Agenda

- Failure Mechanisms in Concrete Marine Structures
- Traditional Repair Solutions
- Crystalline Repair Solutions
- Permeability-Reducing Treatments and Admixtures
- Erosion and Abrasion resisting Admixtures

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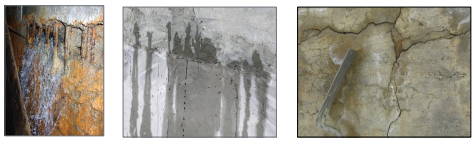
2017 Fall Convention | November 15-17 | New Orleans, LA

Definition of Durability

"…the ability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties."

- Portland Cement Association, www.cement.org



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Failure Mechanisms

Concrete – 2 Key Properties

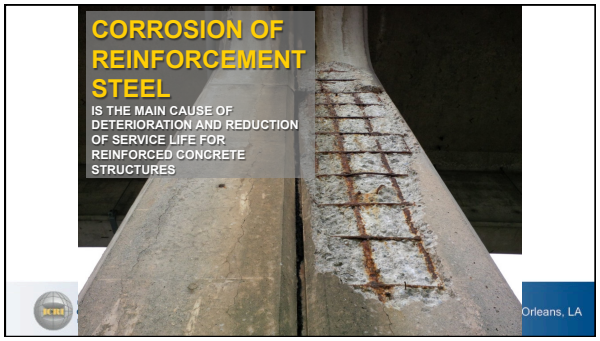
- Concrete will crack
- Concrete is porous

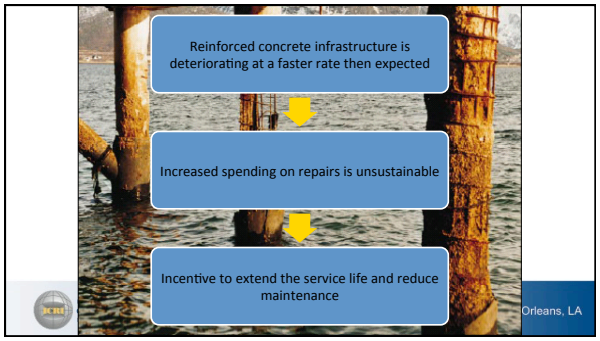
There doesn't always need to be a crack

- Joints
- Rock pockets
- Sand layers
- Poor consolidation

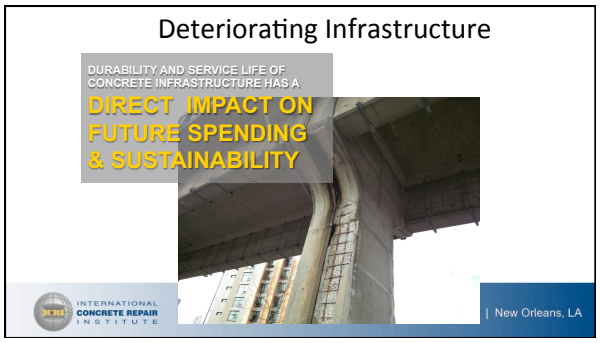
Factors for Deterioration of Concrete

- Corrosion of Embedded Metals
  - Concrete and the passivating layer
  - The role of chloride ions
  - Carbonation
  - Dissimilar metal corrosion
- Freeze-Thaw Deterioration
  - Deicer scaling
  - Aggregate expansion
- Chemical Attack
  - Acids
  - Salts and alkalis
  - Sulfate attack
- Alkali-Aggregate Reactivity
  - Alkali-silica reactivity
  - Alkali-carbonate reactivity
- Abrasion /Erosion
  - Traffic surfaces
  - Hydraulic structures
- Fire /Heat
- Restraint of Volume Changes
  - Plastic shrinkage cracking
  - Drying shrinkage cracking
  - Thermal stresses
- Overload and Impact
- Loss of Support





Deteriorating Infrastructure



Corrosion

Protecting Concrete - Membrane

TRADITIONALLY
CONCRETE HAS BEEN PROTECTED FROM WATER BY USING SURFACE APPLIED MEMBRANES

TRADITIONAL SURFACE APPLIED WATERPROOFING ARE OFTEN INSTALLED INCORRECTLY, EASILY DAMAGED AND
DETERIORATE WITH AGE

Protecting Concrete – Epoxy Coated Rebar

MIXED REVIEWS
HAS QUESTIONABLE PERFORMANCE AS A STANDALONE SOLUTION

Protecting concrete – Mix Design

CONCRETE DESIGN

- PROPER MIX PROPORTIONS
- POZZOLANS / SCM'S
- CORROSION INHIBITORS
- PLASTIC AND WORKABLE MIX
- THICK CONCRETE COVER.
- PLACEMENT

Traditional
Repair Systems

Hydraulic Cement

- Cementitious material used to stop Leaks
- Mixed on-site and applied directly to leaking cracks


Hydraulic Cement - Advantages

- Low cost
- Easy to use
- Readily available
- Compatible with Concrete

Hydraulic Cement - Limitations

- Repairs are short-term
- Increased pressure can lead to new leaks
- Movement or shrinkage can open cracks
- Only the surface of the crack is patched

Epoxy Injection

Epoxy injection is commonly used to repair cracks.


Epoxy Injection

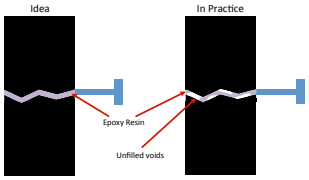
- Recommended for structural cracks
- Application by pressure injection using surface-attached ports or drilled ports.


Epoxy Injection

- High Strength
- Restores load carrying ability

Epoxy Injection- Limitations

- Not intended for waterproofing
- Substrate must be dry – typically poor adhesion to wet concrete
- Not able to fully displace water trapped in cracks and voids
- Can only be used for non-moving applications
  - Likely to crack again if movement is experienced



Polyurethane Injection

- Installed similarly to epoxy by drilling across crack and injected through installed ports
- Reacts with water present to expand and fill voids and cracks

Polyurethane Injection

- Can be applied into active leaks
- Flexibility allows for minor movement at crack locations
- Can normally be used as a single component product with no pre-mixing required

Polyurethane Injection

- Expensive
- Very difficult to be sure of filling all voids and cracks
- It is common to find yourself chasing leaks from one place to another
- Low strength
- Typically will shrink with age, possibly leading to loss of adhesion to the substrate

Failed Leak Repair Analysis

- Cores were analyzed to discover why concrete continued to leak.
- Little resin is visible in the crack, despite port being clearly visible.
- This proves that injected resin does not always fill and seal the complete crack, as intended.

Crystalline
Repair Systems

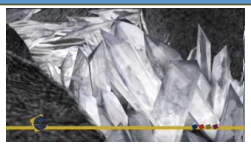
What is Crystalline Technology?

Chemical technology that reacts with water and cementing materials to grow a network of needle-shaped crystals within the concrete's capillary pores and cracks.

Microscopic, needle-like crystals fill the naturally occurring pores and capillary tracts of concrete for guaranteed waterproof structures.

How Does It Work?

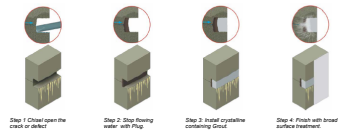
ICW reacts with water and un-hydrated cement to make millions of microscopic needle like crystals.



These crystals block the water pathway. Waterproofs concrete from the inside out.

100% Effective Leak Repair

- The waterproofing crack repair system that works under any jobsite condition
- Designed for maximum waterproofing protection with minimum hassle
- Easy step by step installation
- Eliminates stress and costly call backs



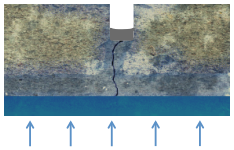
Step 1: Chisel open the crack or defect | *Step 2: Stop flowing water with Plug* | *Step 3: Install crystalline containing Grout* | *Step 4: Finish with broad surface treatment*

Plug

- Rapid setting, hydraulic cement product
- Sets within two minutes after mixing with water
- Has high compressive strength, allowing it to stop water under high hydrostatic conditions
- Can be used even when leak is active


Plug

- Stops flowing or seeping water – even under pressure

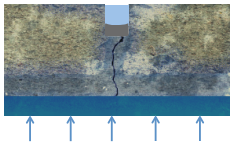


Crystalline Grout

- Uses Hydrophilic Crystalline Technology to waterproof concrete from the inside.

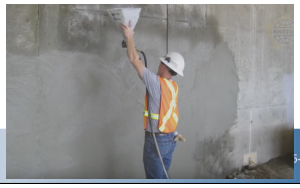
Crystalline Grout

- Crystalline waterproofing product
- Stops water flow to permanently repair leaks
- Uses fiber technology and shrinkage controlling additives to prevent future cracking

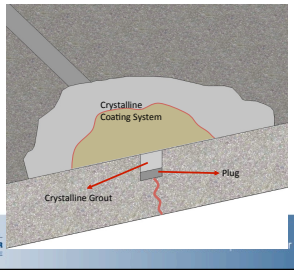


Crystalline Coating System

- Surface applied crystalline slurry treatment
- Turns concrete into permanently waterproof barrier
- Crystalline chemical diffuse into the concrete pores and micro-cracks where they grow crystals



Crystalline Leak Repair and Protection System



Integral Crystalline Systems

Integral Crystalline Waterproofing

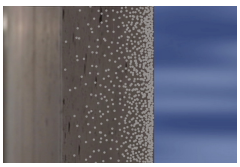
New or Existing Structures

The first crystalline waterproofing admixture was invented and pioneered by Kryton during the 1980's and 90's.

Powder admixture added directly to ready mix truck or at batch plant (pails or soluble bags)

Integral Crystalline Waterproofing

New or Existing Structures



American Concrete Institute®
Advancing concrete knowledge

ACI 212 Committee on Chemical Admixtures
ACI212 R-10
Chapter 15 – Permeability Reducing Admixtures

PRAH – Permeability Reducing Admixture for Hydrostatic Conditions

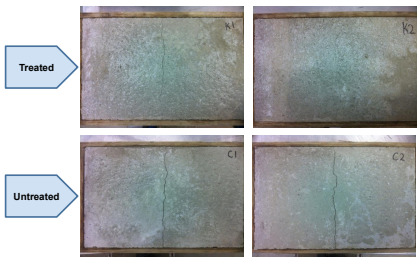
Integral Crystalline Waterproofing

New or Existing Structures

KEY BENEFITS

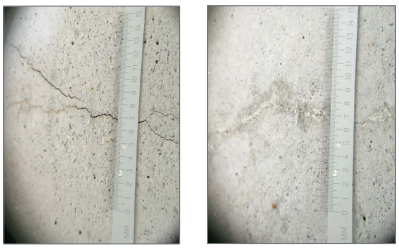
- Reduces Permeability
- Reduces Shrinkage
- Self Seals Cracks
- Improves Chemical Resistance
- Improves Durability

Reduced Drying Shrinkage



Orleans, LA

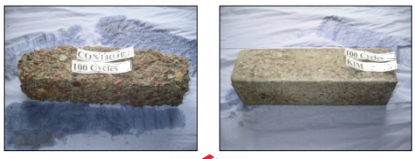
Self-sealing of cracks

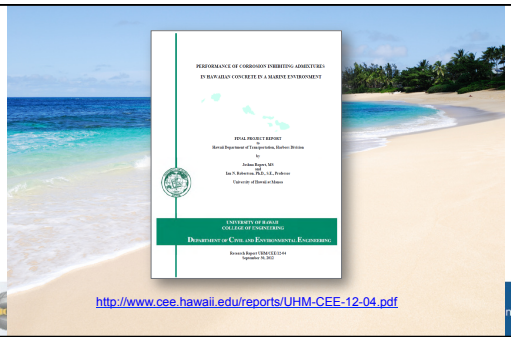


Orleans, LA

Reduced Permeability

Resistance to cycles of freezing and thawing





http://www.cee.hawaii.edu/reports/UHM-CEE-12-04.pdf

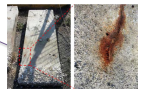
Independent Long-term Corrosion Study

25 reinforced concrete panels were placed in the intertidal zone in Honolulu Harbor.

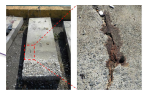
Resistance to corrosion was evaluated over 10+ years

Independent Long-term Corrosion Study

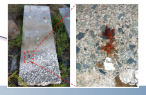
Control



Corrosion Inhibitor F



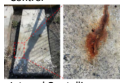
Hydrophobic Waterproofing Admixture X



Crystalline Waterproofing Admixture K

Study Results

Control



Integral Crystalline

"THE PANEL USING 2% (INTEGRAL CRYSTALLINE) PERFORMED WELL DURING THE FIELD EXPOSURE, WITH LOW HALF-CELL READINGS AND

NO VISIBLE SIGNS OF CORROSION

AFTER 10 YEARS EXPOSURE"

Independent Long-term Corrosion Study

- Panels using corrosion inhibiting admixture F and hydrophobic waterproofing admixture X exhibited inconsistent to poor results
- Panels using corrosion inhibiting admixtures D & R performed well only at dosages of 20L/m^3
- Panel using crystalline waterproofing admixture K performed well during the field exposure, with low half-cell readings and no visible signs of corrosion after 10 years exposure

Independent Long-term Corrosion Study

Final recommendations:

1. Use a w/c ratio as low as possible, and not > 0.40
2. Include fly ash with at least 15% replacement of cement, or silica fume with at least 5% replacement of cement. Mix well.
3. Include D or R at minimum dosages of 4 gal/cuyd (20L /m3).
4. As added protection, consider including K at 2%.

http://www.cee.hawaii.edu/reports/UHM-CEE-12-04.pdf

Integral Abrasion & Erosion Resistance

A new solution to an old problem

Integral Hardening Admixture

Abrasive & Erosive Wear

- *As per ACI 210R-93: Erosion of Concrete in Hydraulic Structures, fluid borne erosion is defined as "the progressive disintegration of a solid by abrasion, cavitation, or chemical action."*

Abrasion Erosion

Eroded Concrete Surface

"Erosion refers to the loss of surface material as a result of either the action of solid particles being carried by moving water or a process known as 'cavitation'. The former of these forms of erosion is very similar to abrasion." Thomas Dyer, "*Concrete Durability*," CRC Press, Taylor & Francis Group, 2014.

Erosion of Concrete Structures

Early stages of abrasion-erosion on a dam spillway wall

(source: "Guide to Concrete Repair"; US Department of the Interior Bureau of Reclamation)

Severe abrasion-erosion damage of dam stilling basin

(source: "Guide to Concrete Repair"; US Department of the Interior Bureau of Reclamation)

Abrasion-Erosion: suspended solids in fast moving water abrades concrete surfaces.

Case Study - Field Performance

Control concrete (no HC)

HC Concrete

Location: Vernon, CA.

Project: Ready mix Co. placed HC and non-HC (control) exit slabs side-by-side at the batch plant truck exit (severe wear environment – heavily loaded ready mix trucks – sand, cement and water spilled on slab – abrasive.)

The slabs are approximately 4 years old and the HC concrete is exhibiting substantially less wear than the slab with no HC (much more loss of control concrete surface paste.).

Wear close-up (HC concrete – right)

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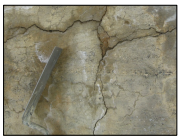

Thank you