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



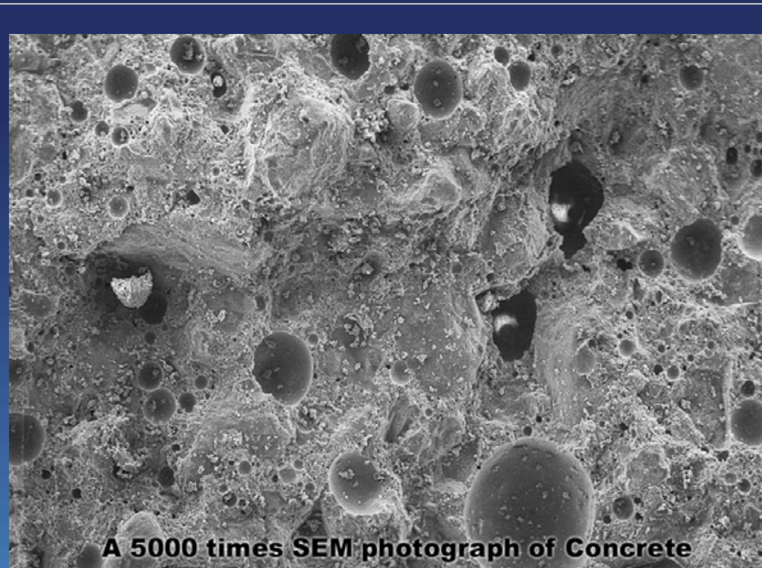
The History of Crystalline Waterproofing

- Early to Mid 40’s – Vandex invents Crystalline Waterproofing
  - Coatings and Hydraulic Cements
- Late 60 – mid 75’s
  - NA Manufacturer’s Establish – Xypex, Kryton, Others follow
- Mid 80’s to Mid 90’s
  - Crystalline Admixture introduced
- 2005 – 2010 Majors Introduce Crystallines – BASF, Sika, Chryso

Crystalline Waterproofing Technology

Crystalline Waterproofing Materials

Concrete is Porous and Permeable



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

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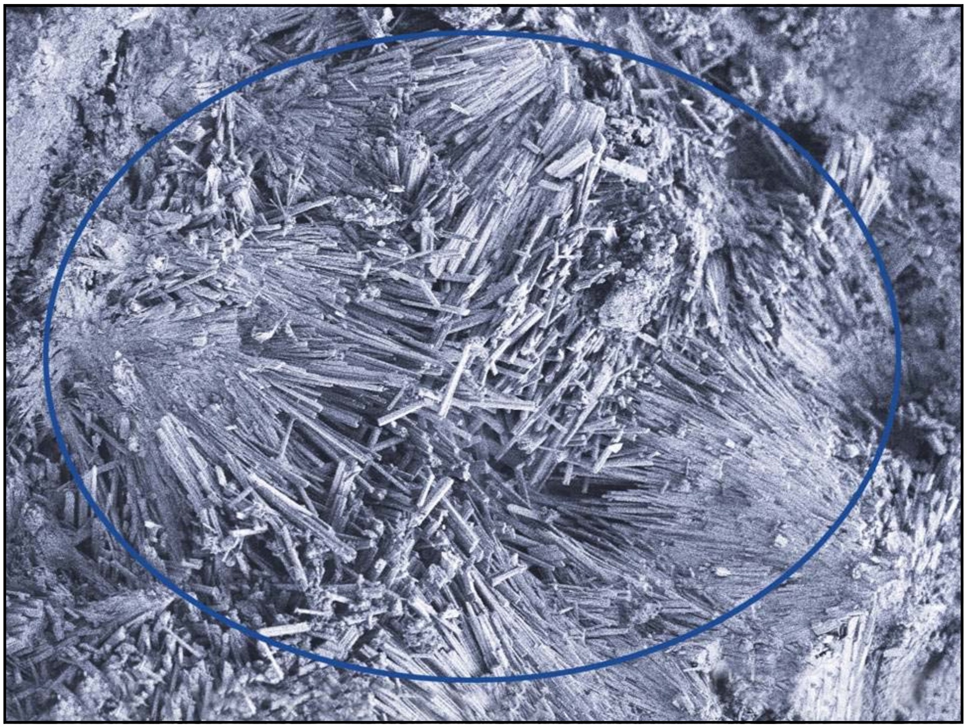
Bleed Tract Without Crystalline Waterproofing	Bleed Tract With Crystalline Waterproofing
	



Characteristics

- 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

Permeability

Taywood Engineering, CRDC C48-73, Singapore

Sample Reference	Control Concrete						Crystalline treated Concrete					
Date of Cast	22/01/97						14/01/97					
Date of Coring	30/01/97			20/02/97			22/01/97			2/12/97		
Age of Curing (days)	8			29			8			29		
Specimen Size (mm)	150 x 50						150 x 50					
Specimen Reference	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Volume of water moving through the sample (mL):												
At 1 bar on 1st day	0	0	0	0	0	0	0	0	0	0	0	0
At 2.4 bar on 2nd day	0	0	0	0	0	0	0	0	0	0	0	0
At 4.2 bar on 3rd day	0	0	0	0	0	0	0	0	0	0	0	0
At 7.0 bar on 4th day	0	0	0	0	0	0	0	0	0	0	0	0
5th day	10	0	4	10	0	0	0	0	0	0	0	0
6th day	30	20	25	74	13	0	0	0	0	0	0	0
7th day	65	20	60	78	20	0	0	0	0	0	0	0
8th day	70	30	60	45	10	0	0	0	0	0	0	0
9th day	70	30	60	35	10	0	0	0	0	0	0	0
10th day	70	30	60	46	10	0	0	0	0	0	0	0

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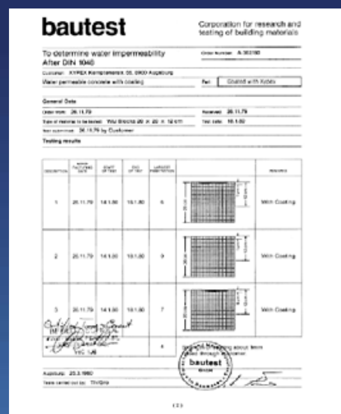
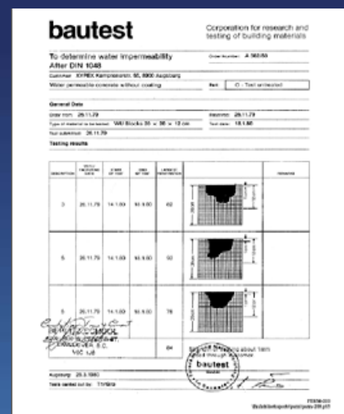
Permeability

Bautest, DIN 1048, Germany, 1980



treated



untreated

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

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Crack Sealing Test

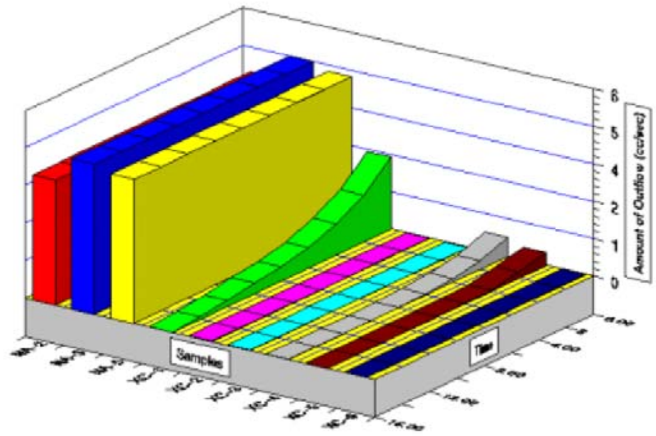

Figure 3: Change in Amount of Outflow with Time

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Independent Testing

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

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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

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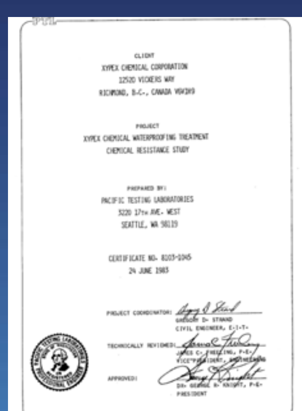
General Test to Establish Chem. Resistance

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



PTL

CLIENT

XYPEX CHEMICAL CORPORATION
12520 VICKERS WAY
RICHMOND, B.C., CANADA V6V1H9

PROJECT

XYPEX CHEMICAL WATERPROOFING TREATMENT
CHEMICAL RESISTANCE STUDY

PREPARED BY:

PACIFIC TESTING LABORATORIES
5220 17TH AVE. WEST
SEATTLE, WA 98119

CERTIFICATE NO. 8103-1045
24 JUNE 1983

PROJECT COORDINATOR: GREGORY D. STRAND, CIVIL ENGINEER, E.I.T.

TECHNICALLY REVIEWED: JAMES C. FREELING, P.E., VICE PRESIDENT, ENGINEERING

APPROVED: DR. GEORGE R. KNIGHT, P.E., PRESIDENT

PACIFIC TESTING LABORATORIES

Identification No.	Solution
1	Hydrochloric Acid (HCl 3.5 pH)
2	Brake Fluid
3	Transformer (Mineral) Oil
4	Ethylene Glycol (50% by volume)
5	Toluene
6	Pool Chlorine (Undiluted)
7	Caustic Soda (11.0 pH)

TABLE II
SUMMARY OF COMPRESSIVE STRENGTH RESULTS

	Solution	Compressive Strength, P.S.I. Specimen Untreated	Treated (Avg.)	Xypex specimens compared to untreated samples % difference
1)	Hydrochloric Acid	8653	9828	+14.8
2)	Brake Fluid	6303	7440	+18.0
3)	Transformer(Mineral) Oil	6446	7377	+14.4
4)	Ethylene Glycol	5905	7639	+29.4
5)	Toluene	6605	7671	+16.1
6)	Pool Chlorine	7544	8539	+13.2
7)	Caustic Soda	8308	9470	+14.0
			Average	+17.13

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-1000NF MODIFIED COMMERCIAL CONCRETES

AUSINDUSTRY START RESEARCH PROJECT

By Gary Kao
B.Mat.E, MSc, UNSW
Research Engineer

Table 2-A Description of Chloride Resistance Test Methods

Test Method	Source	Objectives
Rapid Chloride Ion Test	CSIRO Modified ASTM C1202 (1)	Electrical indication of concrete's ability to resist chloride ion penetration
NordTest	NT BUILD 443, 1995 (2)	Determination of chloride penetration depth and chloride diffusion coefficients of concrete after immersed in 16.5% sodium chloride solution for 35 days

Table 3-A Summary of Test Results

Mix Code	W/C Ratio	Cement Type and Content (kg)	Xypex Admix C-1000NF (% of Cement Content)	Compressive Strength		CSIRO Modified ASTM C1202	NT BUILD 443 (Chloride Penetration Depth)
				3 days	28 days		
GPC	0.55	GP (330)	Nil	24.1	43.8	Control	Control
GPX1	0.55	GP (330)	0.8%	26.1	46.0	- 7%	- 10%
GPX2	0.55	GP (330)	1.2%	27.2	46.8	-16%	- 32%
FAC	0.50	20% Fly Ash (360)	Nil	25.4	42.0	Control	Control
FAX1	0.50	20% Fly Ash (360)	0.8%	25.4	44.6	- 27%	- 38%
FAX2	0.50	20% Fly Ash (360)	1.2%	26.1	44.9	- 41%	-
FAX3	0.48	40% Fly Ash (380)	0.8%	21.1	39.3	-	-
SC	0.55	38% Slag (330)	Nil	17.4	40.2	-	Control
SX1	0.55	38% Slag (330)	0.8%	17.8	42.7	-	- 3%

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Improves Concrete's Durability - Chlorides

Restricts Chloride Ion Diffusion & Protects Reinforcing Steel

Australian Centre for Construction Innovation, University of New South Wales (Sydney 2003)

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

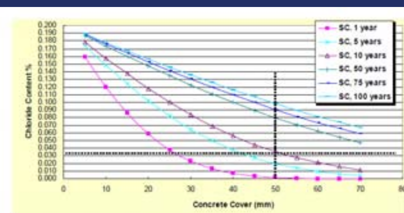


Fig 3.2.1-A Chloride Content vs. Cover Depth Model in Control Mix-SC

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

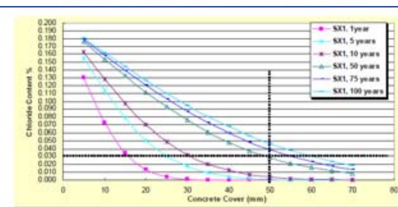


Fig 3.1.2- B Chloride Content vs. Cover Depth Model in Xypex Modified Concrete Mix-SX1

Crystalline addition increases time to corrosion by a factor of 5

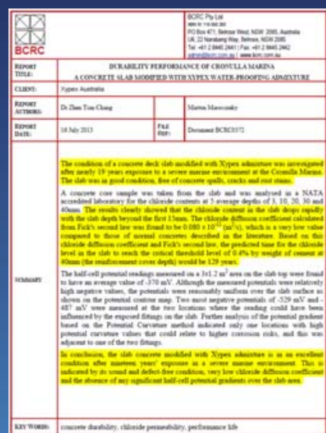
Chloride Resistance

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



BCRC

BCRC Pty Ltd

PO Box 471, Belrose West, NSW 2085, Australia

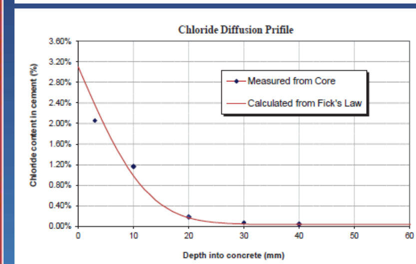
Tel: +61 2 9445 2441 | Fax: +61 2 9445 2442

www.bcrc.com.au

REPORT TITLE:	DURABILITY PERFORMANCE OF CRONULLA MARINA A CONCRETE SLAB MODIFIED WITH XYPEX WATER-PROOFING ADMIXTURE
CLIENT:	Xypex Australia
REPORT AUTHORS:	Dr Zhen Tian Chang; Marton Marosszeky
REPORT DATE:	18 July 2013; FILE REF: Document BCRC0372
SUMMARY	The condition of a concrete deck slab modified with Xypex admixture was investigated after nearly 19 years exposure to a severe marine environment at the Cronulla Marina. The slab was in good condition, free of concrete spalls, cracks and rust stains. A concrete core sample was taken from the slab and was analysed in a NATA accredited laboratory for the chloride contents at 5 average depths of 3, 10, 20, 30 and 40mm. The results clearly showed that the chloride content in the slab drops rapidly with the slab depth beyond the first 13mm. The chloride diffusion coefficient calculated from Fick's second law was found to be 0.080×10^{-12} (m^2/s), which is a very low value compared to those of normal concretes described in the literature. Based on this chloride diffusion coefficient and Fick's second law, the predicted time for the chloride level in the slab to reach the critical threshold level of 0.4% by weight of cement at 40mm (the reinforcement cover depth) would be 129 years. The half-cell potential readings measured on a 3x1.2 m^2 area on the slab top were found to have an average value of -370 mV. Although the measured potentials were relatively high negative values, the potentials were reasonably uniform over the slab surface as shown on the potential contour map. Two most negative potentials of -529 mV and -487 mV were measured at the two locations where the reading could have been influenced by the exposed fittings on the slab. Further analysis of the potential gradient based on the Potential Curvature method indicated only one locations with high potential curvature values that could relate to higher corrosion risks, and this was adjacent to one of the two fittings. In conclusion, the slab concrete modified with Xypex admixture is in an excellent condition after nineteen years' exposure in a severe marine environment. This is indicated by its sound and defect-free condition, very low chloride diffusion coefficient and the absence of any significant half-cell potential gradients over the slab area.
KEY WORDS:	concrete durability, chloride permeability, performance life

Table-1. Chloride Contents in the Concrete Slab Core

Range of Sample Depths (mm)	Average Sample Depth (mm)	Chloride Content by Weight of Concrete (%)	Chloride Content by Weight of Cement (%)
0 - 6	3	0.46	2.057
7 - 13	10	0.26	1.163
17 – 23	20	0.041	0.183
27 – 33	30	0.019	0.085
37 – 43	40	0.009	0.040



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

Results of Exposure Trials

	MIX DESIGNATION					
Component	**GB80**	**GP**	**LH**	**SR**	**SF**	**ADMIX**
Total Percentage Weight Loss	14.60	12.00	28.40	7.20	8.80	**8.80**
Loss Percentage Length Change	0.01	–	0.12	0.00	-0.01	**-0.02**

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.

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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

SULPHATE RESISTANCE ON XYPEX ADMIX C-1000NF MODIFIED COMMERCIAL CONCRETES

AUSINDUSTRY START RESEARCH PROJECT

By Gary Kao
B.Mat.E, MSc, UNSW
Research Engineer

Table 3-A Summary of Test Results

Mix Code	W/C Ratio	Cement Type and Content (kg)	Xypex Admix (% of Cement Content)	Compressive Strength		Sulphate Expansion
				3 days	28 days	
GPC	0.55	GP (330)	Nil	24.1	43.8	Control
GPX1	0.55	GP (330)	0.8% C-1000NF	26.1	46.0	Similar
GPX2	0.55	GP (330)	1.2% C-1000NF	27.2	46.8	- 15%
FAC	0.50	20% Fly Ash (360)	Nil	25.4	42.0	Control
FAX1	0.50	20% Fly Ash (360)	0.8% C-1000NF	25.4	44.6	- 7%
FAX3	0.48	40% Fly Ash (380)	0.8% C-1000NF	21.1	39.3	-
FAX4	0.50	20% Fly Ash (360)	1.2% C-2000NF	30.4	48.9	- 27%
SC1	0.55	38% Slag (330)	Nil	17.4	40.2	Control
SX1	0.55	38% Slag (330)	0.8% C-1000NF	17.8	42.7	- 58%
SX2	0.48	60% Slag (380)	0.8% C-1000NF	20.2	50.3	-

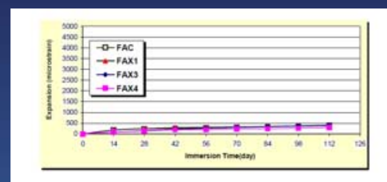


Fig. 3.2-A Expansion in Sulphate Solution of Fly Ash Concrete Samples

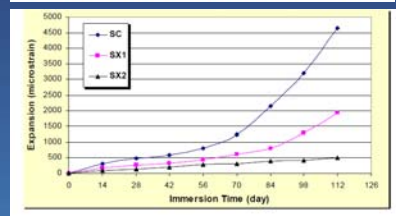


Fig 3.3-A Expansion in Sulphate Solution of Slag Concrete Samples

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

3. Completed Testing and Results

The tests were completed on cubes with 150 mm sides, which were cast in the laboratory of the Rohansky Island central concrete plant. Concrete of all cubes met the C30/37 classification. A total of 14 cubes were tested:

- additive C-1000 - 1% - 3 cubes
- additive C-1000 - 2% - 3 cubes
- additive NF - 0.5% - 3 cubes
- additive NF - 1% - 3 cubes
- concrete with no additive - 2 cubes

Samples were placed in plastic containers with constant concentration of sulfates at 36,000 mg/l for the entire duration of the experiment. The testing started on October 2006 and was completed in February 2007. The total exposure time of the samples was approximately 4 months.

After the samples were fully saturated their mass was recorded with 0.1g precision. After the test was completed the samples were rinsed with running water and again their mass recorded. The mass difference was considered the mass loss caused by sulfate attack/corrosion. At the same time photographic documentation of the samples was completed.

The results show that mass loss of samples made with the XYPEX Admix C additive in both concentrations as well as with the additive NF in both concentrations was between 5 and 50 g/m² and the samples were characterized by visual examination as showing no deterioration.

In the case of the control samples, the mass loss was 4,880.0 g/m².

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**

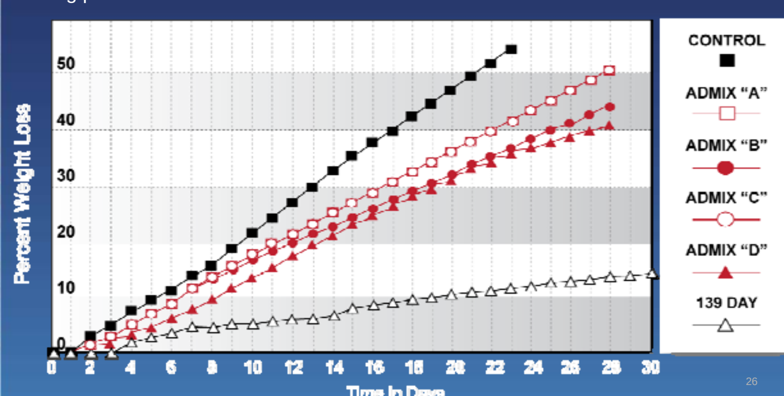
UNTREATED | Crystalline | UNTREATED | Crystalline | UNTREATED | Crystalline

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



Acid Resistance

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% $H_2(SO_4)$ 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.

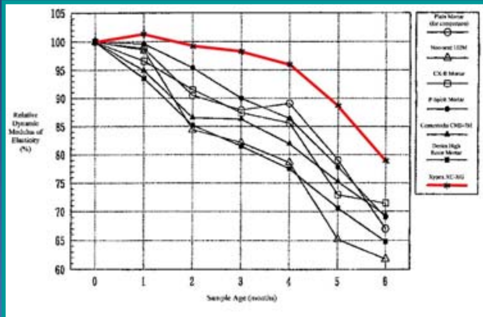


Figure 1. Relationship between the relative dynamic modulus of elasticity and the sample age for various types of mortar materials.

Acid Resistance

Sulfuric Acid Exposure

Japan Atomic Energy Research Institute – Tokyo, Japan (1989)

As part of a study on the diffusion of Cesium137 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%

JAERI - M
89-211

セメントモルタル中の137Csの拡散に関する研究

日本原子力研究所
Japan Atomic Energy Research Institute

Table 2 Physicochemical characteristics of cement mortar and impermeable cement mortar.

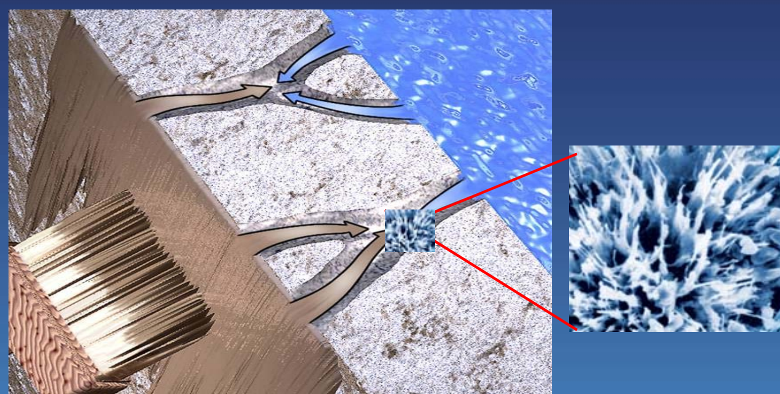
Physicochemical characteristics	Cement mortar	Impermeable cement mortar	Analytical method
Specific gravity (g/cm^3)	1.989	2.028	JIS-A-1202-1978
Tri-axial compressive strength (kg/cm^2)	300	344	JIS-A-1108
Water permeation distance (mm)	84	4	DIN-1048 Permeability test (Input method, Contact time ;4day)
Corrosion ratio	0.210	0.117	Resistance to acid attak test (5% H_2SO_4 solu., Contact time;100day)
Carbonated thickness (mm)	14.4	8.4	(CO_2 gas conc. 5%, Temp. 30℃, Contact time;100day)
Drying shrinkage ratio	1.2×10^{-3}	1.0×10^{-3}	JIS-A-1129 (Measurement of length change, Contact time;100day)

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

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

Admixture Application Benefits

- 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

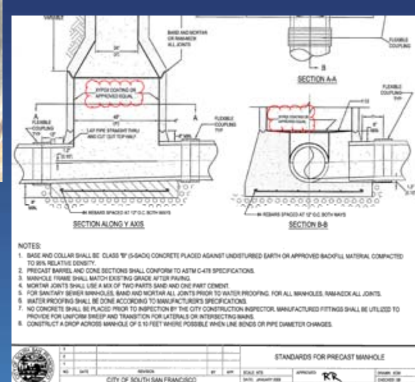
Case Studies

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.

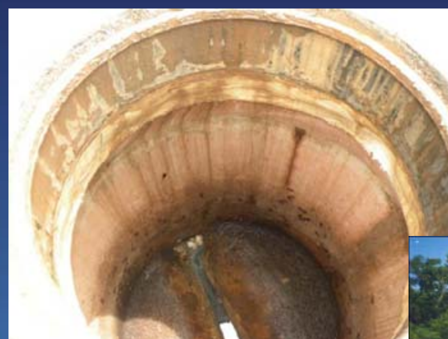
City of San Francisco standard repair drawings name Crystalline Materials for repair and rehabilitation of deteriorated manholes



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.

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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 pre-cast elements to provide waterproofing in the below grade level and protect the concrete from aggressive battery acid leakage.

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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

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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.

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Silage

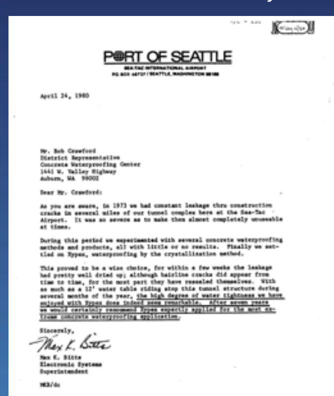
Kozojedy u Plzne Silage Pits, Czech Republic

Crystalline coatings and admixtures used in walls and slabs of silage pits to stop leakage and protect concrete from degradation

Longevity of Crystalline Effect

Sea-Tac Airport Seattle, USA

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.



PORT OF SEATTLE
SEA-TAC INTERNATIONAL AIRPORT

April 24, 1980

Mr. Bob Crawford
District Representative
Concrete Waterproofing Center
1441 W. Valley Highway
Auburn, WA 98002

Dear Mr. Crawford:

As you are aware, in 1973 we had constant leakage thru construction cracks in several miles of our tunnel complex here at the Sea-Tac Airport. It was so severe as to make them almost completely unuseable at times.

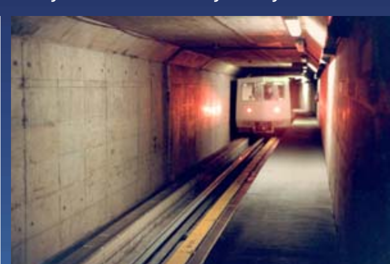
During this period we experimented with several concrete waterproofing methods and products, all with little or no results. Finally we settled on Xypex, waterproofing by the crystallization method.

This proved to be a wise choice, for within a few weeks the leakage had pretty well dried up; although hairline cracks did appear from time to time, for the most part they have resealed themselves. With as much as a 12' water table riding atop this tunnel structure during several months of the year, the high degree of water tightness we have enjoyed with Xypex does indeed seem remarkable. After seven years we would certainly recommend Xypex expertly applied for the most extreme concrete waterproofing application.

Sincerely,

Max K. Bitte
Electronic Systems
Superintendent

MKB/ds



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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.

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Thank you for your time.

Questions?

Contact Information
Jim Caruth, Tel: 800-961-4477