C5.2 Decks

C5.2.1.1 Policy Overview

01 August 2023 ~ Deck Thickness and MASH Rails

The following commentary was added in 2023 to have a historical record of changes to the deck design and details for easy reference. The changes listed below were made for projects in the September 2024 letting unless granted an exemption.

- Interior deck thickness increased from 8 inches to 8.5 inches.
- Exterior deck edge thickness increased from 8.75 inches for PPCBs and 9 inches for steel beams to 10 inches for both.
- Exterior deck thickness at edge of top flange increased from a range of 9 to 10.25 inches to 10.25 to 11 inches.
- The built-in wearing surface thickness increased from 0.50 inches to 0.75 inches.
- The depth of cover for top transverse reinforcement increased from 2.50 inches to 2.75 inches.
- The depth of cover for bottom transverse reinforcement increased from 1.00 to 1.50 inches.
- The top transverse bar reinforcement (a-bars) used to extend from edge to edge of deck with additional j1 bars in the deck overhang between the a-bars. The top transverse bar reinforcement (a-bars) now only extend partially into the exterior beam bays and are lapped with the j1 bars which are used exclusively in the deck overhangs.
- The j1 bars went from straight bars to having hooks on one end of the bar at the edge of deck.
- The lap and development lengths were updated to meet the 2017 AASHTO LRFD Bridge Design Specifications, 8th Edition.
- The standard 34-inch tall TL-4 and 44-inch tall TL-5 NCHRP 350 F-shape barrier rails were replaced with standard 38-inch tall TL-4 and 44-inch tall TL-5 MASH single slope barrier rails.

C5.2.2.4 Railing

01 August 2023 ~ NCHRP 350 and MASH Rails

The following commentary was added in 2023 to have a historical record of past practice for easy reference. Table C5.2.2.4-1 is reproduced from AASHTO LRFD Table A13.2-1, 9th Edition, 2020 and is applicable for decks/rails developed under NCHRP 350. The standard 34-inch tall TL-4 and 44-inch tall TL-5 NCHRP 350 F-shape barrier rails used the yield line values in Table C5.2.2.4-2 based on NCHRP 350 requirements. The F-shape rails have been phased out for all projects starting with the September 2024 letting unless granted an exemption.

Table C5.2.2.4-1. Design Forces for Traffic Railings

Design Forces and Designations	TL-4	TL-5
Rail Height, H (inches)	≥ 32	≥ 42
F_t, Transverse (kips)	54	124
F_L, Longitudinal (kips)	18	41
F_v, Vertical (kips)	18	80
L_t and L_L (ft)	3.5	8
L_v (in)	18	40
H_e (in)(1)	32	42

Table Notes:

(1) Vertical height of the resultant load.

(2) Definition of variables:

F_t = Transverse force applied perpendicular to the barrier

F_L = Longitudinal force applied by friction along barrier's direction

F_v = Vertical force applied downward on the top of the barrier

L_t = Length of the transverse force

L_L = Length of the longitudinal force

H_e = Height of the peak force from ground level
L_v = Length of the vertical distributed design load

Table C5.2.2.4-2. Yield line values for F-section barrier rail

Rail rating and condition	R_w kips	L_c feet	M_c, average ft-k
TL-4, interior	117	11.5	13.0
TL-4, end	74	8.0	13.0
TL-5, interior	128	16.7	13.9
TL-5, end	133.6	9.7	13.9

C5.2.4.1.2 Detailing

01 October 2020 ~ Deck Pour Section and Sequence

The following commentary was added in 2020 to address issues related to deck pour section and sequence.

- Bridge plans should always provide a baseline section and sequence concrete pour diagram for the following reasons.
    - It establishes a biddable sequence for the contractor that minimizes deck cracking.
    - It establishes a manageable pour sequence option for smaller bridge contracting firms and, therefore, opens the project up to more bidders.
    - It establishes header locations in each span which assists contractors with stop locations for larger pours when emergency situations arise, such as, inclement weather or equipment issues.
- Section and sequence concrete pours should be planned so as to minimize the potential for deck cracking due to tension during the deck pour and to minimize cold joints in the deck. Generally speaking, the stress in any portion of the hardened concrete in the top of the deck should not exceed the modulus of rupture at any point during the deck pour. Even though this is desirable, AASHTO C6.10.3.2.4 does permit the concrete to exceed the modulus of rupture for steel beam bridges if longitudinal reinforcement is included to control cracking according to Article 6.10.1.7. The Iowa DOT does include the total amount of this longitudinal reinforcement in the deck per AASHTO; however, it does not put two-thirds of it in the top of the deck (per AASHTO), but rather allows it to be distributed equally between the top and bottom layers [BDM 5.5.1.4.1.18] primarily to limit congestion.
- Baseline section and sequence concrete pours are rarely used by the contractor since it requires additional wait times between deck pours and requires additional forming for headers. Designers should, if possible, indicate an option for one continuous deck concrete placement from one end of the bridge to the other if there are no structural or constructability concerns and the total volume of deck concrete is 500 CY or less. If total volume of deck concrete exceeds 500 CY the designer should generally provide a section and sequence option that includes section sizes from 300 CY to 500 CY. The benefits of this approach are as follows.
    - The DOT can realize savings from reductions in headers and construction time.
    - The DOT can spend less time reviewing alternate pours.
    - The quality of the deck pour is generally better if there are fewer cold joints.
    - It gives the contractors clear bidding expectations to eliminate uncertainty if an alternate would be approved.
    - It reduces the possibility of disparate treatment of contractors by the various RCEs.
- A key factor in deck pours is maintaining plasticity of concrete. If concrete plasticity can be maintained the issue of tensile stress deck cracking due to concrete placement loads in adjacent spans is generally alleviated since fluid concrete cannot crack. Most contractors can maintain plasticity of the concrete for deck pours of 500 CY or less. Some contractors can maintain plasticity for significantly larger pours. For this reason, plan notes should not explicitly exclude a deck pour sequence that involves a deck pour larger than 500 CY simply because the deck pour is larger than 500 CY. A contractor should be allowed to propose a deck pour sequence that exceeds 500 CY and approval should be granted or denied based on the viability of their proposal. Designers should also keep in mind that long narrow bridges may be less of an issue than wide bridges. Concrete placement on a narrow bridge in a span far removed from a span that was poured earlier as part of the same continuous pour and is beginning to harden has little influence on deck cracking in the span poured earlier.

- CADD notes were modified for adjacent deck pours to include a minimum 2 day waiting period and a requirement that the previous pour must achieve 75% of the its 28-day concrete strength for the following reasons.
    - The restriction ensures header removal does not damage the adjacent deck concrete.
    - Deck concrete cracking may be reduced in any concrete that may undergo tension as a result of the adjacent pour.
- CMB or experienced RCEs generally review and approve/reject alternate pours submitted by contractors. Concurrence from the engineer of record may be sought.
- In general, CADD notes for deck pours should indicate within the note the reasons for any restrictions imposed by the note. For example, contractors are better able to prepare bids if the note includes language stating that beam end span uplift is an issue that restricts a pour sequence. A contractor proposing an alternate pour that includes girder uplift may request to include additional concrete dead load as a counterweight, but this method of countering uplift is unusual. A more common approach is to use positive anchorages similar to what is shown in the figure below. Contractor requests for alternate pour sequences involving uplift must submit calculations and details signed by an Iowa Professional Engineer for approval by the bridge design engineer of record.

https://www.fhwa.dot.gov/bridge/pubs/nhi15044.pdf

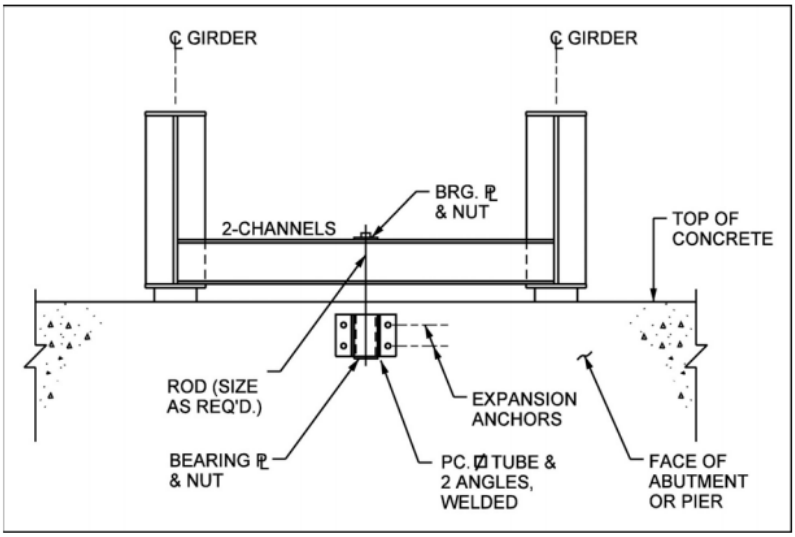
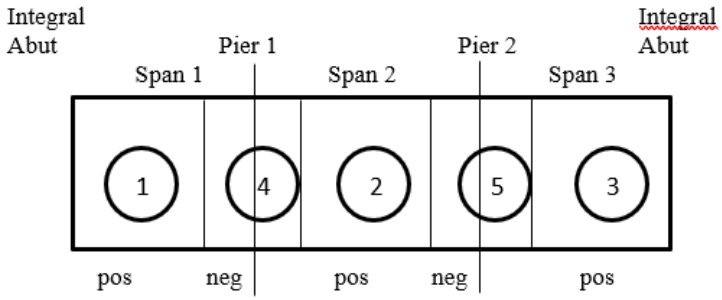


Figure 3-35 Hold-Down Assembly for Steel Girders

Example 1 Three span non-continuous PPCB bridge with integral abutments

Note: This example is technically independent of abutment type.



Section	Qty (CY)
1	100
2	90
3	100
4	40
5	40
Total	370

While there are several possible pour sequence options, there are only two pour sequences that should be covered by plan note for this example. Pour option 1 is the baseline sequence. The baseline sequence establishes a pour sequence that should be workable for bridge contracting firms of any size and, therefore, opens the project up for more bidders. Additionally, the option 1 baseline sections establish locations where headers are ideally placed in each span. Establishing ideal header locations for other larger pour options assists contractors with stop locations when emergency situations arise, such as, inclement weather or equipment issues. Pour option 2, which is the most likely sequence a contractor will follow, is an end-to-end pour. An end-to-end pour option will generally be an acceptable pour sequence for all PPCB bridges with total deck concrete quantities of 500 CY or less.

Pour Option	Sequence
1	1-2-3-4-5
2	(1+4+2+5+3) end-to-end pour

Notes:

- Dashes separate individually poured sections within a pour sequence.
- Parenthesis around a group of sections with plus signs indicates a singular larger section comprised of the individual sections that is placed in one continuous pour from one end to the other.

Note E926 for "Prestressed concrete beam bridge, deck placement" with appropriate modifications would be included in the plans as follows:

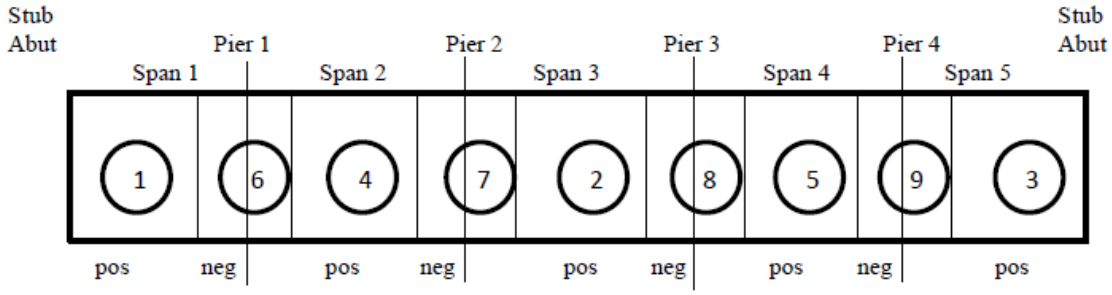
CONCRETE DECK SHALL BE PLACED IN SECTIONS AND SEQUENCES INDICATED. AN APPROVED ALTERNATE PROCEDURE IS TO PLACE THE CONCRETE DECK IN ONE CONTINUOUS POUR BEGINNING AT ONE END OF THE BRIDGE. ALTERNATE PROCEDURES FOR PLACING DECK CONCRETE MAY BE SUBMITTED FOR APPROVAL TOGETHER WITH A STATEMENT OF THE PROPOSED METHOD AND EVIDENCE THAT THE CONTRACTOR POSSESSES THE NECESSARY EQUIPMENT AND FACILITIES TO ACCOMPLISH THE REQUIRED RESULTS. THE BRIDGE ENGINEER SHALL REVIEW ANY ALTERNATE PROCEDURES. THE COST OF ANY ADDITIONAL ANALYSIS AND PLAN MODIFICATIONS SHALL BE PAID FOR BY THE CONTRACTOR. THE ENGINEER SHALL DETERMINE IF A RETARDING ADMIXTURE IS REQUIRED TO MAINTAIN PLASTICITY OF THE CONCRETE DECK DURING PLACEMENT.

DECK CONCRETE SECTIONS SHALL CURE FOR A MINIMUM OF 48 HOURS AND SHALL ACHIEVE A MINIMUM STRENGTH OF 75% OF THE 28 DAY DECK CONCRETE STRENGTH PRIOR TO REMOVING DECK HEADERS AND BEGINNING AN ADJACENT POUR.

Example 2 Five span continuous steel girder bridge with stub abutments

Notes:

- This example also applies to semi-integral abutments since this abutment type also allows for end girder rotation.
- This example is not appropriate if integral abutments were specified.
- This example assumes there are no uplift issues.



Section	Qty (CY)
1	100
2	90
3	100
4	90
5	90
6	40
7	40
8	40
9	40
Total	630

There are numerous pour sequences that would likely be permitted. The listing below contains several possible options. The two options that should normally be included in the plans are options 1 and 6. Pour option 1 is the baseline sequence. Pour option 6 is the most likely sequence a contractor will follow if they are constrained in their pouring capability to 500 CY. Since total deck concrete exceeds 500 CY, an end to end pour will not be explicitly permitted by plan note, but it will also not be explicitly prohibited by plan note. The designer will need to explicitly verify their design for Pour Option 1 and 6 and should also verify their design for an end to end pour as that is a likely alternative that will be requested by the contractor.

Pour Option	Sequence
1	1-2-3-4-5-6-7-8-9
2	1-4-2-5-3-6-7-8-9
3	1-(6+4)-(7+2)-(8+5)-(9+3)
4	(1+6+4)-(7+2+8+5)-(9+3)
5	(1+6+4)-(2+8+5)-7-(9+3)
6	(1+6+4+7+2)-(8+5+9+3)
7	End to end pour would not be explicitly permitted by plan note, but it would also not be explicitly prohibited by plan note. The contractor would need to submit and get approval for an alternate procedure involving an end to end deck pour.

Notes:

- Dashes separate individually poured sections within a pour sequence.
- Parenthesis around a group of sections with plus signs indicates a singular larger section comprised of the individual sections that is placed in one continuous pour from one end to the other.

Note E1040A for “Deck placement sequence, steel girder” with appropriate modifications would be included in the plans as follows:

CONCRETE DECK SHALL BE PLACED IN ONE OF THE TWO SECTIONS AND SEQUENCES INDICATED.

OPTION 1: NINE SECTIONS IN THE FOLLOWING SEQUENCE 1-2-3-4-5-6-7-8-9
OPTION 2: TWO SECTIONS IN THE FOLLOWING SEQUENCE (1+6+4+7+2)-(8+5+9+3)

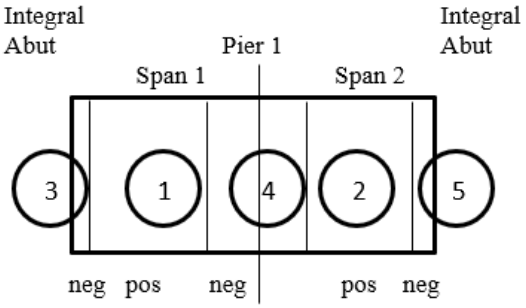
ALTERNATE PROCEDURES FOR PLACING DECK CONCRETE MAY BE SUBMITTED FOR APPROVAL TOGETHER WITH A STATEMENT OF THE PROPOSED METHOD AND EVIDENCE THAT THE CONTRACTOR POSSESSES THE NECESSARY EQUIPMENT AND FACILITIES TO ACCOMPLISH THE REQUIRED RESULTS. THE BRIDGE ENGINEER SHALL REVIEW ANY ALTERNATE PROCEDURES. THE COST OF ANY ADDITIONAL ANALYSIS AND PLAN MODIFICATIONS SHALL BE PAID FOR BY THE CONTRACTOR. THE ENGINEER SHALL DETERMINE IF A RETARDING ADMIXTURE IS REQUIRED TO MAINTAIN PLASTICITY OF THE CONCRETE DECK DURING PLACEMENT.

DECK CONCRETE SECTIONS SHALL CURE FOR A MINIMUM OF 48 HOURS AND SHALL ACHIEVE A MINIMUM STRENGTH OF 75% OF THE 28 DAY DECK CONCRETE STRENGTH PRIOR TO REMOVING DECK HEADERS AND BEGINNING AN ADJACENT POUR.

Example 3 Two span continuous steel girder bridge with integral abutments

Notes:

- Since this steel girder bridge is continuous and has integral abutments, the regions near the integral abutments (sections 3 and 5 in the figure) are intended to be completed in sequence with the negative moment regions (see BDM 5.2.4.1.2).
- If this bridge had stub abutments or semi-integral abutments, then the regions near the ends of the abutments (sections 3 and 5) would be omitted and become part of the positive moment regions (sections 1 and 2).
- This example assumes there are no uplift issues.



Section	Qty (CY)
1	90
2	90
3	10
4	40
5	10
Total	240

Two span continuous steel girder bridges are a special case as they require both positive moment regions (sections 1 and 2) to remain plastic until both sections are poured. This is done to reduce the potential for cracking in the section that is poured first since the second pour tends to produce tension in top of the deck of the first pour if it were allowed to harden prior to the second pour. The deck at the integral abutments and the integral abutment diaphragms are poured as part of the negative moment sections since they would have a tendency to create restraining moments and cause cracking if they were poured as part of the positive moment region pours. There are only two pour sequences that should be covered by plan note for this example. Pour option 1 is the baseline sequence. Pour option 4, which is the most likely sequence a contractor will follow, is an end-to-end pour. Option 4 is included in the plan note since the total deck concrete quantities are less than 500 CY. The designer will need to explicitly verify their design for Pour Option 1 and 2. Pour Options 2 and 3 recognize the fact that one of deck sections at an integral abutment may be poured with the last positive moment section without detriment to the deck. Options 2 and 3 also

have the benefit of removing a transverse construction joint. These options are currently left out of the plan notes since they tend to create confusion and, in most instances, contractors will seek to do an end-to-end pour.

Pour Option	Sequence
1	1-2-3-4-5
2	1-(2+5)-3-4
3	2-(1+3)-5-4
4	(3+1+4+2+5) end-to-end pour

Notes:

- Dashes separate individually poured sections within a pour sequence.
- Parenthesis around a group of sections with plus signs indicates a singular larger section comprised of the individual sections that is placed in one continuous pour from one end to the other.

Note E1040B for "Deck placement sequence, steel girder, two span" with appropriate modifications would be included in the plans as follows:

CONCRETE DECK SHALL BE PLACED IN SECTIONS IN THE FOLLOWING SEQUENCES:

A. SECTION 1 AND SECTION 2 SHALL BE PLACED IN THE SAME DAY. HOWEVER, THE SECTION PLACED FIRST MUST REMAIN PLASTIC UNTIL THE OTHER SECTION IS COMPLETELY PLACED.

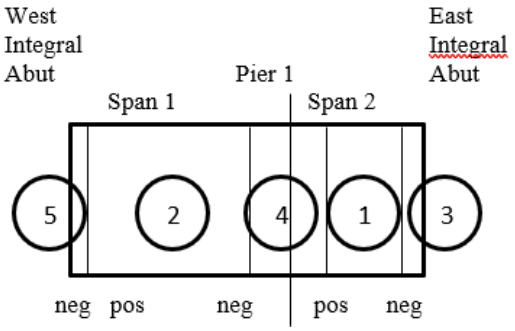
B. SECTIONS 3, 4 AND 5 MAY NOT BE PLACED UNTIL SECTIONS 1 AND 2 HAVE CURED FOR A MINIMUM OF 48 HOURS AND ACHIEVED A MINIMUM STRENGTH OF 75% OF THE 28 DAY DECK CONCRETE STRENGTH. DECK HEADERS SHALL ONLY BE REMOVED AFTER MEETING THESE REQUIREMENTS.

AN APPROVED ALTERNATE PROCEDURE IS TO PLACE THE CONCRETE DECK IN ONE CONTINUOUS POUR BEGINNING AT ONE END OF THE BRIDGE. ALTERNATE PROCEDURES FOR PLACING DECK CONCRETE MAY BE SUBMITTED FOR APPROVAL TOGETHER WITH A STATEMENT OF THE PROPOSED METHOD AND EVIDENCE THAT THE CONTRACTOR POSSESSES THE NECESSARY EQUIPMENT AND FACILITIES TO ACCOMPLISH THE REQUIRED RESULTS. THE BRIDGE ENGINEER SHALL REVIEW ANY ALTERNATE PROCEDURES. THE COST OF ANY ADDITIONAL ANALYSIS AND PLAN MODIFICATIONS SHALL BE PAID FOR BY THE CONTRACTOR. THE ENGINEER SHALL DETERMINE IF A RETARDING ADMIXTURE IS REQUIRED TO MAINTAIN PLASTICITY OF THE CONCRETE DECK DURING PLACEMENT.

Example 4 Unbalanced two span continuous steel girder bridge with integral abutments

Note:

- Since this steel girder bridge is continuous and has integral abutments, the regions near the integral abutments (sections 3 and 5 in the figure) are intended to be completed in sequence with the negative moment regions (see BDM 5.2.4.1.2).
- If this bridge had stub abutments or semi-integral abutments, then the regions near the ends of the abutments (sections 3 and 5) would be omitted and become part of the positive moment regions (sections 1 and 2).
- This example assumes girder uplift issues at the east abutment in Span 2 would occur if span 1, section 2 were poured first.



Section	Qty (CY)
1	50
2	130
3	10
4	40
5	10
Total	240

Two span continuous steel girder bridges are a special case as they require both positive moment regions (sections 1 and 2) to remain plastic until both sections are poured. This is done to reduce the potential for cracking in the section that is poured first since the second pour tends to produce tension in top of the deck of the first pour if it were allowed to harden. The deck at the integral abutments and the integral abutment diaphragms are poured as part of the negative moment sections since they would have a tendency to create restraining moments and cause cracking if they were poured as part of the positive moment region pours. In this example, span 2 is considerably shorter than span 1 and therefore the girder ends at the east abutment of span 2 could undergo uplift if section 2 in span 1 were poured first. If this potential exists, the designer should designate pour sequences that preload the span with the potential for uplift in order to prevent it. There are only two pour sequences that should be covered by plan note for this example. Pour option 1 is the baseline sequence. Pour option 2, which is the most likely sequence a contractor will follow, is an end-to-end pour. Option 2 is included in the plan note since the total deck concrete quantities are less than 500 CY. The designer will need to explicitly verify their design for Pour Option 1 and 2.

Pour Option	Sequence
3	1-2-3-4-5
4	(3+1+4+2+5) end-to-end pour

Notes:

- Dashes separate individually poured sections within a pour sequence.
- Parenthesis around a group of sections with plus signs indicates a singular larger section comprised of the individual sections that is placed in one continuous pour from one end to the other.

Note E1040C for “Deck placement sequence, steel girder, unbalanced two span” with appropriate modifications would be included in the plans as follows:

CONCRETE DECK SHALL BE PLACED IN SECTIONS IN THE FOLLOWING SEQUENCES:

A. SECTION 1 AND SECTION 2 SHALL BE PLACED IN THE SAME DAY. HOWEVER, DUE TO UPLIFT CONCERNS AT THE EAST END OF THE BRIDGE, SECTION 1 MUST BE PLACED FIRST AND REMAIN PLASTIC UNTIL SECTION 2 IS COMPLETELY PLACED.

B. SECTIONS 3, 4 AND 5 MAY NOT BE PLACED UNTIL SECTIONS 1 AND 2 HAVE CURED FOR A MINIMUM OF 48 HOURS AND ACHIEVED A MINIMUM STRENGTH OF 75% OF THE 28 DAY DECK CONCRETE STRENGTH. DECK HEADERS SHALL ONLY BE REMOVED AFTER MEETING THESE REQUIREMENTS.

AN APPROVED ALTERNATE PROCEDURE IS TO PLACE THE CONCRETE DECK IN ONE CONTINUOUS POUR BEGINNING AT THE EAST ABUTMENT DUE TO UPLIFT CONCERNS. ALTERNATE

PROCEDURES FOR PLACING DECK CONCRETE MAY BE SUBMITTED FOR APPROVAL TOGETHER WITH A STATEMENT OF THE PROPOSED METHOD AND EVIDENCE THAT THE CONTRACTOR POSSESSES THE NECESSARY EQUIPMENT AND FACILITIES TO ACCOMPLISH THE REQUIRED RESULTS. ALTERNATE PROCEDURES MUST ADDRESS THE POTENTIAL FOR GRIDER UPLIFT AND WILL, AT A MINIMUM, REQUIRE CERTIFICATION BY A PROFESSIONAL ENGINEER LICENSED IN THE STATE OF IOWA IF POSITIVE RESTRAINTS OR COUNTERWEIGHTS ARE INCORPORATED TO ADDRESS UPLIFT. THE BRIDGE ENGINEER SHALL REVIEW ANY ALTERNATE PROCEDURES. THE COST OF ANY ADDITIONAL ANALYSIS AND PLAN MODIFICATIONS SHALL BE PAID FOR BY THE CONTRACTOR. THE ENGINEER SHALL DETERMINE IF A RETARDING ADMIXTURE IS REQUIRED TO MAINTAIN PLASTICITY OF THE CONCRETE DECK DURING PLACEMENT.