Unique Application of Epoxy Repair Gel to Eliminate Draft-Tube Surface Wear and Cavitation Potentially Improving Turbine Power Generation Efficiency

Norm Klapper / PEC
Milamar Coatings, LLC
Division of CASS POLYMERS
Oklahoma, City, OK

ICRI - San Juan, P.R.
March16-21, 2016

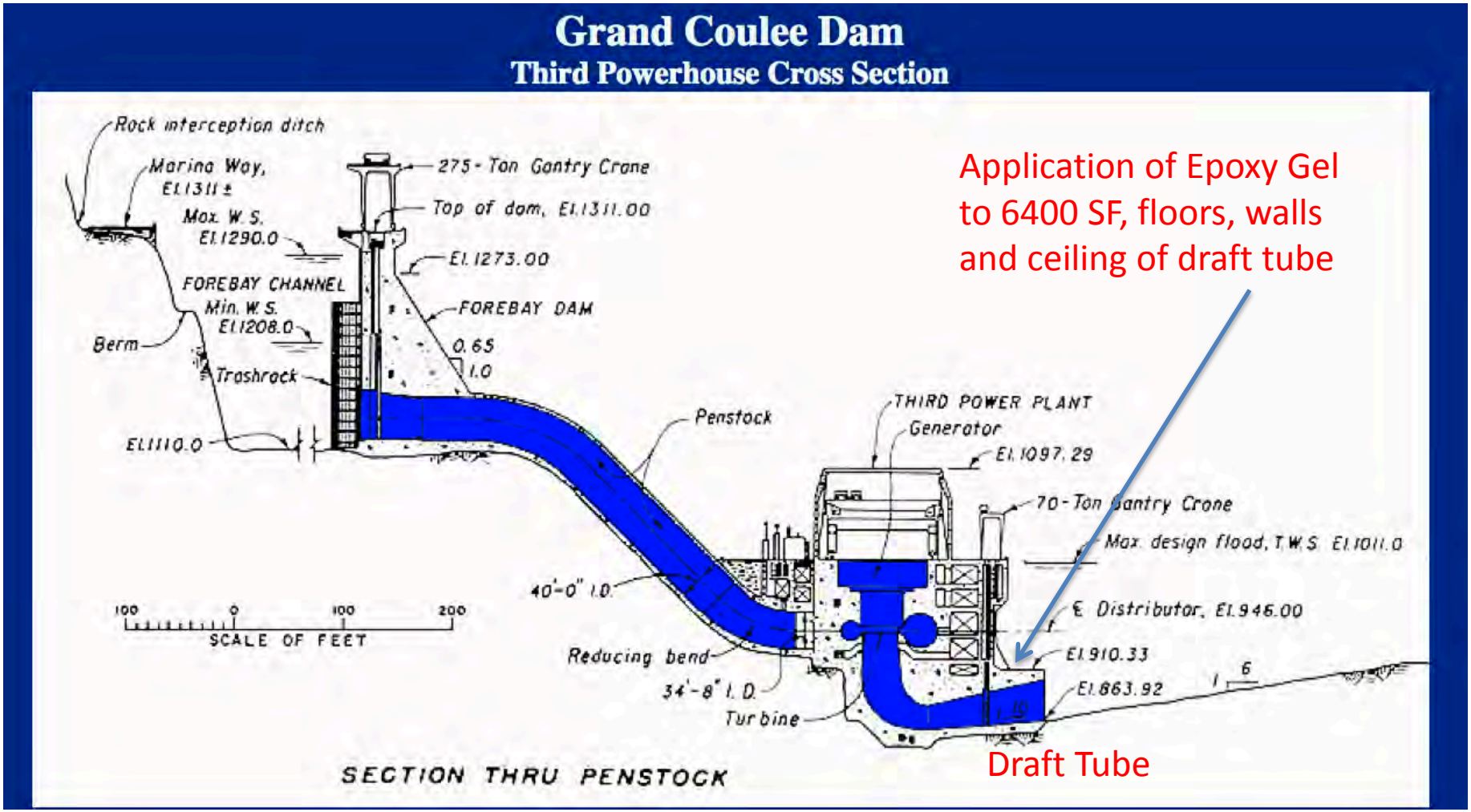
PROJECT DESCRIPTION

- Grand Coulee Dam, Western Washington state
- Largest hydroelectric dam in Western Hemisphere
- Turbine Unit #23 – current contract (3 Turbines)
- Complete refurbishment of Powerhouse #3 – a three-year project in total (GC - Andritz-Hydro)
- Draft tube repairs / resurfacing – added to general scope of turbine refurbishment

Grand Coulee Dam
Pacific Northwest, Washington

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Cross-Section Sketch



INTERNATIONAL CONCRETE REPAIR INSTITUTE

Site Specific Challenges

- 230 feet down for access to draft tube
- Access only by lift/basket hoist for all tools, materials, manpower
- 55 degree °F work environment
- No solvents allowed (for cleaning tools, potential automated application equipment)
- Confined space safety requirements
- Concrete walls under extreme water pressure - tried to inject water stop, hydraulic cements, other polyurethane products
- Some areas were left unrepaired / coated as a result of steady leaks

Bureau of Reclamation Product Evaluation Criterion

- Good Bond Strength – ***especially*** to damp surfaces
- Minimal surface prep requirements
- Good compressive & tensile strengths
- Smoothness / good flow characteristics
- Extensive testing and evaluations conducted of over 50 products
- Conclusions led to an Epoxy Gel and a single cementitious option
  - Cementitious – thickness issue as application was only a “skim-coat” – average ½” thickness
  - May require application of a mesh base

INTERNATIONAL CONCRETE REPAIR INSTITUTE

EPOXY GEL
KEY PHYSICAL CHARACTERISTICS

- Tensile Strength: 1810 psi
- Shore Hardness: 80
- Tensile Elongation: 10%
- Compressive Strength: 6170 psi
- Bond Strength (properly prepared concrete): >1000 psi
- No priming required – single step application
- EPOXY GEL MC - @55°F – 60 minutes working time,48 hours full cure

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Interesting Access Challenges

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Field Conditions

- Extremely deep wear/erosion from abrasion on entire concrete surface
  - ½” to ¾” deep linear wear lines, over entire 6400 SF surface, 40” x 40’ x (4) surfaces
  - Holes, severe surface wear
  - Dirt and debris deeply impregnated in surface
- Potential cavitation from draft tube outflow
  - Back-pressure on water flow exiting from turbine
- Poor flow characteristics due to cavitation
  - Hazen-Williams friction factor

Initial Site Inspection

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Concrete Surface Restoration

- Surface Preparation Options
  - Acid Etching – Not allowed!
    - Environmental concerns for outflow to river
    - Confined space considerations
  - Shot Blasting
    - Difficult equipment, sand + solid waste generated
  - Diamond Grinding
    - Sparks, safety, confined space rules, “Hot Work”
  - High Pressure Washing – Chosen Method
    - Minimum 4000 psi
    - Relatively easy method
    - Little to no waste, only water and some solids
    - Convenient / lower skill level
    - Tested with pull test apparatus to confirm

INTERNATIONAL CONCRETE REPAIR INSTITUTE

High Pressure Water Blasting

INTERNATIONAL CONCRETE REPAIR INSTITUTE

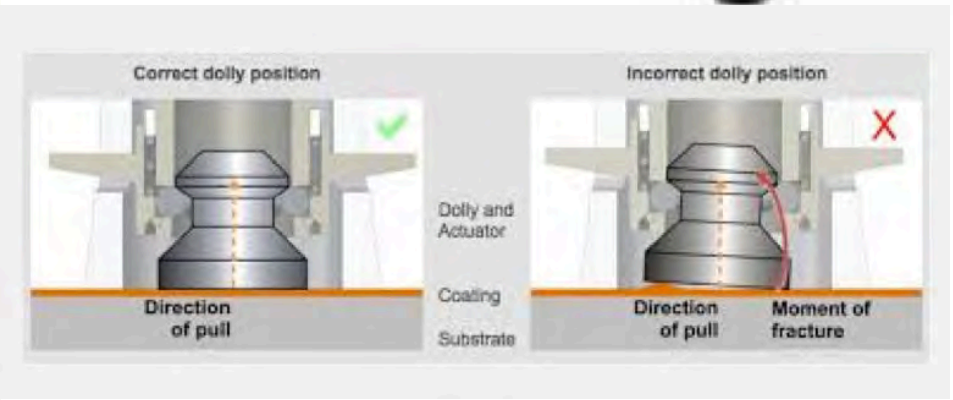
Final Surface Preparation Prior to Application of Epoxy Gel

- Air lance – used to blow out remaining “liquid water”, dampness is OK.
- Temperature control – not an issue, a steady 55°F / product selection took into account
- Additional need to water-plug leaks from cracks and fissures in concrete walls –
  - Polyurethane resin – not 100% effective

Bond Strength Characteristics

- Medium Cure (MC) Epoxy – initial cure time 14-16 hours at 55°F / full cure after 48 hours
- Achieves maximum bond strength after 48 hours
- Bare, prepped concrete typically fails at 360-480 psi
- EPOXY GEL – failed at 460 psi, sheered at concrete NOT epoxy interface

Failure Mode Pull Testing Devices (Elcometer™)



INTERNATIONAL CONCRETE REPAIR INSTITUTE

Pull Tests on Prepared Bare Concrete

Header

Andritz Hydro Draft Tube Adhesion Test: Concrete Only Test Date: 12/16/13

Three (3) 50mm dia. test dollies were placed in the following areas:

1.) North Wall

2.) North Pier

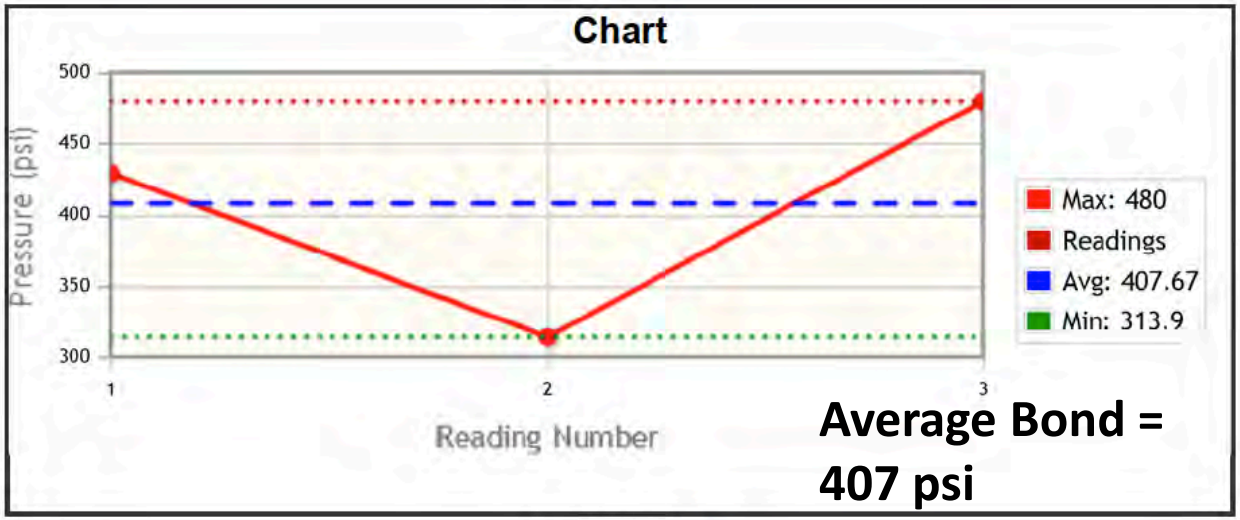
3.) South Pier

Summary

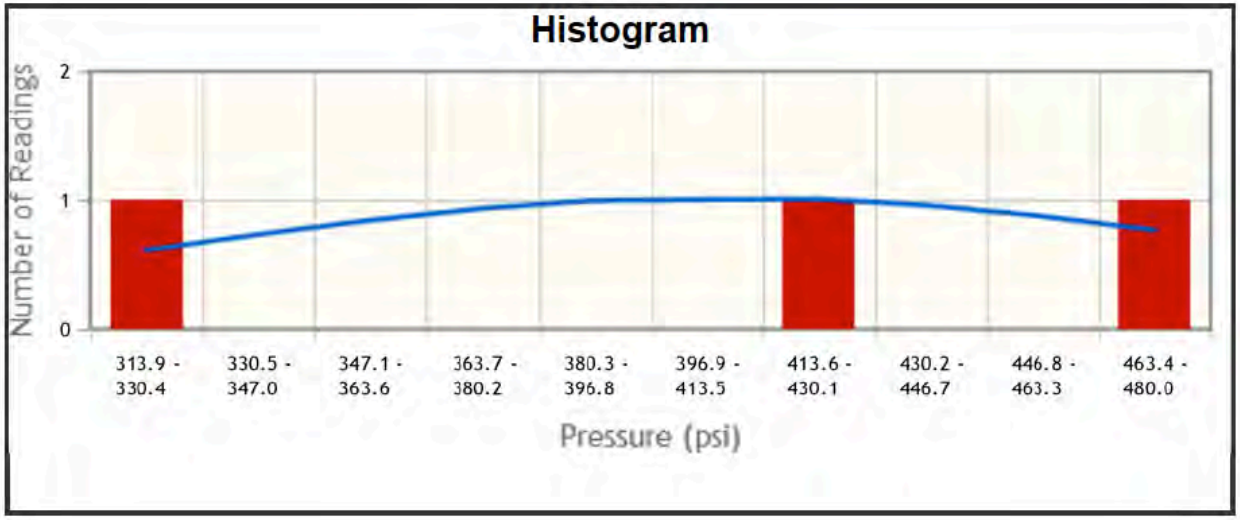
	#	$\bar{x}$	σ	$\downarrow$	$\uparrow$
Exist Concrete	3	407.67	85.10	313.9	480.0

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Pull Tests on Prepared Bare Concrete



Average Bond = 407 psi



INTERNATIONAL CONCRETE REPAIR INSTITUTE

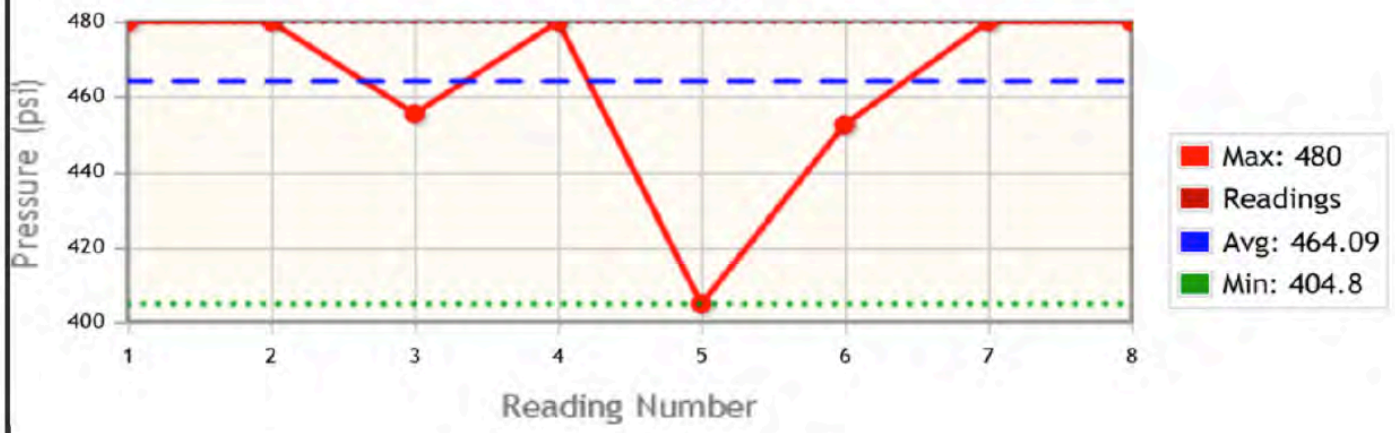
Table of Bond Strength Testing
Epoxy Gel over Prepped Concrete

Readings

#	Reading psi	Ignore	Notes
1	480.0	☐	Rate 8.0 psi/sec, Dur. 57.66 sec, Dolly 50 mm.
2	480.0	☐	Rate 8.0 psi/sec, Dur. 57.66 sec, Dolly 50 mm.
3	455.4	☐	Rate 8.0 psi/sec, Dur. 54.68 sec, Dolly 50 mm.
4	480.0	☐	Rate 8.0 psi/sec, Dur. 57.66 sec, Dolly 50 mm.
5	404.8	☐	Rate 8.0 psi/sec, Dur. 48.40 sec, Dolly 50 mm.
6	452.5	☐	Rate 8.0 psi/sec, Dur. 54.30 sec, Dolly 50 mm.
7	480.0	☐	Rate 8.0 psi/sec, Dur. 57.60 sec, Dolly 50 mm.
8	480.0	☐	Rate 8.0 psi/sec, Dur. 57.60 sec, Dolly 50 mm.

Average Bond = 464 psi (concrete failed)

Chart



INTERNATIONAL CONCRETE REPAIR INSTITUTE

TEST DOLLIES

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Small Batches –Most Efficient Hand Power Tool Batch Mixed

Potential Automated Application Equipment

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Main Water Gate to Columbia River
40’ x 40’

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Application of Epoxy Gel

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Application of Epoxy Gel

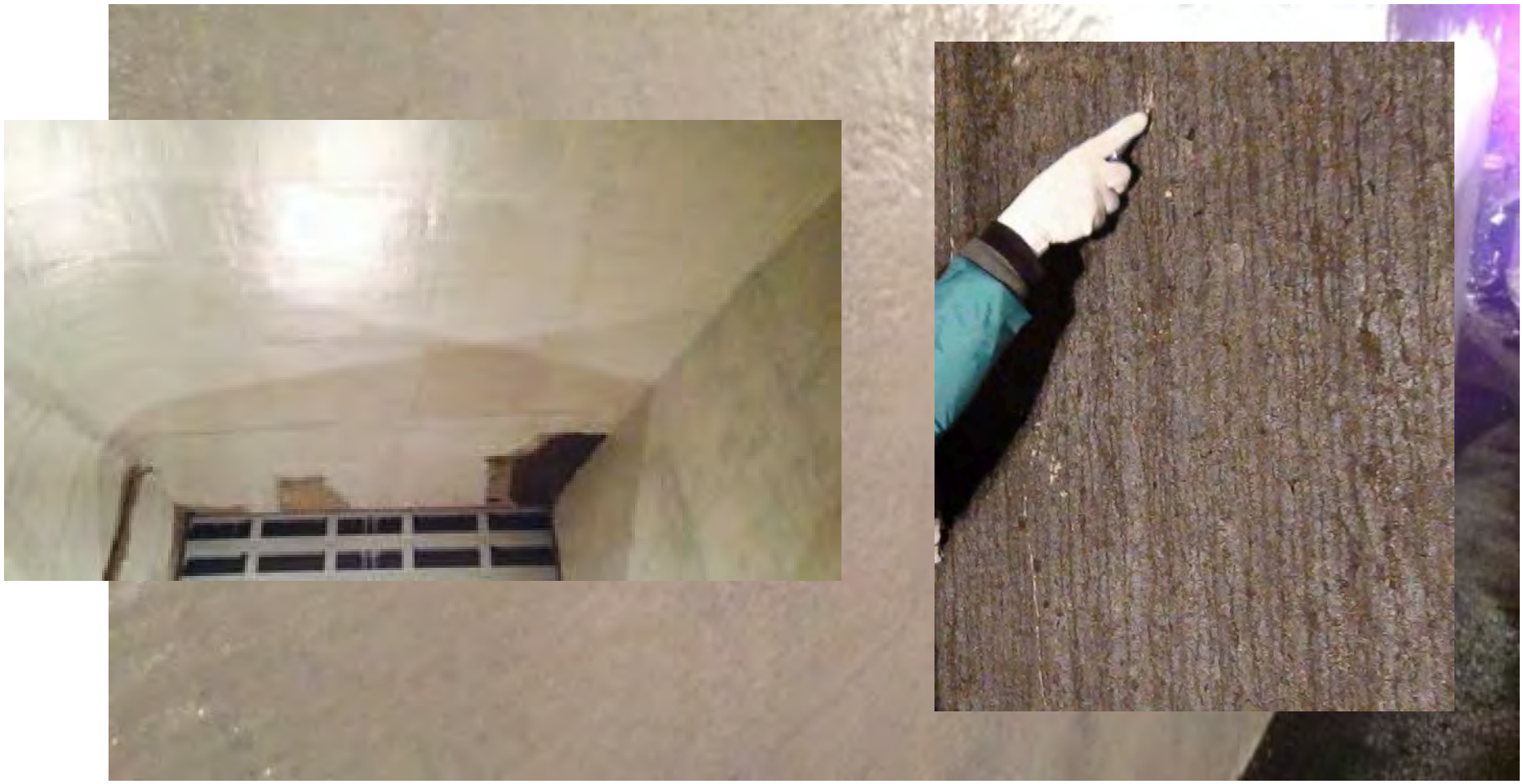
INTERNATIONAL CONCRETE REPAIR INSTITUTE

Man-lift Access Application

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Draft Tube Completed

Completed Application

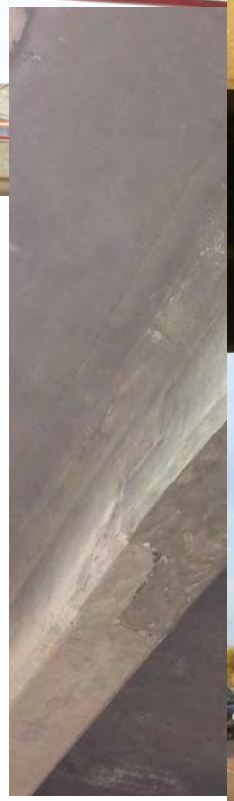


INTERNATIONAL CONCRETE REPAIR INSTITUTE

Other Applications of Epoxy Gel

- Any location where concrete has bug holes, excessive wear, cleanable surface desired
- Any thickness is possible – 100% solids, not solvent or air- cured, NO odor
- Berms, containment curbs
- Filler prior to application of top coats
- Cove base fabrication
- Overhead repairs, bridge underpasses
- Dam spillway surfaces

Colorado CDOT Bridge Repair

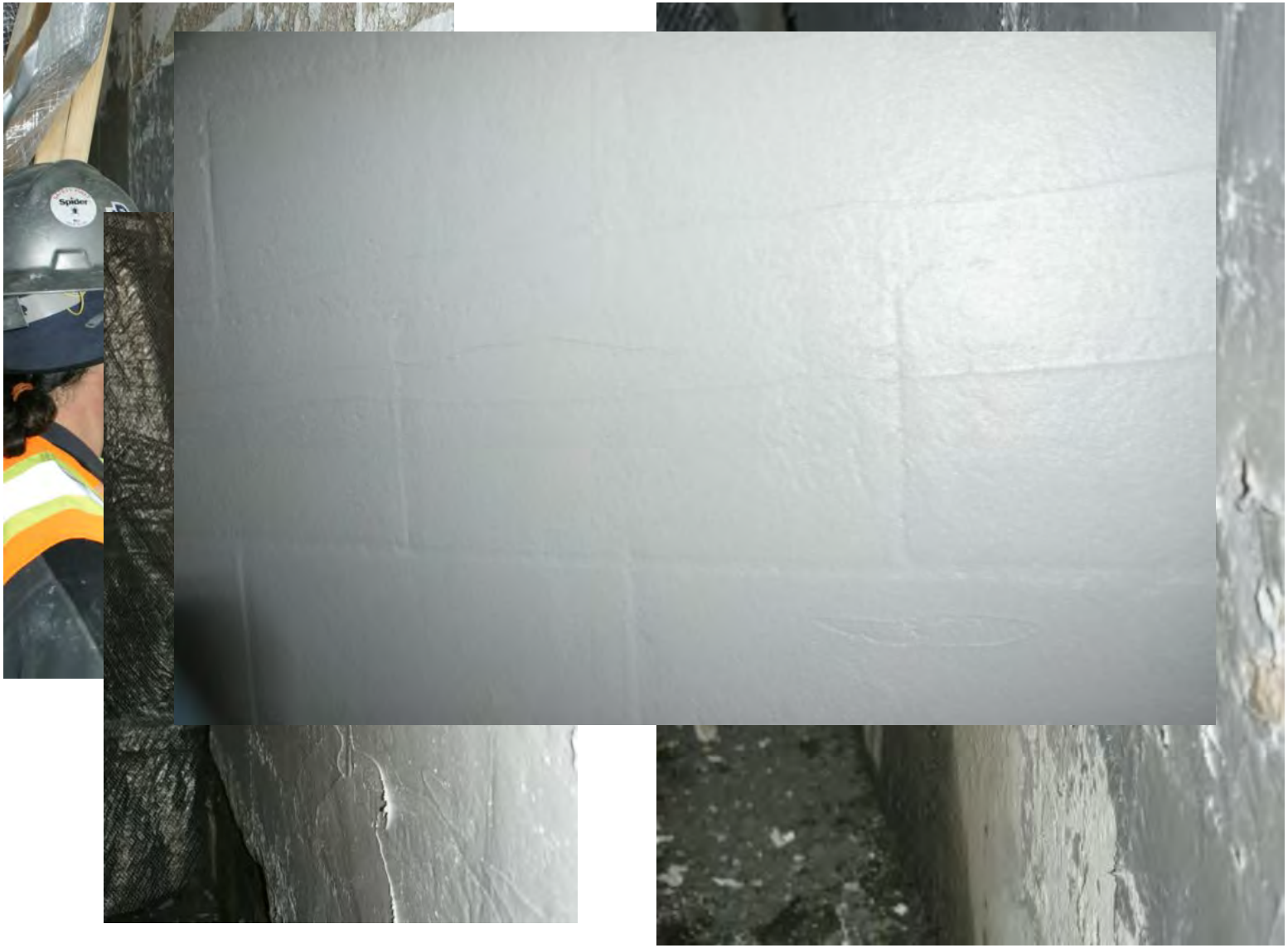


INTERNATIONAL CONCRETE REPAIR INSTITUTE

UPPER STILLWATER DAM

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Dairy Facility - Indoor Concrete Block Repair



INTERNATIONAL CONCRETE REPAIR INSTITUTE

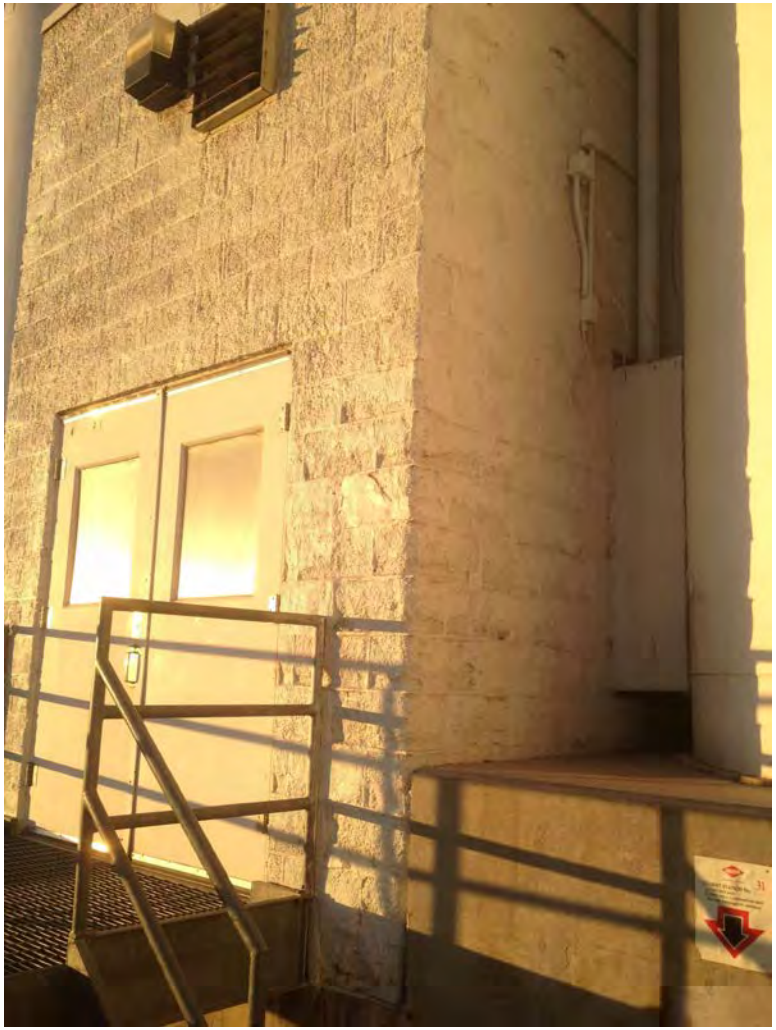
Dairy Facility – Outdoor Concrete Block Repair

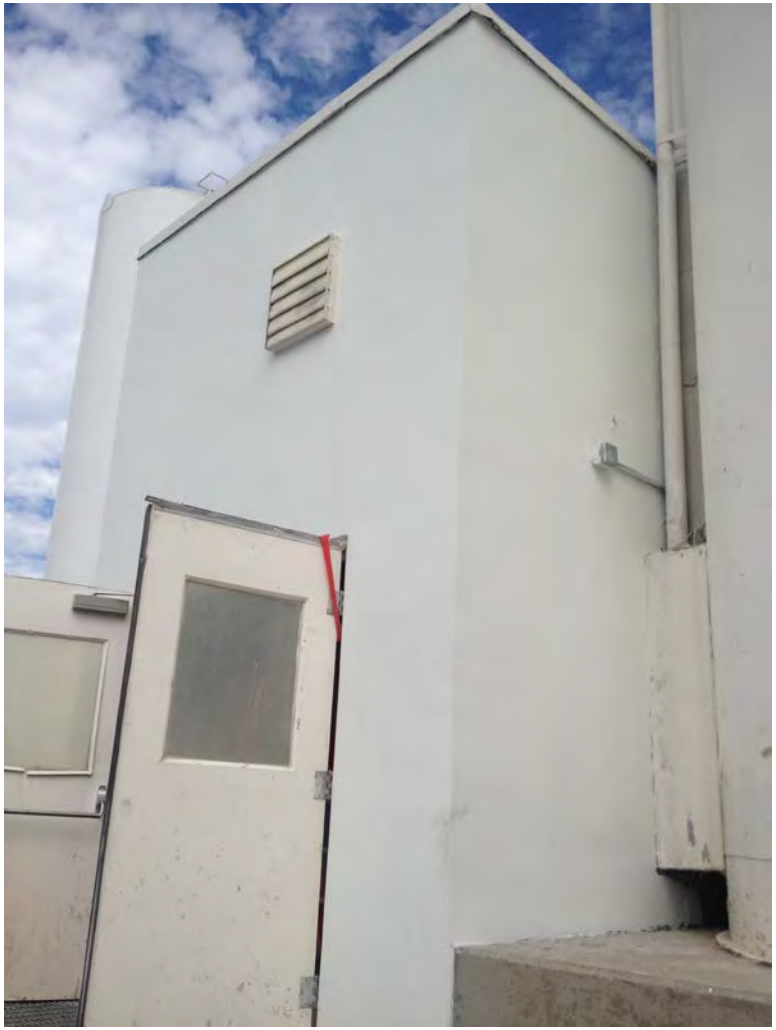
INTERNATIONAL CONCRETE REPAIR INSTITUTE

Dairy Facility – Outdoor Concrete Block Repair

INTERNATIONAL CONCRETE REPAIR INSTITUTE

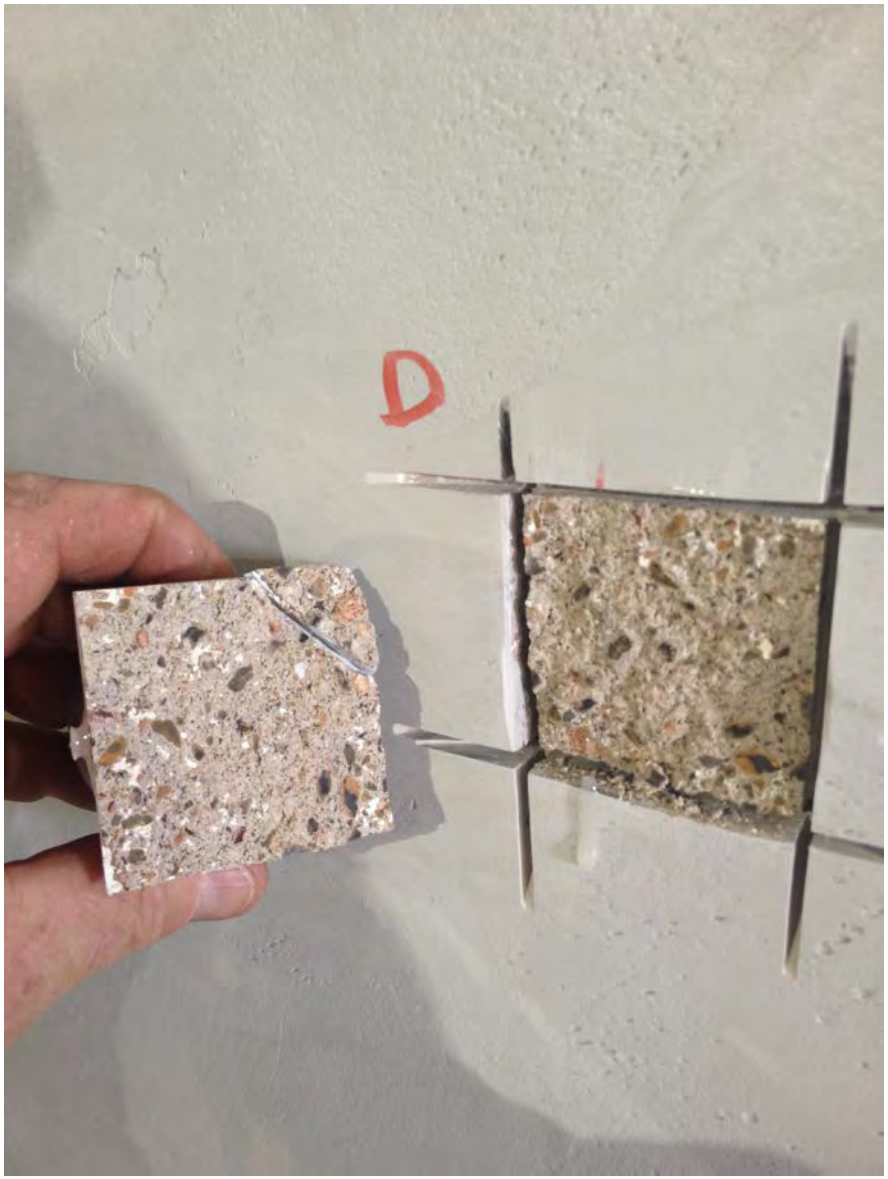
Dairy Facility – Outdoor Concrete Block Repair





INTERNATIONAL CONCRETE REPAIR INSTITUTE

Dairy Facility – Outdoor Concrete Block Repair



Elcometer™ Pull Test
Concrete Failure @ 380 psi
Bond Strength of Epoxy Gel
Was Adequate –Note Concrete
Present on Surface

INTERNATIONAL CONCRETE REPAIR INSTITUTE

Conclusions

- Coating concrete surface of Draft Tube with Epoxy Gel - wear prevention is greatly improved by the presence of an epoxy repair compound
- Potentially and intuitively, with better friction flow characteristics, the generator output ***should*** be improved…..very difficult to quantify since so many other factors also improved-
  - Bearings, windings, major equipment overhaul etc.
- BOR confident in the outcome - proceeding with second unit this month and third in 2017-18
- Brief Video of Installation
- Questions?

INTERNATIONAL CONCRETE REPAIR INSTITUTE

THANK YOU!

- For more information, Please contact:

- Norm Klapper / PEC
  - 2635 Pine Street
  - Boulder, CO 80302
  - (303) 449-5702 W
  - (303) 548-2416 C
  - nklapper@pecboulder.com

INTERNATIONAL CONCRETE REPAIR INSTITUTE