A Fresh Look at Cementitious Materials

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Kari L. Yuers, FACI, is the President and Chief Executive Officer of Kryton International Inc. based out of Vancouver, B.C., Canada. Kari joined Kryton in 1991 in the position of Vice President, Technical Services. Since taking the reins at Kryton, Kari has focused on developing award-winning products that create dry and durable concrete structures through integral crystalline waterproofing. Her research interests are concrete admixtures related to permeability, durability and sustainability of concrete structures as well as materials for concrete repair and protection. She is a currently the Chair of ACI's International Advisory Committee (IAC); Member and Secretary of Committee 212, Chemical Admixtures; E702, Design of Concrete Structures; and E701, Materials for Concrete Construction. Kari is the document Chair for the E701 E4-12 document on Chemical Admixtures. In addition, Kari serves on the Convention Committee, Financial Advisory Committee and Committee 362, Parking Structures. In 2005 she won the American Concrete Institute's Young Member Award for Professional Achievement and in 2010 she was appointed Fellow of the Institute.

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Admixtures Part 2

Permeability Reducing Admixtures and Admixtures for controlling ASR

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Permeability Reducing Admixtures
PRA's

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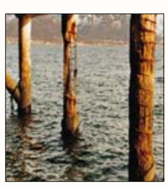
Concrete Durability

- The most common mechanisms that deteriorate concrete all involve water

1. Freeze/thaw damage
2. Chloride attack/Corrosion of steel reinforcement
3. Sulfate attack
4. Alkali aggregate reaction (AAR) also known as ASR



- Reducing water ingress is a critical factor in making durable concrete.

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 http://www.corrosion-club.com/concreteintro4.htm

How Water Enters Concrete

- Pores and capillaries
- Cracks
- Voids or other defects

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Making Durable Concrete

- Methods to reduce water ingress and increase durability include:
  - Proper mix proportioning
  - Low water-cement ratios
  - Effective placement/consolidation
  - Effective wet curing practices
  - Use of Supplementary Cementitious Materials (SCMs)
  - Use of Permeability Reducing Admixtures (PRAs)

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Permeability Reducing Admixtures (PRA)

- Permeability Reducing Admixtures are chemical admixtures used to protect concrete from the damaging effects of water and water borne chemicals.
- PRAs are a distinct tool for making durable concrete, and compliment rather than replace other tools such as SCMs.
- With proper selection and use, PRAs have been used to replace surface applied sealers, water repellents and membranes.
- Often referred to as "integral systems"

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PRA Advantages

- PRAs provide integral protection against water and chemicals throughout the full depth of a concrete element.
- PRAs can eliminate the labor needed to apply surface protective systems.
- PRAs are not vulnerable to surface damage.
- The installation of PRAs is less affected by environmental factors (particularly rain)

Categories or PRAs

- PRAN
  - **P**ermeability **R**educing **A**dmixture for **N**on-Hydrostatic Conditions
    - Previously referred to as "dampproofing admixtures"
- PRAH
  - **P**ermeability **R**educing **A**dmixture for **H**ydrostatic Conditions
    - Previously referred to as "waterproofing admixtures"

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Benefits of PRAs

- Primary Effect:
  - Reduced water absorption (PRAN)
  - Reduced water permeability (PRAH)
- Benefits:
  - Depends on the PRA, but may include:
    - Reduced chemical ingress
    - Reduced corrosion of steel reinforcement
    - Reduced efflorescence
    - Reduced drying shrinkage
    - Enhanced autogenous sealing of cracks

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PRAN Materials

- PRANs reduce water absorption under non-hydrostatic conditions
- Reduced absorption is commonly achieved through the use of hydrophobic chemicals that repel water
  - Soaps, long chain fatty acids, silanes/siloxanes
- Fine particle fillers may be used to restrict pore size and act as densifiers
  - Talc, bentonite, silicates

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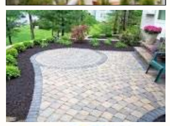
PRANS – Applications and Benefits

- Used to repel rain and minimize dampness for concrete above grade or in damp environments.
- Improved quality of concrete pavers, tiles, bricks, blocks
- Reduced efflorescence and maintenance of clean surfaces.
- Reduced rate of moisture entering exposed concrete, reduced frost damage.
- Improved moisture resistance for concrete in damp service environments.



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PRAH Materials

- PRAHs typically consist of hydrophilic ingredients that react and hydrate with cement particles to generate crystalline, pore blocking deposits, or resinous polymers that coalesce within the pores.

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Applications - PRAHs

- Used to reduce concrete permeability to water under pressure:
  - Basement foundations and parking structures
  - Water containment structures
  - Tunnels
  - Bridges and dams
  - Water features
- With proper mix proportioning and design, watertight structures can be build without membranes.
- PRAHs with crystalline reactivity can self seal leaking cracks.

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Testing and Evaluation

- Testing must represent the actual field conditions the PRA must withstand.
- Primary Testing
  - PRAN – Absorption Testing
  - PRAH – Permeability Testing (pressure driven)
- Secondary
  - Slump, air content, compressive strength, drying shrinkage

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Non-Hydrostatic Testing

- Absorption (wicking)
  - ASTM C1585
  - BS EN 1881: Part 122
- Measures water uptake vs. time.
- Suitable to evaluate PRANs
  - Measures the reduced absorption/water repellent properties
- Does not apply hydrostatic pressure, not suited to evaluate PRAHs for below grade applications.

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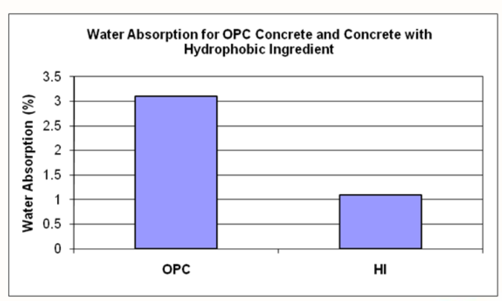

Water absorption for OPC concrete (w/c = 0.4) at an age of 28 days using BS EN 1881-122

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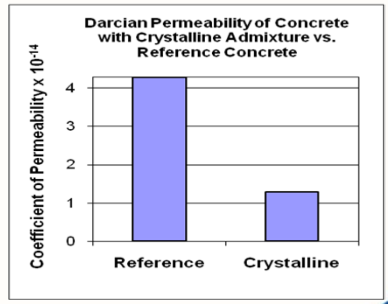
Hydrostatic Testing

- Pressure Driven Tests
  - DIN 1048-5
  - BS EN 12390-8
  - USACE CRD C48

- Applies pressurized water to one face of a concrete specimen.
- Results reported as depth of water penetration or a coefficient of permeability.
- Measures the permeability reducing properties of crystalline materials and polymer resins
- Used to evaluate and select PRAHs



Permeability reduction using modified BS EN 12390-8 (Pressure 150 psi, 96 hours)

Georgetown South Project Toronto, Ontario

- Underground Sewer Tunnel
- 1700 feet with numerous formwork penetrations
- Construction environment was constantly damp
- Waterproofed with crystalline admixture in conjunction with crystalline grout for joints and penetrations.

Structural shotcrete – Telus Garden Vancouver BC

- Premium residential and office space.
- Shotcrete placement can damage or dislodge membranes.
- The PRAH admixture doubled the productivity of erecting perimeter shotcrete walls by eliminating a bentonite membrane.

City Center, Las Vegas

Marina Bay Sands Integrated Resort Singapore

- Asia Pacific's largest resort, $5.7 B investment.
- Over 80 feet below grade, built on reclaimed land and surrounded by the ocean.
- The scale of the project made waterproofing a logistical challenge.
- 60000 m^3 of waterproof concrete was used as the sole waterproofing system.

Summary

- PRAs are useful for protecting concrete from water ingress and increasing durability.
- PRAs are an alternative to surface applied protective systems
- PRAs are based on a diverse range of materials with different features and abilities.
- Select PRAs based on the expected service conditions.
- Evaluate PRAs using tests methods appropriate to the intended use:
  - Absorption testing – PRANs
  - Pressure driven (permeability) testing - PRAHs

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Admixtures for Controlling ASR

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Lithium Admixtures for Alkali-Silica Reaction (ASR)

- ASR can occur in concrete when susceptible siliceous minerals in the aggregate begin to dissolve and form gels which absorb moisture and produce tensile stresses that disrupt the structure of the concrete
- Proper diagnosis in the field requires petrographic examination of specimens from structures in question

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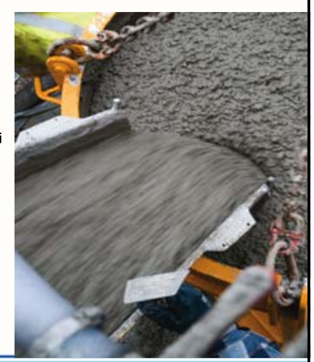
Approaches to minimize ASR in concrete are:

- Use of non-reactive aggregates
- Limit the alkali content in the concrete (with low alkali cements, e.g.,)
- Use appropriate SCMs
- Use lithium admixtures
- Combinations of these approaches



Lithium Admixtures for Alkali-Silica Reaction (ASR)

- The most common lithium admixture for ASR control is a 30% solution of lithium nitrate in water
- The dose is determined first by performance testing, and is proportional to the alkali content in the concrete
- It is expressed in terms of percent of a ‘standard’ dose, which is equal to 0.55 gal per lb of alkali supplied by the portland cement (4.6 liters per kg of alkali)
- It is added during batching, usually with the mix water

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Lithium Admixtures for Alkali-Silica Reaction (ASR)

- Lithium admixture has been used in the US primarily in bridge structures, pavements, and repairs
- The effects on concrete properties are generally minimal, with the main effect, when it occurs, is the acceleration of set time
- While lab and field studies have shown very little effect on set times, some experiences with some cements have shown strong accelerations, particularly in combination with fly ash
- This is due to the nitrate ion present in the admixture
- As with all admixture use, mix designs must be evaluated in the lab prior to use

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2001 ITD Project
23% Class F Fly ash (2010)

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ACI E701 E4-12 Doc Chemical Admixtures by Kari L. Yuers

2001 ITD Project
23% Class F Fly ash (2010)

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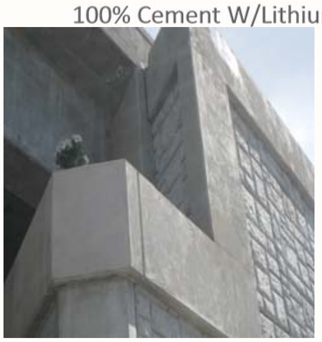
2003 ITD Project
100% Cement W/Lithium



Feb 2010
No visible
cracking

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2003 ITD Project
100% Cement W/Lithium

Sept 2013
No visible
cracking

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Thank you

For more information please consult:
E701 E4-12 Chemical Admixtures
212 3R-10 Chemical Admixtures

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