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State-of-the-art Report On FULL-DEPTH PRECAST CONCRETE BRIDGE DECK PANELS

(SOA -01-1911)

Precast/Prestressed Concrete Institute

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Report

PCI Precast/Prestressed Concrete Institute

State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels

Prepared by the
PCI Committee on Bridges
and the PCI Bridge Producers
Committee

Under the direction of the
Sub-committee for the
State-Of-The-Art Report on
Full-Depth Precast Concrete
Bridge Deck Panels

U.S. Department of Transportation
Federal Highway Administration

Co-sponsored by:

First Edition

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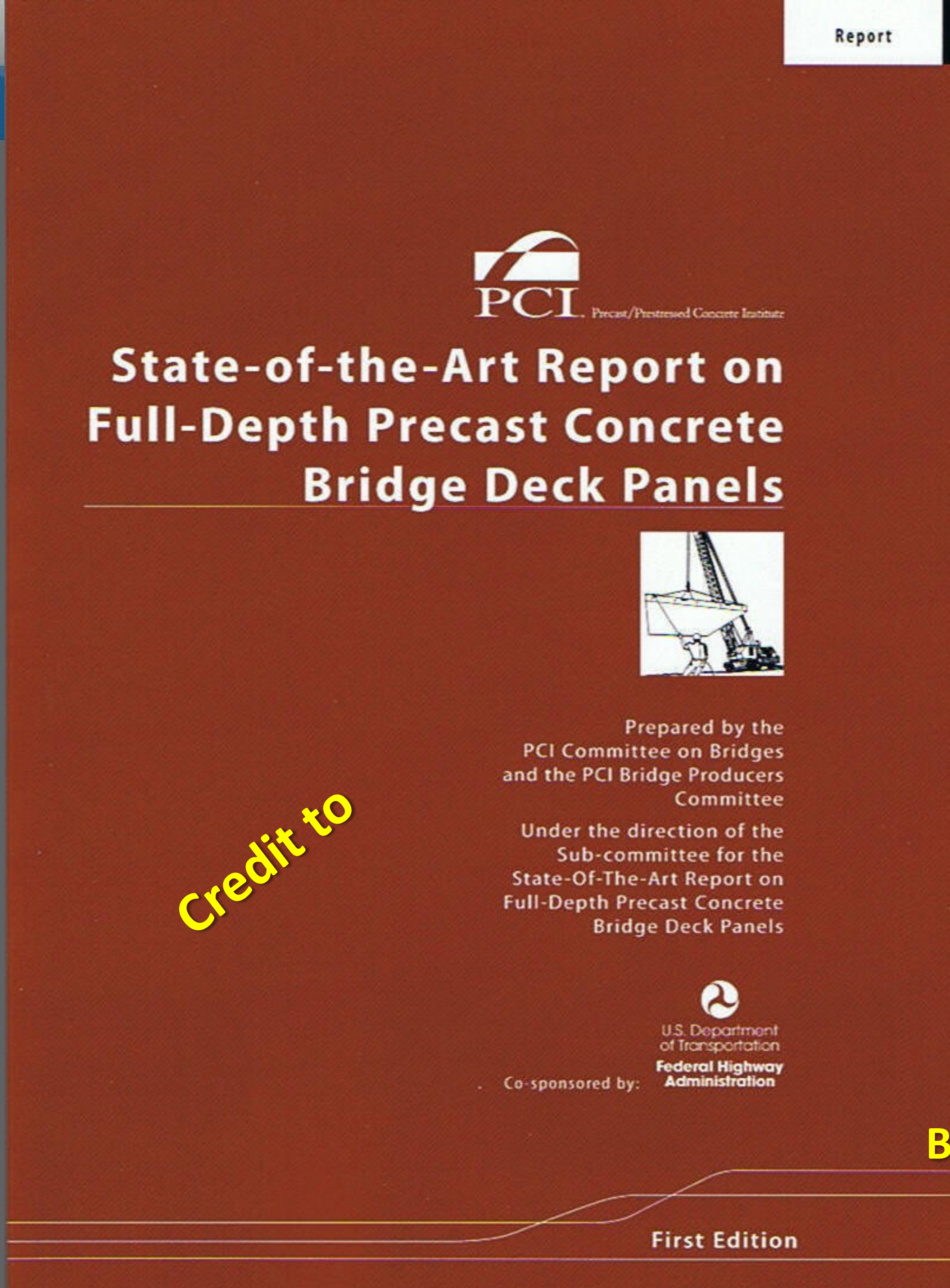
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Credit to

Precast/Prestressed Concrete Institute

Vince Campbell
Former president of
Bayshore Concrete Products Corporation, VA

Concrete Institute

STATE-OF-THE-ART REPORT ON FULL-DEPTH PRECAST CONCRETE BRIDGE DECK PANELS

With the sponsorship of
PCI Committee on Bridges and the PCI Bridge Producers Committee
(Technical Activities Council)

Under the direction of the sub-committee for the
State-Of-The-Art Report on Full-Depth Precast Concrete Bridge Deck Panels

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Several others that deserve special recognition for their contributions include: Vince Campbell for his vision to create a document on this topic; Nghi Nguyen, Parul Patel, and Sameh S. Badie who helped with the example in Appendix D and Kromel Hanna who assisted the technical editor to create the final publication.

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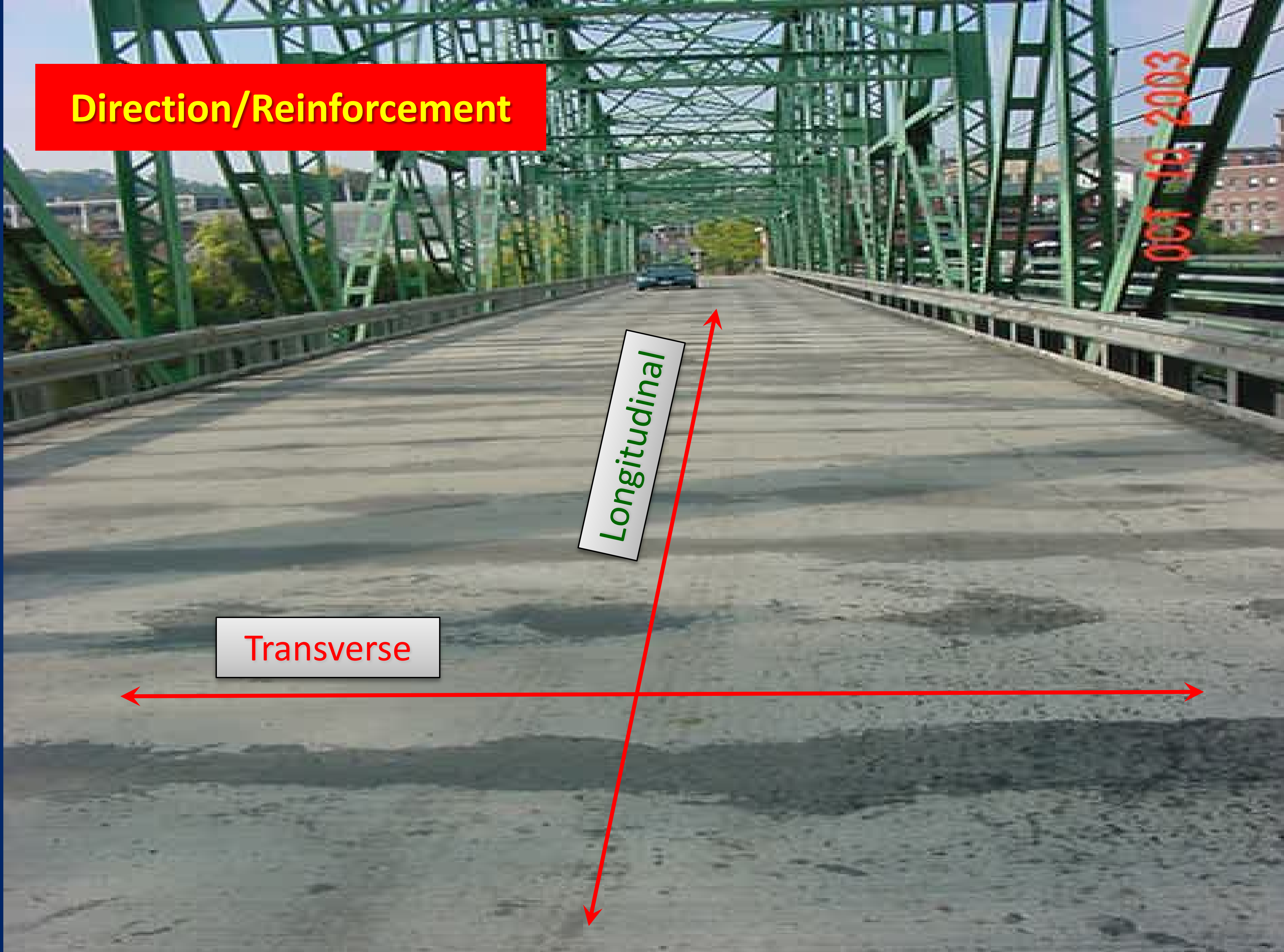
C. Details of the FDDP*

D. Miscellaneous issues

E. Examples of successful projects

F. Available resources

(* FDDP = Full-Depth Precast Concrete Deck Panels)


Direction/Reinforcement
Longitudinal
Transverse
OCT 10 2003

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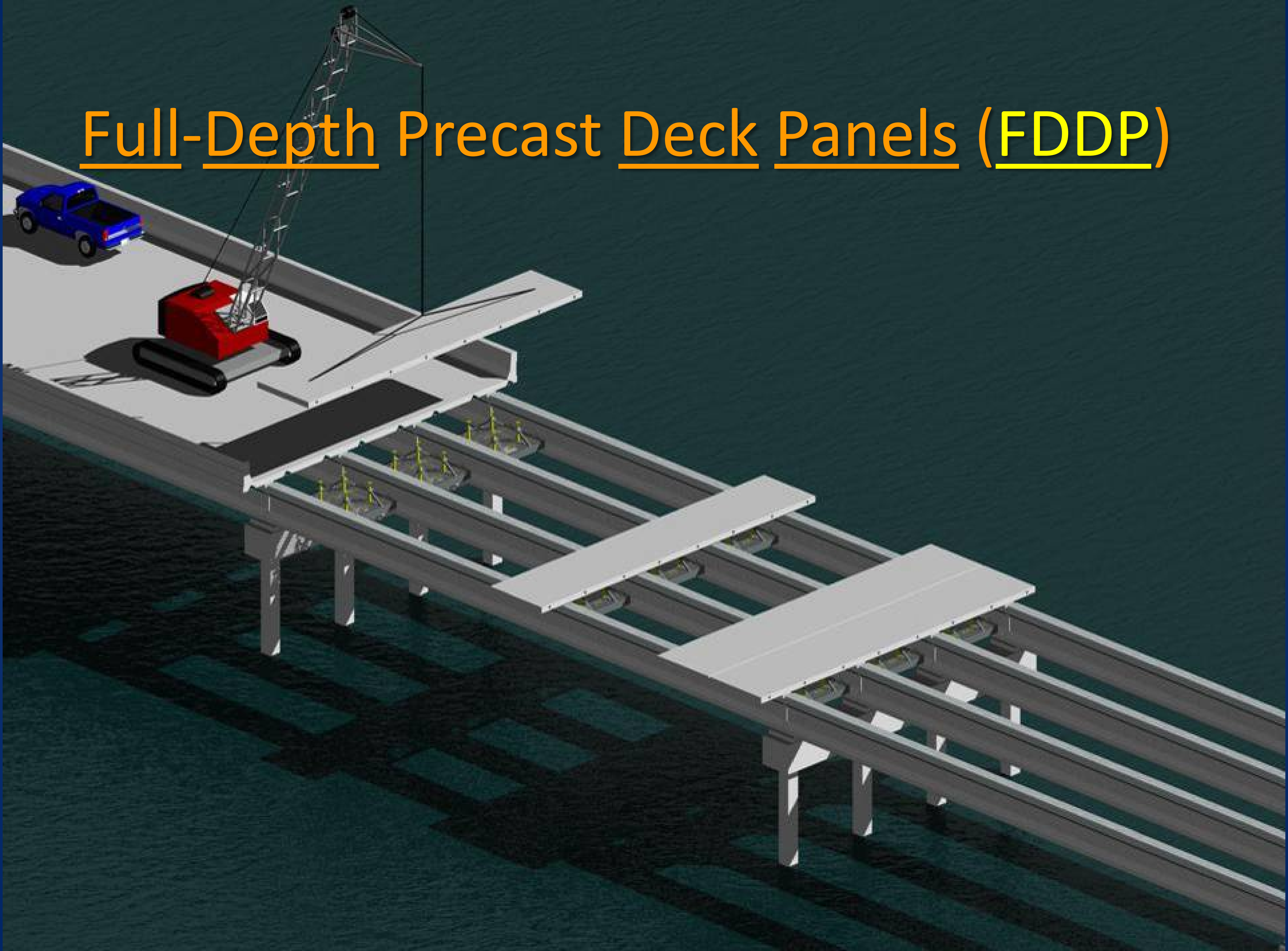
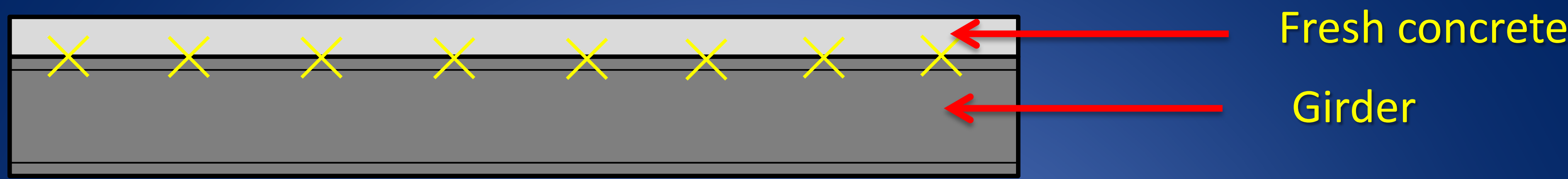
Full-Depth Precast Deck Panels (FDDP)



Full Depth Precast Panels Do not Crack

- Cracking of FDDP is substantially controlled Because :
  - Concrete is mature. It has already undergone most of its cement hydration temperature change, shrinkage and creep
  - The panels can be prestressed in the plant and post-tensioned at the site, creating two-way precompression.



Fresh concrete shrinks because:

1. Temperature drops after the concrete sets (by as much as 80 degrees)

   $\varepsilon_{Temp.\ drop} = \alpha * \Delta T = (6x10^{-6})(80) = 4.8x10^{-4}$

2. Loss of hydration water (by as much as 300 micro strains)

   $\varepsilon_{shrinkage} = 3.0x10^{-4}$

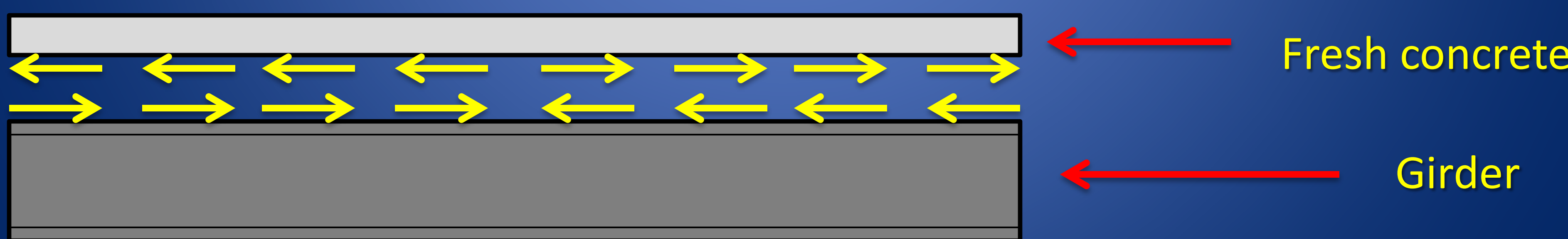
   Thus, total shrinkage strain, $\varepsilon_{total} = 4.8x10^{-4} + 3.0x10^{-4} = 7.8x10^{-4}$

   If concrete compressive strength, f’c = 1,000 psi at one day

   Modulus of elasticity, E_c = 57,000 (Sqrt 1,000) = 1,800 psi

   Tensile stress due to combined actions = $\varepsilon_{total} * E_c$ = 1,400 psi

   Modulus of rapture = 7.5* Sqrt(f’c) = 237 psi



Since the deck concrete is restrained by girders, it cracks

Advantages of FDDP

	FDDP
Construction Speed	High
Shrinkage cracking	Eliminated
Hydration temperature cracking	Eliminated
Formwork	Eliminated
Maintenance cost	Low
Structural integrity	Maintained
Adaptability for continuous span bridges	Yes
Initial cost	Relatively High
Service life	Long

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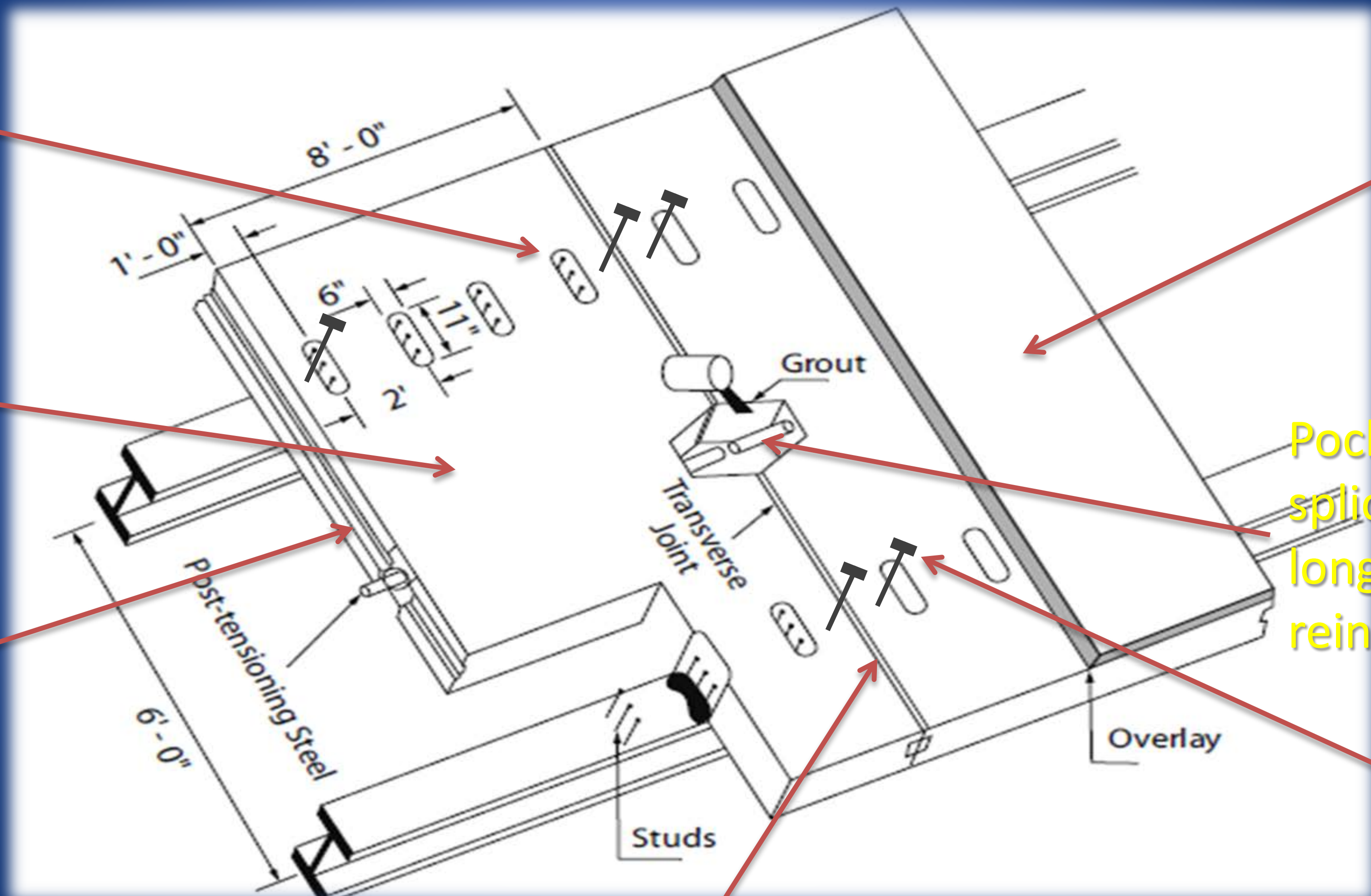
Components of the FDDP

Shear pockets

Precast panels

Shear key



Overlay (may be omitted)

Pockets for splicing longitudinal reinforcement

Leveling bolts

Transverse joints

Longitudinal joint

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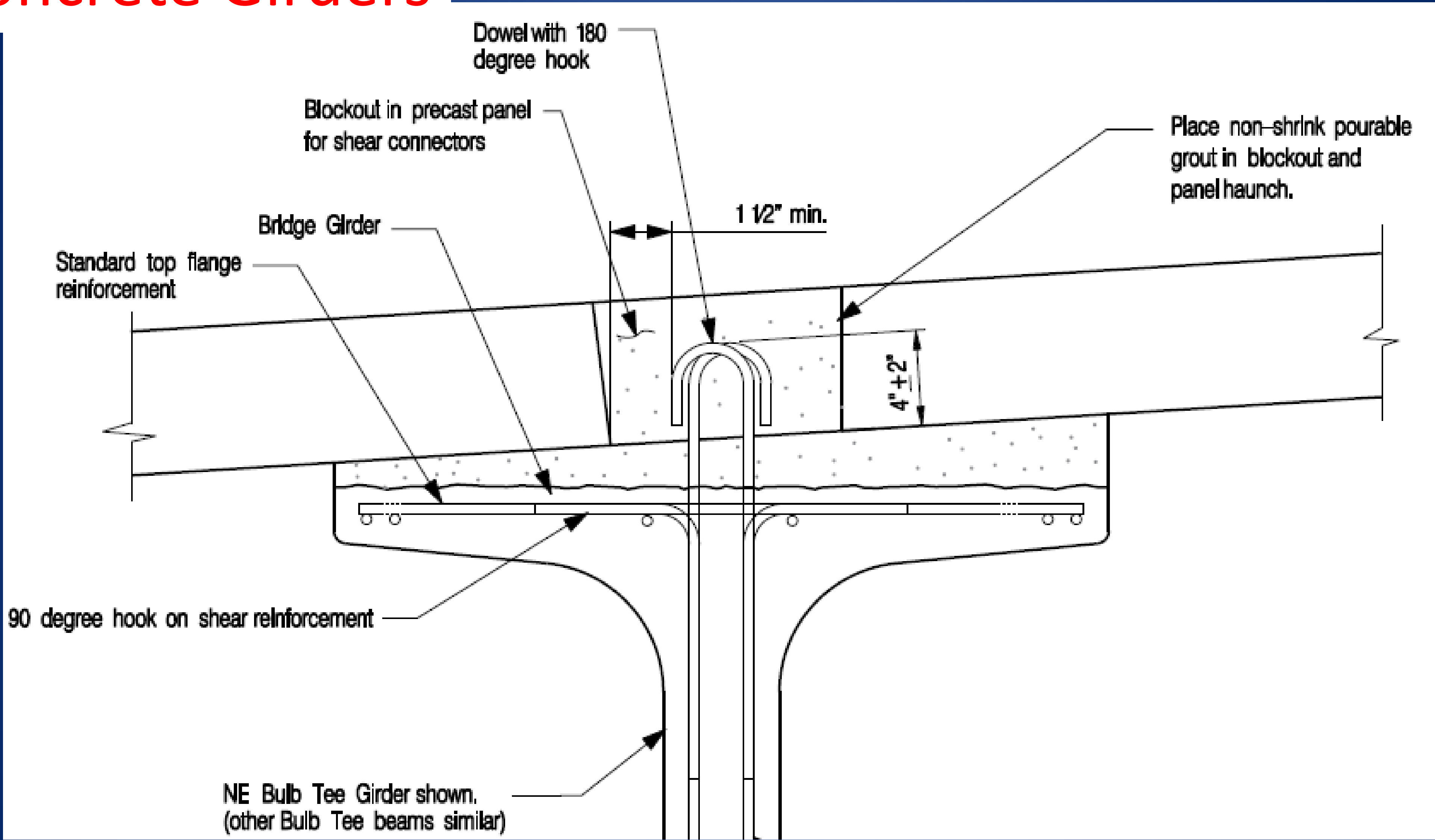
Panel-to-Girder Connection

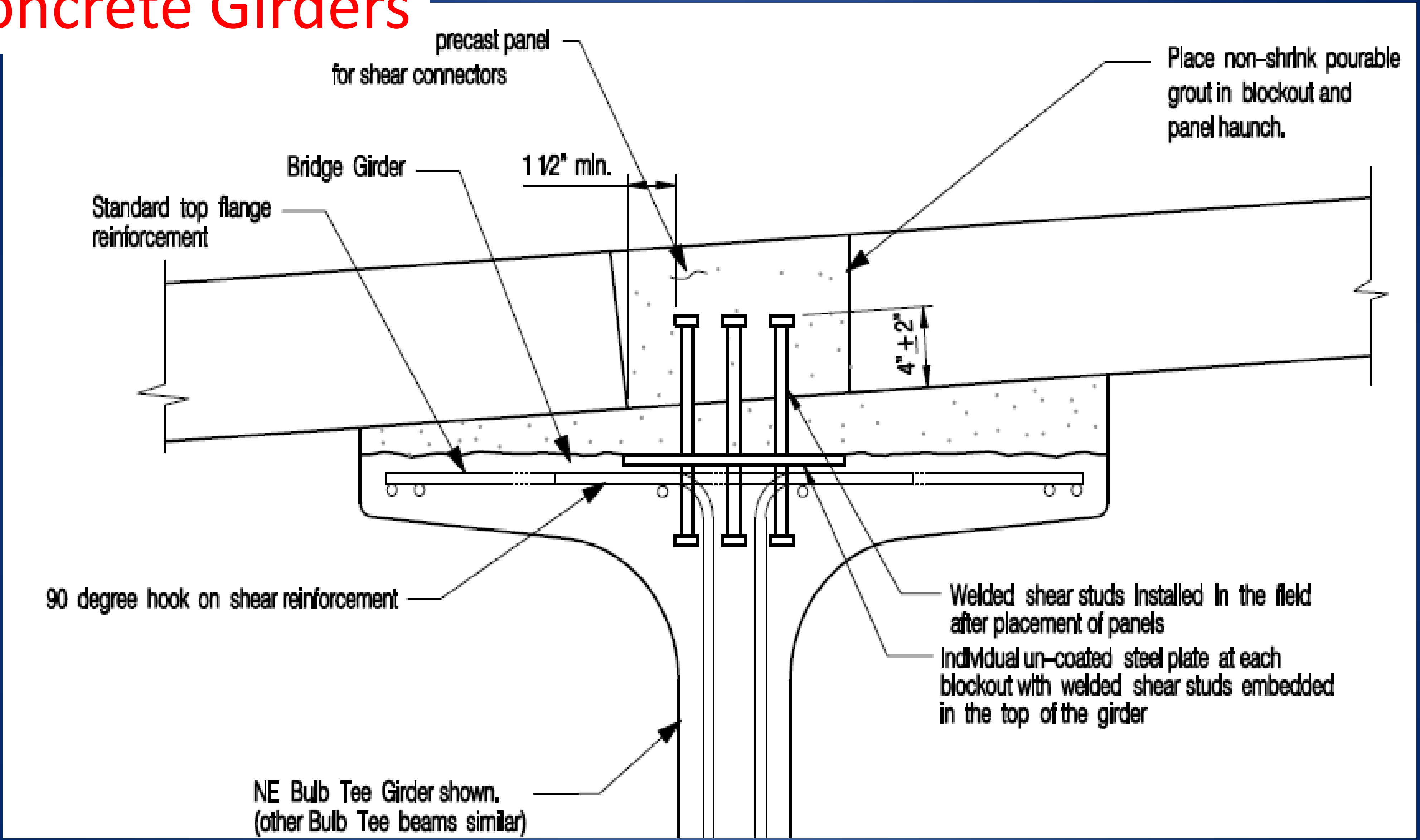
A positive connection between the precast panels and the supporting girders is required to create a composite deck-girder system

Concrete Girders



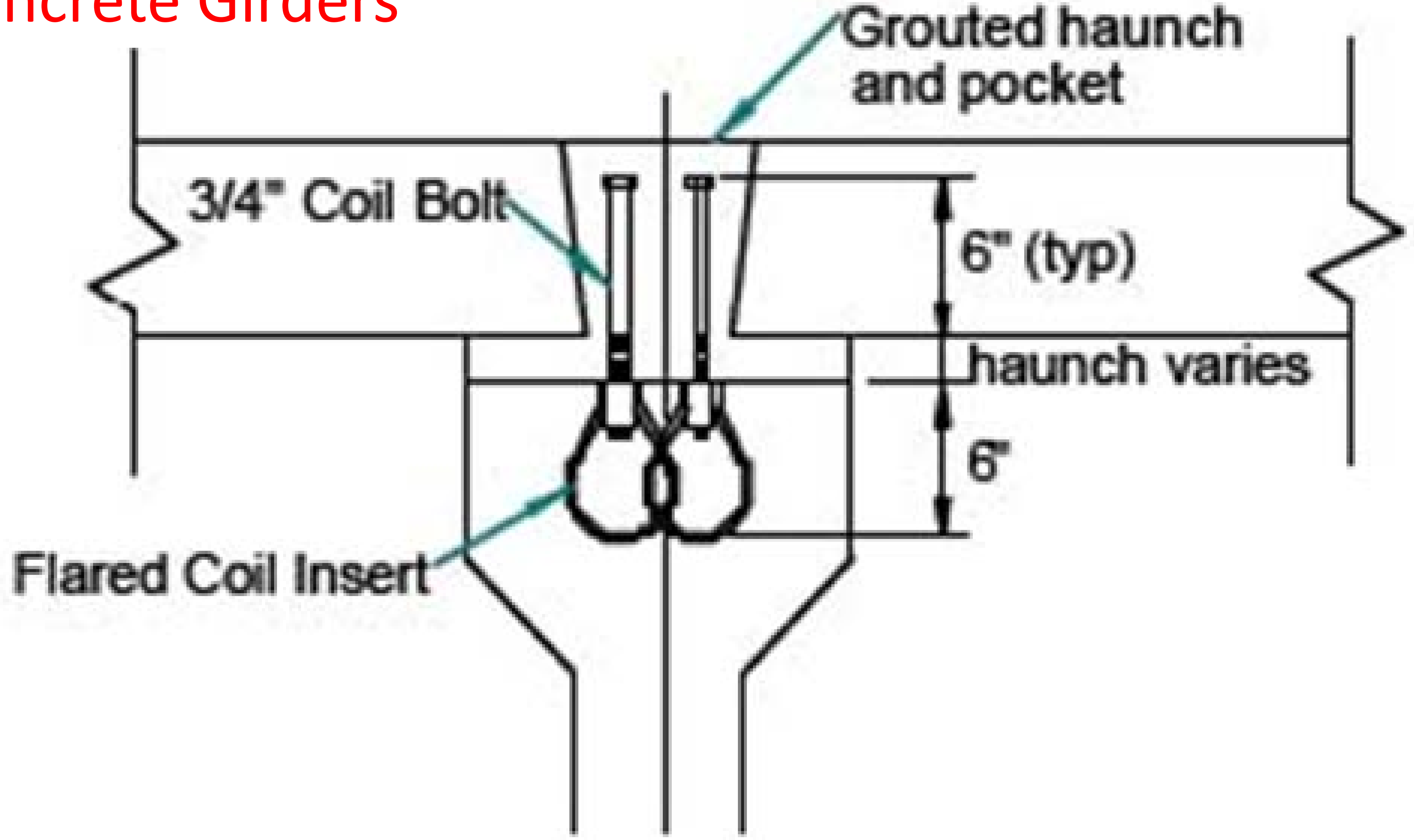
NEW CONSTRUCTION WITH PROJECTING REINFORCING CONNECTION

Concrete Girders



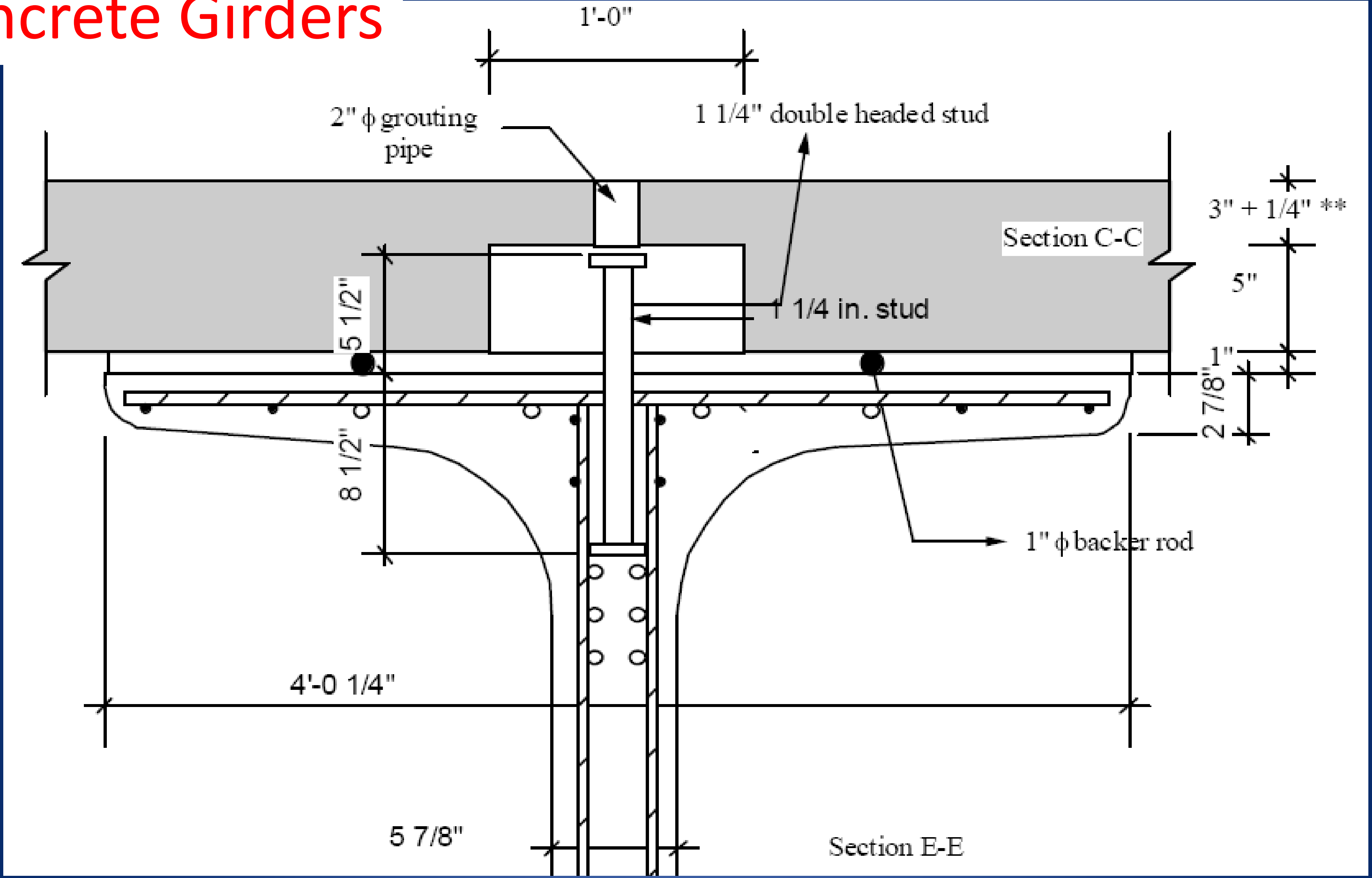
NEW CONSTRUCTION WITH WELDED STUD CONNECTION

Concrete Girders



NEW CONSTRUCTION WITH COIL INSERTS AND COIL BOLTS

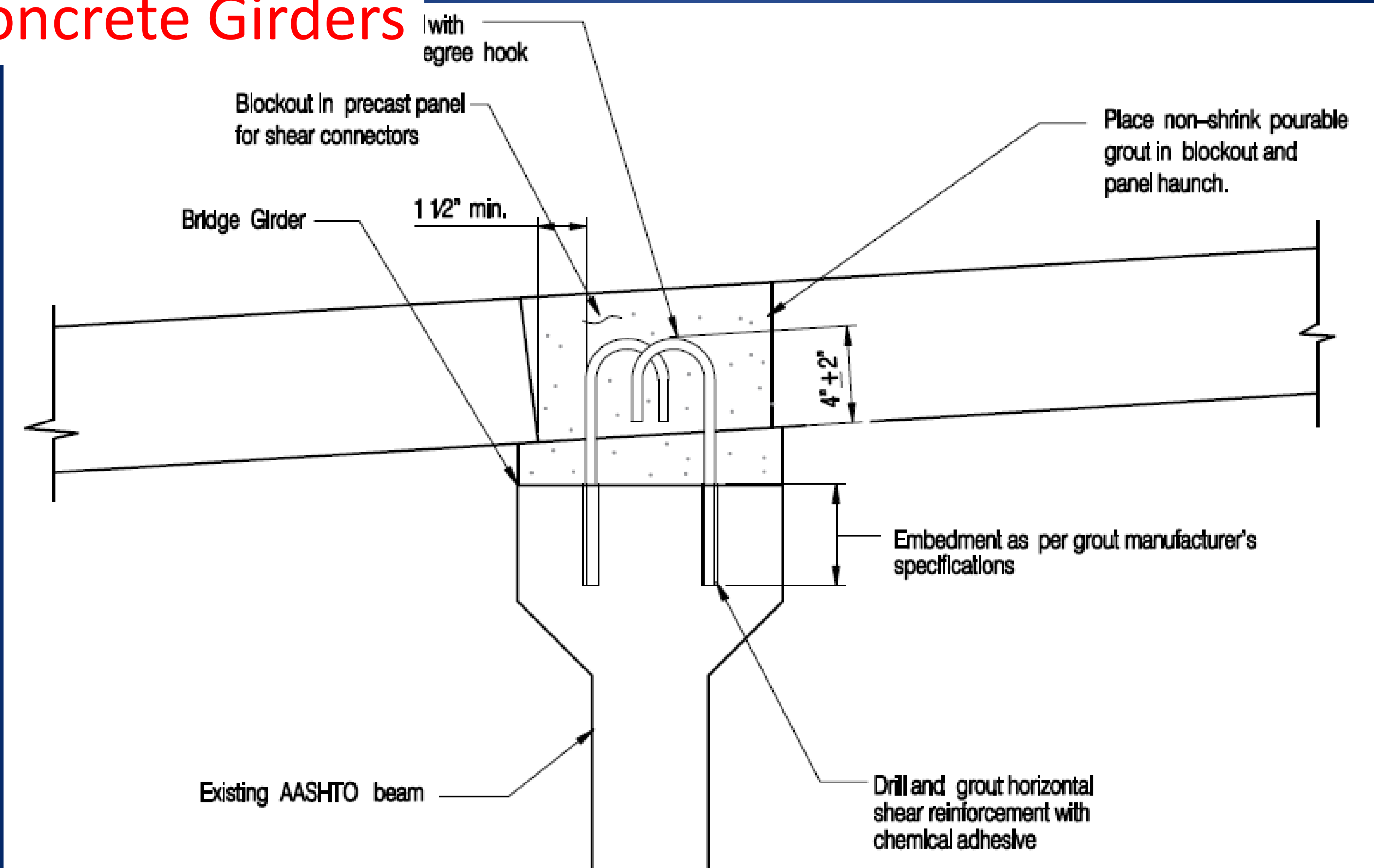
Concrete Girders



NEW CONSTRUCTION WITH PROJECTING DOUBLE HEADED STUD

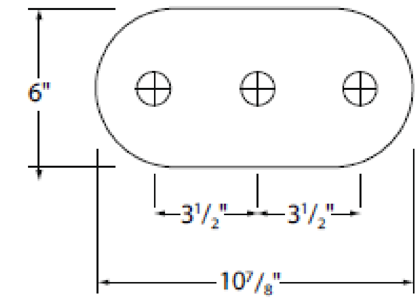
Live Oak Bridge, TX

Concrete Girders



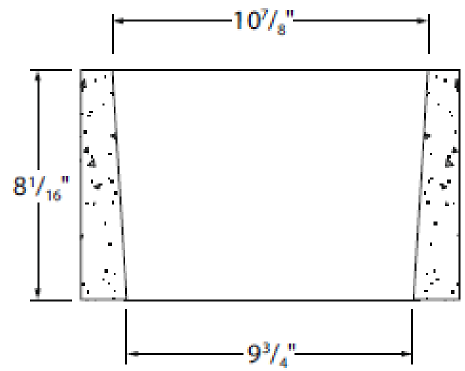
DECK REPLACEMENT

Steel Girders

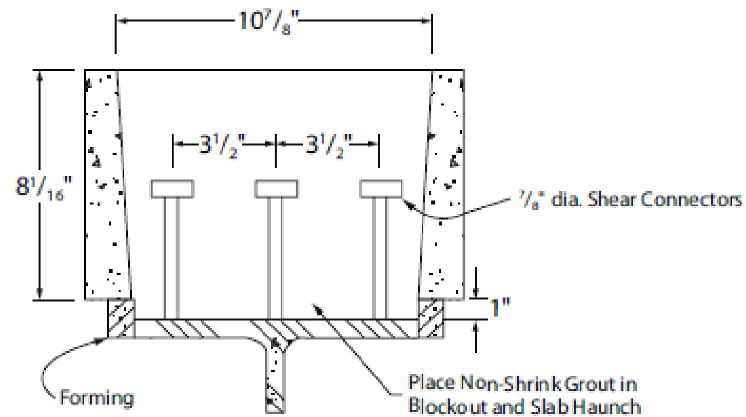


PLAN

NEW CONSTRUCTION Or DECK REPLACEMENT WITH PROJECTING HEADED STUD



SECTION

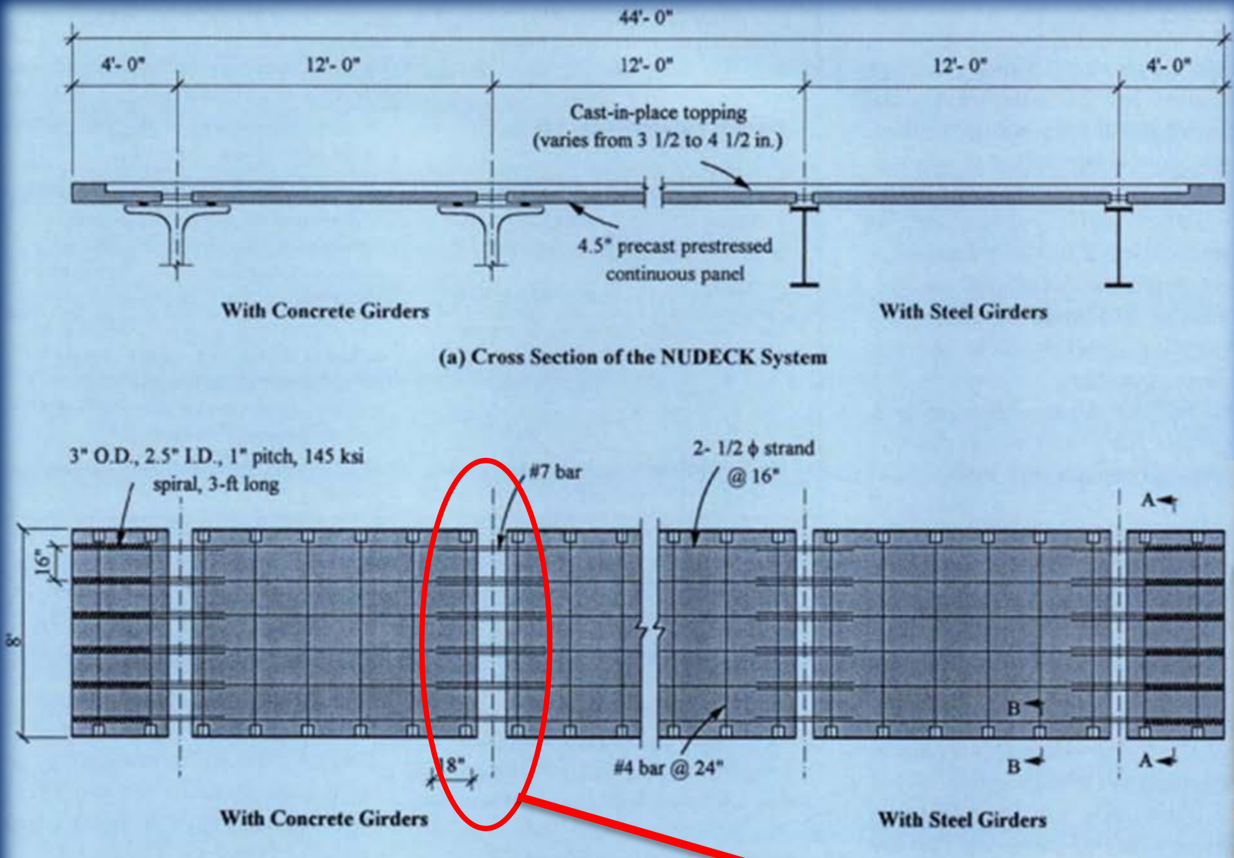


SECTION

Types of Shear Pockets

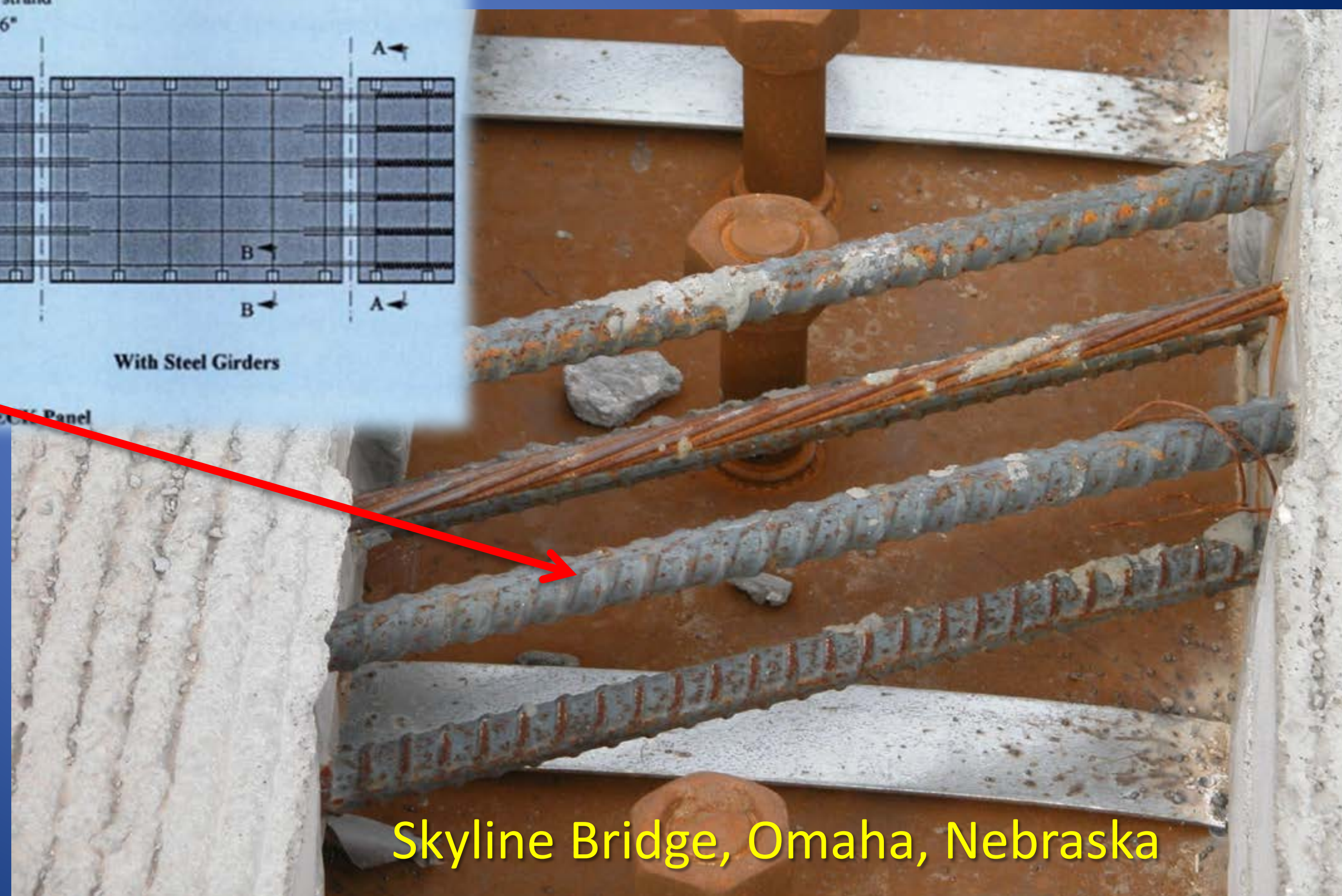
FDDP with individual Open shear pockets

FDDPs with continuously open channels for PT and composite connection



(a) Cross Section of the NUDECK System

(b) Plan View of the Precast NUDECK Panel

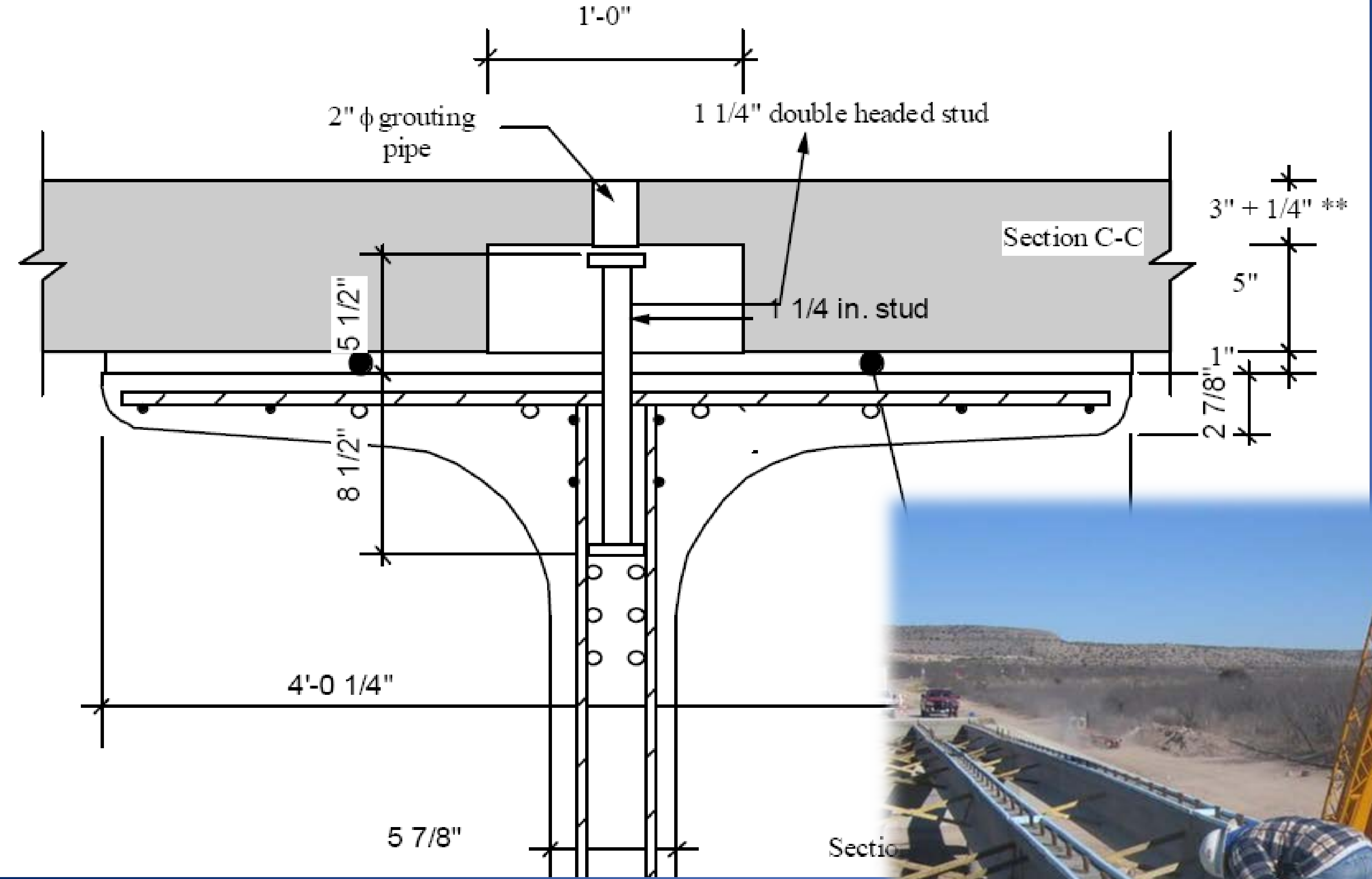


Skyline Bridge, Omaha, Nebraska

NCHRP 12-41

NUDECK System

FDDPs with individual hidden shear pockets



NCHRP 12-65

Live Oak Bridge, TX

Spacing Between Shear Pockets

S = 2 ft
ASSHTO LRFD

S = 4 ft
NCHRP 12-65
Wis. DOT

Panel-to-Panel Transverse Connection

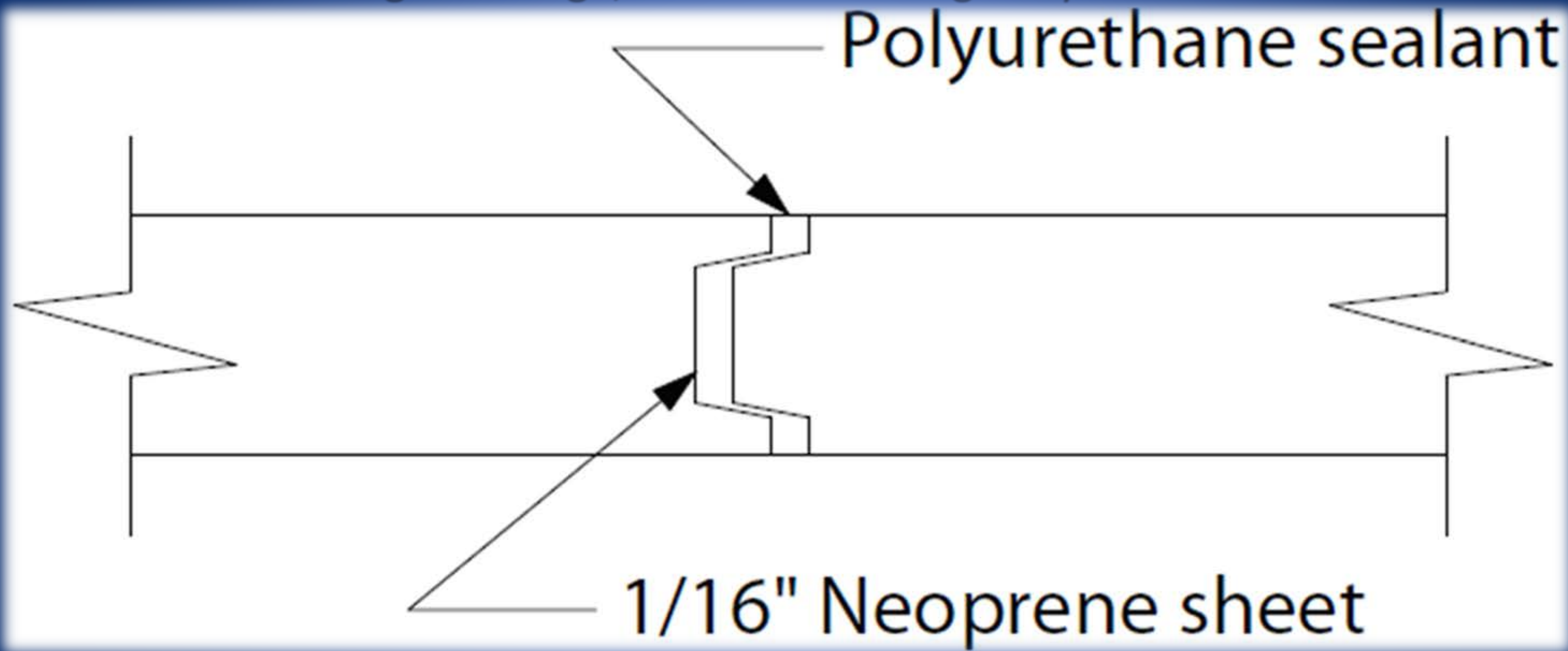
The transverse edges of the precast panels are usually provided with shear keys. Typically, the shear key that extends along the transverse edges of a precast deck panel plays an important role in the service performance of the finished deck. The shear key must be designed to eliminate relative vertical movement between adjacent panels and to transfer the traffic load from one panel to the next.

Under traffic load, a panel-to-panel joint experiences two types of loading:

1. A vertical shear force that tries to break the bond between the panel and the grout filling the joint, and
2. A bending moment that puts the top half of the joint in compression and the bottom half of the joint in tension.

Male-Female (Tongue/Groove) Shear Key

Bloomington Bridge, Indiana State Highway Commission

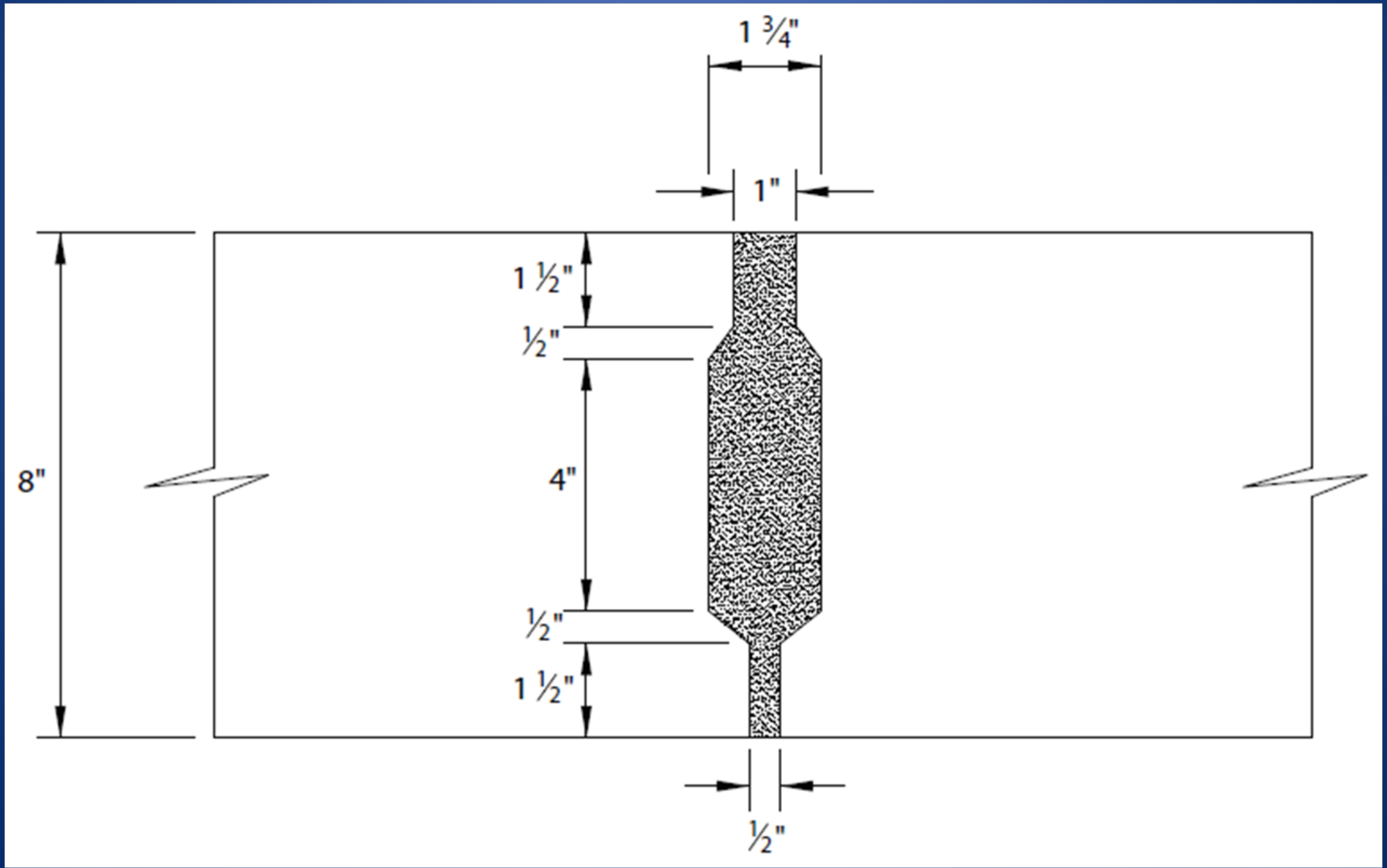


Cracking, spalling & leakage were observed.

Due to elevation adjusts and fabrication tolerances , the tongue/groove detail did not provide 100% match.

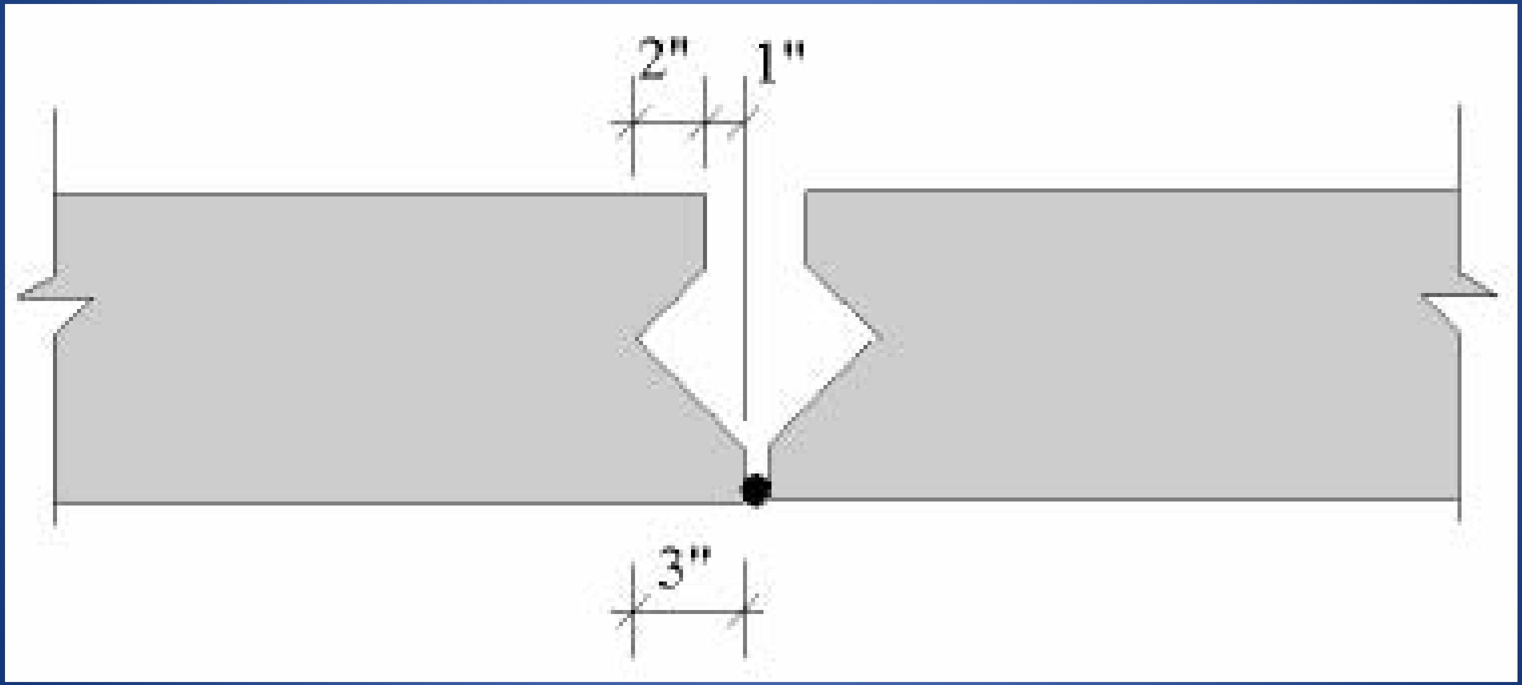
Female-to-Female Shear Key

Bulb Shape (NCHRP 12-41)

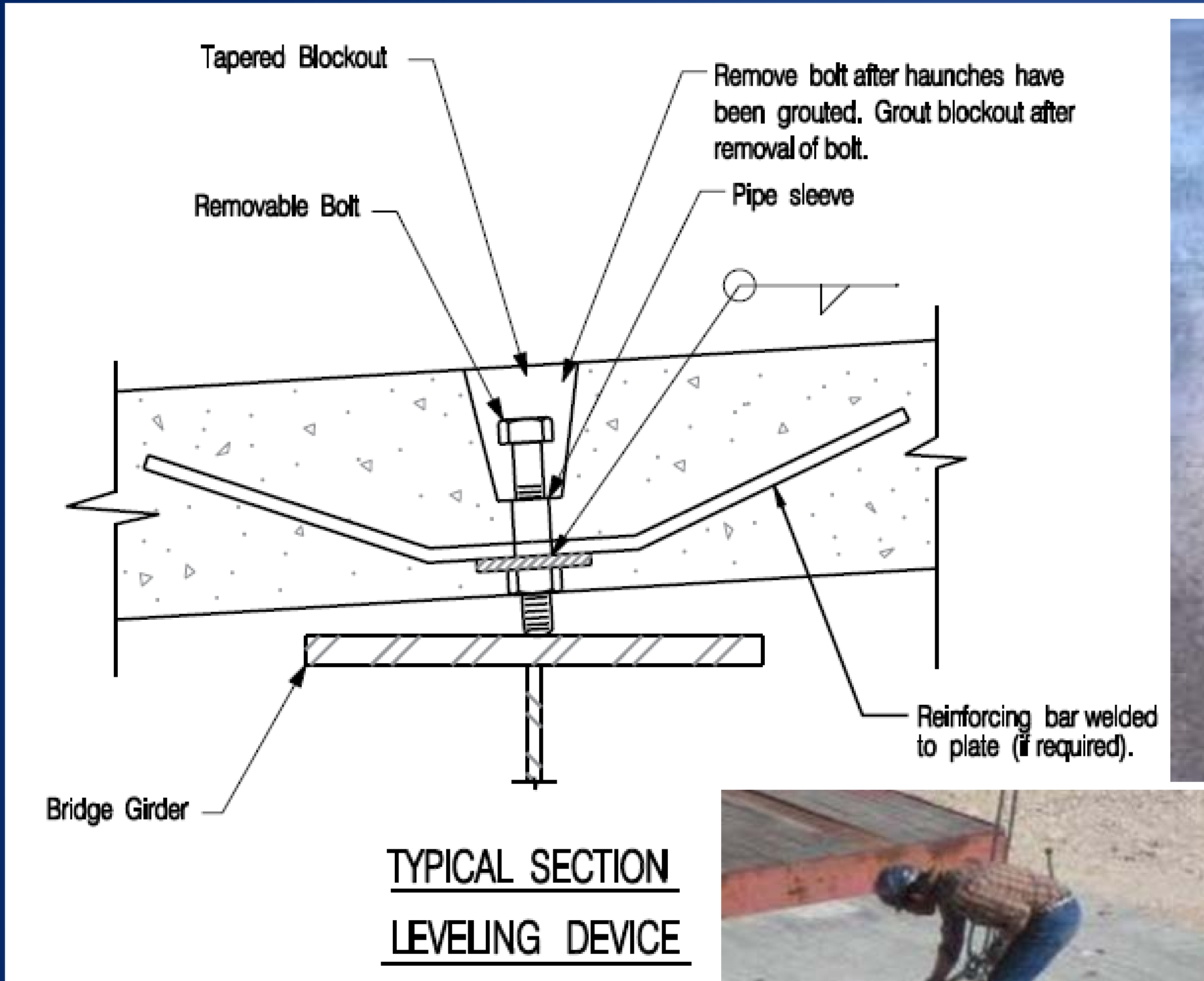


Female-to-Female Shear Key

Diamond Shape (NCHRP 12-41)



More flexible detail with higher level of mechanical interlocking capacity

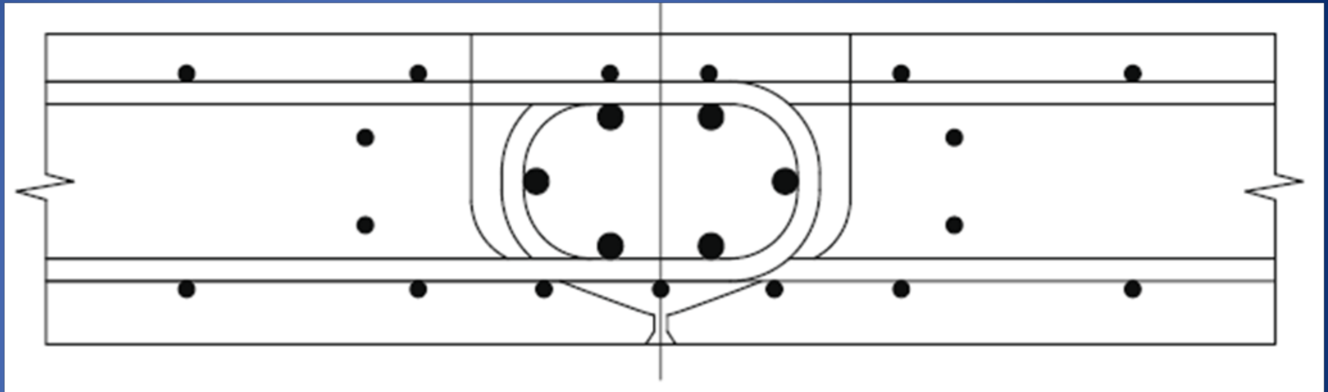


Leveling Bolts

Splicing Longitudinal Reinforcement

Case 1: Reinforcing Bars, No PT

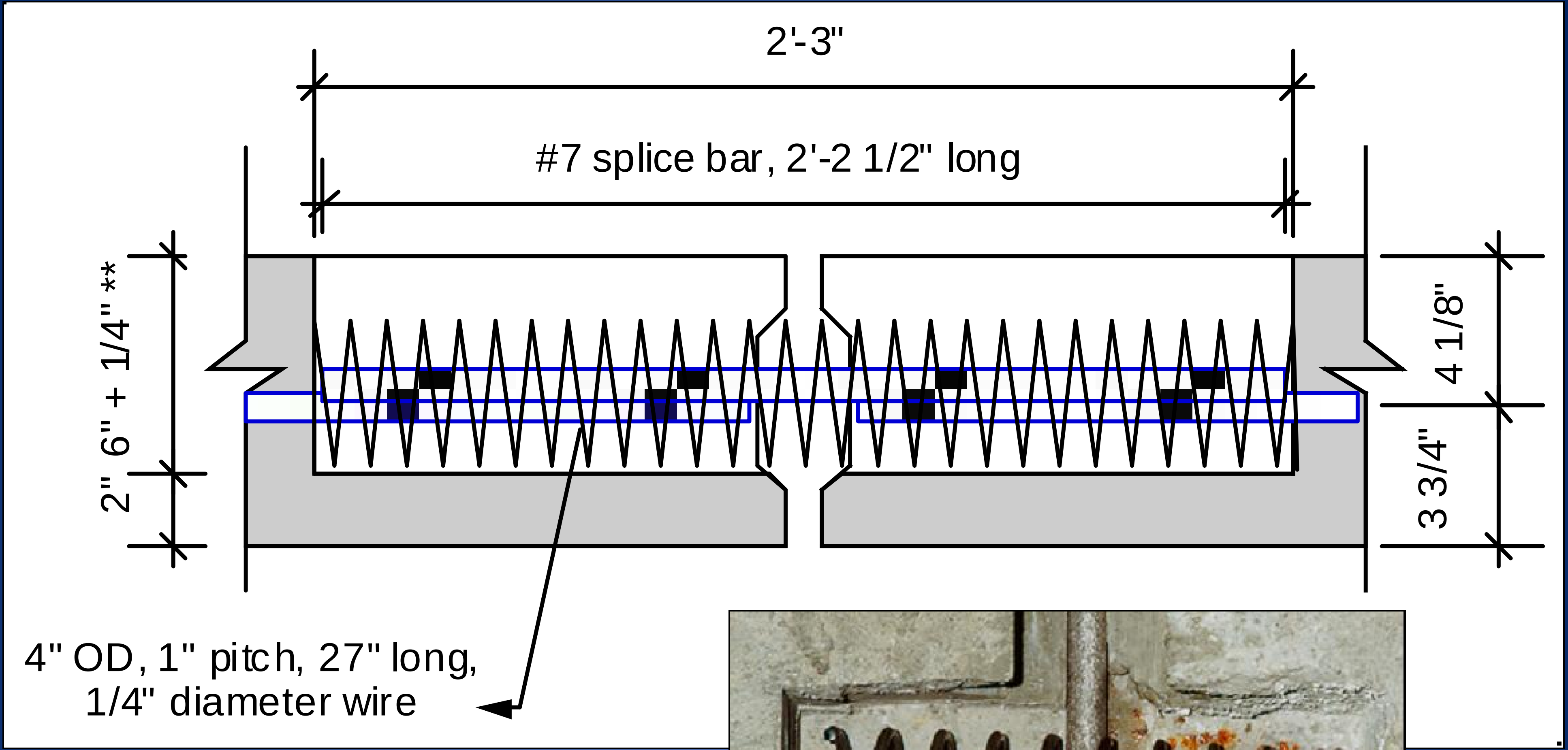
Overlapping U-bars



Notes

- Extending bars outside the panels
- Bending diameter vs the panel thickness
- Use U-shape bars separate from panel reinforcement

Bill Emerson Memorial Bridge, Missouri DOT

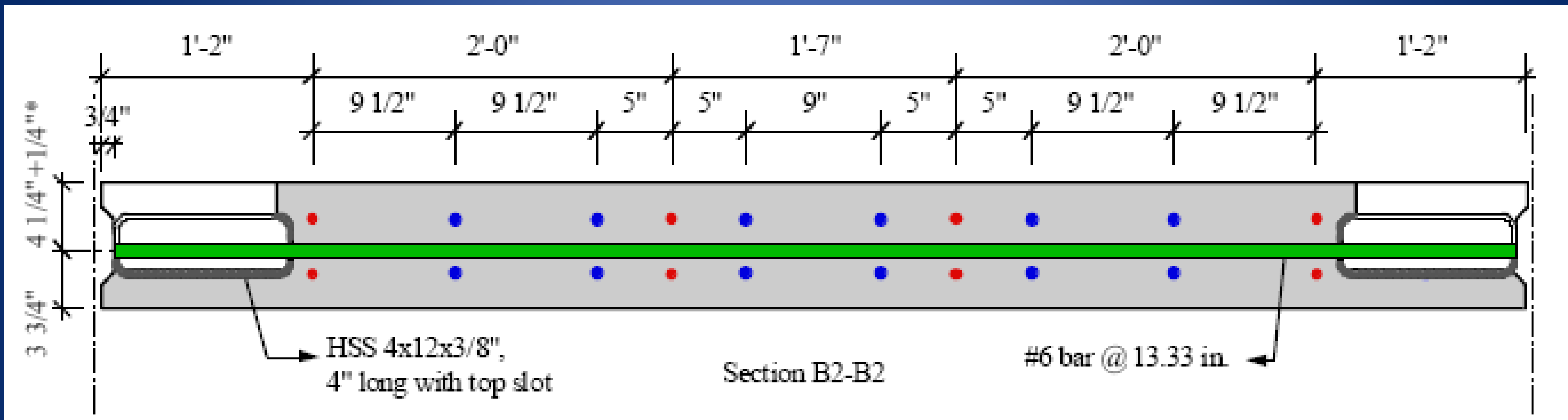


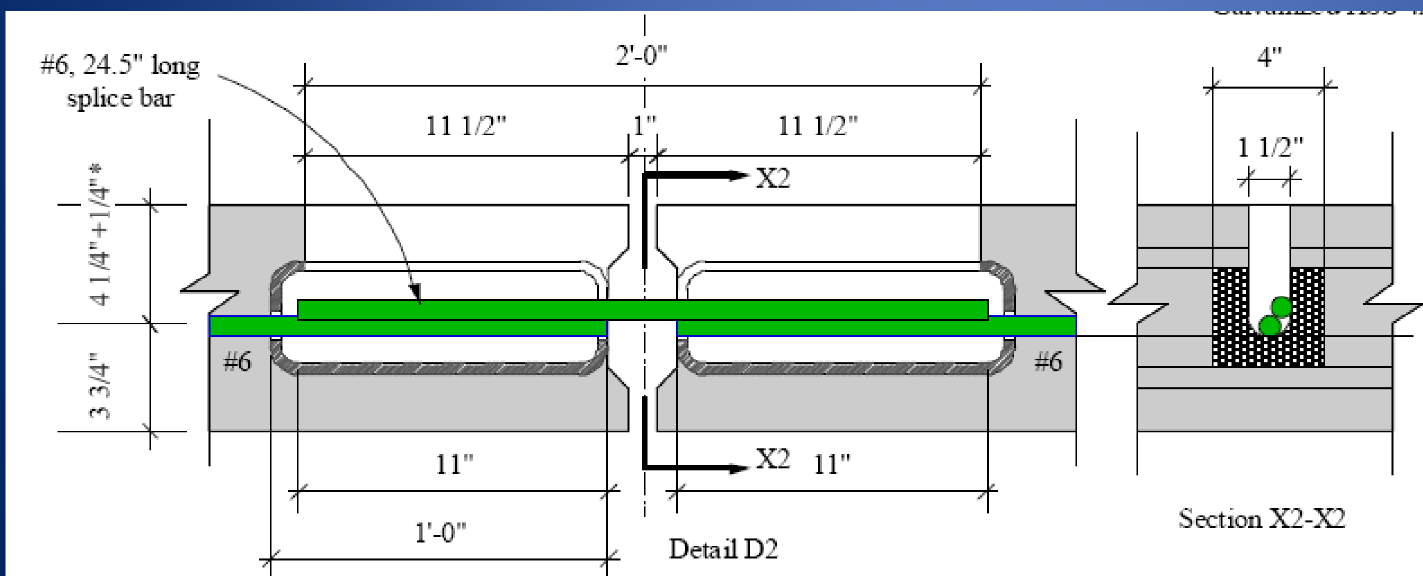
Using HS Spirals

NCHRP 12-41

Using Open Steel Tubes

NCHRP 12-65

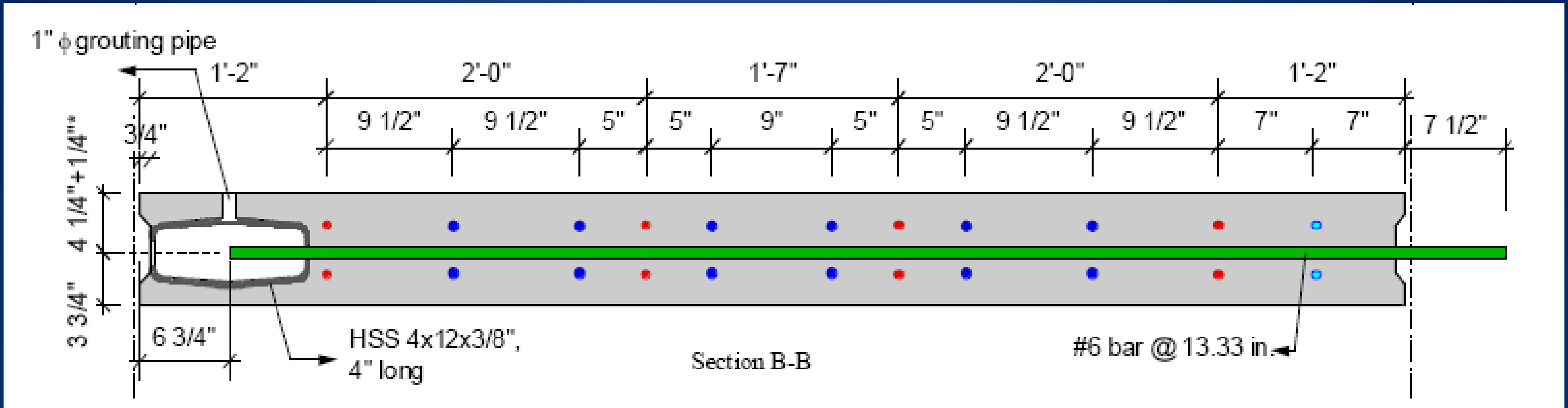




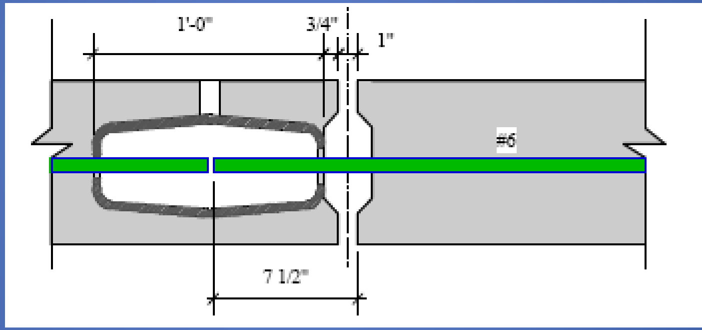
Live Oak Bridge, TX

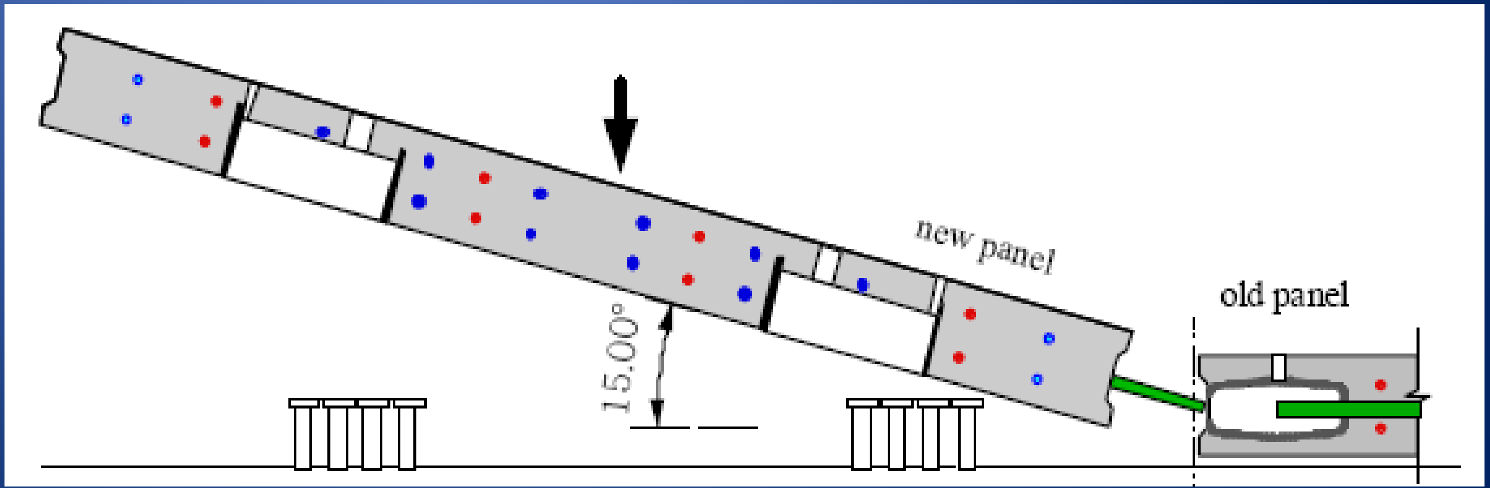
Notes

- Alignment of slots
- Tight fabrication tolerance
- Durability was enhanced by minimizing the exposed surface area of the grout (using hidden shear pockets and the open steel tube detail for splicing the longitudinal reinforcement)



Using Closed Steel Tubes (NCHRP 12-65)



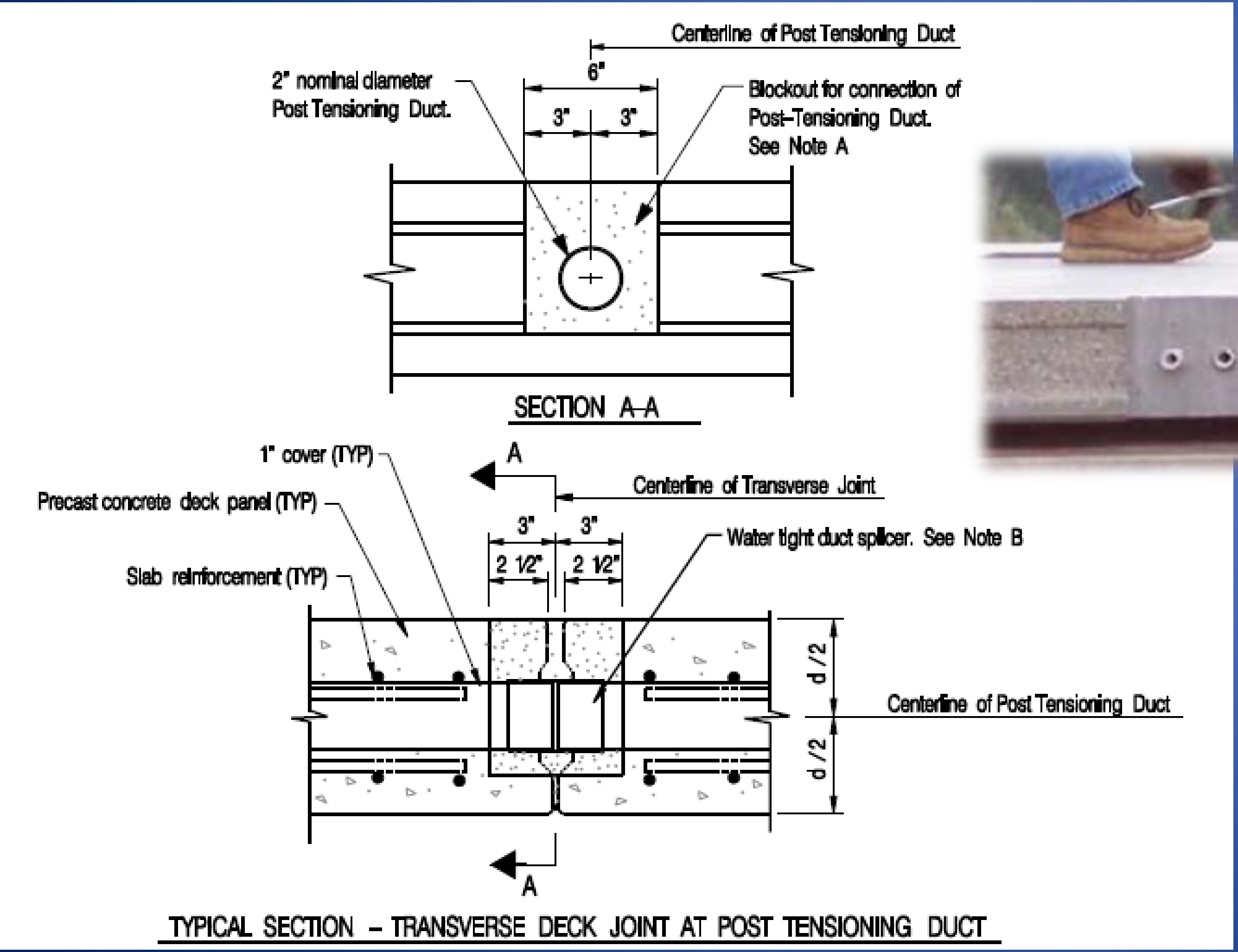


<u>Notes</u>

- Tilting panels during installation

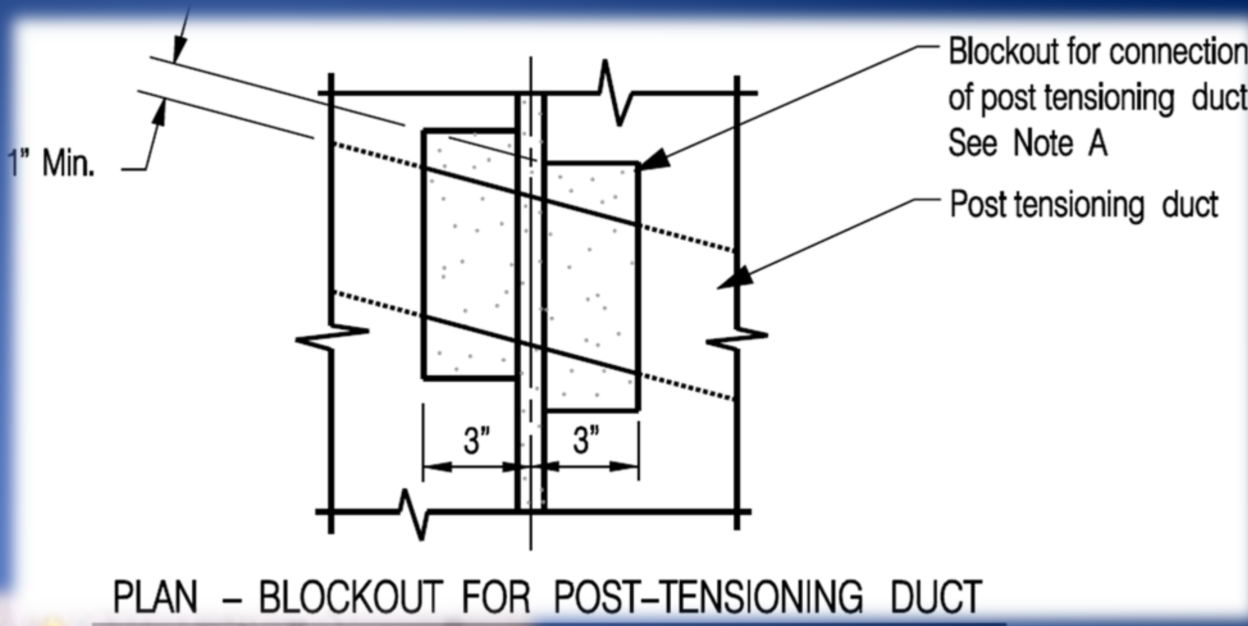
Splicing Longitudinal Reinforcement

Case 2: Longitudinal Post Tensioning



longitudinal PT is distributed over the width of the panel

I-39/90 Bridge over Door Creek, McFarland, Wis.



Notes

- Pocket is wide enough to allow for splicing of the ducts


NUDECK
NCHRP 12-41
longitudinal PT is concentrated at girder lines
Skyline Bridge Omaha, Nebraska
Note: Continuously open channel, one line of studs, visible strand for longitudinal PT

Transverse joints must be grouted before the longitudinal PT tendons are tensioned

I-39/90 Bridge over Door Creek, MacFarland, Wis

Special end panel is required for anchorage of the PT strands

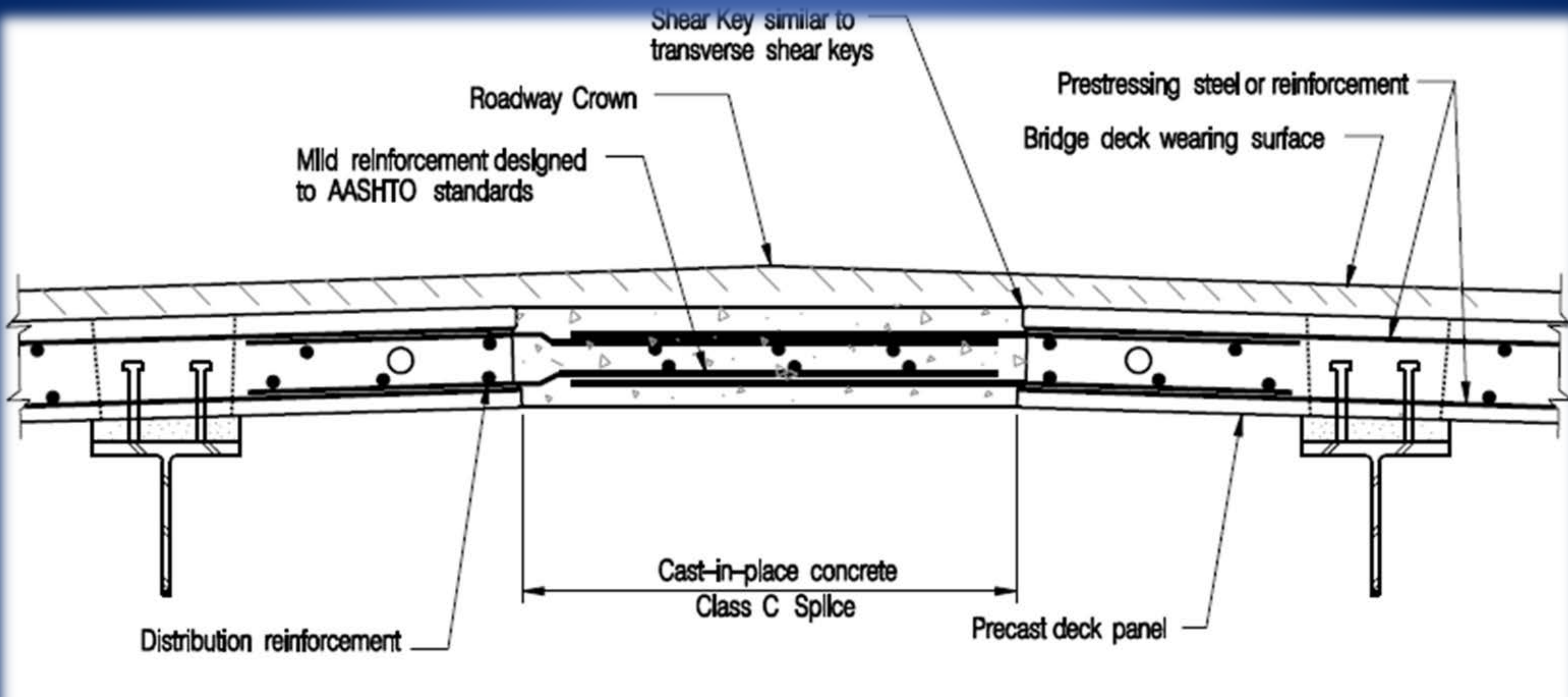
Skyline Bridge, Omaha, Nebraska

- PT done with a small jack, borrowed from UNL Lab
- Contractor worker was trained by UNL technician
- Anchorage plate was locally fabricated

Longitudinal PT ducts are grouted

Grout shear pockets and haunches

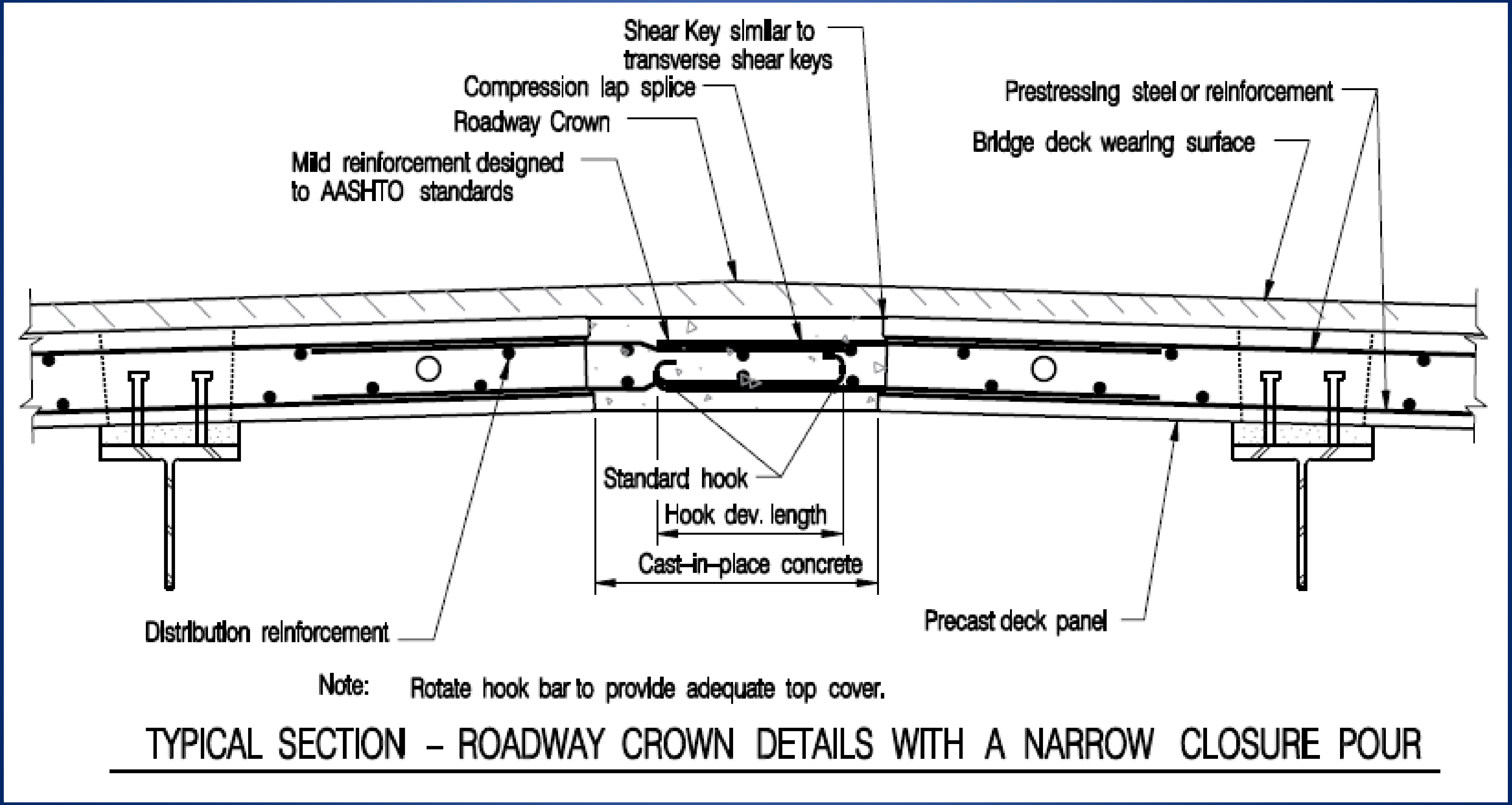
Panel-to-Panel Longitudinal Connection



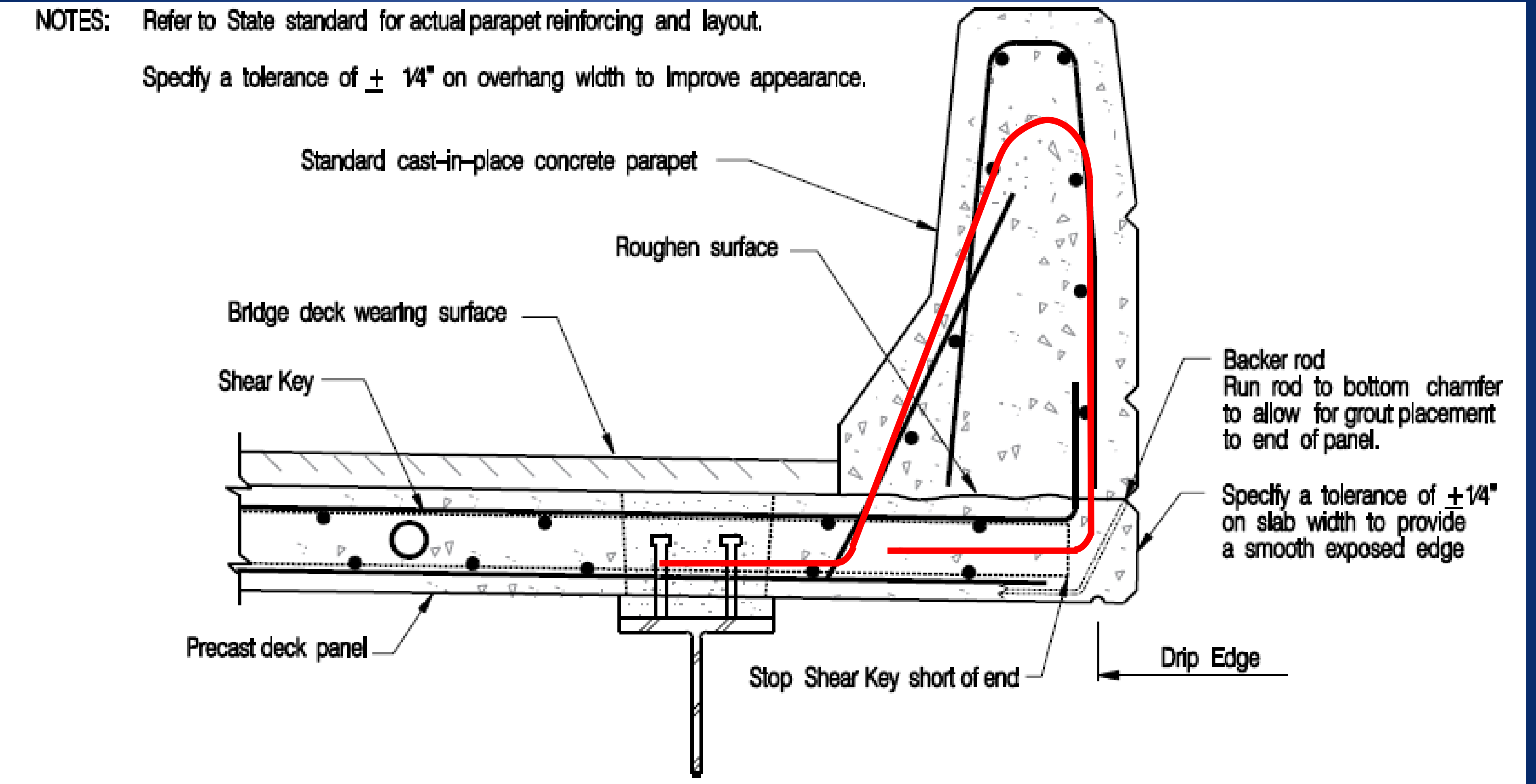
TYPICAL SECTION – ROADWAY CROWN DETAILS WITH A LAP SPLICE

It is recommended to create the connection in a positive moment area

Panel to Panel Longitudinal Connection

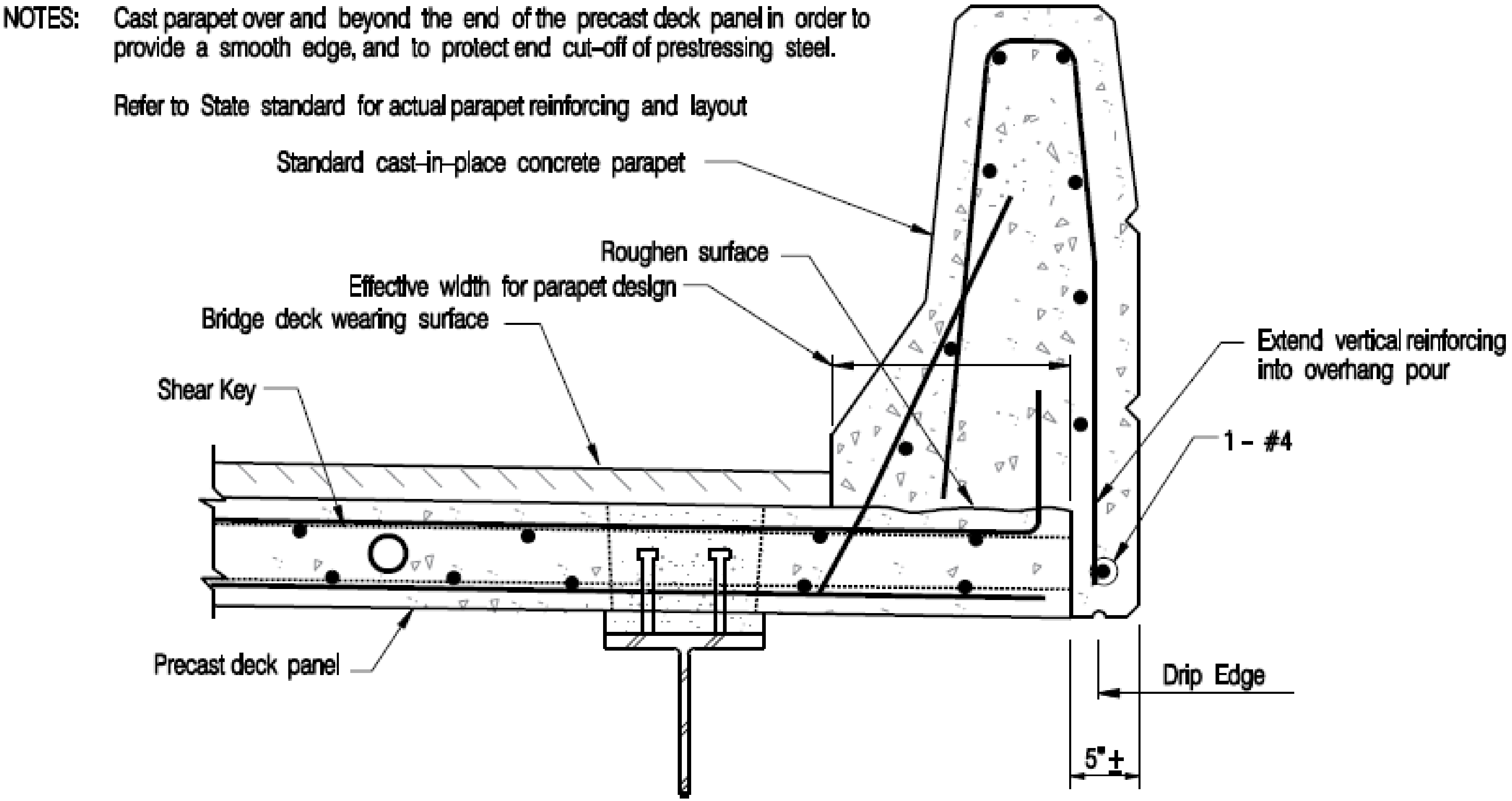


Panel to Barrier Connection



TYPICAL SECTION – PARAPET DETAILS WITH EXPOSED EDGE

Panel-to-Barrier Connection



TYPICAL SECTION – PARAPET DETAILS COVERING EDGE

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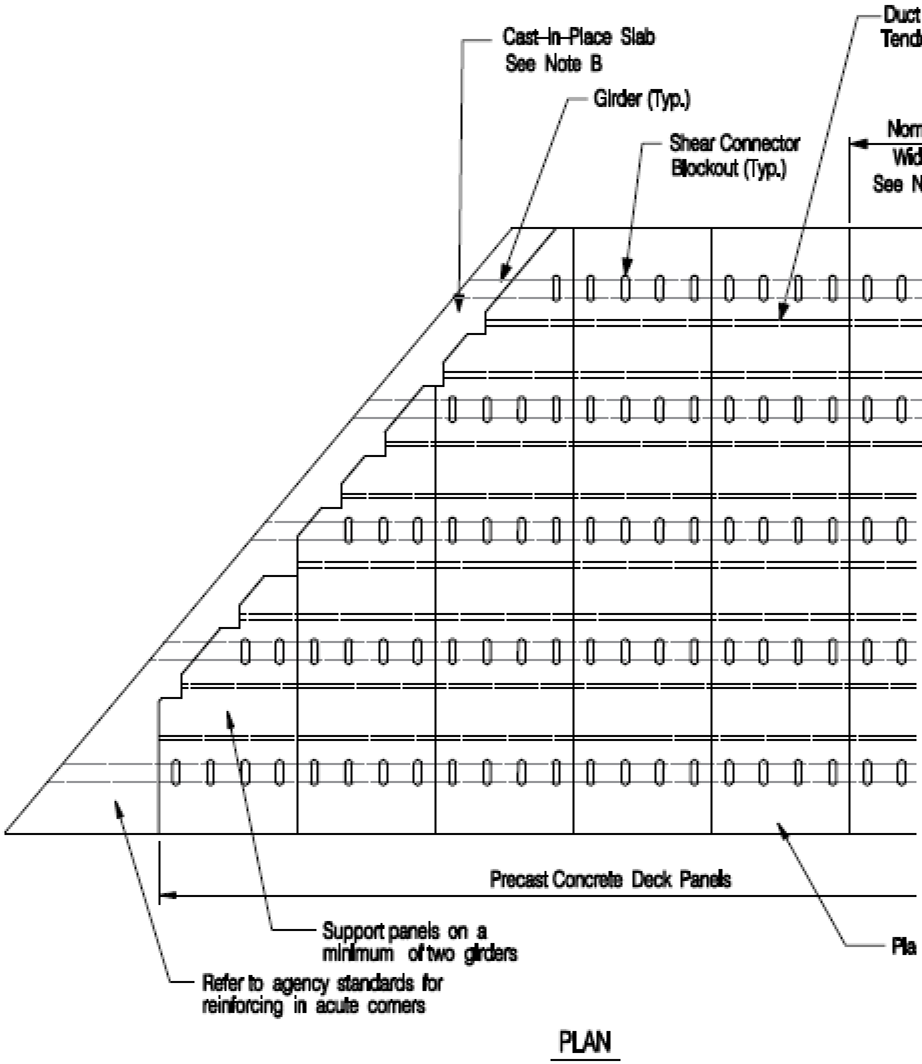
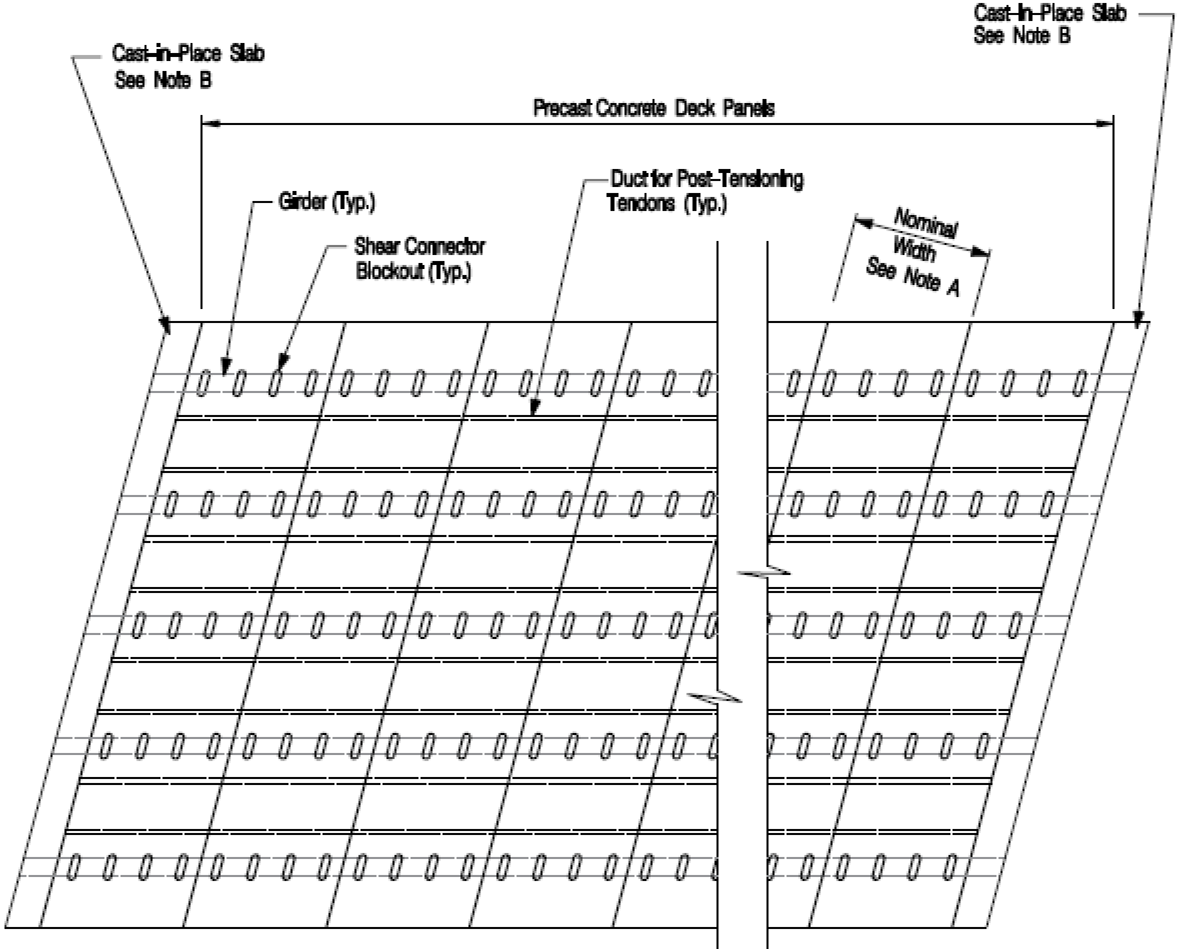
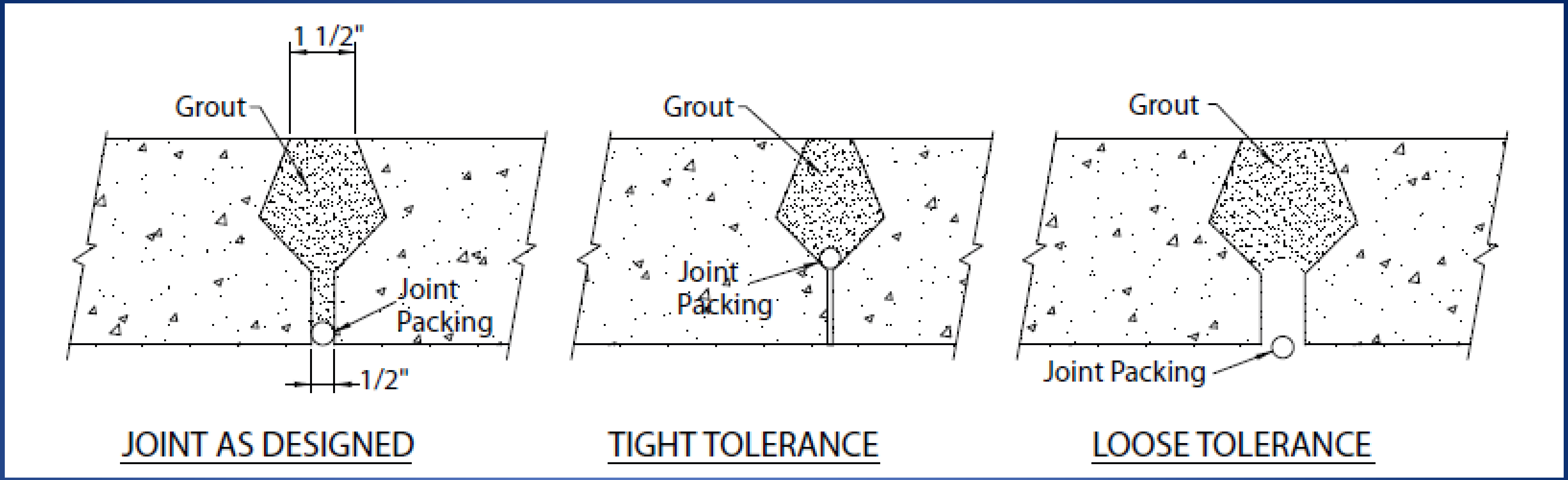
How to Handle Skew





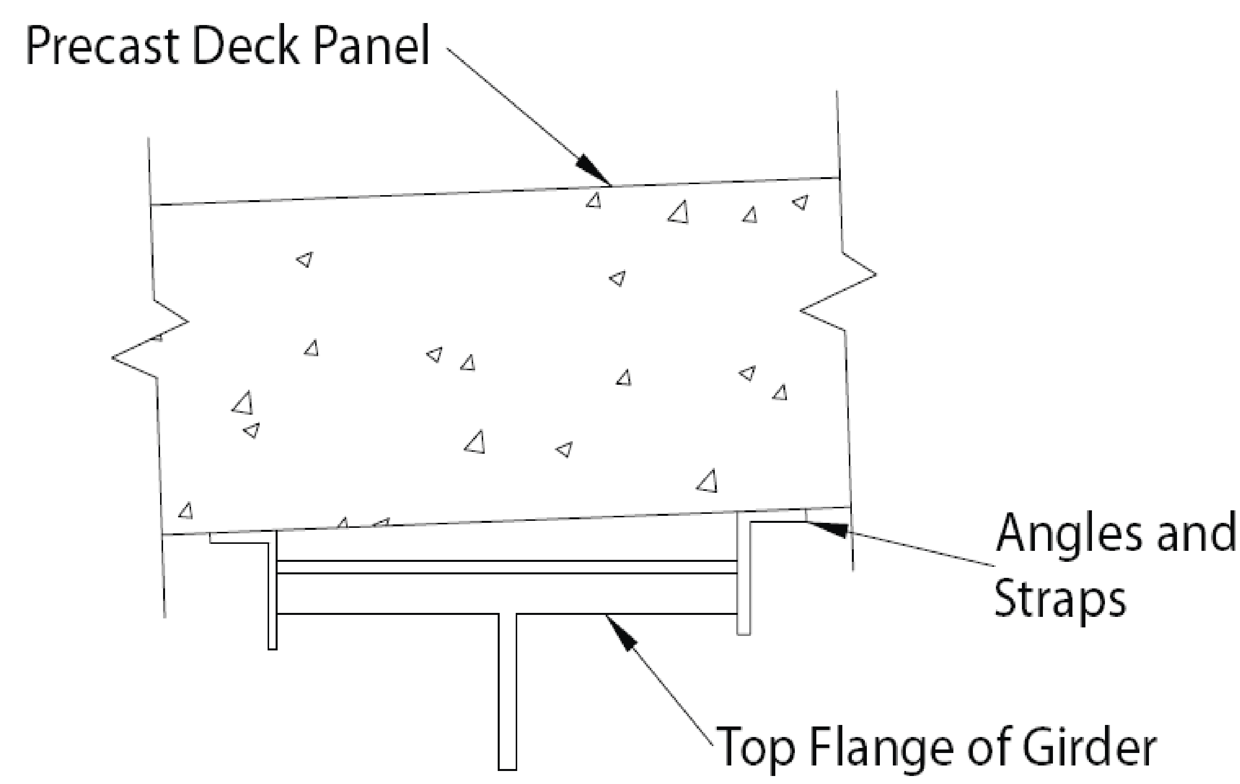


Building Grout Barriers for Transverse Connections

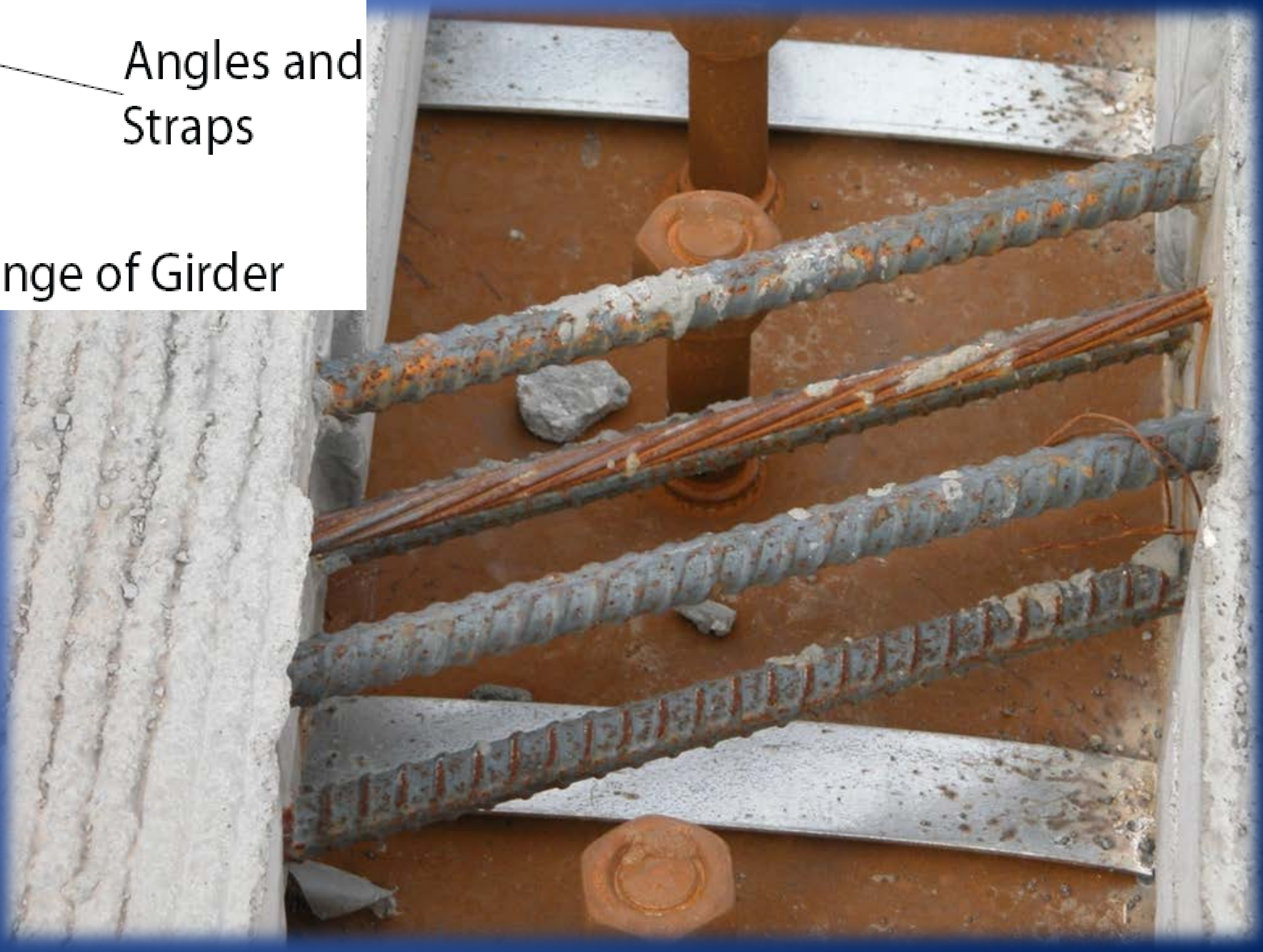
Grout Barriers for Haunches

(between the Deck and the Girders)

Using wood forms

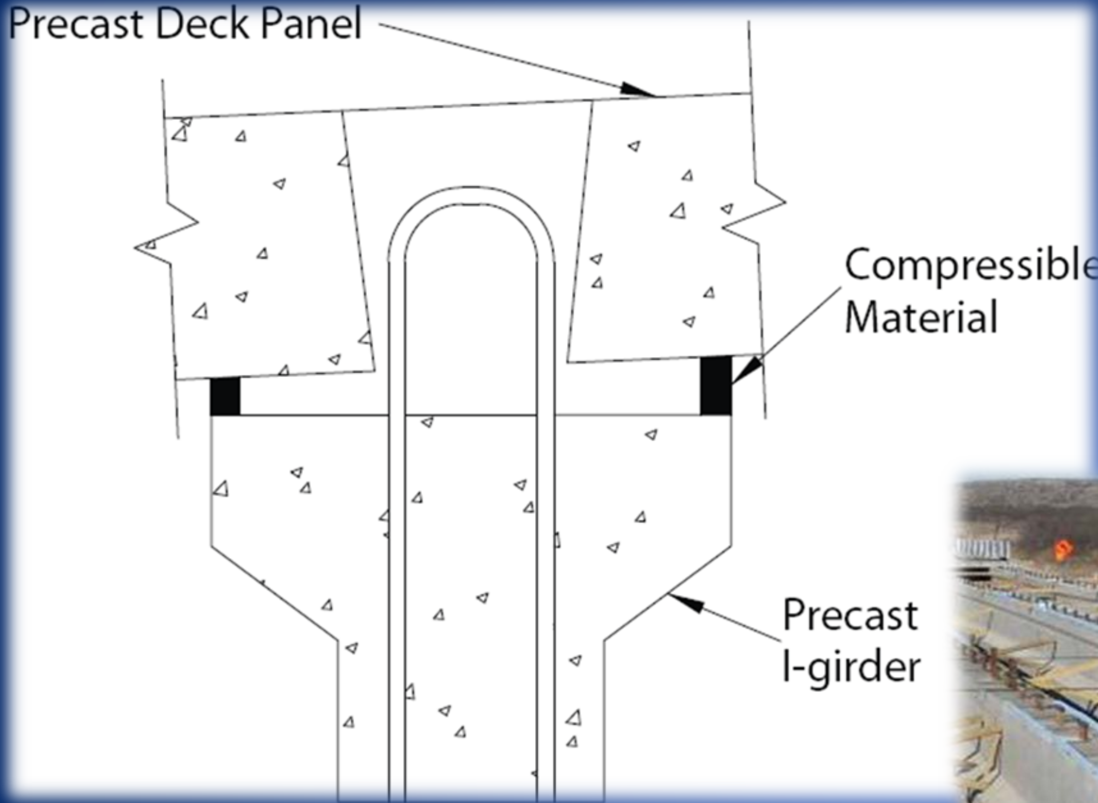


Skyline Bridge, Omaha, Nebraska



Grout Barriers for Haunches

Using steel angles



Grout Barriers for Haunches

Using compressible material

Live Oak Bridge, TX

Overlay Options

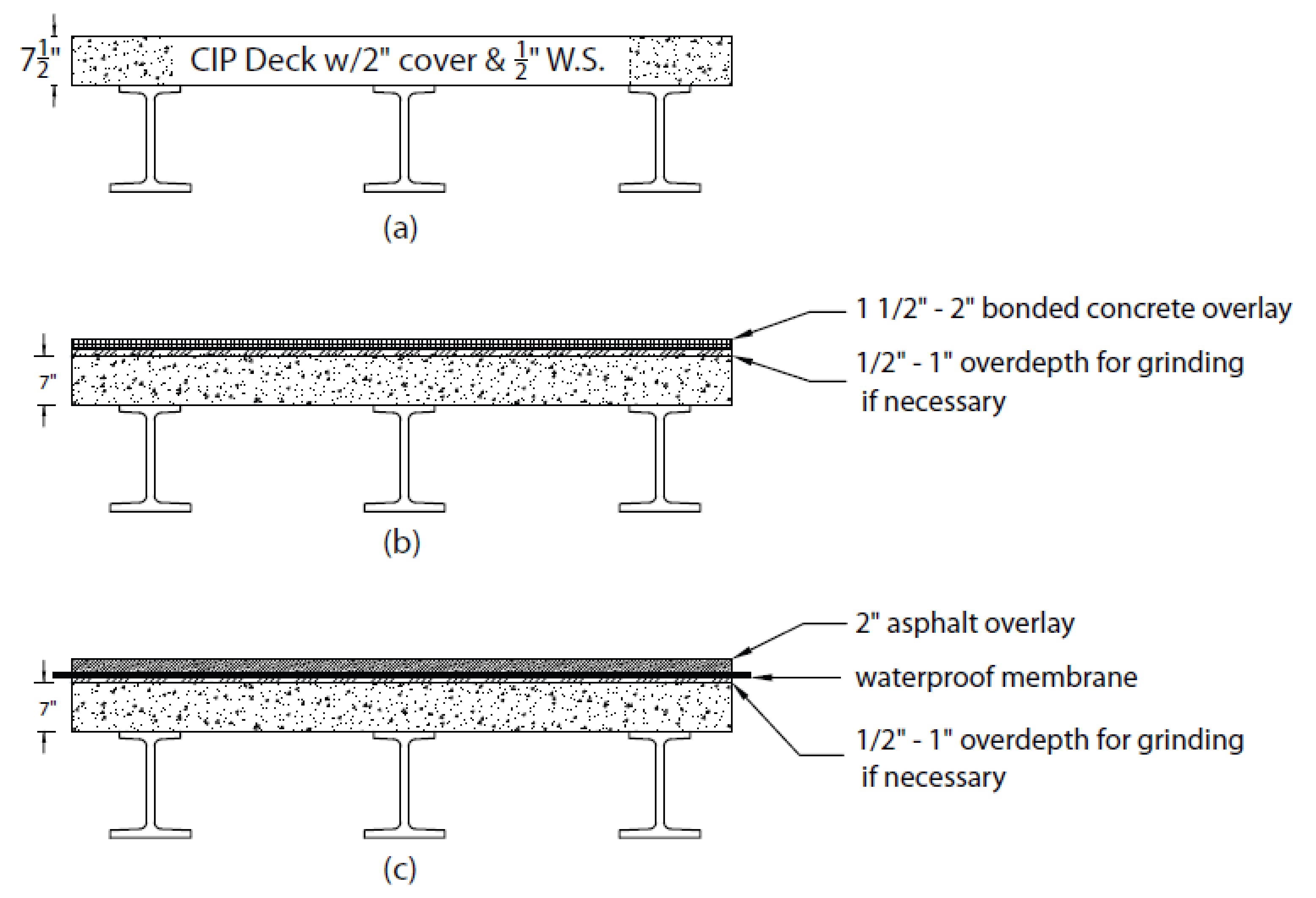


Figure 4.4.2-1. Wearing and protection systems include: (a) typical CIP deck (reference), (b) bonded concrete overlay, (c) waterproof membrane overlaid with asphalt, (d) epoxy overlay, (e) monolithic concrete overlay, (f) low permeability panel with no overlay.

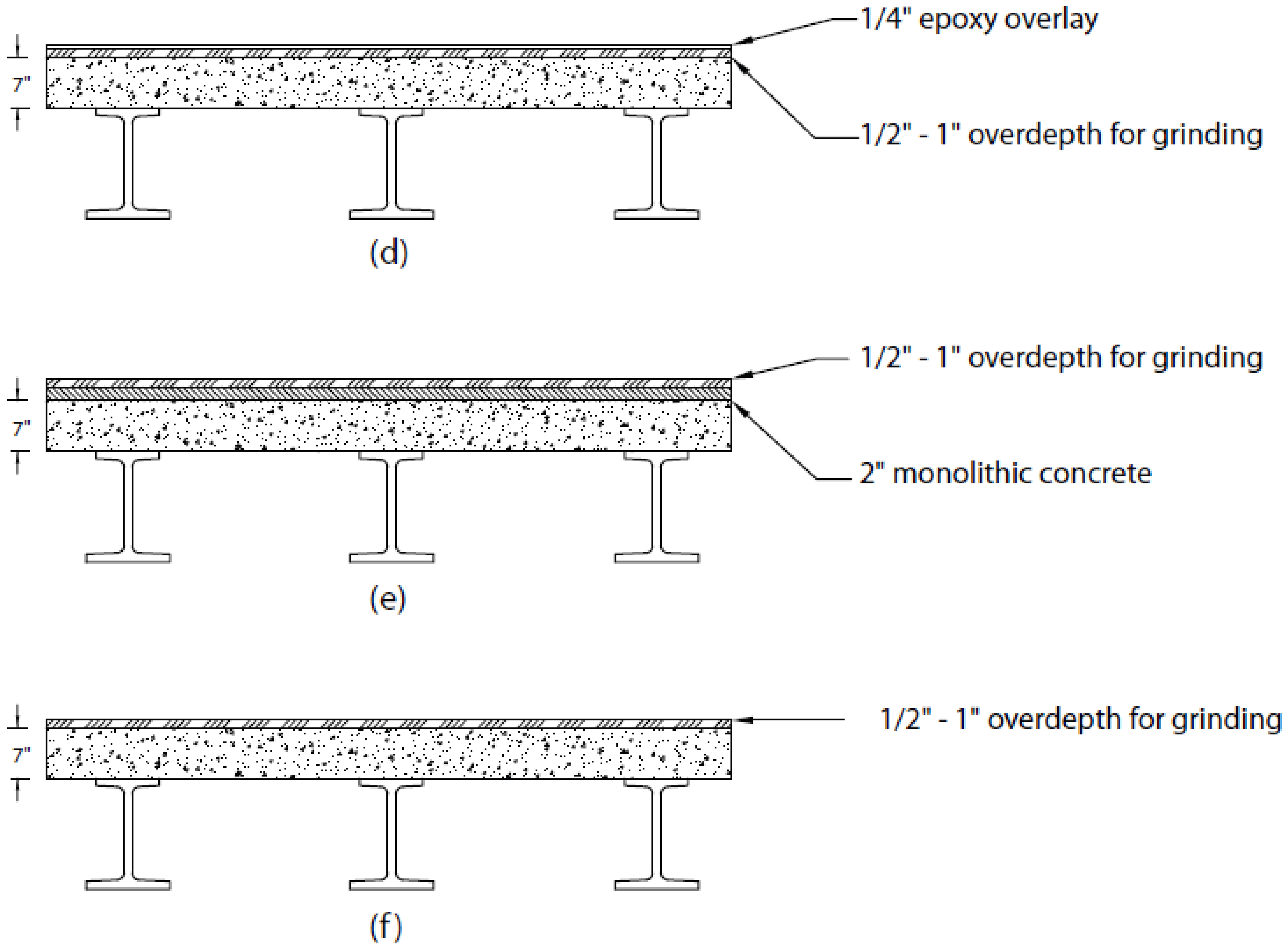


Figure 4.4.2-1. Wearing and protection systems include: (a) typical CIP deck (reference), (b) bonded concrete overlay, (c) waterproof membrane overlaid with asphalt, (d) epoxy overlay, (e) monolithic concrete overlay, (f) low permeability panel with no overlay.

Overlay Options

- The least expensive option is Option “f”. Provide an extra “wearing surface” thickness. Use standard roadway profiling grinders to smooth out the surface
- Provide extra protection of the reinforcement.
- Discoloration due at grouted joints and pockets may be objectionable by some owners.

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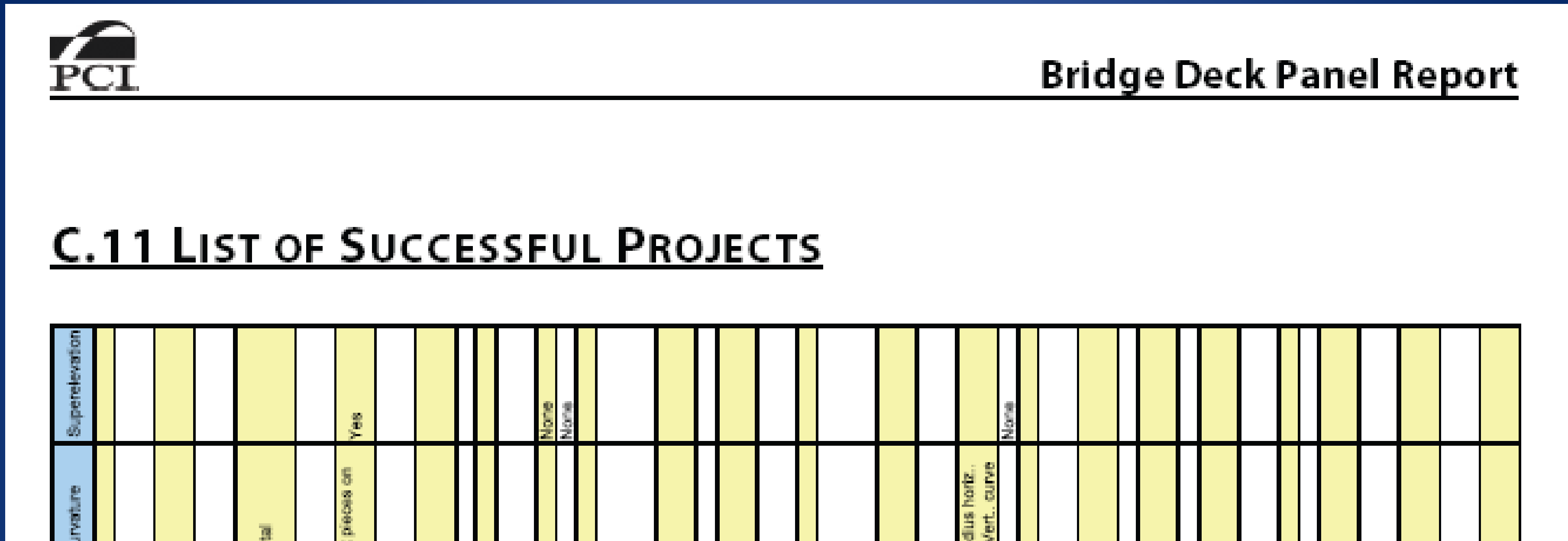
(* FDDP = Full-Depth Precast Concrete Deck Panels)

APPENDIX C – SUCCESSFUL PROJECTS

C.1 Woodrow Wilson Bridge; Washington, D.C. ....
C.2 Skyline Bridge – NUDECK System; Omaha, Neb. ..
C.3 US-24 Mississippi River Bridge; Quincy, Ill. ....
C.4 Seneca Bridge; LaSalle County, Ill. ....
C.5 George Washington Memorial Parkway over Dead Run and Turkey Run; Washington, D.C. ....
C.6 The 24 th Street Council Bluffs, Iowa Bridge..
C.7 Utah Precast Deck Panel System ....
C.8 Cable-stayed Bridges...
C.9 Required Post-tensioning Stress Across Longitudinal Joint .
C.10 Projects Using Longitudinal Joints ....


Bridge Deck Panel Report

C.11 List of Successful Projects

- The list include information on about 60 projects about: Location (state, county), Year Completed, Girder Type, Rehab/New, Span Length, Skew………….

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APPENDIX D – DESIGN EXAMPLE

ACKNOWLEDGEMENT

This example was originally developed by the following team of George Washington University, Washington D.C.: Sameh S. Badie, Ph.D., PE, Associate Professor, Nghi Nguyen, D.Sc., and Parul Patel, M.Sc., Former Graduate Students.

The prestress loss calculations were updated according to the 2008 Interim Revisions to the *LRFD Specifications* by Sameh S. Badie, Ph.D., PE, Associate Professor, George Washington University, and Kromel Hanna, Ph.D., Post-Doctoral Associate, University of Nebraska-Lincoln.

Design example Outline

D.1 Design Criteria

D.2 Design of the Precast Deck Panel System

D.2.1 Design of the Positive Moment Areas between Girder Lines

D.2.1.1 Estimate Required Prestress Force

D.2.1.2 Estimate Prestress Losses

D.2.1.3 Check of Concrete Stresses at Service Loads at the Positive Moment Area

D.2.1.4 Check of flexural strength

D.2.1.5 Check of maximum reinforcement limit

D.2.1.6 Check of Minimum Reinforcement Limit

D.2.2 Design of Panel-to-Girder Connection for Full Composite Action

D.2.3 Design of the Negative Moment Areas over Interior Girder Lines

D.2.4 Design of the Overhang (negative moment section at exterior girder line)

D.2.4.1 Case I: Due to Transverse Vehicular Collision Loads Using Extreme Event Limit State II

D.2.4.2 Case 2: Due Dead and Live Loads

D.2.5 Design of Longitudinal Reinforcement

D.2.6 Miscellaneous Design Issues

D.2.6.1 Check of Concrete Stresses at Time of Transferring the Prestressing Force

D.2.6.2 Check of Concrete Stresses during Lifting the Panel from the Prestressing Bed

D.3 Details of the Precast Deck Panel System

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Available Resources

PCI (www.pci.org)

- *State-of-the-art Report On Full-depth Precast Concrete Bridge Deck Panels*, PCI Report No. SOA - 01-1911 (2011)
- *Full Depth Deck Panels Guidelines For Accelerated Bridge Deck Replacement Or Construction*, PCI Report No. PCINER-11-FDDP, 2nd edition (2011)
- *PCI Journal Papers* (30+ papers, 1970s-2011). Citation of many of these papers is provided in the SOA report.

Available Resources

NCHRP reports (http://www.trb.org/NCHRP/NCHRPProjects.aspx)

- M. Tadros et al., *"Rapid Replacement of Bridge Decks,"* NCHRP 12-41, Report # 407 (1998)
- S. Badie & M. Tadros, *"Full-Depth, Precast-Concrete Bridge Deck Panel Systems,"* NCHRP 12-65, Report # 584 (2008)
- C. French et al., *"Evaluation of CIP Reinforced Joints for Full-Depth Precast Concrete Bridge Decks,"* NCHRP 10-71, Web only document 173 (2011)

Available Resources

Miscellaneous

- DOT Reports
- Journal papers:
  - ASCE Bridge Journal,
  - ACI Structural Journal,
  - Concrete International…..

Thank You...........

PCI

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