Evaluation of Penetrating Sealers Applied to Saw Cut Faces in Concrete Pavement Joints

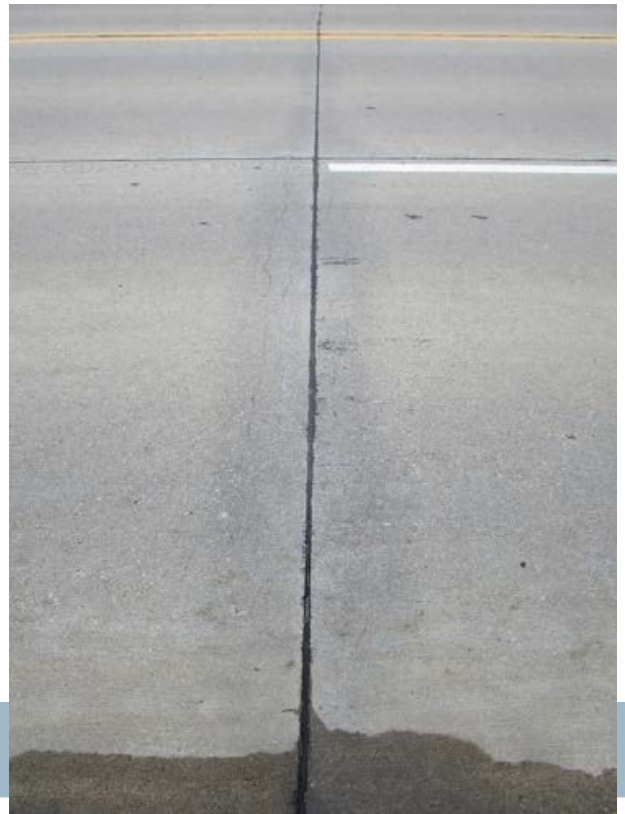
Xuhao Wang, Ph.D.
Peter Taylor, Ph.D., PE(IL)
Erica Mack
Xin Wang

National Concrete Pavement Technology Center
Tech Center

Iowa State University
Institute for Transportation

Outline

- Mechanisms of failure
- Solutions
- Do they work?



Outline

- Mechanisms of Failure
  - Saturated Freezing and Thawing
    - Commonly associated with marginal air system
  - Chemical Attack
    - De-icing salts result in oxychloride formation
  - Combined

Saturation of the Paste

- Water is trapped
- Air may be marginal
- Paste gets saturated
- Flakes formed (near surface)

Effect of salts

- Typical deicing salts
  - NaCl-based – fewer worries
  - $MgCl_2$-based – the most complicated
  - $CaCl_2$-based – relatively simple, the worst
  - Others: calcium magnesium acetate, potassium acetate
- Some salts prevent drying

Mechanism of Deterioration

- $MgCl_2$ (10 to 28% by mass; ~10˚C)
  - Primary deleterious phases: Calcium or Magnesium oxychloride
  - Other phases: brucite, gypsum, M-S-H, Friedel's salt
- $CaCl_2$ (10 to 28% by mass; 38˚C)
  - Primary deleterious phase: Calcium oxychloride
  - Other phases: Friedel's salt

Chemical attack

- Calcium/Magnesium oxychloride
  - Calcium hydroxide (CH) from cement hydration
  - Chlorides from MgCl2 and CaCl2
  - 30% expansion of oxychloride itself
  - Severity: wet/dry > immersion > F/T
  - Shows as flaking or incremental cracking

15% $MgCl_2$

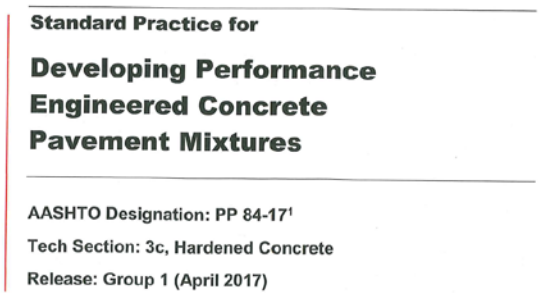
17% $CaCl_2$

Recommendations

- Drainage
  - Avoid joint details with reservoirs
  - Ensure the water can get away
- The mixture
- Consider penetrating sealers

The Mixture

- 5% air minimum <u>behind the paver</u>
- 0.42 max w/cm
- Use appropriate SCMs
  - May need 35% to control oxychloride
- Guidance in AASHTO PP 84


Standard Practice for

Developing Performance Engineered Concrete Pavement Mixtures

AASHTO Designation: PP 84-17[1]

Tech Section: 3c, Hardened Concrete

Release: Group 1 (April 2017)

AASHTO

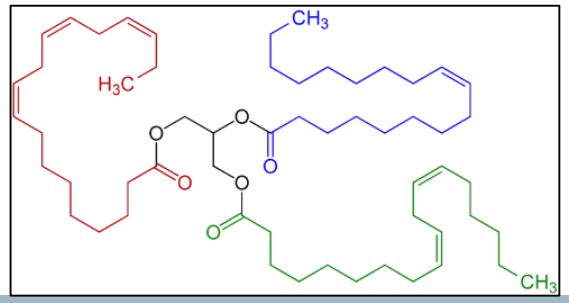
American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

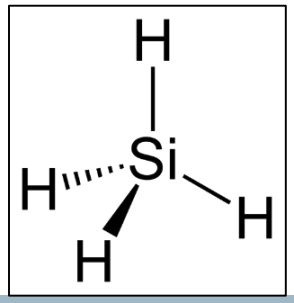
Sealers

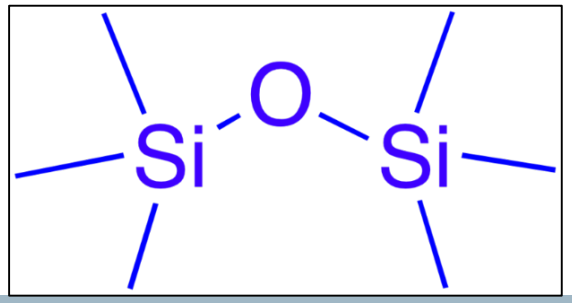
- Which ones work?
- How much?
- When?
- Where?

Products Available

- Linseed oil
  - Dried seeds from flax plant
  - Effective at reducing salt water absorption and surface scaling
- Silane / siloxane
  - Lines the pores
  - Depth of penetration ~12 mm
  - Siloxanes are bigger molecules

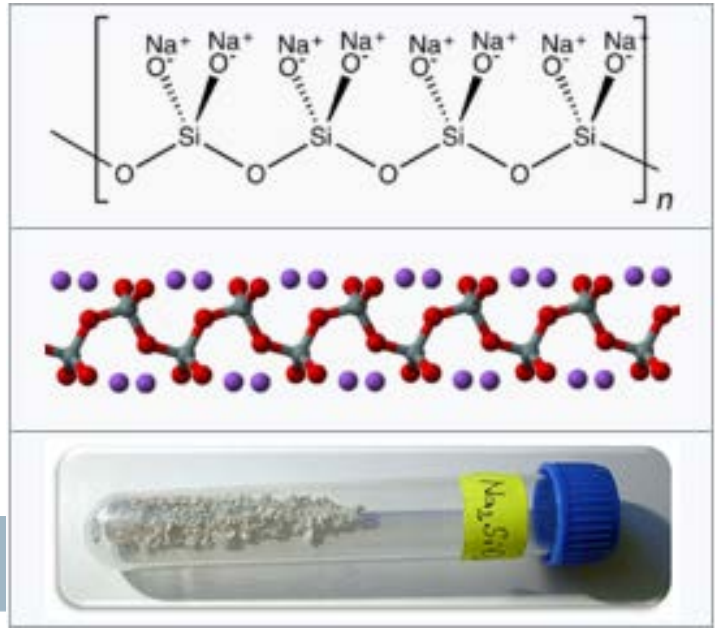






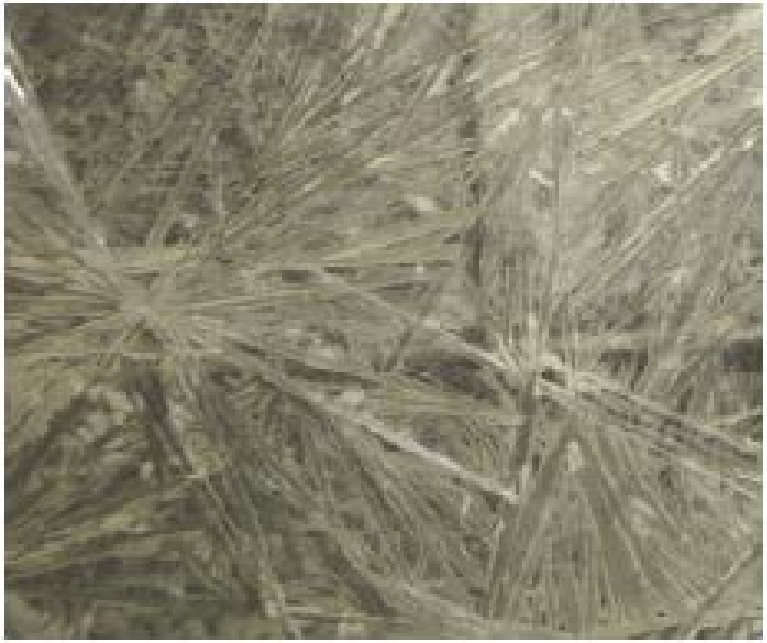
Products

- Soy-methyl esters (SME)
  - Oils extracted from soybeans
  - Slows water penetration up to 95%
  - Admixture or surface application
- Lithium or sodium silicate
  - Densifies surface



Products

- Crystalline
  - Two types of crystals and water repellency
  - Hygroscopic and hydrophilic properties



Iowa Program

- Funded by ICPA
- 4 Sites
  - Site 1: Des Moines (Siloxane)
  - Site 2: Davenport (Crystalline)
  - Site 3: West Des Moines (a) (Crystalline)
  - Site 4: West Des Moines (b) (Silane-Siloxane)

Iowa Program

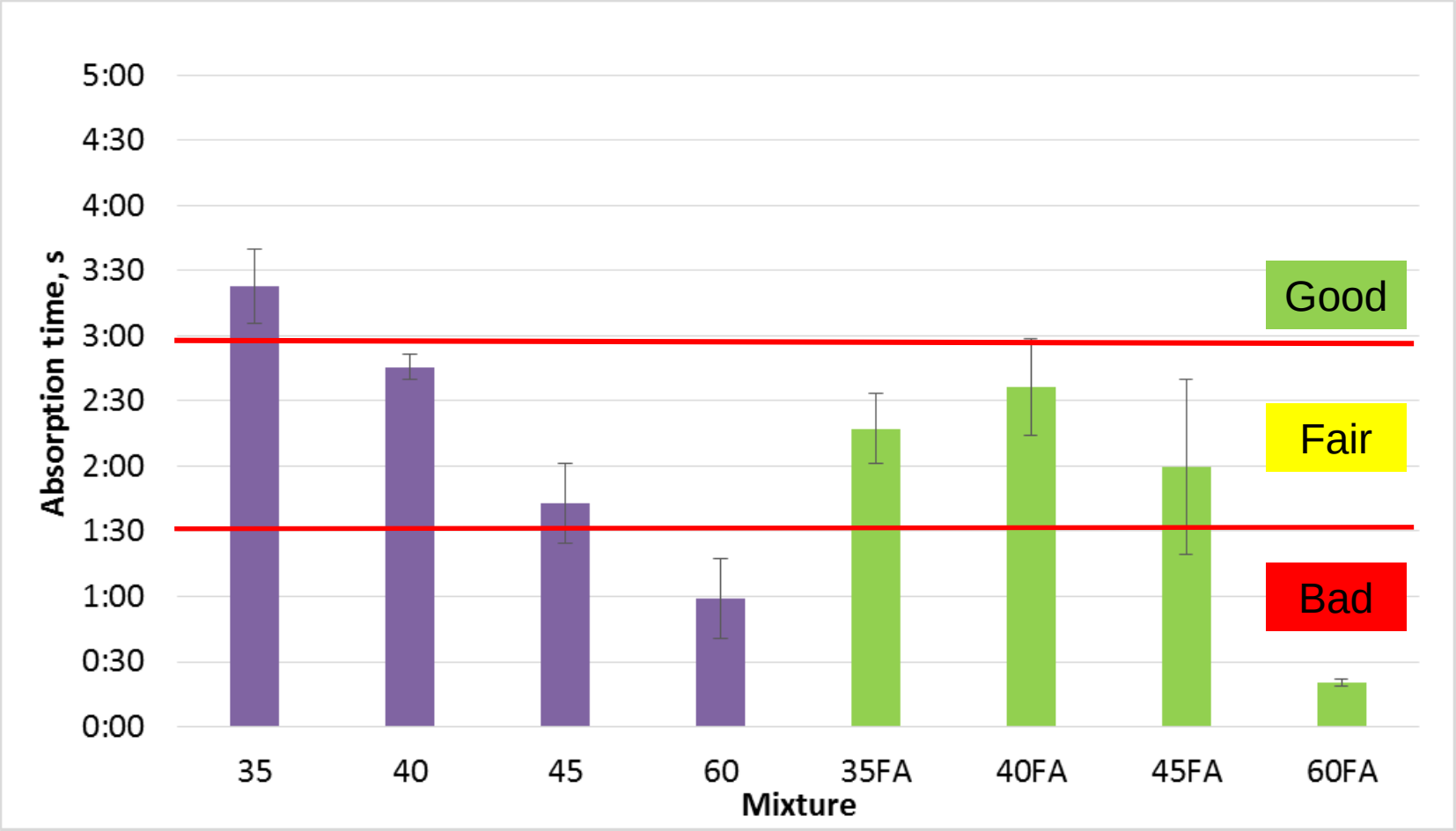
- Approach
  - Pre-application evaluation
  - Application by the manufacturer
  - Re-evaluation periodically
- Detailed Photo-log
- Extract cores – two over good joints, two over bad joints, two off joints
  - Drop-absorption test on sawn face and on top surface

Evaluation

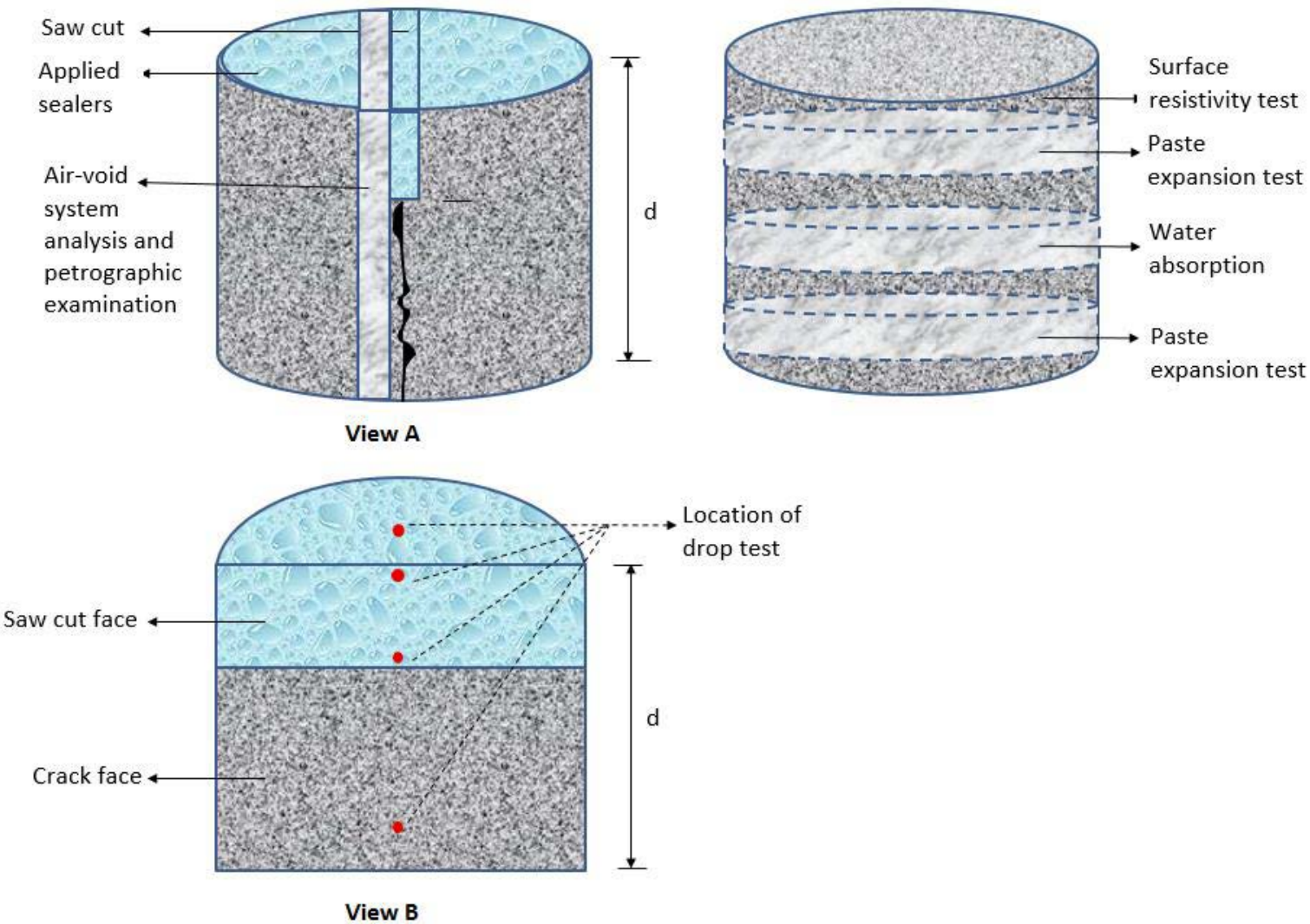
- Test
  - Drop test (ISU) - assess the quality of paste in an exposed surface at a local scale of less than 0.5 in^2

Evaluation

- Drop test calibration (56 days)

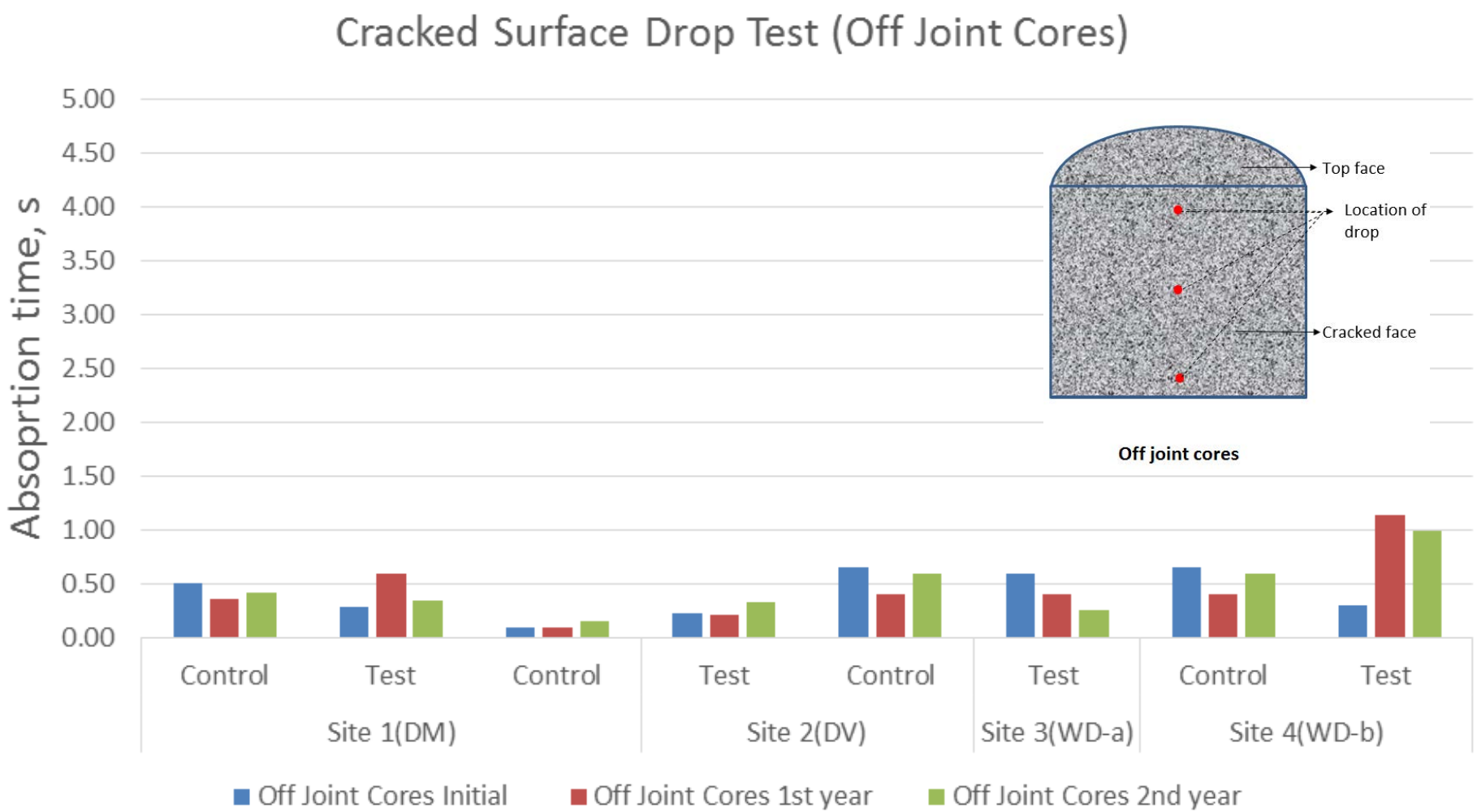


Proposed Field Investigation



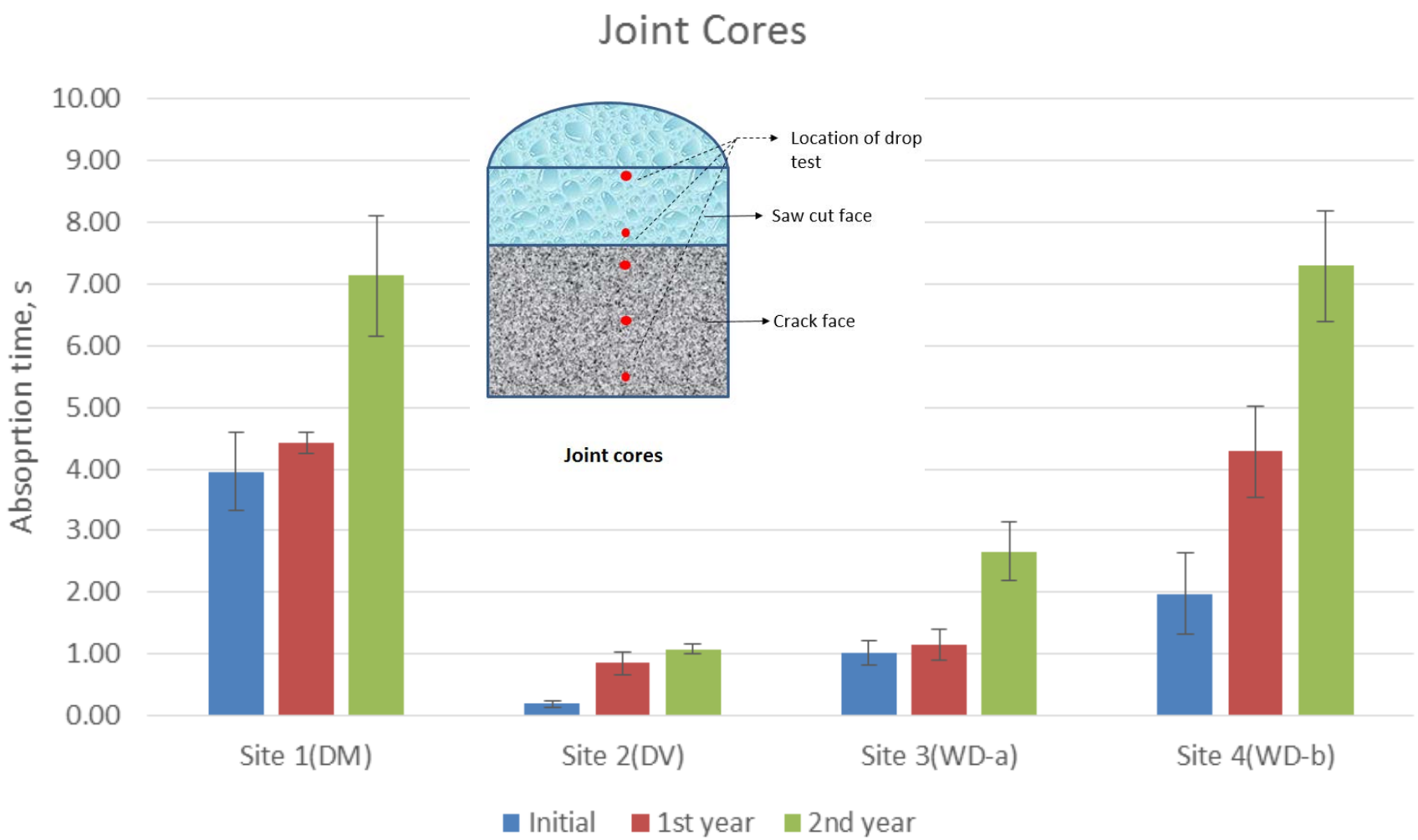
Iowa Program – Off Joint

- Drop-absorption test



Iowa Program – On Joint

- Drop-absorption test



Iowa Program

- Site 3 photo-log (control)

Initial Year (2014)

Second Year (2016)

Iowa Program

- Site 3 photo-log (test)

Initial Year (2014)

Second Year (2016)

Sealer Evaluation

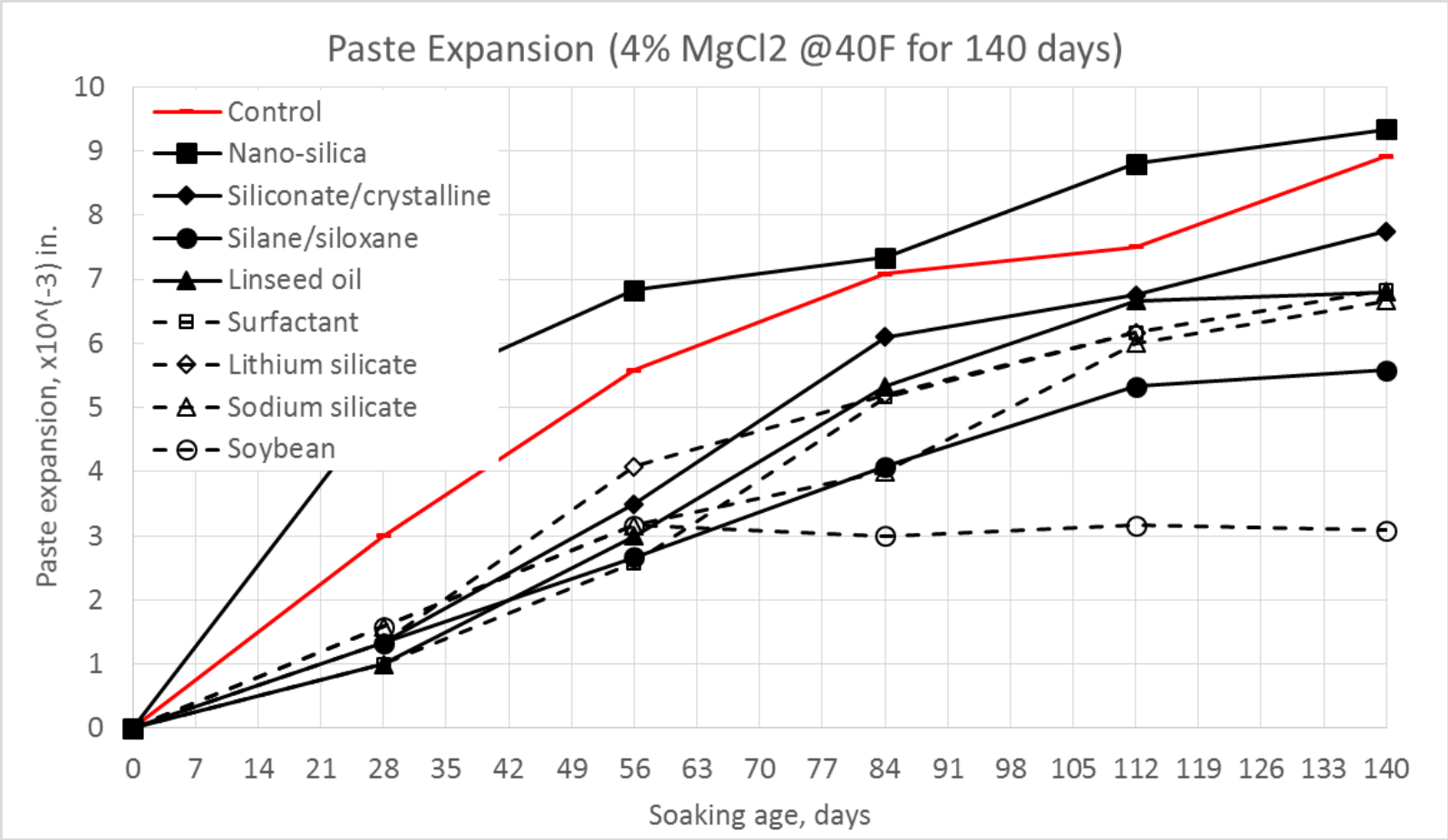
- Test
  - Chemical reaction assessment
    - Paste expansion test (ISU) – assess the ability to resist oxychloride formation
      - Topically treated slices
      - Immerse in 4%, 20% $MgCl_2$ and $CaCl_2$ solution at 40˚F for 8 weeks

4% $MgCl_2$ @ 40°F for 28 days

20% $CaCl_2$ @ 40°F for 28 days

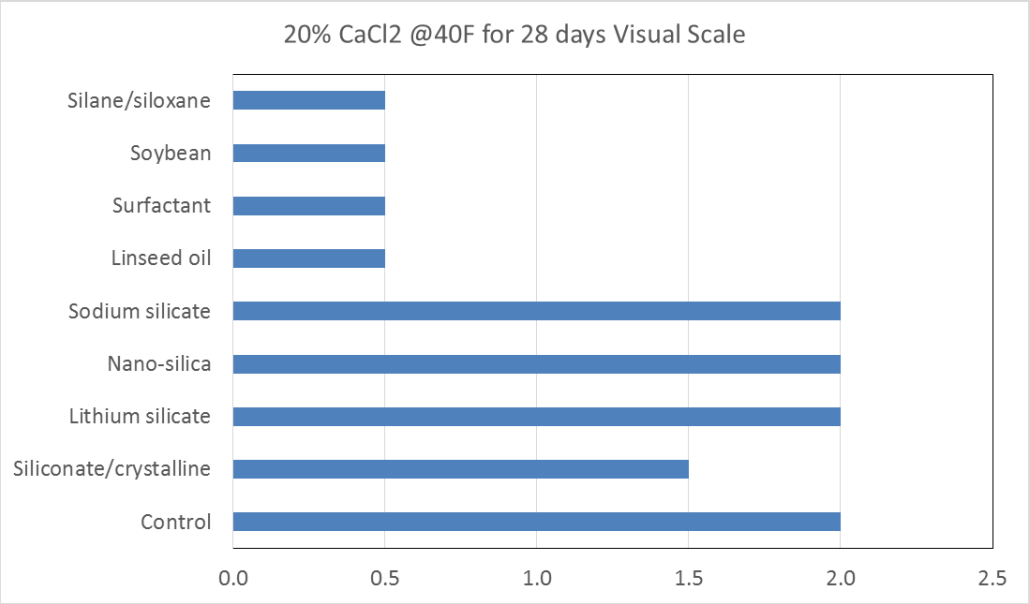
Sealer Evaluation

- Paste Expansion
  - 4% $MgCl_2$ – paste expansion with a thin film formed



Sealer Evaluation

- Paste Expansion
  - 20% $CaCl_2$ – scaling failure type
  - 4% $CaCl_2$ – no sign of deterioration/paste expansion



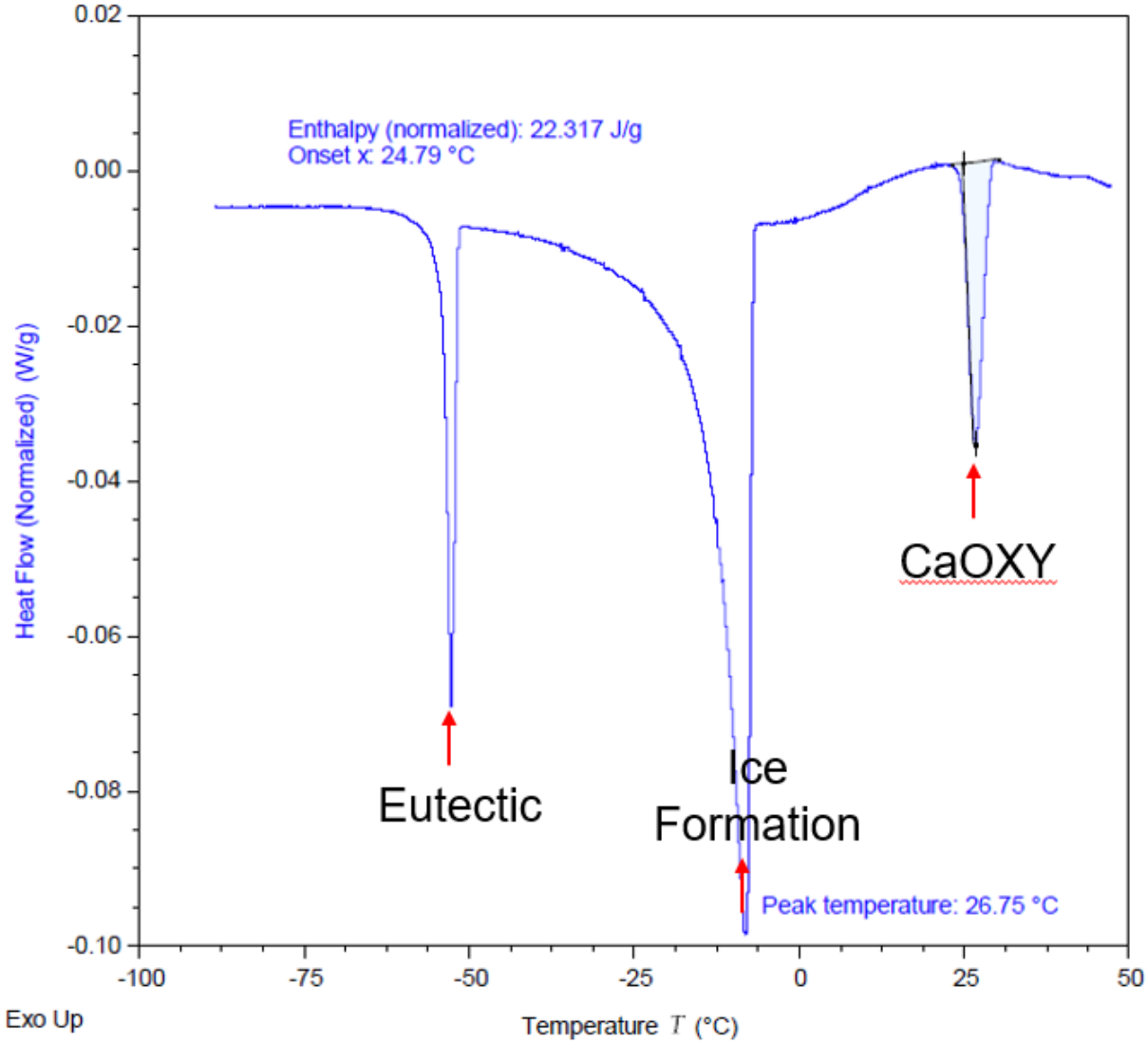
Visual rating of the surface after 28, 56, 84, and 112 days of soaking @40F in accordance with the following scale	
Rating	Condition of Surface
0	no scaling
1	very light scaling, about 10% aggregate surround mortar scales with minor edge breaking
2	slight to moderate scaling, about 20% aggregate surround mortar scales with moderate edge breaking
3	moderate scaling, about 40% aggregate surround mortar scales and tears off, moderate edge breaking and expasnion
4	moderate to severe scaling, about 60% aggregate surround mortar scales and tears off, severe edge braking and expansion

Sealer Evaluation

- Chemical reaction assessment
  - LT-DSC – quantitatively measure oxychloride formation
    - Grind topically treated slices mix with 20% $CaCl_2$
    - Measure the enthalpy between 25 - 45˚C
    - Target: <0.15 g CaOXY/g paste (AASHTO PP84)

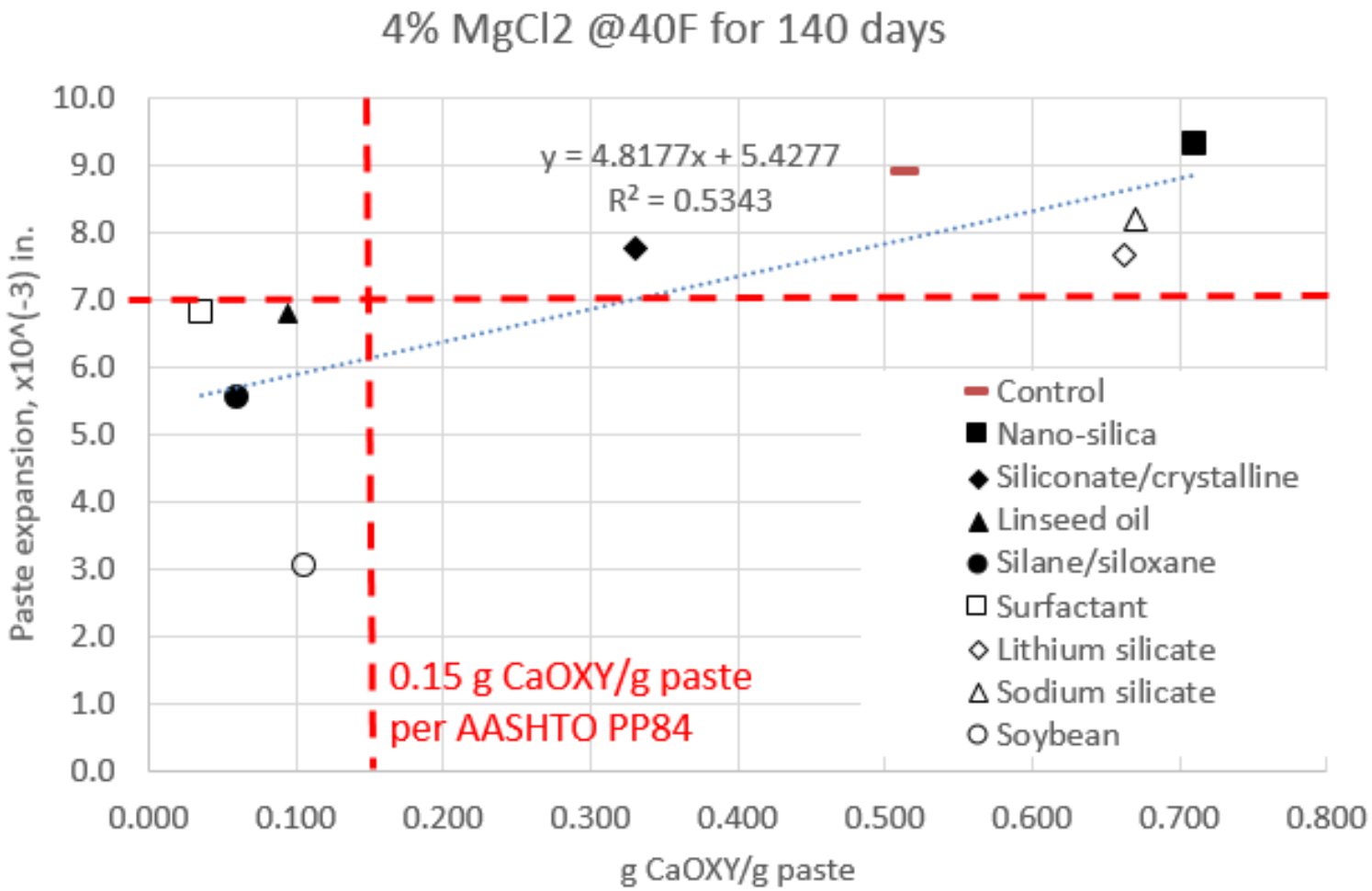
Sealer Evaluation

- Typical LT-DSC result



Evaluation

- Test results
  - Comparison between paste expansion and LT-DSC



Closing

- Reactions are complex
- Drop test and paste expansion test appear to identify sealer performance
- Some sealers appear to be reducing the risk of expansion