The Condition Assessment Term Project

Applying Materials Knowledge in the Real-World

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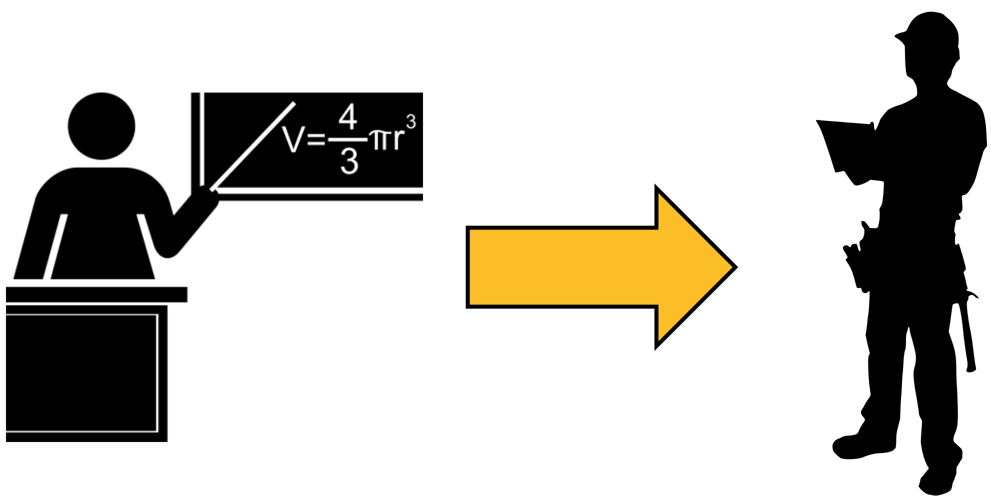
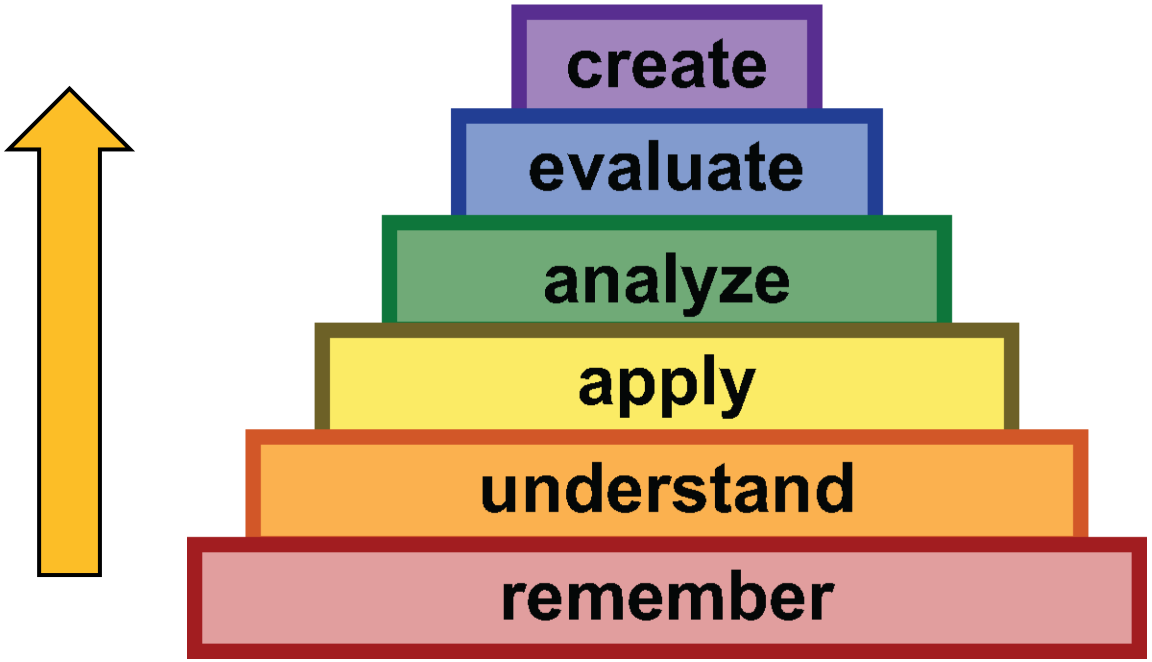
Why Project-Based Learning?

- **Deeper engagement with course content than lectures alone**
  - Students get invested in their topics
  - Typically longer-term, if structured well
- **Couples course content to the "real world"**
  - Novel opportunities to implement learning
  - Leads to <u>longer-term</u> knowledge retention
- **Promotes Professional Identity** (Johnson et al. *IEEE Frontiers in Education 2015*)
  - Students learn aspects of professional practice



Why Project-Based Learning?

- **Fosters growth of higher-order skills**
  - Move from “cramming” to “creating”



Bloom’s Taxonomy

Challenges of Project-Based Learning

- **Challenges for Students**
  - “I don’t have time for this” or “This is WAY too much work”
  - “I don’t feel prepared for this”
  - Either “I hate group work” or “We should have groups”
  - “Why don’t you just give us an exam?”
- **Challenges for Educators**
  - More time to grade than typical assignments or exams
    - More feedback = better student product
  - Must build in throughout the course
  - Managing group dynamics
  - Motivating students to engage

My [limited] Experience

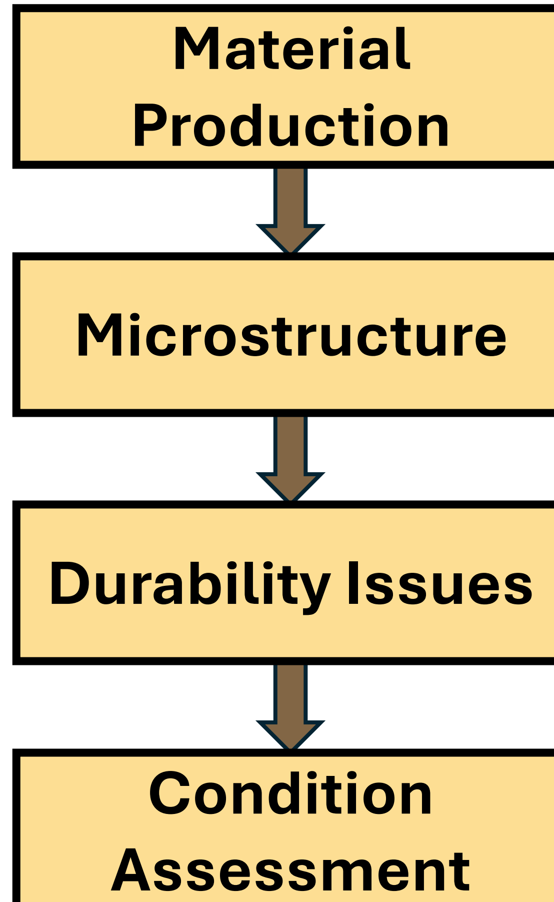
Forays into PBL…

- **Advanced Materials (Graduate Course) -> Fall 2024**
  - Production, microstructure & durability of construction materials
  - Term Project: Condition Assessment Report

- **Structural Timber Design (Senior Design Elective) -> Spring 2025**
  - Allowable Stress Design of wood buildings per the NDS
  - Term Project: Design a 2-Story Wood Building

Course Outline

- **Goal:** Provide mechanistic understanding of performance & durability for cementitious materials, steel & wood
- Similar content structure for each material
  - ~6-8 wks on concrete
- Each component is paired with “Active Learning” activity
- Students are assigned term project ~3/4 through course



Active Learning Along the Way

Opportunities to Practice & Apply Techniques Prior to Term Project

Material Production ← Lab Activity: Concrete Mix Design & Batching
- Fresh Concrete Testing
- Hardened Concrete Testing

↓

Microstructure ← Discussion Post for Microstructure “Models”

↓

Durability Issues ← Discussion Post for Student-Reported Durability Issues

↓

Condition Assessment ←
- “Site Visit” to Degraded Structure
- Jigsaw activity on Condition Assessment Techniques

“Soft Skills” Along the Way

Cultivating research skills & professionalism through activities

Lab Activity: Concrete Mix Design & Batching
- Fresh Concrete Testing
- Hardened Concrete Testing

Lab Reports Evaluate Writing

Discussion Post for Microstructure “Models”

Discussion Post for Student-Reported Durability Issues

Professional Communication, Peer Review

- “Site Visit” to Degraded Structure
- Jigsaw activity on Condition Assessment Techniques

Exposure to Professional Standards/Practices & Reporting
Literature Review

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Goal: Apply materials knowledge to real structures
"Civil Engineering Worldview"

Students take on role of forensic engineer to:

1. Identify & **visually inspect** a structural system
2. Report **key durability issues**
3. Perform a **literature review** of one key durability issue, including diagnostic methods & mitigation strategies
4. **Discuss** how the literature relates to their specific observations
5. **Recommend actions** for the building owner
6. **Present** findings to the class

The Term Project

Deliverables: Each item submitted in "draft form" every week, reviewed, and returned for revision prior to final report

Students take on role of forensic engineer to:

1. Inspection Report -> **Submittal 1**
2. Summary of Key Issues -> **Submittal 1**
3. Literature Review-> **Submittal 2**
4. Discussion -> **Submittal 3**
5. Recommendations -> **Submittal 4**
6. Presentation -> **Last Day of Class**
7. **Final, revised report**

Provide feedback & opportunities for growth

The Term Project

Feedback: Each submittal has ***detailed instructions & rubric*** so students have clear expectations of what they should do & how they will be evaluated

Score:	3	2	1	0
Literature Review (15-pts)				
Introduction (1.5-pts)	- A short description is provided of the specific issue identified in your structure (i.e. types of cracks,	• Some description of the observed durability issue is included, but it	• A description of the observed durability issue or a summary of the durability	Missing
Body (9-pts)	- Each prompt question is thoroughly discussed and includes - The relevance of each cited work to the current review is noted. - The review is well-formatted, easy to read, and follows a logical flow. - 7-10 references are cited in the text using a standard citation format.	- Each prompt question is specific contributions or relevance to the current review are missing. - 7-10 references are cited in the text using a standard citation format but may have some errors.	- Discussion of one or more prompts is relevance - Review is difficult to read due to poor formatting or logical flow - Some References are missing	Missing

A rubric is an instructional document

Can be implemented in Canvas for easy grading

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Feedback:

- Provide comments to explain grade
- Require/incentivize students to address comments in revision

Body	**Excellent** - Each prompt question is thoroughly discussed and includes relevant citations. - The contribution of each cited work to the literature is summarized . - The relevance of each cited work to the current review is noted. - The review is well-formatted, easy to read, and follows a logical flow. - 7-10 references are cited in the text using a standard citation format. **Comments** Very good job on summarizing the issue and calling out relevant sources - especially the ACI sources describing the repair strategy. Your formatting needs a little bit of work to distinguish the section headings. You could use numbered headings (2.0 - Mechanism; 3.1 Assessment of Corrosion). This just helps the flow a little bit. 8 / 9 pts

The Term Project – Example Final Report

BRIDGE CONDITION ASSESMENT IN LARAMIE AND DETAILED REPORT

Term Project: Final Report

DESCRIPTION

This project is a part of the course works for CE 5230: Advanced Materials, Spring'2024, University of Wyoming.

[redacted]

Graduate Research Assistant, Department of Civil & Architectural Engineering & Construction Management, University of Wyoming.

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BUSINESS MEMO

[redacted]
University of Wyoming
1000 E University Ave
Department 3295
Laramie, Wyoming
[redacted]

Professional Communication

Date: 12/06/2024
Dr. Garrett Tatum
Engineering 3029
1000 E University Ave – Dept 3295
Laramie, WY 82071

Dr. Tatum:

This report summarizes the inspection and assessment of the bridge on Snowy Range Road, conducted on November 9, 2024, to evaluate the durability issues related to moderate sulfate attack. Key findings included longitudinal cracks with efflorescence on the abutments, inadequate drainage contributing to damage, and visible signs of sulfate-induced deterioration. To address these issues, we recommend improving the soil with Ground Granulated Blust Furnace Slag with Lime, sealing cracks and joints with low-C3A cementitious grout, improving drainage systems to prevent water accumulation, and conducting regular non-destructive testing to monitor the structure's condition.

We sincerely thank the Wyoming Department of Transportation (WYDOT) for the opportunity given to us to perform this assessment and look forward to collaborating further to ensure the bridge's long-term safety and functionality.

Thank you,

[redacted]

Graduate Research Assistant

University of Wyoming

[redacted]

Enclosures:

- Site Visit & Condition Assessment Report
- Literature Review on Sulfate Attack
- Discussion and Recommendations on the Concern

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VISUAL INSPECTION REPORT CHECKLIST

General	Inspector's Name	[redacted]
	Date of Inspection	11/09/2024
	Purpose of Inspection	Educational
	Weather Conditions During Inspection	• Snowy, with heavy snowfall an hour before the visit • Temperature 2° C (felt like -5° C) (*Figure* 1) • Windy, and clear skies
Description of Structure	Name	Officially unnamed.
	Location	A bridge connecting East and West Laramie on Snowy Range Road, located above Laramie River, accessed underside via Laramie River Greenbelt Trail, Laramie, Wyoming, USA. Coordinates: 41.314581, -105.605641 (Google Maps) (*Figure* 2)
	Type	Highway Bridge
		: Maps measurement

Locations and Weather References

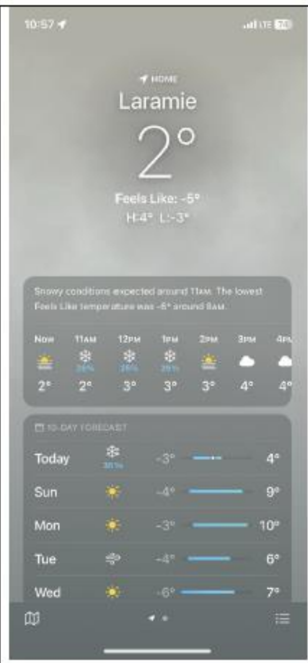

Figure 1: Inspection Day Weather

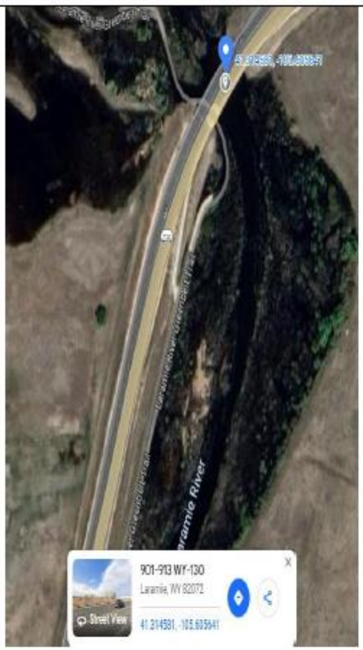

Figure 2: Coordinates from Google Maps

Figure 3: Historical Image from Google Earth

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CE 5230 SITE VISIT & CONDITION ASSESSMENT [redacted]

2) Transverse Cracks Seeping Water on the Bottom Side of the Main Bridge Deck (Drying Shrinkage with probable jointing issue):

Observations and Locations:

Transverse cracks were observed on the underside of the main bridge deck, with a pattern of lines. These cracks display a white residue seeping out along the lines, indicative of potential water movement within the deck slab, probably through the joints (*Figure* 11). The bottom side of the deck could not be reached because of the inaccessibility of tools, which could take me a little longer to touch its surface.

Dimensions and Deterioration:

Crack lines were spaced 8-10 inches apart, with line thickness around 2 inches, and the lengths are estimated to be over 6-7 feet.

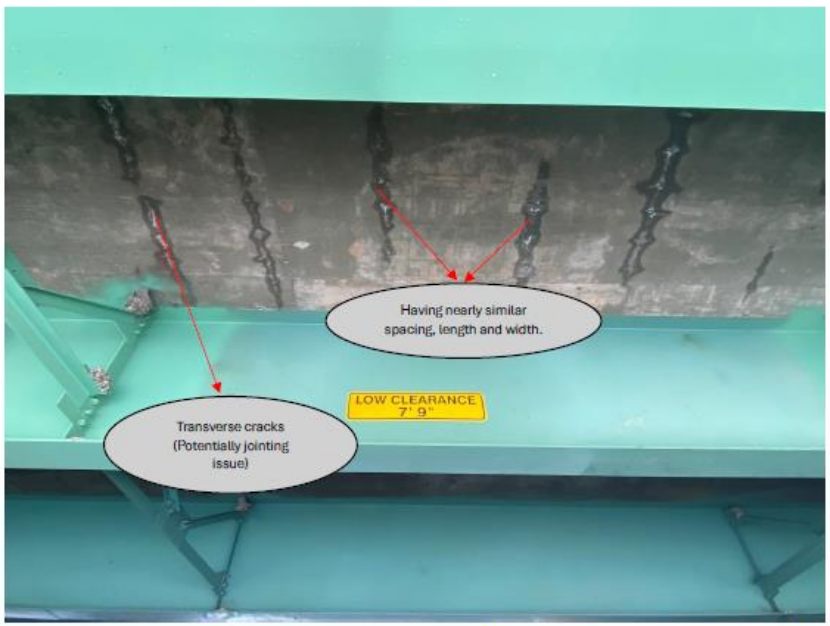

Figure 11: Transverse Crack Seeping Water (Drying Shrinkage with potential jointing issue)

Likely Material Mechanism:

The observed white substances and the cracking pattern indicate poor joint design. Also given the snowy conditions during the inspection and Laramie's extremely cold weather, the chances of shrinkage of the concrete panels are really high. Drying shrinkage due to temperature drop can help

× Comments 17

Add a comment

[redacted]
Dec 4

The instructor's comment was,
"There is definitely water seeping through the cracks - though I'm not sure that this will be F/T, mainly b/c I'm not sure this would be able to maintain the high degree of saturation required (the water would fall out). I'm guessing this is shrinkage, related to the joints as you mentioned, or even flexural cracking"

=> **This whole section (2) is revised according to the instructor's comment. Yellow highlighted portions are the UPDATED lines.**

Add a reply

Page 13 1

[redacted]
Dec 4
Figu ... e/thaw
cycl
Repl

Responding to feedback

Page 15 1

[redacted]
Dec 4

The instructor's comment was to provide an approximate number and sizing of the minor surface defects.

=> The yellow line covers the requirement.

Reply

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LITERATURE REVIEW ON SULFATE ATTACK

1) Introduction

The most pressing issue from the site visit and condition assessment report is determined to be Sulfate Attack which is one of the most challenging durability problems faced by reinforced cement concrete structures, especially in environments rich in sulfates. During the site investigation, longitudinal cracks on the abutment of the bridge, accompanied by a white, powdery substance(efflorescence) (*Figure* 22) were observed. This visible damage is a clear indicator of sulfate attack, a process where sulfate ions interact with the hydration reactants and products in concrete. These reactions result in the formation of expansive compounds such as ettringite and gypsum, which gradually weaken the concrete by causing internal stress, cracking, and also spalling. Over time, this deterioration compromises the structural integrity and longevity of the material. This review draws on eight peer-reviewed scientific papers to dive into the mechanisms behind the problem, how it propagates damage from the microstructure to the larger structural scale, its impact on the lifespan of concrete structures, and discusses the common strategies for both repair and prevention.

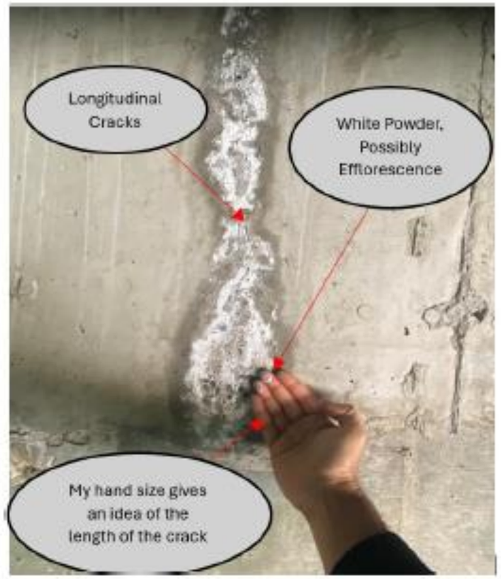

Figure 22: Efflorescence from Sulfate Attack

In this review, the key aspects of sulfate attack in concrete will be reviewed:

- Beginning with an analysis of the microstructural mechanisms that initiate this durability issue is explored [2.1].
- Then how these microstructural changes propagate into visible damage at the structural level is examined [2.2].
- Following this, the discussion focuses on how sulfate attack impacts the service life of affected structures, highlighting its long-term consequences [2.3].
- Finally, most common and effective repair techniques and prevention strategies to mitigate this issue and ensuring the durability of concrete structures in sulfate-rich environments will be reviewed [2.4].

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DISCUSSION ON THE CONCERN

Brief: The observed durability issue is Chemical Sulfate Attack, and it is well-supported by both field observations and the literature reviewed. During the site visit, longitudinal cracks and efflorescence (*Figure* 6) were documented on the west side of the abutment, particularly near areas exposed to moisture and potentially sulfate-rich soils. These visible signs align with the processes described in the literature(Najjar et al., 2017), where sulfate ions react with hydration products in concrete, forming expansive compounds like ettringite and gypsum, eventually resulting in similar crack patterns with efflorescence. This happens when these ettringite needles generate internal stress that leads to irregular cracking, and microstructural disintegration (Zhang et al., 2020). The field observation of white, powdery efflorescence is consistent with the chemical reactions of sulfate attack, as highlighted by Najjar et al. (2017), who described similar patterns in sulfate-exposed concrete for different lab samples exposed to high concentrations of sulfates.

Initially, the observed mechanism was diagnosed as potentially Physical or Chemical Sulfate Attack, but the observed damage is unlikely to be caused by Physical Sulfate Attack (PSA) because PSA typically occurs in partially saturated environments where sulfates crystallize from evaporating moisture, creating external pressure on pore walls. In this case, the efflorescence observed on the abutment is indicative of internal chemical reactions, not external salt crystallization. This is because of the absence of visible scaling or flaking on the surface of the abutment(Meng et al., 2020). As the longitudinal cracks look like they are internally degraded, Chemical Sulfate Attack (CSA) aligns really well where sulfate ions penetrate the concrete from the soil near the abutment and react with hydration products like monosulfate and C3A and forming expansive ettringite and gypsum, thus breaking the microstructure internally.

Further Test Methodologies

i) Chemical Identification of the White Powdery Substance:

- California Test 417 can be performed for the determination of sulfate content of soils and waters. In this test method, the sulfate ion is precipitated with barium chloride, in an acidic medium, to barium sulfate crystals of uniform size. The barium sulfate present in suspension is determined by a measurement of its turbidity and comparison with a known standardization curve(California Test 417, 1999).
- Also, ASTM C1012/C1012M – 24a can confirm whether the observed powdery substance is sulfate-related by preparing cement mortar bars from the samples from the structure (if can be retrieved) and immersing them in a sulfate solution to simulate exposure. Dimensional changes over time indicate susceptibility to sulfate-induced expansion, providing direct evidence of reactions like ettringite or gypsum formation and validating the diagnosis of sulfate attack.

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RECOMMENDATIONS

To mitigate the effects of the Sulfate Attack on an important bridge connecting the East and West Laramie and to ensure the long-term stability of the structure, the following actions are recommended to the Wyoming Department of Transportation (WYDOT):

1) Soil Improvement beside the Abutment: To mitigate sulfate attack and improve soil stability, in-situ stabilization using a combination of Ground Granulated Blast Furnace Slag (GGBFS) and lime is recommended. Mixed in a 5:1 ratio, this method reduces sulfate-induced swell by neutralizing reactive sulfates while enhancing soil strength and lowering plasticity. The use of 5% GGBFS to 1% dry weight of lime results in the least amount of swell than any other option(Harris et al., 2006).

2) Surface Coatings: It is recommended to avoid using exterior coatings like epoxy or sheet materials, as they may trap moisture and cause hidden deterioration behind the coating(Haynes et al., 1996). Also, it is not possible to put coating as suggested by researchers(Suleiman et al., 2014) because the back end of the abutment cannot be coated as soil removal is highly risky.

3) Seal Cracks and Joints: Visible cracks and joints should be repaired using cementitious grout (containing low C3A content). This will restore the concrete's structural integrity and prevent further sulfate ingress, which could accelerate degradation(Elahi et al., 2021).

Key Takeaways

Feedback from Students:

- Most difficult part of project was identifying a structure
  - Can work with others on campus to identify potential sites
- Students felt supported by rubrics & instructions
- Project was effective at applying course material
- Students felt it was “realistic” experience

Key Takeaways

Elements of successful project-based learning:

- Well-integrated into course content
    - Students should be developing skills throughout the term
- Instructor support is critical
    - Clear expectations
    - Quality feedback
- Integrates “soft-skills”
- Student engagement
    - Consistent active learning helps
    - Feels like “real life”

Thank you!

Questions?

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Google Drive Folder with my Project Materials

EnDURES Lab Group