CONCRETE REPAIR
Restore | Repurpose | Renew

2025 SPRING CONVENTION

AUSTIN, TEXAS • APRIL 13 – 16, 2025

www.icri.org

Bio-Inspired Technologies for Concrete Repair and Rejuvenation

Colloidal Silica – Extending Concrete Life-Cycles

Jon S. Belkowitz, PhD, PE
Chief Technical Officer
Intelligent Concrete, LLC

Overview

- Purpose
- Define and Describe
- Review Practical Impl.
- Illustrate the Impact
- Summary
- QnA

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Problem

America's infrastructure is falling apart. The American Society of Civil Engineers has given U.S. infrastructure a grade of D+

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Opportunity

Concrete is the most widely used building material on the planet.

600K	$48B	$8.3B
The U.S. alone has more than 600,000 concrete bridges	The US concrete industry is over $48B annually	Every year, $8.3B is spent maintaining concrete infrastructure

Purpose

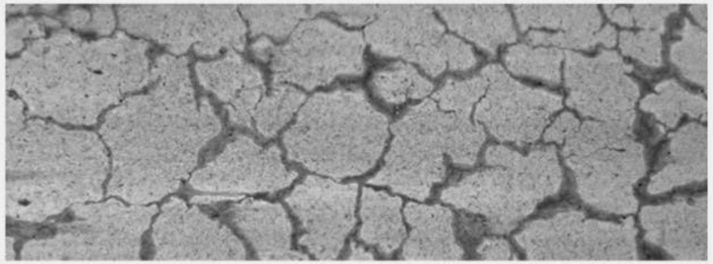
- **Learning Objective 1 – Define and describe the innovative nature of nano silica healing and self-healing concrete technologies, its objectives, and approach, for cracked and deteriorated concrete,**
- **Learning Objective 2 – Review the practical implications of nano silica technologies in improving infrastructure durability and resilience,**
- **Learning Objective 3 - Illustrate the impact of nano silica technology interventions from on-going research and case studies from the field.**

Overview

- Purpose
- Define and Describe
  - Concrete Cracks
  - Healing Mechanisms
- Review Practical Impl.
- Illustrate the Impact
- Summary
- QnA

Problem

Over time, water and contaminates cause the slow breakdown of concrete.



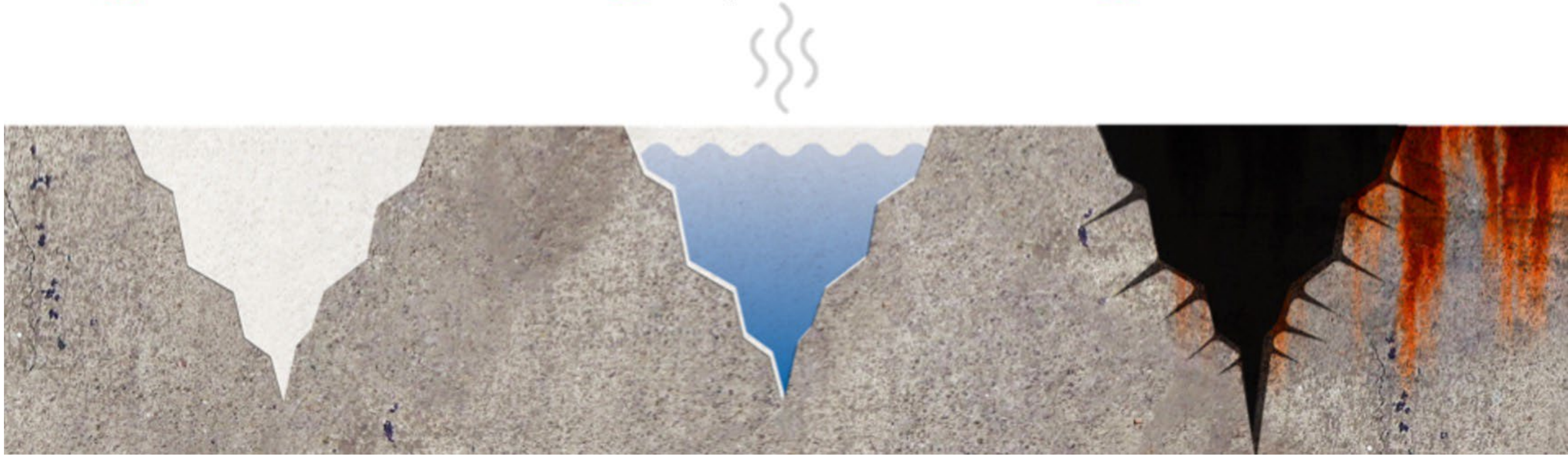
Chemical attack leads to the steady breakdown of concrete as it absorbs moisture.

Concrete placed in marine environments, including key bridges, are especially susceptible to breakdown from seawater and tidal wear.

Problem

How water and contaminates break down concrete over time.

1. Concrete pores are dry and open to the elements.
2. Concrete pores fill with water + contaminates and evaporates.
3. Over time, this leads to cracks and eventual structure failure.



Definitions for Concrete Antibiotics

- ## Healing

Concrete healing involves integrating or spraying a product onto the surface which uses existing cracking in the structure as pathways for migration. Unlike self-healing additives, concrete healing additive products must be applied after concrete installation when fractures are already present from degradation caused by physical and chemical attack.

- ## Self-Healing

A concrete with self-healing properties has had an additive or admixture (SHA) added to the concrete while it was still in its fresh state, either during the mixing or placement process. As the concrete hardens and ages, the SHA lays dormant in the concrete until it is triggered by a mechanical (crack, virbration) or chemical (pH, impurity content) change.

Technologies Applied to and through the Surface of the Concrete

1.Colloidal Nano Silica

- When applied to the surface, colloidal nano silica diffuses deep into the concrete via pore-water solution. It bridges cracks and forms a C-S-H (calcium-silicate-hydrate) hydrogel, effectively healing the cracks and rejuvenating the concrete.

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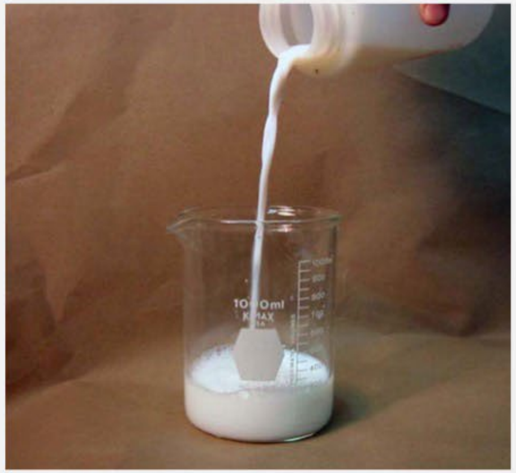
Start with A Definition

Liquid Dispersion of Nano Silica Sized Particles

- **Liquid Dispersion**
- **Clear to Milky Appearance**
- **Specific Surface Area – 80 to 500 m^2/g**
- **Solids Content – 15 to 50%**



Nano Silica Dispersion

Green, B. ACI Materials Journal, SP-254-8, 121–132, 2008.

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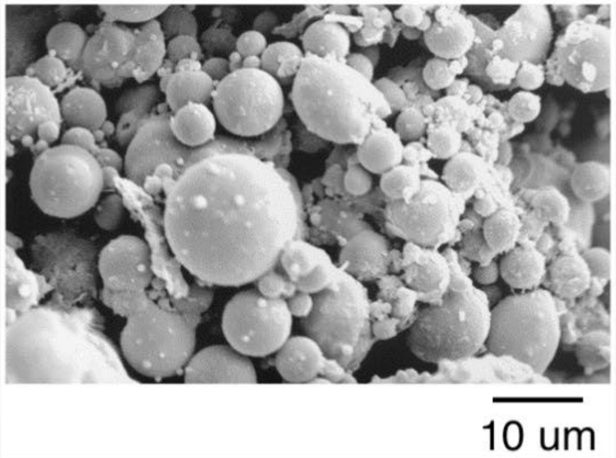
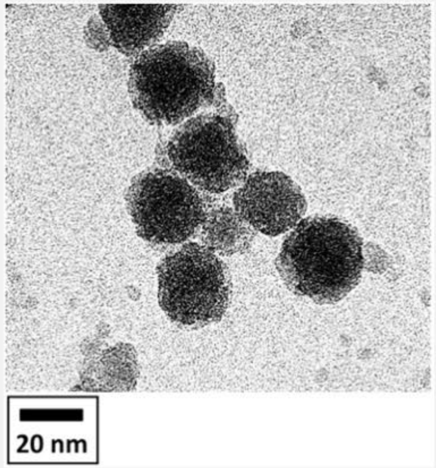
Enhancing with Newer Technology

Not Replacing Current Technologies – Enhancing



- Class F Fly Ash



- Nano Silica

FOR REFERENCE

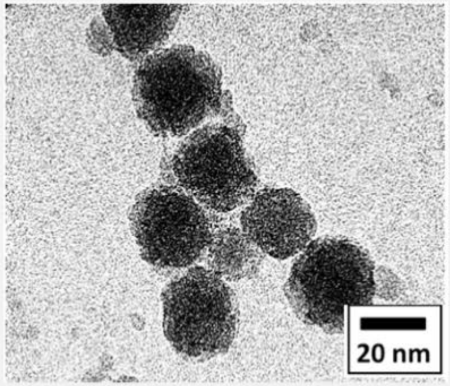
A strand of hair is approximately 100,000 nm in diameter.

- Green, B. ACI Materials Journal, SP-254-8, 121–132, 2008.
- Kudyba-Jansen, A., Hintzen, H., Metselaar, R. Materials Research Bulletin, 36, 1215 – 1230, 2001.

Pozzolanic Reaction

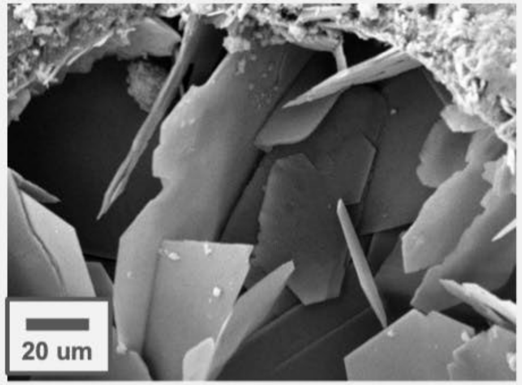
And more…

Colloidal Silica (CS)



+

Calcium Hydroxide (CH)



- CS promotes pozzolanic reaction and the development of C-S-H at the expense of CH
- Particle-to-Particle Packing / Void Filling
- Creates an environment not conducive to Chemical and Physical Attack

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Technologies Applied to and through the Surface of the Concrete

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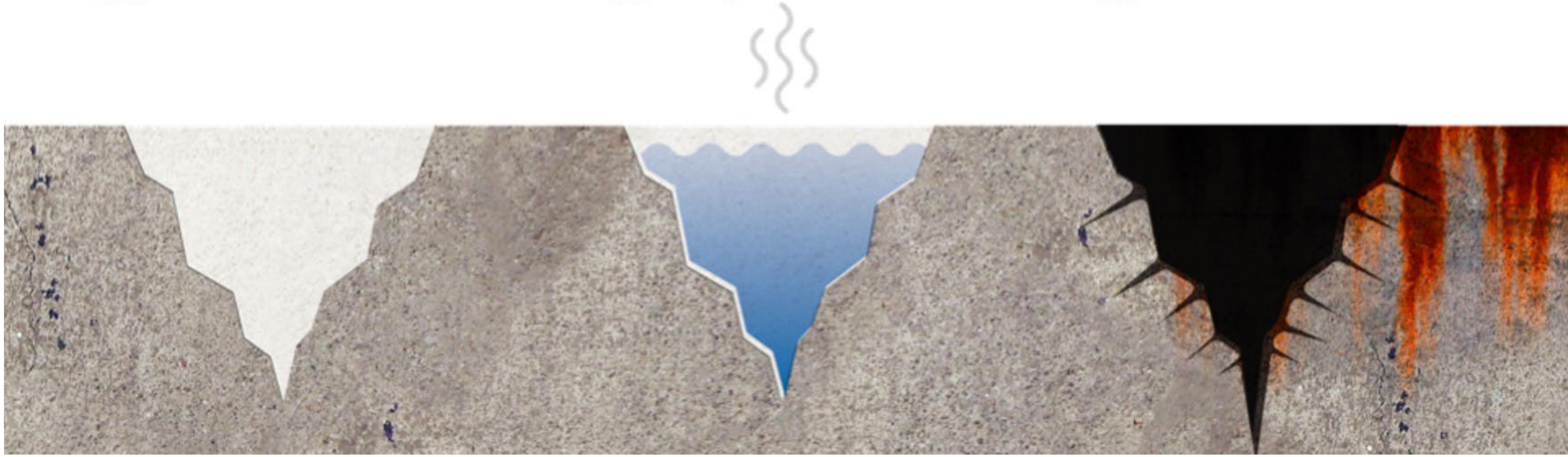
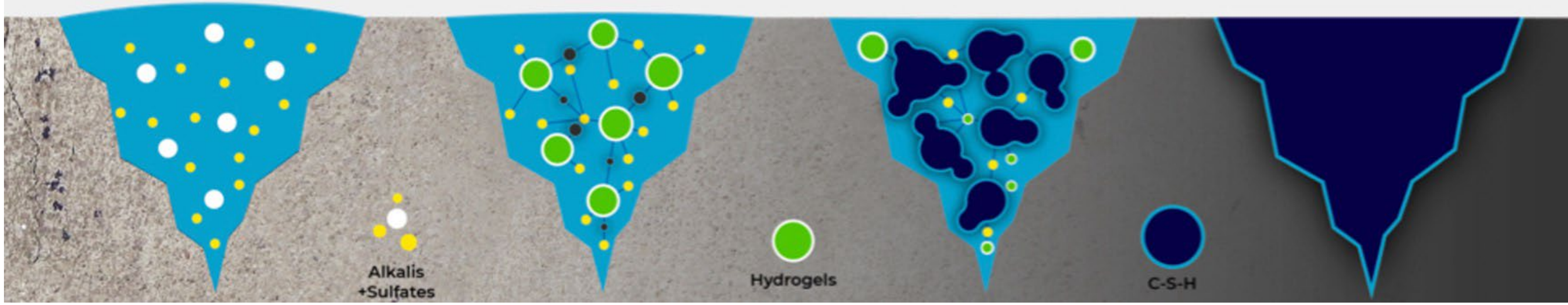


Solution

Nano Silica Hydrogels penetrate and heal deteriorated concrete.

1. The solution is sprayed onto the exterior of concrete and seeps into the pores
2. A hydrogel solution interacts with the alkalis, sulfates, and other chemicals naturally present in concrete pores
3. The suspended components react to create C-S-H, the compound that gives concrete its strength
4. The hydrogels complete their transformation into C-S-H, healing the cracks and sealing the pore



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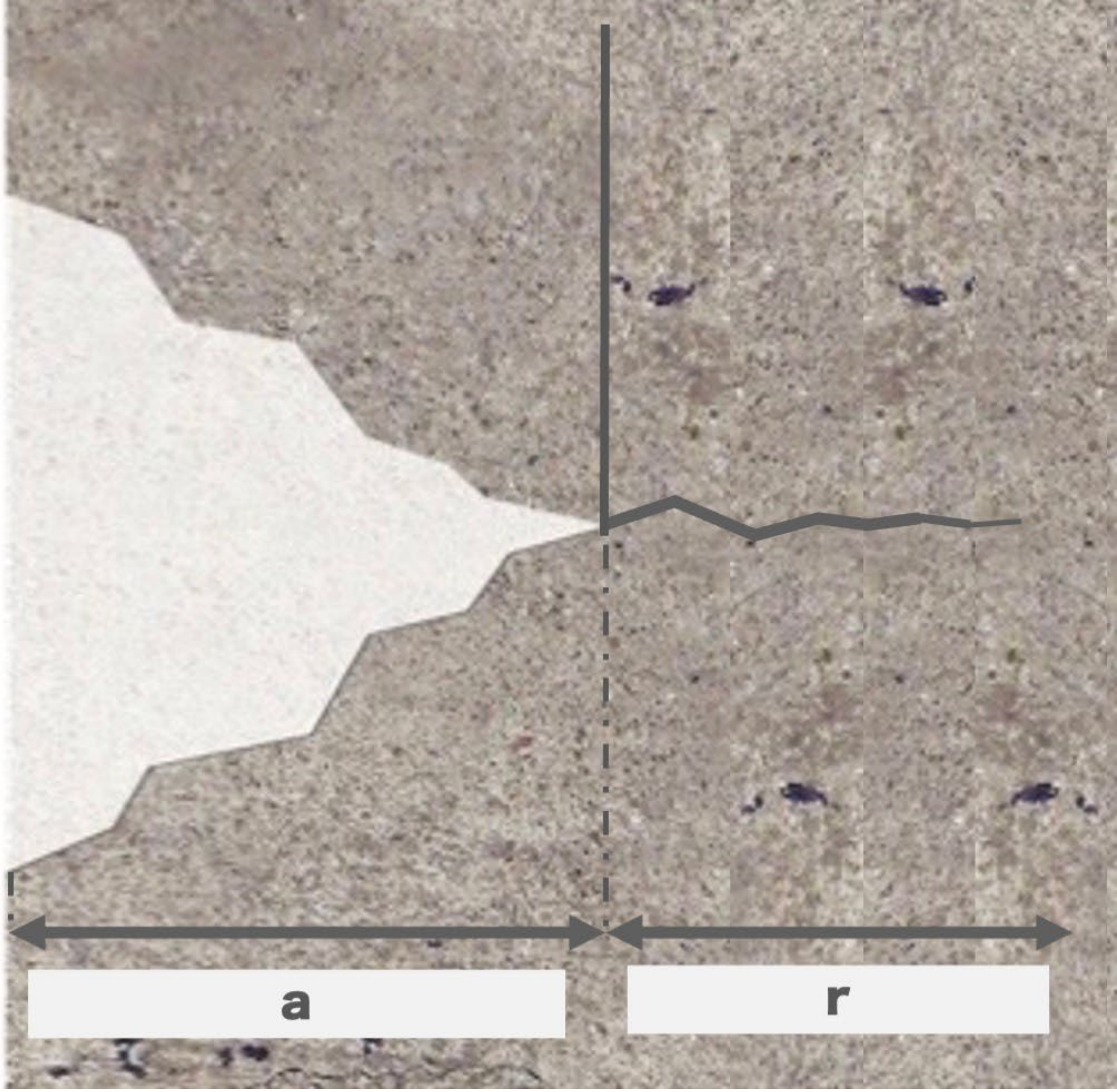
Concrete Crack Review

- **Definitions**
- **Life-Cycle of a Concrete Crack**

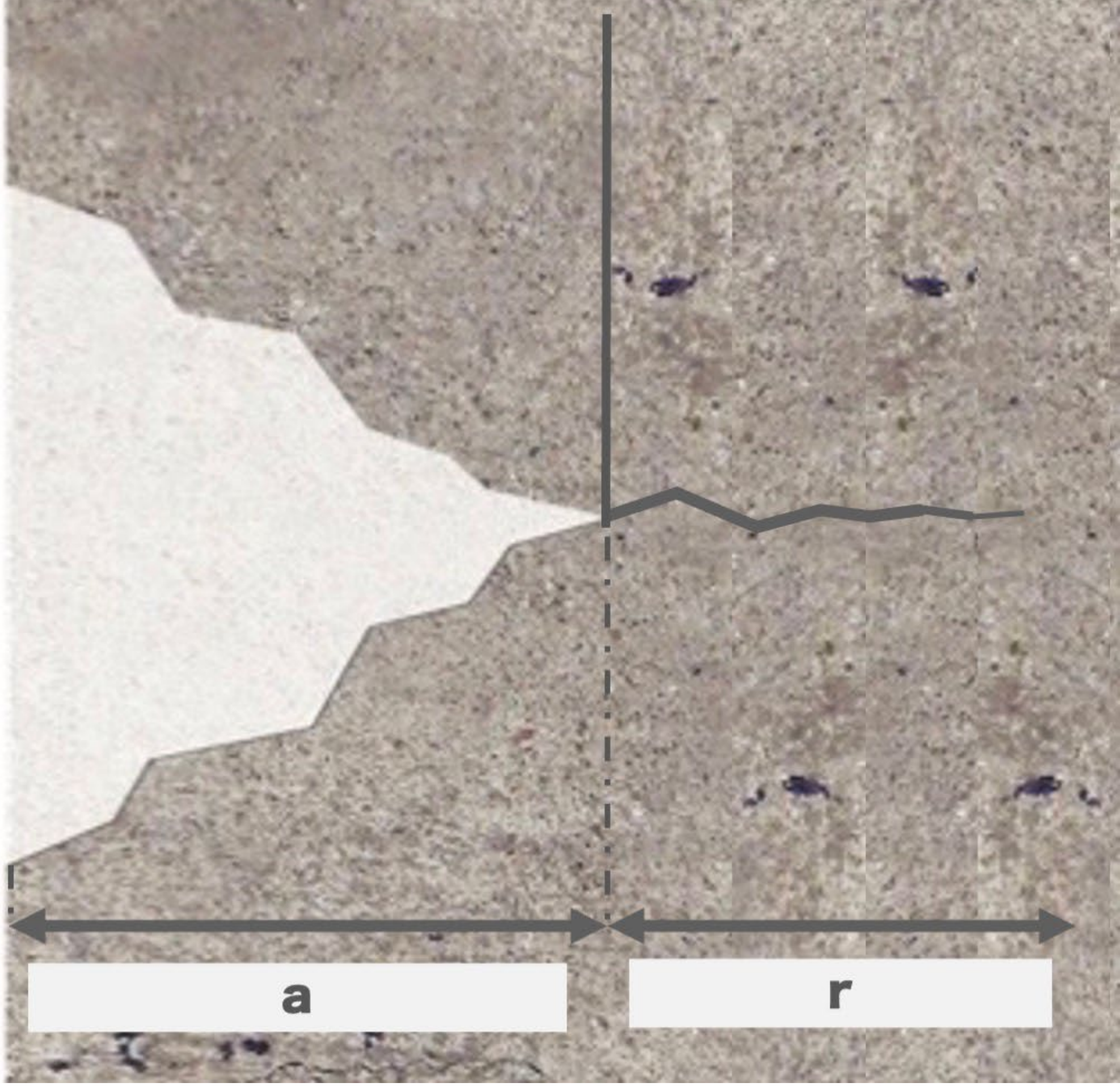
When "Applied Stress" Equals the "Stress Capacity" of the Material, Cracking Occurs

$$\sigma_{applied} = \sigma_{local}$$



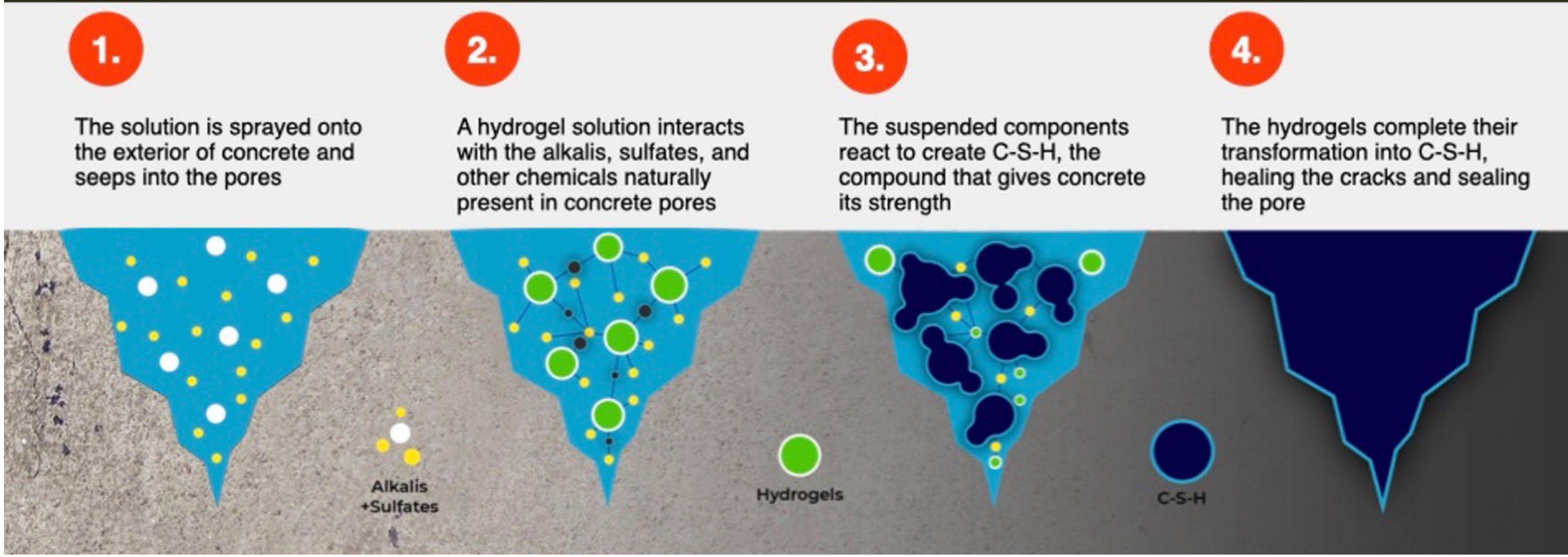
Concrete Crack Blunting

- **Definitions**
- Crack Blunting is recognized as the mitigation effect of stress concentrations caused by cracks.
- The stress is distributed perpendicular to the crack or in a radial direction, blunting the energy that would increase crack length.



Concrete Crack Blunting

- **Hydrogel Development – CRACK Transformation**

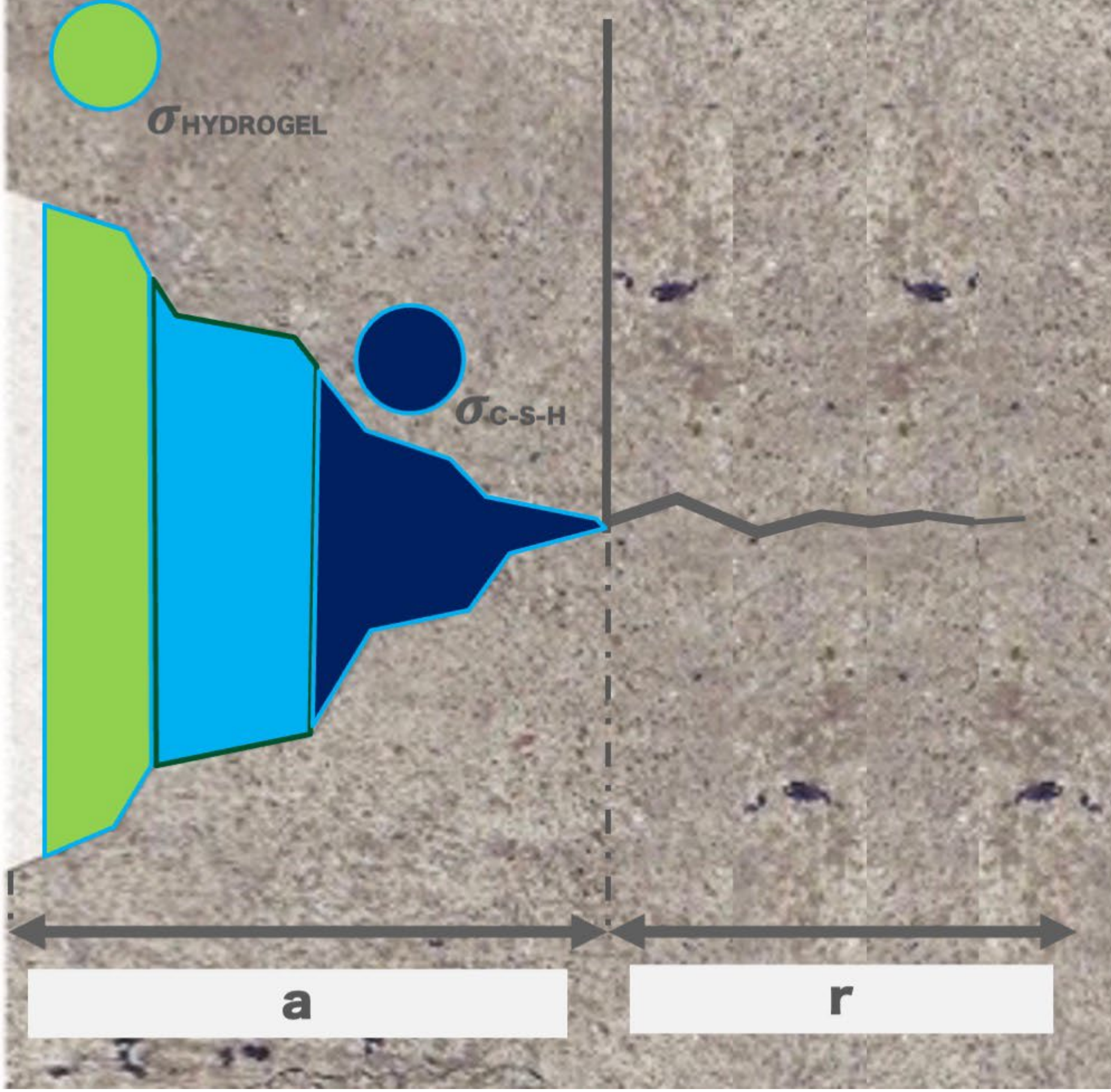


Concrete Crack Blunting

- **Definitions**
- Life-Cycle of a Concrete Crack

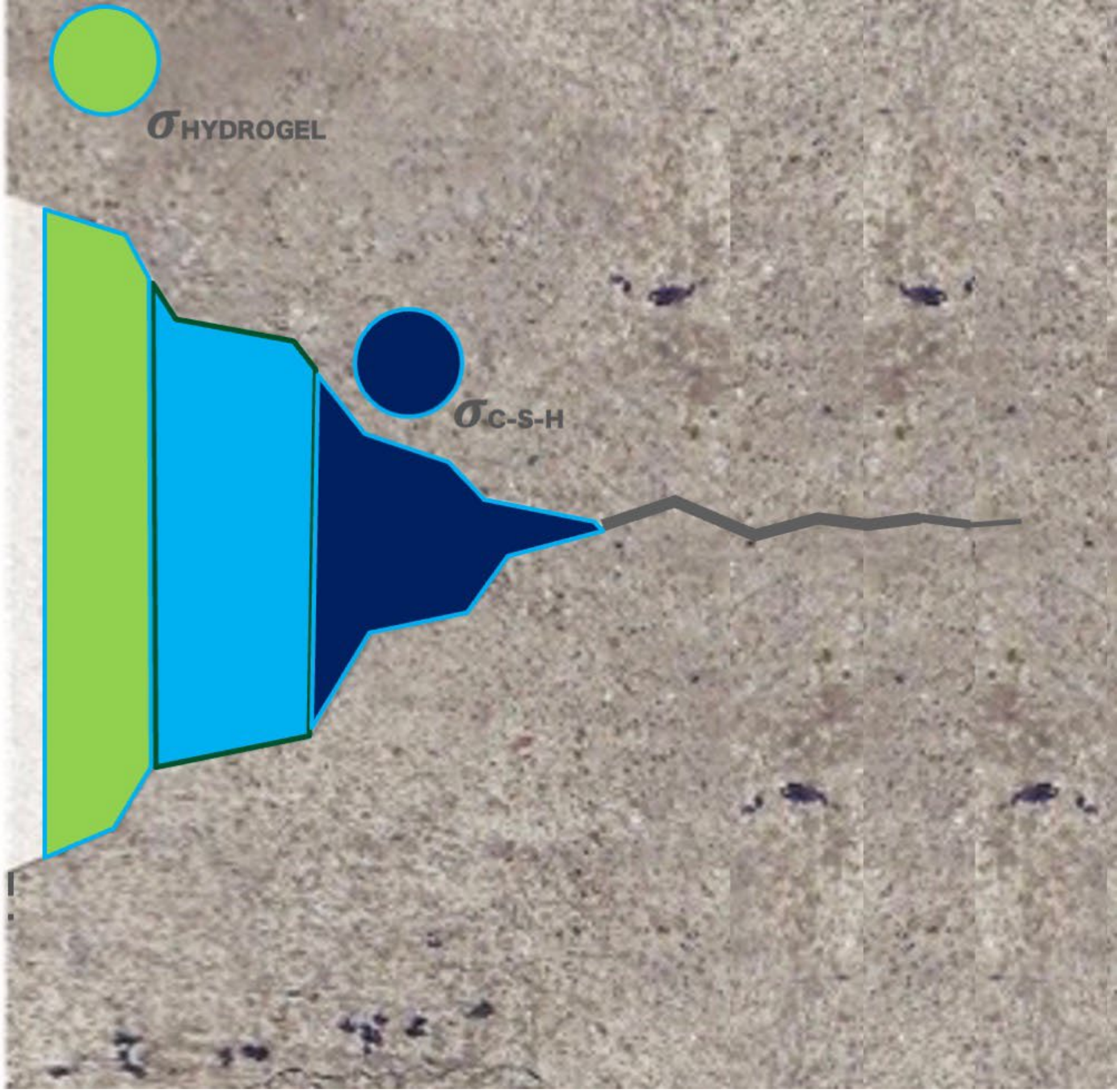
$$\sigma_{local} = \sigma + \sigma\sqrt{\frac{a}{2r}}$$

$$\sigma < \sigma_{Hydrogel} < \sigma_{C\text{-}S\text{-}H}$$



Crack Blunting with Hydrogels

- Hydrogel development in the concrete crack
- Crack blunting impacts the geometry and material properties of the concrete crack.



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Application and Cost

Prep and Application

1. **Power wash (3000–3500 psi) to remove salt and weak concrete.**

2. **Allow the surface to dry (SSD).**

3. **Apply Hydrogel Technology in successive coats**
   - **(125 sq ft Per Gallon Max)**

4. Cost for Application

- **$12.00 per sq ft – Prep work**
- [redacted] **per sq ft – EDYSTON**

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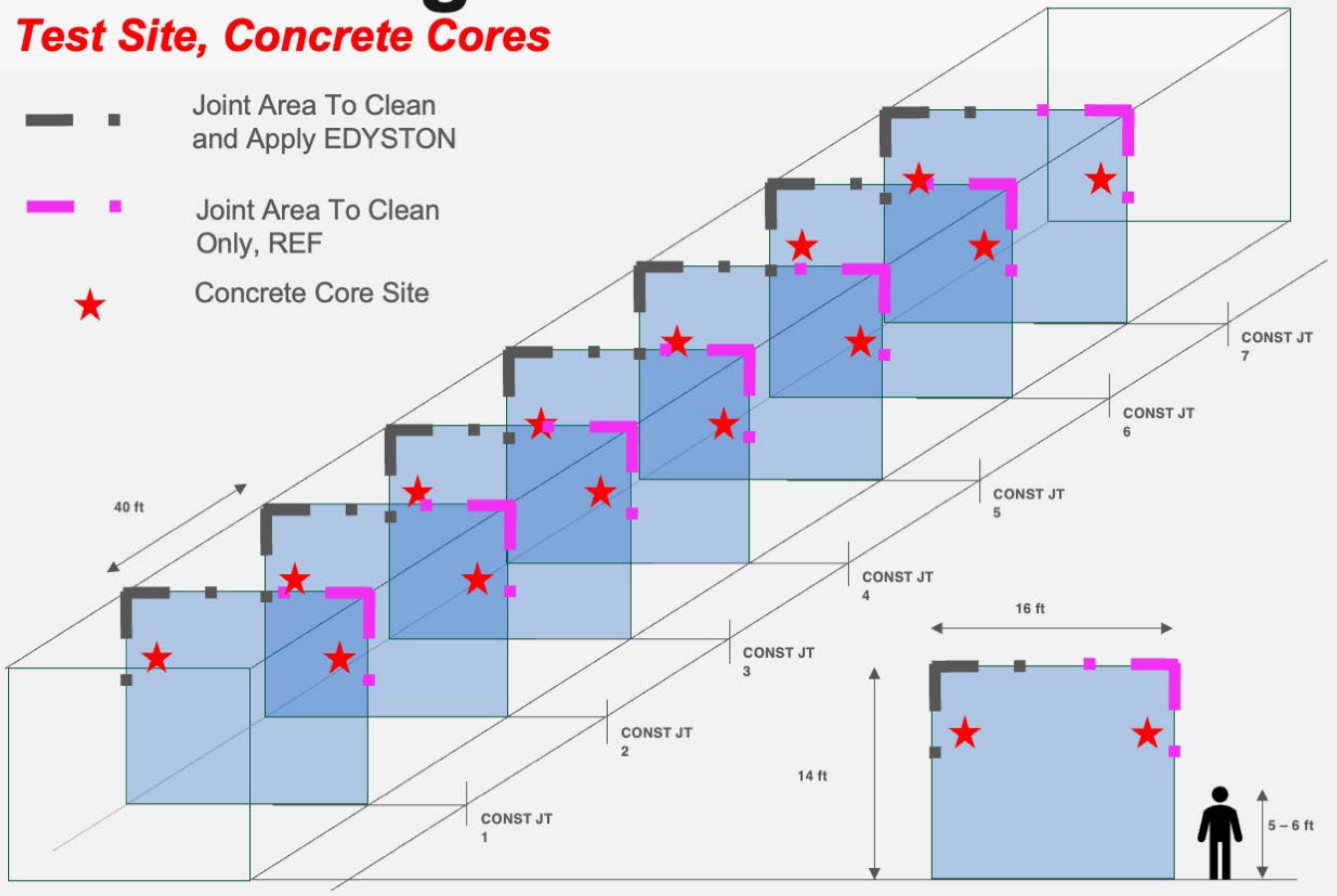
Evaluating Perf.

Test Site, Concrete Cores



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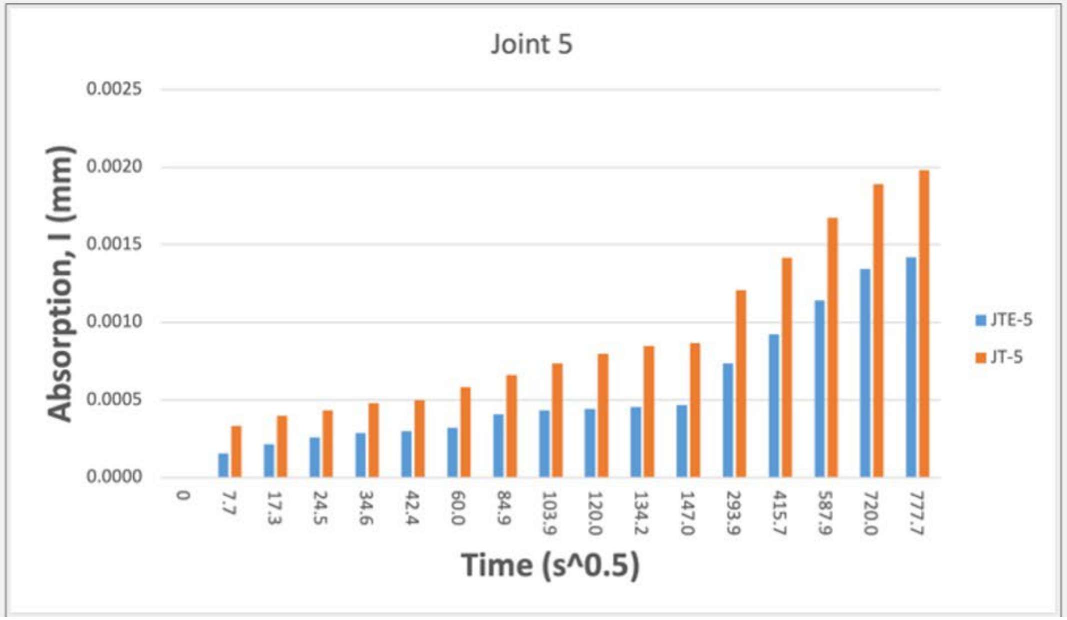
Results, 5-7

AFTER 4 MONTHS

Level of Deterioration	3
EDYSTON TYPE / ORDER	DENSYGEL / DURYGEL
DOSAGE (sq ft per gal)	250 / 250



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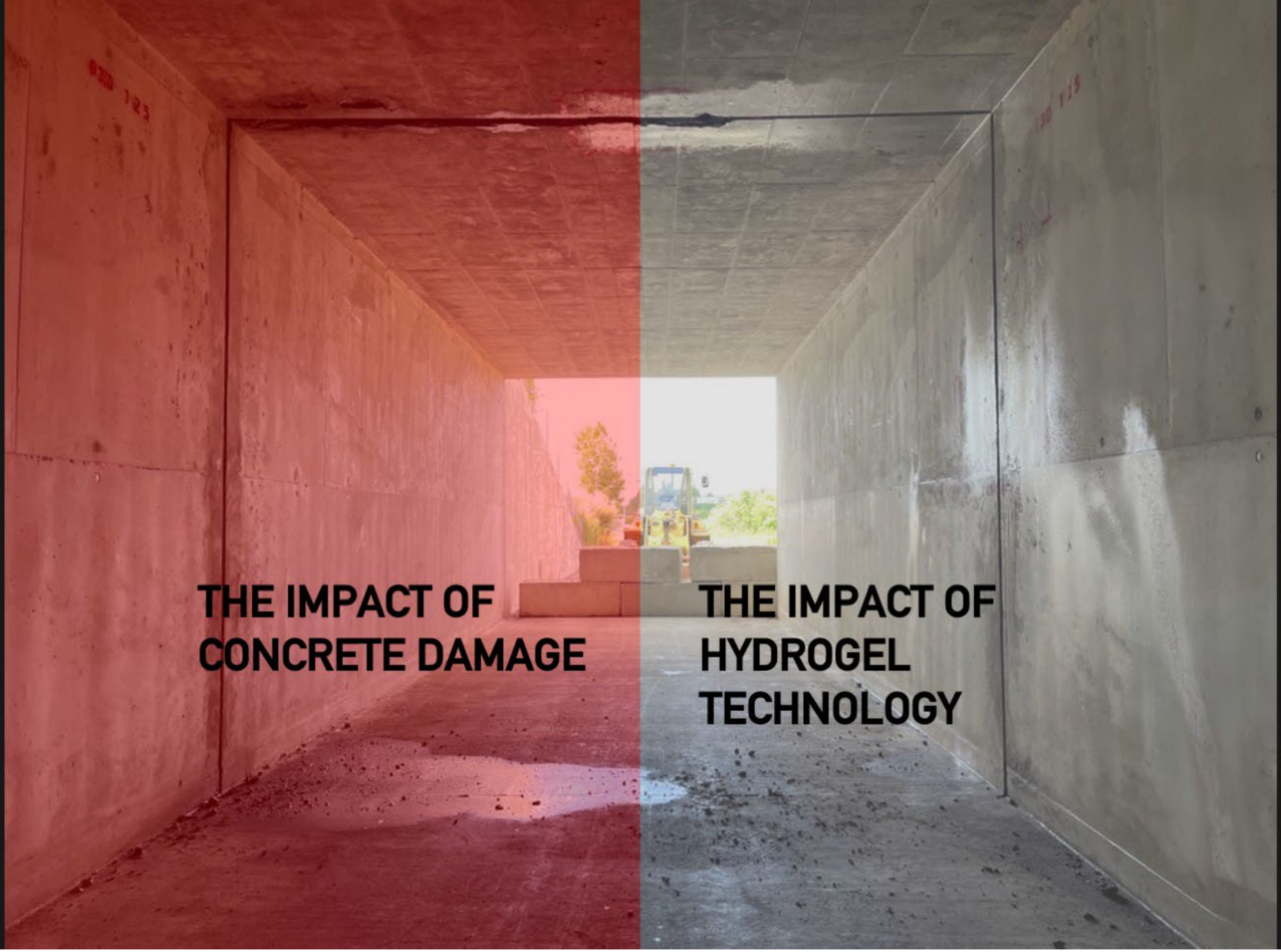
Results, AFTER 4 MONTHS

REFERENCE CONCRETE

EDYSTON TECHNOLOGY


THE IMPACT OF
CONCRETE DAMAGE
THE IMPACT OF
HYDROGEL
TECHNOLOGY

Case Study – Bridge Deck

Concrete overlay after topical addition Colloidal Silica.

Application and Cost

Prep and Application

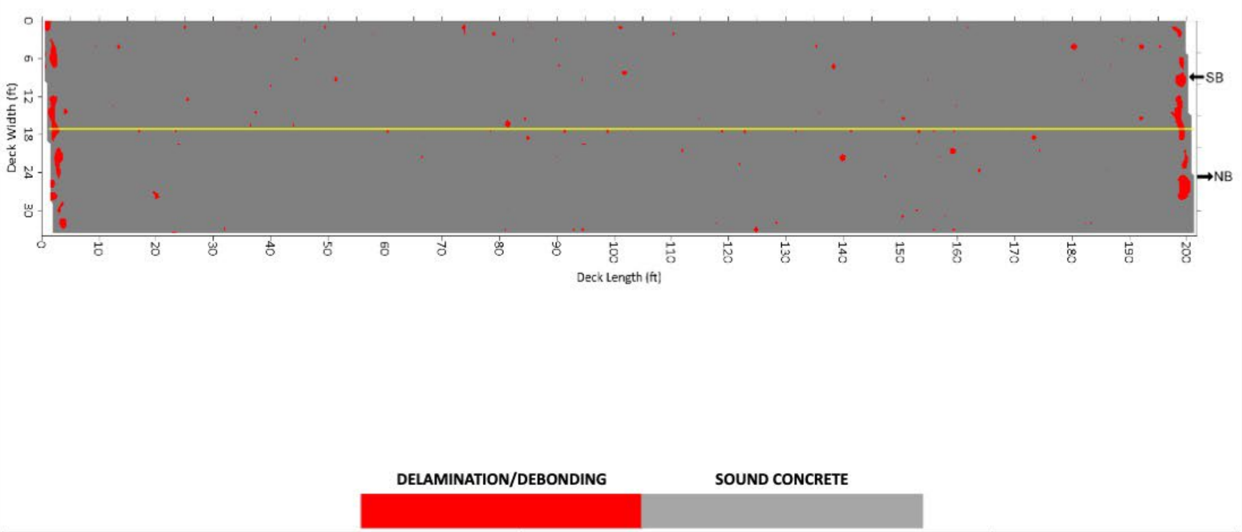
1. **Power wash (3000–3500 psi) to remove salt and weak concrete.**
2. **Allow the surface to dry (SSD).**
3. **Apply Hydrogel Technology in successive coats**
   - **(750 sq ft Per Gallon Max)**

4. Cost for Application

- **$5.00 per sq ft – Prep work**
- [redacted] **per sq ft – EDYSTON**

Evaluating Perf.

Test Site, Concrete Cores

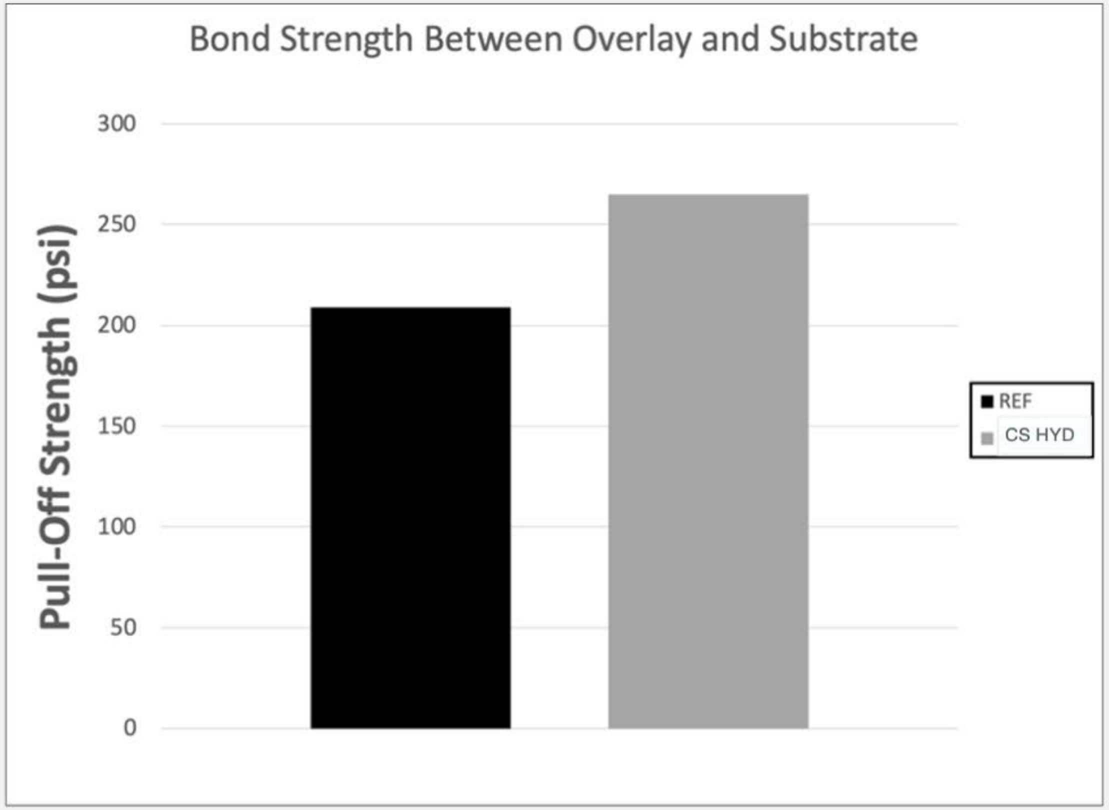


TEST PERFORMED BY: MS & DL	TEST ID: B2409160001	DATE: 11/18/2024
TEST DATE: 10/23/2024	ANALYZED BY: PB	1/1

*Bottom delamination with overlapping top delamination at same location could not be determined.

Evaluating Perf.

Test Site, Concrete Cores



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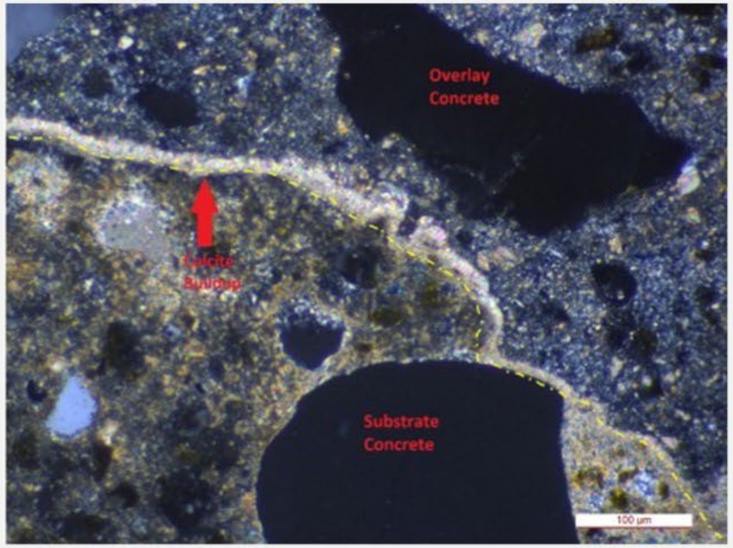
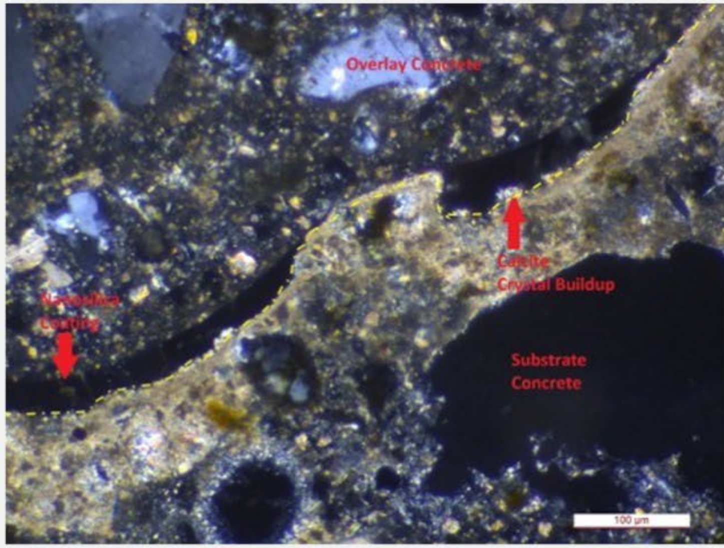
Evaluating Perf.

Test Site, Concrete Cores – Petrographic Analysis of Concrete / Overlay Interface

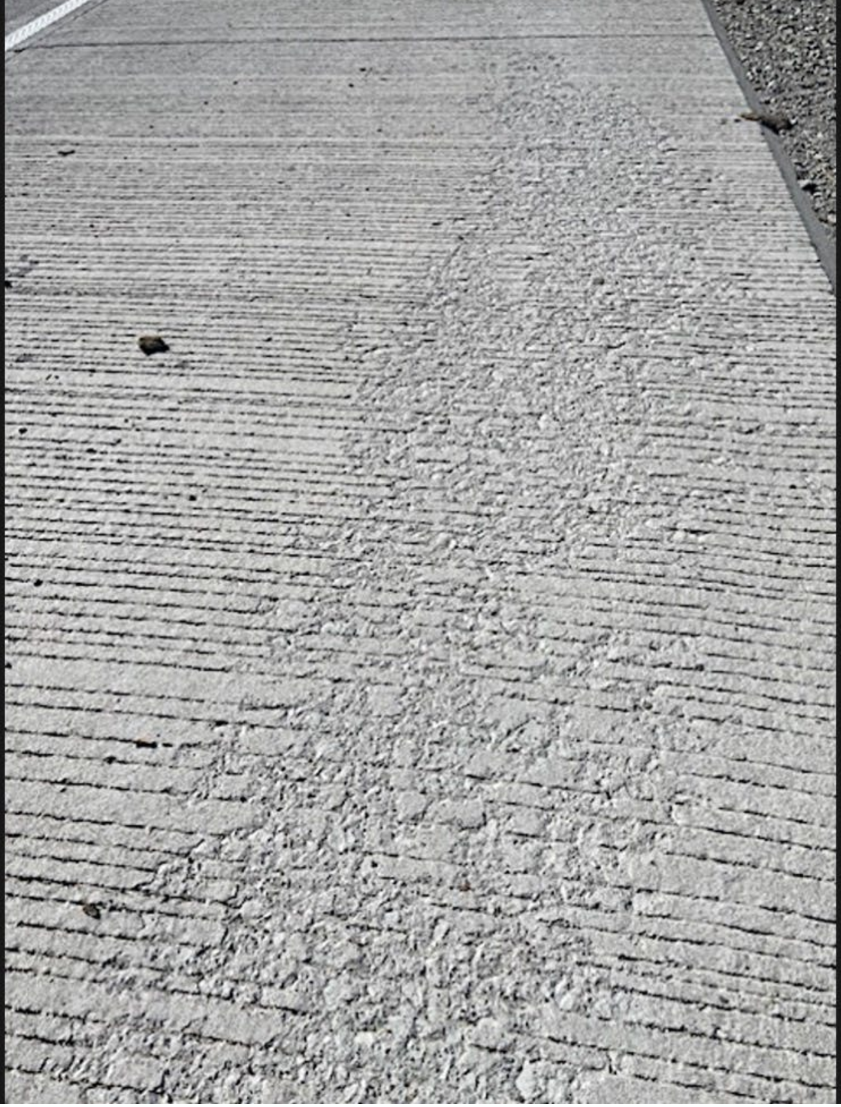


REFERENCE

- Examination of ITZ between Overlay and Concrete Deck
- **REF** – a calcite layer has developed at the ITZ
- **EDYSTON** – absence of the calcite layer – better contact between the Overlay and Concrete Deck



EDYSTON



Case Study – Bridge Deck

Topical addition Colloidal Silica after grooving

Application and Cost

Prep and Application

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2. **Allow the surface to dry (SSD).**
3. **Apply Hydrogel Technology in successive coats**
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4. Cost for Application
- **$5.00 per sq ft – Prep work**
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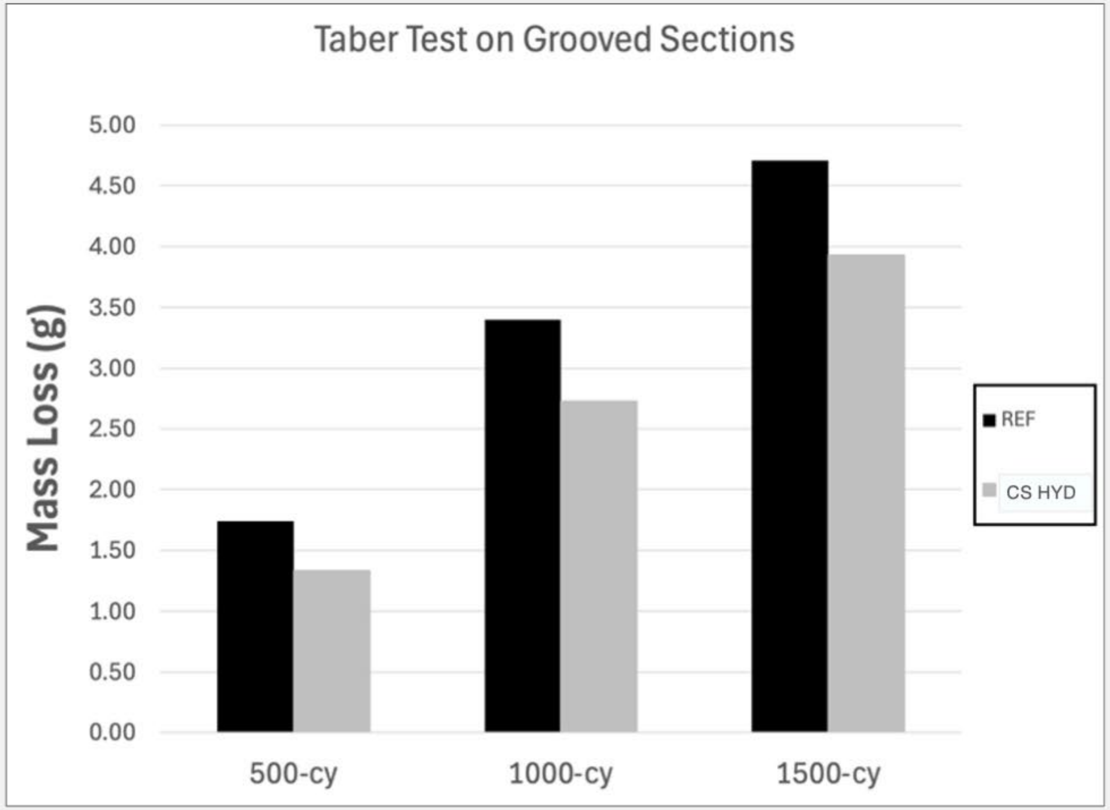
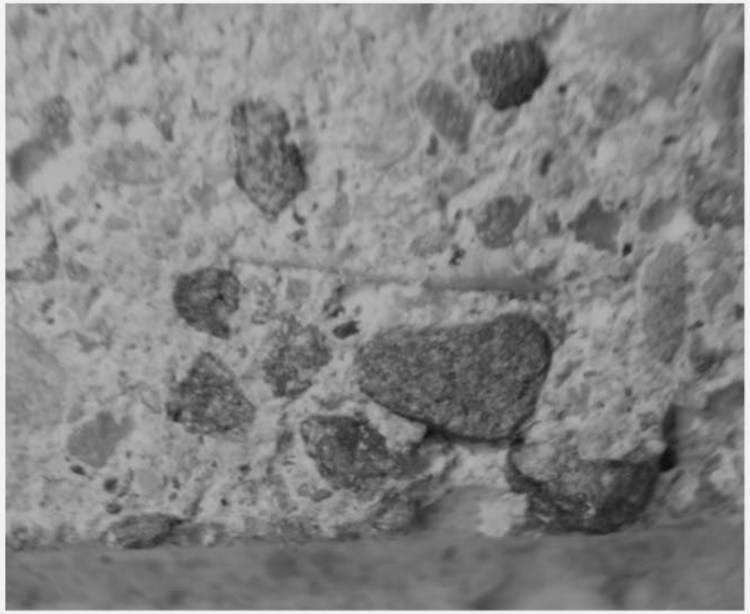
Evaluating Perf.

Test Site, Concrete Cores



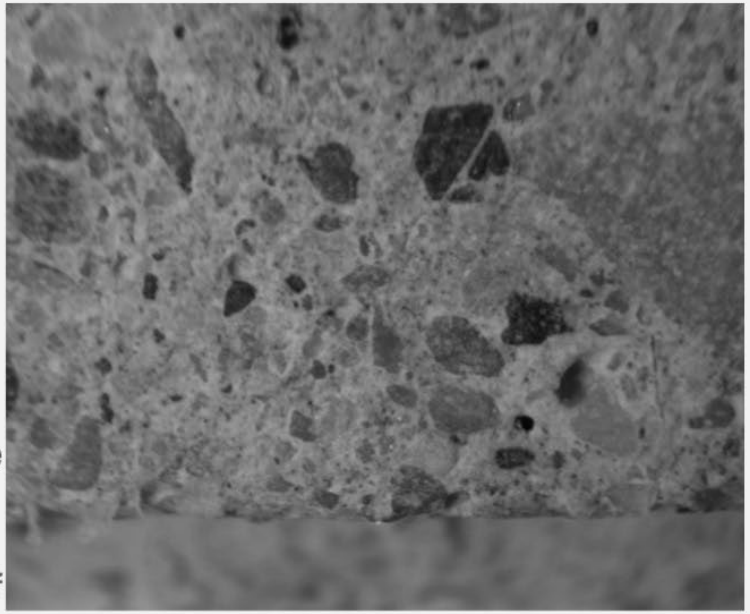
Evaluating Perf.

Test Site, Concrete Cores – Petrographic Analysis of Grooves after Abrasion



REFERENCE

- Examination of Grooved surface AFTER Abrasion Test
- **REF** – The aggregate is rounded and ITZ is exposed consistent with pullout from abrasion.
- **EDYSTON** – aggregate is worn down and polished down to the paste layer indicative of a good bond during abrasion.



EDYSTON

1 mm

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- **Learning Objective 1 – Define and describe the innovative nature of bio-inspired healing and self-healing concrete technologies, its objectives, and approach, for cracked and deteriorated concrete,**

- **Learning Objective 2 – Review the practical implications of bio-inspired technologies in improving infrastructure durability and resilience,**

- **Learning Objective 3 - Illustrate the impact of bio-inspired technology interventions from on-going research and case studies from the field.**

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Acknowledgements

CSCA
COLLOIDAL SILICA IN CONCRETE ASSOCIATION

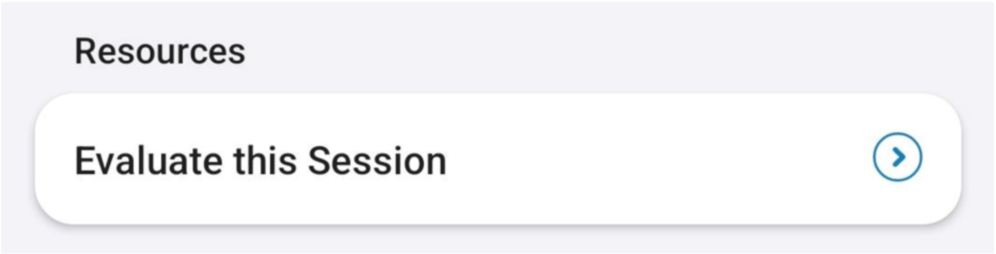
EDYSTON™

INTELLIGENT CONCRETE®

Questions

"Our Biggest Problem, We Are Solving Today's Problems with Yesterday's Technologies" – WB, 2012

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.

ANY QUESTIONS?

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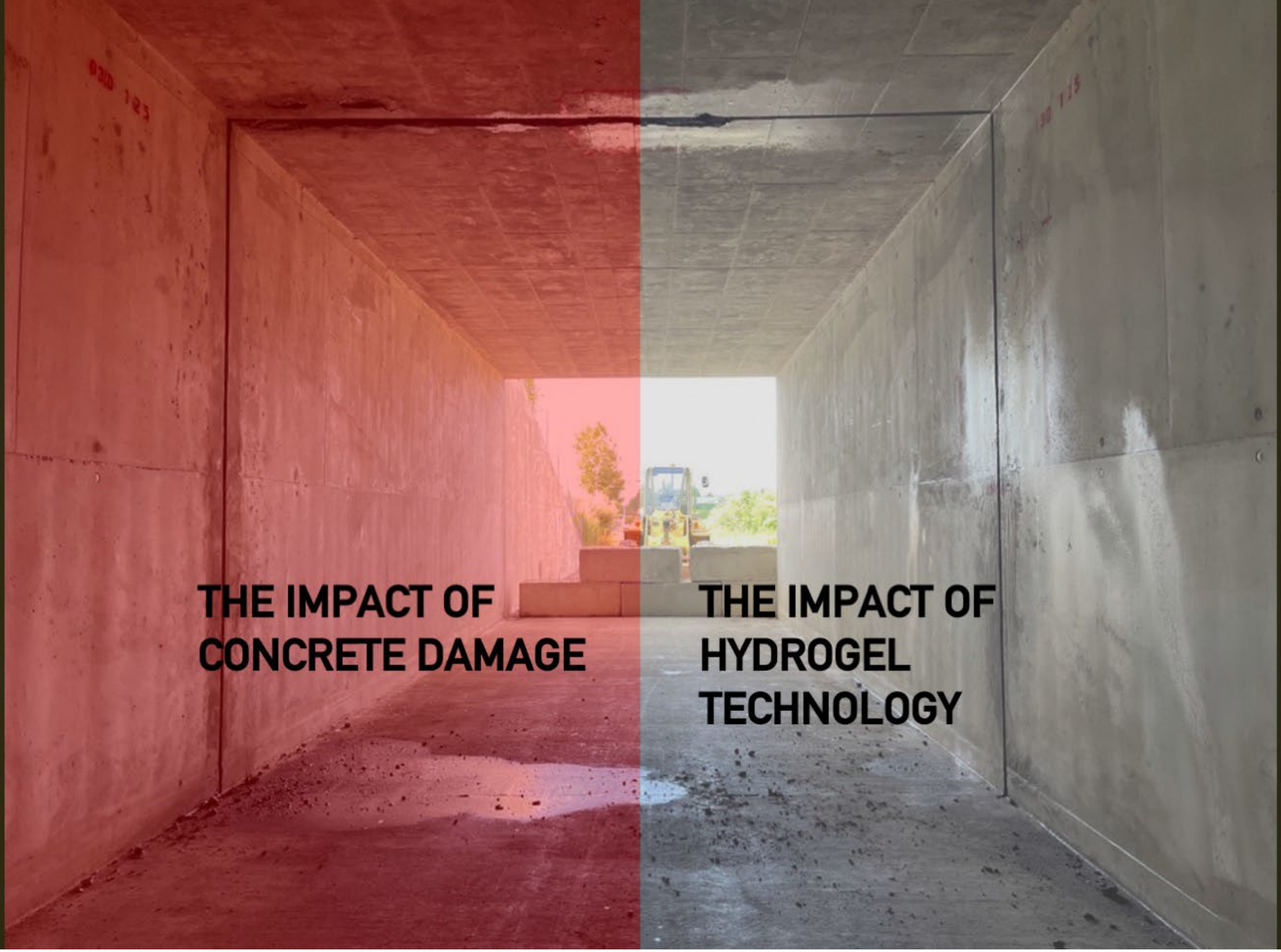

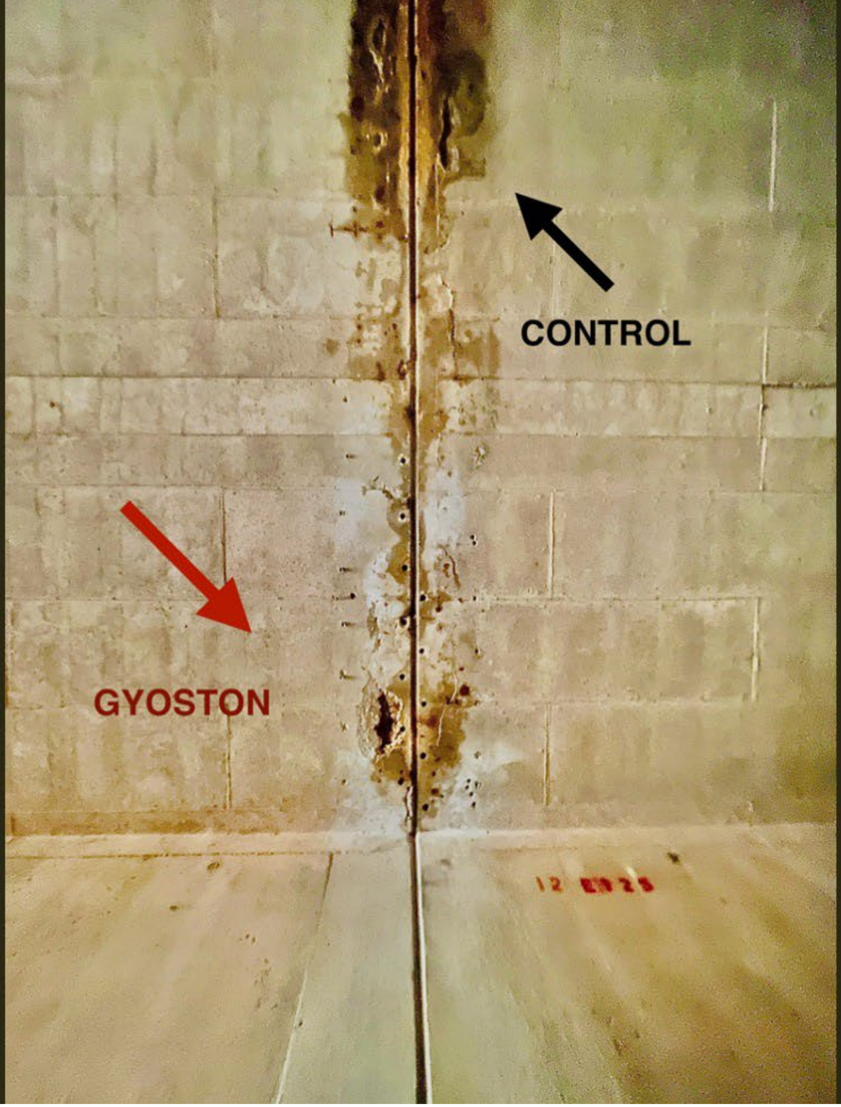
CONTROL
GYOSTON

Steel Corrosion

Rapid Corrosion Evaluation

1. Reduced Corrosion: Visual inspection of the EDYSTON-treated sample consistently showed significantly less rust formation and corrosion-related discoloration than the untreated REFERENCE sample.

2. Slower Corrosion Rate: The treated sample exhibited a notably slower degradation process, suggesting the introduction of EDYSTON colloidal silica into the sodium chloride solution played a proactive role in suppressing the corrosive activity.

3. Structural Integrity Impact: The reduced corrosion in the EDYSTON sample indicates enhanced stabilization of the steel's surface, a critical factor in prolonging the lifespan and load-bearing ability of reinforced concrete structures.

Deicing Salt Attack

Rapid Corrosion Evaluation

1. **Reduced Mass Loss**

EDYSTON-treated samples exhibited significantly lower mass loss throughout the second set of 15 cycles compared to the reference samples. This metric highlights the additive's superior capacity to protect and reinforce concrete surfaces against freeze-thaw-related scaling.

2. **Enhanced Concrete Durability**

The advanced colloidal silica chemistry within EDYSTON forms additional C-S-H gel and robust bridging hydrogels. These components:

- Fill micro-cracks and pores, reducing permeability to water and chlorides.
- Increase the resilience of the concrete matrix to crack propagation and scaling damage, effectively mitigating structural degradation.
- Blunt crack development ("crack blunting") by strengthening weak links within the material's microstructure.

3. **Improved Resistance to Deicing Salts**

The EDYSTON-treated samples exhibited a notable defense against the deleterious effects of deicing salts. The hydrogels' consumption of alkalis and chlorides further reduces internal chemical distress, enhancing long-term performance.