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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/Caroline 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 (1999-2011)
Principal Investigator for NCHRP Report 517 “Extending Span Ranges of PC PS Concrete Girders”

Education
Georgia Institute of Technology, BCE
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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
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 required to overcome strains from elastic shortening, creep, & shrinkage and still have significant stress.

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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

**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

**Prestressing Strand**

- 7-wire strands are standard
- 0.6 in. diam. strand is typical
  - Also stainless steel, carbon fiber, and epoxy coated for corrosion resistance
- Grade 270 strands are standard
- 270 ksi ultimate tensile strength (UTS)
- No defined yield point – use 0.2% offset: \( f_{yp} = 243 \) ksi
- Grade 300 strands now available
Post-Tensioning Anchors
Permanent hardware to anchor tendons

Pretensioned Concrete Beams
No tendon anchor hardware – anchorage by bond only

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
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

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

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
**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 superstructure material with growth since 1950

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

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

Now FREE from PCI online bookstore!

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**Prestressed Concrete Bridge Design Seminar**

Session 1 – April 13, 2021

1. Introduction to Prestressed Concrete

Questions?