Prestressed Concrete Bridge Design Seminar

Session 1 – April 13, 2021

1. Basic Concepts of Prestressed Concrete

PCI Mid-Atlantic
A Chapter of the Precast/Prestressed Concrete Institute

PCI Northeast
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Reid W. Castrodale, PhD, PE

Castrodale Engineering Consultants, PC – Concord, NC

- Structural engineering consultant - Prestressed concrete, LWC, and ABC
- 39 years bridge experience in design, research, promotion, & specifications
  - Previously Portland Cement Assn. (PCA), Ralph Whitehead Assoc. (STV), & Carolina Stalite (LWA)
  - Georgia/Carolinas PCI Bridge Consultant (> 20 yrs)
  - Managing Technical Editor of *ASPIRE*® magazine
  - Director of Engineering – ESCSI & Stalite
  - Consultant on 3 NCHRP research project teams: 0.7" strand; deck girders; & stainless steel strands
- Chair, PCI Committee on Bridges (COB) (1992-1998)
- Co-Chair, *PCI Bridge Design Manual* Steering Committee (1993-2011)
- Principal Investigator for NCHRP Report 517 "Extending Span Ranges of PC PS Concrete Girders"

Education

- Georgia Institute of Technology, BCE
- University of Texas at Austin, MS & PhD in Structural Engineering

reid.castrodale@castrodaleengineering.com (704) 904-7999

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Why use Prestressed Concrete?

"Transforms" concrete from a material that cracks into an elastic uncracked material at service limit state

- Prevents concrete cracking at service limit state
- Gross cross-section maintained for improved stiffness
- Provides active force to close flexural cracks
- Prestress force balances loads

An ideal combination for bridges

- Allows longer and/or shallower spans
- Improves durability

Adaptable to many design situations

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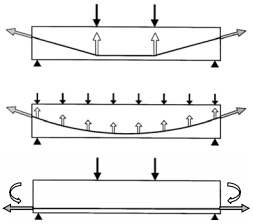
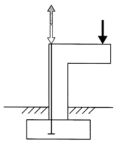
Prestressed Concrete

High strength steel is pre-tensioned (i.e., prestressed) to pre-compress concrete to counteract tensile stresses and cracking at service limit state

Prestressing "balances" the applied loads





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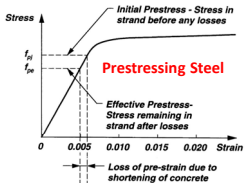
Prestressed Concrete

Prestressed (PS) concrete combines

- **High performance concrete**
- **High strength steel**

High strength prestressing steel is <u>required</u> to overcome strains from elastic shortening, creep, & shrinkage and still have significant stress



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Prestressed Concrete

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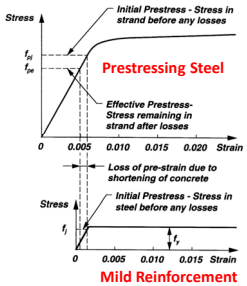
High strength prestressing steel is <u>required</u> to overcome strains from elastic shortening, creep, & shrinkage and still have significant stress

Mild reinforcement is not effective for prestressing – not enough strain capacity to overcome other strains



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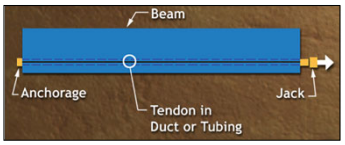
Post-tensioning

One method for applying prestress to concrete

- Ducts cast into concrete (CIP or precast)
- Strands are tensioned against hardened concrete member
- Permanent anchorage hardware is used to transfer force to concrete
- After stressing, duct is typically grouted for bond and corrosion protection



Many figures in this session are from the PCI Bridge Design Manual

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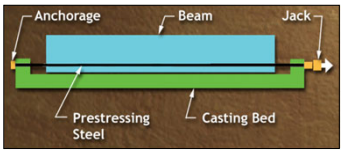
Pretensioning

Second method for applying prestress to concrete

- Strands are tensioned between abutments, then concrete is placed
- When concrete reaches required strength, force is transferred from strands to concrete
- Force is transferred to concrete by bond only - there is no permanent anchorage hardware



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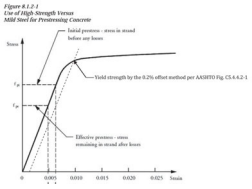
Prestressing Strand



- 7–wire strands are standard
- 0.6 in. diam. strand is typical
- *0.7 in. diam. strand is being studied*
- *Also stainless steel, carbon fiber, and epoxy coated for corrosion resistance*

- Grade 270 strands are standard
- 270 ksi ultimate tensile strength (GUTS)
- No defined yield point – use 0.2% offset: f_{py} = 243 ksi
- *Grade 300 strands now available*

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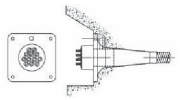
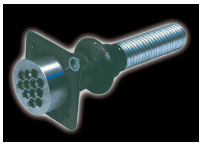
Post-Tensioning Anchors

Permanent hardware to anchor tendons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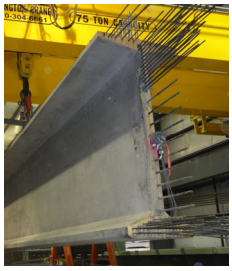
Pretensioned Concrete Beams

No tendon anchor hardware – anchorage by bond only



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Compare Reinforced and PS Concrete

At Service Limit State Conditions

- **Reinforced Concrete:** Cracked section
  Reduced stiffness

- **Prestressed Concrete:** Uncracked section
  Gross section stiffness

At Strength Limit State Conditions

- **Reinforced Concrete:** Reinforcement yields
- **Prestressed Concrete:** Strands are past yield, nearing strength
- **Concrete stress block is the same for either**

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Benefits of Prestressed Concrete

- Structural Efficiency
- Cost Effectiveness
- Durability – crack control and high quality precast concrete
- Low Maintenance
- Quality – PCI certified
- Standardization
- Aesthetics
- Accelerated Bridge Construction (ABC)
- Fire Performance
- Proven Track Record

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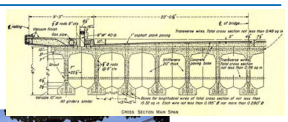
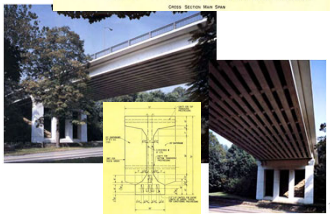
History of Prestressed Concrete in US

Introduced in 1949

- Walnut Lane Memorial Bridge in Philadelphia, PA
- An innovative bridge
  - Girders precast on-site
  - Post-tensioned using wires
  - 160 ft main span
- Sparked the emergence of prestressed concrete in the US
- Bridge was replaced in 1990
  - See articles in *PCI Journal*, especially May-June 1992





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Growth of the Industry

Rapid development of technology and materials in 1950s

- Seven-wire strand
- Plant pretensioning in long-line beds
- Chemical admixtures
- High-early strength concrete
- Steam curing

By 1958, there were more than 200 prestressing plants in the US

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Growth of the Industry

Design standards continued to evolve and develop

Industry recognized need to focus on quality

PCI's Plant Certification program was developed

- In place since 1967
- Assures specifiers that plants have processes and capability to consistently produce quality products
- Certification programs are also in place for plant personnel

Many DOTs require PCI Certification for prestressed concrete products

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Quality Control

Quality is controlled during production at precasting plant

- Rigorous inspections
- Product is inspected at each stage of fabrication to provide quality control
- PS concrete members are essentially load-tested at transfer of PS, giving an indication of quality

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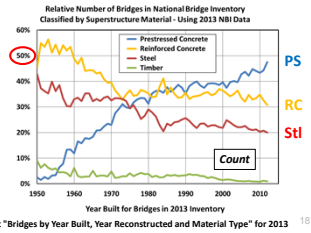
Growth in Use of PS Concrete Bridges

Current preference for prestressed concrete is revealed in NBI data (2013) for total inventory (all states)

- Nearly half of the number of new bridges built each year are PS concrete – from none in 1950
- PS concrete is only super-structure material with growth since 1950

Using the FHWA InfoBridge Portal, 46% of bridges constructed in most recent 5 yr period were PS concrete

- Consistent with earlier data



Data source: FHWA Report "Bridges by Year Built, Year Reconstructed and Material Type" for 2013

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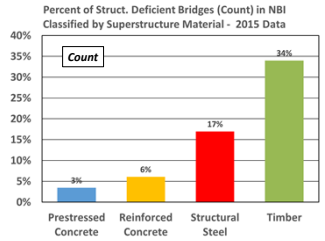
PS Concrete Bridge Performance

Number of structurally deficient bridges of equal ages

- Based on superstructure material using NBI data



- **Superstructure material is a significant factor in performance**
- **PS concrete has fewest no. of structurally deficient bridges**

Data source: FHWA NBI Webpage "Deficient Bridges by Superstructure Material 2015"

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PCI Bridge Design Manual

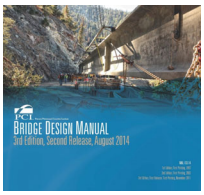
Source of much of the information presented today

Design-related content

- Design procedures and details with background
- Design aids
- Detailed design examples
- Discussion of different applications

Fabrication and Erection – Chapter 3

- ***HIGHLY RECOMMENDED*** **– detailed discussion**



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Questions?

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