

Bridge Construction Loads

Bob McCullouch P.E. Ph.D.

2015 INDOT Bridge Conference

Topics

- Accidents
- Current Specifications and Provisions
- Design Load Recommendations
- Temporary Bracing Recommendations
- Resources
- Summary

2015 INDOT Bridge Conference

Construction Accidents

- Most bridge construction accidents are attributed to a failed temporary structure or system.
- Need for improved understanding of these systems and construction loads.
- Current specifications and standards are sparse.

2015 INDOT Bridge Conference

Maryland Bridge Collapse

- Inadequate Falsework



Photo: United States Park Police

2015 INDOT Bridge Conference

Colorado Bridge

- Inadequate Bracing



2015 INDOT Bridge Conference

Indiana Bridge

- Improper Slings



2015 INDOT Bridge Conference

Cline Avenue Bridge

- Failed support pad
- 12 workers killed



2015 INDOT Bridge Conference

Current INDOT Standards

- Current INDOT standards specify dead and live construction loads.
- Sections 702.13 and 702.14 prescribe concrete dead load and a construction live load.
- Design Memorandum 10-18 prescribes 15psf for formwork dead load and live load 20 psf and 75 plf and where this load is placed.
- No provisions for construction lateral bracing.
- Other states and AASHTO Guide have additional provisions.

2015 INDOT Bridge Conference

Sections 702.13 and 702.14

“In designing forms, fresh concrete shall be considered as a liquid weighing 150 lb/cu ft (2,400 kg/m³) for vertical loads and 100 lb/cu ft (1,600 kg/m³) for horizontal pressure. A live load allowance of 50 lb/sq ft (2.4 kPa) shall be used on horizontal projections of surfaces.”

2015 INDOT Bridge Conference

Construction Dead Load Recommendation

“The combined density of concrete and reinforcing and prestressing steel shall be assumed to be not less than 150 pcf for normal-weight concrete and for lightweight concrete. Exceptions to the lightweight concrete design weight can be requested for approval from INDOT.

The weight of formwork shall be assumed to be not less than 15 psf, including permanent metal stay-in-place deck forms, removable deck forms, and a 2-foot exterior walkway.”

2015 INDOT Bridge Conference

Construction Live Load Recommendation

Incorporating Design Memo 10-18 and AASHTO Bridge and Temporary Works , falsework recommendation is:

- The actual weight of any equipment to be supported, applied as concentrated loads.
- A uniform load of 20 psf, applied over the area supported and extending 2 feet past the edge of coping.
- A 75 plf vertical force, applied at a distance of 6 inches outside the face of coping over a 30-foot length of the deck centered with the finishing machine.
- Formwork live load is 50 psf.

2015 INDOT Bridge Conference

Combined Dead and Live Load Recommendation

- AASHTO Bridge Temporary Works recommendation:

““The minimum total design vertical load for any falsework member shall be not less than 100 psf for the combined dead and live load, exclusive of any increase for impact, regardless of slab thickness.”

2015 INDOT Bridge Conference

Impact Load

- During placement or lifting operations, large number of failures occur:

“For members subject to impact during placement operations, the design dead load must be increased by at least 30 percent of the weight of the material being placed.

For members subject to impact during lifting operations, the static load due to the payload must be increased by at least 30 percent.”

2015 INDOT Bridge Conference

Live Load – Vehicle Impact

Falsework shall not be considered adjacent to roadways or railroads if it is protected from traffic by an approved barrier. If not properly protected, the appropriate loads are as follows:

- Falsework posts adjacent to roadways or railroads shall consist of either steel with a minimum section modulus about each axis of 9.5 inches cubed or sound timbers with a minimum section modulus about each axis of 250 inches cubed.
- Each falsework post adjacent to roadways or railroads shall be mechanically connected to its supporting footing at its base, or otherwise laterally restrained, so as to withstand a force of not less than 2,000 pounds applied at the base of the post in any direction except toward the roadway or railroad track. The posts also shall be mechanically connected to the falsework cap or stringer. The mechanical connection shall be capable of resisting a load in any horizontal direction of not less than 1,000 pounds.”

2015 INDOT Bridge Conference

Horizontal Construction Load

“The horizontal design load shall consist of the sum of any actual horizontal loads due to equipment, construction sequence, or other causes, excluding the specified wind load, but in no case shall the horizontal design load be less than 2 percent of the total dead load to be supported at the point under consideration.”

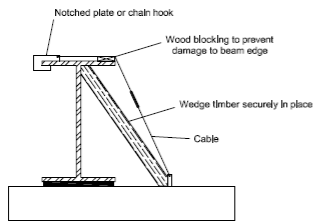
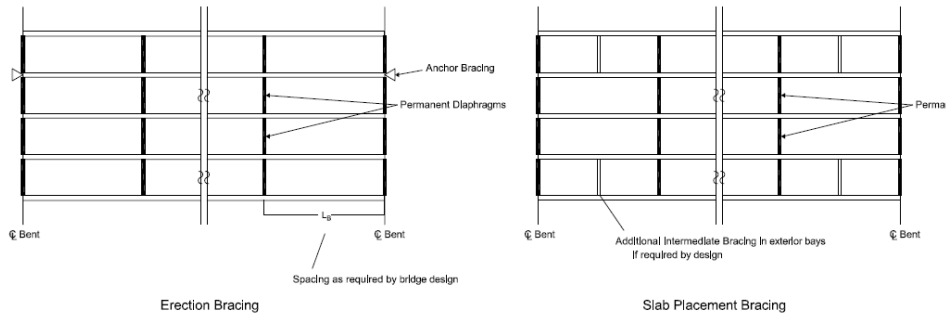
2015 INDOT Bridge Conference

Wind Load

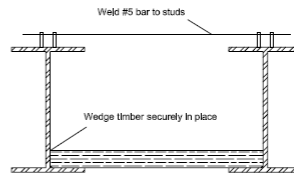
- Based on ASCE 7-10 provisions.
- Design Wind Speed is 115 mph reduced by a duration factor (ASCE 37). Varies 0.75 to 0.9.
- Dependent on Exposure Conditions
 - B , Suburban and Urban setting
 - C, Flat terrain and generally open
 - D, Flat and unobstructed facing large body of water.

2015 INDOT Bridge Conference

Temporary Construction Bracing - Steel Girders



Anchor Bracing Details (Typ.)



Intermediate Bracing Details (Typ.)

MINIMUM BRACING REQUIREMENTS FOR STEEL BEAMS AND GIRDERS

GENERAL NOTES

- Use of systems in these details does not relieve the Contractor of the responsibility for the adequacy of the bracing and the safety of the structure.
- The bracing systems shown in these details are schematic only, and are meant only to show geometry in which bracing should be placed. Bracing members and connections shall be designed and detailed by the Contractor.
- Proposed bracing details are to be designed by an Engineer and submitted to INDOT for review prior to erection.
- All connections must be capable of developing the full strength of the brace member, e.g. cable or brace.
- Timber sections less than 4x4 nominal are not to be used as bracing members.

ANCHOR BRACING

- For straight beams, Anchor Bracing must be used at both ends of the first beam erected in the span, known as the Anchor Beam. The location of the Anchor Beam may vary. All subsequent beams are to be braced against the Anchor Beam sequentially. The Anchor Bracing may be located at an exterior girder provided that all required bolt clear distances are met and overhang bracing is not affected.
- Anchor Bracing must be used at both ends of all curved beams, unless beams are connected on the ground before being lifted onto piers.
- Anchor Bracing must be installed before the Anchor Beam is released from the cranes used to lift it.
- If the obtuse angle between the beam or girder and the pier exceeds 120 degrees, Anchor Bracing shall be placed perpendicular to the beam or girder.
- Anchor Bracing shall not be removed until all girders and all diaphragms in the span are in place.

ERECTION BRACING

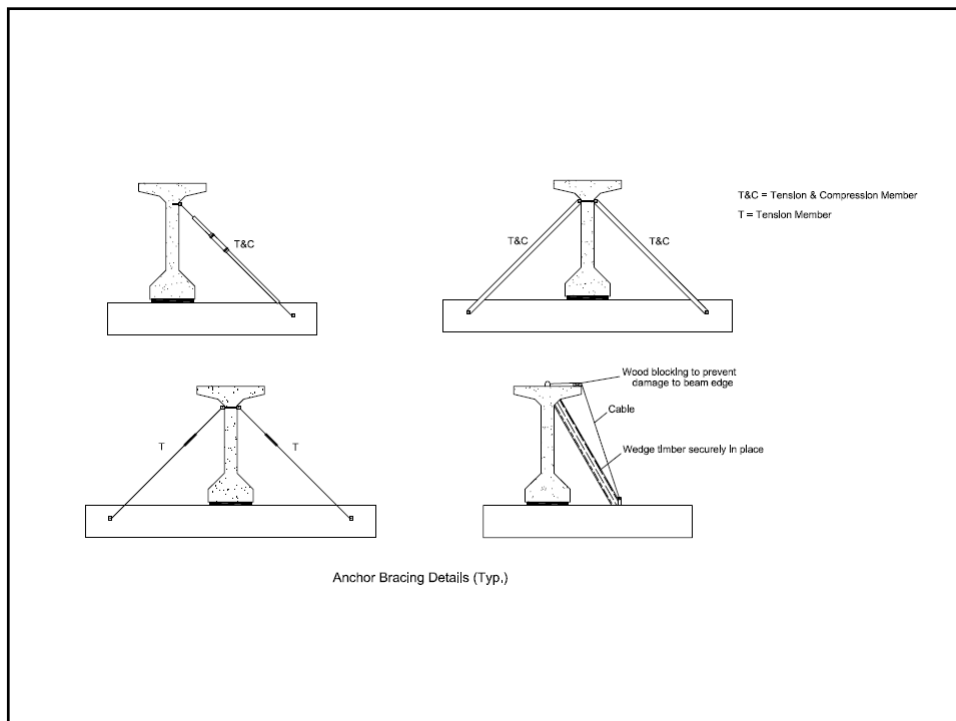
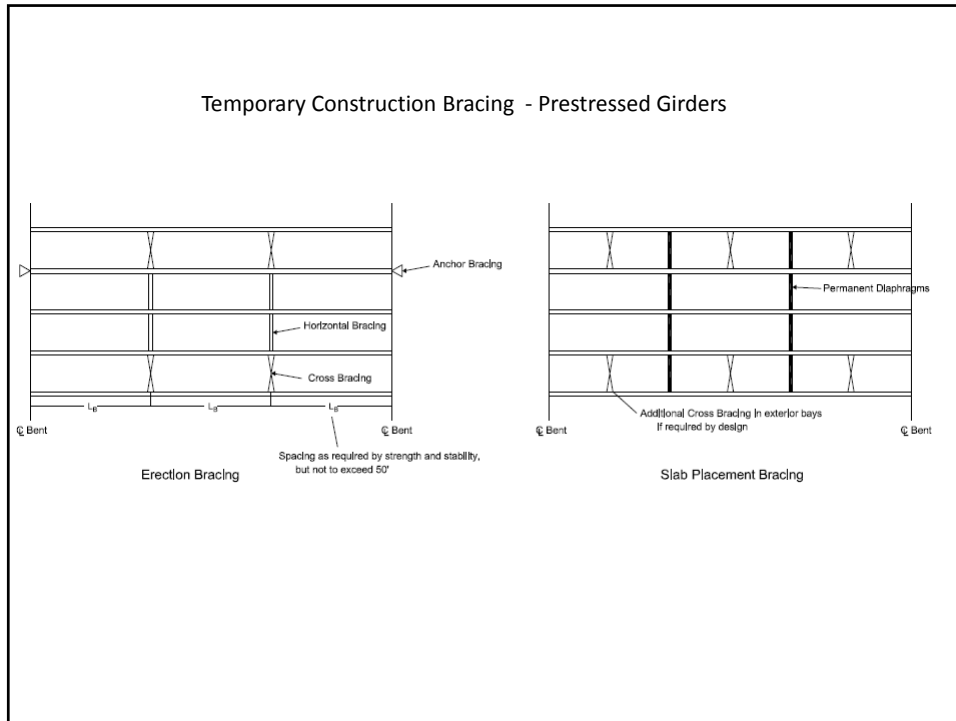
- Required Erection Bracing includes Permanent Diaphragms spaced as required by the design of the bridge.
- Each beam must have at least one diaphragm connecting it to an adjacent beam before it is released from the cranes used to lift it. Remaining diaphragms shall be installed as soon as practical.

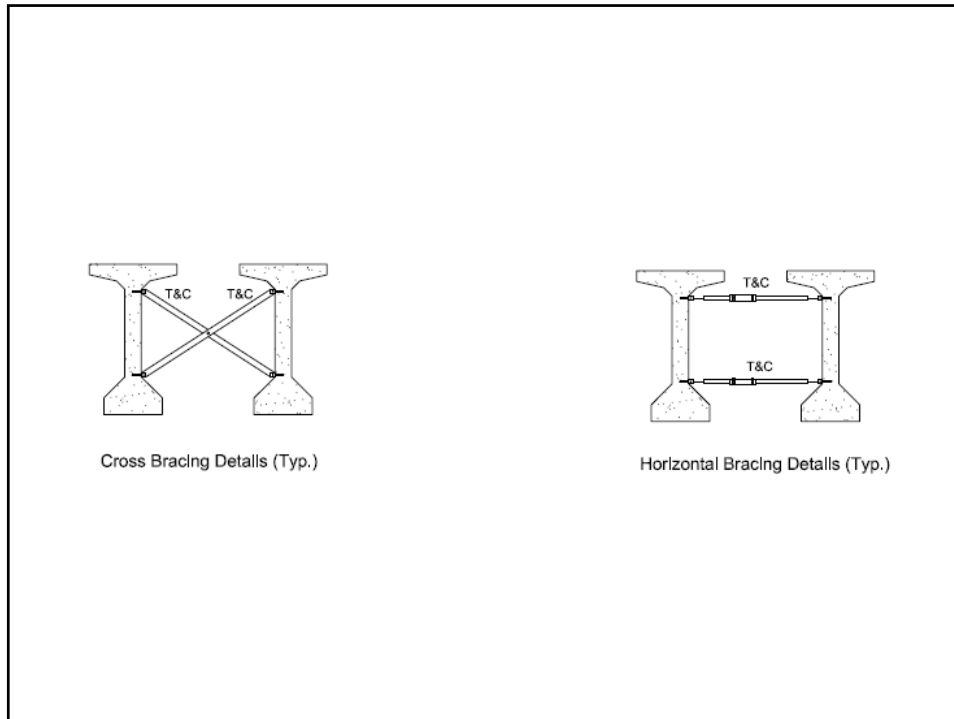
CROSS BRACING

- On curved girders, temporary Cross Bracing must be installed next to all field splices, unless beams are connected on the ground before being lifted onto piers.

SLAB PLACEMENT BRACING

- Slab Placement Bracing includes additional Intermediate Bracing to be installed in exterior bays if required by design.
- Intermediate Bracing must remain in place until slab concrete has attained a compressive strength of 3000 psi.





MINIMUM BRACING REQUIREMENTS FOR PRESTRESSED BEAMS AND GIRDERS

GENERAL NOTES

- Use of systems shown in these details does not relieve the Contractor of the responsibility for the adequacy of the bracing and the safety of the structure.
- The bracing systems shown in these details are schematic only, and are meant only to show geometry in which bracing should be placed. Bracing members and connections shall be designed and detailed by the Contractor.
- Proposed bracing details are to be designed by an Engineer and submitted to INDOT for review prior to erection.
- All connections must be capable of developing the full strength of the brace member, e.g. cable or brace.
- Bracing details are for spans less than 150'. Bracing details for spans greater than 150' are not provided.
- Bracing details are not provided for beams or girders with lateral spacing greater than or less than typical values.

ANCHOR BRACING

- Anchor Bracing must be used at both ends of the first beam or girder erected in the span, known as the Anchor Beam. The location of the Anchor Beam may vary. All subsequent beams are to be braced off the Anchor Beam sequentially. The Anchor Bracing may be located at an exterior girder provided that all required bolt clear distances are met and overhang bracing is not affected.
- Anchor Bracing must be installed before the Anchor Beam is released from the cranes used to lift it.
- If the obtuse angle between the beam or girder and the pier exceeds 120 degrees, Anchor Bracing shall be placed perpendicular to the beam or girder.
- Anchor Bracing shall not be removed until all girders and all Horizontal and Cross Braces in the span are in place.

ERECTION BRACING

- Required erection bracing must be installed immediately after erection of each beam and remain in place until slab concrete has attained a compressive strength of 3000 psi.
- Use brace spacing required by strength and stability, but spacing is not to exceed 50'.
- Cross Bracing or Horizontal Bracing at both beam ends is recommended.
- Spans no longer than 100' may have one brace placed at midspan in each bay, rather than the two braces between beam ends shown in the details, if such spacing is adequate according to design.

SLAB PLACEMENT BRACING

- Permanent diaphragms, spaced as required by the design of the bridge, shall be installed prior to slab placement.
- Additional Cross Bracing in exterior bays shall be installed if required by design.
- Temporary bracing must remain in place until slab concrete has attained a compressive strength of 3000 psi.

CROSS BRACING

- Cross Bracing must be placed between the first two beams/girders erected, in exterior bays, and in every fourth bay. At the Contractor's option, remaining bays may have either cross bracing or horizontal bracing.
- Cross Bracing members must be capable of developing tension and compression, and positively attached to the beam web or flange.
- Each beam using Cross Bracing must have at least one brace installed to connect it to an adjacent beam before it is released from the cranes used to lift it. Remaining braces shall be installed as soon as practical.
- A permanent diaphragm is an acceptable substitute for Cross Bracing.

HORIZONTAL BRACING

- Horizontal Bracing systems are to use members which are capable of developing tension and compression, and are positively attached to the beam web or flange.
- Each beam using Horizontal Bracing must have at least one brace installed to connect it to an adjacent beam before it is released from the cranes used to lift it. Remaining braces shall be installed as soon as practical.
- A permanent diaphragm is an acceptable substitute for Horizontal Bracing.

HAULING & ERECTION

- The Contractor's attention is directed to the possible lateral instability of pre-stressed concrete beams and girders over 130' long, especially during hauling and erection. The use of the following methods to improve stability is encouraged:
 - Locate lifting devices at the maximum practical distance from beam ends.
 - Use lateral stiffening devices during hauling and erection.
 - Lift with vertical lines using two cranes.
 - Take care in handling to minimize inertial and impact forces.

