W-02: Today’s Concrete Bridge Design

Wednesday, December 11, 2019
8:00 a.m. to 12:00 p.m.

Today's Concrete Bridge Design
Preconference Workshop
December 11, 2019 Morning Workshop

Representatives of the members of the National Concrete Bridge Council (NCBC) listed below will give a series of presentations that focus on key elements of concrete bridge design and construction, including topics related to accelerated bridge construction (ABC). Some are covered in the *AASHTO LRFD Bridge Design Specifications*, while many concepts and practices are addressed through concrete industry publications. Speakers will discuss recent state-of-the-art reports, industry manual updates, and other activities including recent developments in concrete solutions that are becoming more common practice in construction and renewal of concrete transportation projects. Presentations will include discussion of how institute-based balloting and collaboration serve to establish consensus documents and certification programs that contribute to the body of knowledge within institutes and within the industry as a whole. Participants will receive industry handouts, presentations, and manuals.

NCBC Organizational Member	**Presenter**
Introduction of NCBC (current and future)	Reid Castrodale (Confirmed)
Portland Cement Association (PCA)	Alpa Swinger (Invited)
Expanded Shale, Clay and Slate Institute (ESCSI)	Reid Castrodale (Confirmed)
Silica Fume Association (SFA)	Jim Wolsiefer (Invited)
National Ready Mixed Concrete Association (NRMCA)	Brian Killingsworth (Confirmed)
Concrete Reinforcing Steel Institute (CRSI)	Danielle Kleinhans (Invited)
Epoxy Interest Group of CRSI (EIG)	Pete Fosnough (Confirmed)
Wire Reinforcement Institute (WRI)	www.wirereinforcementinstitute.org
Post-Tensioning Institute (PTI)	Tony Johnson (Confirmed)
American Segmental Bridge Institute (ASBI)	Gregg Freeby (Confirmed)
Precast/Prestressed Concrete Institute (PCI)	William Nickas (Confirmed)
Close out panel discussion with Industry Organizations	All above

Topic	**Presenter**	**Pages**
Introduction of NCBC (current and future)	8:00 to 8:15	4-7
Concrete Materials		
Portland Cement Association (PCA)	8:15 to 8:30	8-11
Expanded Shale, Clay and Slate Institute (ESCSI)	8:30 to 8:50	12-19
Silica Fume Association (SFA)	8:50 to 9:00	20-25
National Ready Mixed Concrete Association (NRMCA)	9:00 to 9:20	26-33
Session Q/A on Concrete Materials	9:20 to 9:30	
Break	9:30 to 9:45	
Concrete Reinforcing Solutions		
Concrete Reinforcing Steel Institute (CRSI) Epoxy Interest Group of CRSI (EIG)	9:45 to 10:00	34-41
Wire Reinforcement Institute (WRI)	10:00 to 10:20	
Post-Tensioning Institute (PTI)	10:20 to 10:40	42-53
Session Q/A on reinforcing methods	10:40 to 10:50	
Concrete Bridge Systems		
American Segmental Bridge Institute (ASBI)	10:50 to 11:10	54-65
Precast/Prestressed Concrete Institute (PCI)	11:10 to 11:30	66-82
Session Q/A on concrete bridge system designs	11:30 to 11:40	
Closeout		
Close out panel discussion with Industry Organizations	11:40 to 12:00	

Today's Concrete Bridge Design

National Concrete Bridge Council (NCBC)

2019 International ABC Conference
Preconference Workshop W-02
Miami, FL – December 11, 2019 8:00 AM – 12:00 PM

Reid W. Castrodale, PhD, PE
Castrodale Engineering Consultants, P
Concord, NC

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National Concrete Bridge Council (NCBC)

The National Concrete Bridge Council (NCBC) is a council of allied industry organizations dedicated to:

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

From NCBC website: www.nationalconcretebridge.org

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Current NCBC Members

American Segmental Bridge Institute (ASBI)
Concrete Reinforcing Steel Institute (CRSI)
Epoxy Interest Group of CRSI (EIG)
Expanded Shale, Clay, and Slate Institute (ESCSI)
National Ready Mixed Concrete Association (NRMCA)
Portland Cement Association (PCA)
Precast/Prestressed Concrete Institute (PCI)
Post-Tensioning Institute (PTI)
Silica Fume Association (SFA)
Wire Reinforcement Institute (WRI)

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History

NCBC was formed in 1987

First meeting with FHWA was September 15, 1988

Back row (L to R):
Stan Gordon – FHWA
Bob Nickerson – FHWA
Walter Podolny – FHWA
Basile Rabbat – PCA
John Dick – PCI
Ted Neff – CRSI

Seated:
Jim Rossberg - NRMCA

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NCBC Activities

Meetings with FHWA twice a year
- At Professor's Workshop in summer
- At FHWA in DC in fall – at FHWA's Turner Fairbank Lab in recent years

PCA Professor's Workshop – now ACI Professor's Workshop
- Summer meeting with various tracks, including bridges

Informal support for AASHTO Technical Committees
- Especially Concrete Design (T-10)
- Joint meetings of T-10 and the PCI Committee on Bridges began in mid-1990s
- Joint meetings of T-10 at the ASBI Convention started some time later

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NCBC Activities

Website
- www.nationalconcretebridge.org
- Front page currently has a web training video on FHWA's *Post-Tensioned Box Girder Design Manual.*

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NCBC Activities

HPC BridgeViews / Concrete BridgeViews

- Cooperative newsletter with FHWA
- First issue was Jan./Feb. 1999
- Last issue was #80 – March/April 2016
- Issues are still available
  - www.concretebridgeviews.com

First issue

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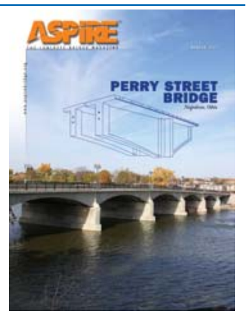
NCBC Activities

ASPIRE, the concrete bridge magazine

- About all types of concrete bridges
- First issue was Winter 2007
- All issues are available online
  - www.aspirebridge.org
  - Can search an issue or across all issues
- Free subscription
- Supported by several members of NCBC

Let us know if you have projects or topics

First issue



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NCBC Activities

Resources for Concrete Bridge Design and Construction

- Intended to be a catalog or "bookshelf" of important resources for the design and construction of concrete bridges
- The list is not exhaustive
- Other documents may be included that will be useful for the practitioner such as research reports, journal articles, or other publications
- First draft is in handout

This document was the impetus for today's workshop

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Agenda from Program

NCBC Organizational Member	Presenter
Introduction of NCBC (current and future)	Reid Castrodale (Confirmed)
Portland Cement Association (PCA)	Alpa Swinger (Invited)
Silica Fume Association (SFA)	Richard Wolf (Invited)
Expanded Shale, Clay and Slate Institute (ESCSI)	Reid Castrodale (Confirmed)
Concrete Reinforcing Steel Institute (CRSI)	Danielle Kleinhans (Invited)
Epoxy Interest Group of CRSI (EIG)	Pete Fosnough (Confirmed)
Wire Reinforcement Institute (WRI)	TBA (Invited)
Post-Tensioning Institute (PTI)	Tony Johnson (Confirmed)
National Ready Mixed Concrete Association (NRMCA)	Brian Killingsworth (Confirmed)
Precast/Prestressed Concrete Institute (PCI)	William Nickas (Confirmed)
American Segmental Bridge Institute (ASBI)	Gregg Freeby (Confirmed)
Close out panel discussion with Industry Organizations	All above

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Actual Agenda

NCBC Organizational Member	Presenter
Introduction of NCBC (current and future)	Reid Castrodale
Portland Cement Association (PCA)	Reid Castrodale
Silica Fume Association (SFA)	
Expanded Shale, Clay and Slate Institute (ESCSI)	Reid Castrodale
Concrete Reinforcing Steel Institute (CRSI)	Pete Fosnough
Epoxy Interest Group of CRSI (EIG)	Pete Fosnough
Wire Reinforcement Institute (WRI)	
Post-Tensioning Institute (PTI)	Tony Johnson
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Castrodale Engineering Consultants, PC
Concord, NC

NCBC

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PCA Since 1916
America's Cement Manufacturers™

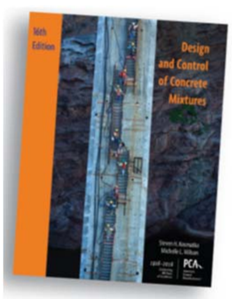
Portland Cement Association

The Portland Cement Association (PCA), founded in 1916, is the premier policy, research, education, and market intelligence organization serving America's cement manufacturers.

W-02 NCBC Workshop

1

Design and Control of Concrete Mixtures



REFERENCE:
Kosmatka, Steven H. and Wilson, Michelle L.,
Design and Control of Concrete Mixtures,
EB001, 16th edition,
Portland Cement Association,
Skokie, Illinois, USA, 2016, 632 pages.

W-02 NCBC Workshop

2

Design and Control of Concrete Mixtures

- First Published in 1924
  - 24-page Bulletin
  - Focused on the Mix Design Method
- Proportioning Concrete Mixtures (1916)
  - Available for free at link below

www.cement.org/DesignandControl

W-02 NCBC Workshop

3

Premier Reference on Concrete Technology

Backed by over 100 years of research by PCA.
Reflects the latest information on standards, specifications, and test methods:

- *ASTM International (ASTM)*
- *American Association of State Highway and Transportation Officials (AASHTO)*
- *American Concrete Institute (ACI)*

4

Abstract

- The fresh and hardened properties of concrete, such as workability, strength, volume change, and durability, are presented.
- All concrete ingredients (cementing materials, water, aggregates, chemical admixtures, and fibers) are reviewed for their optimal use in designing and proportioning concrete mixtures.

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Abstract

- Applicable ASTM, AASHTO, and ACI standards are referred to extensively.
- The use of concrete from design to batching, mixing, transporting, placing, consolidating, finishing, and curing is addressed.
- Concrete pavements and structures along with sustainability and high-performance concretes, are also reviewed.

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Table of Contents

Presentations for each chapter are available for free at:
www.cement.org/DesignandControl

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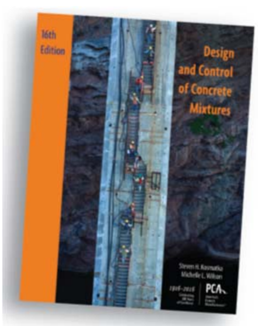

Retail: $75
For More Information:
www.cement.org/DesignandControl

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The Expanded Shale, Clay and Slate Institute (ESCSI)

Reid W. Castrodale, PhD, PE
Director of Engineering – ESCSI

2019 International ABC Conference
Preconference Workshop W-02
Miami, FL – December 11, 2019 8:00 AM – 12:00 PM

1

The Expanded Shale, Clay and Slate Institute (ESCSI)

The Expanded Shale, Clay and Slate Institute (ESCSI) was founded in 1952 and is the international trade association for manufacturers of ESCS lightweight aggregate.

ESCSI sponsors limited research and development on applications of LWA. Results of research and other work is then developed and disseminated to all parts of the building industry.

ESCSI works closely with other technical organizations, ACI, ASTM, etc., to maintain product quality, life-safety, and professional integrity throughout the construction industry and related building code bodies.

2

What is Lightweight Aggregate?

ESCSI members manufacture lightweight aggregate (LWA) using rotary kilns where raw materials (shale, clay & slate) are expanded at temperatures of around 2000 deg. F

The LWA produced in this manner

- is a vitrified ceramic
- is about as hard as quartz
- is about ½ as dense as NWA
- has 6-30% absorption

3

Uses for Lightweight Aggregate

- Structural lightweight aggregate (LWA) has been commercially manufactured in USA since 1920 – not a new material!
- It was immediately used to produce structural lightweight concrete (LWC)


USS Selma 1918

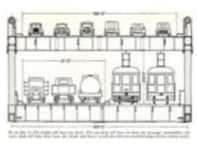

San Francisco Oakland Bay Bridge 1936

- Obvious benefit was reduced density
- Also found that the material was very durable

4

Uses for Lightweight Aggregate

- LWC used on San Francisco-Oakland Bay Bridge – built in 1936
- Used "all LWC" (95 pcf air dry) for upper deck of suspension spans
- Lower deck was reconfigured for highway traffic in 1958 using LWC
- Both decks are still in service today - protected by wearing surfaces



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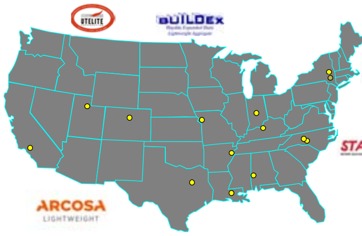
ESCS Plants in the US



14 plants in the US
See www.escsi.org for locations of member company plants

6

Applications of LWA for Transportation Facilities

- Structural Lightweight Concrete (LWC)
  - Precast concrete
  - Prestressed concrete
- Internal Curing of Concrete
- Geotechnical
- Rain Gardens
- Water Treatment
- Asphalt Chip Seal



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Lightweight Concrete Bridges

LWC has been successfully used for
- Decks
- Prestressed and post-tensioned concrete
- Other elements, especially when precast

Many examples are available
- Three are shown here

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Beach Bridge in North Haven, ME

- Replace two-span bridge on island off coast of Maine
- Sand LWC used for NEXT D beams
  - Allowed re-use of existing pier
  - Avoided design & construction of a new foundation in difficult soil conditions
  - Bridge closure shortened by eliminating pier reconstruction
    - Bridge was only access to several homes, the local fishing wharf, and beach
  - Reduced beam weight for shipping and handling at remote location
- SCC LWC mix properties
  - Design f'_c = 6 ksi; max. plastic density = 120 lb/ft^3; spread of 22 to 28 in.

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Benicia-Martinez Bridge, CA

- I-680 over the Carquinez Strait north of San Francisco (completed in 2008)
- Cast-in-place box girder
  - 82 ft wide deck
  - 658 ft max. spans
- LWC was used for the entire segmental box girder cross-section
  - LWC used for full length of 6500 ft bridge except for pier segments
  - Reduced seismic forces, foundations & cost
- If research on LWC ductility now completed was available at design, the bridge would probably have used LWC from the top of footing

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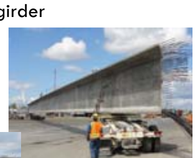
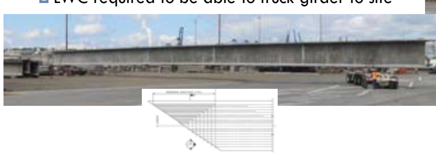
Portland Ave/Puyallup River - Tacoma, WA

- New US record for the longest single piece PS girder
  - 223 ft long – plus severe skews (add 7 ft)
  - WF100G Mod – 8'-4" tall; 5'-1" wide top flange
  - Same LWC mix as I-5 over the Skagit River
  - LWC required to be able to truck girder to site





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Internal Curing of Concrete with LWA

Replace a portion of the conventional sand in a concrete mixture with prewetted LWA to deliver curing water to the interior of concrete

- Reduces shrinkage and cracking
- Reduces permeability through better hydration of cement
- Slightly reduces density
- Does not affect w/cm since water comes out after concrete has set

NYS DOT now requires the use of internal curing for decks on continuous multi-span bridges because of success in using it

- Also reduce wet curing from 14 days to 7 days with internal curing

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Internal Curing of Concrete with LWA

Example of internal curing in the field

Test pour for 10Mgal water storage tank - Highlands Ranch, CO

- Internal Curing vs. No Internal Curing
- Concrete placed at 92 deg F air temp. & 20% RH
- No conventional curing of any type was applied

Surface still moist

Surface is dry

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ESCSI Resources - www.escsi.org

The ESCSI website has a section for Structural Applications

- Many references and reports are available here – all that are posted are available free of charge
- A few resources require purchase from the publishing organization.
- Check out these webpages for Structural Applications:
  - Technical Docs: www.escsi.org/structural-lightweight-concrete/technical-docs/
  - Latest Papers: www.escsi.org/structural-lightweight-concrete/latest-papers/

Website also has a "Find a Producer" tab to allow you to find LWA producers that supply your area

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ESCSI Resources - www.escsi.org

Manuals & Specifications

- *ESCSI Reference Manual for the Properties and Applications of Expanded Shale, Clay and Slate Lightweight Aggregate*
  - Comprehensive document on production, properties and use of ESCS LWA for the wide range of applications
- *Guide Specification for Structural Lightweight Concrete (2001)*
- *Guide Specifications for Internally Cured Concrete (2012)*

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ESCSI Resources - www.escsi.org

References – Selected titles shown

- *Cracking Tendency of Lightweight Concrete (2010)*
  - Report on testing three types of LWC using three types of LWA for a typical bridge deck mix
- *Effect of Lightweight Aggregate on Early-Age Cracking of Mass Concrete (2017)*
  - Report on tests of LWC to demonstrate reduction in cracking potential for mass concrete
- *Specified Density Concrete, (2005)*
  - Paper describing benefits of using a specified density concrete rather than the usual definitions of LWC based on constituents

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ESCSI Resources - www.escsi.org

Training

A series of courses on internal curing presented by Dr. Jason Weiss of Oregon State Univ. in 2013 are available free of charge

- *Module 1: Improving the Performance of Concrete with Internal Curing*
- *Module 2: Internal Curing Concept, Proportioning and Aggregate*
- *Module 3: Internal Curing Shrinkage and Shrinkage Cracking*
- *Module 4: Internal Curing Mechanical and Transport Properties*
- *Module 5: Improving Sustainability with Internal Curing*

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ESCSI Resources - www.escsi.org

Training

Four videos demonstrating test methods and field production procedures for internally cured concrete are available free of charge

- *Centrifuge Test for Internal Curing Lightweight Aggregate*
- *Internally Cured Concrete Part One: Lightweight Aggregate Preparation, Moisture Testing and Mix Design*
- *Internally Cured Concrete Part Two: Plant Charging and Batching Considerations*
- *Determining the Moisture Content of Lightweight Aggregate Using the Towel Dry Method*

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ESCSI Resources - www.escsi.org

Training

A video that demonstrates proper test procedures for the Volumetric Air Meter is available free of charge

- *ASTM C173 Volumetric Air Meter Test Video*

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ESCSI Resources – Lightweight Design eNews

Newsletter

Lightweight Design eNews is an electronic newsletter that provides article on recent projects that have used LWA or LWC

Most issues include at least one article related to bridges

Free subscription is available by using the “Quick Link” at the bottom of any page on the website, and select “Lightweight Design eNews”

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ESCSI Resources - www.escsi.org

- Additional papers, reports, and promotional info are available on website
- Presentations from some past workshops are also available
- Recent publications on LWC include:
  - Service life extension with LWC
  - Reduced cracking in mass concrete
  - Mitigation of ASR
  - Internal curing of concrete with prewetted LWA
- Upcoming publications on LWC include:
  - LWC Primer for Bridges - FHWA

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The Expanded Shale, Clay and Slate Institute (ESCSI)

QUESTIONS?

Reid W. Castrodale, PhD, PE
Director of Engineering – ESCSI

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The Silica Fume Association (SFA)

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Jim Wolsiefer
Presented by Reid W. Castrodale, PhD, PE

www.silicafume.org

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F. Sanchez, K. Sobolev / Construction and Building Materials 24 (2010) 2060–2071

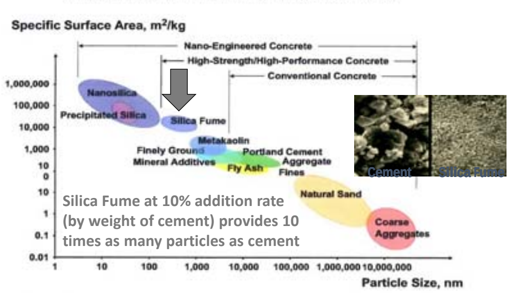

Fig. 4. Particle size and specific surface area related to concrete materials. Adapted from [108].

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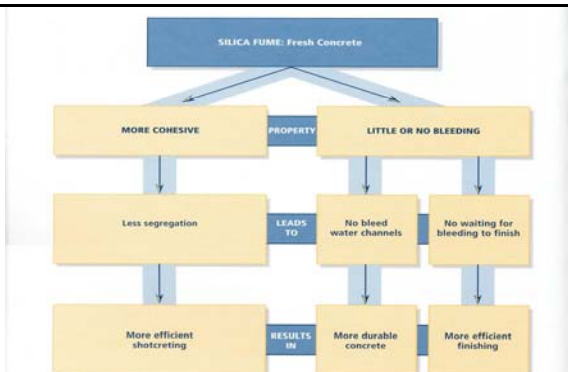

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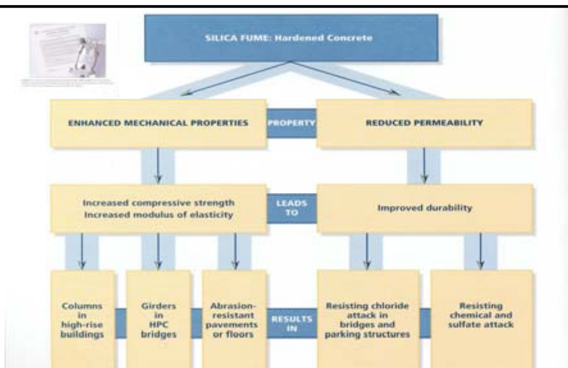

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Supplementary Cementitious Materials (SCM) that are also Recovered Mineral Components (RMC)

In 2008, the U.S. Environmental Protection Agency (EPA) designated concrete containing RMC as meeting the requirements of the Resource Conservation and Recovery Act (RCRA).

Silica fume
A very fine, dust-like material generated during alloyed metal production. Concrete additive used to increase strength and durability.

Coal combustion fly ash
A finely-divided mineral residue resulting from the combustion of ground or powdered coal in coal-fired power plants. Replacement for cement in concrete applications.

Slag cement
A ferrous slag, produced during the production of iron, as a result of removing impurities from iron ore. Quick quenching (chilling) of molten slag yields glassy, granular product. If finely ground and mixed with free lime, slag cement can be used as cement replacement.

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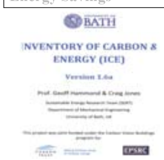
RMC Environmental Impact & Energy Savings

Recovered Mineral Component	Fly Ash	Slag Cement	Silica Fume
	per pound:		
Avoided CO2 Emissions	**0.318 lbs**	**0.304 lbs**	**0.318 lbs**
Energy Savings	**$ 0.059**	**$ 0.053**	**$ 0.411**
	per kilogram:		
Avoided CO2 Emissions	0.70 kg	0.67 kg	0.70 kg
Energy Savings	$ 0.129	$ 0.116	$ 0.905



Carbon Footprint / per metric ton

Portland Cement	Slag Cement	Fly Ash	Silica Fume
959 kg	155 kg	93 kg	14 kg

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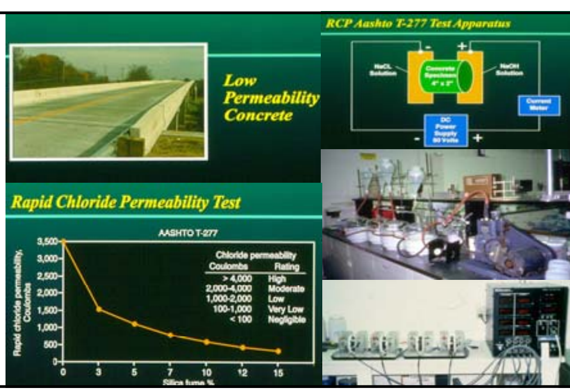

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Sustainability

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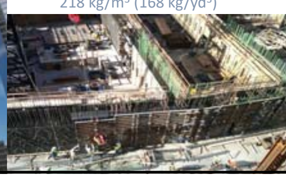
World Trade Center, NYC

Total Binder Content
518 kg/m³ (873 lbs/yd³)

55% Slag Cement / 3% Silica Fume
7% Fly Ash / 35% Portland Cement

16,160 psi (111MPa) @ 56 days
binder efficiency = 18.5 psi/lb

Carbon Footprint :
218 kg/m³ (168 kg/yd³)



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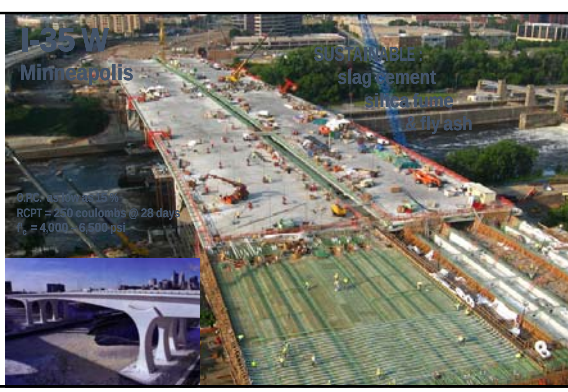

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Panama Canal 100 year design life

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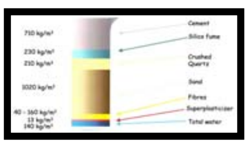
Ultra High Performance Concrete



Density	2500 kg/m 3
Compressive strength	150 - 180 MPa
Bending strength	32 MPa
Tensile strength	8 MPa
Young modulus	50 000 MPa
Poisson ratio	0.2
Shrinkage	0
Creep factor	0.15 - 0.3
Resistance to fatigue	> 10 millions cycles
Thermal expansion coefficient	12.10^{-6} m/m

Chlorine ion diffusion (AASHTOO T259)	2.10^{-14} m²
Carbonation (CEN standard)	nil
Gas permeability (Nitrogen)	$1.5\ 10^{-20}$ m²
Freeze thaw resistance (Young modulus after 300 cycles	100 %
Abrasion resistance (CNR test index)	1.1
Water porosity	1.9%
Tritium water diffusion	10^{-5} cm²/day

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The Silica Fume Association (SFA)

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Jim Wolsiefer
Presented by Reid W. Castrodale, PhD, PE

www.silicafume.org

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NCBC National Concrete Bridge Council

Brian Killingsworth, P.E.
Executive Vice President
National Ready Mixed Concrete Association
bkillingsworth@nrmca.org

1

What are we talking about?

- Plant/Truck Certification and Personnel Accreditations
- Concrete Materials & Innovations
- Material Disclosures and Life Cycle Thinking
- Resiliency

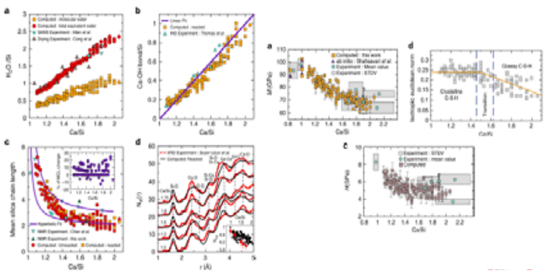
2

National Ready Mixed Concrete Association

- Founded in 1930
- Represent the Ready Mixed Concrete Industry Through Activities:
  - Promotion
  - Education
  - Advocacy
  - Regulatory
  - Engineering
  - Safety, Operations, and Environmental
  - Work Force Development
- State Associations in All 50 States
- Represents Equipment Manufacturers Through Mixer and Truck Bureaus

3

Concrete, It's Really Quite Simple…



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Certification Encouraged For Agencies & Suppliers

NRMCA Personnel Certifications:

- Concrete Exterior Flatwork Finisher Program
- Certified Concrete Sales Professional (CCSP)
- Certified Sustainability Professional
- Concrete Delivery Professional Certification
- Concrete Field Testing Technician Grade II
- Concrete Green Building Certification
- Concrete Sustainability Professional Certification
- Concrete Technologist Level 2 "Technical Short Course"
- Concrete Technologist Level 3
- Concrete Technologist Level 4 "Durability Course"
- Effective RMC Supervisor Certification
- Environmental Professional Certification for the Ready Mixed Concrete Industry
- Fleet Manager Certification
- NRMCA Safety Certification
- OSHA 10-Hour Safety Certification for General Industry
- Pervious Contractor Certification
- Plant Manager Certification
- Sales Manager Certification

NRMCA Plant Certifications:

- Quality: Plant and Truck Certification and/or Quality Certification Program
- Environmental Stewardship: Green-Star Certification Program
- Sustainability: Sustainable Concrete Plant Certification

Testing Agency Qualifications (ASTM and AASHTO):

- ASTM C1077 and ASTM E329 for Quality Assurance Testing
- Concrete Mixture Design: CCRL AASHTO Accreditation Program (AAP)

Testing Personnel Certifications:

- Field: ACI Concrete Field Testing Technician Grade 1 (according to ACI CP-1)
- Laboratory Technician: ACI certified Concrete Strength Testing Technician or Concrete Laboratory Testing Technician - Level I
- Laboratory Supervisor: ACI certified Concrete Laboratory Testing Technician - Level II

NRMCA Product Certifications:

- NRMCA Certified Environmental Product Declaration

5

NRMCA Resources

- User's Guide to ASTM Specification C94
- Plant Inspector Guide & Qualification
- Improving Concrete Quality
- Guide to Improving Specifications for Ready Mixed Concrete
- Online Safety Series

6

In Practice Series

Concrete in Practice Series (CIP)
- Dusting Concrete Surfaces
- Scaling Concrete Surfaces
- Crazing Concrete Surfaces
- Cracking Concrete Surfaces
- Plastic Shrinkage Cracking
- Joints in Concrete Slabs on Grade
- Cracks in Residential Basement Walls
- Discrepancies in Yield
- Low Concrete Cylinder Strength
- Strength of In-Place Concrete
- Curing In-Place Concrete

Concrete in Practice Series (CIP)
- Hot Weather Concreting
- Blisters on Concrete Slabs
- Finishing Concrete Flatwork
- Chemical Admixtures for Concrete
- Flexural Strength of Concrete
- Flowable Fill
- Radon Resistant Buildings
- Curling of Concrete Slabs
- Delamination of Troweled Concrete Surfaces
- Loss of Air Content in Pumped Concrete
- Grout

Concrete in Practice Series (CIP)
- Discoloration
- Synthetic Fibers for Concrete
- Corrosion of Steel in Concrete
- Jobsite Addition of Water
- Cold Weather Concreting
- Concrete Slab Moisture
- Vapor Retarders Under Slabs on Grade
- Supplementary Cementitious Materials
- Ordering Ready Mixed Concrete
- Concrete Pre-Construction Conference
- High Strength Concrete

Concrete in Practice Series (CIP)
- Making Concrete Cylinders in the Field
- Testing Compressive Strength of Concrete
- Structural Lightweight Concrete
- Self-Consolidating Concrete (SCC)
- Pervious Concrete
- Maturity Methods to Estimate Concrete Strength
- Aggregate Popouts
- Acceptance Testing of Concrete
- Thermal Cracking of Concrete
- Alkali Aggregate Reactions (AAR)
- Durability Requirements for Concrete

- Available in English and Spanish
- Digital Copies are Free
- Printed Copies for Purchase

7

In Practice Series

Technology in Practice Series (TIP)
- Quantifying Concrete Quality
- Aggregate Sampling for Laboratory Tests
- Aggregate Sample Reduction for Laboratory Tests
- Capping Cylindrical Concrete Specimens with Sulfur Mortars and Unbonded Caps
- Aggregate Moisture and Making Adjustments to Concrete Mixtures
- Creating and Using Three Point Curves for Laboratory Trial Batches
- Concrete Yield
- Density of Structural Lightweight Concrete
- Mixing Water Quality for Concrete
- Testing Concrete Cores
- Slump Loss of Concrete

Technology in Practice Series (TIP)
- Chloride Limits in Concrete
- Time of Setting of Concrete Mixtures
- Estimating Concrete Strength Using Maturity
- Evaluating Strength Test Results
- Drying Shrinkage of Concrete
- Managing Concrete Temperature for Specified Requirements
- Reuse of Returned Concrete
- Understanding Variability of Test Methods—Precision Statements

Specification in Practice (SIP)
- Limits on Quantity of Supplementary Cementitious Materials
- Limits on Water-Cementitious Materials Ratio (w/cm)
- Minimum Cementitious Materials Content
- Restrictions on Type and Characteristics of Fly Ash
- Restrictions on Aggregate Grading

- Digital Copies are Free
- Printed Copies for Purchase

8

Cement and Concrete Innovations

- Limestone cements – ASTM C595 or AASHTO M 240 - Type IL (5-15% interground limestone):
  - Manufactured for equivalent performance to ASTM C150 cements
- Natural pozzolans and ground glass pozzolans
- Mineral fillers – ASTM C1797 (ground calcium carbonate or aggregate mineral fillers)
- Workability retaining admixtures
- Crack reducing admixtures (besides shrinkage reducing)
- Nano-carbon fibers for improved durability (likely expensive)
- Integral water proofing admixtures for reduced permeability
- Latex Modified Concrete-Very Early Strength (w/sulfoaluminate cements - SAC):
  - e.g. bridge deck overlays reaching 3,500 psi in 24 hr
- Technology for consistent fresh properties:
  - in-transit water and admix adjustments
  - real time air monitoring

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Self-Cleaning Concrete

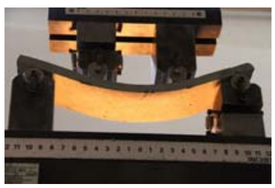
- Concrete made with titanium dioxide (TiO_2) cement
- TiO_2 breaks down harmful pollutants
- Reaction catalyzed by light…photocatalysis
- Intended for projects in urban centers
  - e.g. Nitrous dioxide (NO_2) produced by burning fuels in cars and trucks.
  - Responsible for acid rain, smog, respiratory problems and staining
  - Reaction with sunlight converts NO_2 to NO_3
  - A harmless salt which is dissolved by water

Courtesy of Lehigh Hanson

10

Bendable Concrete

- Developed by Dr. Victor C. Li of the University of Michigan
- 300-500 times more tensile strain capacity than normal concrete
- Tiny fibers disbursed throughout
- Can absorb greater quantities of energy without being damaged
- Applications
  - Paved surfaces with repeated loading of heavy vehicles
  - Viaduct dampers
  - Earthquake resistance in tall buildings
- Self-healing capabilities
  - Keeps cracks relatively small
  - Natural reactions through carbon mineralization
  - Repairs the cracks and restores the durability
- Has been commercialized



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Ultra High Performance Concrete (UHPC)

- Manufacturer distributes the premix powder, fibers and admixtures to partners
- Can use high carbon metallic fibers, stainless fibers, poly-vinyl alcohol (PVA) fibers or glass fibers
- Improves strength and ductility
- Less porous than conventional concrete
- More resistant to chlorides, acids, and sulfates
- Has self-healing properties

NM 186 crossing the La Union Canal in Anthony, New Mexico
Courtesy of New Mexico State University

Courtesy of LafargeHolcim/Ductal®

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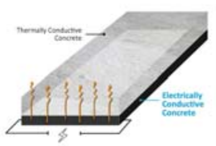
Graphene Concrete

- Graphene is single layer of carbon atoms
- Tightly bound in a hexagonal honeycomb lattice
- Layers of form graphite, naturally occurring, crystalline form of carbon
- Commonly used in pencils and lubricants
- Graphene is the thinnest, lightest and strongest compound discovered
- Over 100 times stronger than steel
- Graphene concrete is made with flakes of graphene
- Inexpensive, compatible with large scale manufacturing
- Improves strength and permeability
- Requires less cement to make concrete
- Electrically conductive
  - Underfloor heating
  - Clearing ice and snow from pavements
- Not yet commercialized



NRMCA NCBC

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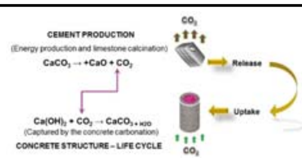
Carbon Capture



- Like most manufactured materials
- Concrete is a carbon dioxide (CO_2) emitter
- Mainly due to the cement manufacturing process
- Carbonation: carbon dioxide (CO_2) penetrates the surface of hardened concrete and chemically reacts with cement hydration products to form carbonates
- For in-service concrete, slow process
- Given enough time and ideal conditions
  - all of the CO_2 emitted from calcination could be sequestered via carbonation.
  - Real world conditions are usually far from ideal
  - Estimates cumulative CO2 sequestered in concrete is 4.5 Gt 1930-2013[1]
  - 43% of the CO2 emissions from production of cement

Carbonation depends on:

- Exposure to air
- Surface orientation
- Surface-to-volume ratio
- Binder constituents
- Surface treatment
- Porosity
- Strength
- Humidity
- Temperature
- Ambient CO_2 concentration

[1] "Substantial Global Carbon Uptake by Cement Carbonation," Nature Geoscience

NRMCA NCBC

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Enhanced Carbonation

- Inject CO_2 into concrete
- Creates artificial limestone CO_2
- Sequesters small amount of CO_2
- Enhances compressive strength
- Reduces cement content

Courtesy of CarbonCure

NRMCA NCBC

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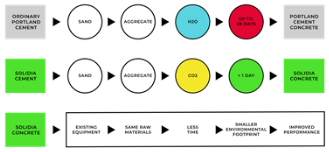
Enhanced Carbonation

- Specially formulated cement
- Primarily in the precast concrete products industry
- About the same cost as portland cement
- Significantly reduces CO_2 emissions through reduced production energy
- Uses less limestone, fired at lower temperatures
- Produces 30% less greenhouse gases
- Concrete cures in contact with a CO_2 atmosphere in curing chamber under pressure
- Sequesters CO_2 equal to 5% of its weight
- Claims concrete's carbon footprint is reduced by 70%.



Courtesy Solidia Technologies

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Enhanced Carbonation

- Another company combines industrial CO_2 emissions with metal oxides
- CO_2 sequestered construction aggregate (limestone)
- 44% by mass permanently sequestered CO_2
- Substrate is small rock particles or recycled concrete
- Carbon-negative concrete is achievable
  - One cubic yard of concrete contains 3,000 pounds of aggregate
  - 44% comprised of sequestered CO_2, roughly 1,320 pounds
  - Offsets more than the amount of CO_2 produced by cement
  - Roughly 600 pounds per cubic yard
- Used on Interim terminal at San Francisco International Airport
- Concrete met all necessary specifications

Courtesy of Blue Planet

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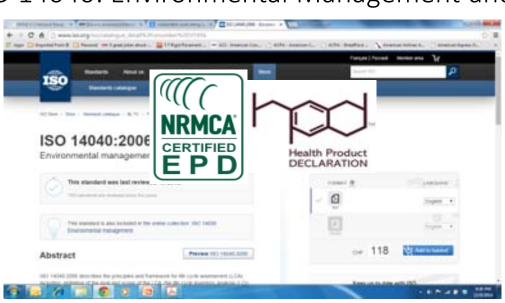
ISO 14040: Environmental Management and LCA



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Material Disclosures (Cradle to Gate)

Life Cycle Impact Results (per m³)

OPERATIONAL IMPACTS (per m³)	Residential Concrete
Plant Operating Energy Consumption (MJ)	15.8
On-Site Plant Fuel Consumption (MJ)	172.9
Concrete Batch Water (m³)	1.94E-01
Vehicle and Equipment Wash Water (m³)	6.2E-01
On-Site Waste Disposed (kg)	0.68
ENVIRONMENTAL IMPACTS	
Total Primary Energy (MJ)	3,136
Climate Change (kg CO_2 eq)	364
Ozone Depletion (kg CFC11 eq)	1.34E-08
Acidification Air (kg SO_2 eq)	2.41
Eutrophication Air (kg N eq)	5.55
Photochemical Ozone Creation (kg O3 eq)	1.14

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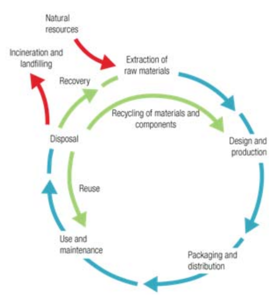
Life Cycle Thinking (LCT)



Life Cycle Initiative

The main goals of LCT are to reduce a product's resource use and emissions to the environment as well as improve its socio-economic performance through its life cycle.

Economic = Life Cycle Cost Analysis
Environment = Life Cycle Assessment

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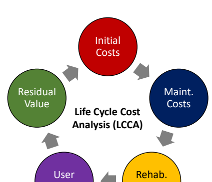
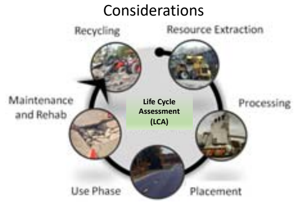
Life Cycle Thinking (LCCA/LCA)



Economic Considerations

Environmental Considerations



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Resiliency

https://informedinfrastructure.com/16469/dot-helps-states-local-communities-improve-transportation-resilience/

http://www.planhillsborough.org/resilient-tampa-bay-transportation/

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Thank You

Brian Killingsworth, P.E.
Executive Vice President
National Ready Mixed Concrete Association

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Overview

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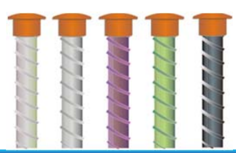
CRSI Concrete Reinforcing Steel Institute

1

CRSI Concrete Reinforcing Steel Institute

Founded in 1924, the Concrete Reinforcing Steel Institute (CRSI) is a technical institute and Standards Developing Organization (SDO) that stands as the authoritative resource for information related to steel reinforced concrete construction. CRSI offers many industry-trusted technical publications, standards documents, design aids, reference materials, and educational opportunities.

CRSI members include manufacturers, fabricators, material suppliers, and placers of steel reinforcing bars and related products as well as professionals who are involved in the research, design, and construction of steel reinforced concrete structures and bridges.



2

Resources

- Case Studies
- Design Guides
- Detailing Supplements
- Engineering Data Reports
- Research Reports
- Standard Documents
- Technical Notes

3

Manual of Standard Practice

- Recommended industry practices for estimating, detailing, fabricating, and placing reinforcing steel for reinforced concrete construction
- Includes suggested specifications for reinforcing steel

CRSI Concrete Reinforcing Steel Institute

4

Research

- Use of High Strength Steel (Grades 80 & 100)
- Evaluation of End Anchors and Hooks
- Anchorages and Splices
- Harmonization of ASTM 615 and A706

CRSI Concrete Reinforcing Steel Institute

5

Standards

- CRSI RB4.1 - Supports for Reinforcement Used in Concrete (2016)
- CRSI CG1.1 - Epoxy Coating Plant: Straight Bar Lines (2016)
- CRSI CG1.2 - Epoxy-Coated Facilities: Custom Lines (2016)
- CRSI CG2.1 - Epoxy-Coated Steel Reinforcing Bar Fabrication Facilities (2016)
- CRSI IPG4.1 - Stainless Steel Reinforcing Bar Fabrication Facilities (2016)

https://www.crsi.org/index.cfm/standards/standards_docs

CRSI Concrete Reinforcing Steel Institute

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e-Learning

On-Demand Webinars

High-Strength Steel Reinforcement

www.crsi.org

Interactive Courses

Steel Reinforced Concrete: Essentials

CRSI Concrete Reinforcing Steel Institute

7

Overview

Peter Fosnough
Managing Director
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Schaumburg, IL 60173
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630-380-5876

EIG CRSI EPOXY INTEREST GROUP

CRSI Concrete Reinforcing Steel Institute

8

What is EIG?

EIG CRSI EPOXY INTEREST GROUP

In 1991, CRSI initiated a Certified Plant Program for epoxy-coated bar producers and today there are 35 certified coating plants.

In March 2008, a new group was formed within CRSI. The Epoxy Interest Group (EIG) of CRSI operates within the charter of CRSI to promote and market epoxy-coated bars and is able to create awareness and interest in epoxy coated reinforcing steel (rebar) and its important benefits for DOT's, engineering specifiers and contractors.

The Epoxy Interest Group consists of 17 companies operating 28 coating operations and 5 powder manufacturing plants in North America.

CRSI Concrete Reinforcing Steel Institute

9

Advantages of Greenbar

EIG EPOXY INTEREST GROUP

- Optimum corrosion protection
- Strong cathodic disbanding resistance
- Maximum flexibility for fabrication
- Designed for application on fast production lines
- Proven barrier to de-icing salts and chlorides

Meets or Exceeds:

ASTM A775
AASHTO M284
ASTM A884
AASHTO M254 for dowel bar
FHWA

www.epoxyinterestgroup.org

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Resources

EIG EPOXY INTEREST GROUP

- Publications
- Presentations
- Papers
- Research Reports
- Industry Practices
- Videos

www.epoxyinterestgroup.org

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Research

EIG EPOXY INTEREST GROUP

- Comparative Laboratory Study of Metallic Reinforcing Steel for Corrosion Protect (FHWA-HRT-15-078) - SK Lee
- Laboratory Evaluation of Corrosion Resistance of Various Metallic Dowel Bars (FHWA-HRT-15-079) – SK Lee
- Hot Dip (A767) vs Continuous Galvanized (A1094)

www.epoxyinterestgroup.org

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Research

- New Epoxy Technologies
  - Abrasion Resistant Coat
  - Dual-Coated (A1055)
  - Textured Coat
  - Self-Healing

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Dual Coat

- Greenbar+ powder designed for improved adhesion over Continuous Galvanized Rebar
- ASTM A1055 testing in Progress
- No change in IR signature; readily acceptable by DOTs owing to credibility of Greenbar (base formula)
- Ready plug-in on customer lines, same application
- Prof. Castaneda's (Texas A&M) research shows Epoxy over CGR is better than Stainless on several corrosion performance tests and will result in longer lifespan of the infrastructure project.

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Textured Coat

- High Performance Roughcoat powder for improved mechanical adhesion to concrete
- Exhibits superior damage tolerance, reduced microcracking & extends bridge life
- Significant possible code advantages in seismic and commercial building zones
- Reduced steel congestion for bridge piers and commercial buildings in high $/sq.ft.
- Increased traction of workers during installation, reducing workplace injuries
- Collaboration with several DOTs & Universities for independent evaluation

www.epoxyinterestgroup.org

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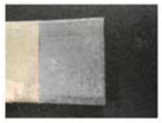
Textured Coat

EIG EPOXY INTEREST GROUP

Concrete failure mode

Textured Rebar pulled from concrete



Smooth (uncoated) bar pulled from concrete

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Questions?

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POST-TENSIONING CONTRIBUTIONS TO ACCELERATED BRIDGE CONSTRUCTION

Tony Johnson, P.E.
Executive Director
Post-Tensioning Institute

PTI POST-TENSIONING INSTITUTE ®

1

BRIDGES NEED POST-TENSIONING

PTI POST-TENSIONING INSTITUTE ®

2

PRECAST SPLICED GIRDERS – EFFICIENCY GAINED BY CONTINUITY ENABLED BY POST-TENSIONING

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3

SUCCESSFUL PROJECT SPECIFICATIONS & TRAINING

- Materials (Specifications)
  - Selection of materials
  - Qualification testing
  - Conformance testing
  - QA, QC
  - Inspection
- Execution (Specifications and Training)
  - Materials handling
  - Installation
  - Knowledgeable workforce
  - Inspection
- Both Required for a Successful Project
  - Follow PTI specifications
  - Insist on Field Personnel Training

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4

M50.3 AND M55.1 SPECIFICATIONS FOR POST-TENSIONING

- PTI/ASBI M50.3-19, Specification for Multistrand and Grouted Post-Tensioning
- PTI M55.1-19, Specification for Grouting of Post-Tensioned Structures
- State-of-the-Art Post-Tensioning Specifications

- Industry stakeholders
- ANSI Consensus process including public review
- Set of rules for the contractor
- Materials
- Testing
- Installation
- Stressing
- Grouting
- Post-grouting inspection

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M50.3 AND M55.1 SPECIFICATIONS FOR POST-TENSIONING

- Specification (mandatory)
  - Minimum requirements
  - Based on proven knowledge
- Commentary (guidance)
  - Additional explanations and guidance
- Applicability
  - Any project with post-tensioning
- Comprehensive
  - Acceptance for Post-Tensioning Systems
  - Details and installation methods for multistrand and grouted PT

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STAKEHOLDER CONSENSUS AND BALANCE OF INTEREST:
OWNERS (FHWA, STATE DOTS), DESIGNERS, RESEARCHERS, CONTRACTORS, SUPPLIERS

7

TENDON PROTECTION LEVELS (PL) *

Four levels of increasing protection:

- **Protection Level 1A (PL-1A):** Basic – providing durable corrosion protection
- **Protection Level 1B (PL-1B)**: PL-1A plus engineered grout & permanent grout caps
- **Protection Level 2 (PL-2):** PL-1B plus airtight envelope
- **Protection Level 3 (PL-3):** PL-2 plus monitorable / inspectable at any time

* Unified approach from the PTI/ASBI M50.3-19 Specification for Multistrand & Grouted Post-Tensioning

8

PL-1A

PERFORMANCE REQUIREMENTS*:

- Galvanized duct
- Basic grout Class A
- Temporary grout caps

* Performance requirements per PTI/ASBI M50.3-19 and PTI M55.1-19

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PL-1B

PERFORMANCE REQUIREMENTS*:

- All of PL-1A's requirements, plus:
- Permanent grout caps
- Engineered grout Class B

* Performance requirements per PTI/ASBI M50.3-19 and PTI M55.1-19

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PL-2

PERFORMANCE REQUIREMENTS*:

- All of PL-1B's requirements, plus:
- Permanent grout caps
- Galvanized or epoxy coated bearing plates
- Plastic duct
- Precast segmental duct couplers
- Engineered grout Class C or D

* Performance requirements per PTI/ASBI M50.3-19 and PTI M55.1-19

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PL-3

PERFORMANCE REQUIREMENTS*:

- All of PL-2's requirements, plus:
- Electrically isolated tendons (EIT)
- Monitorable or inspectable

* Performance requirements per PTI/ASBI M50.3-19 and PTI M55.1-19

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WHY TO USE M50.3 AND M55.1 SPECIFICATIONS FOR POST-TENSIONING?

- Uniform Standards
- Use in its entirety
- No need for modifications/exceptions
- Reduces/eliminates unnecessary differences in requirements, and potential for errors/misunderstanding
- Avoids provisions out of context or “holes” when aspects not covered
- Consistency and standardization; allows focus on proper execution
- Example: TXDOT full adoption of M50.3 and M55.1, with minor exceptions

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PTI/ASBI M50.3-19, SPECIFICATION FOR MULTISTRAND AND GROUTED POST-TENSIONING

- First Edition published in 2012
- Second Edition – **September 2019**

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PTI/ASBI M50.3-19, SPECIFICATION FOR MULTISTRAND AND GROUTED POST-TENSIONING GOALS & BENEFITS FOR STAKEHOLDERS

- Minimum Standard
- Performance Levels – Durability Goals
- Design and Testing Requirements for PTS
- Technically Sound Methods
- Grouting materials, testing, and procedures referred to PTI M55.1 Specification
- Reduction or elimination of unnecessary differences in requirements – Reduces potential confusion
- Proven best practice procedures
- Specification allows for different protection levels (PLs)
- Significant simplification of PTS prequalification

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PERSONNEL QUALIFICATIONS – CERTIFICATION

- Direct Supervisor
  - PTI Level 2 Multistrand & Grouted PT Specialist
- Foreman of Installation and Stressing Crew
  - PTI Level 2 Multistrand & Grouted PT Specialist
- Foreman of Grouting Crew
  - PTI Level 2 Multistrand & Grouted PT Specialist and
  - ASBI Grouting Technician
- Crew (at Least 25%)
  - PTI Level 1 Multistrand & Grouted PT Installation

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M50.3 SPECIFICATION, SUMMARY OF MAJOR MODIFICATIONS IN 2019

- Addition of Commentary
  - Additional guidance for most provisions
- Tendon Protection Level (PL)
  - Guidance on selection of PTs
- PTS components
  - Detailed guidance for component specification and testing
- Materials and Testing
  - Example: PT duct specifications per *fib* Bulletin 7 or Bulletin 75
- Grouting related items
  - Grout vents and other grouting related items needed during tendon installation moved from M55.1 here (grout inlets and outlets)

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M50.3 SPECIFICATION, FUTURE OUTLOOK – NEW BUSINESS ITEMS

- Tendon Protection Level, PL-3
  - Options when appropriate
- **Replaceable Tendons**
  - FHWA Draft
  - Diabolos at deviators
  - Duct inserts at anchorages for replaceability
  - Design of space at anchorages for access
  - Drafting and balloting in M-50
  - For external tendons
- **Electrically Isolated Tendons, EIT**
  - FHWA Draft
  - International PT Technology Exchange
  - Study Group to Italy and Switzerland in May 2019
  - Final meeting in May 2020 – Final Report
  - Final drafting and balloting in M-50
  - Augmented quality of installation
  - Isolation effectiveness tested after completion
  - Monitoring in intervals available

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PTI M55.1-19, SPECIFICATION FOR GROUTING OF POST-TENSIONED STRUCTURES

- First Edition published in 2001
- Second Edition 2003
- Third Edition 2012; w. Addendum 2013
- Fourth Edition – **September 2019**

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PTI M55.1-19, SPECIFICATION FOR GROUTING OF POST-TENSIONED STRUCTURES

- Comprehensive Grouting Specification
  - Grout Plan
  - Grout materials
  - Engineered grout
  - Testing for QC and QA
  - Lab testing
  - Field trial testing
  - Mock up testing
  - Production testing
  - Grouting procedures
  - Contingencies

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PTI M55.1-19, SPECIFICATION FOR GROUTING OF POST-TENSIONED STRUCTURES

- Standard for the Materials Used for Grouting of Post-Tensioning Tendons
  - Standard for All Classes of Post-Tensioning Grout Materials related to the Protection Levels of the PTS
  - Design and Qualification Testing Requirements for Post-Tensioning Grout Materials
- Standards for Grouting Procedures of Post-Tensioning Systems
  - Mixing and Pumping Procedures to Ensure Quality Workmanship
  - Production Testing of Grout to Ensure the Durability Goals Will be Achieved
  - Post Grouting Inspection Methods

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M55.1 SPECIFICATION, SUMMARY OF MAJOR MODIFICATIONS IN 2013

- Chlorides
- Cement Variability
- Bleed/Segregation
- Constituent Materials
- Construction Procedures
- Soft Grout Potential
- Corrosion

- Field testing for acid-soluble chloride ion (Cl-) on the mixed grout once per project and minimum every 40,000 lbs
- Blaine value 300 to 400 m2/kg
- Inclined tube test
- Range also given for the Class C (prepackaged grouts)
- No tendon flushing; grout testing also at outlet; lower pressure
- No aggregates and inert fillers for Classes A, B, and C grouts
- No additional sulfates

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M55.1 SPECIFICATION, SUMMARY OF MAJOR MODIFICATIONS IN 2019

- Weight / Water
- Shelf life of materials
- Corrosive Agents
- Robustness Test
- Testing / Documentation

- Grout material bag weight certification and sampling on site
- Flushing prohibition of tendons further clarified
- New addition / manufacturer' certification
- Sulfate ion level certification
- Chloride ion level content maximum:
  - 0.08% by weight of portland cement
  - 0.03% by weight of mixed grout
- 110% of water, max. and min.
- Wet density test at last outlet of each tendon

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M55.1 SPECIFICATION, FUTURE OUTLOOK – NEW BUSINESS ITEMS

- Inline Density Flowmeter

Flexible Filler

- Inclusion of flexible filler specification in M-50 and/or M-55 specifications

- **PTI Research Project by Dr. Schokker**
  - Completed in early 2019
  - Tested on a segmental bridge in August 2019
  - Flowmeter continuously measures and records:
    - Density
    - Temperature
  - Option 1: Flowmeter installer at the inlet
    - Simple; stays in place
    - No impact on production
    - Allows constant monitoring
  - Option 2: Flowmeter installed at the outlet
    - More complicated – moved from outlet to another
    - Cleaning between tendons – time lag
  - Good correlation between Flowmeter and Mud Ballance
  - Output file exported to Excel and formatted as desired
  - Routine and continuous monitoring of grout density and temperature at the inlet of all tendons possible
  - Documentation available for all tendons

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PTI LEVEL 1&2 MULTISTRAND & GROUTED PT SPECIALIST CERTIFICATION

- Scope
  - PT basics, materials, installation, stressing, and grouting
- Training Duration
  - 3 Days classroom including ½ day field demonstration (with grout testing)
- Exam
  - 60-question written exam (closed book)
- Level 1 Requirements
  - Complete training; pass exam 70%
- Level 2 Requirements
  - Complete training; pass exam 80%; total 1500 hours field work experience (Minimum 250 hours in each, installation, in stressing, and in grouting)
- Renewals
  - Every 4 years; online exam; additional online training; continuing experience for Level 2
- More Information
  - www.post-tensioning.org

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PTI LEVEL 1&2 MULTISTRAND & GROUTED PT SPECIALIST CERTIFICATION

- Comprehensive 3-day class with field demonstration
- Thousands of people certified

- Post-Tensioning (PT) 101
- Tendon Protection Levels (PL)
- PT Systems and Components
- Materials and Testing
- Installation
- Stressing and Safety
- Grout Materials, Prequalification Testing, Production Testing, and Grouting Procedures
- Contract Documents
- Troubleshooting
- Field Demonstration: Grout Testing, Components, Equipment

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PTI LEVEL 1&2 MULTISTRAND & GROUTED PT INSPECTOR CERTIFICATION

- Scope
  - Multistrand and grouted PT Inspector viewpoint
- Training Duration
  - 1 Day classroom: Prerequisite is attendance of the 3-day Specialist training (Level 1 or 2 certification)
- Exam
  - 30-question written exam (closed book)
- Level 1 Requirements
  - Complete training; pass exam 70%
- Level 2 Requirements
  - Complete training; pass exam 80%; total 500 hours field work experience (Minimum 100 hours in each of installation, stressing, and grouting inspection)
- Renewals
  - Every 4 years; online exam; additional online training; and experience for Level 2
- More Information
  - www.post-tensioning.org

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PTI LEVEL 1&2 MULTISTRAND & GROUTED PT INSPECTOR CERTIFICATION

- New Certification Program
- Independent Inspection to ensure compliance with specifications

- Knowledge of post-tensioning – prior certification required
- All aspects of materials and testing, installation, stressing, grouting, post-grouting inspection, finishing, record keeping
- Critical items
- Check points & stop points
- Checklists of inspection items

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PTI DC45.1-18, RECOMMENDATIONS FOR STAY CABLE DESIGN, TESTING, AND INSTALLATION

- **Seventh Edition** – November 2018

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PTI *JOURNAL*

- Published twice a year

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PTI *JOURNAL*

PTI Research

- Inline monitoring of grout density during pumping, Jacob Bray and Andrea Schokker

Fig. 1—Coriolis inline density meter setup.

PTI JOURNAL | July 2019 7

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CONCLUSIONS

- M50 & M55 Specifications
  - Use Standard Specifications to ensure proper materials, testing, and installation
  - M50 & M55 work together for the complete post-tensioning system
- Training of Field Personnel
  - PTI Level 1&2 Multistrand and Grouted PT Specialist Certification
  - ASBI Grouting Technician Certification
  - PTI Level 1&2 Multistrand and Grouted PT Inspector Certification
- Use PTI Resources
  - Other PTI documents and programs

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CONCLUSIONS – NEW ITEMS TO ADVANCE PT CONSTRUCTION ADDED IN 2019

- M50.3 Specifications (New Edition)
  - Added Commentary to most provisions
  - Bulletin 75 also included
  - Updates of some other provisions
- M55.1 Specifications (New Edition)
  - Grout wet density at last tendon outlet
  - Robustness test
  - Water
  - Shelf life
  - Corrosive agents
- Training of Field Personnel
  - New training for Bridge Inspectors

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CONCLUSIONS – NEW ITEMS TO ADVANCE PT CONSTRUCTION TO BE ADDED IN NEAR FUTURE

- **PTI CRT-70 PT System Qualification Testing and Certification**
  - Prequalified PT Systems on PTI website
  - User access permissions
- PTI Quality Management System (QMS)
  - Based on PTI Plant Certification Program
  - ANSI accredited provider
  - Confidentiality; appeal process, etc.
- CRT-70 Administrative Manual
  - Procedures pertaining to the PTS program
  - Independent inspection agency – audits
- CRT-70 Technical Manual
  - Technical requirements and checklists

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Post-Tensioning Contributions to Accelerated Bridge Construction

Thank you for your interest!

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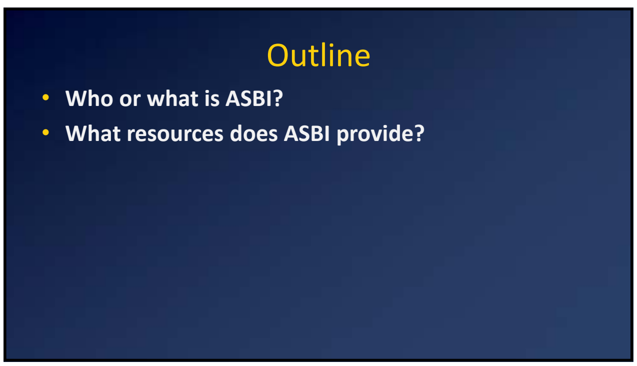
American Segmental Bridge Institute
ASBI
Segmental Bridges
2019 International ABC Convention Workshop
Today's Concrete Bridge Design
December 11, 2019

1


Outline
Who or what is ASBI?
What resources does ASBI provide?

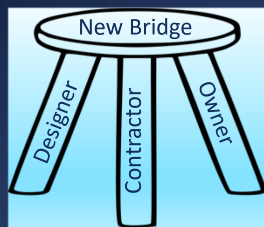
2


What is ASBI?
Incorporated in 1988 as a nonprofit organization to provide a forum where owners, designers, constructors, and suppliers can meet to further advance concrete segmental bridges.
ASBI Founders
The First
CONVENTION
Of The
ASBI
AMERICAN SEGMENTAL BRIDGE INSTITUTE
December 4-5, 1989 at the
OMNI HOTEL
San Diego
American Segmental Bridge Institute

3

Why ASBI?

Segmental is a construction method with design implications.



American Segmental Bridge Institute

4

Mission Statement

ASBI's mission is to advance, promote, and innovate segmental bridging technology; share the knowledge; educate stakeholders; build professional relationships; and increase the value of our infrastructure by providing sustainable solutions.

American Segmental Bridge Institute

5

Promote & Educate

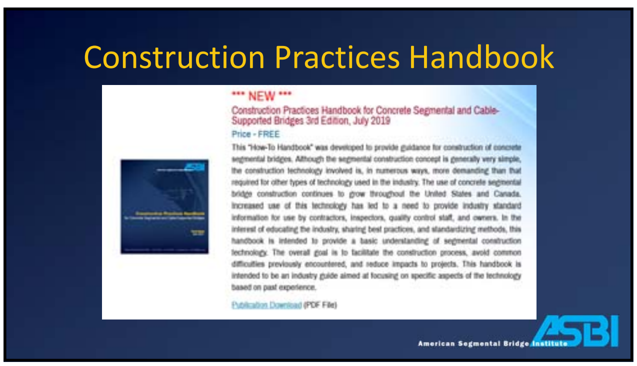
- **Publications**
- **Seminars & Formal Training**
- **Certifications**

American Segmental Bridge Institute

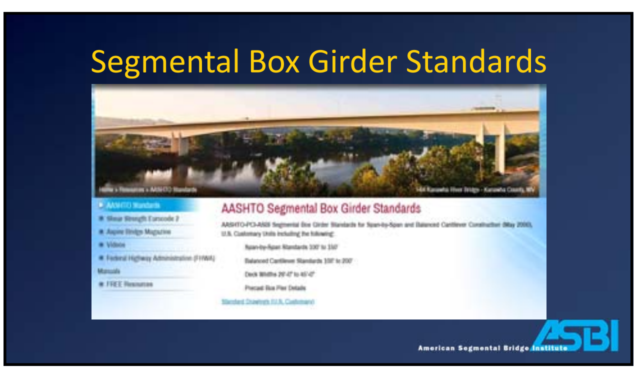
6


What Is ASBI?
American Segmental Bridge Institute

7

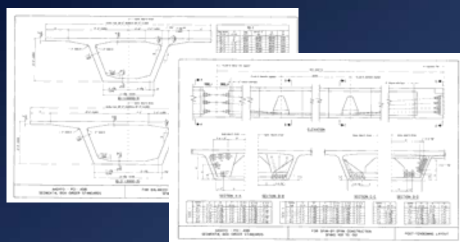

Construction Practices Handbook
*** NEW ***
Construction Practices Handbook for Concrete Segmental and Cable-Supported Bridges 3rd Edition, July 2019
Price - FREE
This "How-To Handbook" was developed to provide guidance for construction of concrete segmental bridges. Although the segmental construction concept is generally very simple, the construction technology involved is, in numerous ways, more demanding than that required for other types of technology used in the industry. The use of concrete segmental bridge construction continues to grow throughout the United States and Canada. Increased use of this technology has led to a need to provide industry standard information for use by contractors, inspectors, quality control staff, and owners. In the interest of educating the industry, sharing best practices, and standardizing methods, this handbook is intended to provide a basic understanding of segmental construction technology. The overall goal is to facilitate the construction process, avoid common difficulties previously encountered, and reduce impacts to projects. This handbook is intended to be an industry guide aimed at focusing on specific aspects of the technology based on past experience.
Publication Download (PDF File)
American Segmental Bridge Institute

8


Segmental Box Girder Standards
AASHTO Segmental Box Girder Standards
American Segmental Bridge Institute

9

Segmental Box Girder Standards



American Segmental Bridge Institute ASBI

10

Segmental Box Girder Standards

- **Developed in cooperation with AASHTO, PCI & ASBI**
- **Provides standard sections for Span-by-Span and Balanced Cantilever Construction**
  - Span-by-Span Standards 100' to 150
  - Balanced Cantilever Standards 100' to 200'
  - Deck Widths 28'-0" to 45'-0"
  - Precast Box Pier Details

Note: Details in Metric units are also available

American Segmental Bridge Institute ASBI

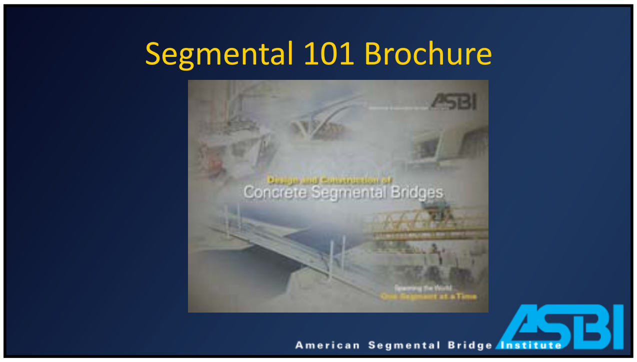
11

Durability Survey of Segmental Concrete Bridges

- The inspection data indicates that these superstructures are performing very well over time, with average condition ratings of 6.9, indicating "good condition" for all segmental bridges reported in the survey.
- Data further indicates that a service life of 100 years for segmental bridges can be expected with proper construction and maintenance

2012 Durability Survey is based on 2011 NBI Data

12


Segmental 101 Brochure
Concrete Segmental Bridges
American Segmental Bridge Institute

13

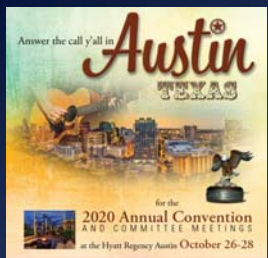

Segments Newsletter
Segments
American Segmental Bridge Institute

14


Project Database
Project Search
American Segmental Bridge Institute

15

Annual Convention



- 300-400 attendees
- Different location each year
- Technical Program
- Networking

American Segmental Bridge Institute ASBI

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Construction Practices Seminar

Who should attend?

- Owners (Free Registration)
- Contractors and Suppliers
- Designers

Planning to host another Seminar in 2020, probably on the West Coast.

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ASBI Grouting Certification Program Purpose

Provide Supervisors and Inspectors of Grouting Operations with the Training Necessary to Understand and Successfully Implement Grouting Specifications for Post-Tensioned Structures

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Purposes of Grouting

- Provide Corrosion Protection to Prestressing Steel
- Develop Structural Bond Between Concrete and Prestressing Steel (Internal Tendons)

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Why Grouting Certification Training?

- Communicate the Importance of Grouting to Long-Term Durability (100 Year + Service Life)
- Ensure That Job Site Grouting Supervisors and Inspectors Fully Understand Grouting Technology
- Provide Assurance to Owners That Grouting is Performed Under the Supervision of Qualified Personnel in Accordance with the Specifications

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ASBI Certified Grouting Technician

- Successfully Complete Training
- Provide 3 Years Experience in Construction of Grouted Post-Tensioned Structures
- Certificate Valid for 5 Years

Note: Per PT M55.1-19, grouting crew foreman must be PTI Level 2 *Multistrand and Grouted PT Specialist* AND hold an ASBI *Grouting Technician Certificate*

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21

ASBI Grouting Training Certificate

- Successfully Complete Training
- Less Than 3 Years Experience in Construction of Grouted Post-Tensioned Structures
- Certificate Valid for 5 Years
  - Obtain 3 Years Experience During This Time
  - Certified Grouting Technician

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Re-Certification

- Required Every 5 Years After Certification
- Online Examination
- Additional 1½ Years Experience Required for Certified Grouting Technician

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Re-Examination

If You Don't Pass the Examination:

- Retake Exam at Next Training Event
- Don't Have to Attend Training Class
- No Registration Fee

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Records

- Participants Records Maintained by ASBI
- Lists of Certificate Holders Available

  Online: www.asbi-assoc.org

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2019 Grouting Certification Training

- 3 Classes Held
  - Alabama - 31 Attendees
    - 1 Technician Certified
  - New Mexico – 16 Attendees
  - Austin – 98 Attendees
    - 7 Technicians Certified
- 36 Re-Certifications in 2019
- 2020 Training in Austin, April 6

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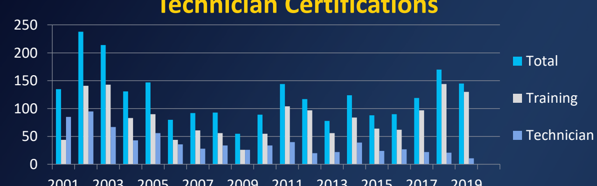
2001 – 2019 Grouting Training and Technician Certifications



Total Attendees – 2349
Total Training Certificates – 1592
Total Technician Certificates – 735

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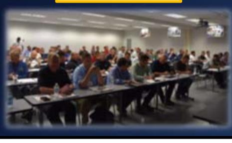
Flexible Filler Training





- August 12-13, 2019
- Tallahassee, FL
- 42 Attendees

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Summary of Available Resources

- Construction Practices Handbook
- Segmental Box Girder Standards
- Durability Survey
- Segmental 101 Brochure

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Summary of Available Training

- Annual Seminar
- Construction Practices Seminar
- Grouting Training & Certification
- Flexible Filler Training

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Questions?
ASBI
American Segmental Bridge Institute

31


ASBI
American Segmental Bridge Institute
Gregg A. Freeby
gfreeby@asbi-assoc.org
512.523.8214

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HOW PRECAST BUILDS

FIU ABC Conference
W-2 Concrete Workshop
Industry News from PCI

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

PCI

1

LEARNING OBJECTIVES

1. Concept of the Body of Knowledge and Training for Plants, QC staff and Auditors
2. Cover a few Transportation Publications. These include Manuals, Recommended Practices and State-of-the-Art reports
3. eLearning for engineers (Free PDH/CEUs)
4. Opportunities to improve and lower the costs of ABC components
5. The future changes including UHPC efforts and why
6. NCBC

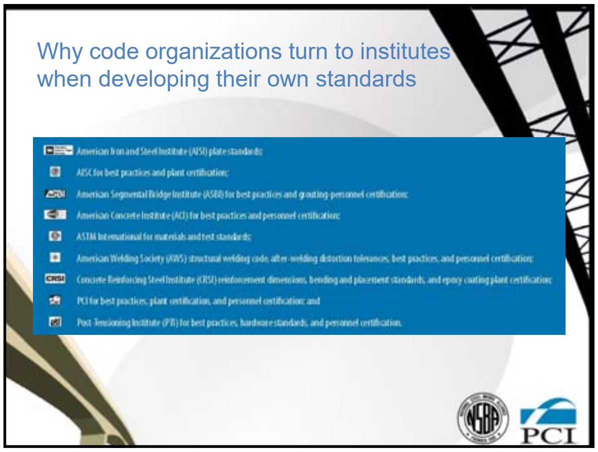
PCI

2

HOW PRECAST BUILDS

Concept of the Body of Knowledge and Institute based certification programs for Plants and Personnel

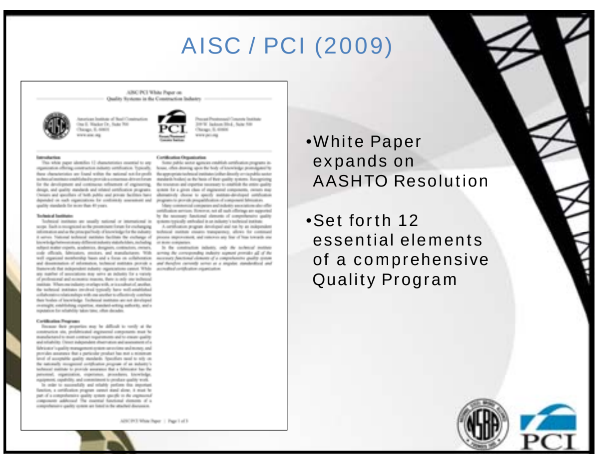
3


Why code organizations turn to institutes when developing their own standards
American Iron and Steel Institute (AISI) plate standards;
AISC for best practices and plant certification;
American Segmental Bridge Institute (ASBI) for best practices and grouting-personnel certification;
American Concrete Institute (ACI) for best practices and personnel certification;
ASTM International for materials and test standards;
American Welding Society (AWS) structural welding code, after-welding distortion tolerances, best practices, and personnel certification;
Concrete Reinforcing Steel Institute (CRSI) reinforcement dimensions, bending and placement standards, and epoxy coating plant certification;
PCI for best practices, plant certification, and personnel certification; and
Post-Tensioning Institute (PTI) for best practices, hardware standards, and personnel certification.
PCI

4


AASHTO SCOBS and SOM (2009)
AASHTO
•Recognizes contributions of National Technical Institutes
•Bridge Code calibrated based on quality standards set forth from the practices formulated by Nation Institutes
PCI

5


AISC / PCI (2009)
PCI
•White Paper expands on AASHTO Resolution
•Set forth 12 essential elements of a comprehensive Quality Program
PCI

6

PCI Personnel Training & Certification

Precast/Prestressed Concrete Plant & Quality Personnel Certifications
- Level III
- Level II
- Level I

Field Quality Personnel Certification
- Certified Field Auditor (CFA)
- Certified Company Auditor (CCA)

7

HOW PRECAST BUILDS

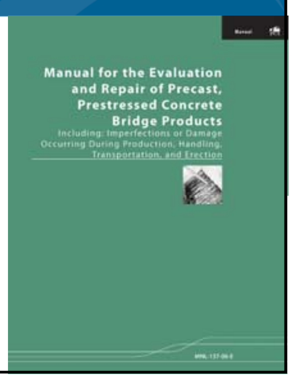
Transportation Publications.

These include Manuals, Recommended Practices and State-of-the-Art reports

8

Manual for Evaluation and Repair

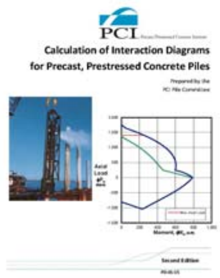
- Organized to address: Root Cause and Solutions
- May be adopted by some plants as part of QSM
- Offers Trouble shooting, Repair and Injection processes



9

Precast, Prestressed Concrete Piles

- Excel Workbook addresses:
  - Pile lofting
  - multi point picking and handling
  - Design Interaction Diagrams
  - Sample Parallel Calculations
  - and User Guidance

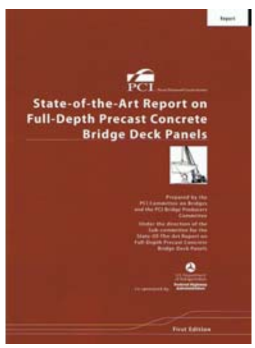


10

Full-Depth Precast Concrete Deck Panels

- Table of Contents
  - Introduction,
  - Concept & Advantages
  - Component of the FDDP*
  - Details of the FDDP*
  - Miscellaneous issues
  - Examples Projects
  - Design Example
  - Available resources

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



11

Precast Pavement

- Addresses Accelerated Construction goals
- PCI Guidance Documents
- 4 parts
  - Applications
  - Design & Maintenance
  - Manufacturing
  - Construction

12

www.precastconcretepavement.com

13

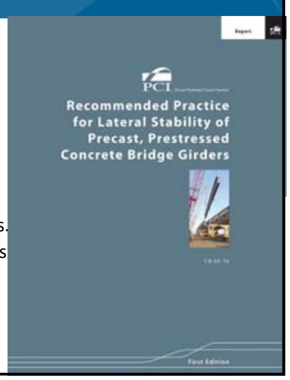
Curved Precast Concrete Bridges

- Address how to build curved Structures with corded & curved precast Prestressed concrete girders
- Illustrate how Colorado standardized and developed an economical system

14

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.



15

Advanced Precast Element Design and Construction State of Practice

Prefabricated Bridge Elements and Systems for Horizontally Curved Alignments Manual

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

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Advanced Precast Element Design and Construction State of Practice

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

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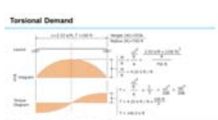
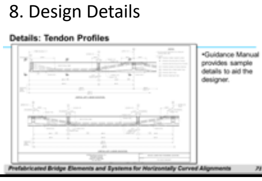
Advanced Precast Element Design and Construction State of Practice

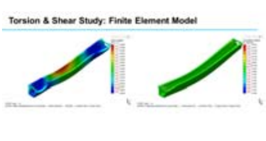
Prefabricated Bridge Elements and Systems for Horizontally Curved Alignments Manual

Guidance Manual Chapters

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







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Advanced Precast Element Design and Construction State of Practice

Bridge Geometry Manual

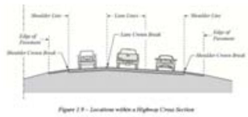
Guidance Manual Chapters

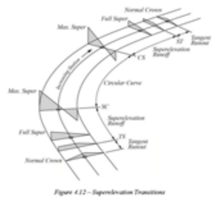
1.Introduction

2.Horizontal Roadway Geomtry

3.Vertical Geometry

4.Roadway Super Elevation





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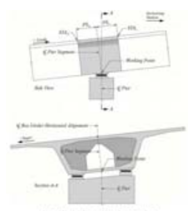
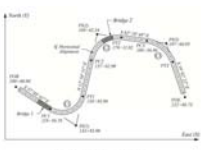
Advanced Precast Element Design and Construction State of Practice

Bridge Geometry Manual

Guidance Manual Chapters

5. Working with Horizontal Roadway
6. Geometry of Straight Bridges
7. Geometry of Curved Bridges
8. Segmental Bridges





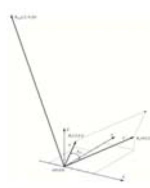
20

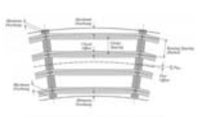
Advanced Precast Element Design and Construction State of Practice

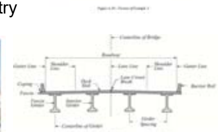
Bridge Geometry Manual

Guidance Manual Chapters

- Appendix A Vector Geometry
  - Definitions
  - Vector Addition and Subtraction
  - Three Dimensional Vectors
  - Vector Multiplication
  - Coordinate Transformation
- Appendix B Example Alignment Geometry







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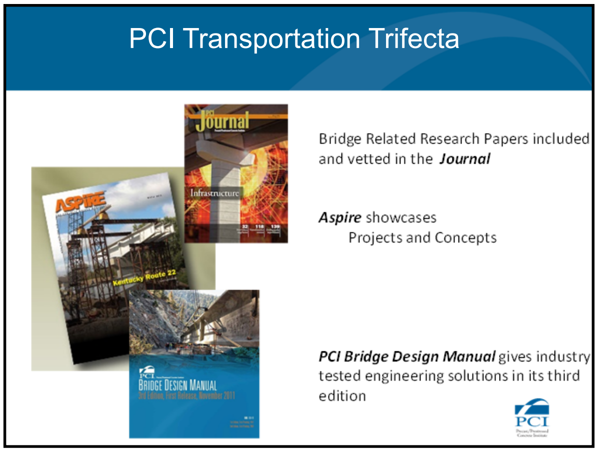
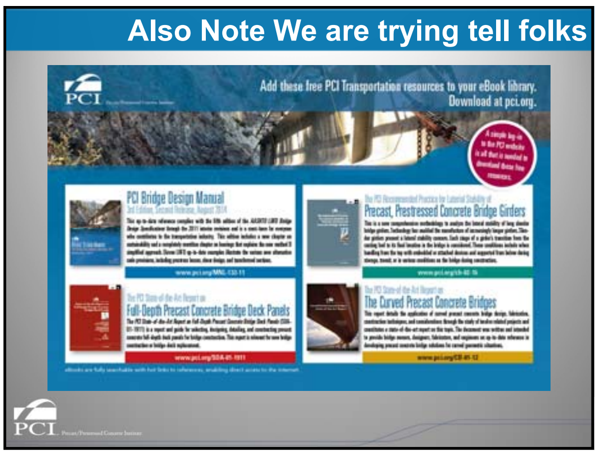
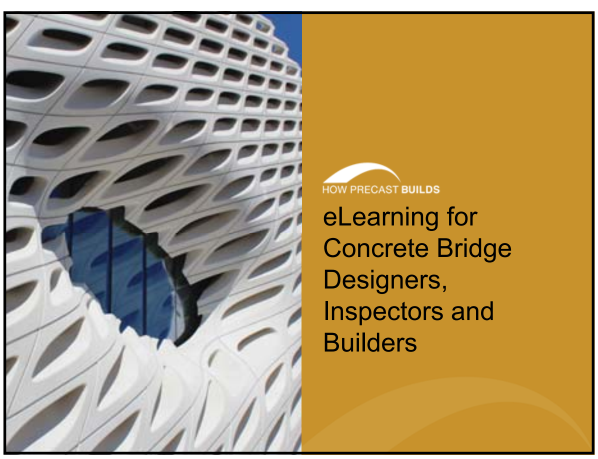

PCI Transportation Trifecta
Bridge Related Research Papers included and vetted in the *Journal*
Aspire showcases Projects and Concepts
PCI Bridge Design Manual gives industry tested engineering solutions in its third edition

22


Also Note We are trying tell folks
Add these free PCI Transportation resources to your eBook library.
Download at pci.org.
PCI Bridge Design Manual
Precast, Prestressed Concrete Bridge Girders
Full-Depth Precast Concrete Bridge Deck Panels
The Curved Precast Concrete Bridges

23


HOW PRECAST BUILDS
eLearning for Concrete Bridge Designers, Inspectors and Builders

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Link http://elearning.pci.org/

Search for released. Best to use "Transportation Systems"

25

FHWA/AASHTO/PCI Complex Concrete

eLearning #	Module Title
	PCI Bridge Design Manual
T110	Preliminary Design
T115	Materials and Manufacturing
T120	Loads and Load Distribution
T125	Flexural Analysis & Design: Service Limit State
T130	Flexural Analysis & Design: Strength Limit State
T135	Refined Losses for Members w/o or Prior to Decking
T145	Shear (MCFT)
T160	End Zone Design
T310	Extending Spans
T710	Load Rating (Overview & Methods)
T450	Bearing Pads - Theory and Method A
T455	Bearing Pads - Method B

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FHWA/AASHTO/PCI Complex Concrete Bridge Geometry manual map to ILT

Four Instructor Led Training Courses (ILT Courses) are being developed to facilitate the use of the Bridge Geometry Manual. The relationship between the chapters of the manual and the four ILT Courses are shown in the figure below.

Chapter 1 - Introduction Chapter 2 - Roadway Horizontal Geometry Chapter 3 - Roadway Vertical Geometry Chapter 4 - Roadway Superelevation	**T501**
Chapter 5 - Working with Horizontal Geometry	T505
Chapter 6 - Geometry of Straight Bridges	T510
Chapter 7 - Geometry of Curved Bridges Chapter 8 - Precast Concrete Segmental Bridge Geometry Chapter 9 - Curved Precast U-Girder Bridge Geometry	T515

27

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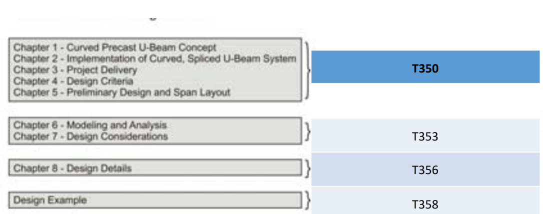
FHWA/AASHTO/PCI Complex Concrete Curved Spliced Manual map to eLearning



Interface between Guide Document for the Design of Curved Spliced Precast Concrete U-Beam Bridges and the ILT Courses

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FHWA/AASHTO/PCI Complex Concrete

eLearning #	Module Title
Full Depth Precast Bridge Decks State-of-Art	
T210	Introduction on Full-Depth Panel Precast Concrete Deck System and its Advantages
T215	Design and Detailing of Full-Depth Precast Concrete Deck Panels
T220	Production and Construction Details of Full-Depth Precast Concrete Deck Panels
T225	Case Studies and Emerging Developments of Full-Depth Precast Concrete Deck Panels
Stability User Manual and Excel Calculator	
T520	Introductory Material and Hanging Girders
T523	Stability of Transported Girders
T525	Seated Girders and Stability Issues from Bed to Bridge
T527	Calculations and Sensitivity Analysis

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FHWA/AASHTO/PCI Complex Concrete

eLearning #	Module Title
Bridge Geometry Guidance Document and Training	
T501	Roadway Geometry Basics
T505	Working with Horizontal Alignments
T510	Geometry of Straight Bridges
T515	Curved Bridge Geometry
Curved U Girder Guidance Document and Training	
T350	Introduction, Implementation and Delivery
T353	Modeling, Analysis and Design Considerations
T356	Design Details
T358	Design Example

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HOW PRECAST BUILDS

Opportunities to improve and lower the costs of ABC components

32

Distance Learning and a changing profession

These slides are just a sampling of how you can be part of the BOK

- On line classes are Self Paced
- Need to stay current with Structure Codes today that are more detailed
- New Generation very rooted in rigorous mathematics based theories
- New Materials coming on line

EDITORIAL

Those That Show Up Help Make the Rules

EDITORIAL

Make a New Year's Resolution: "Stay in Touch with Suppliers"

ASBI

PCI

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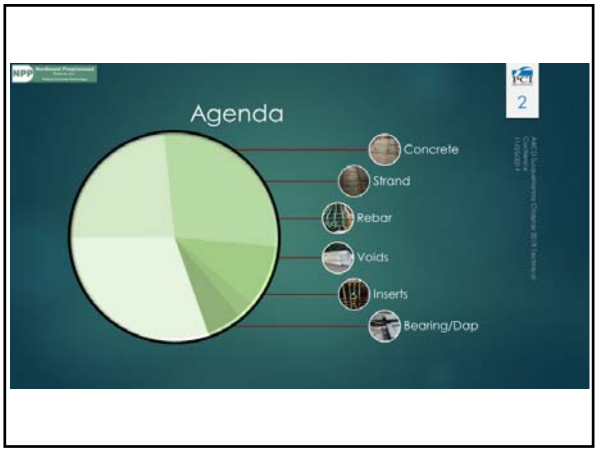
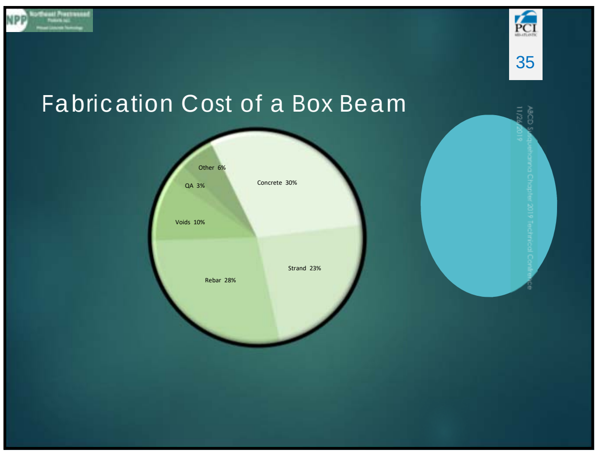

Agenda
Concrete
Strand
Rebar
Voids
Inserts
Bearing/Dap
2

34


35
Fabrication Cost of a Box Beam
Other 6%
QA 3%
Concrete 30%
Voids 10%
Strand 23%
Rebar 28%

35

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HOW PRECAST BUILDS
The future changes including UHPC efforts and why

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PCI TechnoQuest 2016

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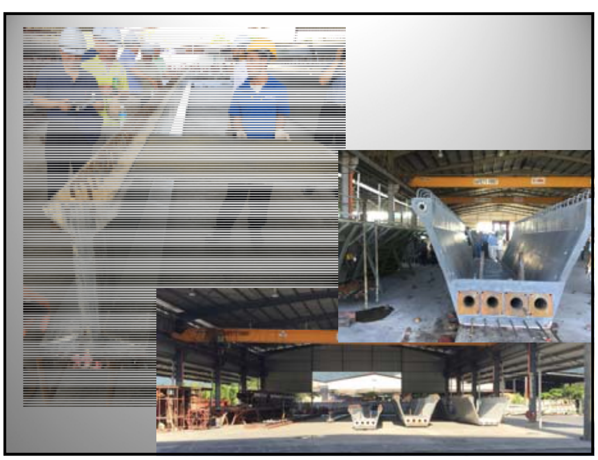

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Malaysia Precast Dura Update

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Changes in LRFD Concrete Bridge Design **Training coming in 2020 from TRB**

- **Purpose**: Accelerate implementation of the new LRFD section for concrete anchor design and minimize State Highway Agency (SHA) overlapping efforts in implementation through the use of a "deployment kit" for nationwide implementation.

- **NCHRP 639**: Adhesive Anchors in Concrete Under Sustained Load (exploratory report 67 pages plus references)
- **NCHRP 757:** Long Term Performance of Epoxy Adhesive Anchor Systems

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Implementation of Concrete Anchors

Results of the project to date:

The project to date has focused on adhesive anchors. With the adoption of the eighth edition *AASHTO LRFD Bridge Design Specifications*, Section 5.13, Anchors, is noted as being applicable to headed studs, headed bolts, certain hooked bolts, adhesive anchors, post installed expansion anchors and post installed undercut anchors. The design specification references ACI 318-14, ACI 355.2, and ACI 355.4. These ACI documents cover structural design of anchors and qualification testing for mechanical and adhesive anchors. It is probable that many design, materials, construction engineers in state DOTs and the transportation industry may not be familiar with these ACI documents or the proper application of these documents and other related documents for design, specification, procurement, or inspection of the various anchor types.

NATIONAL TRANSPORTATION SAFETY BOARD
Public Meeting of July 10, 2007
(Information subject to editing)

Highway Accident Report
Ceiling Collapse in the Interstate 90 Connector Tunnel, Boston, Massachusetts, July 10, 2006
NTSB/HAR-07/02

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of the July 10, 2006, ceiling collapse in the D Street portal of the Interstate 90 connector tunnel in Boston, Massachusetts, was the use of an epoxy anchor adhesive with poor creep resistance, that is, an epoxy formulation that was not capable of sustaining long-term loads. Over time, the epoxy deformed and fractured until several ceiling support anchors pulled free and allowed a portion

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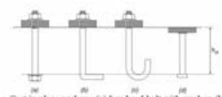
Implementation of Concrete Anchors

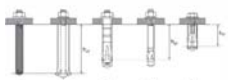
Test reports
- ICC-ES ESRs or ACI 355.2 or ACI 355.4 information
  - Anchor is graded on performance Anchor categories

Product qualification standards
- ACI 355.2 (AC193)
  - Mechanical expansion anchor qualification
  - Concrete screw anchor qualification
  - Report of design requirements
- ACI 355.4 (AC308)
  - Adhesive anchor qualification
  - Report of design requirements



Cast-in-place anchors: (a) hex head bolt with washer; (b) L-bolt; (c) J-bolt; and (d) welded headed stud

A State Highway Agency does not need to repeat the ICC-ES AC (ACI) testing protocol for anchor qualification



Post-installed anchors: (a) adhesive anchor; (b) undercut anchor; (c) Torque-controlled expansion anchors (c-1) sleeve-type and (c2) stud type; and (d) drop-in type displacement controlled expansion anchor

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Implementation of Concrete Anchors PCI contracting with TRB

PCI-AASHTO Bridge Engineers

Draft of One-day Seminar on Anchoring to Concrete/Masonry

General Outline

1. Scope and objectives of seminar
2. General background on anchor behavior
3. Available codes
4. Available design software
5. Anchorage selection process
6. Product qualifications, specifying anchors for a project, and anchor procurement
7. Adhesive anchor installer and installer inspector certification
8. Construction compliance testing

Knapsack Material

Items that will be given to each participant after the class

Leave workshop with a model Agency Implementation Plan and toolkit

Two Pilots and then ready for broad dissemination 12 months from contract execution.

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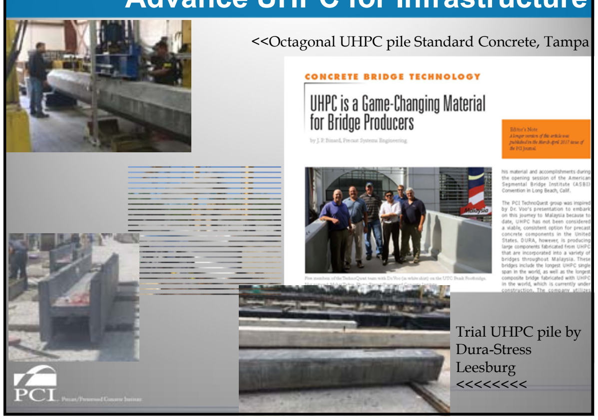
Advance UHPC for Infrastructure



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HOW PRECAST BUILDS
Stay in touch with NCBC for changes in Concrete Bridge solutions

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Aspire Messaging since winter 2007
THEN
Process for Revisions and Additions
Background to the Specifications
ASPIRE
THE CONCRETE BRIDGE MAGAZINE
NOW
A PROFESSOR'S PERSPECTIVE
STRUT-AND-TIE MODEL
Concrete bridge design by STM
PERSPECTIVE
Benefits of the FHWA-NHI Strut-and-Tie Modeling Workshop
An Attendee's Perspective
by Dr. Tess Ahlborn, Michigan Technological University
AASHTO LRFD
AASHTO LRFD Bridge Design Specifications: Service IV Load Combination
PCI

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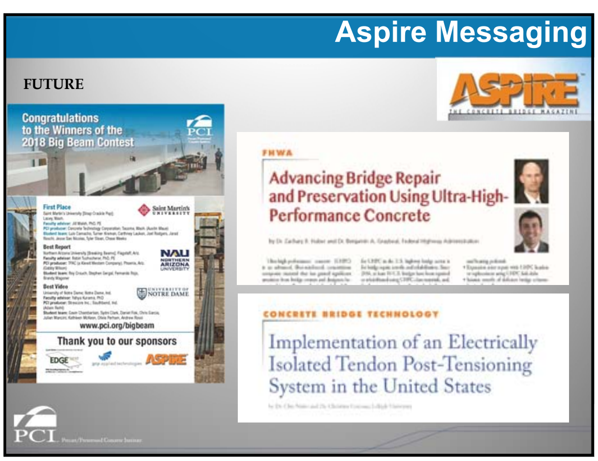
Aspire Messaging
FUTURE
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THE CONCRETE BRIDGE MAGAZINE
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CONCRETE BRIDGE TECHNOLOGY
Implementation of an Electrically Isolated Tendon Post-Tensioning System in the United States
PCI

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ASPIRE Messaging

ASPIRE Editorial Team feedback capture humor:

"Not that I know Richard well, but when I read this I hear the inflections in his voice and visualize his hand movements."

A PROFESSOR'S PERSPECTIVE

Let's Teach Engineering Like We Teach Baseball

by Dr. Richard Miller, University of Cincinnati

PCI

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2019 NCBC

- 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

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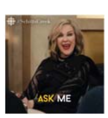
LEARNING OBJECTIVES

1. Concept of the Body of Knowledge and Training for Plants, QC staff and Auditors
2. Cover a few Transportation Publications. These include Manuals, Recommended Practices and State-of-the-Art reports
3. eLearning for engineers (Free PDH/CEUs)
4. Opportunities to improve and lower the costs of ABC components
5. The future changes including UHPC efforts and why
6. NCBC
7. THE END……………………..



PCI

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