CONCRETE DURABILITY WITH SMART CONCRETE

Fadi Farhat
Regional Manager – Middle East
Kryton International
Who is Kryton?

Leader in integral waterproofing and durability enhancing solutions
Smart Concrete solutions

- Makes concrete last longer; extends service life
- Solutions that work better and increase reliability
- Improves construction practices
- Makes jobsites safer
- Lowers costs
- Speeds up installation
Smart Concrete products

• Waterproofing and Durability Enhancing Admixtures
• Surface-Applied Waterproofing
• Construction Joints & Details
• Waterproofing & Leak Repair Systems
The Kryton Story

- Founded in 1973
- Inventor of the crystalline waterproofing admixture
- One of the largest concrete waterproofing research centers in North America
  - Specializing in concrete permeability and self-sealing testing
  - Inventor of the only reliable and accurate test method for measuring self-sealing of concrete (US Patent 9,038,477)
In 2017 Kryton acquired Cementec Industries

- Hard-Cem: World’s first integral concrete hardening admixture
  - Used to increase abrasion and erosion resistance of concrete
Concrete is the most used man-made material in the world.

Twice as much concrete is used around the world than the total of all other building materials, including wood, steel, plastic and aluminium.

Nearly 3000 kg used annually for each man, woman and child.
“… the ability of concrete to resist *weathering* action, *chemical* attack while maintaining its desired *engineering* properties.”

(Portland Cement Association)
Concrete is known as durable material but there is extensive evidence to show that concrete structures around the world are not meeting their designed service life due to rapid deterioration.
With the exception of mechanical damage, all the adverse influence on durability involve the transport of fluids through the concrete. (Properties of Concrete, Neville)

Water Permeability determines the rate of deterioration

Service life - Durability

Sustainability
Concrete is a hard material with a network of openings (capillaries, pores, cracks, and micro cracks). The water passes through the unprotected concrete.

Water can directly damage concrete (Freeze – Thaw). Water acts as a carrier of aggressive chemicals (Chloride).
Aesthetic Damage (Efflorescence)
- Structural Damage (Corrosion)
Waterproofing systems are designed to resist hydrostatic pressure in order to:

• Keep water in (and out of) concrete and
• Increase durability of concrete structures.
Traditional Waterproofing / Membrane Surface Waterproofing

Membrane forms a barrier against water penetration

Sheet membranes
Fluid-applied membranes
Wet Soil
Membrane failure stems from the following sources:

- Design errors
- Installation mistakes
- Membrane reaches the end of its effective service life
Question:
Why not use the concrete as a membrane?

Integral Waterproofing
Traditional waterproofing
Apply a barrier to the concrete

An alternate Solution is:

Improve concrete matrix &
Make concrete the barrier
The principles are similar to the Hydration of concrete.

- Untreated concrete (C)
  
  Cement + Water $\rightarrow$ CSH + CH

- Treated concrete (C+K) with Krystol
  
  Cement + Water $\rightarrow$ CSH + CH + Needle Shape Crystals
Integral Crystalline Waterproofing Technology

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.
Comparison

ICW Concrete

Regular Concrete
ICW admixture can replace the need for external waterproofing membranes.

Admixture is added to concrete by weight of total cementitious content.

With ICW admixture, batch and deliver concrete as normal.

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Wet Soil
Integral Crystalline Waterproofing
Krystol Admixture (KIM)

Crystalline waterproofing as an admixture was invented and pioneered by Kryton during the 1980’s.

- Powdered form
- Dosed at 2% or less by weight of cementitious material
- Added directly to ready mix truck or at batch plant
- Is compatible with other concrete admixtures
- Effective against hydrostatic pressure.
Integral Crystalline Waterproofing
Krystol Admixture (KIM)

KEY FUNCTIONS

- Reduces Permeability
- Reduces Shrinkage
- Self Seals Cracks up to 0.5mm
- Improves Chemical Resistance
- Improves Durability
1983 - Boeing – Everett, WA - 767

18,000 Feet of Tunnels
2010 - Marina Bay Sands, Singapore

25m below sea level
60,000m³ of KIM concrete
5 contractors on site – 1 waterproofing system
Standard Developing Organizations

ACI 350

ACI 212.3 R-10 (Chapter 15)

BS 8102 – Type B

BBA
ACI 212 – Chapter 15

Similar reactions may exist involving the calcium aluminates, but the aforementioned process is expected to predominate due to the abundance of calcium silicates. These crystalline deposits develop throughout the depth of the concrete and become a permanent part of the concrete mass. The crystalline deposits resist water penetration against hydrostatic pressure, and can be categorized as PRAHs. As hairline cracks form over the life of concrete, crystalline admixtures continue to activate in the presence of moisture and seal additional gaps (Kubal 2000; Skoglund and Johansson 2003). Cracks may still develop that exceed the self-sealing property, and admixture suppliers should be consulted regarding the recommended method of repair. It has been reported that once fully cured, crystalline systems contribute to reducing concrete permeability and can be a complementary component in a well-proportioned mixture incorporating permeability-reducing admixtures. Figures 15.3 and 15.4 demonstrate the permeability under pressure of concrete mixtures containing fly ash and similar mixtures containing a crystalline PRA at the age of 10 months. The crystalline admixture resulted in a significant reduction in permeability when added to the fly ash mixture.

Unlike hydrophobic materials, crystalline admixtures are hydrophilic, and the active ingredients react with water and cement particles in the concrete to form calcium silicate hydrates and/or pore-blocking precipitates in the existing microcracks and capillaries. The mechanism is analogous to the formation of calcium silicate hydrates and the resulting
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KRYSOL WATERTIGHT CONCRETE SYSTEM

KRYSOL INTERNAL MEMBRANE — HS (KIM-HS)


18.5 Concrete mixes containing the product are suitable for Type B constructions as defined in BS 8102: 2009, and can meet the requirements for all grades defined in Table 2 of this Standard. For Grade 3 (where control of water vapour is required), it will be necessary to provide a mix with a sufficiently low vapour permeability in combination with an adequate section thickness (see sections 6.2 and 6.3). The use of suitable ventilation, dehumidification or air-conditioning, appropriate to the intended use, must also be considered.
# KIM BBA results

**Table 3** Effects of KIM-HS on the hardened properties of concrete

<table>
<thead>
<tr>
<th>Property</th>
<th>Control concrete</th>
<th>KIM-HS</th>
<th>Test reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water permeability (m·s⁻¹)</td>
<td>4.29 x 10⁻¹⁴</td>
<td>1.28 x 10⁻¹⁴</td>
<td>Taywood/Valenta</td>
</tr>
<tr>
<td>Drying shrinkage (%)</td>
<td>0.040</td>
<td>0.030</td>
<td>BS 1881-5</td>
</tr>
<tr>
<td>Wetting expansion (%)</td>
<td>0.030</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td>Freeze/thaw expansion (%)</td>
<td>0.742</td>
<td>0.099</td>
<td>BS 5075-2</td>
</tr>
<tr>
<td>Compressive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours</td>
<td>18.0</td>
<td>13.0</td>
<td>BS EN 12390-3</td>
</tr>
<tr>
<td>28 days</td>
<td>54.3</td>
<td>59.0</td>
<td></td>
</tr>
<tr>
<td>Flexural strength (N·mm⁻²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours</td>
<td>2.5</td>
<td>2.0</td>
<td>BS EN 12390-5</td>
</tr>
<tr>
<td>28 days</td>
<td>5.5</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Modulus of elasticity (N·mm⁻²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 days</td>
<td>35000</td>
<td>40500</td>
<td>BS 1881-122</td>
</tr>
<tr>
<td>Water vapour permeability [g·m⁻¹(N·s)⁻¹]</td>
<td>561 x 10⁻¹²</td>
<td>463 x 10⁻¹²</td>
<td>BS 3177</td>
</tr>
</tbody>
</table>
How to select Integral Waterproofing BBA Comparison

The BBA is the UK’s major authority offering approval of construction products, systems.

![Percentage Reduction in Permeability](image)

- Fine Filler: Reference 19, Treated 70
- Crystalline: Reference 39, Treated 49
- Pore Blocker: Reference 49, Treated 70
- Hydrophilic Crystalline: Reference 70, Treated 70

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Global Certifications & Approvals
The second durability problem:

Wear created by abrasion and erosion
Abrasive and Erosive Wear

Abrasive & erosive wear of concrete reduces service life
Abrasive wear

**SLIDING ABRASION**
Hard objects sliding across concrete surface

**ROLLING ABRASION**
Hard wheels rolling across concrete surface (pallet jacks, carts, etc.)

**FOREIGN PARTICLE ABRASION**
Hard particles trapped between tires and concrete surface
Abrasive wear (Light industrial floor)

Concrete surface wear from forklifts, trucks and pallet jacks moving heavy pallets

- Safety concerns and operational efficiency loss
  - Too rough to use pallet jacks
  - Increased wear on forklift
  - Tripping hazards
  - Floor joints expanding
  - Difficult to keep clean

- Facility taken out of service for repairs after 15-20 years
Abrasive wear (Heavy industrial floor)

30 MPa concrete exposed to skid steer loaders and abrasive wet ore

- In Service in 2011
- Concrete surface paste worn away within 1 year
- Worn through to reinforcement within 3 years
- Unsafe and not functional within 5 years of service
- Facility taken out of service for costly repairs
Erosive wear

Suspended solids in fast moving water abrades and erodes concrete surfaces

*source: “Guide to Concrete Repair”; US Department of the Interior Bureau of Reclamation*
Significance of Abrasive & Erosive Wear

Functionality
- Reduced productivity / operational efficiency
- Increased wear and tear on equipment
- Reduced cleanliness
- Increased repairs, shut-downs and reduced service life

Accelerated Deterioration
- Increased wear, pitting and degradation
- Reduced friction and makes pavements unsafe, particularly in wet weather
- More susceptible to freeze-thaw deterioration, chloride ion penetration, chemical infiltration and severity of cavitation.

Safety
- Increased chance in loads tipping, injury and product damage.
- Mass loss affects structural integrity
- Wear creates dust which is unacceptable in many factories and warehouses.
Significance of Abrasive & Erosive Wear

- Functionality
- Accelerated Deterioration
- Safety

Reduced Concrete Structure Service Life

Increased Maintenance Costs
Traditional methods:

Traditional methods of reducing concrete wear caused by abrasion and erosion
Traditional Method #1
- Dry Shake Hardeners

Cement, mineral or metal based aggregates and other additives that are broadcast and worked into wet concrete surface.
 Installed product; takes time, costs money and can lead to mistakes

• Mixed performance based on application
  ▪ Difficult to install; dosage and application uniformity
    – Effects performance
    – Often leftover material
#1 Dry Shake Hardeners - limitations

- Limited application window
  - Too early: bleed water can be trapped, surface can delaminate
  - Too late: cannot work in required dosage and compromise surface strength

- Installation is weather dependent
  - Temp restrictions
  - Can’t be installed when windy

- Cannot be used with mixes containing Supplementary Cementing Materials like fly ash
#1 Dry Shake Hardeners - limitations

- Cannot be used on air entrained concrete
- Cannot be used on vertical or inclined concrete or behind formwork
- Health hazard – occupational exposure to on-site dust
Traditional Method #2
- Liquid Densifiers

Silicate based products that fill surface pores
Common misconception is that they reduce wear

- Typically referred to as dust-reducers
  - Originally sold to minimize dust caused by abrasion
- Often show no abrasion resistance over regular concrete

“Do liquid hardeners help concrete floors resist wear?”

“Going just on my own testing, I would have to answer no. I’ve tested hardeners on multiple floors, and not once did the hardener significantly reduce wear depth.”

George Garber, Concrete Floor Consultant
The Solution:
Hard-Cem®

Hard-Cem: Integral Hardening Admixture used to increase abrasion and erosion resistance of concrete.

- Added to the concrete during batching to harden the concrete paste against abrasion and erosion.
Hard-Cem®

Extends service life and reduces maintenance costs

CONTROL CONCRETE  HARD-CEM CONCRETE

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Real time updates on: Facebook, Twitter
Hard-Cem® – Benefits

Best-in-class abrasion and erosion concrete wear resistance

- Concrete wear resistance increased 2 to 6 times
- Removes risks associated with installation

Easy Application

- Added to concrete at the time of batching
  - 40 kg per m³ (67 lbs per yd³)
- No negative side effects on plastic / hardened concrete
Hard-Cem® – Benefits (continued)

Outperforms and replaces the need for dry shake hardeners

- Fully compatible with air entrained concrete
- Can be used on horizontal / vertical concrete
- Saves time
- Improves concrete finishing
- Removes installation complications
- Can be used in pre-cast or shotcrete
- Consistent dosage and performance
- Not constrained by weather
- No harmful dust exposure
Superior value and performance than traditional methods; dry shake, densifiers or high performance concrete
Performance
## Compatibility with concrete

<table>
<thead>
<tr>
<th>#</th>
<th>Concrete Property</th>
<th>Test Methodology</th>
<th>Significant Hard-Cem Effect?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water demand and Workability (slump)</td>
<td>CSA A23.2-5C / ASTM C143</td>
<td>NO</td>
</tr>
<tr>
<td>2</td>
<td>Setting Time (warm and cool temp)</td>
<td>ASTM C403</td>
<td>NO</td>
</tr>
<tr>
<td>3</td>
<td>Bleed water evolution</td>
<td>ASTM C232</td>
<td>YES</td>
</tr>
<tr>
<td>4</td>
<td>Entrained Air Content and Stability</td>
<td>ASTM C231</td>
<td>NO</td>
</tr>
<tr>
<td>5</td>
<td>Compressive Strength Development</td>
<td>CSA A23.3-3C / ASTM C31, C192</td>
<td>NO</td>
</tr>
<tr>
<td>6</td>
<td>Drying Shrinkage</td>
<td>Based on water demand</td>
<td>NO</td>
</tr>
</tbody>
</table>

ASTM C627: Robinson Floor Tester

Robinson is the most aggressive abrasion test available

- Measures mass loss and wear depth
  - Total of 800 lbs (273 kg)
  - Hardened steel wheels
  - 5000 revolutions
  - 6+ hours

- Large Test specimen
  - Allows for real life concrete finishing

- Modified for concrete abrasion resistance testing
  - Testing modifications by Dr. Rusty Morgan, AMEC (wheels, revolutions)
  - Adopted as a standard by Lafarge WCAN Lab
Robinson Floor Tester Wear Profiles

Control Concrete

Concrete with Integral Hardener Hard-Cem

Filings from metal wheels sitting on surface
Robinson Floor Tester – competitive results

Hard-Cem vs Control
(25 MPa concrete)
Robinson Floor Tester – competitive results

Hard-Cem vs Shake-on Hardeners
(25 Mpa concrete)
Robinson Floor Tester – competitive results

Hard-Cem vs Silicate Sealers and Fibers
(25 Mpa concrete)
Field Performance – side by side test

Hard-Cem showed significantly less wear after 4 years in severe wear environment

- Concrete batch plant truck exit
  - Heavily loaded ready mix trucks
  - Abrasives; Sand, cement and water
- Brush finish vs surface paste lost resulting in aggregate exposure
Applications for Hard-Cem

14 years and over 60,000,000 ft² of proven performance
### Applications - air/non-air concrete

#### Industrial
- Super-flat floors
- Warehouses
- Distribution facilities
- Service bays
- Wash bays
- Manufacturing facilities
- O&G facilities

#### Transportation
- Highways
- Bridges
- Intersections
- Ramps
- Bus barns
- Bus lanes
- Parking structures
- Runways/ aprons

#### Waterworks
- Spillways
- Dykes
- Stilling basins
- Pre-cast pipes
- Canals
- Dams
- Breakwaters
- Revetments
AGLC – Agent for the Government of Alberta

- Main distribution centre for beverages for the Province of Alberta, Canada
  - 44,500 m² (479,000 ft²)
  - 40 cm (16 inch) slab stratified
    - 18 cm (7 inch) Hard-Cem concrete on 22 cm (9 inch) 35 MPa concrete
  - 15 slabs x 400 m³ (523 yd³) each

- Increasing service life, reducing repairs and keeping this distribution center efficient was critical
Heavy Industrial Project: Kitimat, BC

Rio Tinto Alcan Modernization (Metals Refining)

- $3.3B modernization of the 60 year old smelter
- Hard-Cem concrete used in all smelter potlines, exterior building aprons and service building floors
- Flatwork ranged in thickness from 20-30 cm (8-12 inches) thick under heavy equipment
- Approximately
  - 46,450 m$^2$ (500,000 ft$^2$) treated concrete
  - 12,500 m$^3$ (16,350 yds$^3$) of treated concrete
  - 500 tonnes of Hard-Cem
Military Project: CFB Gagetown, NB

Department of National Defense

- Armoured Vehicle Maintenance Facility
- 2790 m² (30,000 ft²) treated concrete
- Additional 7,900 m² (85,000 ft²) repeat specified for expansion
Infrastructure Project: Burlington, ON

Wastewater Treatment Plant

- Upgrades and expansion to increase plant capacity
  - New treatment facility and upgrade secondary treatment
  - 1,000 m$^3$ (1307 yds$^3$) of Hard-Cem concrete
    - 40 tonnes of Hard-Cem

- Integral waterproofing (KIM) also used on this Hard-Cem project
THANK YOU

FOR ANY QUESTIONS PLEASE CONTACT
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