First Fully Prefabricated Full-Depth Deck Panel Bridge System in Michigan: Challenges & Lessons Learned

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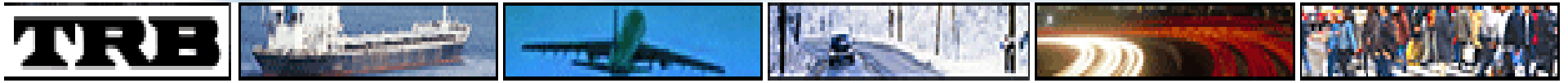
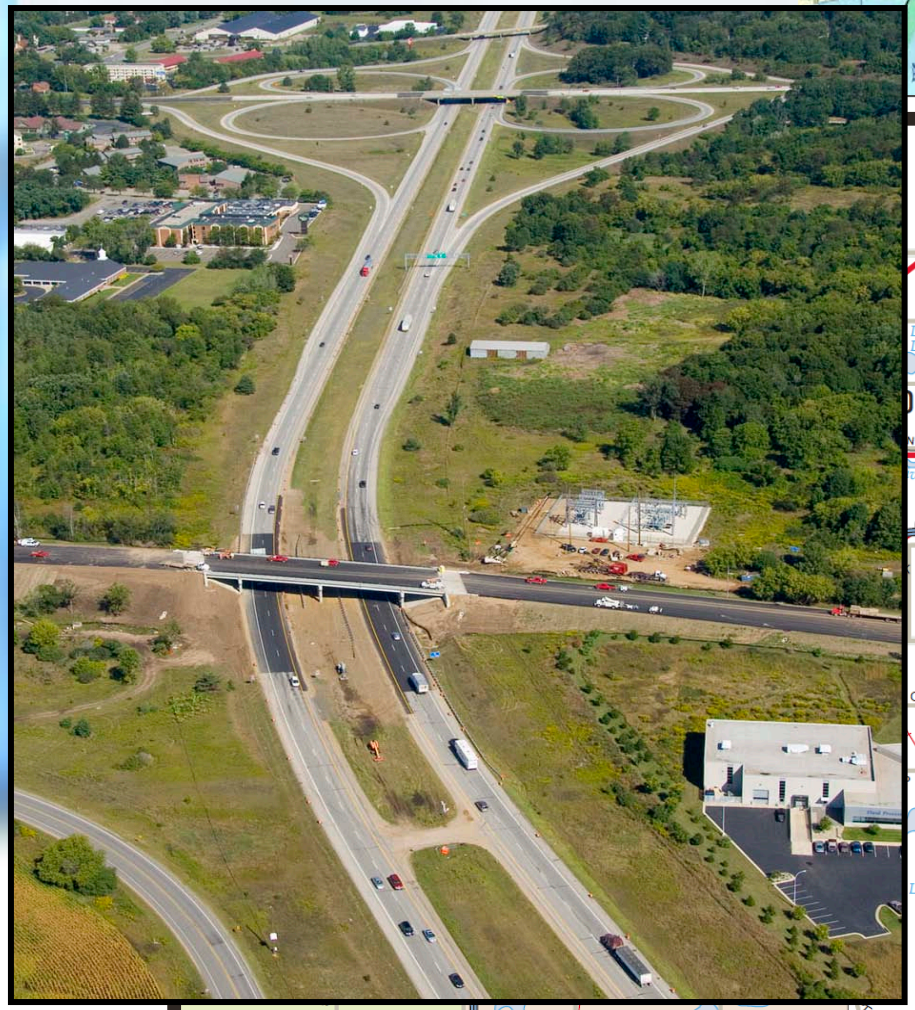


Outline

- Project overview
- Bridge design details
- Project requirements
- Construction challenges
- Lessons learned and recommendations

Project overview

Location of the site



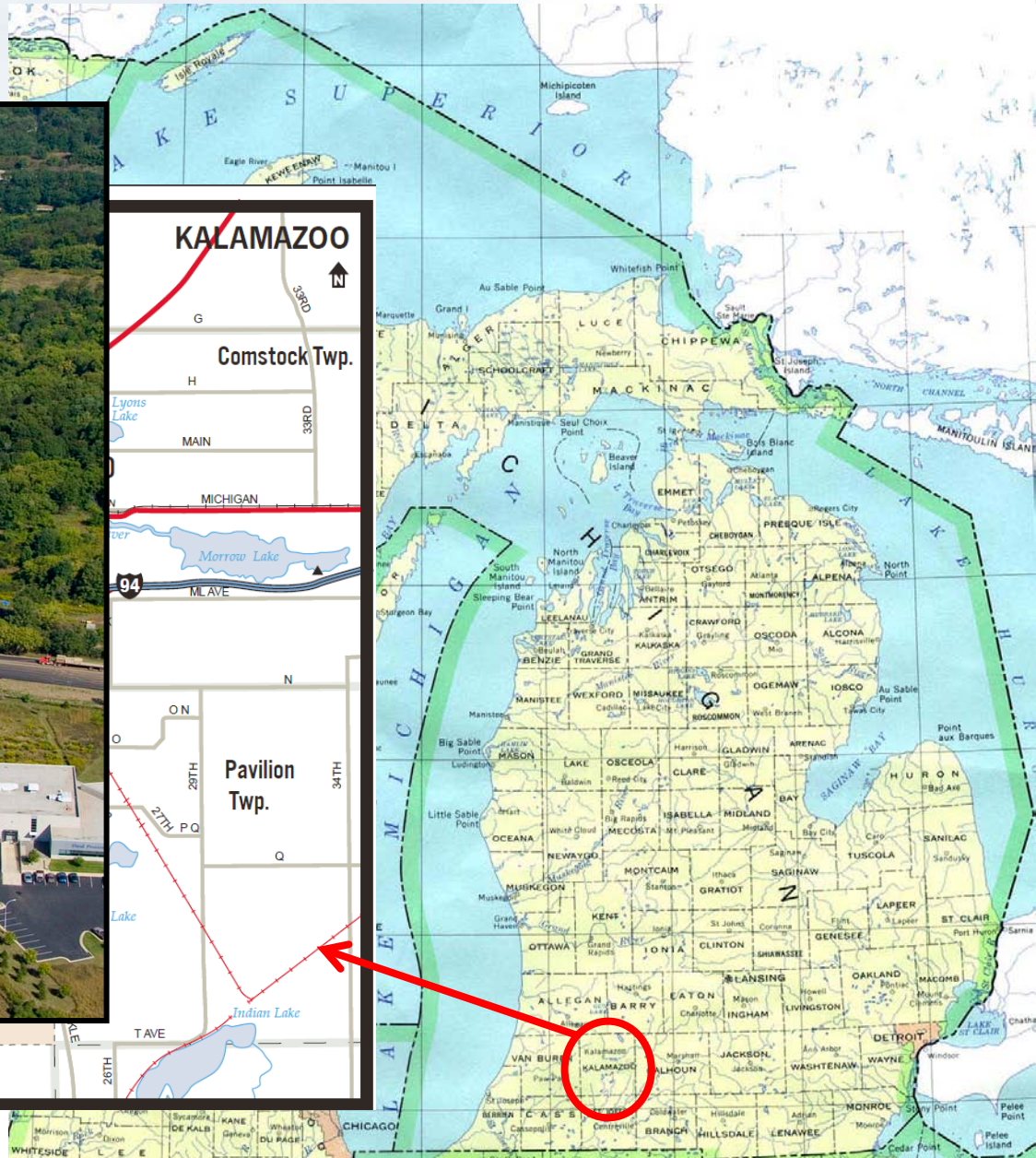


Photo Credits: Michigan DOT

Project overview

Challenges

- Build a 23^0 skew, 249 ft. long, 4 span totally prefabricated bridge
- Open road to traffic within 12 weeks
- Relocate an 8” high pressure gas main
- Integrate the Western Michigan University data collection system into the bridge deck
- Coordinate with other projects in the area

Project award

- Pre-bid meeting was held on September 17, 2007
- Requirements:

  Project Start: April 7, 2008

  Open to Traffic: June 27, 2008

  Completion: July 25, 2008
- 2 ½ months vs. 7 months
- Engineers estimate: $2.75M
- Low bid to Anlaan Corp: $2.85M

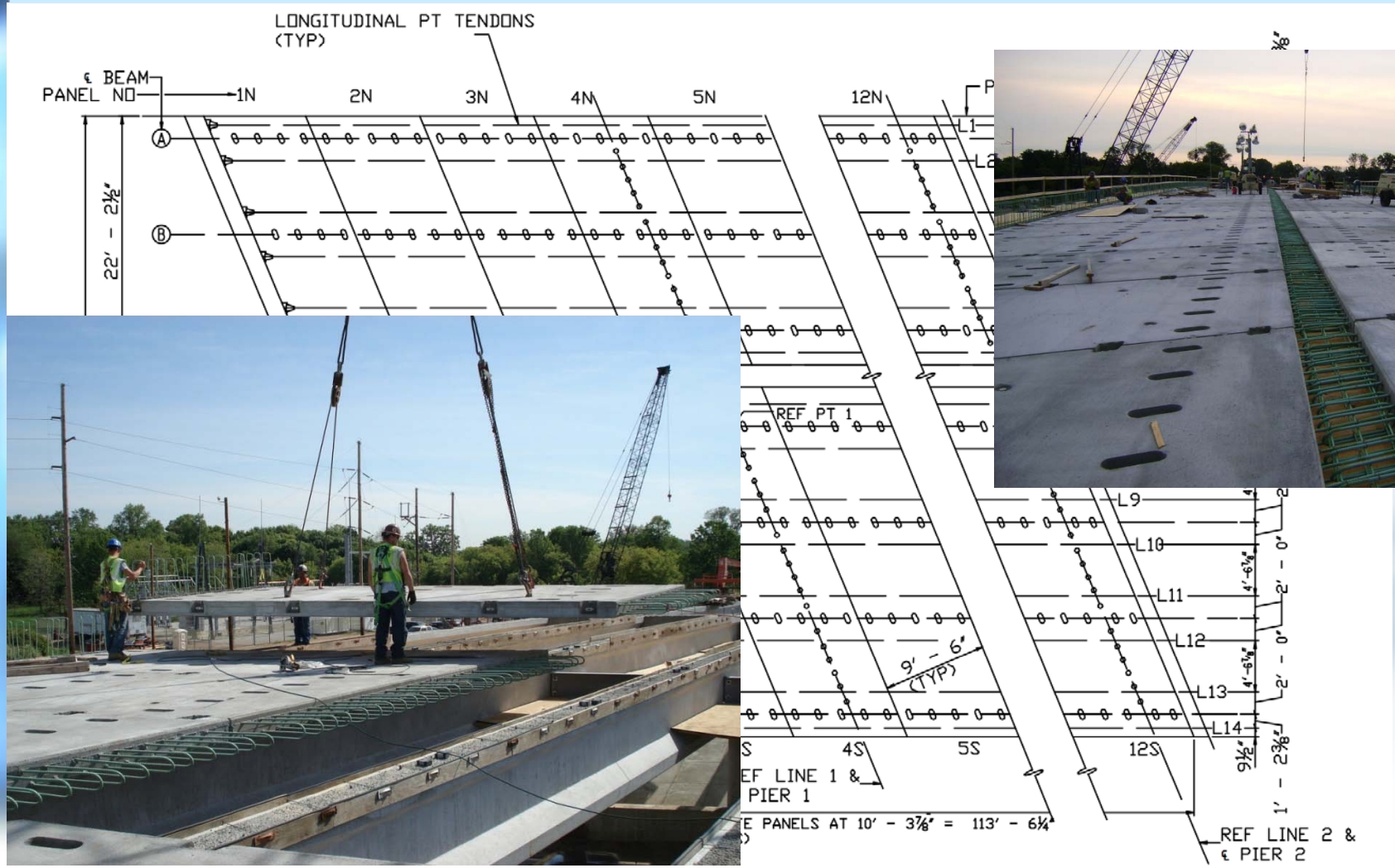
Project overview

Project management

- Progress monitoring: field visits, google earth, and two cameras
- Same cameras were used for traffic monitoring

Photo Credits: Michigan DOT

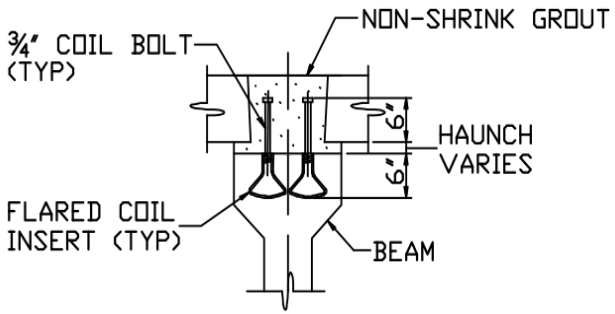
Bridge Design Details



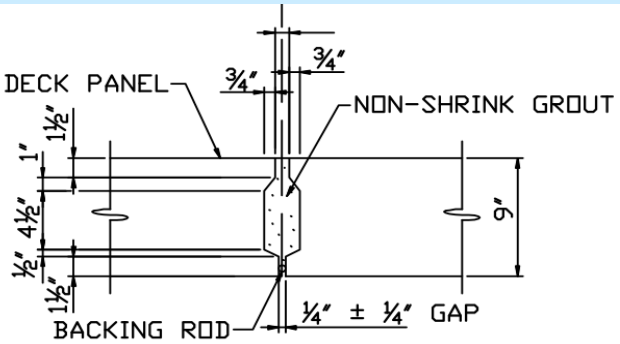
- 48, 9 in. thick partial width full-depth deck panels
- PC-I Type III girders
- 24 in. – longitudinal closure
- Grouted shear keys and longitudinal post-tension

Photo Credits: Michigan DOT

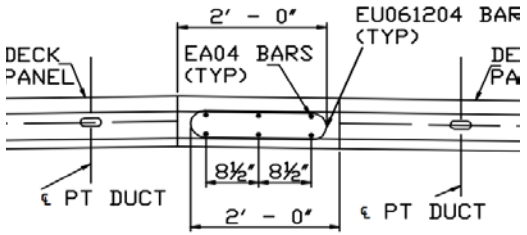
Bridge Design Details



Flared coil inserts – shear studs connection

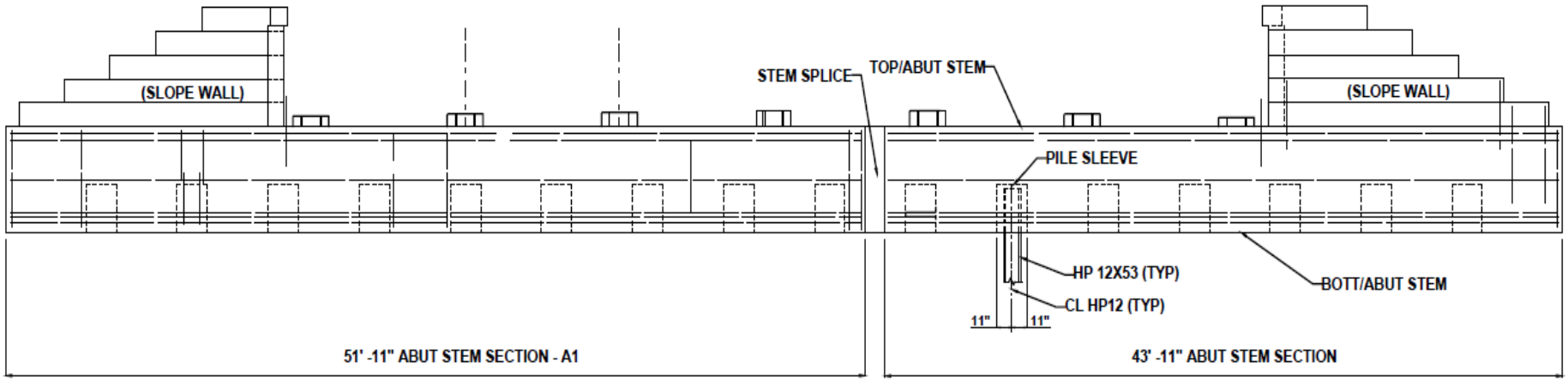


Transverse joint



Longitudinal closure

- Non-shrink grout for haunch
- Waterproofing membrane and a 1.5 in. asphalt wearing surface



Abutment stem and slope walls

Bridge Design Details

- 16 H-piles
- Cast-in-place footing for piers
- Four precast concrete columns /pier
- Precast pier cap

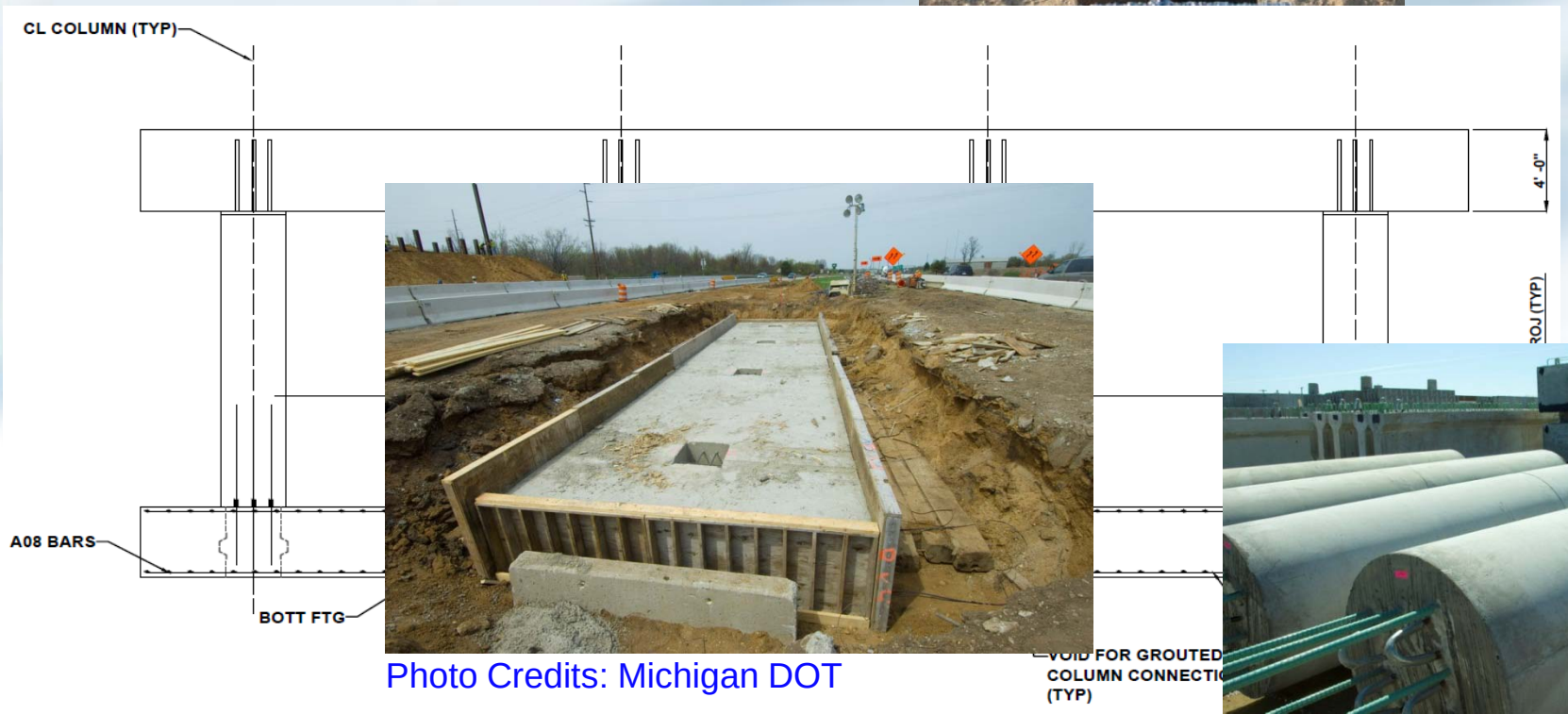


Photo Credits: Michigan DOT

Tolerance Specifications

Precast concrete substructure	Tolerance specifications
Stub abutment and pier cap length (transverse direction of the bridge)	+/- 1 in.
Stub abutment and pier cap width (longitudinal direction of the bridge)	+/- 1/8 in. per ft. or +/- 1 in., whichever is smaller
Stub abutment and pier cap depth	+/- 1/8 in. per ft. or +/- ½ in., whichever is smaller
Column height	+/- 1/4 in.
Column diameter	+/- 1/8 in.
Corrugated grout duct location	+/- 1/8 in.
Precast concrete deck panels	**Tolerance specifications**
Length (transverse direction of the bridge)	+/- 1/16 in. per ft. or +/- 3/4 in., whichever is smaller
Width, not cumulative (longitudinal direction of the bridge)	+/- 1/8 in. per ft. or +/- 3/4 in., whichever is smaller
Depth	+/- 1/8 in.
Grade of form edge and fascia	+/- 1/8 in. in 10 ft.
Tendon hole/duct location	+/- 1/8 in.

Tolerance Specifications

How should we deal with the tolerances?

Extracts of Special Provisions

- Non-shrink grout to be used for all grouting procedures
- Non-shrink grout technical assistance from grout manufacturer
- Abutment to be on grade level and pile embedment of 30 in. into the abutment
- Fill 30 in. pile sleeve with non-shrink grout
- Connect pier columns to footing using square pockets in the latter
- Connect pier columns to pier cap using 8 – #9 bars from each column into 4 in. diameter corrugated ducts in the pier cap

Photo Credits: Michigan DOT

Photo Credits: Michigan DOT

Extracts of Special Provisions

- Contractor proposals to be implemented with approval of engineer
- Special surface preparation to expose well bonded aggregates in a cast-in-place joint (i.e., connecting abutment stems, full-depth deck panels, etc.)
- Saturated surface dry condition should be achieved for precast component surfaces (in contact with joint material) (i.e., wetting the surfaces for min. of 3 hrs)
- Inspect all components for defects: after casting, after moving to storage, and before erection (inspection by Engineer, Contractor, and Contractor's Engineer)
- In the case of full-depth deck panels, it was required to inspect, as a minimum, the first five panels for defects and/or damages.
- Employing people with Level 1 or 2 Post-Tensioning Institute certifications
- A technician with minimum 5 yrs of experience and Level 2 post-tensioning certification to act as an advisor
- Grouting operation plan to be approved by the engineer
- Grout manufacturer's field representative to provide technical assistance

Construction Challenges

- **Longitudinal post-tensioning duct misalignment**
  - Due to calculation error (skew misinterpretation)
  - Contractor chose to re-cast all panels
  - “Cast-Match” technique used (different from “Match-Cast” technique)

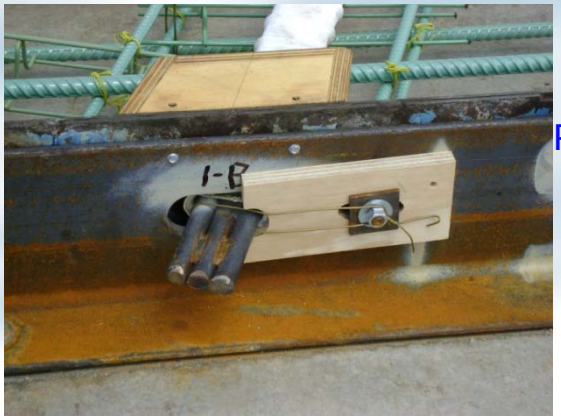
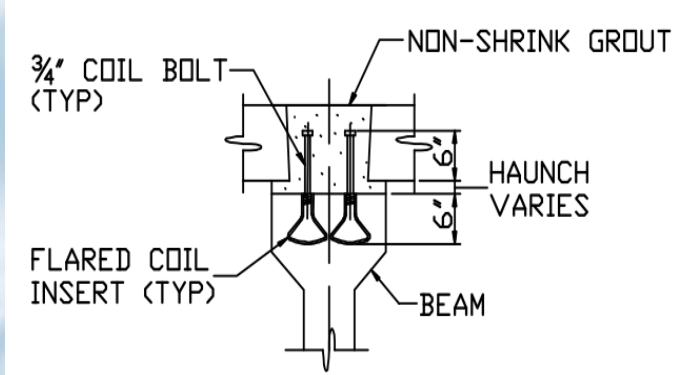


Photo Credits: Michigan DOT

Construction Challenges

- **Shear stud blockout to flared coil inserts misalignment**
  - Due to girder twist (exact reason unknown)
  - Potential reasons:
    - Eccentricity in prestressing strands and/or storage issues (Culmo 2009)
- Around 20% shear studs required drilling holes – challenge was to drill within small space of shear connector pockets

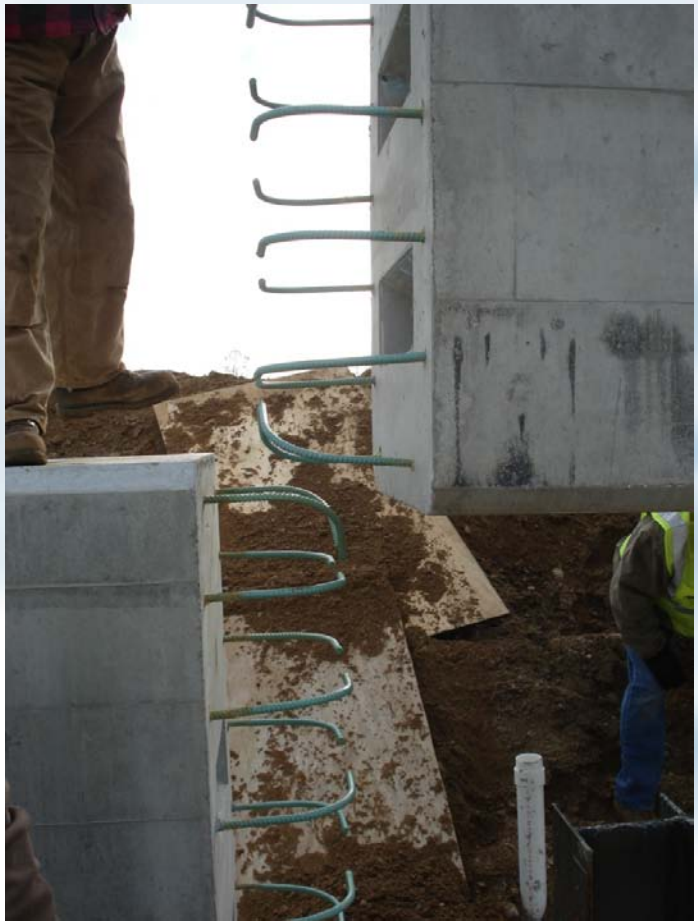


Culmo, M.P. (2009). "Connection Details for Prefabricated Bridge Elements and Systems," *Federal Highway Administration*, No. FHWA-IF-09-010.

Construction Challenges

- **Abutment stem closure reinforcement overlap**
- **Longitudinal closure reinforcement overlap**
  - Field bending and adjustment of reinforcement

Photo Credits: Iowa DOT



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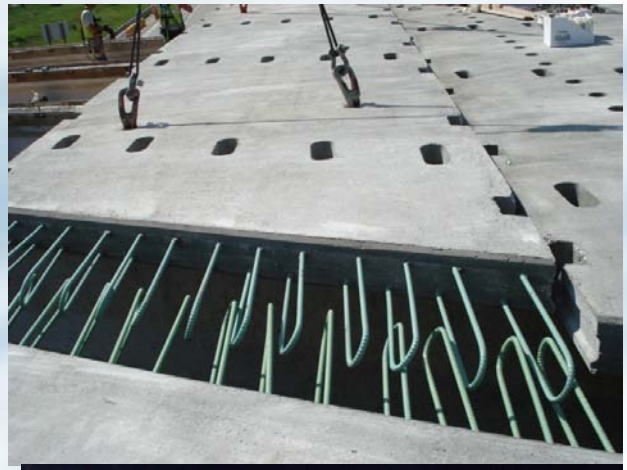


Construction Challenges

- **Grouting haunches**
  - Due to lack of grouting procedures in the specifications
  - Contractor used shim packs for deck super-elevation
  - Formwork installation - a major challenge
  - Grout flow under gravity
  - Voids were observed in haunches after removing the formwork
  - Contractor was allowed to patch the voids in haunch

Photo Credits: Michigan DOT

Construction Challenges

- **Abutment stem-to-foundation connection**
  - Maintaining tolerances – contractor used a steel template
  - Grout lift limit of 6 in. was imposed by manufacturer but pile embedment of 30 in. was specified in the project specifications.
  - 4 in. diameter plastic tubes fitted in 4 in. thick concrete slab placed under the abutment stem were used to fill abutment-to-pile connection with latex concrete leaving 6 in. to be filled with grout.

Photo Credits: Michigan DOT

Photo Credits: Michigan DOT

Construction Challenges

- **Pier column-to-footing connection**
  - 6 in. grout lift limit constrained filling the square pocket with grout
  - Contractor beveled corners of the pocket and placed grade D concrete (658 lb/yd^3 cement + 70% of 6AA coarse aggregate per unit volume of concrete + sufficient water to produce a 3.5 in. high slump).

Photo Credits: Michigan DOT

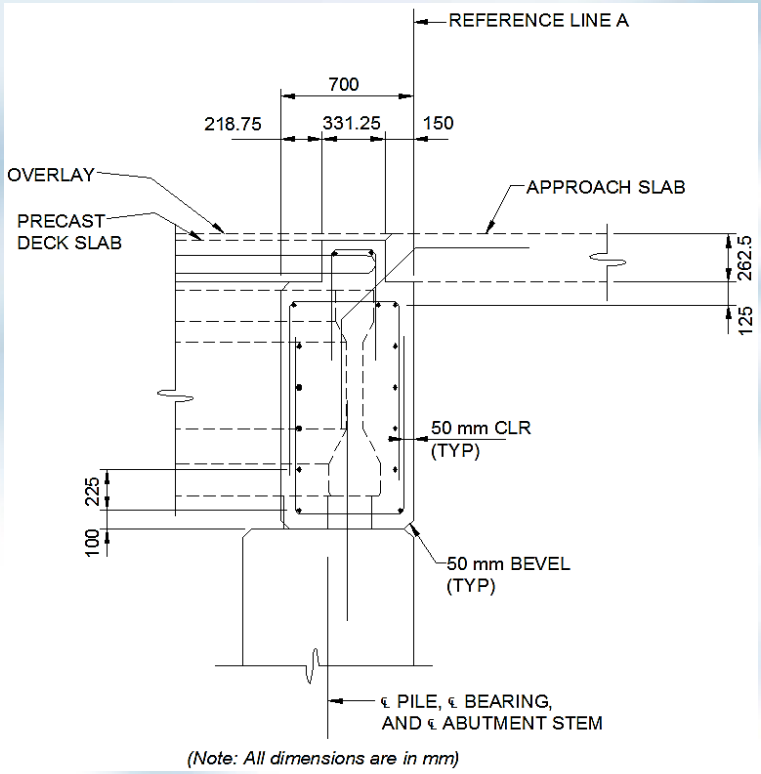
Construction Challenges

- **Pier column-to-pier cap connection**
  - Pier cap lifted by two cranes of 110 t and 150 t capacities
  - Difficulty in aligning total of 32 bars from four columns into corrugated ducts of 60 t pier cap

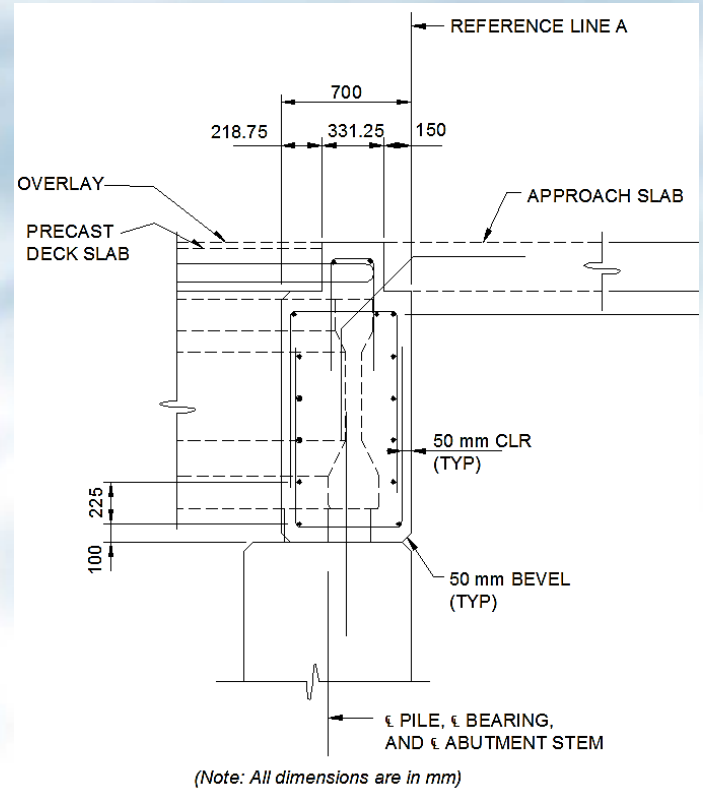
Photo Credits: Michigan DOT

Construction Challenges

- **Connection detail at reference line of the bridge**
  - Design details required backwall stem terminated at the same elevation as the deck panels (i.e., to place waterproofing membrane and asphalt wearing surface over backwall stem).
  - During construction, the detail was modified because of presumed potential asphalt cracking along the cold joint between full-depth deck panels and the backwall stem.



(Note: All dimensions are in mm)



(Note: All dimensions are in mm)

Lessons learned & Recommendations

- **Longitudinal post-tensioning duct misalignment**
  - Require a stringent quality control and quality assurance program with a detailed check list

- **Shear stud blockout to flared coil inserts misalignment**
  - Requires tolerance specifications for girder twist and/or shear stud blockout dimensions to account for such deviations.
    An example for such specifications can be found in the *Prestressed concrete construction manual* (NY State DOT 2000) or in PCI full-depth deck panel report (2011).
  - Advantageous to evaluate integrity of the deck-girder assembly for missing few shear connectors

NY State DOT (2000). "Prestressed Concrete Construction Manual," *Structures Design and Construction Division - New York State Department of Transportation (DOT).*

PCI. (2011). "State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels – First Edition," *Precast Prestressed Concrete Institute (PCI).*

Lessons learned & Recommendations

- **Grouting haunches**
  - *State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels* (PCI 2011) –
    - Leveling device for deck panels should be embedded during prefabrication
    - Formwork for haunches range from removable formwork to stay-in-place compressible backer rod
  - Specifications should require contractor to build a mock-up of the joint to demonstrate proficiency of the methods planned for placing grout
  - Specifications should include material types and application procedures after carefully reviewing the manufacturer requirements

PCI. (2011). "State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels – First Edition," *Precast Prestressed Concrete Institute (PCI).*

Lessons learned & Recommendations

- **Pier column connection**
  - Substructure size should be optimized considering crane capacity
  - Abutment stems, pier columns, and pier caps – large components and less complicated details could prompt for fabrication at construction site or at nearby location owned by DOT
  - Template used by Iowa DOT may be an alternate to alleviate rebar alignment issues at pier column-pier cap connection

Source: Wolf 2005

Source: Hubbard 2011 (HNTB)

Hubbard, F. (2011). "SHRP 2 – R04 Innovative Bridge Designs for Rapid Renewal," *Proc. APC / Penn DOT Fall Seminar by HNTB Corporation.*

Wolf, L. M. (2005). "Texas DOT Experience with Prefabricated Bridge Construction," *Proc. TxDOT Bridge Division, Texas Department of Transportation*, TX.

Concluding Remarks

- Access to lessons learned reports is limited
- Most of the reports are brief and do not provide adequate information

THANK YOU