b and add the text from Section 1 of this EI, using appropriate cross-referencing; e.g.:

  - "...Section 2 of this EI." should read "...Section 3.1.1."
  - "...Section 3 of this EI." should read "...Section 3.1.3c."

  2). Modify Section 3.1.1 to indicate 3 inches (75 mm) cover to top steel, 1-1/2 inches (35 mm) cover to bottom steel, and 9-1/2 inches (240mm) deck slab thickness.

  3). Delete the first sentence of Section 3.1.3 and place the following paragraph at the beginning of the section:

  > "The deck slab reinforcement shall be detailed in accordance with Section 3.1.3b except for those cases where the bridge does not meet the Selection Criteria for Isotropic Bridges. For those exceptions the deck slab shall be designed in accordance with the load factor provisions of the Standard Specifications for Highway Bridges and the requirements below."

  4). Add the text from Section 3 of this EI to a new Section, numbered 3.1.3c.

- This EI shall amend the NYS Standard Specifications for Highway Bridges as follows:

1). In Article 10.38.4.2 of NYS Blue Page NY227, add the following to the end of the second sentence: "..., except as noted in 10.38.4.4, below."

2). In Article 10.38.4.4 of NYS Blue Page NY227, add the following to the end of the first sentence: "...except as required when using isotropic reinforcement design for the deck slab. In that case there shall be a minimum of 2 connectors at 24" (600 mm) spacings, and the section shall be considered composite. The designer shall also check the stress range on these connectors, based on the fatigue category for this detail, and ultimate strength requirements. Additional connectors may be required."

3). In Article 10.5.2 on NYS Blue Page NY246, add the following sentence: "When using an isotropic reinforced deck slab, a minimum of 2 shear connectors at 24" (600 mm) spacings shall be placed in the negative moment region. The section shall be considered composite with the longitudinal reinforcing steel. The designer shall check the stress range on the connector, based on the fatigue category for this detail, and ultimate strength requirements. Additional connectors may be required."

- Additional coordination with appropriate groups/committees will be carried out over time to implement these directives into forthcoming issuances of the NYS Bridge Manual, BD Sheets, and other appropriate NYS "Blue Pages".

CONTACT PERSON:

Any questions regarding these instructions should be directed to Thomas Morreale of the Bridge Design Section of the Structures Division at (518) 485-7260.

COMPANION REFERENCES:

The directives given in this instruction were taken from the report by the Bridge Deck Task Force to the Chief Engineer dated October 31, 1995 titled *The "State-of-the-Art" Bridge Deck.*