The Future of Prestressed Concrete Bridges and Industry Innovations

William N. Nickas, P.E.
Managing Director, Transportation Services
Precast/Prestressed Concrete Institute
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LEARNING OBJECTIVES

1. Cover a few Transportation Publications. These include Manuals, Recommended Practices and State-of-the-Art reports
   a. Precast Prestressed beams and decks
   b. Extending Spans (Long Single Piece Girders & Spliced Girders)
   c. U Girders, Including Curved
   d. Precast Pavements and others

2. FHWA-AASHTO-PCI contract for advancing complex concrete initiatives.

3. PCI launch of Transportation modules with eLearning system

4. Recent Case History of Game Changing accomplishments
Knowledge Transfer

Back Story or Event that caused the writeup? YES… got an idea? Want to share a perspective?
Why Change.... Lag in productivity growth!

... Construction in General Needs to Close the Innovation Gap rapidly

<table>
<thead>
<tr>
<th>Industry</th>
<th>~ 1940s</th>
<th>~ 2016</th>
<th>Key advantage</th>
<th>Productivity growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td>Land assembly and automation for scale Advanced bioengineering to increase yields</td>
<td>1,512</td>
</tr>
<tr>
<td>Manufacturing</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td>Entirely new concepts of flow Modularized and standardized designs Aggressively automated to increase production</td>
<td>760</td>
</tr>
<tr>
<td>Retail</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td>Utilized scale advantages and cutting edge logistics to provide affordable goods to the masses</td>
<td>699</td>
</tr>
<tr>
<td>Construction</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td>Limited improvements in technological capabilities, production methods, and scale</td>
<td>6</td>
</tr>
</tbody>
</table>
More than 15 years ago, the concrete bridge industry in the United States became aware of several isolated performance issues related to girded post-tensioning (PT) tendons. In response, several responsible stakeholders—owner agencies, consultants, contractors, and technical institutes—mobilized to rectify and improve the state-of-the-practice. New PT durability details to enhance tendon protection and facilitate post-construction inspection were incorporated. Proprietary prepackaged grout materials were developed to replace field formulations and to improve overall grout performance. The technical institutes created education and certification programs related to PT grouting practice. Updated project specifications soon began to incorporate requirements for these certifications, the enhanced details, and the new grouts. The bridge engineering and construction community demonstrated it could work together to improve the long-term durability of post-tensioned bridges.

Later, experiences showed that the use of the prepackaged grout materials had unintended consequences. While the engineered grouts were generally very effective in controlling grout bleeding, which had been the cause of most of the reported problems in 15 to 20 years ago, some were found to be susceptible to a new problem—namely, segregation or soft grout. Research has shown that some of these proprietary mixtures included a high percentage of inert material that contributed to the formation of soft grout in some instances—particularly when excess water was used. When these new performance issues were reported in 2009, the industry again responded by revising the Post-Tensioning Institute material specification, M5S, to prohibit the addition of inert fillers.

At the 2016 annual meeting of the AASHTO Subcommittee on Bridges and Structures, a state department of transportation (DOT) engineer reported that a bridge constructed in 2007 with prepackaged grout materials was now in distress. The DOT representative reported that the PT tendons contained grout with an excess amount of water—estimated to be twice the manufacturer’s recommended level. These experiences have shown that both quality materials and proper workmanship are needed to achieve reliability and long-term performance. The industry responded again with new specifications and new technologies. For more information, see the articles on pages 53, 54, and 59 in this issue.

When specified work procedures performed by qualified personnel go awry, corrective actions and perhaps revised job site procedures are needed. Conversely, the positive results achieved from consistently practicing quality work that leads to the good long-term performance of the vast majority of PT bridges should also be recognized.

During a recent safety workshop, presenter Michael Fechtih used a slogan, “R&A” standing for responsibility, authority, and accountability. “R&A” can be defined for our industry as follows:

- Responsibility—the obligation to ensure that appropriate action is taken to follow the plans and specification documents developed through standards of care from industry and set forth in the contract documents.
- Authority—the jurisdiction and right to decide and take action to achieve a compliant installation by the installer and inspector.
- Accountability—to be accountable to the specified entity and the jurisdictional authority for a particular process or procedure.

Prime construction contracts and subcontracting agreements must include the following items for assurance and to frame an accountable system:

- Clearly specify authority and responsibility of each party,
- Provide adequately qualified (certified and permitted) personnel to meet the assigned responsibilities,
- Conduct independent monitoring and assessment of individual processes,
- Establish appropriate consequences for noncompliance or failing to take action,
- Enforce consistent and unbiased application of accountable standards.

We must do a better job of controlling quality, identifying problems during construction, and taking appropriate corrective actions when necessary. We cannot rely only on updated specifications to replace reliable workmanship and inspection. The entire bridge industry must assure quality of the responsibility of every single person involved in the project.

Confusion exists among bridge owners and designers regarding the terms design life and service life as evidenced by the fact that the two are often used interchangeably. Article 1.2 of the American Association of State Transportation Officials’ AASHTO LRFD Bridge Design Specifications defines design life and service life as follows:

- Design Life: "Period of time on which the statistical derivation of transient loads is based: 75 yr for these Specifications."
- Service Life: "The period of time that the bridge is expected to be in operation."

The use of a combination factor desi is one of the most common ways to ensure that a bridge will last for its entire service life. However, this approach is not always effective in ensuring that the bridge will last for the expected period of time. Therefore, it is important to carefully consider the various factors that can affect the durability of a bridge and to select the appropriate combination factor design.

The AASHTO LRFD specifications do not currently define service life for bridges. The provisions are termed “avoidance of deterioration” and “deemed-to-satisfy” approaches in AASHTO LRFD. If and when service life performance data becomes available, efforts should be made to quantify and calibrate the effects. Efforts to quantify and calibrate service life are under way with projects such as the Federal Highway Administration’s Long-Term Bridge Performance Program and the newly initiated NCHRP 12-108B, which will culminate in a guide specification for
These include Manuals, Recommended Practices and State-of-the-Art reports.
Recommended Practice for Stability

- Understand the various stages in the life of a girder
- Understand root causes of lateral instability and the need for analysis.
- Understanding of the concept of roll axis and variety of support conditions.
- Identify the equilibrium conditions for supported girder.
- Case studies of knowledge gained calculation and modification to improve stability.
 PCI Design Handbook

- First Published in 1971
- Used as a general reference for decades
- Load tables
- Design Aids
- Handling criteria
PreCast, Prestressed Concrete Piles

Excel Workbook addresses:

- Pile lofting
- Multi point picking and handling
- Design Interaction Diagrams
- Sample Parallel Calculations
- And User Guidance
PRECAST, PRESTRESSED CONCRETE PILES

INTERACTION DIAGRAMS

EXPLAINED BY AND TO BE USED IN CONJUNCTION WITH
PCI COMMITTEE REPORT
Recommended Practice for Design Manufacture and Installation of Prestressed Concrete Piling
PCI JOURNAL V 38 NO 2 MARCH/APRIL 1993

This free eBook, Calculation of Interaction Diagrams for Precast, Prestressed Concrete Piles, Second Edition, provides context and instructions for the use of the 2015 revised version of a Microsoft Excel workbook to compute pile stresses, plot interaction diagrams, and compute lifting points of precast concrete piles.

The Appendix of Calculation of Interaction Diagrams for Precast, Prestressed Concrete Piles contains detailed instructions and example problems using the 2015 workbook. Examples are also solved using Mathcad to validate the workbook solution, and a table of results compares the two methods.

To download Calculation of Interaction Diagrams for Precast, Prestressed Concrete Piles for free, go to:

pci.org/PD-01-15
SUPPLEMENT TO ASPIRE

SHARING NEW TECHNOLOGY THROUGH PCI BRIDGE TECHNOQUESTS
Industry throws a curve to traditional ideas—the curved, trapezoidal box girder bridges

William N. Nolick and John S. Dick

The Perfect Time
The advancement of the precast, prestressed concrete industry over its 65-year history has been largely incremental and methodical. Improvements in materials, manufacturing and construction efficiencies, product size and shapes, and quality assurance and reliability resulted in steady industry growth. In contrast, however, are recent developments in the deployment of bridge technology. A remarkably short time span, not only has a new bridge solution been provided to the design community, but, as a result, a new segment of the market has opened up to manufacturers in the precast concrete industry. Nine, for the first time, horizontally-curved trapezoidal box girder bridges are being built in national locations with spans approaching 300 ft.

As the industry grew, it was noticed that in terms of long-term forming techniques, multiple products in a form and usually production all at one time from end to end. Horizontally-curved products generally haven’t been considered due to deep-sided plant processes, complex formwork, and other constraints that have recently been

Figure 1. Two photographs of the Fyfe Klamath Falls bridge project that was built in 2008, which was the first precast-produced curved box girder bridge built in Oregon at that time. Photos: Summit Engineering Group.

Figure 8. TechnoQuest 2 tour of Duras-Bridge Inc. plant in Leesburg, Fla. Photos: J Dick Precast Concrete Consultant.

The Perfect Time
8a) Section of interior bucket form for casting trapezoidal U-girder. 8b) Workers use a custom bending machine to fabricate special welded wire reinforcement of No. 5 bars. 8c) Work in progress to preassemble a reinforcement cage containing post-tensioning ducts. 8d) No. 9 reinforcing bars are headed at top and bottom to provide development in a short length. These bars will terminate in the cast-in-place deck.

Figure 9. As it arrives at the jobsite, the length of the truck and trailer is 150 ft. Photo: Dura-Stress Inc.

8a) Section of interior bucket form for casting trapezoidal U-girder. 8b) Workers use a custom bending machine to fabricate special welded wire reinforcement of No. 5 bars. 8c) Work in progress to preassemble a reinforcement cage containing post-tensioning ducts. 8d) No. 9 reinforcing bars are headed at top and bottom to provide development in a short length. These bars will terminate in the cast-in-place deck.

The Const
9a) The steerable dollies of the trailer visible at right center. Photo: J Dick

9b) The steerable dollies of the trailer visible at right center. Photo: J Dick

9c) The trailer’s axes extend laterally on command to 19 ft out-to-out. This provides a high degree of maneuverability in closed access locations.

from the plant manufacturing and fabricated curved steel forms.

The final step shown in Figure 8a were able to stay under construction temporary and maintain temporary support for the foundation.

On the second presentation, prominent partners of the project and those in attendance from the CD-PCI, the precast concrete industry, featured projects from various special construction. The class was conducted by the Field Engineer Group.

The PCI Bridge was well-received by all in attendance that had the view to experience the process, and the 150-

It is understood that Alabama, Illinois, and Oregon may have plans for implementation.

Already, preferring for PCI Bridge location to be attending, see this project in the future.

The Const...
FIRST BEAM PULLED FROM FORM - 5-19-2014 - 7:22 AM.
Superstructures

CONCRETE BRIDGE TECHNOLOGY

U-Girder Standards Upgraded for External Post-Tensioning Tendons

New Go By sheets/concept drawings for curved, precast concrete spliced U-girders using bonded and unbonded post-tensioning for the next generation of structures

by Sam Fallaha, Florida Department of Transportation, and William N. Nickas, Precast/Prestressed Concrete Institute

INDEX OF DRAWINGS

Example of reinforcement, tendon, and anchorage details for pier diaphragm. All Drawings: Precast/Prestressed Concrete Institute and Florida Department of Transportation.
Precast Pavement

• Addresses Accelerated Construction goals
• PCI Guidance Documents
• 4 parts
  • Applications
  • Design & Maintenance
  • Manufacturing
  • Construction
Prestressed/Precast Concrete Pavement (PPCP) Repository
Includes prestressed and other precast concrete pavement systems

Please visit the [PCI Precast Concrete Pavements ePub fulfillment site](https://www.precastconcretepavement.com) for PCI Pavement Committee Reports.

www.precastconcretepavement.com
Manual for Evaluation and Repair

• Organized to address: Root Cause and Solutions
• May be adopted by some plants as part of QSM
• Offers Trouble shooting, Repair and Injection processes
Table 1
DISPOSITION OF CRACKED CONCRETE OTHER THAN BRIDGE DECKS
[see separate Key of Abbreviations and Footnotes for Tables 1 and 2]

<table>
<thead>
<tr>
<th>Elev. Range</th>
<th>Crack Width Range (inch)</th>
<th>Cracking Significance Range per LOT (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x = crack width</td>
<td>Isolated Less than 0.005%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Occasional 0.005% to 0.017%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate 0.017% to 0.029%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severe 0.029% or grt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environment Category</td>
</tr>
<tr>
<td></td>
<td>x ≤ 0.004</td>
<td>SA MA EA</td>
</tr>
<tr>
<td></td>
<td>0.004 &lt; x ≤ 0.008</td>
<td>NT NT PS</td>
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<td></td>
<td>0.008 &lt; x ≤ 0.012</td>
<td>NT PS EI</td>
</tr>
<tr>
<td></td>
<td>0.012 &lt; x ≤ 0.016</td>
<td>PS EI (6)</td>
</tr>
<tr>
<td></td>
<td>0.016 &lt; x ≤ 0.020</td>
<td>Investigate to Determine Appropriate Repair (4,5) or Rejection</td>
</tr>
<tr>
<td></td>
<td>0.020 &lt; x ≤ 0.024</td>
<td>Reject and Replace</td>
</tr>
<tr>
<td></td>
<td>0.024 &lt; x ≤ 0.028</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x &gt; 0.028</td>
<td></td>
</tr>
</tbody>
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Elev. More Than 6 ft AMHW

<table>
<thead>
<tr>
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<tr>
<td>x ≤ 0.004</td>
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<td></td>
</tr>
<tr>
<td>x &gt; 0.028</td>
<td></td>
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</tbody>
</table>
Summary
The additional design criteria in FDOT Structures Design Bulletin 17-08 and the curved, precast concrete spliced U-girder concept drawings came about due to the focused and persistent efforts of industry, FPCA, and FDOT staff to create a collaborative solution that could meet the goals of each stakeholder. It is imperative that designers be provided successful concepts of the new generation of curved, precast concrete post-tensioned structures with replaceable tendons and optimize them to meet the requirements of the owner.

Reference

Sam Fallaha is assistant state structures design engineer at the Florida Department of Transportation in Tallahassee, Fla. William N. Nickas is managing director of transportation systems at PCI in Chicago, Ill.

Editor’s Note
While the revisions to the PCI Zone 6 U-girder details discussed in this article were made to address FDOT’s use of wax-filled external tendons, the concepts and details can also be used with grouted external tendons that have been successfully used around the world. The full set of drawings is available at www.aspirebridge.org or www.fdot.gov/design.
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
FHWA-AASHTO-PCI contract for advancing complex concrete initiatives.
Advanced Precast Element Design and Construction State of Practice

• PCI eLearning Courses T100 series address:
  • Preliminary Design
  • Materials and Manufacturing
  • Loads
  • Flexural SLS
  • Flexural ULS
  • Refined Losses w/o decks
  • Refined and L.S. w/decks
  • Shear
  • End Zone
Advanced Precast Element Design and Construction State of Practice

- PCI eLearning Courses T200 series address Full Depth Precast Decks
  - Introduction
  - Design
  - Manufacturing and Construction
  - Case studies
Objective

- Provide guidelines for preliminary and final design of curved, spliced U-Beam systems
- Design and detailing using examples and reference to constructed projects
- Communicate the current state-of-the-art as represented by recent completed projects
- Not all encompassing, nor limiting the ingenuity of design professionals
Prefabricated Bridge Elements and Systems for Horizontally Curved Alignments Manual

Guidance Manual Chapters

1. Curved Precast U-Beam Concept
2. Implementation of Curved, Spliced U-Girder System
3. Project Delivery
Prefabricated Bridge Elements and Systems for Horizontally Curved Alignments Manual

Guidance Manual Chapters

5. Preliminary Design and Span Layout
6. Modeling and Analysis
7. Design Considerations
8. Design Details

Details: Tendon Profiles

Torsional Demand

\[ T = \frac{Vl^2}{24R} + \frac{Vl^2}{2R} \]

\[ T = 4.22 \text{ kips/ft} \times \frac{100 \text{ ft}}{3} = \frac{4.22 \times 100}{3} \text{ kips/ft} \]

Torsion & Shear Study: Finite Element Model

Guidance Manual provides sample details to aid the designer.
Bridge Geometry Manual

Guidance Manual Chapters

1. Introduction
2. Horizontal Roadway Geometry
3. Vertical Geometry
4. Roadway Super Elevation
Bridge Geometry Manual

Guidance Manual Chapters

5. Working with Horizontal Roadway
6. Geometry of Straight Bridges
7. Geometry of Curved Bridges
8. Segmental Bridges
Advanced Precast Element Design and Construction State of Practice

Bridge Geometry Manual

Guidance Manual Chapters

• Appendix A Vector Geometry
  • Definitions
  • Vector Addition and Subtraction
  • Three Dimensional Vectors
  • Vector Multiplication
  • Coordinate Transformation

• Appendix B Example Alignment Geometry
Also share this notice for free PDHs!!

PCI Offers New eLearning Modules

Courses on Design and Fabrication of Precast, Prestressed Concrete Bridge Beams

The PCI eLearning Center is offering a new set of courses that will help an experienced bridge designer become more proficient with advanced design methods for precast, prestressed concrete flexural members. There is no cost to enroll in and complete any of these new bridge courses. The courses are based on the content of the 1600-page PCI Bridge Design Manual, now available for free after registering with a valid email. While the courses are designed for an engineer with 5 or more years’ experience, a less experienced engineer will find the content very helpful for understanding concepts and methodologies. Where applicable, the material is presented as part of a “real world” design of a complete superstructure example so that the student can see how actual calculations are completed according to the AASHTO LRFD specifications. All courses on the PCI eLearning Center are completely FREE.

PCI eLearning Series T100 Courses

Preliminary Precast, Prestressed Concrete Design (T110)

Preliminary design is the first step in designing an economical precast, prestressed concrete bridge. This first course in the series on design, presents the preliminary plan, superstructure, substructure, and foundation considerations, and member selection criteria with design aids and examples.

Materials and Manufacturing of Precast, Prestressed Concrete (T115)

This second course on design explores the constraints related to type, size, and method selection. Materials control strength and durability characteristics. The industry’s manufacturing capabilities are important conditions on design assumptions. Plant handling and transportation constraints need to be considered in design. This course presents the important initial information required before beginning design, enabling designers to take advantage of the flexibility and economy of precast, prestressed concrete products while avoiding pitfalls that could make solutions less cost effective.

Design Loads and Load Distribution (T120)

This third course on bridge design teaches one of the fundamental tasks of collecting information on permanent and transient loads that may act on a bridge and how these forces are distributed to the structural components. It presents the load types and load distribution provisions of the LRFD Specifications related to superstructure systems.

This web-based training course was developed by the Precast/Prestressed Concrete Institute (PCI) for the Federal Highway Administration (FHWA) through a contract with the American Association of State Highway and Transportation Officials (AASHTO).
Video of sample of PCI eLearning
GUIDE TO NAVIGATING COURSE

- After selecting course, your start page is the “Status Page”
- Click through all “Course Content” and “Resources” to explore all that the course has to offer.

You are here:

PCI Learning
Welcome, Dave Anians
- PCI Courses
- My PCI Courses
- Profile
- Log Off

Course Content
- Status Page
- 02_Design_and_Detailing
- Final Test & Evaluation

Resources
- PCI Bridge Deck Report Design Details
- PCI Bridge Deck Report Sample Design Calculations
- 1984 Deck Widening and Replacement of Woodrow Wilson Memorial Bridge
- 1986 Precast Bridge Deck Design Systems
- 1987 Precast Prestressed Concrete Bridge Deck Panels
- 1985 Field Performance of Full Depth Precast Panels

2.2 Design and Detailing
2.2 Design and Detailing uploaded 8/10/16
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- Viewed 02_Design_and_Detailing
- Not Viewed Final Test & Evaluation
- Viewed PCI Bridge Deck Report Design Details
- Viewed PCI Bridge Deck Report Sample Design Calculations
- Viewed 1984 Deck Widening and Replacement of Woodrow Wilson Memorial Bridge
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- Not Viewed 1987 Precast Prestressed Concrete Bridge Deck Panels
- Not Viewed 1985 Field Performance of Full Depth Precast Panels
- Not Viewed 1998 Analysis of Full Depth Precast Concrete Bridge Deck Panels
- Not Viewed 2004 NUDECK Panel System for Nebraska's Skylite Bridge
- Not Viewed 2005 Behavior of Horizontal Shear Connections for Full-Depth Precast Concrete Bridge Decks on Prestressed I-Beams
- Not Viewed 2006 Composite Behavior of Full Depth Prestressed Panels in Bridge Deck Reconstruction
- Not Viewed 2008 NCHRP Report 594 - Full-Depth Precast Concrete Bridge Deck Panel Systems

Please complete course material to receive a completion certificate.
- The course module itself and all resources will open in a new browser tab or window:

- When back on Status Page, “refresh” to see which modules and resources you have viewed:
Recent Case History of Game Changing accomplishments
Knowledge transfer in UAE
PCI TechnoQuest 2016
Oak Ridge National Laboratories

Project with PCI and Gate Concrete Products for making Concrete Molds saves labor
First (2)
Production
Panels
First attempt at North mold as printed
Blow-up of Horizontal voids on North mold
New print process on North mold

Very small void.
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The Future of Prestressed Concrete Bridges and Industry Innovations

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THANK YOU