Concrete Waterproofing and Chemical Protection

with CRYSTALLINE TECHNOLOGY

Presenter Profile - Jim Caruth

- BASc Civil Eng, U of Waterloo, 1984
- Member of APEGBC
- 25 Years Experience in Concrete and Concrete Construction
  - Hilti Canada
  - Ocean Construction Supplies Ltd. – Concrete Division
  - Lehigh Cement – Pozzolanic
  - Lehigh Northwest Materials – Aggregate
  - Sika Canada Limited
  - Xypex Chemical Corporation
- Member of American Concrete Institute – BC Chapter Board
- Past Voting Member of CSA A3000 Committee
- Past Committee Chair – BCRMCA
## The History of Crystalline Waterproofing

<table>
<thead>
<tr>
<th>Period</th>
<th>Key Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early to Mid 40’s</td>
<td>Vandex invents Crystalline Waterproofing</td>
</tr>
<tr>
<td></td>
<td>- Coatings and Hydraulic Cements</td>
</tr>
<tr>
<td>Late 60 – mid 75’s</td>
<td>NA Manufacturer’s Establish – Xypex, Kryton, Others follow</td>
</tr>
<tr>
<td>Mid 80’s to Mid 90’s</td>
<td>- Crystalline Admixture introduced</td>
</tr>
<tr>
<td>2005 – 2010</td>
<td>- Majors Introduce Crystallines – BASF, Sika, Chryso</td>
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</table>

## Crystalline Waterproofing Technology
Crystalline Waterproofing Materials

Concrete is Porous and Permeable

A 5000 times SEM photograph of Concrete
How Crystalline Waterproofing Works

Calcium Hydroxide and other by-products of cement hydration / un-hydrated cement particles

+ Crystalline Waterproofing Chemicals

= Non-soluble crystalline formation permanently fixed within the concrete’s pore structure

Bleed Tract Without Crystalline Waterproofing

Bleed Tract With Crystalline Waterproofing
Because the crystalline waterproofing formation is within the concrete it cannot be punctured or damaged like a membrane or surface coating.

- Crystalline waterproofing will withstand high hydrostatic pressure from both the positive and negative side.

- Self heals cracks up to 0.4mm.

- Crystalline waterproofing is highly resistant to chemicals.

- Crystalline waterproofing is unaffected by humidity, ultraviolet light and oxygen levels.
## Proven Performance

Taywood Engineering, CRDC C48-73, Singapore

### Sample Reference Control Concrete Crystalline treated Concrete

<table>
<thead>
<tr>
<th>Date of Cast</th>
<th>22/01/97</th>
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<tr>
<td>Age of Curing (days)</td>
<td>8</td>
<td>29</td>
<td>8</td>
</tr>
<tr>
<td>Specimen Size (mm)</td>
<td>150 x 50</td>
<td>150 x 50</td>
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</tr>
<tr>
<td>Specimen Reference</td>
<td>1 2 3 1 2 3 1 2 3 1 2 3</td>
<td></td>
<td></td>
</tr>
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</table>

**Volume of water moving through the sample (mL):**

- **At 1 bar on:**
  - 1st day: 0 0 0 0 0 0 0 0 0 0
  - 2nd day: 0 0 0 0 0 0 0 0 0 0
  - 3rd day: 0 0 0 0 0 0 0 0 0 0
  - 4th day: 0 0 0 0 0 0 0 0 0 0
  - 5th day: 0 0 0 0 0 0 0 0 0 0
  - 6th day: 0 0 0 0 0 0 0 0 0 0
  - 7th day: 0 0 0 0 0 0 0 0 0 0
  - 8th day: 0 0 0 0 0 0 0 0 0 0
  - 9th day: 0 0 0 0 0 0 0 0 0 0
  - 10th day: 0 0 0 0 0 0 0 0 0 0

## Permeability

Taywood Engineering, CRDC C48-73, Singapore

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  - 9th day: 0 0 0 0 0 0 0 0 0 0
  - 10th day: 0 0 0 0 0 0 0 0 0 0
Permeability

Bautest, DIN 1048, Germany, 1980

Untreated control sample had average 84 mm of water penetration. Crystalline treated control sample had average 6 mm of water penetration. Hydrostatic pressure equivalent to 224 ft of hydraulic head.

Crack Sealing Test

The Construction Bureau of Chubu District, Japanese Ministry of Construction (Sept 1996)

Photo 1: Evidence of cracking in concrete on underside of the deck slab.
Crack Sealing Test

- General Test for pH Range
- Chloride Resistance
- Sulphate Resistance
- Sulphuric Acid Resistance

Independent Testing

*Figure 3: Change in Amount of Outflow with Time*
General Test to Establish pH Range

- ASTM C-267-77 “Chemical Resistance of Mortars”
- 4,000 psi, non-air entrained concrete
- Crystalline treated and untreated samples had 84 day exposure time
- Seven chemicals with pH range from 3.5 – 11.0
- Compressive strength testing at conclusion

General Test to Establish Chem. Resistance

Broad pH Resistance - 1983
Pacific Testing Laboratories – Seattle, Washington
ASTM C-267-77 “Chemical Resistance of Mortars”

Report on chemical resistance of Crystalline treated concrete samples constantly immersed for 28 days

<table>
<thead>
<tr>
<th>Identification No.</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hydrochloric Acid (pH 3.5)</td>
</tr>
<tr>
<td>2</td>
<td>Brake Fluid</td>
</tr>
<tr>
<td>3</td>
<td>Transformer Mineral Oil</td>
</tr>
<tr>
<td>4</td>
<td>Stearine Oイル (5% by volume)</td>
</tr>
<tr>
<td>5</td>
<td>Hot Water</td>
</tr>
<tr>
<td>6</td>
<td>Pure Chlorine (Undiluted)</td>
</tr>
<tr>
<td>7</td>
<td>Quatric Soda (31.0 pH)</td>
</tr>
</tbody>
</table>

<table>
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<th>Table 1: Summary of Compressive Strength Results</th>
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<tbody>
<tr>
<td>Compression Strength, P.S.I.</td>
</tr>
<tr>
<td>Species</td>
</tr>
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<td>1) Hydrochloric Acid</td>
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<td>5) Hot Water</td>
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<tr>
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Chloride Resistance

Restricts Chloride Ion Diffusion & Protects Reinforcing Steel
Australian Centre for Construction Innovation, University of New South Wales (Sydney 2003)

CHLORIDE PENETRATION TESTS ON XYPEX ADMIX C-1000F MODIFIED COMMERCIAL CONCRETES

Table 2.4 Description of Chloride Resistance Test Methods

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Source</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid Chloride Ion Penet.</td>
<td>ASTM C 4032-1</td>
<td>Measurement of chloride penetration depth and chloride diffusion coefficients of concrete after exposure to 10% sodium chloride solution for 10 days.</td>
</tr>
<tr>
<td>Sandblast</td>
<td>C1-1000H, 1000X</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.4 Summary of Test Results

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Concrete Type / Content Type</th>
<th>Age (days)</th>
<th>Compressive Strength</th>
<th>Chloride Diffusion Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td></td>
<td>28</td>
<td>44.6</td>
<td>0.1%</td>
</tr>
<tr>
<td>Specimen</td>
<td></td>
<td>90</td>
<td>48.6</td>
<td>0.1%</td>
</tr>
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Chloride Resistance Improves Concrete’s Durability - Chlorides

Restricts Chloride Ion Diffusion & Protects Reinforcing Steel
Australian Centre for Construction Innovation, University of New South Wales (Sydney 2003)

By Gary Kao
B.Eng., B.Sc., UNSW
Research Engineer

0.55 w/cm ratio, 38% Slag Concrete with no Crystalline

0.55 w/cm ratio, 38% Slag Concrete with 1.6% Crystalline C-1000

Crystalline addition increases time to corrosion by a factor of 5
Chloride Resistance

Restricts Chloride Ion Diffusion & Protects Reinforcing Steel
BCRC Pty Ltd. – NSW, Australia
Analysis and report of precast docks exposed to marine environment for 19 years
Time to initiation of reinforcing steel corrosion computed at 129 years

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<tr>
<th>Component</th>
<th>GB80</th>
<th>GP</th>
<th>LH</th>
<th>SR</th>
<th>SF</th>
<th>ADMIX</th>
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<tbody>
<tr>
<td>Total Percentage Weight Loss</td>
<td>14.60</td>
<td>12.00</td>
<td>28.40</td>
<td>7.20</td>
<td>8.80</td>
<td>8.80</td>
</tr>
<tr>
<td>Loss Percentage Length Change</td>
<td>0.01</td>
<td>–</td>
<td>0.12</td>
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<td>-0.01</td>
<td>-0.02</td>
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Note 1: Total Percentage Weight Loss is given for 25 weeks exposure.
Note 2: Percentage Length Change is given as the change compared to the GP mix, at 25 weeks.

Sulfate Resistance

Ammonium Sulfate Exposure
Taywood Engineering, Sydney, Australia
1 molar - 132 g/l
Six mixes: control, low slag cement, silica fume, high slag cement, silica fume cement, Crystalline Admix

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Sulfate Resistance

Ammonium Sulfate Exposure
Australian Centre for Construction Innovation, University of New South Wales (Sydney 2003)
Sulfate resistance testing per AS 2350.14

Table 1.4 Summary of Test Results

<table>
<thead>
<tr>
<th>Material</th>
<th>Concrete Type and Treatment</th>
<th>Expansion</th>
<th>Sulfate Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beton</td>
<td>20% Na2SO4, 20% NaOH, 0%</td>
<td>0.8%</td>
<td>Moderate</td>
</tr>
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Fig 3.2A Expansion in Sulfate Solution of Fly Ash Concrete Samples

Fig 3.3A Expansion in Sulfate Solution of slag Concrete Samples

Sulfate Resistance

Ammonium Sulfate Exposure
Betonconsult s.r.o.
Building Materials Testing Laboratory – Prague, Czech Republic (2006)
Sulfate resistance test in 36,000 mg of SO4/L exposure for 4 months

The test was conducted on normal cast concrete samples, which were cured in the laboratory under humidity control. The samples were divided into two groups. One group was exposed to a solution containing 5% NaOH and 5% Na2SO4, while the other group was exposed to a solution containing 5% NaOH. The results showed that the specimens exposed to the 5% NaOH solution had a lower expansion than those exposed to the 5% Na2SO4 solution. The samples were covered with a protective film to prevent moisture loss during the test period.
**Acid Resistance**

**Sulfuric Acid Exposure**
*Chemical Durability, Iwate University, Tokyo, Japan*

The typical means of evaluating the ability of the Crystalline treatment to provide chemical resistance include measuring amount of mass loss, length change or relative dynamic modulus of elasticity.

- Before Soaking
- 5 Weeks
- 10 Weeks

**Acid Resistance**

**Sulfuric Acid Exposure**
*Aviles Engineering, Texas, USA*

40 day cure acid comparison test in 7% H$_2$(SO$_4$)
Control, 3%, 5% and 7% Admix (Regular Grade)
Curing periods were varied to determine effects.
Sulfuric Acid Exposure  
C.R.S. Ltd. – Tokyo, Japan  
Electric Power Central Research Laboratory

Comparison of Crystalline Admix treated mortar to control sample and 5 different commercially available acid resistance mortar for 6 months in 5% H₂SO₄ solution. All samples had comparable mass loss, but Crystalline Admix had least change in relative dynamic modulus of elasticity and had the best performance of all 7 samples.

Acid Resistance

Sulfuric Acid Exposure  
Japan Atomic Energy Research Institute – Tokyo, Japan (1989)

As part of a study on the diffusion of Cesium-137 in Crystalline treated and untreated mortar samples a number of different tests were conducted one of which was the immersion of samples in a 5% sulfuric acid solution for 100 days. Crystalline reduced acid attack by 45%
Where is Crystalline not appropriate?

- Highly Acidic Environments pH < 3
  - High H2S Sewerage Locations
  - Concentrated Acidic Process Environments – HCL mfg plant

- High Alkaline Environments
  - Green Liquor Tanks in Pulp Mills

- Other Exceptions
  - Sugars, Ammonium Phosphate, Low Langelier Water

Application Procedures
Coating

- Applied as a highly concentrated cement slurry solution
- Crystalline chemicals diffuse through water in saturated substrate
- Ideal for ‘negative side’ waterproofing

Coating How Deep Does It Penetrate

1992 Hosei University, Japan – Yasuo Mitsuki
Crystal growth evident in SEM images at a depth of 12” at 1 year
Admixture Application Procedure

Addition to drum ahead of loading at ready mix plant

- Adding crystalline waterproofing admixture at the batch plant ensures uniform distribution throughout the concrete and structure
- Makes concrete waterproof, reduces shrinkage cracking and increases compressive strength
- Same crystalline structure as the coating
- Construction costs significantly reduced – break even to Coatings at about 16" thick profile

Admixture Application Benefits
Case Studies

Sewerage – MIC Application

Ocean Grove Sewage System, Australia
City of San Francisco, USA

The Ocean Grove Sewage System in Australia showed significant deterioration. Crystalline materials were used extensively to restore the integrity of the manholes along the system. Here we see the system in operation after treatment.
Sewerage – MIC Application

Clinton St. Sewer Collection Project, USA

In 1999, 30 Admix-treated precast manholes were produced for Terrebonne Parish in Louisiana for an expected mild to moderate sewerage exposure environment. In 2010 the manholes were inspected and there was no degradation discovered. The owners expressed a high level of satisfaction with the performance of the concrete.

Acid / Caustic Resistance

Milton Creamery, Milton Iowa

Typical Phosphoric Acid / Sodium Hydroxide daily wash routine. Floor treated with experimental double standard Crystalline Admixture dosage. After 7 years floor shows remarkably little degradation.
Acid Resistance

**Better Place Station – Holon, Israel**

These stations are to provide “switchable batteries” for designated electric taxis in Israel. Precast company is using crystalline admixture within the precast elements to provide waterproofing in the below grade level and protect the concrete from aggressive battery acid leakage.

Petrochemical Containment

**Gasoline Vault Containment, USA**

Crystalline now has NM state environmental engineering approvals for secondary containment of petroleum, gasoline and diesel. This vault was coated up past the containment levels of the walls with Crystalline Waterproofing.
**Petrochemical Containment**

**Esso Gas Station, Czech Republic**

Crystalline coatings and admixture used in slabs and containment concrete to stop penetration of petroleum products into soils.

**Other Secondary Containment**

**Summit Leipsic Ethanol Plant, USA**

Crystalline modified concrete used to seal secondary containment basins for ethanol holding tanks. Joints and cracks repaired with crystalline materials.
Crystalline coatings and admixtures used in walls and slabs of silage pits to stop leakage and protect concrete from degradation

In 1973 water leaking into the Sea-Tac Airport tunnel covered the electrified rails. Crystalline materials were successfully applied to leaking cracks and faulty construction joints throughout the 4.5 mile (7 km) long underground tunnel. 1980 Letter of reference says tunnels dry. Tunnels still dry today.
Summary of Crystalline Waterproofing

- **Waterproofs and protects concrete**
  against mild to moderate chemical attack.

- **Permanent, integral solution**
  for new systems and rehabilitation.

- **Advantages of barrier systems,**
  with none of the disadvantages.

- **Proven worldwide**
  through thousands of projects successfully
  completed and independent testing.

Thank you for your time.

Questions?

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