


SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Concrete Industry Perspective

Nation Concrete Bridge Council (NCBC)

William N. Nickas, P.E.
Precast/Prestressed Concrete Institute

September 17, 2015

U.S. Department of Transportation
Federal Highway Administration

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
AASHTO

Pile Driving 101

We may have over-complicated this simple task over the years...not so in other lands.

But here is a short video of a basic pile driving construction technique that remains simple and straightforward.
To analyze the engineering calculations involved, consider that 6 men x 180 lbs = 1080 lbs static force. Jumping up and down creates a 3 times dynamic effect = 3240 lbs/jump = 1.6 ton-thumps.   If the pile is tapered to 2 in x 2 in, cross section at the tip = 4 square inches. So, dynamic pressure/thump at pile tip = 3240/4 = 800 psi. "Adding a man" (foreman guy on the tambourine) increases the power to 950 psi.
Increase the chant rhythm rate and the dynamic force goes up to 5 times to bring about a maximum pressure per thump of 1600 psi for a full 7-man team.
This is quite good and adequate to penetrate hard clay and sandy soil but not hard rock!
Basic stuff, and it doesn't cost a whole lot!
Perhaps some of the "pile-drivers” may incur an occasional fallen arch or two though

Pile Driving made simple

National Concrete Bridge Council

- American Coal Ash Association
- American Segmental Bridge Institute
- Concrete Reinforcing Steel Institute
- Expanded Shale, Clay, and Slate Institute
- National Ready Mixed Concrete Association
- Portland Cement Association
- Precast/Prestressed Concrete Institute
- Post-Tensioning Institute
- Silica Fume Association
- Wire Reinforcement Institute

NCBC Goals

- **Promote** quality in concrete bridge construction.
- **Gather** and disseminate information on design, construction, and condition of concrete bridges.
- **Establish** communication with state & federal transportation departments, public works departments, and consulting engineers.
- **Provide** information on behalf of the concrete industries to codes and standards groups.

http://www.nationalconcretebridge.org

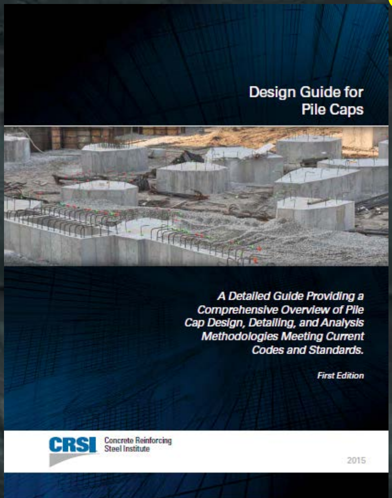
CRSI Research Update

Completed Projects

Project	University
Use of Ultrahigh-Strength Reinforcement in Columns of Frames to Resist Seismic Loads	Purdue University
Evaluation of the Orientation of 90° and 180° Reinforcing Bar Hooks in Wide Members	Missouri University of Science & Technology
Evaluation of the Tensile Mechanical Properties of Coiled Reinforcing Bars	Texas Tech
Lap Splices in Unconfined Boundary Elements	Purdue University
Continuous Transverse Reinforcement – Behavior and Performance	University of Cincinnati

Pile Cap Design Guide (new)

- New stand alone design guide meets ACI 318-14
- Patterns for 2 to 30 pile cap configurations
- Expanded to include allowable pile loads up to 400 tons (800 tons in place)
- Expanded design tables include overturning effects



High-Strength Bar Hooks

School

University of Kansas

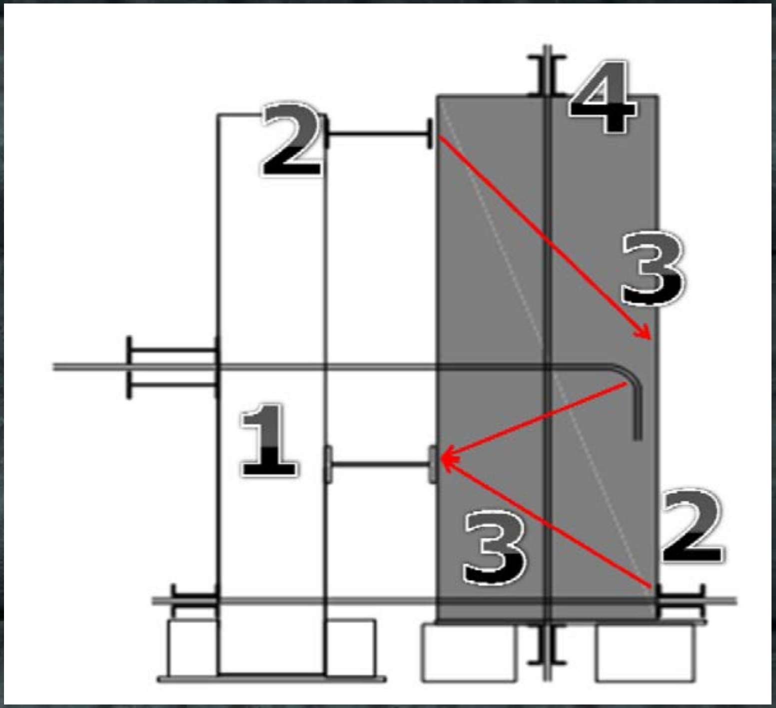
Principal Investigator

Drs. David Darwin &
JoAnne Browning

Funding

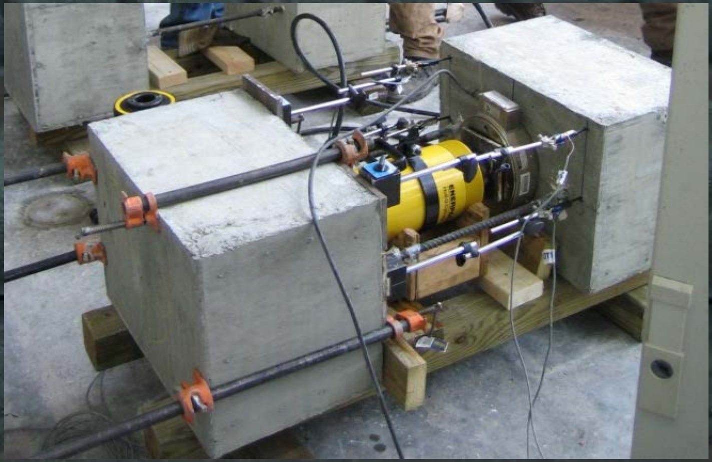
EPRI, CRSI, KDOT, Pankow

Status - Ongoing



Bar Bending

NC STATE UNIVERSITY



School

NC State University

Principal Investigator

Dr. Rudolf Seracino

Funding

CRSI & NC State Foundation

Status - Ongoing

High-Strength Bar Heads

School

University of Kansas

Principal Investigator

Drs. David Darwin &
Adolfo Matamoros

Funding

EPRI, CRSI

Status - Ongoing

Lap Splice Locations

School

Univ. of Massachusetts

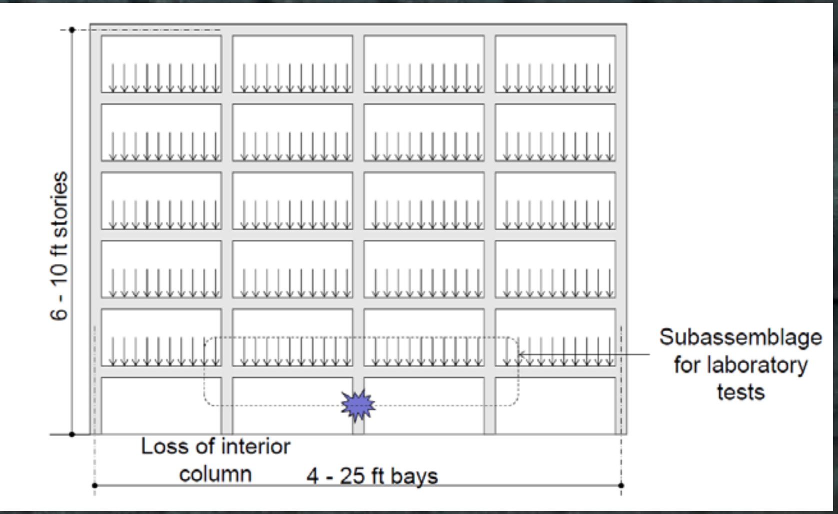
Principal Investigator

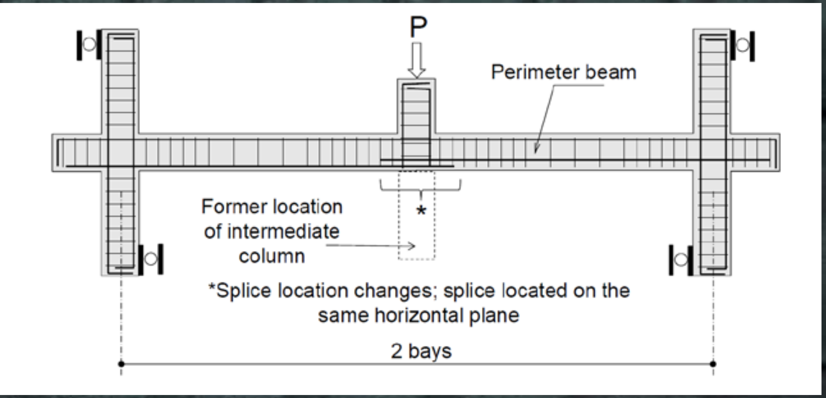
Dr. Sergio Breña

Funding

CRSI, UMass SDI, & Robert Brack

Status - Starting





Slender Columns

School

Purdue University

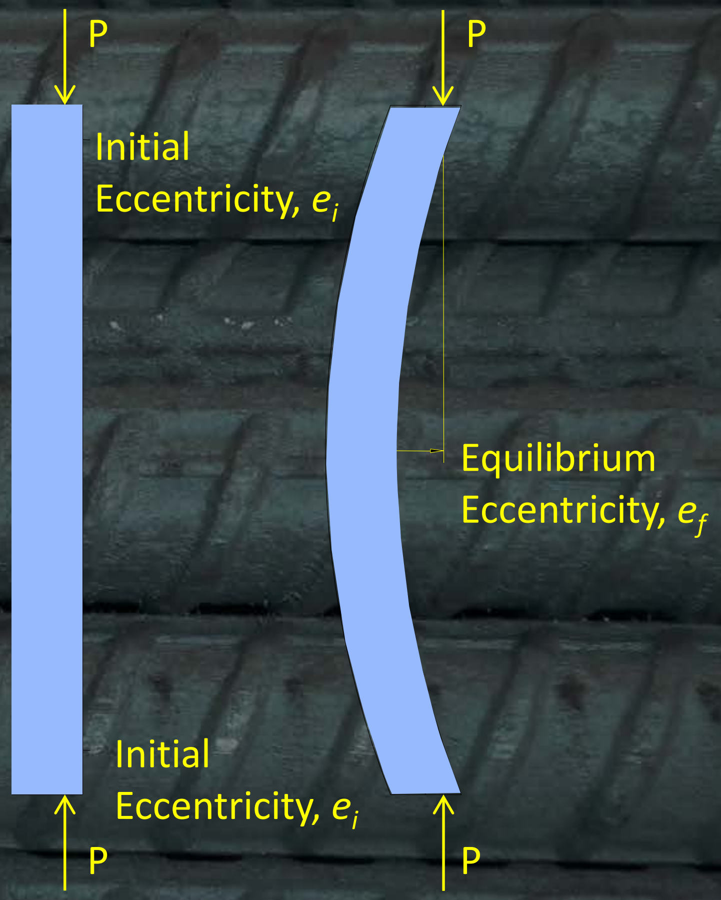
Principal Investigator

Dr. Robert Frosch

Matching Funds

Purdue, ACI, CRSI, PCI, CIF of NYC

Status – Ongoing



High-Strength Rebar

- Classed as yield (f_y) ≥ 80 ksi
- Collaborative research consortium?

CHARLES PANKOW FOUNDATION
Building Innovation through Research

CRSI

NIST

High-Strength Rebar

- Economic analysis
- Develop generic material requirements (ASTM spec)
- Structural research
- Code adoption

High-Strength Rebar

Project	University
Flexural Behavior	UC Berkeley
Seismic Use in Columns	UT Austin
Fabrication Bend Diameters	UT Austin
Shear Walls	U of Kansas
Cold Weather Fabrication	TBD

ESCSI Research Update

Completed Projects

Cracking Tendency of Lightweight Concrete

– Anton Schindler at Auburn University

Internal Curing

– Jason Weiss at Purdue University

Monitoring of Internally Cured Bridge Decks

– Spencer Guthrie at Brigham Young Univ.

LWA Fines for Air Entrainment

– Tyler Ley at Oklahoma State Univ.

ESCSI
Expanded Shale, Clay and Slate Institute
Rotary Kiln Structural Lightweight Aggregate

Using Fine LWA to Mitigate ASR

Oregon State University - Jason Ideker

- Initial research has been completed and has demonstrated reduced expansion of concrete with fine LWA
- Additional studies are underway
- Slabs are being cast and will be placed at three exposure sites – OR, TX & NB
- Michael Thomas at UNB is also on research team

ESCSI
Expanded Shale, Clay and Slate Institute
Rotary Kiln Structural Lightweight Aggregate

Use of LWC for Mass Concrete

Auburn University – Anton Schindler

- Potential performance improvement of mass concrete will be investigated using several types of LWC
- Improvement is expected due to improved thermal properties & reduced stiffness of LWC
- Study is just getting underway

Crack-Reduction Technologies

Kansas University - David Darwin

- Major study to evaluate different crack reduction strategies in field installations
- Identified as an Industry Critical Technology (ICT) by the Strategic Development Council (SDC) of ACI
- LWC and internal curing using LWA are being considered as options
- ESCSI is one of several sponsors
- Work is underway

ESCSI
Expanded Shale, Clay and Slate Institute
Rotary Kiln Structural Lightweight Aggregate

ASTM C1761 – Internal Curing

Standard Specification for Lightweight Aggregate for Internal Curing of Concrete

- Specification was first approved in 2012
- ESCSI continues to work to improve this specification
  - Several refinements have already been approved

ESCSI
Expanded Shale, Clay and Slate Institute
Rotary Kiln Structural Lightweight Aggregate

NRMCA/PCA Research Update

MIT Concrete Sustainability Hub

- $10 million Investment Over 5 Years (2010-2015)
- Funded Equally by RMCREF & PCA
- NRMCA Providing Technical Support and Guidance
- NRMCA and State Associations Have a Critical Role in the Technology Transfer

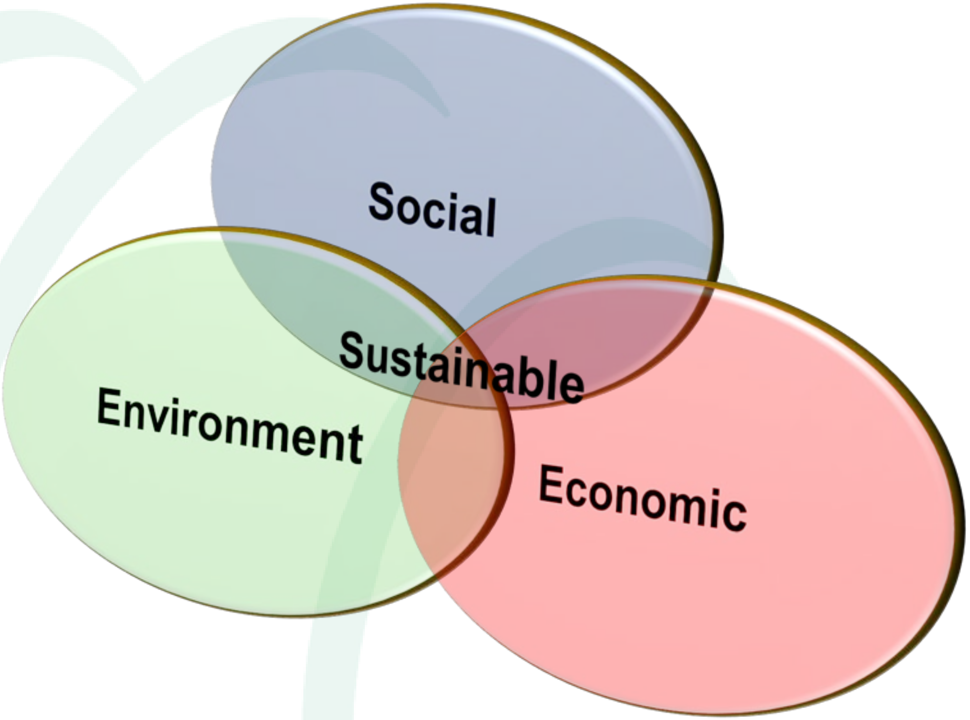
PCA
Portland Cement Association

NRMCA

RMC RESEARCH & EDUCATION FOUNDATION

MIT Concrete Sustainability Hub: Goals

- Identify Areas in Which Concrete Excels
- Identify Opportunities for Improvement
- Create Solid Technical Basis for Future Industry Development



MIT Concrete Sustainability (CS) Hub

- Life Cycle Analysis (LCA)
  - Incorporating Variability
- Life Cycle Cost Analysis (LCCA)
  - Construction Materials: Equal Inflation Rates?
  - Incorporating Variability
- Genesis of Concrete project
  - Develop new generation of "green" cement-based materials

Life Cycle Analysis (LCA)

LCA-investigation and valuation of the environmental impacts of a given product.

Scope Of LCA Pavement Research

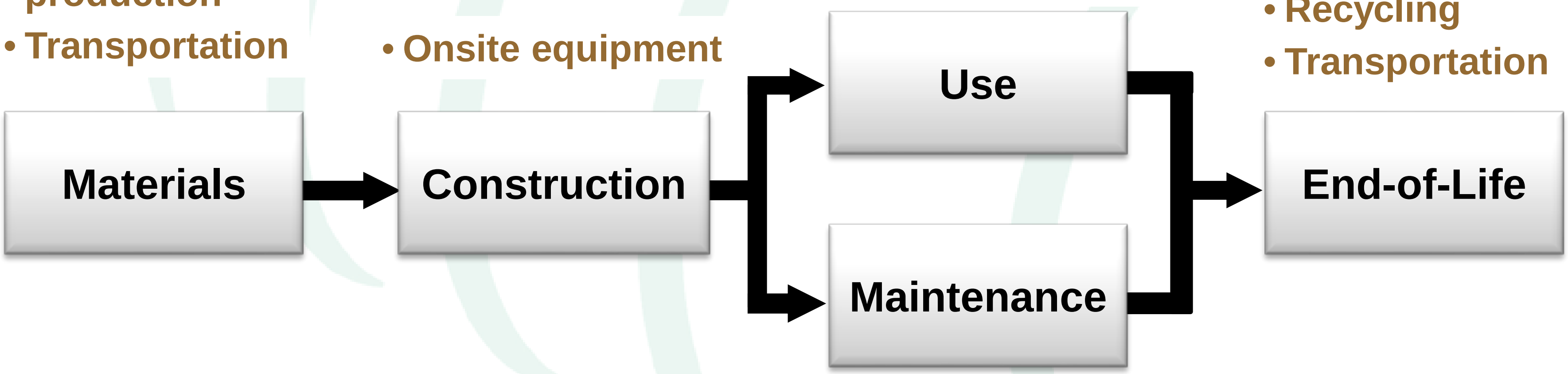
Scope includes all effects attributable to the pavement design.

- Extraction and production
- Transportation

- Onsite equipment

- Pavement-Vehicle Interaction
  - Roughness
  - Deflection
- Albedo
- Carbonation
- Lighting

- Pavement Removal / Milling
- Landfilling
- Recycling
- Transportation

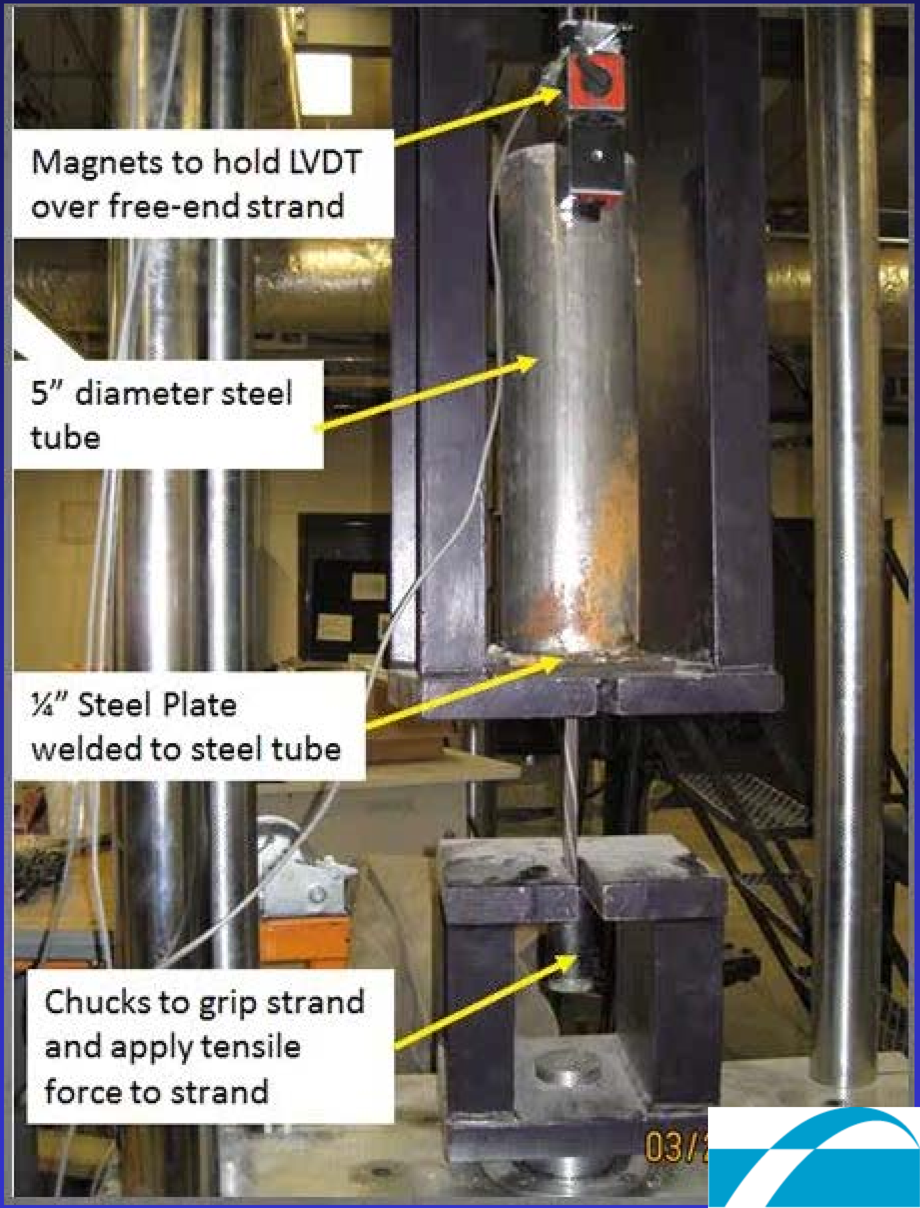


- Materials
- Construction
- Traffic delay

PCI Research Update

Strand Acceptance Criteria

- Kansas State University
  – 2011 to 2014
- Standard Test for Strand Bond (STSB)
  – NCHRP Report 603
  – Pullout strength at 0.1 in. slip



Strand Acceptance Criteria

Beam Flexural Tests

Strand Bond Project

- Strand proposed to be qualified by pullout test in mortar – now ASTM A1081
- Project includes ruggedness testing, reproducibility round robin testing, sensitivity analysis, and beam flexural testing
- Goal – establish an acceptance value for pullout strength

Strand Bond Project

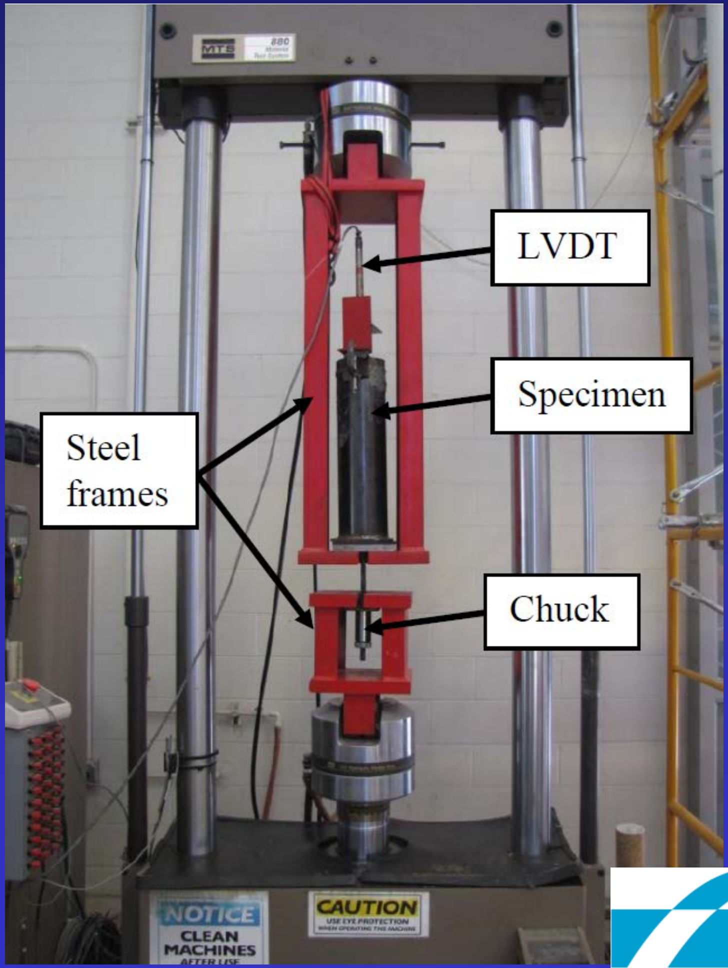
- Status
  - Draft final report under review by PCI R&D Advisory Committee
  - Neil Hawkins retained to review all related data and make recommendation
- Future steps to completion
  - PCI R&D review
  - PCI TAC review
  - Submittal to ACI Committee 423

Round Robin Labs

- FHWA Turner-Fairbanks
- Florida DOT
- Kansas DOT
- Texas DOT
- Missouri DOT
- Ohio DOT
- Louisiana DOT

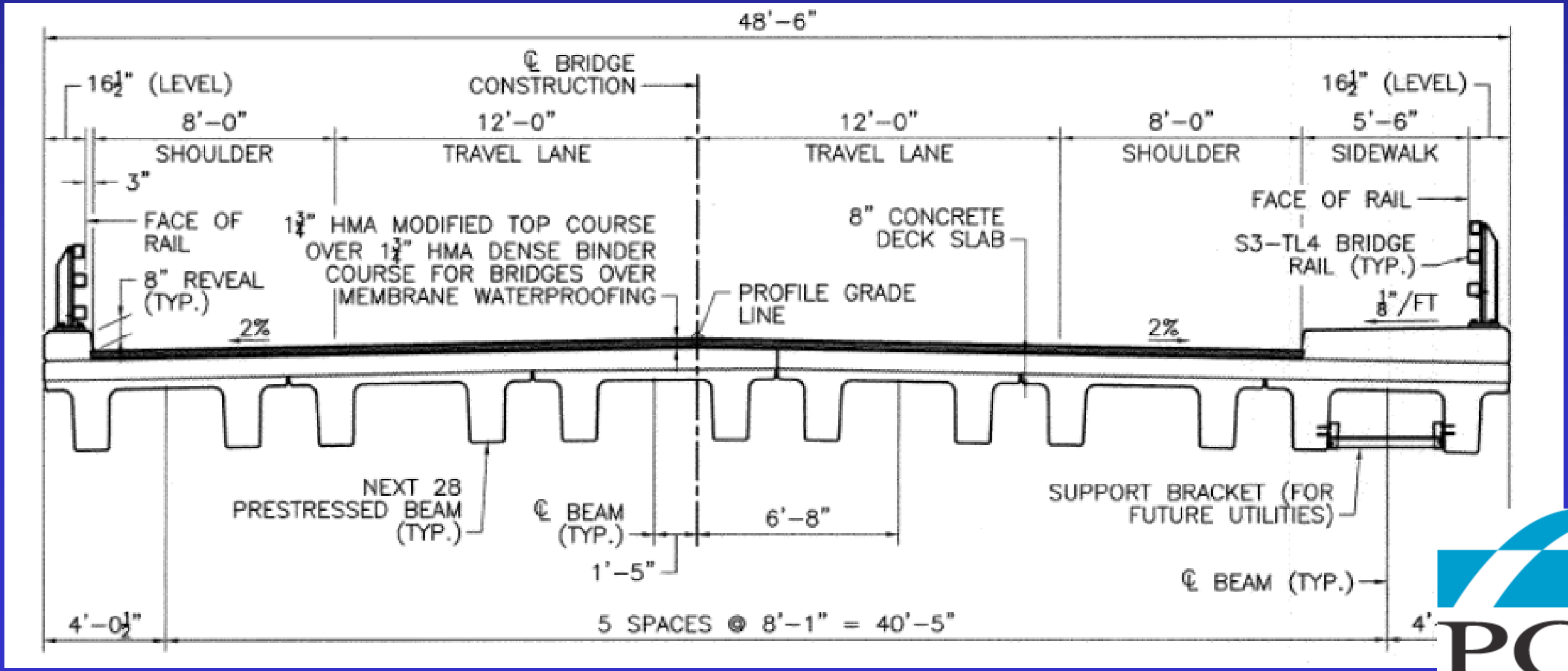
Strand Bond

- Missouri S&T
  - PCI Fellowship
  - SCC and HVFA



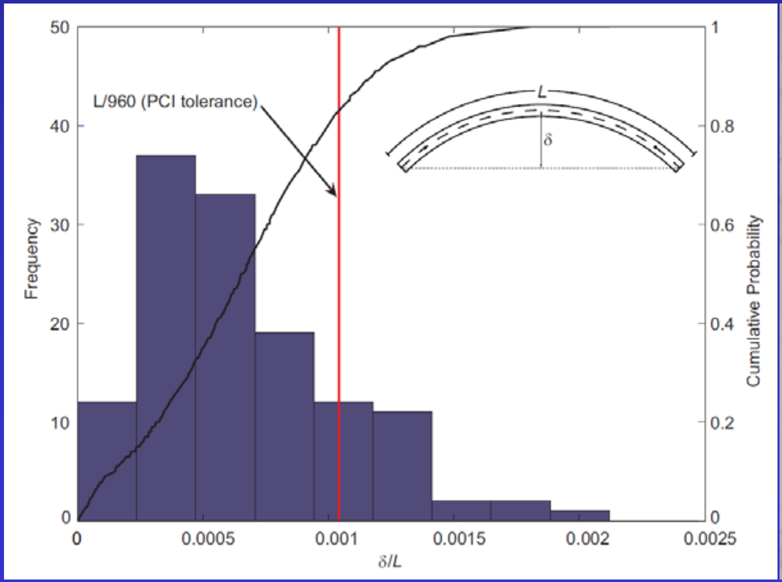
NEXT Beam

- University of Massachusetts Amherst
  - PCI Fellowship
  - Monitoring to refine distribution factors



Beam Deformations

- Virginia Tech
  - PCI Fellowship
  - Variability of sweep in 128 bridge girders ranging from 120-140ft.



FHWA - AASHTO SCANNING PROGRAM - 2004

Prefabricated Bridge Elements and Systems

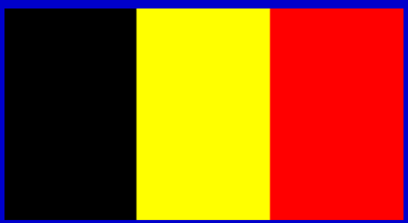
SCAN MISSION

To investigate and document the applications and experience with prefabricated bridges in Japan and selected European countries, with emphasis on:

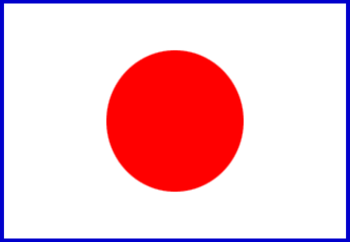
- Routine bridges with 20 ft – 140 ft spans
- Innovative systems
- Replacement and new highway and railroad bridges
- Including seismic considerations and emergency work

SCAN COUNTRIES

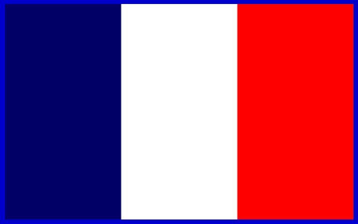
Netherlands



Belgium



Japan



France

Germany

TEAM MEMBERS

FHWA:

- Benjamin Tang, Co-Chair
- Claude Napier, Jr., VA
- Barry Brecto, WA

Academia:

- Eric Matsumoto, CSUS, CA

Industry:

- Henry G. Russell, IL
- Shri Bhide, PCA, IL
- National Steel Bridge Alliance–Invited
- Market Development Alliance FRP-Invited

State DOTs

- Mary Lou Ralls, Co-Chair, TX
- Harry Capers, NJ
- William Nickas, FL
- Dan Dorgan, MN

National Association of County Engineers:

- Eugene Calvert

TOPICS OF INTEREST

- Minimized traffic disruption (Congestion)
- Improved work zone safety
- Minimized environmental impacts
- Improved constructibility
- Improved product quality
- Lower life-cycle costs

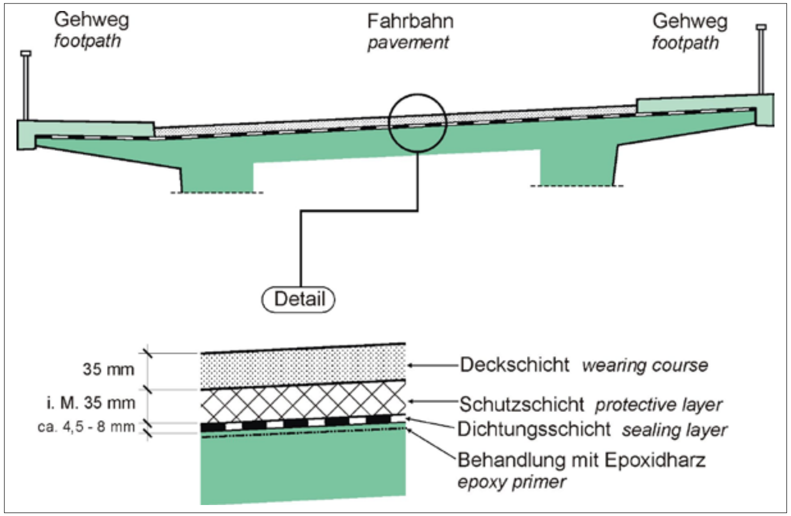
The Scan Team in Japan

NEXT STEP

Nationally

- Scan Technology Implementation Plan
- Technology Transfer activities
  - Engineering Conferences, Pilot Projects, Workshops
- Proposed Funding Programs
  - IBRD, Highway for Life, HBRRP

German Concrete Bridge Constructions Principles

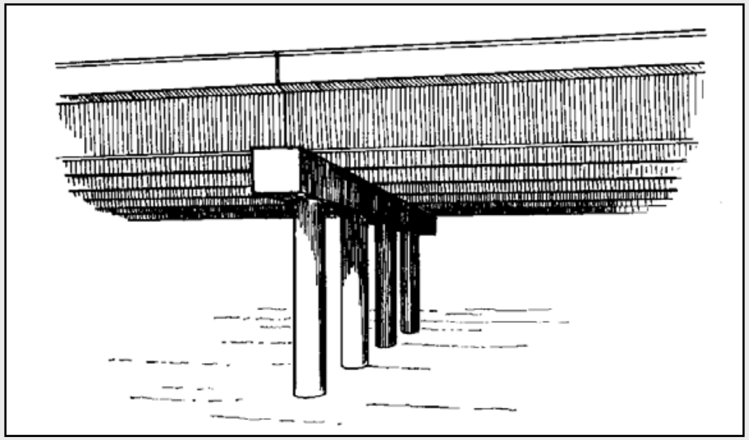


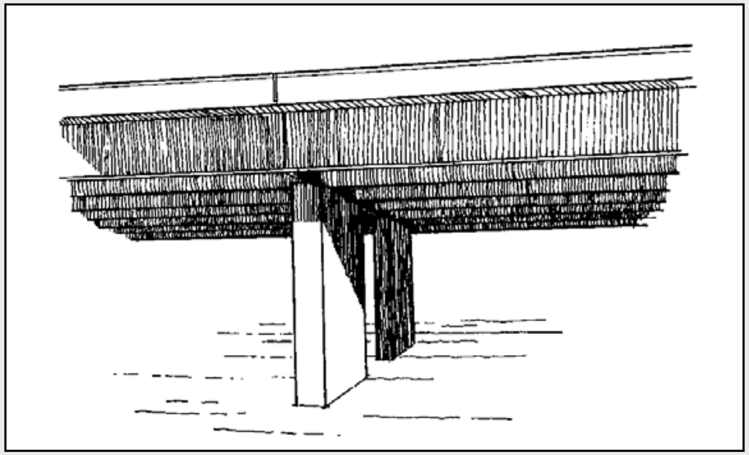
Concrete bridges have preferably:

- Beam as continuous as possible with bearings and expansion joints
- Minimized amount of expansion joints by making structures continuous, only in between or at end abutmends
- For each carriageway separate superstructure
- Balanced section (relatively long cantilevers) $\text{Length}_{\text{cantilever}} \approx l_{\text{cross girder distance}} \times \sqrt{1/6} \leq 0.408$
- Least dimensions and minimum reinforcement
- Sealings/*Waterproofing* (see left)
- Caps (see left; as wear part)
- always designed for bearing replacement with an allowance of 10 mm (0.4 in) for raising the structure

German Standard for Highway crossings with precast Beams

Bridge Design – Improvement of the appearance:



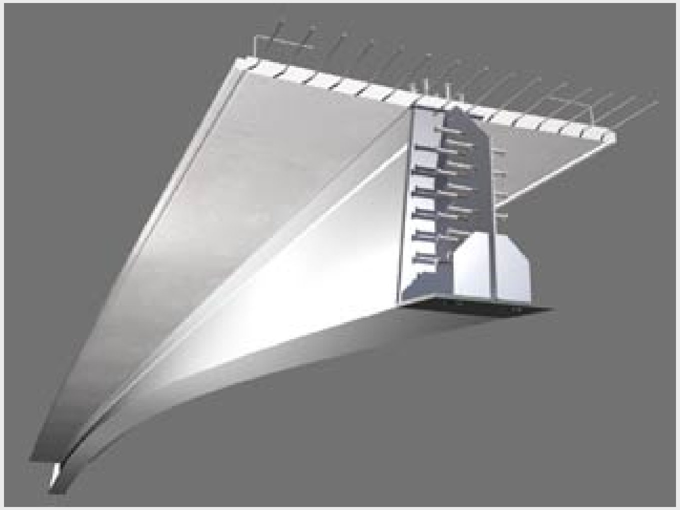


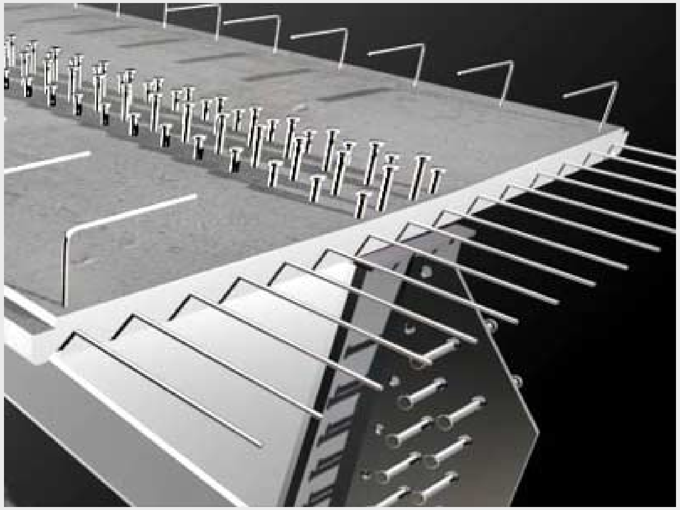
Bridge Vilisbiburg, Bayern, 1999

German Standard for Highway crossings with precast Beams

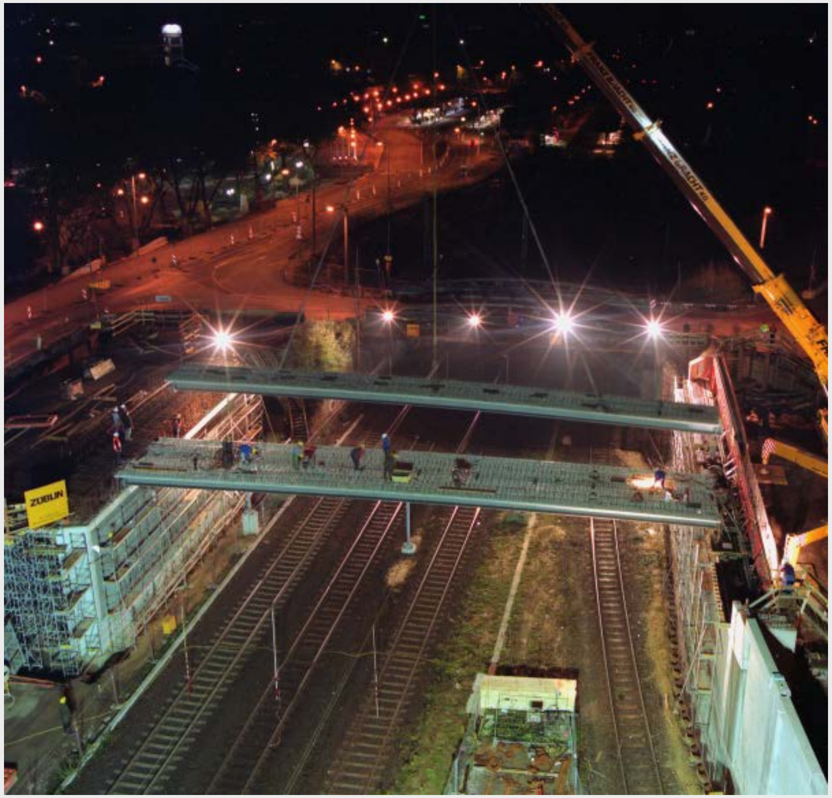
- as far as possible no pre-stressing in the transverse beams
- minimizing the number of bearings
- precast beams only with T-cross sections

Current Developments





- Composite Beams consisting high strength concrete (VFT-Beams)

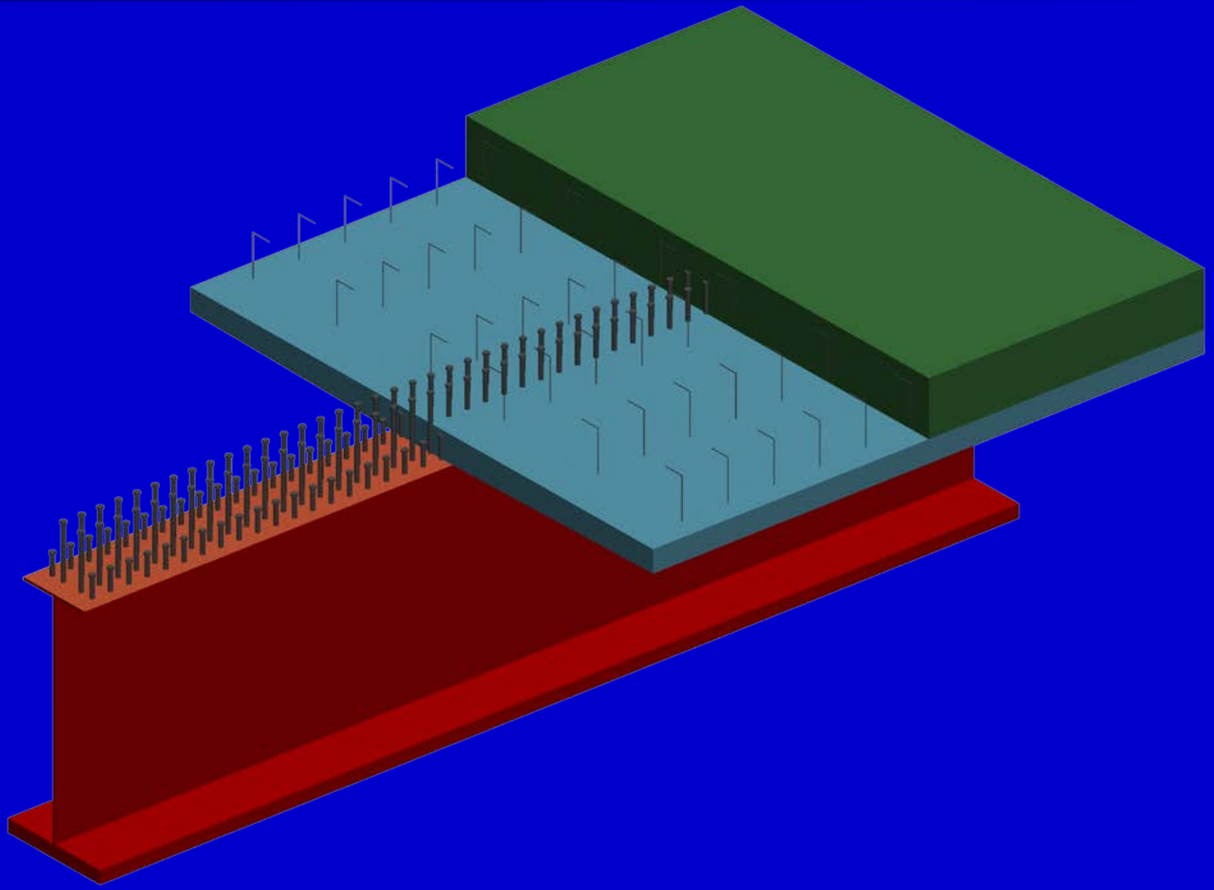


Verbundbrücken- composite bridges

Poutre Dalle System - Inverted Tee

Prefabricated Bridge Systems

Partial-Depth Precast Decks on Steel Beams



Prefabricated Bridge Systems

Applications of Pre-fabricated Structures for Bridges

Substructure:

Pre-cast Form

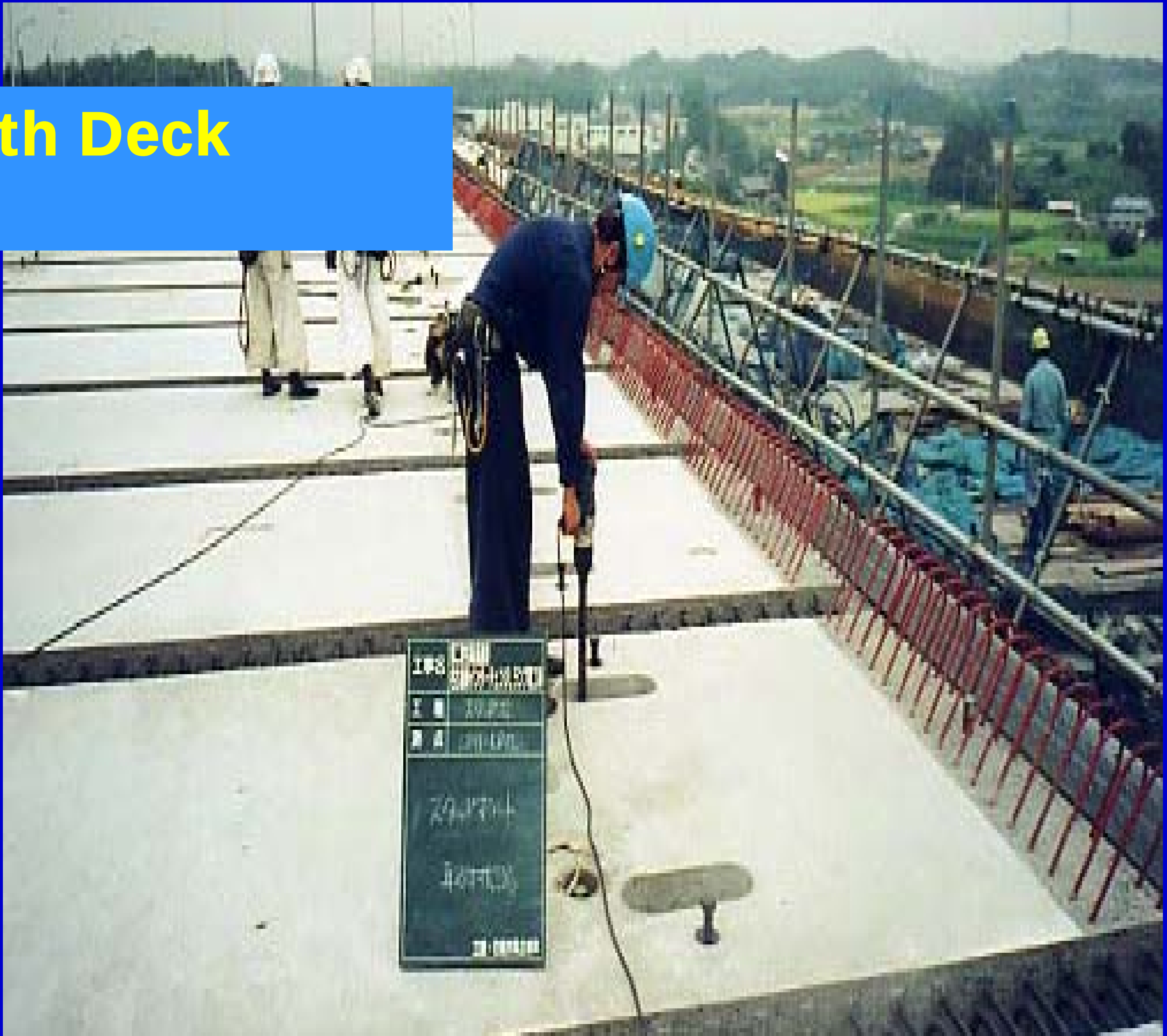
Superstructure:

Factory-produced Core Segment

YOSHIHIKO TAIRA
SUMITOMO MITSUI CONSTRUCTION CO.


神古川高架橋
富士ピー・清水 JV

JAPAN



Full Depth Deck Panels

JAPAN

Japan/ Germany/ France

ALL Require a deck Overlay as a Corrosion Protection

Scan Report Challenges . . .

- Develop joint details that provide good long-term performance with simple construction methods and without overlays
- Minimize or eliminate longitudinal and transverse joints
- Totally prefabricated bridges require new construction methods and new equipment, e.g., SPMTs

Industry Partners and Tools

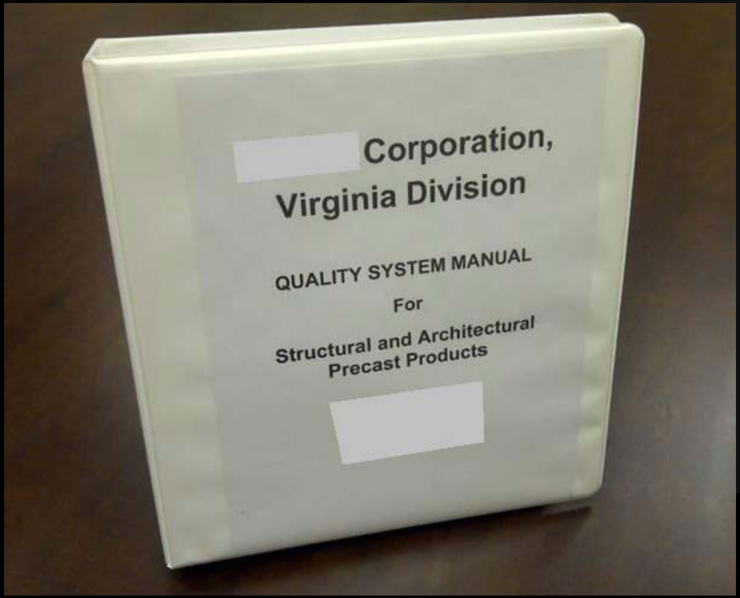
- Knowledge Creation
  - Industry Committees and vetting research
  - Manuals and Standards Development
- Knowledge Dissemination
  - Past Successes and lessons learned
  - Showcases
  - Training
- Continuous Improvement
  - Quality Programs and Continuous Improvement
  - Shape future thru Research

Discover **High Performance** Precast

Versatile | Efficient | Resilient

Manufactured not off site construction

- Precast concrete producers participating in the Plant Certification program are required to create and maintain a Quality Systems Manual that is tailored specific to that manufacturing operation.



Job site precast should be treated with rules of C-I-P concrete. Same strength, same concrete cover, etc… And should never be pre-tensioned.

Required documents for effective inspections:

- Precast Erection Drawings
- Product Data for Materials (as needed)
- Erection Plan (if required)

Varies from project to project

Erection Drawings

- Intended to instruct the erector how to assemble the structure in accordance with the precast specialty engineer's intentions.

- Typically consists of:
  - General notes
  - Foundation embed layout & details
  - Framing plans (for total precast structures)
  - Exterior elevations
  - Interior elevations (where needed)
  - Sections and Connection

Are we just expecting the EOR to know he show this in the plans??

Erection Plan

- Responsibility for preparing the plan may vary from project to project, but input from precast engineer and erector should be present in every instance

- Should cover sequencing, handling, bracing and connection requirements

- Objectives are to assure the structure's stability during erection and its comprehensive compliance with the approved erection drawings at the conclusion of erection.

- Tolerances and field adjustments are important but still not fully vetted with contractors and owners.

Improvement Opportunity

Multiple Involved Parties

- Two contractors (at a minimum)
- Usually two engineers
- Two inspection groups
- Separate erection crew with little or no involvement in prior development

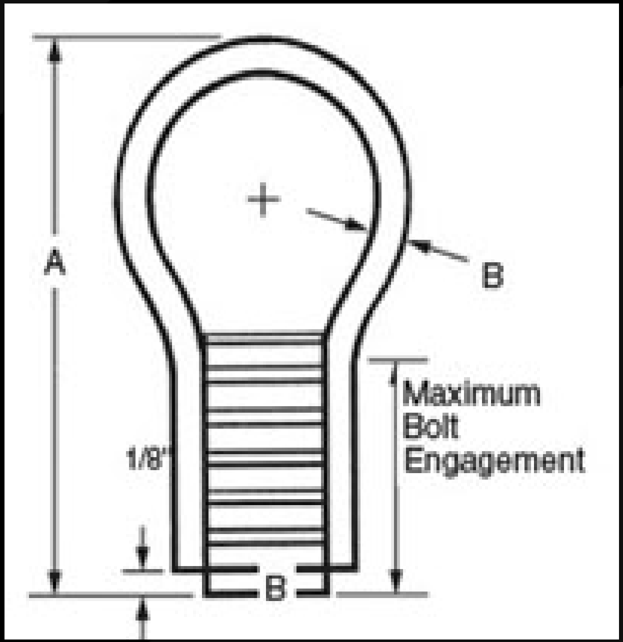
Significant Loads

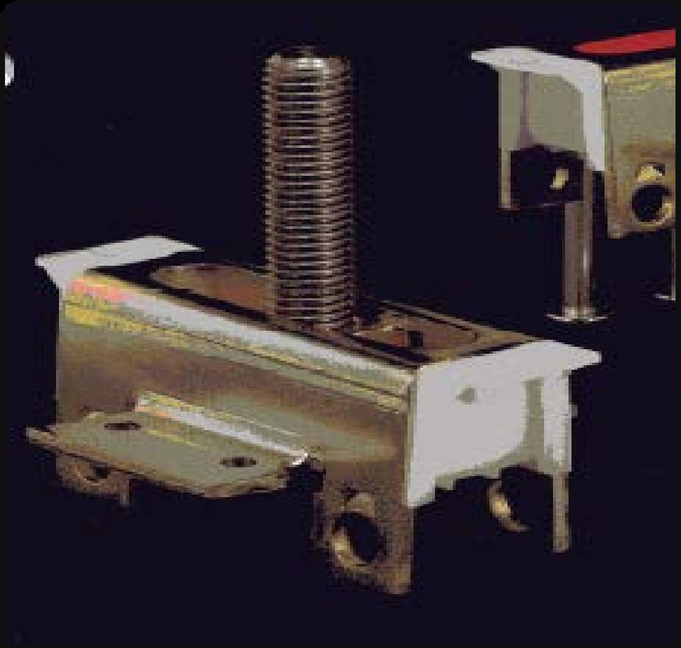
- Vertical loads accumulate throughout structure and culminate at the transition point
- Lateral load systems usually demand high capacity connections, many requiring tight tolerances
- Key components not always visible at time of erection

Bolt Placement

Focus should be on anchor bolt or bar placement and suitable bearing surface.

Bolted Connections





Items to consider:

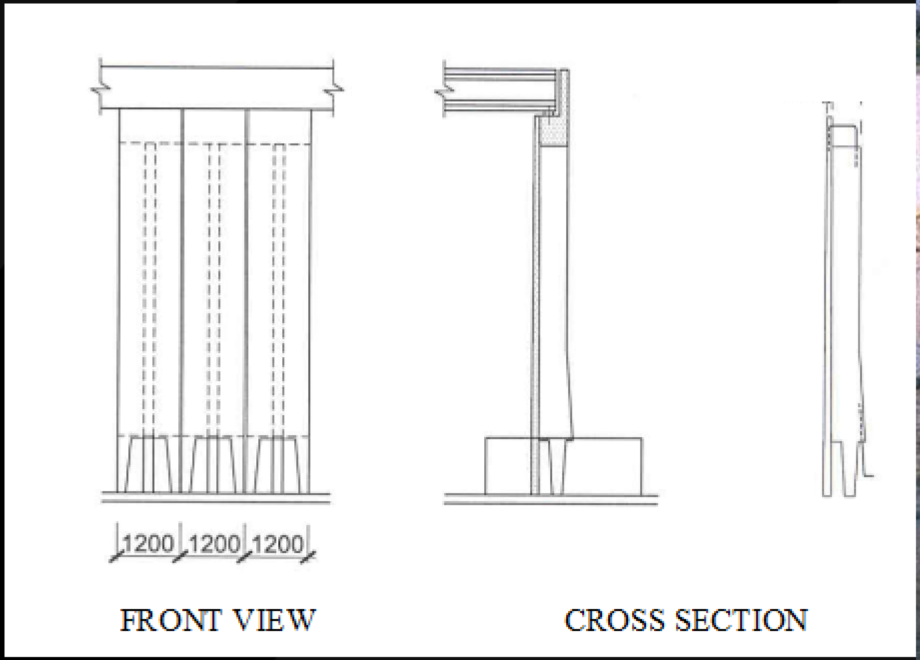
- Connections may use embedded ferrule inserts, coil inserts or adjustable inserts.
- As one might imagine, proper thread engagement is vital to the successful performance of threaded connections

Another Opportunity

Improvement Opportunity

Other structures still controlling projects schedules…..

Retaining Walls



Retaining Walls

Retaining Walls

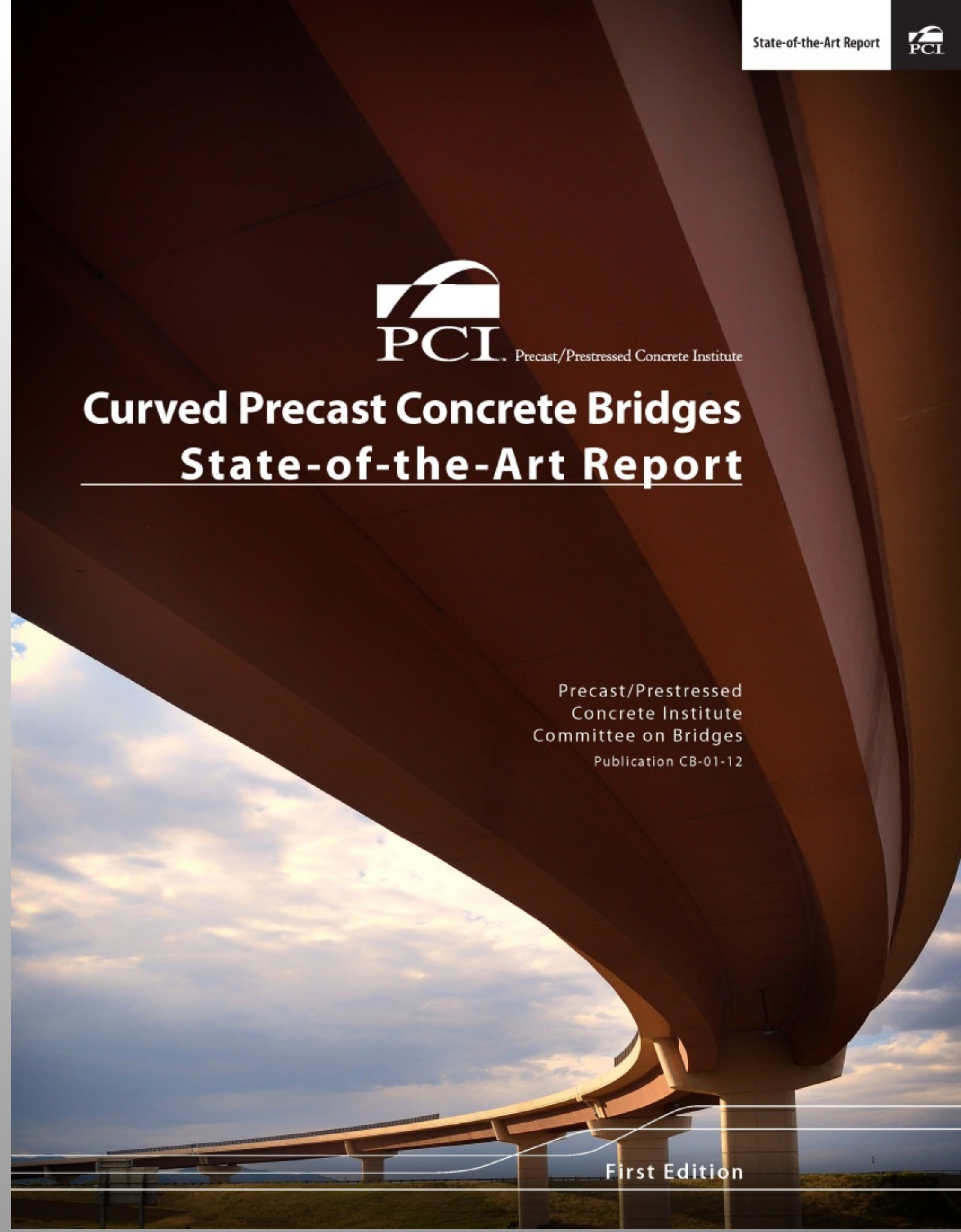
Newest Technologies and Resources

U Girders and CFX

U Girders and CFX

Interior details from Colorado

Curved Precast Concrete Bridges State-of-the-Art Report (CB-01-12)



Superstructures

Superstructures

Superstructures

Superstructures

PCI Handbook Chapter 8

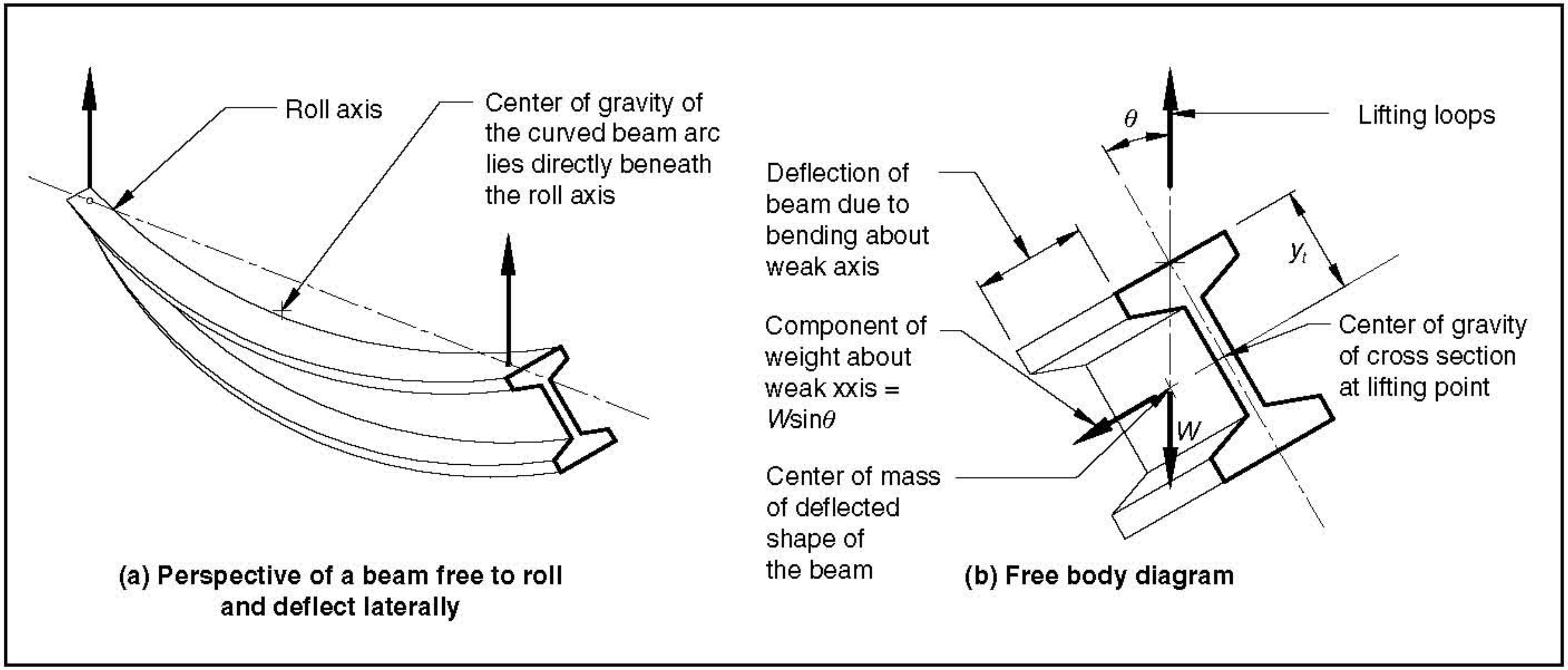


Fig. 8.4.1 Equilibrium of beam in tilted position.


GROVE


TRAIL KING
OVERSIZE LOAD

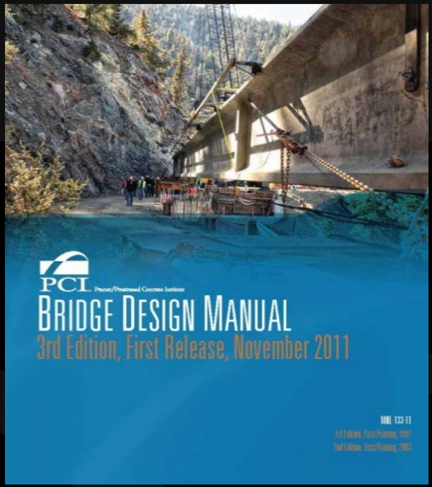
Superstructures

PCI Transportation Trifecta

- Bridge Related Research Papers included and vetted in the ***Journal***

- ***Aspire*** showcases
  Projects and Concepts

- ***PCI Bridge Design Manual*** gives industry tested engineering solutions in its third edition



ABC Ideas

ASPIRE™
THE CONCRETE BRIDGE MAGAZINE

ACCELERATED BRIDGE CONSTRUCTION

The State Highway 86 Bridge over Mitchell Gulch in Colorado.

South Maple Street Bridge

To complete the first, totally precast concrete bridge in the town of Enfield, Conn., town officials used ABC concepts to reduce user costs. As a result, the structure was erected in just 17 days.

The South Maple Street Bridge, which spans the Scantic River, was assembled from 71 precast concrete components. The concept used precast concrete adjacent box beams, with a continuous-length lip extending in front of the abutment panels to hide the horizontal joint. Additional components comprised footing blocks with threaded jacks to level them to grade after setting, 10 abutment walls, 12 wingwall pieces cast in decorative patterns, 4 cheek walls, and 12 pavement approach slabs.

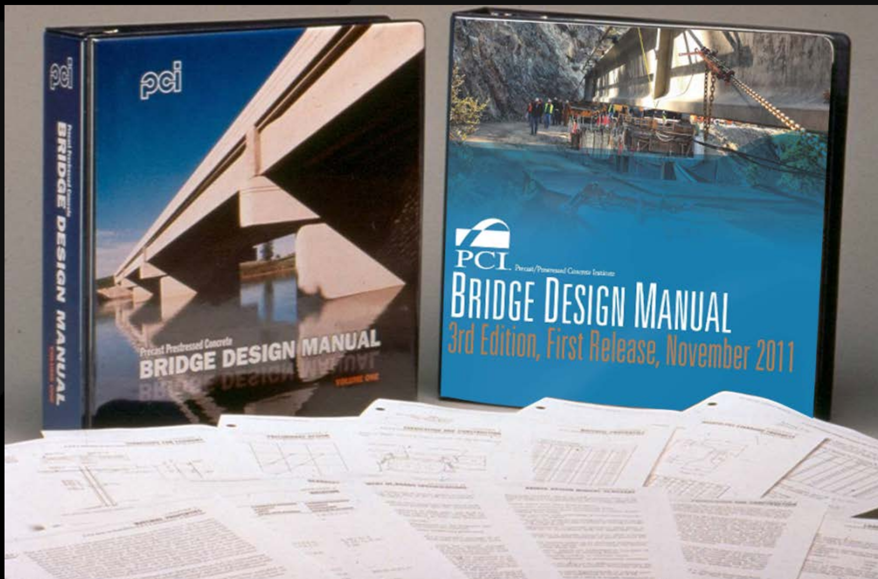
The contractor cast an unreinforced "mud slab" at the abutment sites and set the footing blocks on them. The abutment walls and wingwalls then were set over the reinforcing bars and the dowel bar splice sleeves were grouted. The precast concrete abutment bridge seat was set onto the projecting reinforcing bars from the abutment walls,

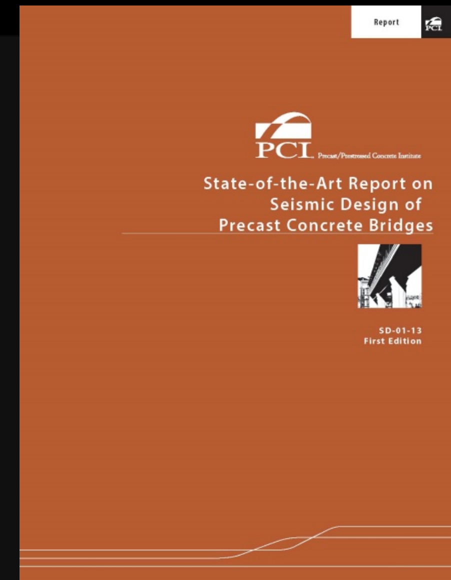
The original timber bridge was replaced with a 40-ft-long, 43-ft-wide, single-span precast concrete slab superstructure and precast, reinforced concrete abutments. The precast concrete abutments and wingwalls with embedded steel plates were erected by crane and welded to the steel H-piles and to each other, finishing in less than two days.

These projects present several innovative ways precast concrete components are being used to accelerate bridge construction while meeting a variety of needs for economy, aesthetics, and durability. By using easily designed techniques, the projects achieve their goals while also ensuring bridges are brought into service quickly.

This is the first in a series of articles examining different approaches to Accelerated Bridge Construction and examples featuring those techniques. Details of these projects can be found in the issue archive at www.aspirebridge.org. They originally appeared in the Spring 2007 issue (Mill Street Bridge and Mitchell Gulch Bridge), Fall 2009 issue (Route 70 Bridge),

Recent Completed Transportation



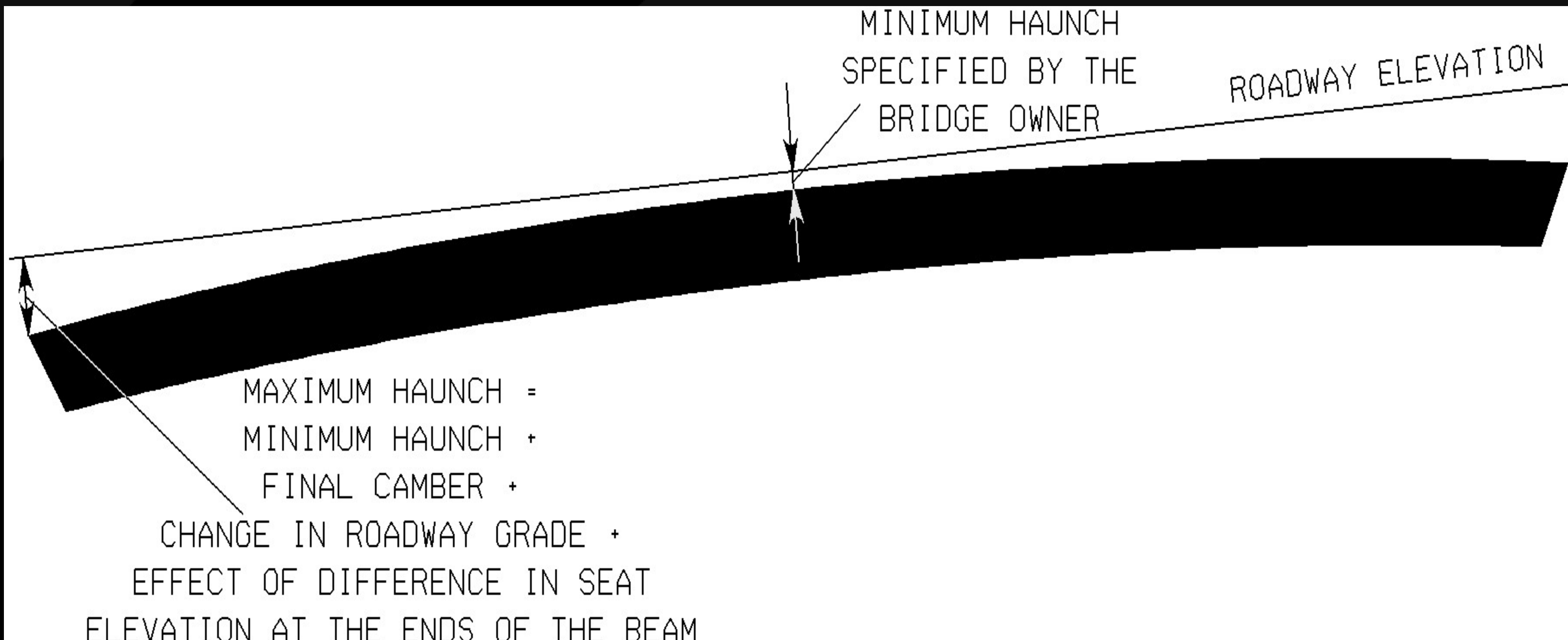


- SOA on Seismic Design
- Chapter 19 on Repairs
- Chapter 21 on Pedestrian

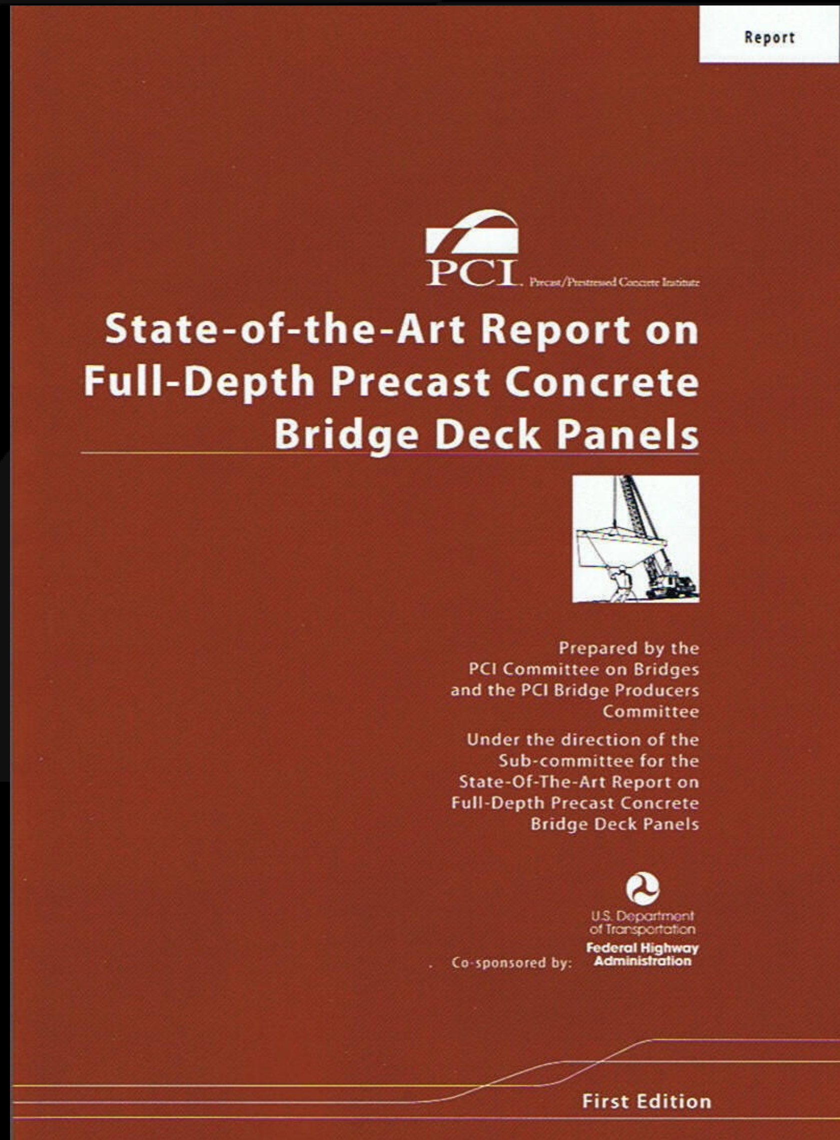
FDDP Leveling Bolts

Grade control in Superstructures

Slab Build-up to address Camber



Guidance Documents

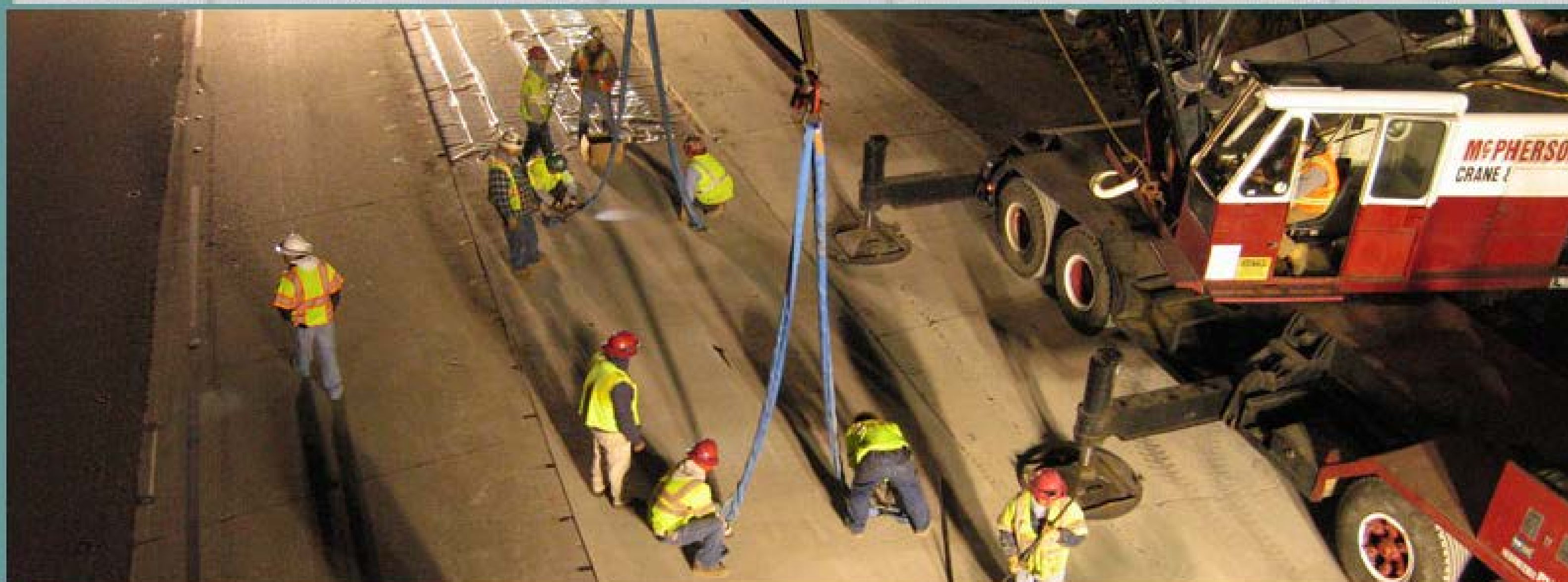


More details, Plans and Specifications

Prestressed/Precast Concrete Pavement (PPCP) Repository

Includes prestressed and other precast concrete pavement systems

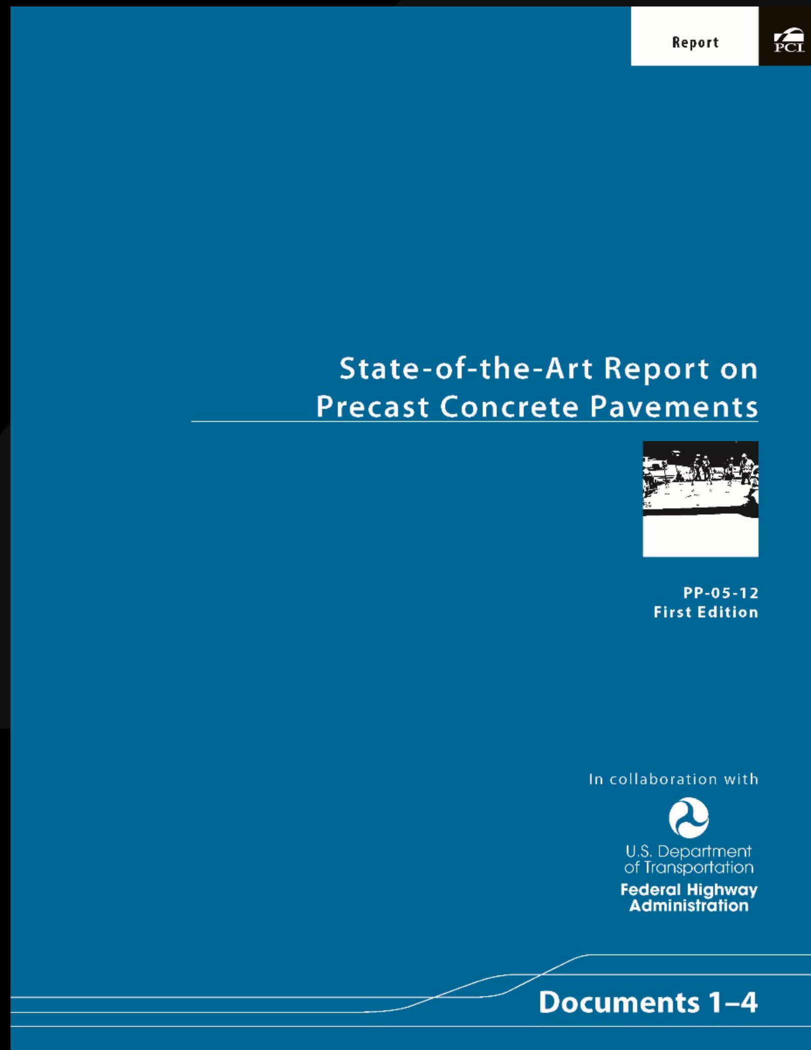
Projects | Technology Presentations | Agency Publications | Reference Material | Videos | Historical Data



Please visit the PCI Precast Concrete Pavements ePub fulfillment site for PCI Pavement Committee Reports.

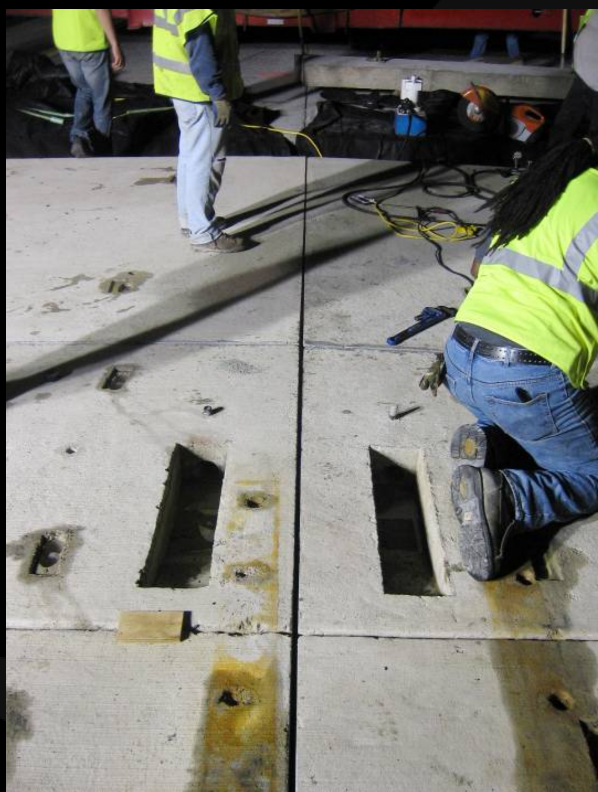
www.precastconcretepavement.com

Guidance Documents



Historical Perspective (I-66 HFL, VDOT)

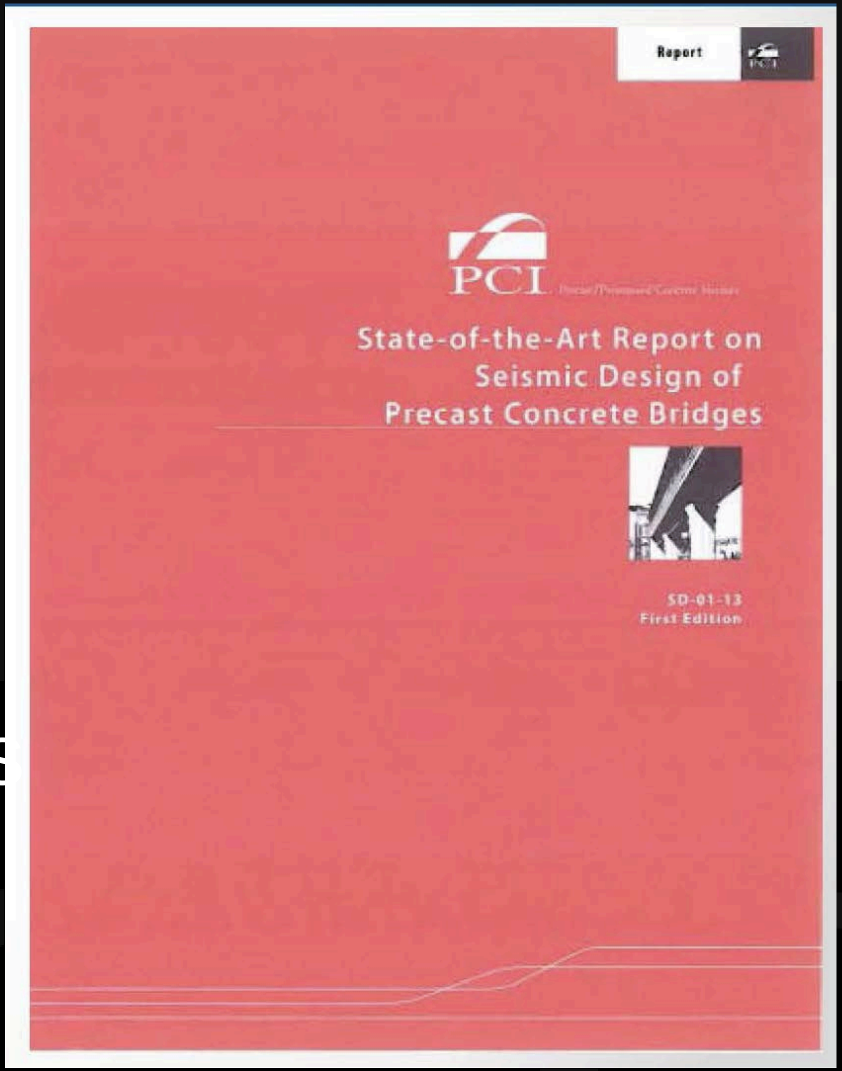
Cost per system
CIP = 225/SY
PCP = 350/SY
PPCP = 410/SY



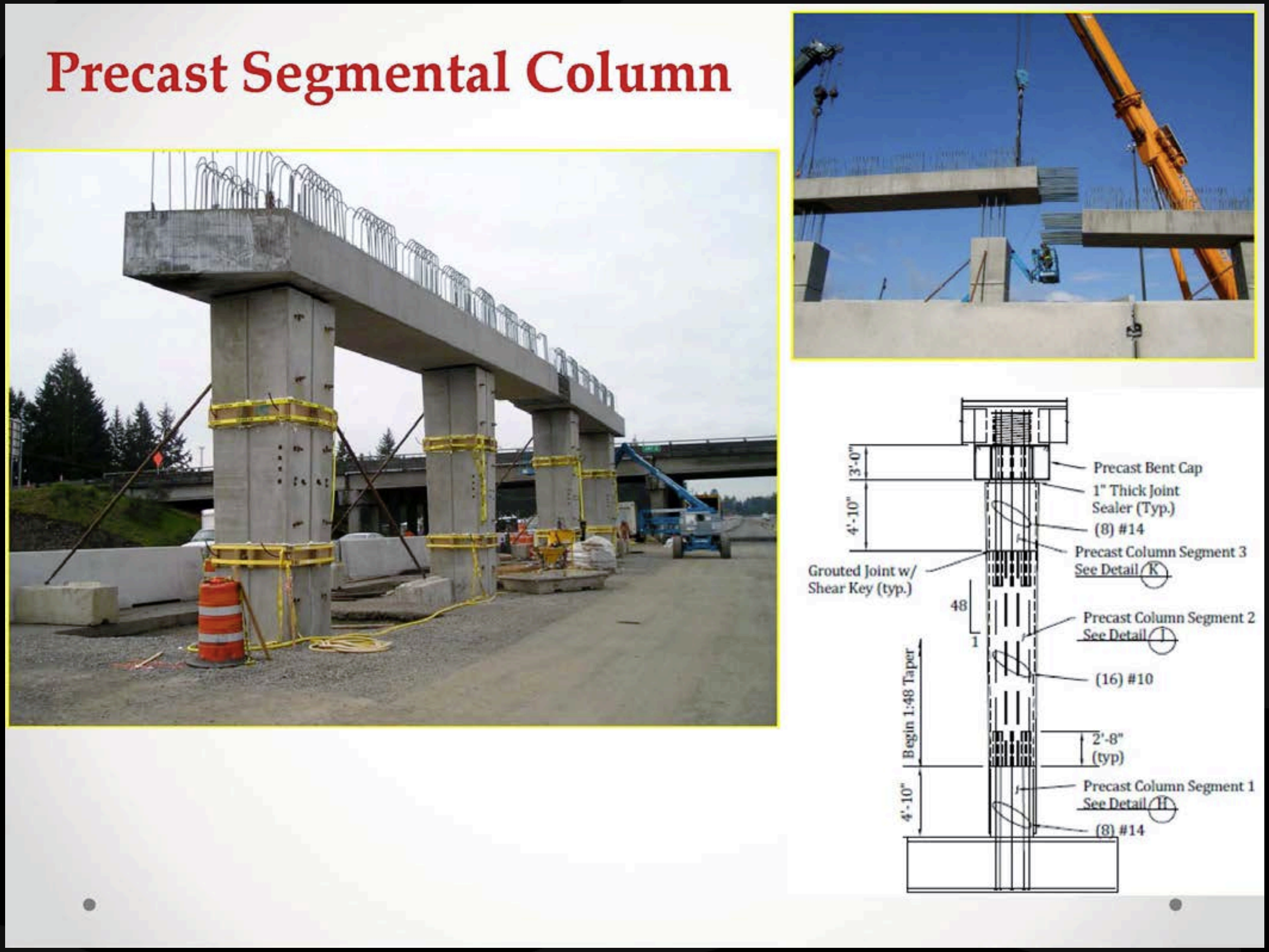
State-of-the-Art on Seismic Design of Precast Concrete Bridges

Content

Ch.1 Introduction
Ch. 2 Structural System Considerations
Ch. 3 Seismic Design Criteria
Ch. 4 Seismic Analysis
Ch. 5 Connection Details
Ch. 6 Design Examples
Appendix:
- Seismic Research of PBES
- Survey Results
- SDC of Japan
- SDC of New Zealand



Seismic Design of Precast Concrete Bridges



Seismic Design of Precast Concrete Bridges

Contact William Nickas, P.E.
Managing Director, Transportation Systems
Precast/Prestressed Concrete Institute
Wnickas@pci.org
Office Phone 312.583.6776
Cell 850.510.8621

The Owner’s Challenge for durable Bridges

- Understand AASHTO Analysis often assumes Monolithic construction this may need codification
- Overseas design Philosophy (over engineered?)
  - Extremely thick decks
  - Always overlay as protection
- Contractor education “perceived better overseas”

The Owner’s Challenge for durable Bridges

- Redundancy thru load paths verses Foreign through “over engineered”
  - Beam spacing generally closer than US
- Consequence of failure or secondary load paths
  - Possible less connection/continuity and therefore a different beta???
- Original LRFD strength calibrated to multi girder and no service calibration
  - Need pre-service requirements in Concrete Section
- Need understanding of transverse Design and Operational issues for various details
  - With PT one faces the concern involving Notional, Legal, Permit and the Service1 and Service3 requirements.

Concrete Under High Compression

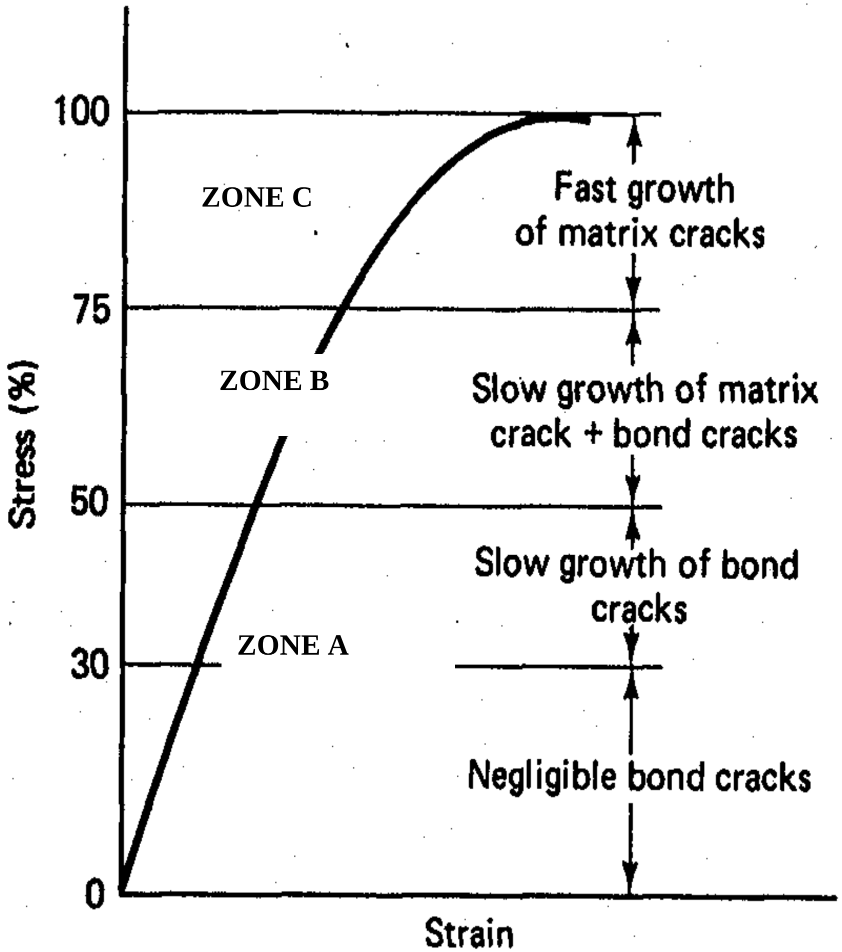


Figure 14.10 Diagrammatic stress–strain curve of concrete in compression. (From J. Glucklich, in *The Structure of Concrete*, ed. A. E. Brooks and K. Newman, Cement and Concrete Association, London, 1968, pp. 176–189.)

Behavior of Concrete

(Ref: *Handbook of Structural Concrete* – Kong, Evans, Cohen, Roll and *Concrete* – Mindess, Young)

Zone A: Stable microcracking: stress 0 to 50- 55 % of f'c

Zone B: Unstable microcracking: stress 50-55 % to 75-80 % of f'c

Zone C: Unstable macrocracking: stress 75-80 % to100% of f'c

Flying under Radar

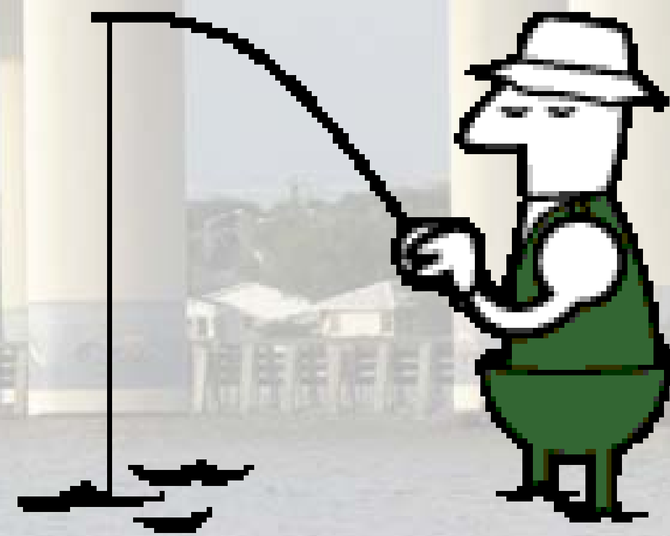
Quotes from DOT folks who may accidentally help a short fall occur:

“They are giving us a warranty why push and enforce fully the specs”

“It is a design/build job and they are writing a project Tech Spec. that covers that special item since it’s proprietary any way”

Let’s go Fishing

Some believe if you look long enough you will find some DOTer who will say yes….. Always look to see if they are asking the right “authorizing official”



Dangerous at times

This may put a DOT person in a position where he or she may be unaware of the “Book of Promises” for D/B or even going against DOT policies/Stds. that the project was advertised under.

Are we Recycling Ideas and Research Topics?

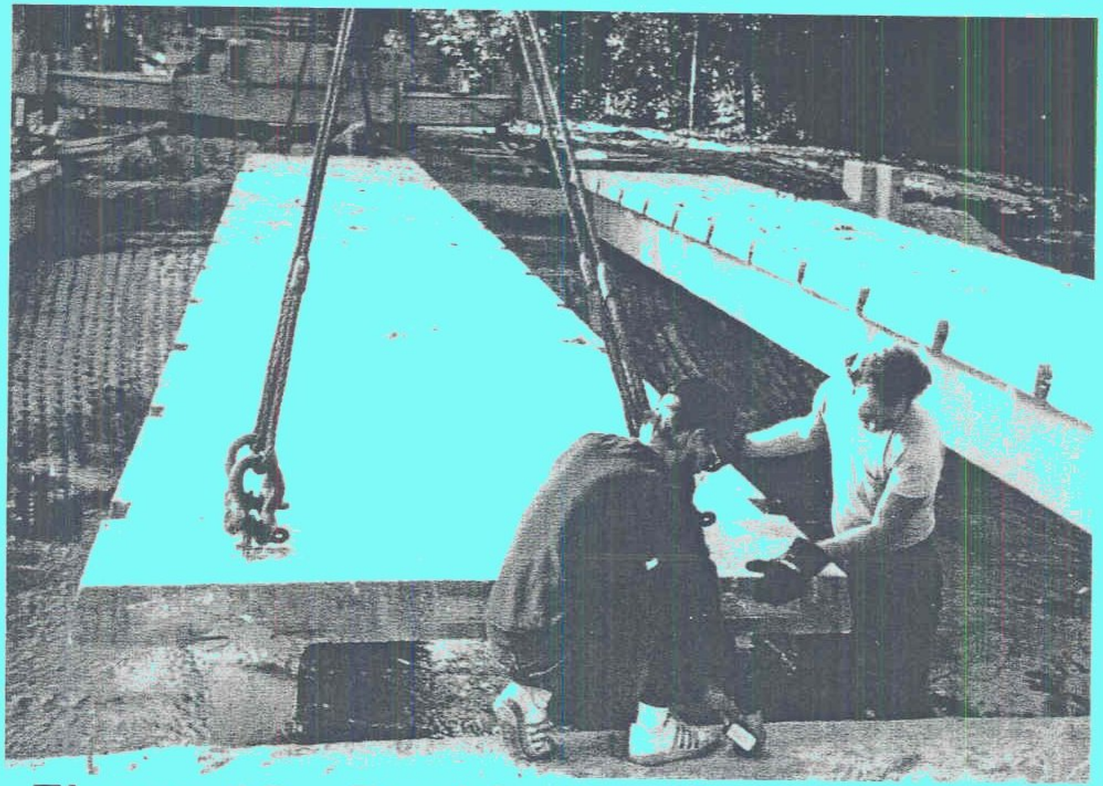
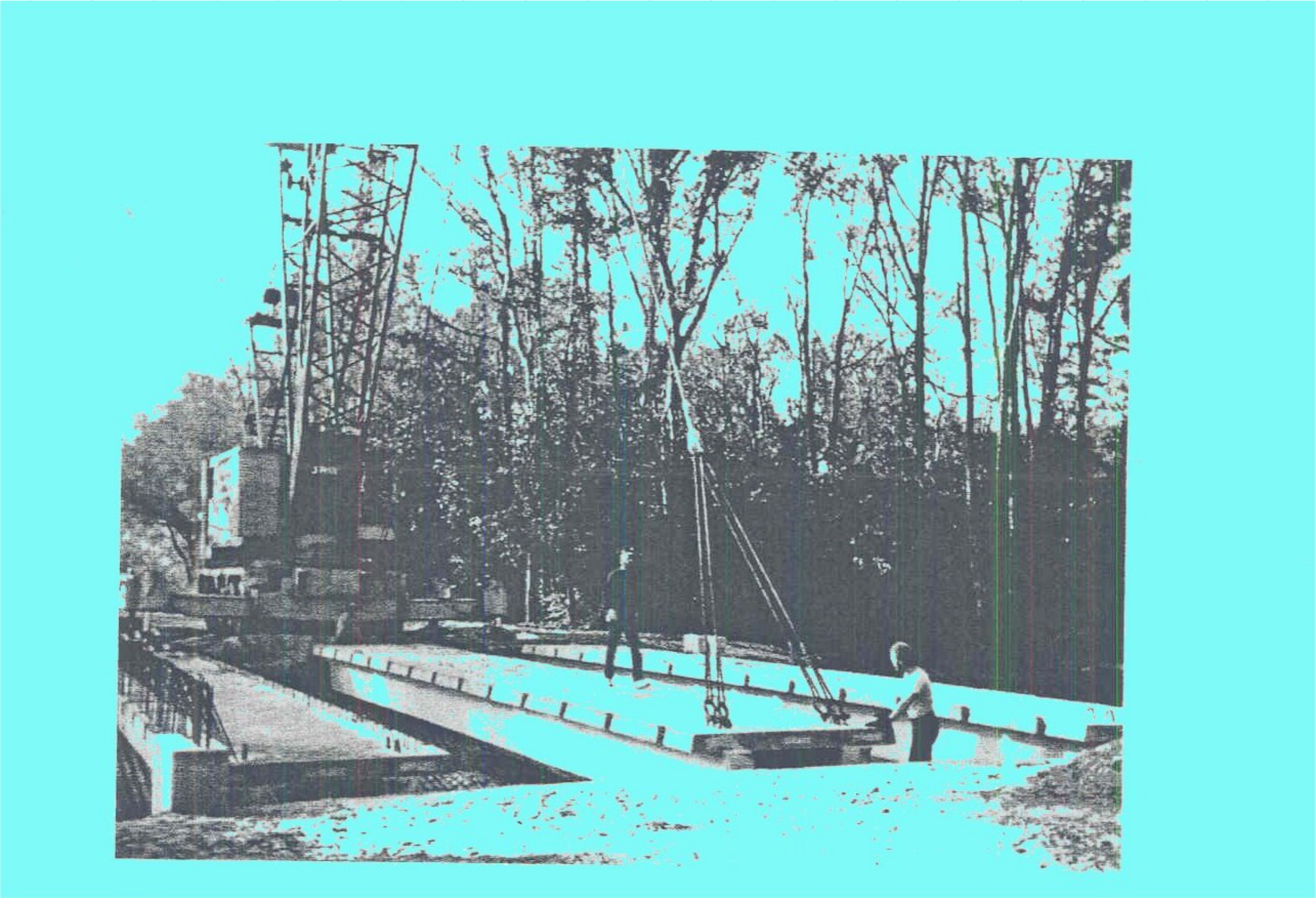


Figure 18. Double-Tee Bridge System During Construction



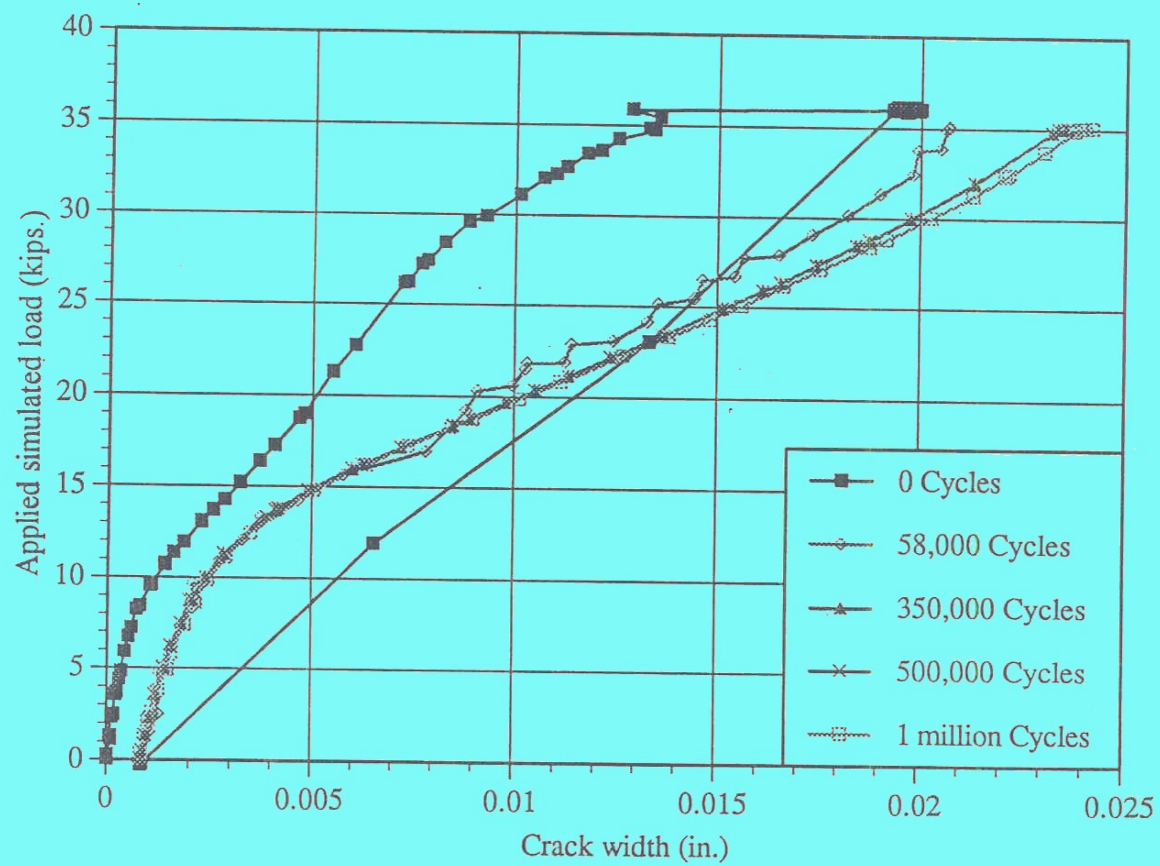
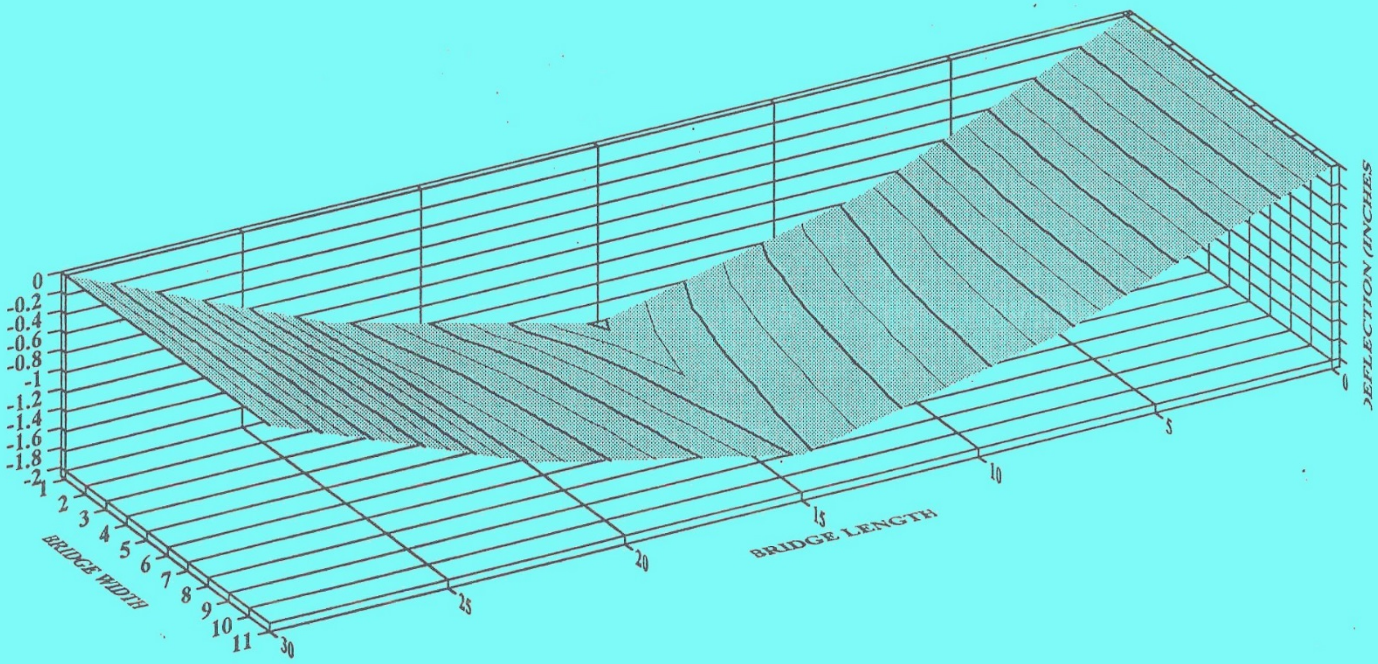


Fig.7.54 Crack width measured in stem 1 at midspan section

Fig. 7.50 The deflection shape of the bridge deck after 58,000 cycle loading at load of 36 kips



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Concrete Bridges

Thank You