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Post-tensioned Gout Update (Design, Specifications, Material & Construction)

Virginia Concrete Conference March 8, 2013

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Topics

- Issues with PT/Grout
- Design Recommendations
- Materials Recommendations
- Construction Recommendations
- VDOT Experience with PT Grouts
- US 460 Tendon Mockups
- 2012 Lab Tests at VCTIR

Topics (Cont.)

- Material Problems
- Design Problems
- Construction Problems
- Need for Mockups
- Conclusions
- Recommendations
- Questions

Issues with PT/Grout

- Failed Tendons Due to Corrosion
- Grouting - Chloride Issue
- Segregation of Grout
- Soft Grout

Failed Tendons Due to Corrosion

- Florida Tendon Failure in 10 Years
- Virginia Tendon Failure in 17 Years
- Not just a U.S. Issue – Problems in Europe

Varina-Enon Bridge – Corrosion Problems

Photo – PT Tendon Failure, May 22, 2007

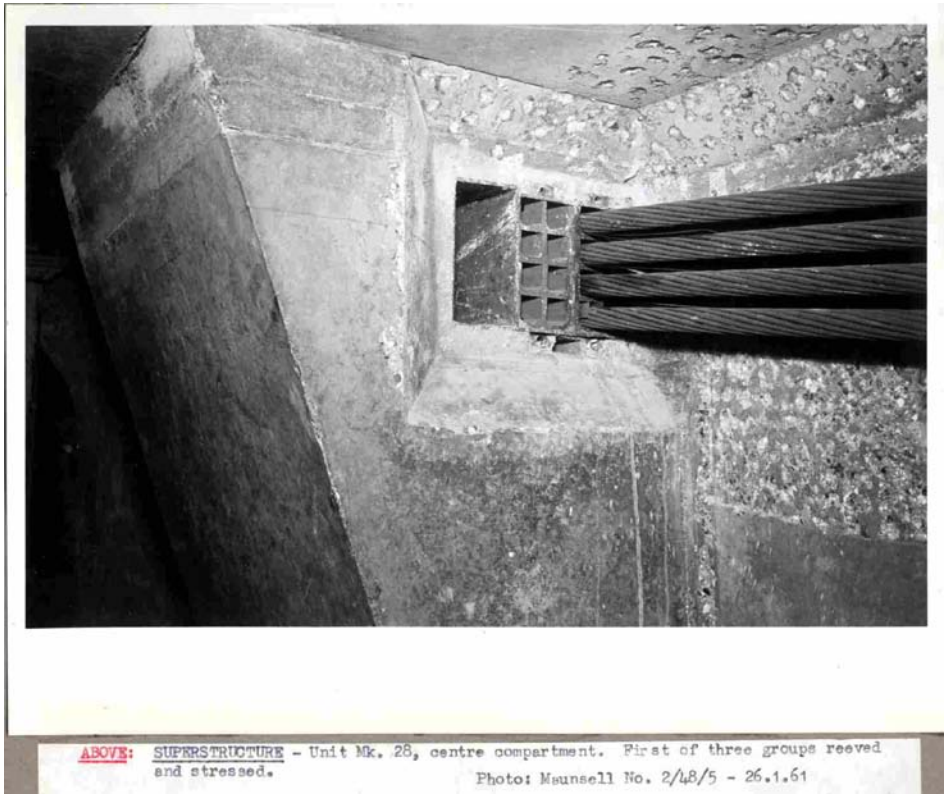
Photo – 3 Broken Wires on Tendon, November 28, 2012

Hammersmith Flyover

Transport for London

BELOW: SUPERSTRUCTURE - Unit Mk. 18A in span AB. East end of South 10" duct in inner compartment. One group of cables reeved and stressed. Saddle type S5/A in cantilever unit Mk. 19A for lower group of cables only. Slip strips visable through saddle. Photo: Msunsell No. 2/49/3 - 26.1.61

ABOVE: SUPERSTRUCTURE - Interior of spine beam showing stressed cables and heater used during jointing in cold weather. Photo: W.J. Longland.

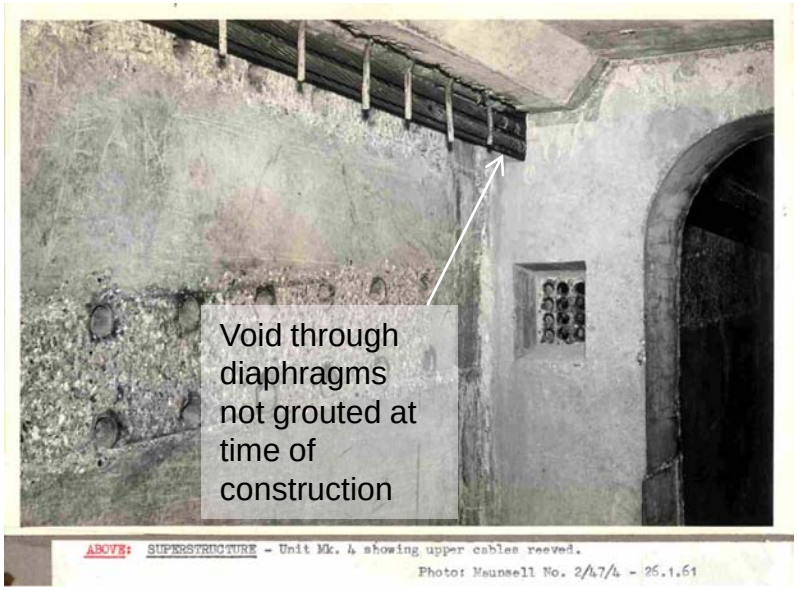


ABOVE: SUPERSTRUCTURE - Unit Mk. 28, centre compartment. First of three groups reeved and stressed. Photo: Msunsell No. 2/48/5 - 26.1.61

Tendons before encasing in grout boxes

Transport for London

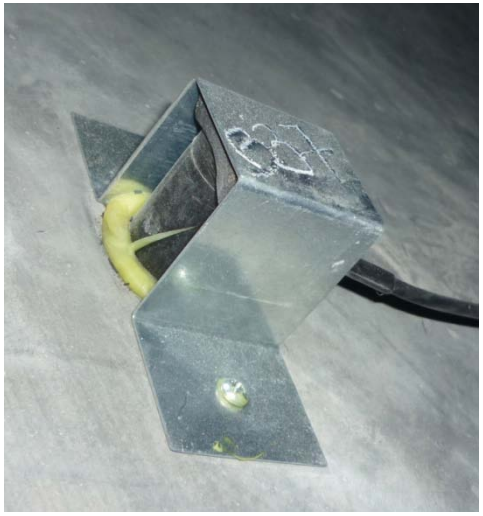
Corrosion concentrated at un-grouted voids through diaphragms

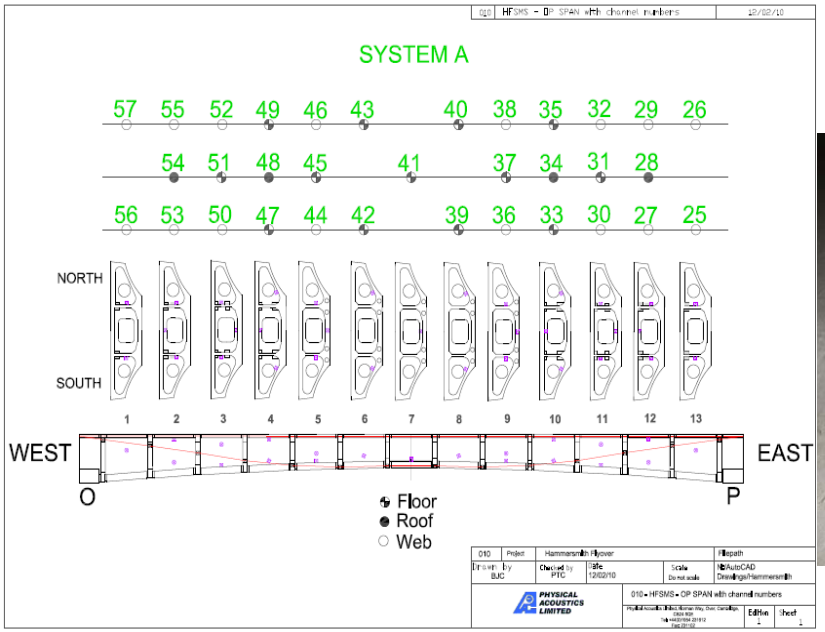


Voids, corroded ducts and broken wires at diaphragms

Transport for London

Acoustic Monitoring System





Grouting – Chloride Issue

- National Issue
- Virginia Bridges Impacted

SikaGrout 300PT from Marion OH Plant - National Issue

- Nov. 23, 2011 FHWA Memo
  - 19 States – 34 projects
- January 15, 2013 – Paul Kelley
  - 35 States, 183 Named Projects
  - 88% of All Marion Ohio Grout
  - 6 Name Projects Have the Greatest Use of grout from Marion Ohio Plant – WWB

SPECIFICATIONS

COMMENTARY

3.3.3 Proportions of Grout

The proportions of grout ingredients in Classes A, B, and C shall meet the requirements given in Table 3.1. Other additives, not included in Table 3.1 must be shown, through additional tests, that there will be no adverse effect, in particular with respect to corrosion of prestressing steel. The grout properties for Class D grouts shall be specified by the Design Engineer to suit the special appli-

C3.3.3 Proportions of Grout

Typically, the materials section of this guide specification provides guidance in producing grouting ingredients. Several ingredients can be employed at very small dosage rates making the batch-to-batch uniformity at the jobsite rather difficult without sensitive measuring devices. When considering the volume of material used in grouting applications, consideration should be given to the specification

3.3.4 Chloride Ion Content

The constituent materials used shall be such that the acid-soluble chloride ion (Cl-) content of the grout shall not exceed 0.08% Cl- by weight of portland cement as measured by ASTM C1152, "Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete".

Independently Certified Laboratory (CCRL) Report and an implemented Quality Assurance Program that can be employed to show quality control results when necessary. This system of grout certification has been successfully mployed in the nuclear power industry for precision grouting of equipment base plates. Quality Assurance Criteria for Nuclear Power Plants, 10CFR1050, Appendix B, Atomic Energy Commission, Code of Federal Regulations, is an example of this type of Certification program.*

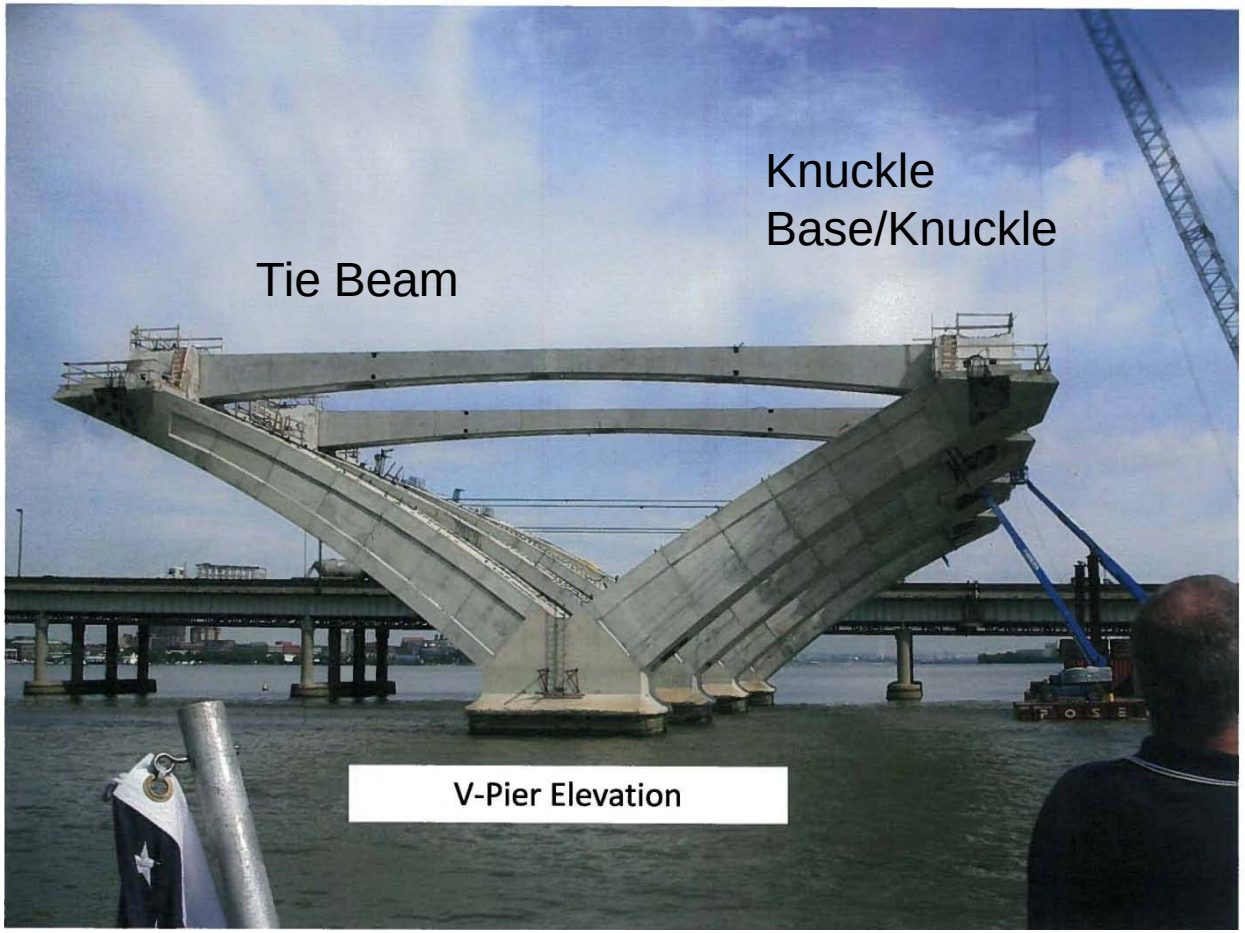
**Cement Concrete Research Laboratory*
[For listing of facilities contact:
National Institute for Standards and Technology
Gaithersburg, Maryland, 20899
Phone: (301) 975-6704, Web: www.bfrl.nist.gov/CCRL]

Grouting – Chloride Issue

- 2011: VDOT Appoints PT Grout Task Group
- Michael Sprinkel, Associate Director, VCTIR
- Claude Napier, Assistant State Bridge Engineer
- Larry Lundy, Concrete Program Manager
- For WWB:
  - Nick Roper, NOVA District Bridge Engineer
  - Fawaz Saraf, NOVA Senior Structural Engineer

Woodrow Wilson Bridge

Woodrow Wilson Bridge



Grout from Marion Ohio Plant:
800,000 pounds

RTE 123 / OCCOQUAN RIVER

RTE. 123/OCCOGUAN
VSL CORPORATION

PROJECT GROUT INFORMATION

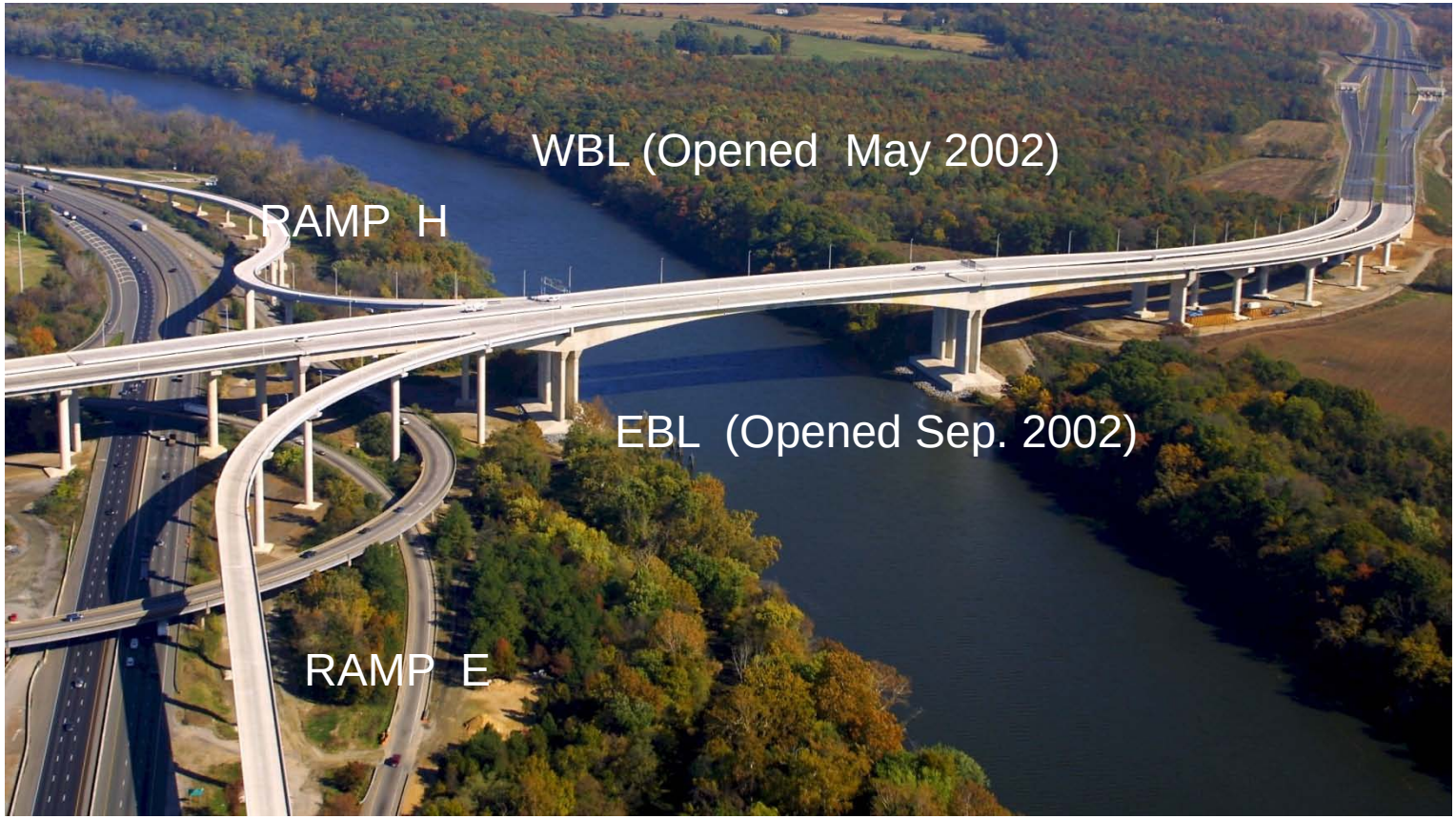
LOT NO.	PRODUCTION DATE	SHIP DATE	GROUT (LBS)	WHERE USED?	COMMENTS
051580126M TO 052010018M	6/07/2005 TO 7/20/2005	11/10/2005 TO 11/10/2005	3,600	SBL T3 BEAM 7	SIKAGROUT 300PT Phase 2
				SBL T3'S BMS 1-6	Euclid PTX Grout Phase 2
TOLLER Bayville, NJ	04/10/2007			NBL	SIKAGROUT 300PT Phases 1 & 2

RTE. 33 / MATTAPONI RIVER

SikaGrout 300PT, Marion Ohio Plant, 40,000 lbs.

RTE. 33 / MATTAPONI RIVER

RTE. 895/JAMES RIVER & RAMPS E & H



Sika Cable Grout, Marion Ohio:440,000 lbs

FHWA INITIATIVES

- Expert Task Group (ETG):
  - FHWA, Academia, Industry, & State Representatives – Michael Sprinkel
- Stakeholder Group (OH, MN, TX, FL, VA….& AASHTO)
  - Ken Walus & Mal Kerley (AASHTO) invited to be on group (Claude Napier – Ken Walus' Designee)
  - Look at what needs to be addressed
  - Need for long term maintenance & inspection protocols
  - What to do to monitor

FHWA INITIATIVES

- Collecting information on number of bridges & states impacted
- Research
  - General Protocol for Sampling
    - ASTM Test – Chlorides
    - Ways of extracting samples
    - Risk – Locations to sample; high points, where concentration may be greatest
  - Guidance document for uniformity & maintenance (Michael Sprinkel reviewed draft)
- Research to compliment UMINN(Duluth) research for Sika (Moved to Villanova University, Aug. 2012)

FHWA INITIATIVES

- Research to compliment UMINN(Duluth) research for Sika
  - Larger scale samples
  - Stressed strands vs unstressed strand
  - Chloride threshold

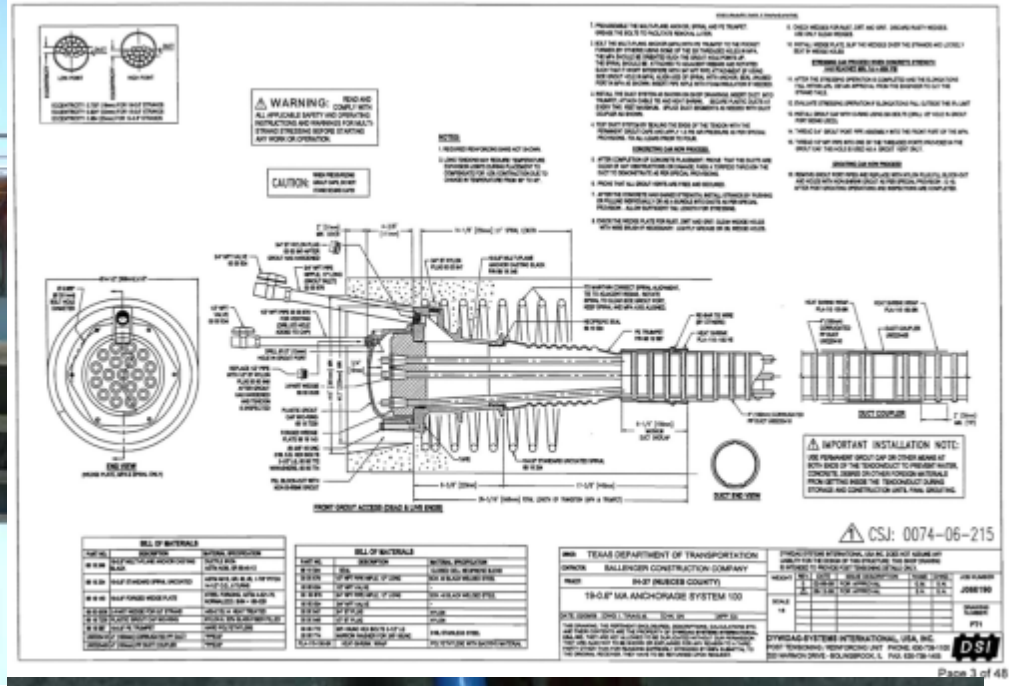
AASHTO INITIATIVES

- Joint Working Group on Grout (JWGG)
  - Keith Platte - AASHTO
  - 3 State official members – SCOBS
  - 3 State official members – SOM
  - Appointee from Chair of SCOBS: Ken Walus
  - Appointee from Chair of SOM: Mark Felag
  - March 27, 2012: Establish Objectives for JWGG
  - Next Teleconference Call/Meeting: May 2012

Issues with Segregation of Grout and Soft Grout

- TD DOT Ramp Structure
- Ringling Bridge, FL DOT
- Virginia DOT, Mockup for Route 460 Connector

TXDOT Ramp…


WARNING:
CAUTION:
IMPORTANT INSTALLATION NOTE:
CSJ: 0074-06-215
TEXAS DEPARTMENT OF TRANSPORTATION
BALLENGER CONSTRUCTION COMPANY
IH-37 (NUECES COUNTY)
19-0.6" MA ANCHORAGE SYSTEM 100
DYWIDAG-SYSTEMS INTERNATIONAL USA, INC.
DSI


Slide 12

Design Recommendations

- Structures requiring post-tensioning (using ducts and grouting) shall not be used without the approval of the State Structure and Bridge Engineer (IIM-SB-80.4, VDOT Modifications to the AASHTO LRFD Bridge Design Specifications, 6th Edition, 2012, dated January 31, 2013)
- Detailed Post-tensioned Specifications meeting the latest requirements of PTI, ASBI, and LRFD Specification.
  - PTI M55.1-12,
  - PTI/ASBI M50.3-12, and
  - PTI Guide Specification for Acceptance Standards for Post-tensioning

Design Recommendations

- Positive Sealed PT System
  - Protection Level 2 (PL-2), PTI/ASBI M50.3-12
  - No galvanized ducts
  - No duct tape
- Multi Level Corrosion Protection System
  - Engineered Grout Class C per PTI M55.1-12
  - Thixatropic
  - Permanent Grout Caps,
  - Pourbacks
  - Elastomeric Coating System

Design Recommendations

- Field Mockup Tests Required for all Major PT Projects
  - Grout a Complete Full Scale Replication of a tendon on the Bridge Using the Same Materials, Equipment and Labor that Would be used During Production
- Personnel Qualifications
  - PTI Certification (PTI Level 2 Bonded PT Field Specialist) and PTI Level 1 Bonded PT Field Installation)
  - ASBI Grouting Certification
- Grouting Logs Showing Lot Numbers and Location of Each Grout Used Shall be Provided to the Engineer to Become Part of the Bridge Permanent Record.

Materials Recommendations

- Preapproved Products List: Cable Grouts Approved List No. 62 is now Preapproved Screening Qualification List
- Require Updated Certification of Cable Grout by Independent Cement and Concrete Reference Laboratory (CCRL) for each Project
- Perform Chloride Ion Concentration Test, Strength Test, Volume Change Test, and Wick-induced Bleed Test or Schupack Pressure Bleed Test on each Grout Lot, before Grouting Operations Begin
- Perform Periodic Testing of Chlorides in the Grout during Production .

Preapproved Products List: Cable Grouts
Approved List No. 62 (Now Screening Qualification List)

- SikaGrout 300PT: Sika Corp. (Removed from List until a new grout formulation is approved.)
  - Shelf Life: 6 months – properly stored
  - Paper bag – plastic liner
- Masterflow 1205: BASF Construction Chemicals, LLC
  - Shelf Life: 9 months – properly stored
  - Paper Bag – plastic liner
- Euco Cable Grout PTX: Euclid Chemical Co.
  - Shelf Life: 1 year – in original unopened container
  - Plastic Container

Construction Recommendations

- Obtain Post-tensioning System Certification and Grouting Certification before PT System is Installed
- Administer Field Mockup Tests and Field Trial Grout Tests for Verification of Grout(s) to be Used
- Obtain Grouting Logs and Provide to District Structure and Bridge Engineer at end of Project for Permanent Bridge Record.
- Recommended that CEI have Post-tensioning System and Grout Certification Training

- Questions?

VDOT Experience with PT Grouts

- Prior to1995 PT tendon grouts were a mixture of water & cement (w/c $\leq$ 0.42) and sometimes an expansive admixture.
- The most significant bridge was the Varina Enon Bridge completed in 1990 which has 480 grouted tendons in the superstructure.

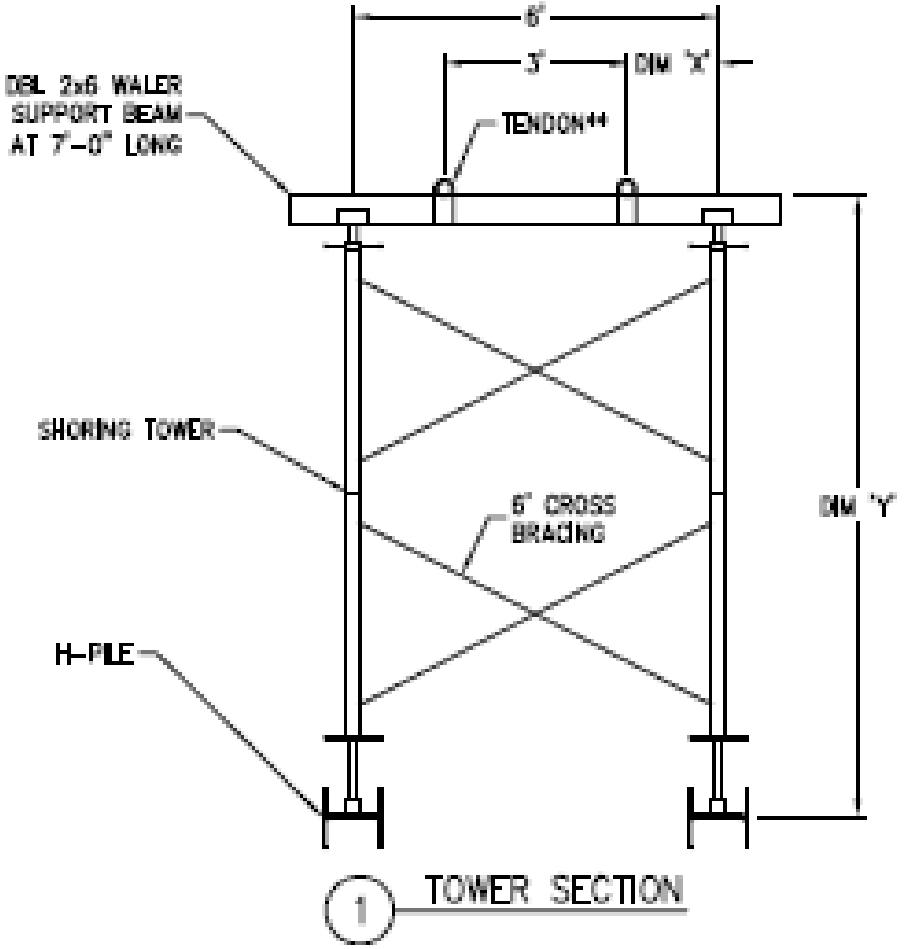
VDOT Experience with PT Grouts

- 2001: Worked with industry to develop a prepackaged high performance grout (HPG).
- 2001: Smart Road bridge first to be grouted with a HPG.

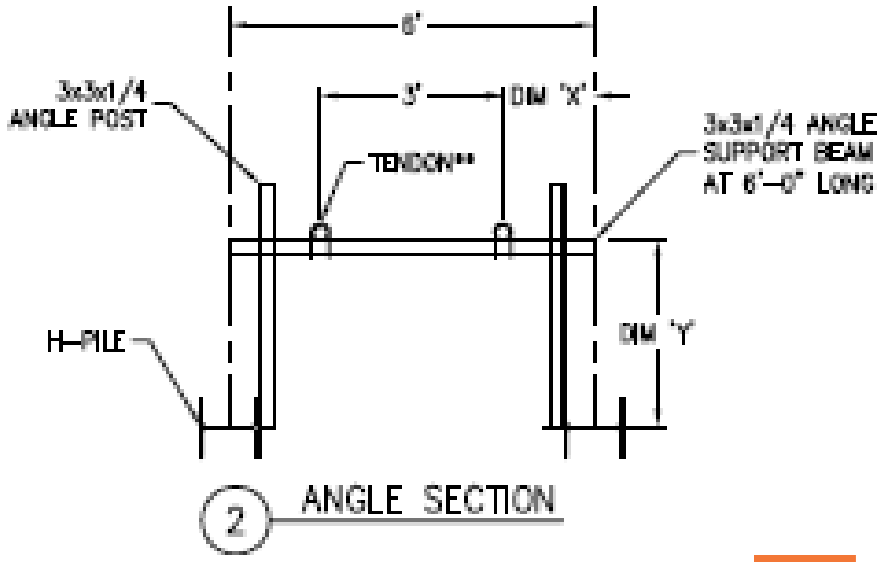
VDOT Experience with PT Grouts

- 2012: Mockup for US 460 segmental bridge identifies voids, segregation and soft grout in tendon grouted with an approved HPG.

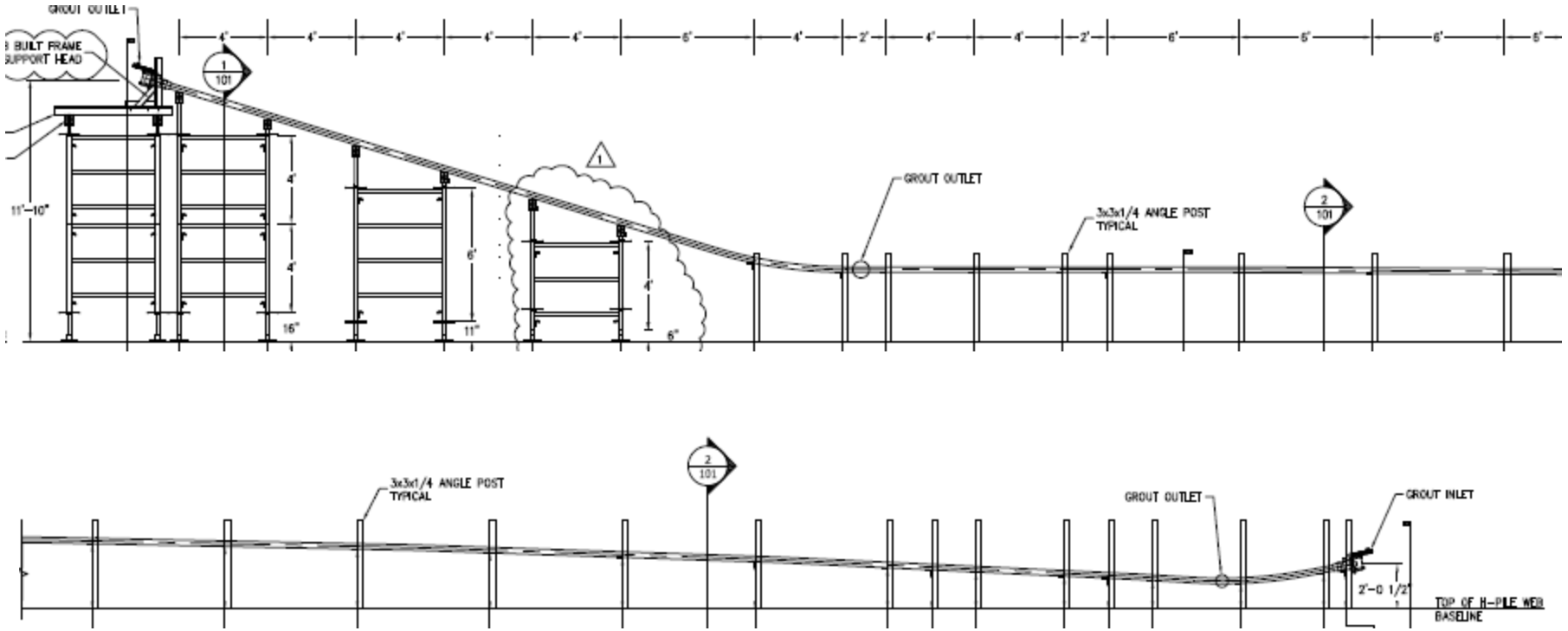
US 460 Tendon Mock up end sections



** TENDONS ARE TO BE TIED DOWN TO SUPPORTING BEAMS WITH STANDARD REBAR TIE WIRE



Tendon Mock up longitudinal sections



US 460 Tendon Mock up outlet end caps

Grout 1 no void or soft grout

Grout 2 void and soft grout

US 460 Tendon Mock up inlet end caps

grout 1 no void or soft grout, grout 2 void and soft grout

US 460 Tendon Mock up

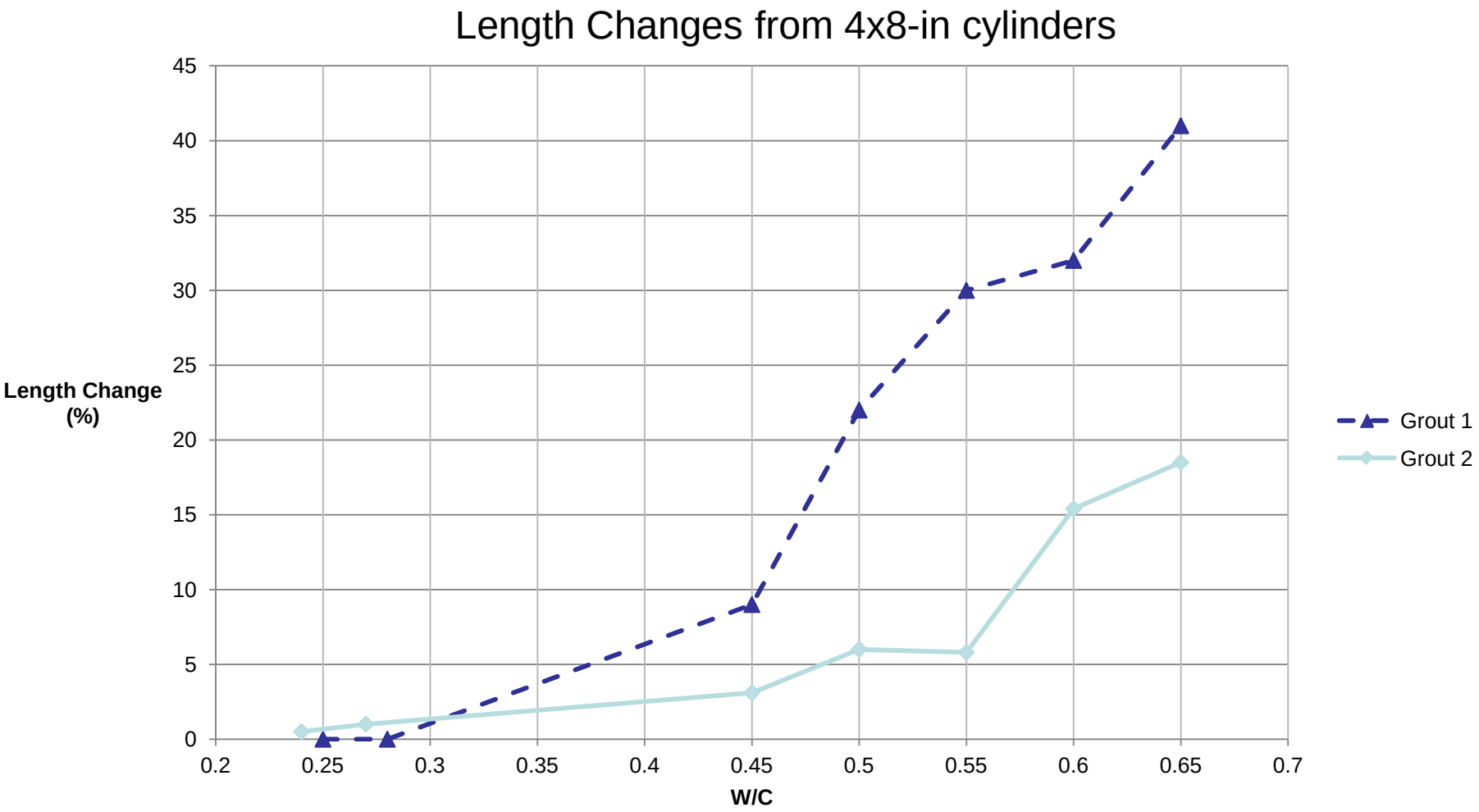
grout 1 provides filled tendon

grout 2 leaves void on top

2012 Lab tests at VCTIR

- Tests were conducted to determine the effect of grout water content on the segregation, length change and compressive strength of 2 HPG.

Length Change Tests @ VCTIR



Length Change Tests with w/b = 0.65
Both HPG are badly segregated

Inadequate Corrosion Protection ???

- Portland cement grout surrounding strands provides corrosion protection.
- Strands are often not protected because they are often not surrounded by grout because of a combination of material, design and construction problems.
- The good news is that few tendons have failed despite the perceived inadequate corrosion protection.

Material problems

- Prior to 1995 grouts bleed and segregate.
- Bleed water evaporates and leaves a void.
- Strands in the voids are not protected by grout.
- Bleeding was approximately 4 percent in a properly batched grout (w/c ≤ 0.42) prior to 1995.
- In a typical 150 ft long tendon 6 ft of void at the high points adjacent to the anchor plates in draped tendons is expected.

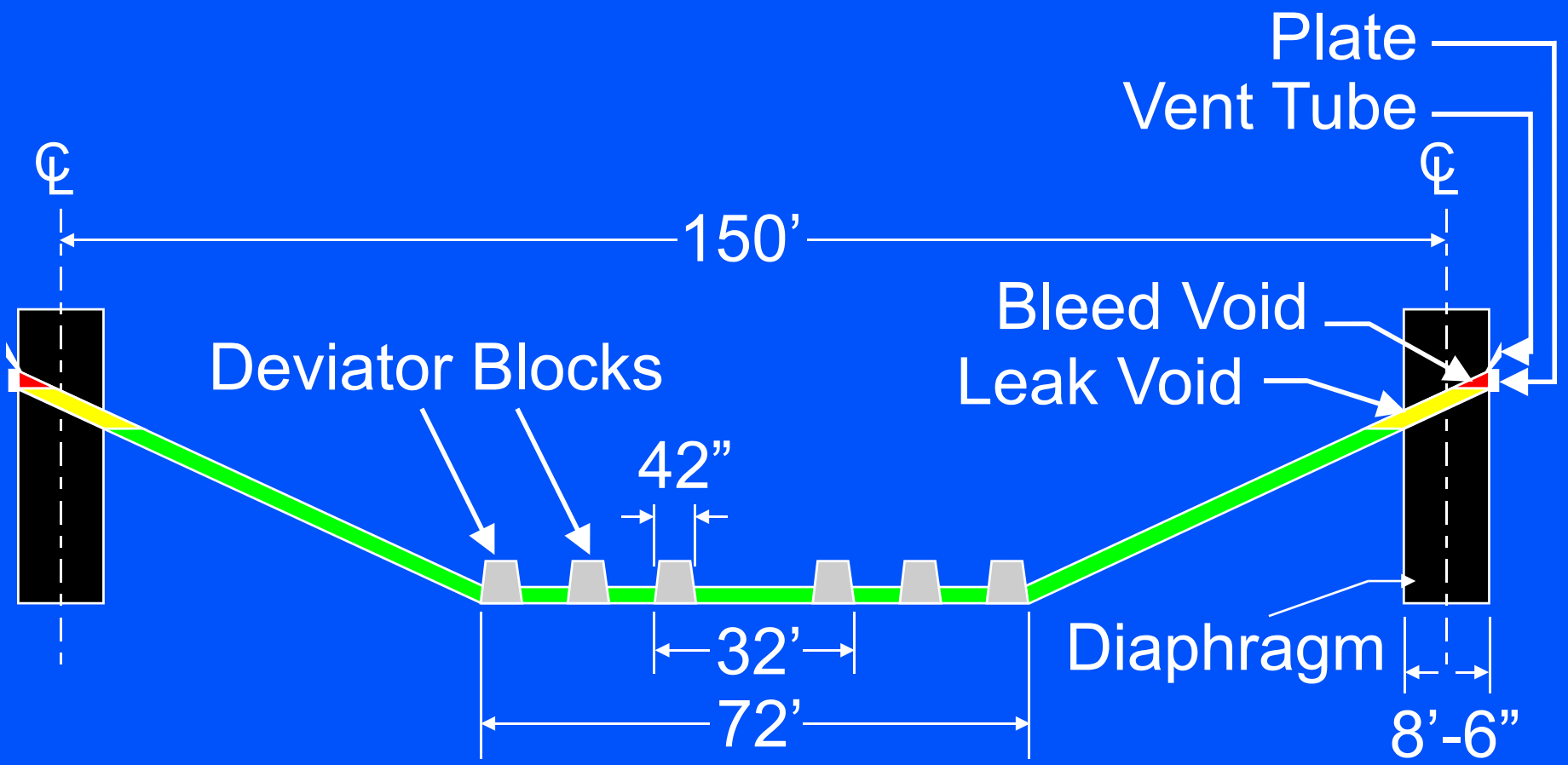
Wick Induced Bleed Test
cement and water, aluminum powder, high performance prepackaged grout (R. Gulyas)

Design problem: Typical grouted draped tendon indicating it is not possible to surround upper strands with grout

Construction problem

- A construction problem is not properly batching and mixing the grout. PTI M55.1-12 requires that equipment consist of measuring devices (5.5.1) and that all materials shall be batched by weight except liquids may be batched by volume (5.6.1).
- Excess water causes the grout to bleed and segregate resulting in strands not being surrounded by grout.

Typical Varina Enon span with draped tendon and bleed, leak and excess water voids



Need for Mockups

- Incorrect batching and mixing, tendon geometry and length, and high pump pressures have been suggested as reasons for the problems.
- Until we have lab tests that can identify acceptable grouts, mockup tests should be done to identify problems prior to grouting the bridge.
- The mockup should include the most critical tendon situation (greatest height change and length) using grouts proposed for the project.
- The mockup done in 2012 for the US 460 bridge was successful.

Conclusions

- Lab tests need to be revised to identify grouts that will not bleed and segregate.
- Representative mock ups can identify a grout that is suitable for a project.
- For a successful project the water in each batch will need to be carefully measured and the bags of grout weighed.

Recommendations

- Until we have lab tests that can identify acceptable grouts, perform a mockup test of the most critical tendon situation (greatest height change and length) using grouts proposed for the project.
- The mockup can be waived if the tendon design is similar and the proposed grout and grouting contractor are the same as approved for another project.
- While grouting, the water in each batch must to be carefully measured and the bags of grout weighed to provide the required w/b.

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QUESTIONS

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