Pavement Preservation and Sustainability Benefits of Using Dual and Multi-Crystalline Technologies

Mr. Radi Al-Rashed, President and CEO
International Chem-Crete Company
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Global Pavement Consultants, Inc.
Mr. Oleg Tataru, Head of Aerodrome Service
Chisinau International Airport, Moldova

International Chem-Crete Co.

- Founded in 1969 in Dallas Texas
- Manufacturing Locations: **USA** (Richardson, Texas), **Europe** (Holic, Slovakia)
- Manufacture Full Line of Construction Chemical Products: water-based, cementitious, epoxies, polyurethanes, ..
- Roadway pavements, airport pavements, bridges, tunnels, rail systems, commercial buildings and a host of others.
- Research and development – green technologies:
  - primary focus on developing cost-effective solutions to the most common types of durability issues facing Portland Cement Concrete (PCC) pavements.
  - Increasing concrete sustainability
  - Reducing maintenance cost
  - Reduce failures and shutdowns
- Internal research, Universities, Independent Labs, Industry & Filed Consultants

TECHNOLOGIES

- Dual Crystalline – Topical treatment for old & green concrete

CHEM-CRETE®
PAVIX CCC100

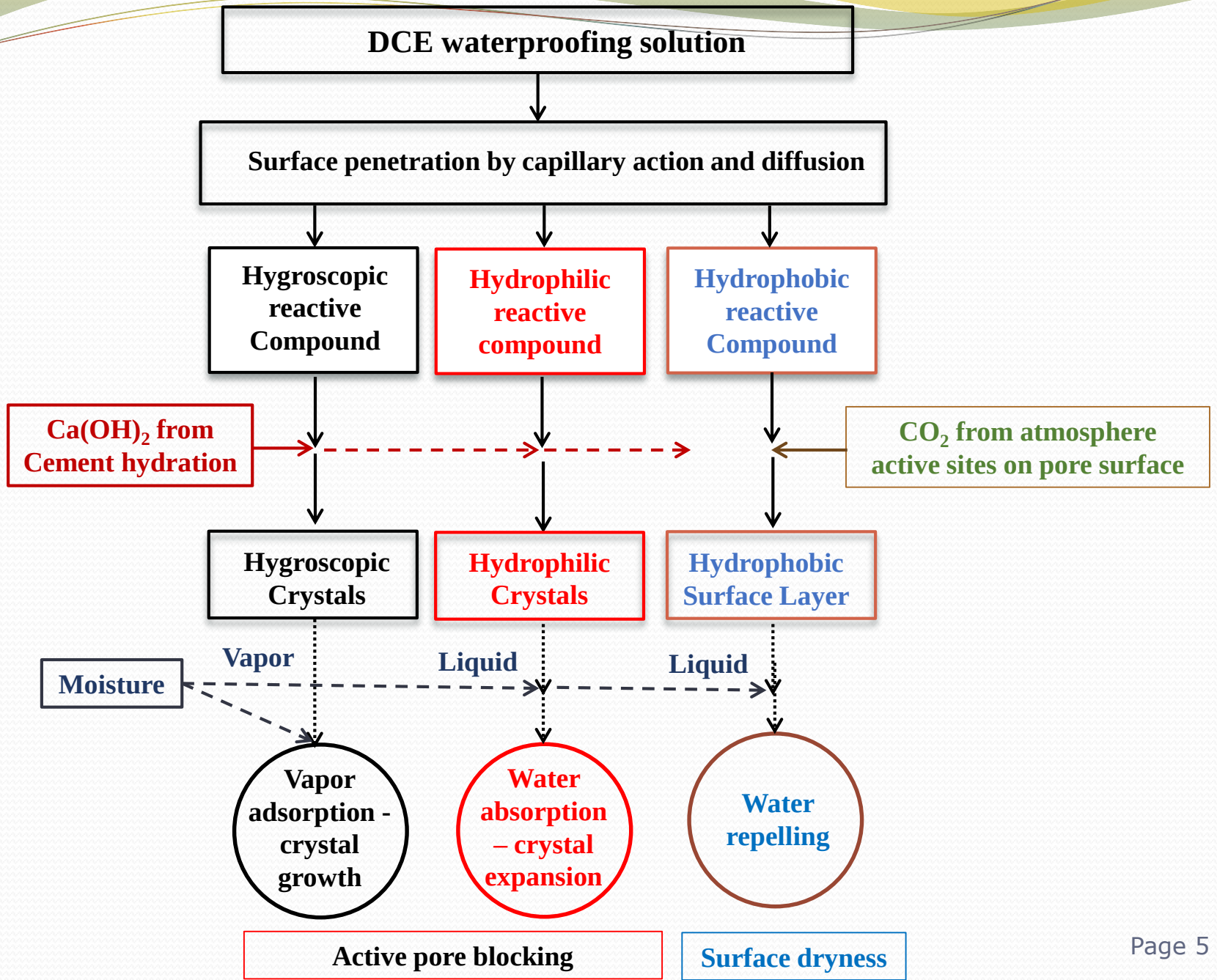
- Multi Crystalline Technology – Intermixed Concrete Enhancer

CHEM-CRETE®
MCE
CONCRETE ENHANCER

Latest & Most Advanced Patented Technologies for Protecting PCC Against all Water Related Problems

Chem-Crete Crystallization Waterproofing Technology

- Product Chemistry
- Theoretical Briefing - Functionality
- Thermal Management
- ASR Mitigation – Comparative Approach


DCE waterproofing solution
Surface penetration by capillary action and diffusion
Hygroscopic reactive Compound
Hydrophilic reactive compound
Hydrophobic reactive Compound
Ca(OH)2 from Cement hydration
CO2 from atmosphere active sites on pore surface
Hygroscopic Crystals
Hydrophilic Crystals
Hydrophobic Surface Layer
Moisture
Vapor
Liquid
Liquid
Vapor adsorption - crystal growth
Water absorption – crystal expansion
Water repelling
Active pore blocking
Surface dryness

Theoretical Briefing - Chem-Crete Pavix and MCE Functionality

After the formation of Pore Blocking Crystals and Pore Lining Molecular Layers

(1) consuming the available moisture through additional crystal growth and then releasing it back through its reversibility,

(2) storing thermal energy in crystal growth by water adsorption and then releasing it back through its reversibility,

(3) minimizing water penetration into the pores

(4) allowing concrete breathing through MCE performance of partial blocking mechanism.

As consequences of these capabilities of the MCE,

1) Hindering the penetration of harmful materials into concrete

2) Reducing-Preventing water freezing within pores by

   1) eliminating the availability of water

   2) hindering the adhesion of ice on to the cementitious surface (icephobicity is corelated to hydrophobicity).

Thermal Management by Chem-Crete Pavix and MCE

Based on dynamic crystallization mechanism

This leads to the ability of Pavix and MCE for controlling temperature, humidity and water phase change within concrete:

(1) Reducing Conduction Heat Transfer

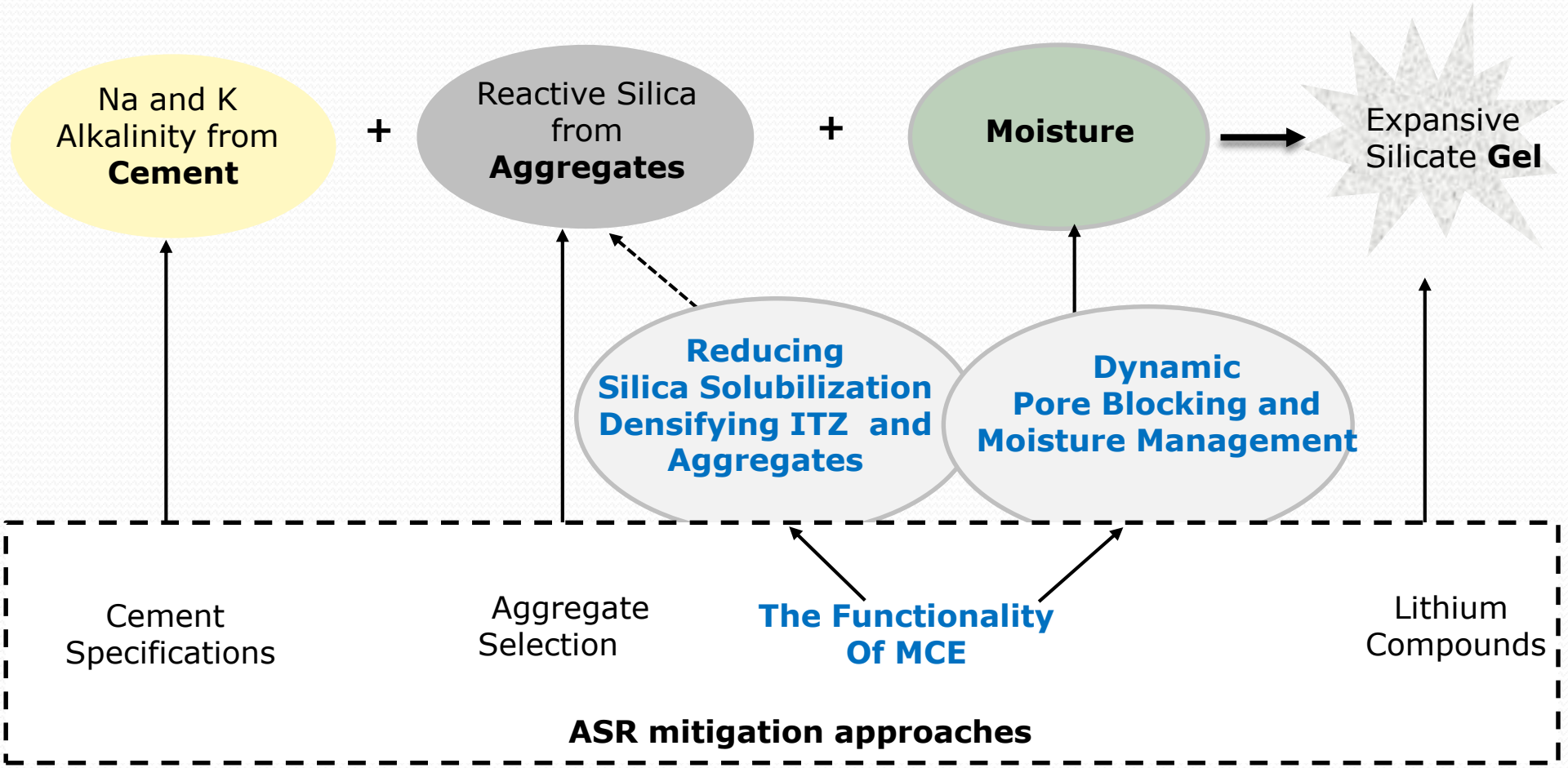
(2) Managing Phase Change within Concrete Pores

(3) Managing Moisture Content Though Combined Heat and Mass Transfer Processes

(4) Preventing Freezing in Fresh Concrete through Heat Generation and Storage

(5) Minimizing Ice Adhesion by Thermodynamic and Heat Transfer Mechanisms

Thermal Management by Chem-Crete Pavix and MCE



Presentation Overview

- This presentation focuses on the use of topically applied International Chem-Crete Company PAVIX CCC-100, a dual crystalline “sealer”, and MCE, a multi-crystalline enhancer.
- The information to be presented has been consolidated from a large amount of laboratory data and field trials.
- Please note that PAVIX is often used in conjunction with MCE for critical applications.

Modes of Distress

- Failure in concrete roadways, airfields, parking areas, industrial facilities, etc. can be categorized as structural or functional.
- Functional distress typically involves ride quality, surface texture (friction) and noise.
  - Functional distresses are very important to the public and are typically simple to address (diamond grinding).
- Structural distresses impact the ability of the pavement to carry the imposed loads.
  - Structural distresses are significantly more difficult and expensive to address (full-depth repairs, partial-depth repairs load transfer restoration, support restoration, etc.)
- <u>Sustainability considerations must focus on both distress types.</u>

Critical Factors in Concrete Roadway Longevity

- Design
  - Considers traffic, support, climate and available materials.
- Construction
  - The construction method must be suited to a specific project.
  - A comprehensive QC/QA program must be in place .
- Materials
  - Concrete durability is often the most important factor in long-term performance

Examples of Distress Related to Moisture Management

Moisture in Concrete Drives the Majority of Durability-Related Distresses

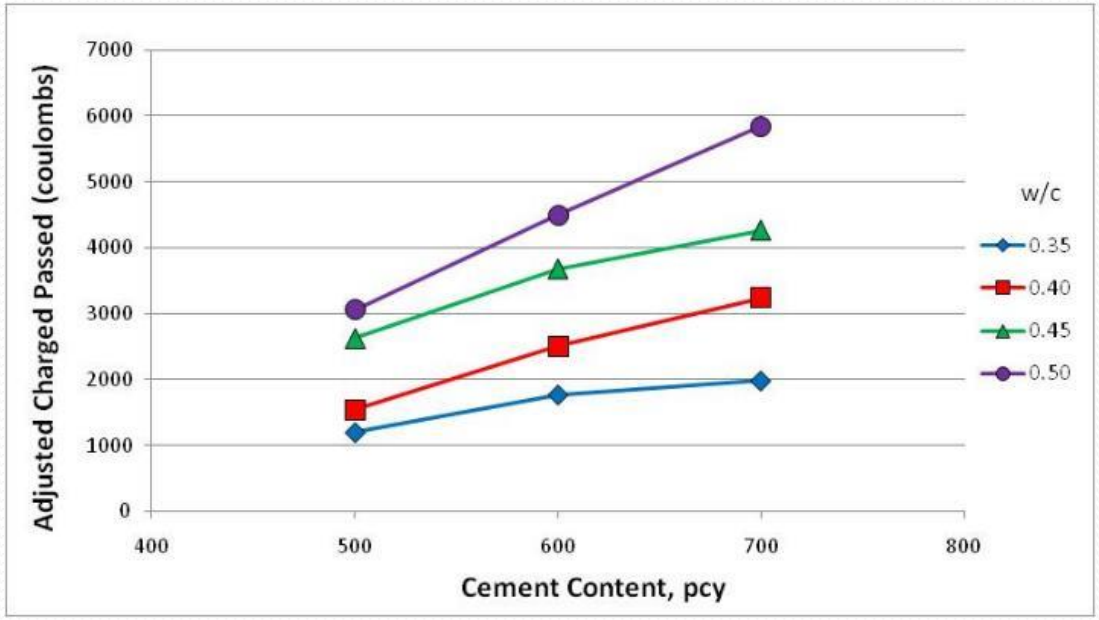
- Simply stated, if you can prevent moisture (vapor, liquid or solid) from entering or migrating in hardened concrete, the majority of durability problems are solved.
- Since pavements are subjected to the harshest conditions possible, how can this be done cost effectively?
- There are relatively few options:
  - Mix design/proportioning.
  - A surface applied “sealer or protectant”
  - An intermixed enhancer

Concrete Mix Design/Proportioning

- Water or water vapor movement in concrete is basically through the capillary pores within the hardened concrete.
- Concrete mixes can be engineered to be less permeable, although often at substantially higher cost.
- There are practical limits for reducing concrete permeability through the mix design process due to workability considerations, materials availability and cost.
- The Performance Engineered Mixture (PEM) approach is the most comprehensive way to achieve this.

How Do We Proportion to Achieve Design Goals?

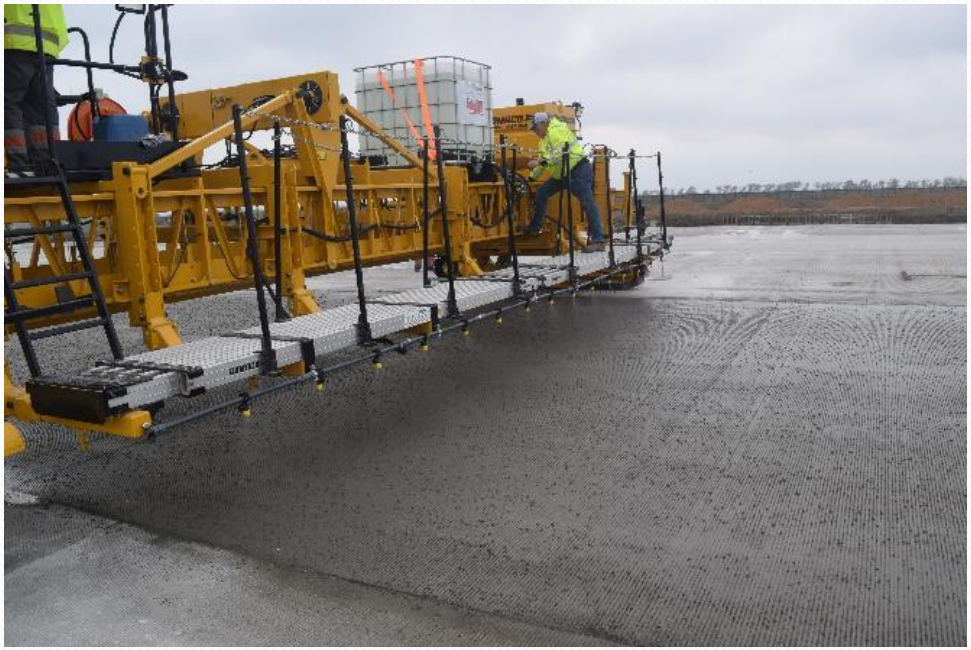
		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	**Type, gradation**	✓✓	-	-	-	-	✓✓
Paste quality	**Air, w/cm, SCM type and dose**	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	**Vp/Vv**	✓	-	-	-	✓✓	-



Other Options

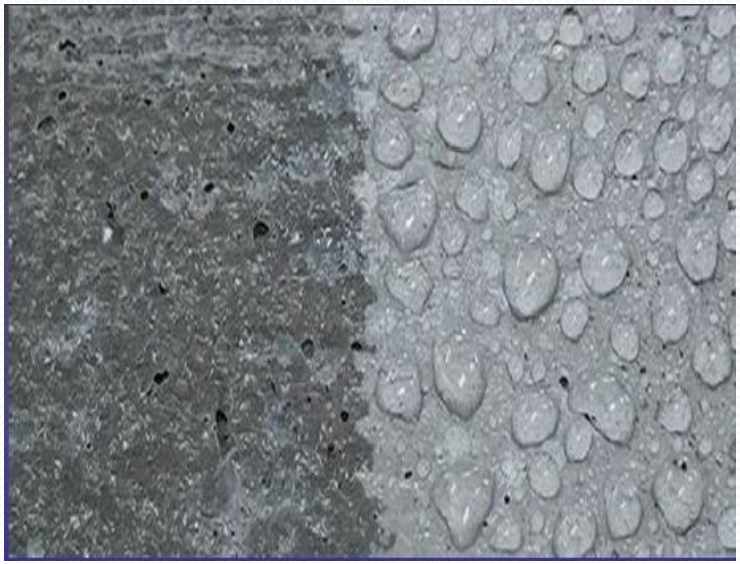
- International Chem-Crete has developed 2 specific patented products that are used to effectively mitigate moisture-related damage in concrete pavements (and structures) and thereby promote sustainability and longevity.
- PAVIX CCC-100 is a dual crystalline penetrating "sealant" that is surface applied to either fresh or hardened concrete.
- MCE is a multi-crystalline enhancer that is added to the concrete at the time of batching to provide uniform and thorough protection.

Typical PAVIX Application

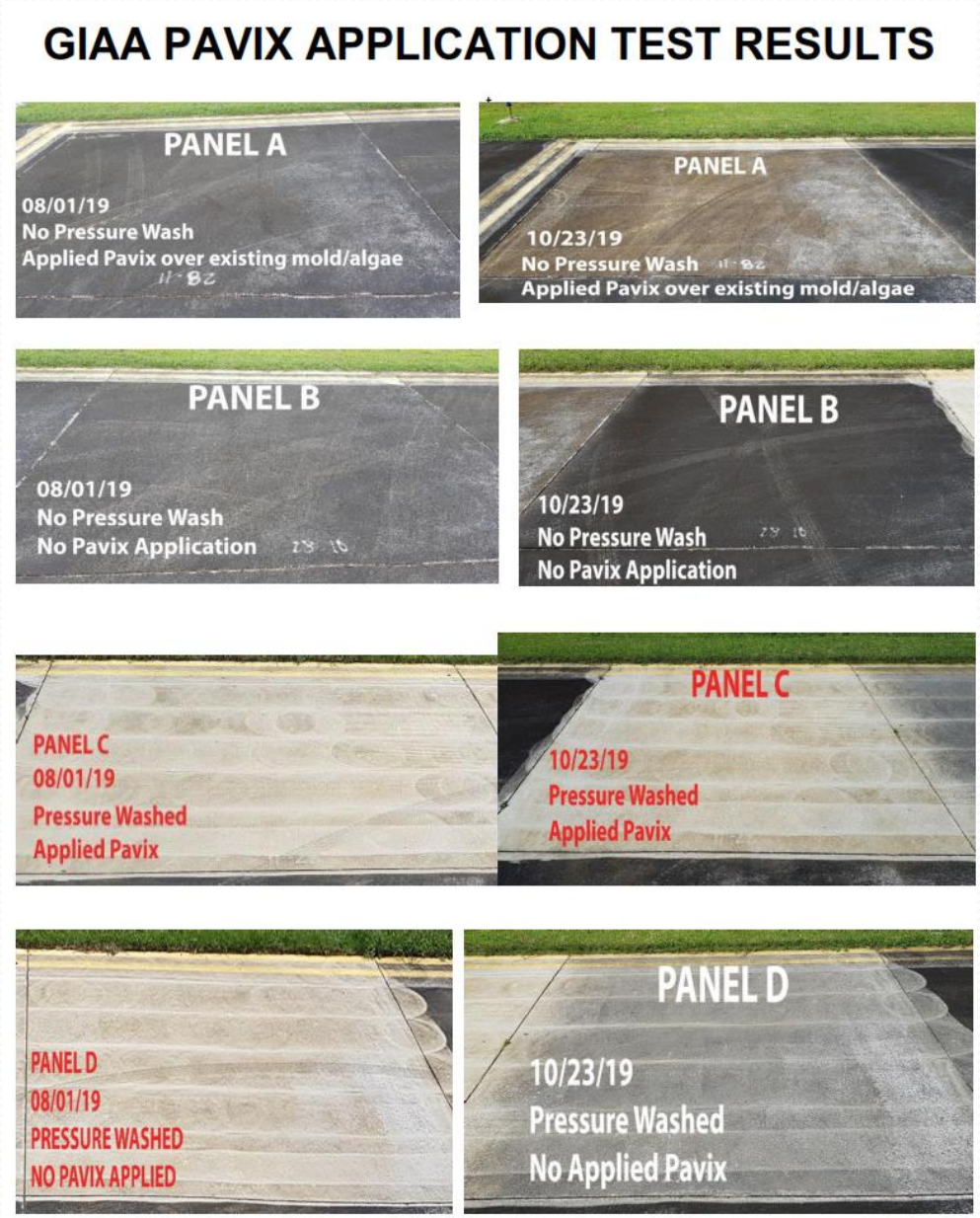


Benefits of Surface Applied PAVIX

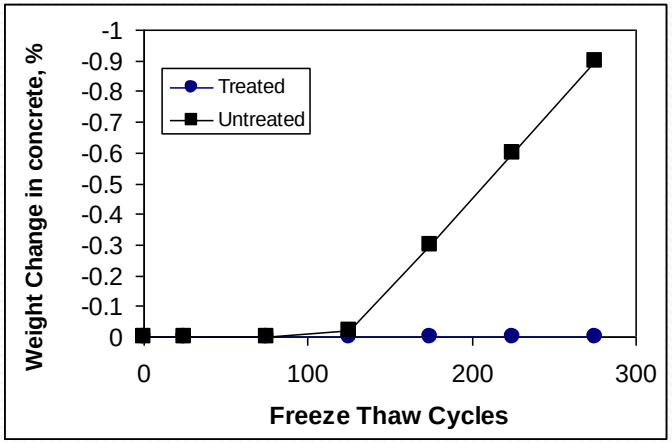
- Reduce moisture transmission
- Reduce water penetration from the surface
- Proven protection against:
  - Water and moisture
  - De-icing chemicals
  - Freeze-thaw cycle damage
  - Pavement staining
  - Mold and algae growth
  - Corrosion of reinforcing steel

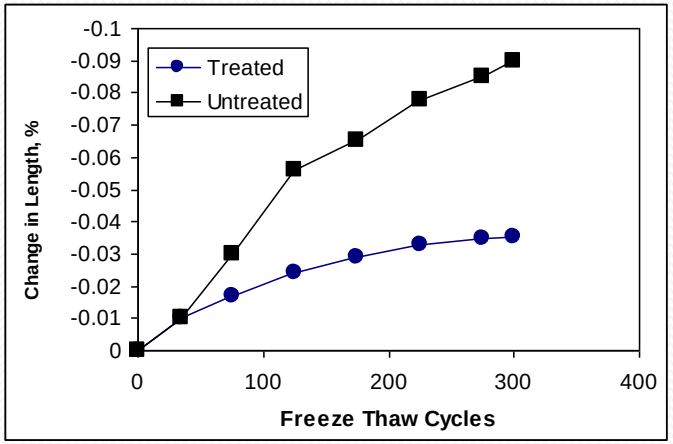


Effect on Mold and Mildew

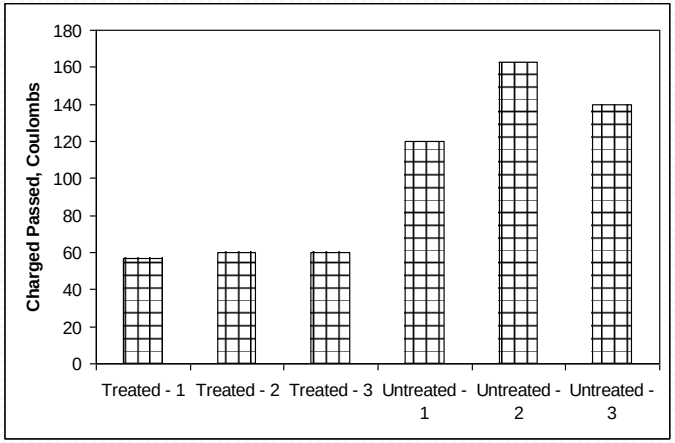


Representative Test Results for PAVIX





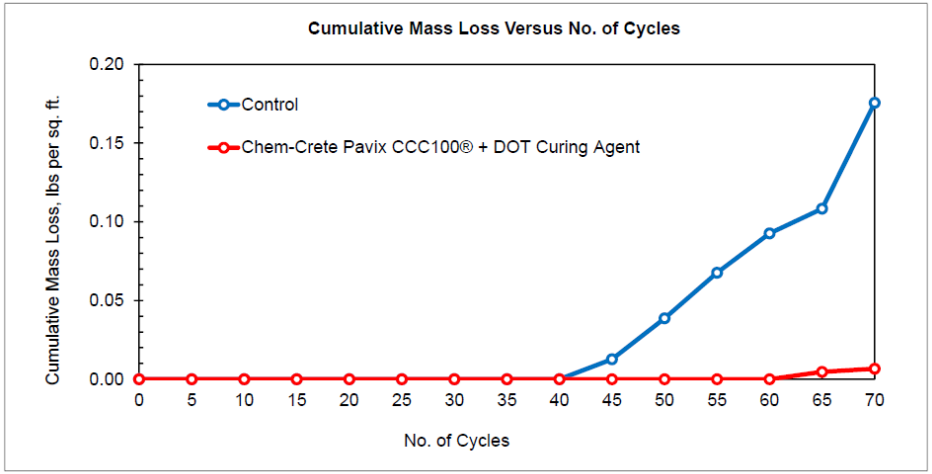
ASTM C666-97: Freezing & Thawing effect on treated & untreated concrete samples



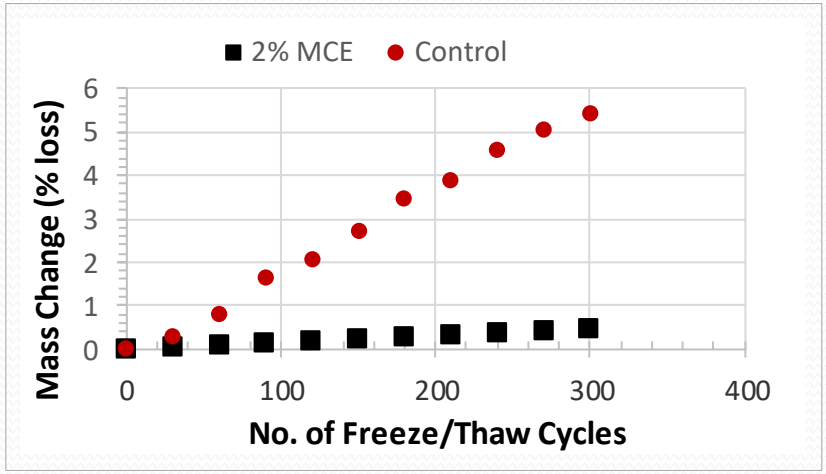
ASTM C1202-91 & AASHTO T259: Chloride Ion Penetration tests on treated & untreated concrete samples

Freeze/Thaw Resistance, PAVIX and MCE

ASTM C672 – Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals.



ASTM C666 Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing with MCE at 2% of cement weight using IDOT C4 PCC mix.



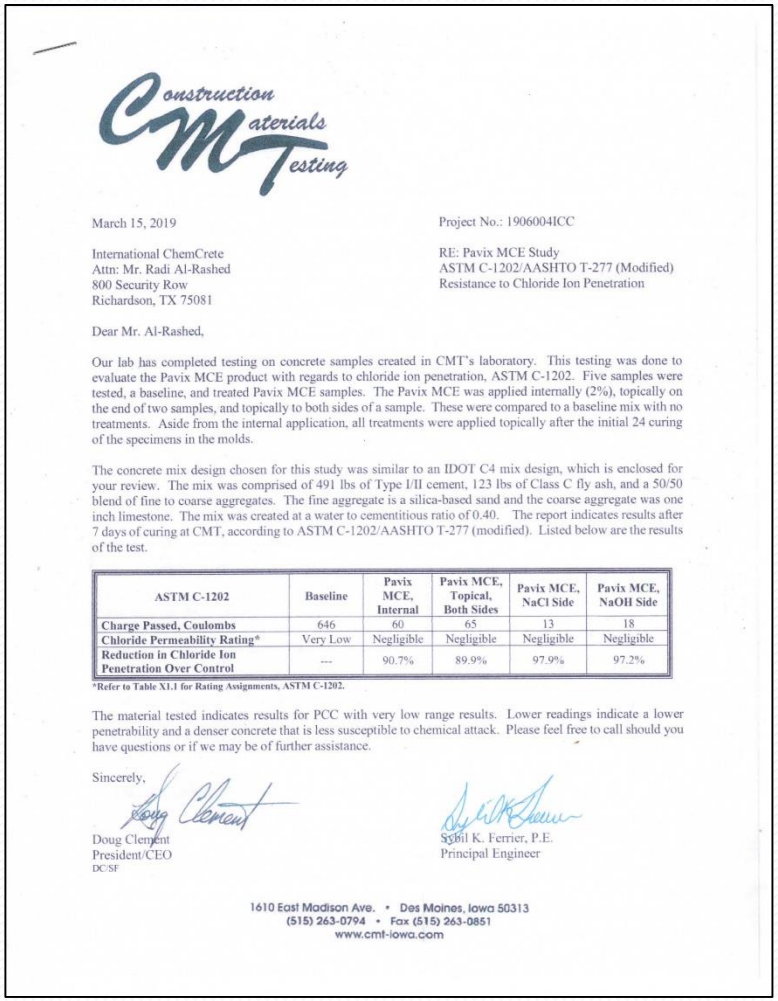
CTL GROUP

Construction Materials Testing

Representative Test Results for MCE

- A extensive amount of testing has been performed on a variety of concrete mixes to determine the effects of the MCE on concrete performance and durability.
- An addition of 2% by weight of cementitious material has shown to be the optimal addition, in most cases, in terms of both benefits and cost.
- The following slides illustrate just a few of the numerous positive test results based on a 2% addition.

Resistance to Chloride Ion Penetration – ASTM C1202



Construction Materials Testing

March 15, 2019

Project No.: 1906004ICC

International ChemCrete
Attn: Mr. Radi Al-Rashed
800 Security Row
Richardson, TX 75081

RE: Pavix MCE Study
ASTM C-1202/AASHTO T-277 (Modified)
Resistance to Chloride Ion Penetration

Dear Mr. Al-Rashed,

Our lab has completed testing on concrete samples created in CMT's laboratory. This testing was done to evaluate the Pavix MCE product with regards to chloride ion penetration, ASTM C-1202. Five samples were tested, a baseline, and treated Pavix MCE samples. The Pavix MCE was applied internally (2%), topically on the end of two samples, and topically to both sides of a sample. These were compared to a baseline mix with no treatments. Aside from the internal application, all treatments were applied topically after the initial 24 curing of the specimens in the molds.

The concrete mix design chosen for this study was similar to an IDOT C4 mix design, which is enclosed for your review. The mix was comprised of 491 lbs of Type I/II cement, 123 lbs of Class C fly ash, and a 50/50 blend of fine to coarse aggregates. The fine aggregate is a silica-based sand and the coarse aggregate was one inch limestone. The mix was created at a water to cementitious ratio of 0.40. The report indicates results after 7 days of curing at CMT, according to ASTM C-1202/AASHTO T-277 (modified). Listed below are the results of the test.

ASTM C-1202	Baseline	Pavix MCE, Internal	Pavix MCE, Topical, Both Sides	Pavix MCE, NaCl Side	Pavix MCE, NaOH Side
Charge Passed, Coulombs	646	60	65	13	18
Chloride Permeability Rating*	Very Low	Negligible	Negligible	Negligible	Negligible
Reduction in Chloride Ion Penetration Over Control	---	90.7%	89.9%	97.9%	97.2%

*Refer to Table X1.1 for Rating Assignments, ASTM C-1202.

The material tested indicates results for PCC with very low range results. Lower readings indicate a lower penetrability and a denser concrete that is less susceptible to chemical attack. Please feel free to call should you have questions or if we may be of further assistance.

Sincerely,

Doug Clement
President/CEO
DC/SF

Sybil K. Ferrier, P.E.
Principal Engineer

1610 East Madison Ave. • Des Moines, Iowa 50313
(515) 263-0794 • Fax (515) 263-0851
www.cmt-iowa.com

2% Internal MCE

90.7% Reduction in Chloride Ion Penetration

Freeze/Thaw Resistance in Terms of Mass Change

Figures 3.a and 3.b show the results of the mass change for the baseline untreated specimens and the intermixed 2% PAVIX MCE™ respectively. These results show a 91.6% reduction in mass loss for the treated specimens compared with the control.

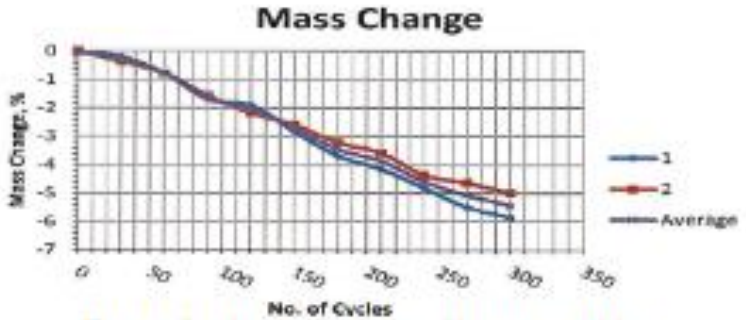


Figure 3.a Mass Change of Untreated Mix

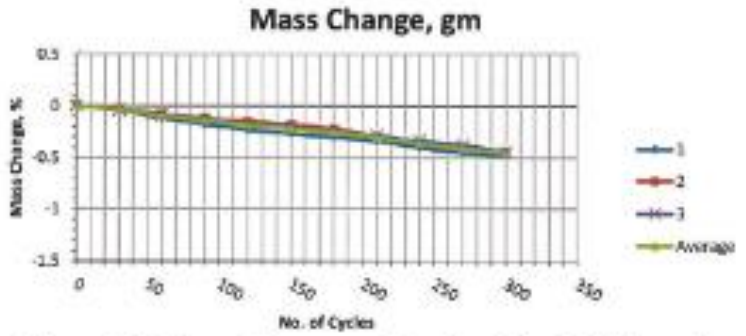


Figure 3.b Mass Change – Treated Mix 2% Internal

Freeze/Thaw Resistance in Terms of Dynamic Modulus

Figures 4.a and 4.b show the relative dynamic modulus change in the untreated and treated specimens respectively. The 2% intermixed PAVIX MCE™ resulted in a 20.3% higher retained dynamic modulus.

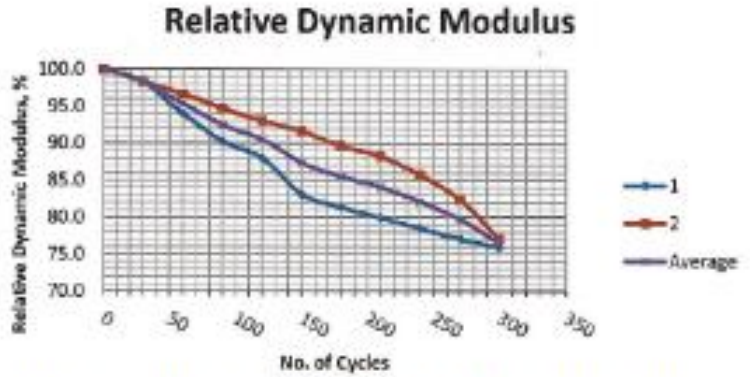


Figure 4.a: Relative Dynamic Modulus – Untreated Mix

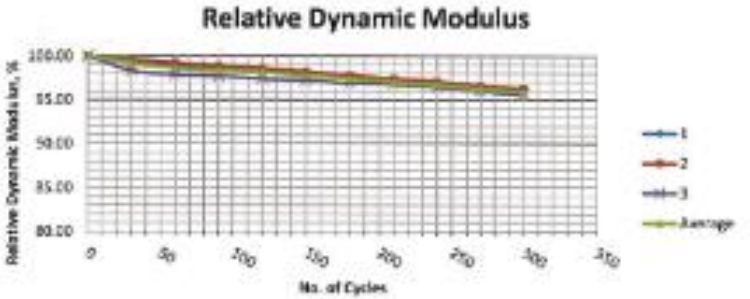


Figure 4.b: Relative Dynamic Modulus – Treated Mix 2%

Alkali-Silica Reactivity (ASR)

Alkali-Silica Reactivity (ASR): the following tests results were based on ASTM C-1567, "Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar Bar Method)". The Platte river aggregates used in the test have been characterized as highly reactive.

The addition of 2% of PAVIX MCE™ by weight of cement reduced expansion from 32% for the 0.47 w/c ratio to 74% for the 0.39 w/c ratio. This significant level of reduction in ASR is due to improved hydration, alteration of the hydration products (CH versus C-S-H) and enhanced moisture control.

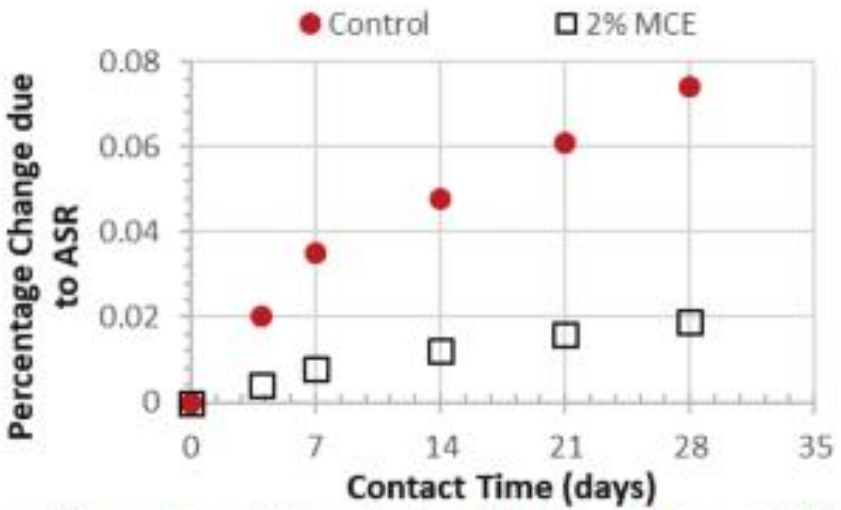
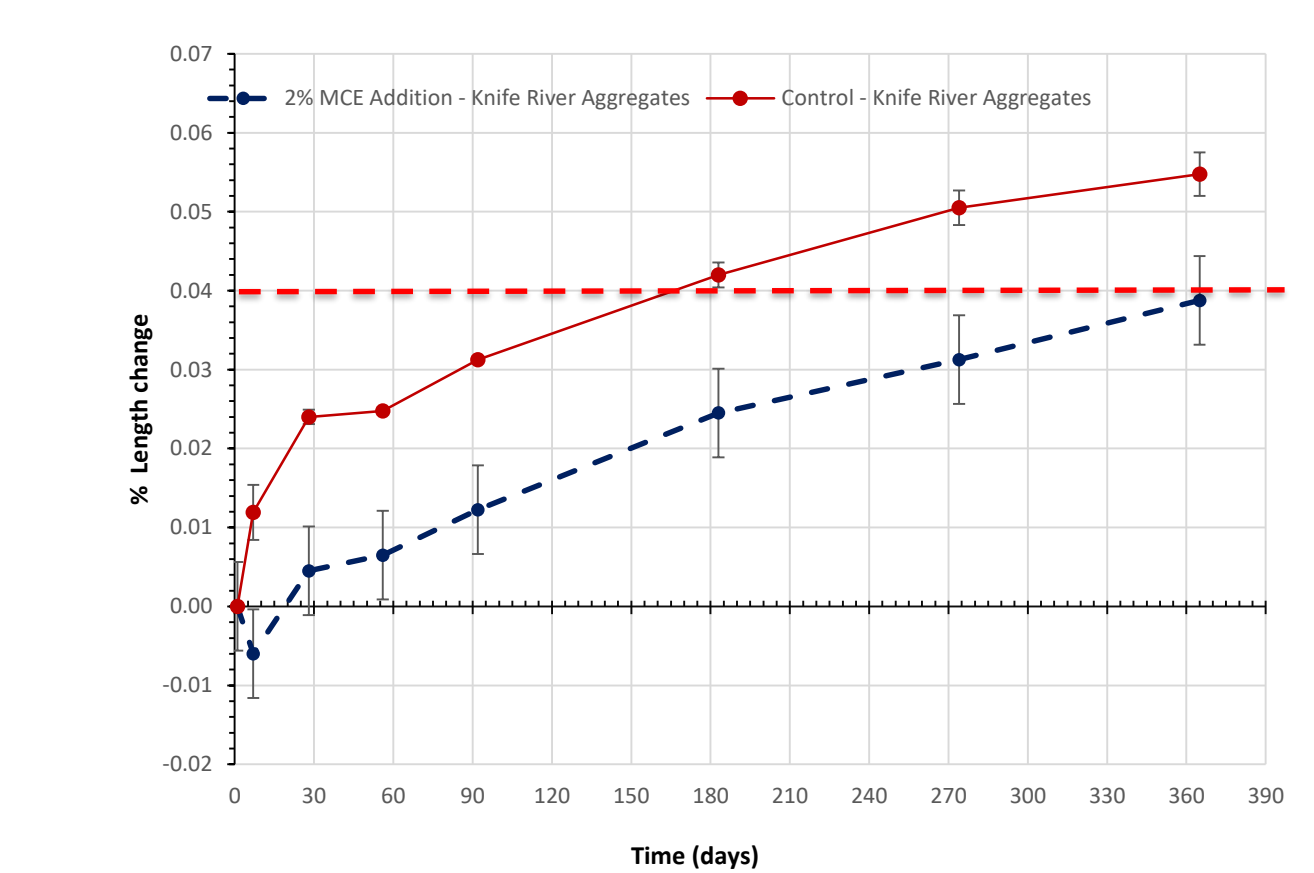


Figure 1: Increasing resistance to the alkali-silica reactions with MCE: According to ASTM C 1567, using IDOT C4 PCC mix.

Recently Completed ASR Research Results



Moisture Emission

Moisture Emission - CMT conducted a modified version of ASTM F-1869, "*Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete.*" The test was conducted on slabs, approximately 11.5 x 9.5 inches in size, cast 2 inches thick. A 1.75 inch diameter hole was cut in the bottom of the form to allow water vapor to be introduced by boiling a flask containing 300 mL of water. Over a period of 40 days, the samples were boiled 6 times for 1 hour durations. Normal emissions were captured when not boiling. Listed below are the results of the moisture emission testing. Refer to attached photo of test apparatus.

	Moisture Emission (lbs in 24 hrs/ 1000 sq. ft.)	Moisture Absorption (gram)	Moisture Absorption (%)	Slab Moisture Weight Gain (%)	Flask Loss Moisture Weight Reduction (%)	Concrete Unit Weight Change (%)
Baseline Mix	15.4	77.1	28.3	0.18	28.3	0.34
Treated Mix	9.7	158.7	58.3	0.26	41.7	1.91

As can be seen from the data presented in the table, the MCE sample released considerably less moisture (9.7 vs. 15.4 lbs. in 24 hours per 1000 ft^2) than the base sample. Earlier relative humidity testing also showed that the internal moisture was likely held in the crystalline structure of the MCE*.

MCE Evaluation May Require a Different Testing Protocol

- The increased water held by the MCE crystalline structure should not be confused with increased absorption.
- In this case, the “held” water does not contribute to internal distresses due to F/T cycles and is not able to participate in adverse reactions such as ASR.
- Standard characterization protocols, unfortunately, don’t differentiate this phenomena.

Water Permeability

The water permeability of the intermixed PAVIX MCE™ was evaluated by CMT and performed according to the United States Corps of Engineers method CRD-C 48-92. The tests were performed on concrete cylinders cast by the University of Texas/Arlington (UTA) and based on 4000 psi Texas DOT mixture proportions. The tests were performed 332 days after the cylinders were cast in the UTA laboratory.

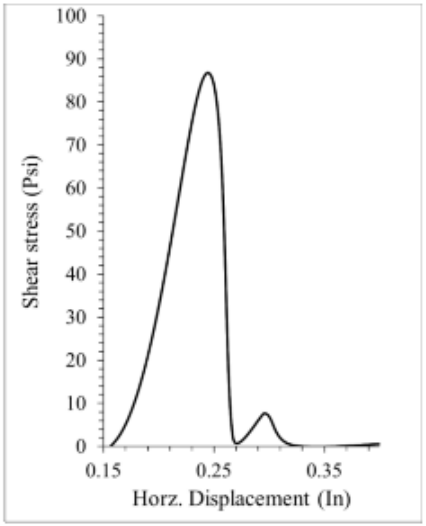
Cylinder ID	Coefficient of Permeability, cm/sec
4 of 12 (2% MCE)	4.985×10^{-10}
7 of 12 (2% MCE)	5.121×10^{-10}
12 of 12 (2% MCE)	4.925×10^{-10}
3 of 11 (2% MCE)	5.621×10^{-10}
7 of 11 (2% MCE)	5.195×10^{-10}
9 of 11 (Control)	2.223×10^{-6}

Note that this test is conducted with a pressure differential of 200 psi and is significantly more stringent that standardized permeability determinations.

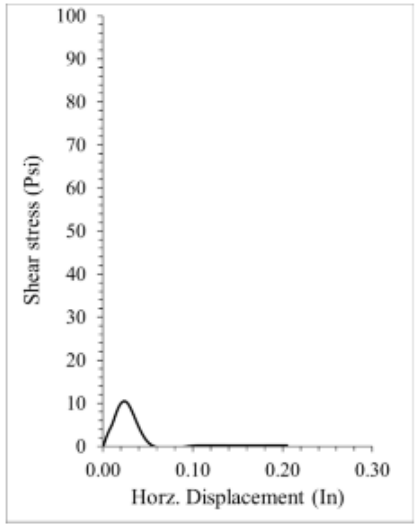
Ice Adhesion

- During the field trials, it became obvious that both the MCE modified and PAVIX coated concrete slabs positively affected ice and snow adhesion.
- An ongoing study at the University of TX, Arlington is quantifying this observation through extensive laboratory testing.
- The shear tests have thus far shown a reduction in ice adhesion of 90% for the PAVIX samples and 70% for the MCE samples (note that this difference is somewhat reflective of surface texture, the MCE samples having much less texture).

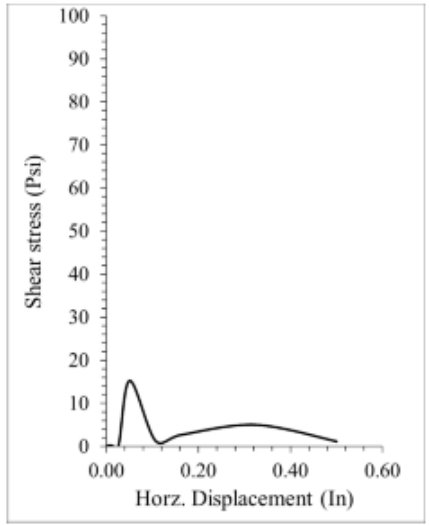
Ice Adhesion Test Results



w/c=2 control
WC2CON04B



w/c=2 PAVIX
WC2SUR01A



w/c=2 MCE
WC2MCE03B

Ice Adhesion

Collins Street Bridge – Treated Nov. 2002

PAVIX® Treated Side

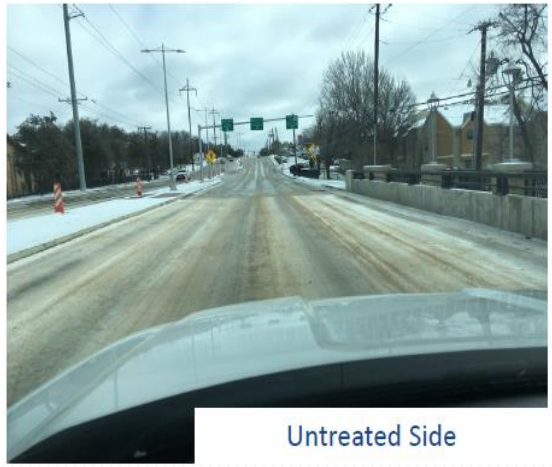
PAVIX® Treated Side

Untreated Side

Untreated Side

Spring Valley Rd. – Treated Jul. 2021

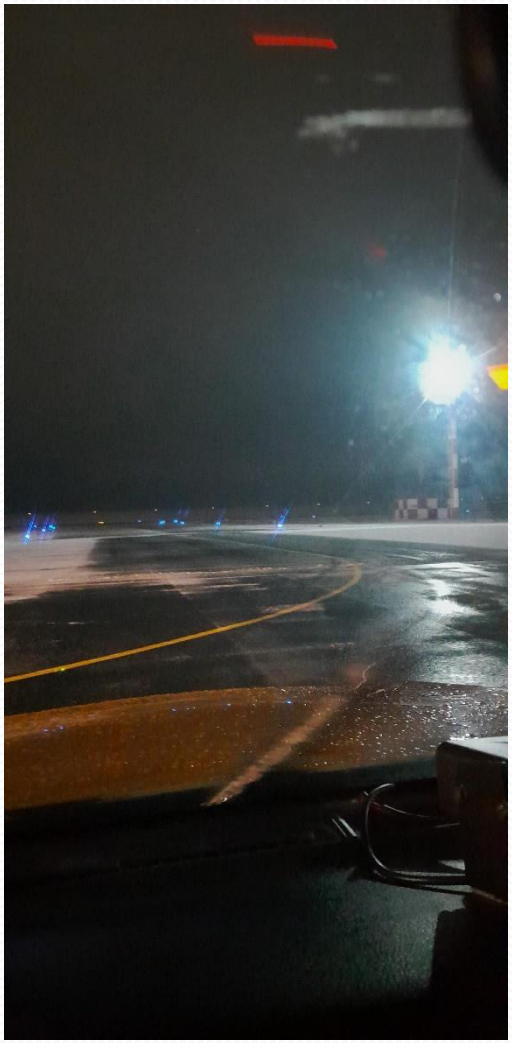
PAVIX® Treated Side



Untreated Side

Ice Adhesion Images – PAVIX® Treated Surfaces – Richardson, TX

PAVIX Application in Moldova

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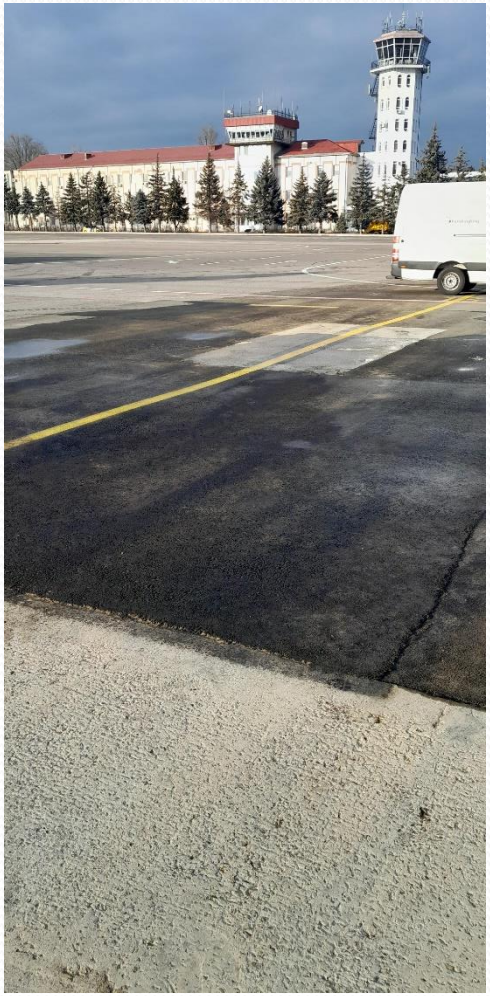


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Additional Information

- Detailed engineering reports showing the testing protocols and results are available for both the International Chem-Crete PAVIX CCC-100 and MCE materials.
- Contact:

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mayers@globalpavements.com

Thank You!