SAND • CEMENT

Back to Basics

WATER • AGGREGATE

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CONCRETE REPAIR
Restore | Repurpose | Renew

2024 FALL CONVENTION

DENVER, COLORADO | OCTOBER 22-25, 2024

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Repairs During Construction

Lessons Learned the Hard Way

Jose Pacheco, PhD, PE, PEng

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2024 FALL CONVENTION
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Outline

- Repairs During Construction
  - *Feature or Bug?*
- Assessing the Repair
  - *Identification*
- Challenges & Constraints
  - *Technical & Non-technical*
- Repair Procedures & Materials
  - *Special cases*
- Durability of Repairs
  - *Often required when service life is specified*
- Case Studies
- Remarks

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Repairs During Construction

- Part of the Construction Industry
  - *Defective vs. repairable*
- Specified vs. Goal-oriented
  - *One-size-fits-all or performance-based*
- Durability
  - *Durability of repair & maintenance considerations*
- Execution
  - *Expertise may not be the same as in new construction*
- Schedule
  - *Delays, adjacent work*
- Cost
  - *Potentially high in certain situations*
- Acceptance
  - *When to punt?*

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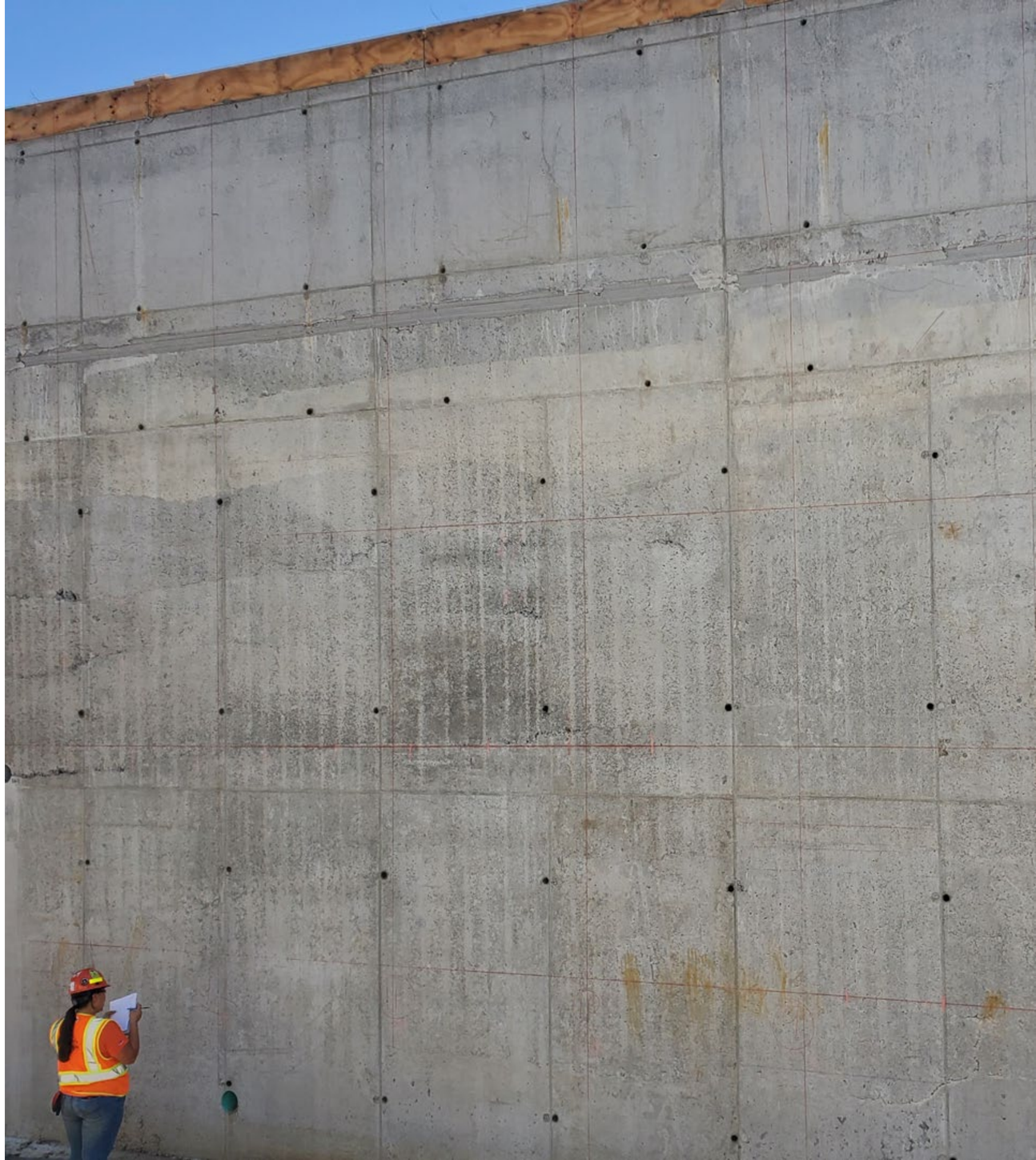

Repairs During Construction

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Assessing the Repair

- Identification
  - *Visual inspection, NDE, etc.*
- Can it be repaired?
  - *Magnitude of issue*
- Impact on Schedule
  - *Include repair preparation & execution*
- Orientation
  - *Horizontal, vertical, and overhead*
- Accessibility
  - *Elevated, confined spaces*
- Stakeholders
  - *Owner, Contractor, Material Supplier(s), QA/QC*
- Accountability
  - *Financial responsibility*

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Challenges & Constraints

- Technical
  - Specification Requirements
    - *one-size-fits-all approach*
  - Mandatory or specified
    - *Adequate in most cases*
  - Project-specific repair conditions
    - *Specification compliance — better solution?*
  - Repair material & method selection
  - Execution
  - Acceptance
- Non-technical
  - Limited time
  - Cost
  - Stakeholder relationship & communication

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1. Wood, and other nonpermanent materials that are more compressible than concrete, may be permitted to be left in the structural concrete of the various excavations outside of the excavated surface when approved by the Engineer.
2. The Engineer will determine if materials are tight in place, provide firm support of the rock, and do not create a continuous soft cushion between the structural concrete and the rock.

G. Concrete Repairs

1. Defective Concrete.
   a. Any concrete that may be found defective at any time before the completion of this Contract shall be cut out to the extent ordered by the Engineer and replaced without additional payment thereafter.
   b. Local repairs shall be made only if explicitly permitted. If local repairs are so ordered by the Engineer, they shall be made immediately on removal of the forms. No thin patches or plastering on concrete will be permitted. Cut recesses of a shape to retain the patches and of a depth to ensure their permanency. If required, set anchor bolts in drilled holes. Embed wire mesh or other suitable devices in the patch.
   c. Any concrete that before the completion and acceptance of all Work under this Contract, develops defects from freezing or from lack of moisture, or from any cause for which the Contractor is responsible, shall be satisfactorily repaired or replaced at the expense of the Contractor.
2. Repair of Cracks
   a. Cracks in concrete shall be repaired by injection of epoxy for structural cracks or by injection of hydrophilic resin for shrinkage cracks as determined by the Engineer. The resulting crack repair shall be watertight. These materials shall be applied in accordance with the manufacturer's recommendations. Initial application of the repair material shall be made in the presence of the Engineer and a representative of the manufacturer. All injection Work shall be performed by experienced personnel certified by the manufacturer.
3. Repair of Formed Surfaces:
   a. The following defects shall be repaired in all types of formed finishes:

6. Methods of Repair of Unformed Surfaces:
   a. Correct high areas in unformed surfaces by grinding, after the concrete has cured sufficiently so that repairs can be made without damage to adjacent areas.
   b. Correct low areas in unformed surfaces during, or immediately after completion of surface finishing operations by cutting out the low areas and replacing with fresh concrete. Finish repaired areas to blend into adjacent concrete. Where the concrete has already set and repairs are required, sawcut around the perimeter of the area to be repaired to a 1/2-inch depth and remove concrete so that the minimum thickness of the repair is 1/2 inch. Apply specified concrete repair mortar in accordance with the manufacturer's directions and recommendations.
   c. Remove defective areas to sound concrete with clean, square cuts, to a minimum depth of 1.5 inches. Provide 3/4 inch clearance all around exposed reinforcing steel. Clean and dampen all concrete surfaces in contact with patching concrete and brush with the specified bonding agent. Place patching concrete while the bonding agent is still tacky. Mix patching concrete of the same materials and proportions to provide concrete of the same type or class and color as the adjacent finished concrete. Place, compact and finish as required to blend with adjacent finished concrete. Cure in the same manner as adjacent concrete.
   d. Where flooring material is to be installed, assure that surface is acceptable for flooring material to be installed in accordance with manufacturer's recommendations.
7. Other Methods of Repair:
   a. Repair methods not specified above may be used with written approval of the Engineer.

FIELD TESTING / QUALITY CONTROL

Field Quality Control Testing:

1. General:
   a. Unless required otherwise by the Contract, all field quality control testing of materials and the resulting concrete for compliance with the technical requirements of the specifications shall be performed by the DEP's Engineering Services group of the Bureau of Engineering Design and Construction and/or the CQAS consultant.

Challenges & Constraints

- Technical
  - Specification Requirements
    - *one-size-fits-all approach*
  - Mandatory or specified
    - *Adequate in most cases*
  - Project-specific repair conditions
    - *Specification compliance — better solution?*
  - Repair material & method selection
  - Execution
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Materials & Procedures

- Compatibility:
  - *Strength, strain, volume, durability*
- Execution
  - *Selection of material & procedures*
- Repair material selection
  - *Resinous, cementitious, others*
- Bagged vs. Produced
  - *Volume of repair & compatibility*
- Placement methods
  - *Hand-placed, form-and-pump, etc.*
- Resources: ICRI & ACI
  - Documents, Committees, etc.

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Case Study: 1 Bridge in MB

- Constructed in 2020
  - *Noticeable deck cracking before the commission*
- Concrete met specification requirements
  - *Compressive strength, chloride penetration*
- Exposure to severe deicing salts
  - *Cracking is a concern for durability*
- Investigation of the potential cause(s)
  - *Document review, coring, petrography, etc.*
- Responsibility
  - *MT, EOR, contractor, material supplier, etc.*
- Repair recommendations
  - *Crack repair vs. crack repair plus overlay*

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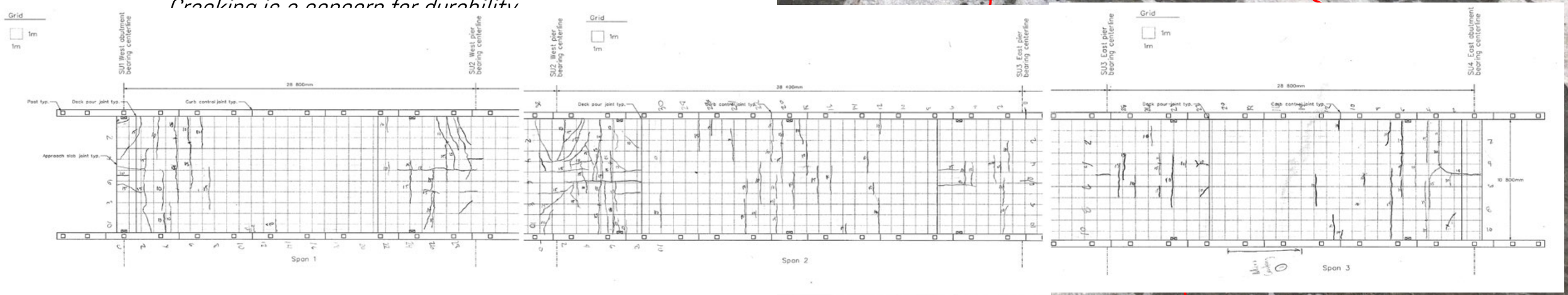

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- **Shrinkage-induced cracking**
- **Crack repair, waterproofing, and overlay**

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Core ID	D1	D2	D3	D4	D5	D6	D7	D8
Core Length	7.2 to 7.5 in. Partial depth	9.3 to 9.4 in. Full depth	2.1 to 2.4 in. Partial depth	8.8 to 8.9 in. Full depth	8.9 to 9.0 in. Full depth	9.0 in. Full depth	10.1 to 10.2 in. Full depth	10.2 in. Full depth
Cracking	None	A few hairline cracks at top surface, extending downward to 0.7 in., locally passing through aggregates	A full-depth vertical crack, passing through and around aggregates.	A full-depth vertical crack, passing through and around aggregates, and narrowing toward bottom. Crack is aligned with rebars.	A vertical crack extending from formed bottom surface upward to 5.5 in., passing through and around aggregates	None	None	A full-depth vertical crack, passing through and around aggregates, and narrowing toward bottom. Crack is aligned with rebar.
Microcracking	• Shallow vertical microcracks in top and bottom surface regions to depth of 0.3 to 0.7 in. • Core D5 exhibits a few vertical microcracks extending to depths of 1.5 to 4.0 in. from top surface, passing through and around aggregates. Two of these vertical microcracks are aligned with major crack. • Short (discontinuous), randomly-oriented microcracks are commonly observed in paste between aggregate particles throughout body of cores; these microcracks are not related to any deleterious reactions within concrete (like shrinkage-related).							
Physical paste properties*	Hard and dense throughout	Hard and dense throughout	Hard and dense throughout	Hard and dense throughout	Hard and dense throughout	Hard and dense throughout	Hard and dense throughout	Hard and dense throughout
W/cm	Moderately low to low	Moderately low to low	Moderately low to low	Moderately low to low (less than 0.40)	Moderately low to low	Moderately low to low	Moderately low to low (less than 0.40)	Moderately low to low
Estimated air content	6 to 8%	6 to 8%	6 to 8%	6 to 8%	6 to 8%	6 to 8%	5 to 7%	7 to 9%

*The paste in the finished top approximately 0.1 to 0.15 in. region of Cores D1, D2, D3, D4, D5, D6, and D8 locally appears somewhat lighter. The paste in this lighter immediate surface region is slightly more absorptive compared to the body, but is still judged to be fairly hard and dense.

Case Study: 2
Marine Structure, CA

- Constructed in 2023-2024
  - *Consolidation issues in cast-in-place concrete*
- Specified Service Life 75 years
  - *Compressive strength, chloride penetration, etc.*
- Exposure to the marine environment
  - *Reinforcing steel concrete cover protection*
- Investigation of the potential cause(s)
  - *Concrete workability, etc.*
- Responsibility
  - *Contractor*
- Repair recommendations
  - *Substrate preparations*
  - *SCC mixture optimization & placement*

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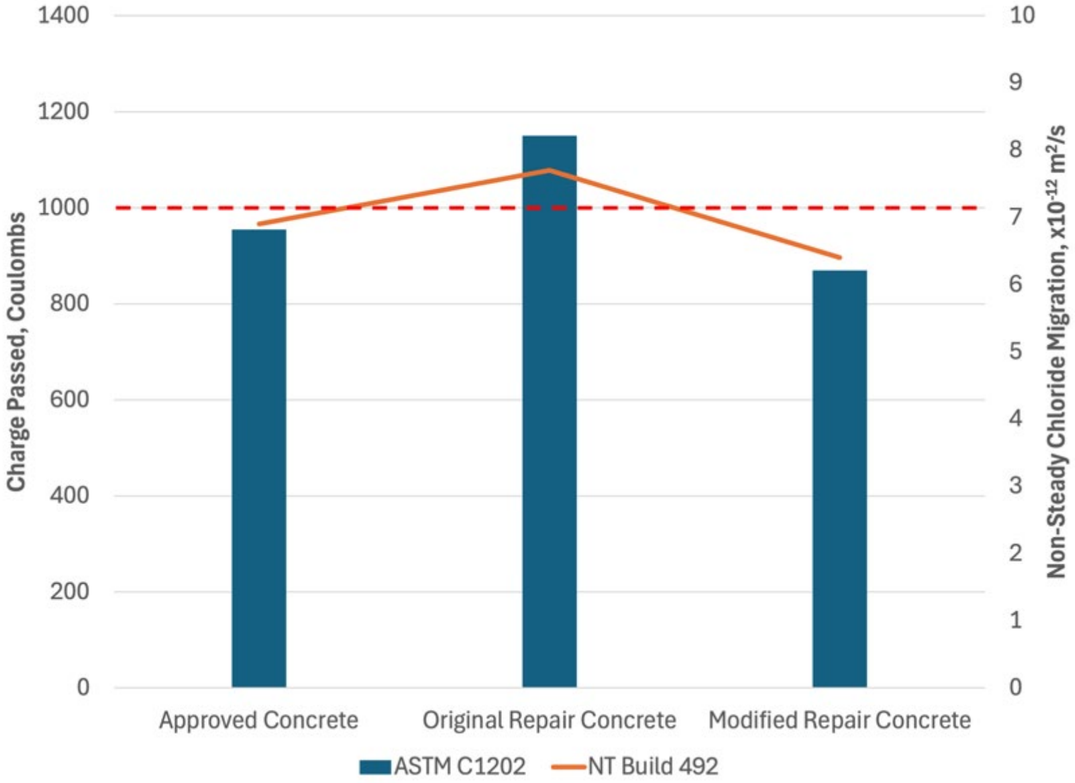
Total cementitious content	752 lbs/yd³
SCM replacement level	30.1%
Info by Volume	
Paste concent, including air	38.9 %
Paste concent, not including air	32.9 %
Mortar content, including air	65.6 %
Coarse-to-fine aggregate ratio	57.0 : 43.0
Total Coarse Aggregate	35.4 %
Total Fine Aggregate	31.3 %
Info by Mass	
Paste concent,	25.9 %
Mortar content, including air	57.2 %
Coarse-to-fine aggregate ratio	57.8 : 42.2
Total Coarse Aggregate	42.8 %
Total Fine Aggregate	31.3 %
Theoretical Density (including air)	147.6 lbs/ft³



Case Study: 3 Abutment, NY

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- Investigation of the impact
  - *NDT by others, coring, depth of consolidation*
- Responsibility
  - *Contractor*
- Repair recommendations
  - *Remove Remove 1" beyond rebar on both faces*
  - *Shotcrete repair*
- **Removed due to schedule impact**

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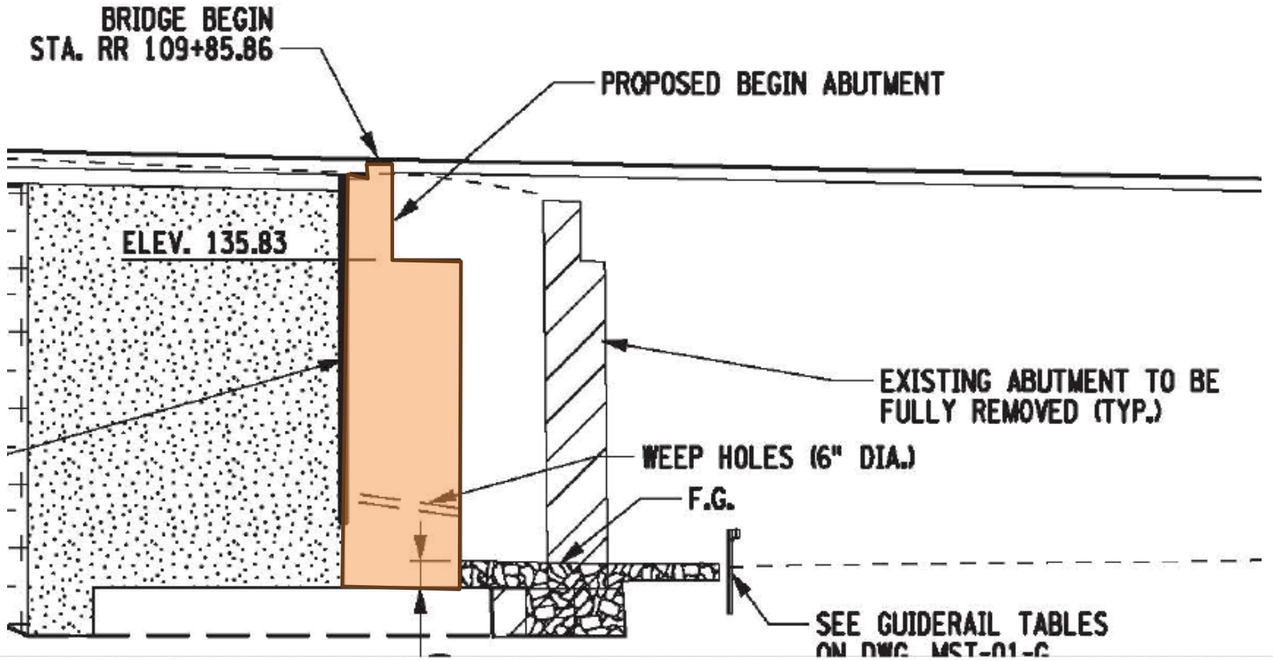

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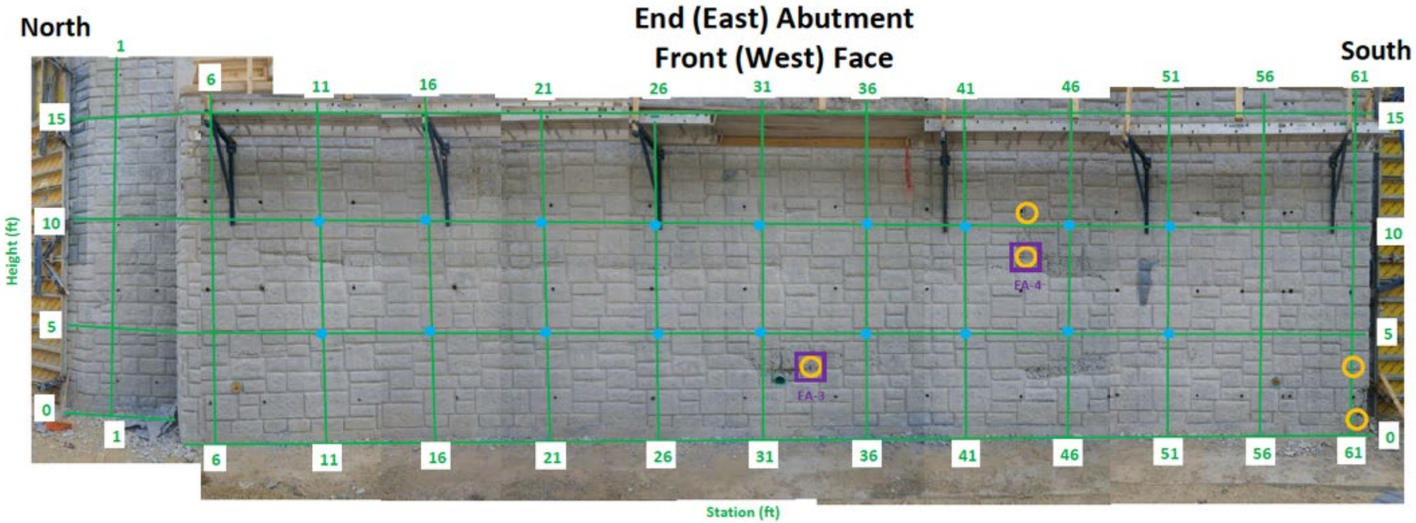

Sensor 3 - Calculated Average Strengths
Surface to 3-6+/- inches

ft	1	3.5	6	8.5	11	13.5	16	18.5	21	23.5	26	28.5	31	33.5	36	38.5	41	43.5	46	48.5	51	53.5	56	58.5	61
25.0																									
22.5																									
20.0	3500																								
17.5	4800																								
15.0	4400																								
12.5	4800		5600		3900		4900		4300								4800	3800	3300	5700	3600		4700		
10.0	4200		4700		4400		4400		5000		5100		5200		4200	5000	4900	2100	4400	4900	5000		4900		5000
7.5	4100		6100		4300		4000		6000		4000		4100	4500	3500	4400	5400	2900	3600	5400	5700		6400		5000
5.0	7000		4900		5000		5000		5500		4600		5000	4500	5500	5000	4700	4600	5200	4800	4900		6500		3000
2.5	4900		5200		4900		4000		5700		4300		3400	1800	4900	4400	5600	4800	4000	4700	4900		4300		2600
0.0	5500		5300		5500		4600		6300		4100		5200	4900	4400	4300	7000	5400	6100	4300	5200		4800		2600

Surface to 6-10+/-inches

ft	1	3.5	6	8.5	11	13.5	16	18.5	21	23.5	26	28.5	31	33.5	36	38.5	41	43.5	46	48.5	51	53.5	56	58.5	61
22.5																									
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17.5	4300																								
15.0	4500																								
12.5	5300		5200		5000		4300		5100								5700	5000	5600	5600	5700		5500		
10.0	4100		5100		4700		4700		5700		5900		6100		5400	5700	5500	6600	5300	5300	6300		5600		5700
7.5	4800		5200		5100		5300		7000		5700		5200	5600	4600	5400	6000	3000	4600	6300	6500		6500		5300
5.0	5500		5400		6400		5400		5500		5100		5800	4900	5200	5300	5600	5000	5600	5400	5700		5900		4700
2.5	6100		5400		5000		4300		6500		4300		4900	3000	5400	4800	5200	6000	5200	5500	6300		6000		4600
0.0	6100		5900		5100		5700		5900		5100		7000	4900	5500	5900	6200	5500	4700	4900	6000		6100		5400

Case Study: 3 Abutment, NY

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  - *Reinforcing steel concrete cover protection*
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  - *NDT by others, coring, depth of consolidation*
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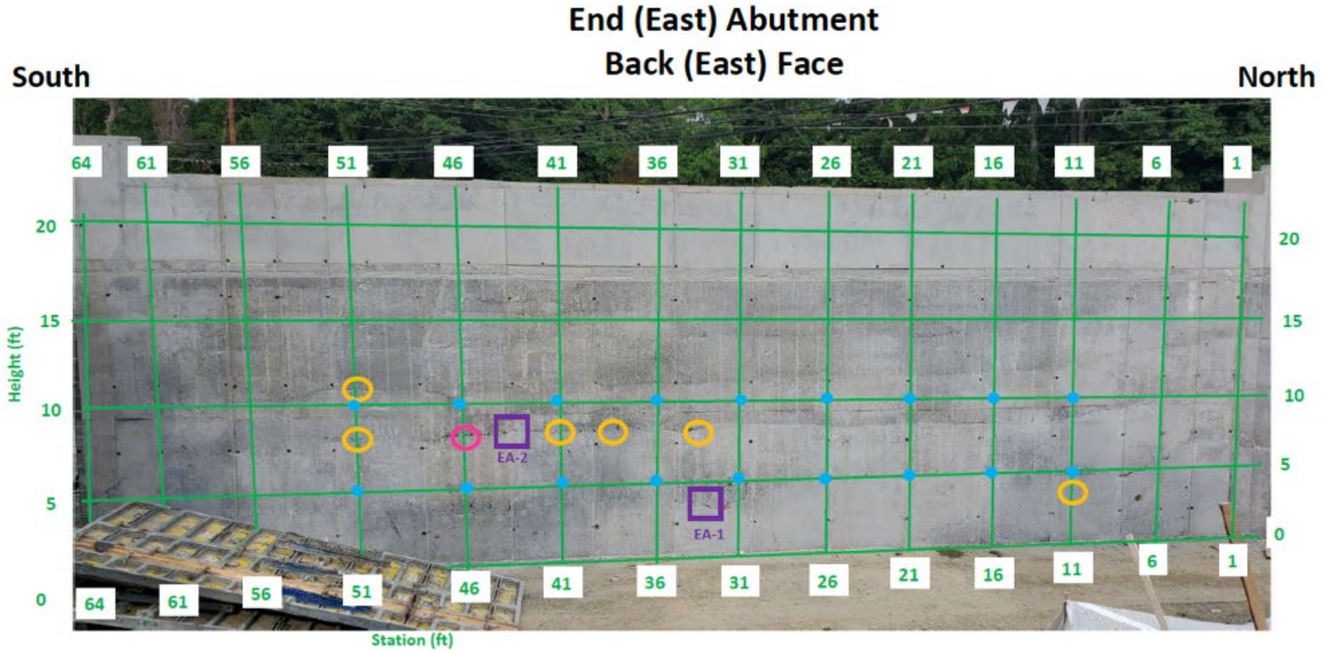

Station (ft)

Sensor 2 - Calculated Average Strengths
Surface to 2-3 inches

	64	61	58.5	56	53.5	51	48.5	46	43.5	41	38.5	36	33.5	31	28.5	26	23.5	21	18.5	16	13.5	11	8.5	6	3.5	1	-1.5
25.0		4600		3800		3300		1900	3100	3800	4300	4600	3300	4300		4300		4300		3300		3500		4000		2700	
22.5		4300		3300		5300		1000	4900	2700	5300	3500	1000	4000		3300		1100		4600		3300		3500		3300	
20.0		4000		3500		4300		2500	4900	2500	1600	4100	3100	4300		4000		2400		1100		3300		3800		5300	
17.5		5700		2500		4300		4000	6400	3800	5700	2100	4000	4300		3500		3500		2700		2100		3800		3800	
15.0		4300		3300		3100		5300	4300	2500	2900	4300	2700	5300		2900		1000		3800		2400		4900		4600	
12.5		3500		4600		1000		1000	1000	1000	1200	3300	1000	4600		4000		1000		3300		3100		6400		5300	
10.0	4600	4600		5700		4900		2700	4300	3100	3500	4600	3100	5300		3500		3500		3800		5300		3500		4000	3700
7.5	4100	4600		5300		4700		3300	4000	4900	3800	4000	1000	4300		4000		4600		4000		2000		6000		3500	
5.0	5000	3500		5700		3500		4300	3500	6000	3500	4000	4900	5300		4300		1000		4000		4300		4300		4300	
2.5																											
0.0																											

Sensor 3 - Calculated Average Strengths
Surface to 3-6+/- inches

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22.5		5300		4100		5700		4400	6500	4800	6000	4500	4900	5000		4300		3200		5800		3200		4200		3200	
20.0		4900		4300		5400		3700	6700	3700	4800	3800	4400	4800		4900		3800		3500		3500		4000		3500	
17.5		6200		4400		5000		4900	6500	4400	4900	4300	5100	4800		5100		4800		3800		4000		5200		5200	
15.0		5200		3200		2800		5400	5900	5200	3900	5400	4600	6200		5300		5400		3800		4300		3200		6000	
12.5		5100		5300		1700		1300	5100	2400	2800	4900	2600	6200		4900		4800		5100		5100		5700		4700	
10.0	6300	5600		5400		5700		4000	5900	5100	4300	5600	4400	4400		4600		5300		5000		4800		5000		5200	5100
7.5	4100	6300		6600		6200		4300	6200	6000	4400	4900	3800	5500		4400		5400		5000		2900		5500		4900	
5.0	3300	3500		6000		5600		5700	5400	6000	5500	5600	5300	6300		5100		4300		5100		5100		5400		5300	
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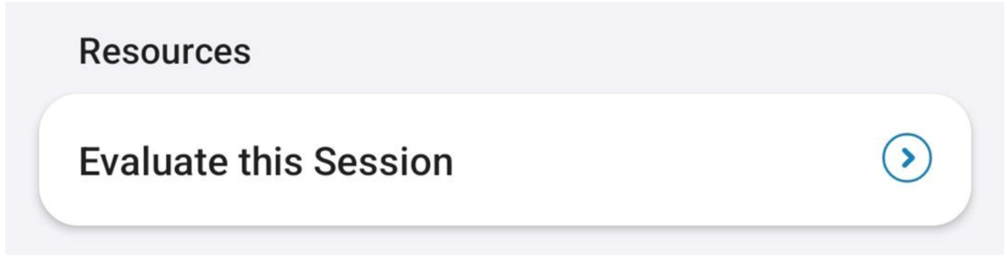
REMARKS

- Repairs during construction are frequent.
- Repair specifications may require adjustments
- Understanding the specification & assessing the repair is crucial
- Stakeholder communication — make or break
- Aim for durable (and sustainable) repairs
- Challenges with repair execution
- Responsibility & accountability

SESSION EVALUATION



To complete the session evaluation, open the ICRI Convention App.

Under **Plan Your Event,** select Schedule, and then the Technical Session you are attending. Select the sub-session you are attending, scroll down to Resources, and select Evaluate this Session.

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2024 FALL CONVENTION
OCTOBER 22-25, 2024

Repairs During Construction

Lessons Learned the Hard Way

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THANK YOU

FOR YOUR ATTENTION

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