Joint Distress in Portland Cement Concrete Pavements

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Background

- Significant levels of premature joint deterioration reported across northern states
  - Not all roads affected
  - Problem is significant enough to cause local agencies to reconsider portland cement concrete pavements


Wisconsin


SALE
SALE
Wisconsin

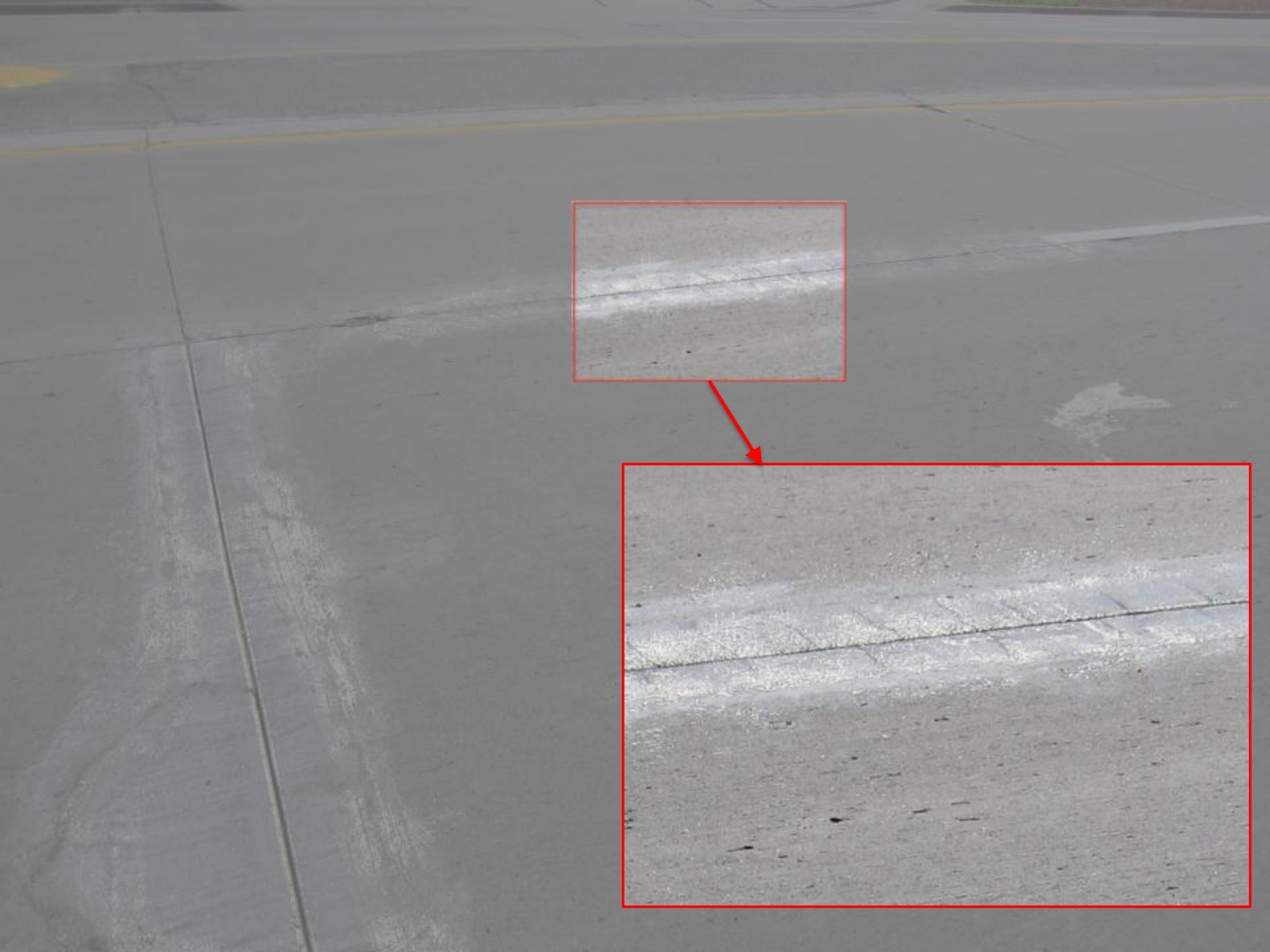
Wisconsin

Wisconsin

Wisconsin


Wisconsin


Wisconsin




Michigan


Michigan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Approach

- Research conducted at multiple universities
  - Purdue
  - Iowa State
  - Michigan Tech

Approach

- Research sponsored by
  - State DOTs
    - ✓ Indiana
    - ✓ Iowa (lead state)
    - ✓ Michigan
    - ✓ Minnesota
    - ✓ New York
    - ✓ South Dakota
    - ✓ Wisconsin
  - Industry
    - ✓ American Concrete Paving Association
    - ✓ Iowa Concrete Paving Association
    - ✓ Michigan Concrete Paving Association
    - ✓ Wisconsin Concrete Paving Association
    - ✓ Portland Cement Association

Many Suspects

- Air entraining agents
- Early entry sawing
- Curing
- Deicing practices

What Do We Know?

- Based on research to date
  - Not a single cause for the deterioration
    - Low air content
    - Compromised air-void systems
    - *w/c* above 0.40
    - Aggressive salt use
    - Marginal or D-cracking aggregates
  - Saturation is a key variable

Field Studies

- Sites in WI, MI, IA, & MN
  - Analysis still on-going
- Different manifestations
  - Related to type/permeability of base, sealant, & materials

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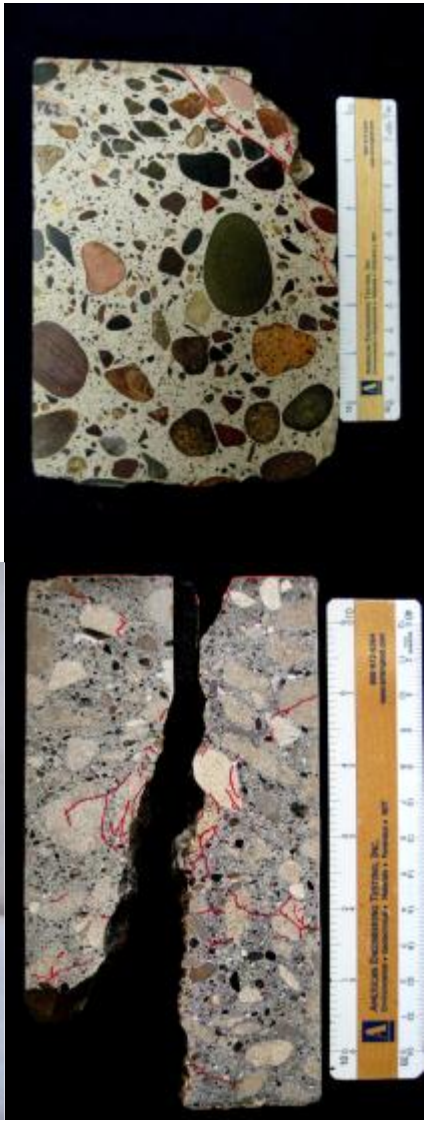
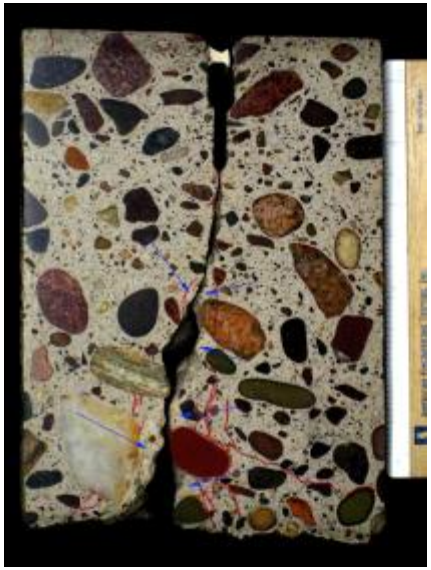
  - Analysis still on-going
- Different manifestations
  - Related to type/permeability of base, sealant, & materials
- Top Down vs. Bottom Up vs. Inside Out…
- Commonalities
  - Entrapped water



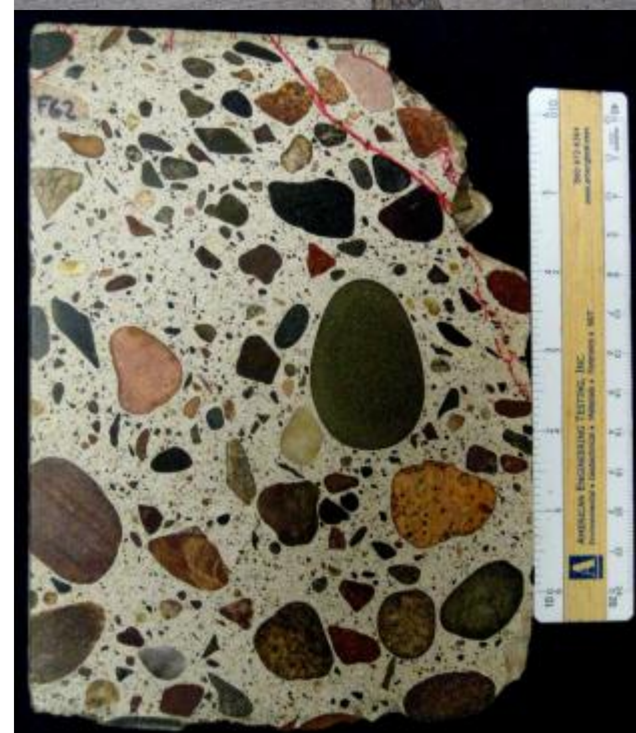
Field Studies

- A Tale of Two Cores
  - Same slab – same joint
- Top Down vs. Bottom Up



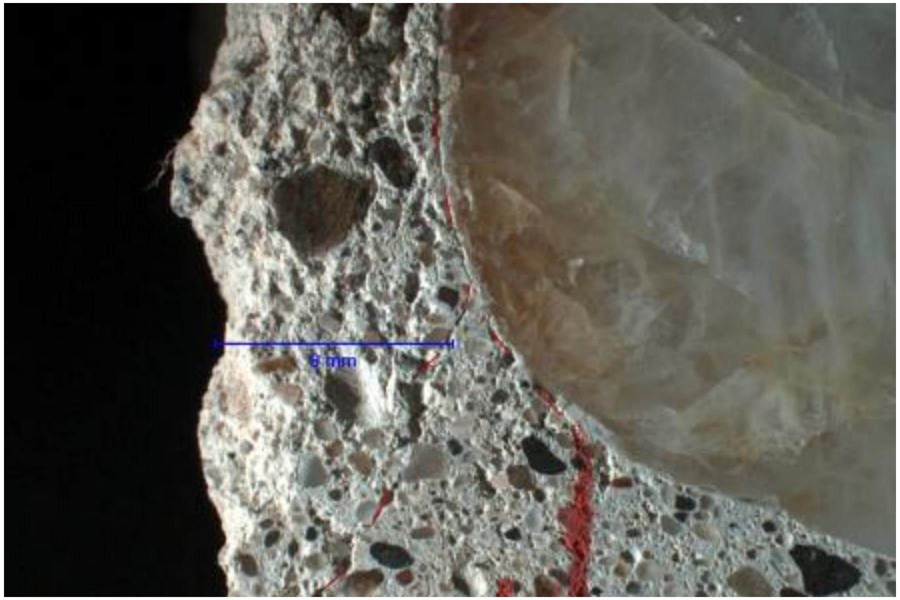
Field Studies

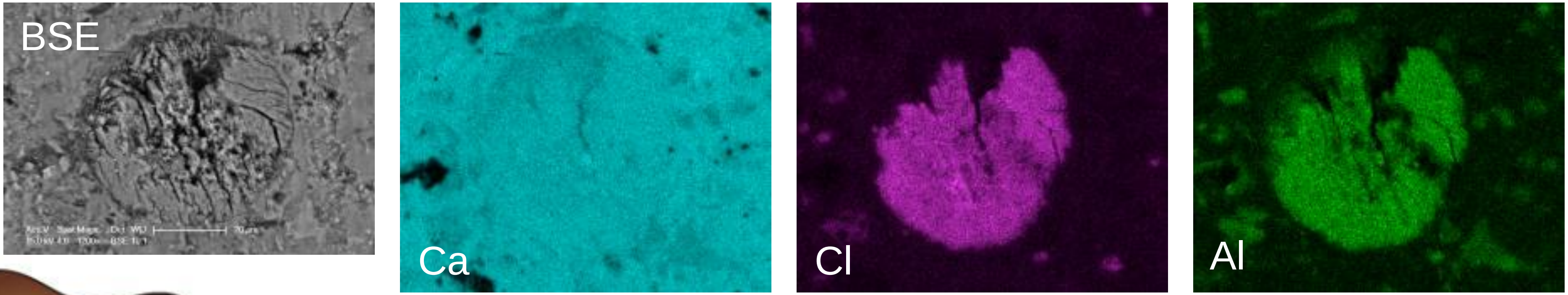
- A Tale of Two Cores
  - Same slab – same joint
- Cracking parallel to the joint observed on the surface
  - Common observation
- Cracking sub-surface appears to be parallel to the deterioration front
  - F-T damage
- Results in the V-shaped top down damage



Field Studies

- A Tale of Two Cores
  - Same slab – same joint
- Also found:
- Significant chemical attack from deicers

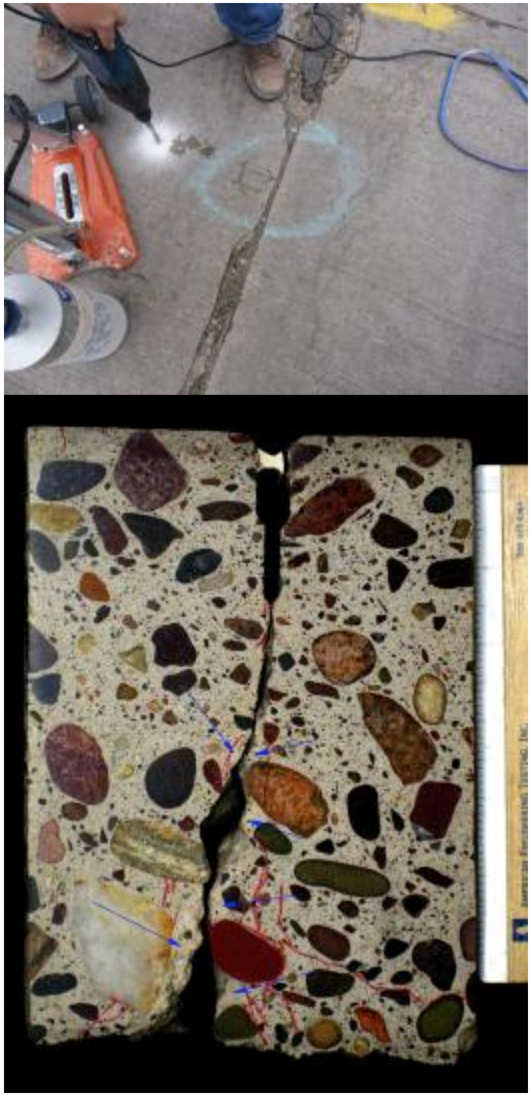




Friedel's Salt

Field Studies

- A Tale of Two Cores
  - Same slab – same joint
- Area with less distress
- Cracking emanating from the bottom up
- Core hole drained significantly slower than all other core holes on the slab
- Water trapped at the bottom but F-T?



I-275, Two Sites, Varying Performance

- Site 2 - showing deterioration at joint
- Site 4 - not exhibiting deterioration at joint

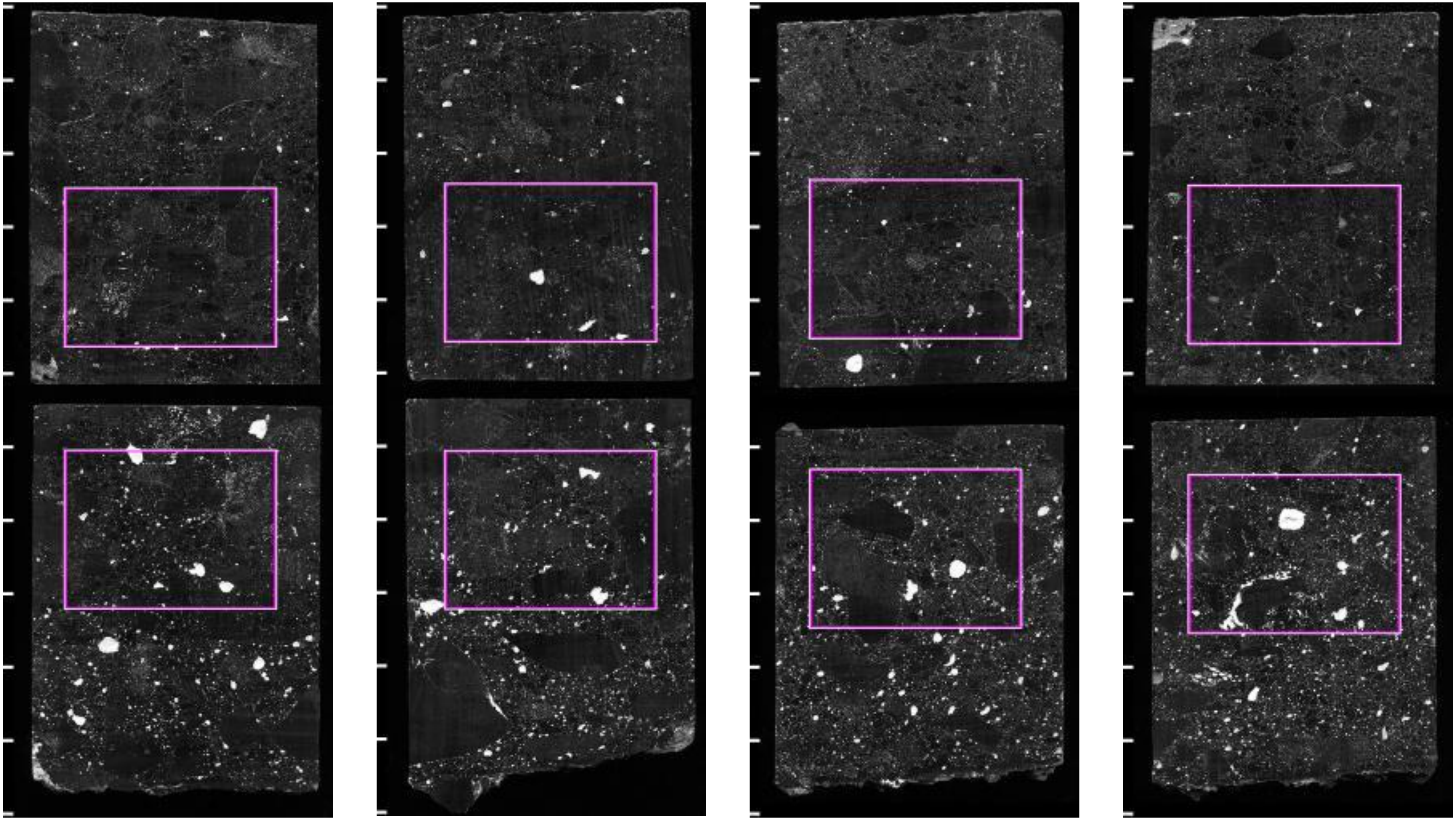
Site 2

Site 4

Summary

- Site 2
  - Poor air-void system
  - Alkali-silica reaction with fine aggregate particles and related <u>cracks extending</u> into hardened paste, but only within the top inch
  - Low paste density, high chloride ingress
- Site 4
  - Adequate air-void system
  - Alkali-silica reaction with fine aggregate particles, but <u>without cracks extending</u> into hardened paste
  - Higher paste density, lower chloride ingress

Site 2, mid-panel Site 2, near joint Site 4, mid-panel Site 4, near joint



Pink boxes show area of automated air void analyses.
Air voids visibly more abundant in bottom halves of all cores.

Sample ID	Air %	Paste %	Voids/ meter	Paste/ Air ratio	Avg. chord length (mm)	Specific surface (mm^{-1})	Spacing factor (mm)
2m - top half	2.0	28.0	214	14.3	0.092	43.5	0.170
2m - bottom half	4.7	27.2	247	5.8	0.191	20.9	0.237
2j - top half	2.4	27.9	161	11.5	0.150	26.6	0.254
2j - bottom half	4.7	27.2	216	5.8	0.218	18.4	0.269
4m - top half	3.0	27.7	323	9.2	0.093	42.9	0.143
4m - bottom half	6.4	26.7	377	4.2	0.169	23.6	0.178
4j - top half	3.0	27.7	327	9.2	0.092	43.4	0.141
4j - bottom half	7.6	26.4	403	3.5	0.189	21.2	0.164

Sample ID	Air %	Paste %	Voids/ meter	Paste/ Air ratio	Avg. chord length (mm)	Specific surface (mm^{-1})	< 0.2 mm Spacing factor (mm)
2m - top half	**2.0**	28.0	214	14.3	0.092	43.5	**0.170**
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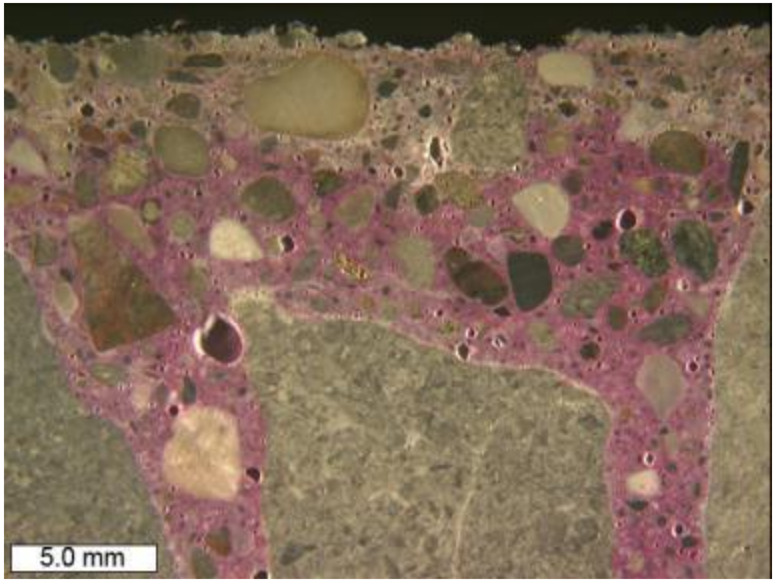
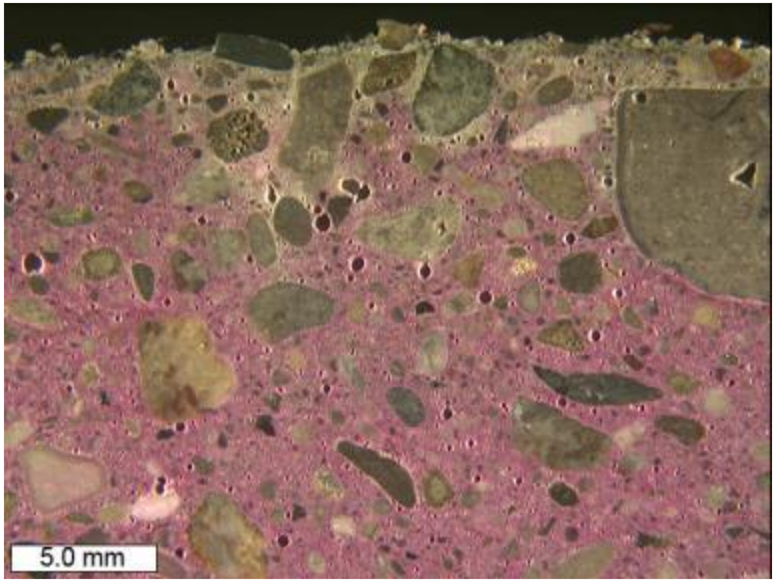




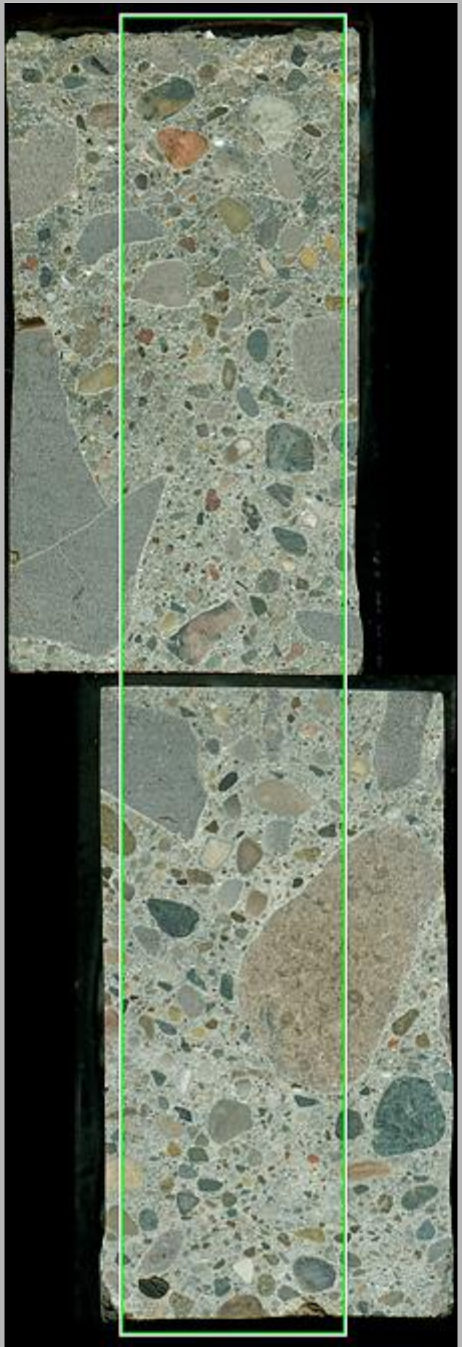
Site 2, (left) with carbonation depth of approx. 3 to 5 mm

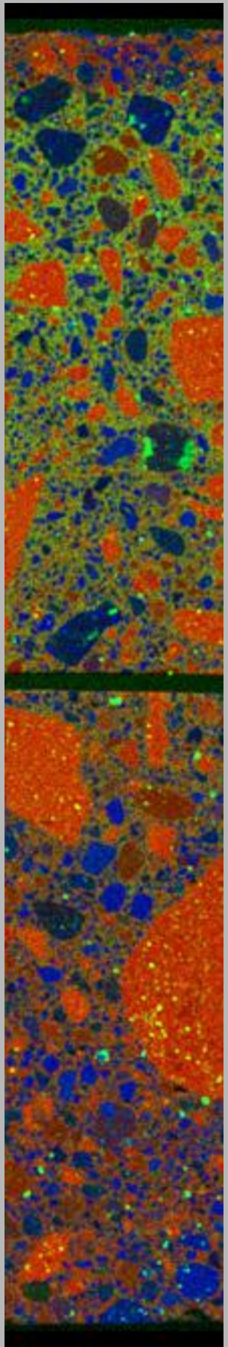
Site 4 (right) with carbonation depth of approx. 2 to 3 mm.

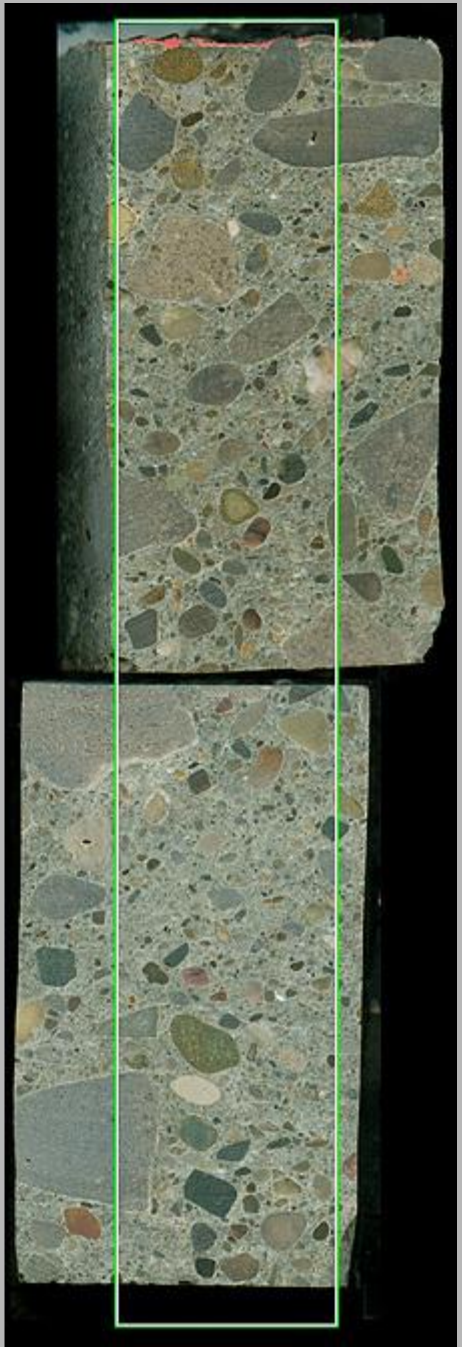
Site 2, mid-panel

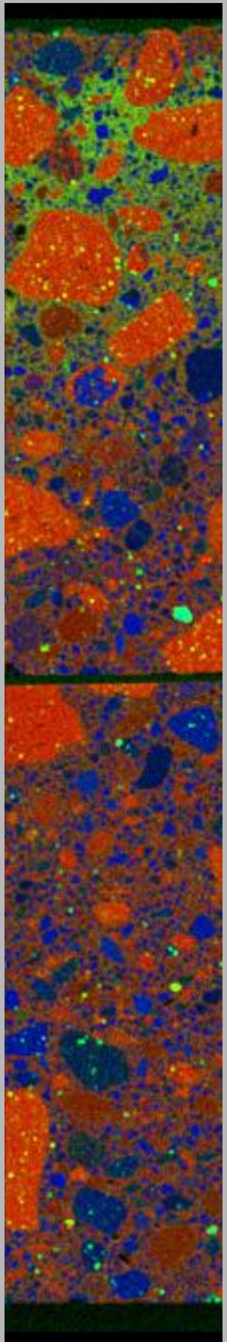
Site 4, mid-panel

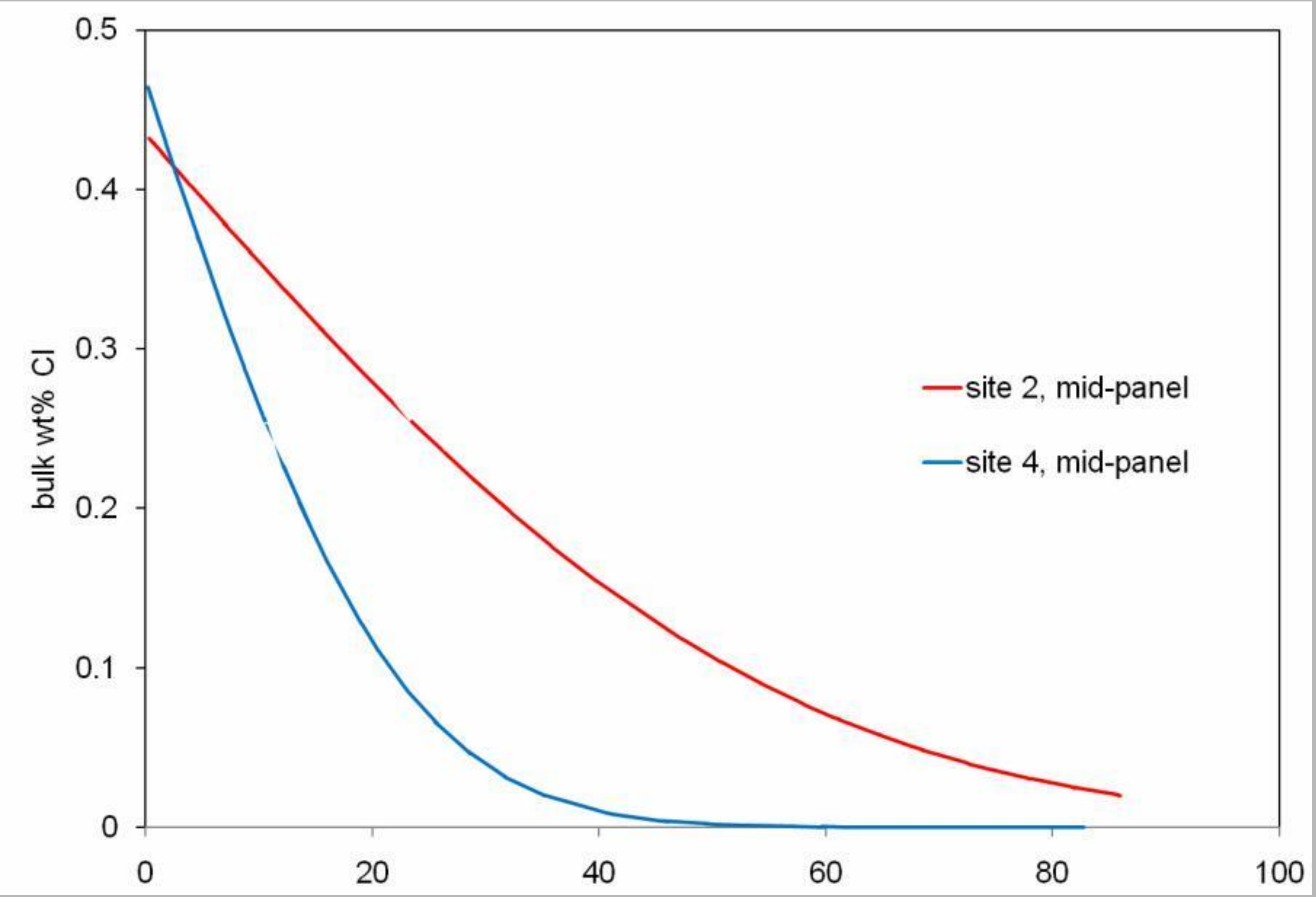
Green = Cl
Red = Ca
Blue = Si







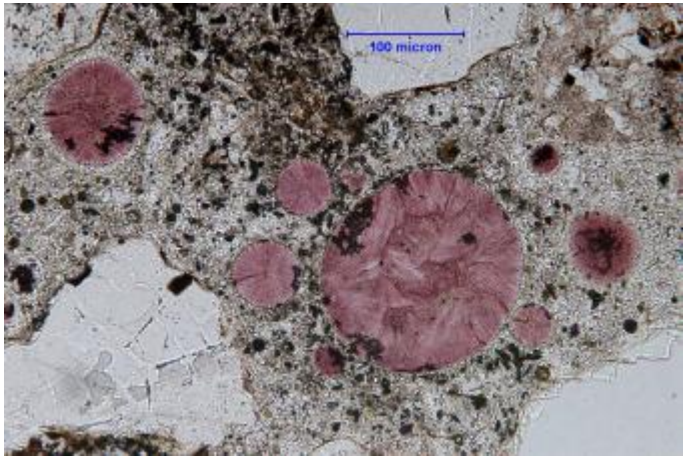


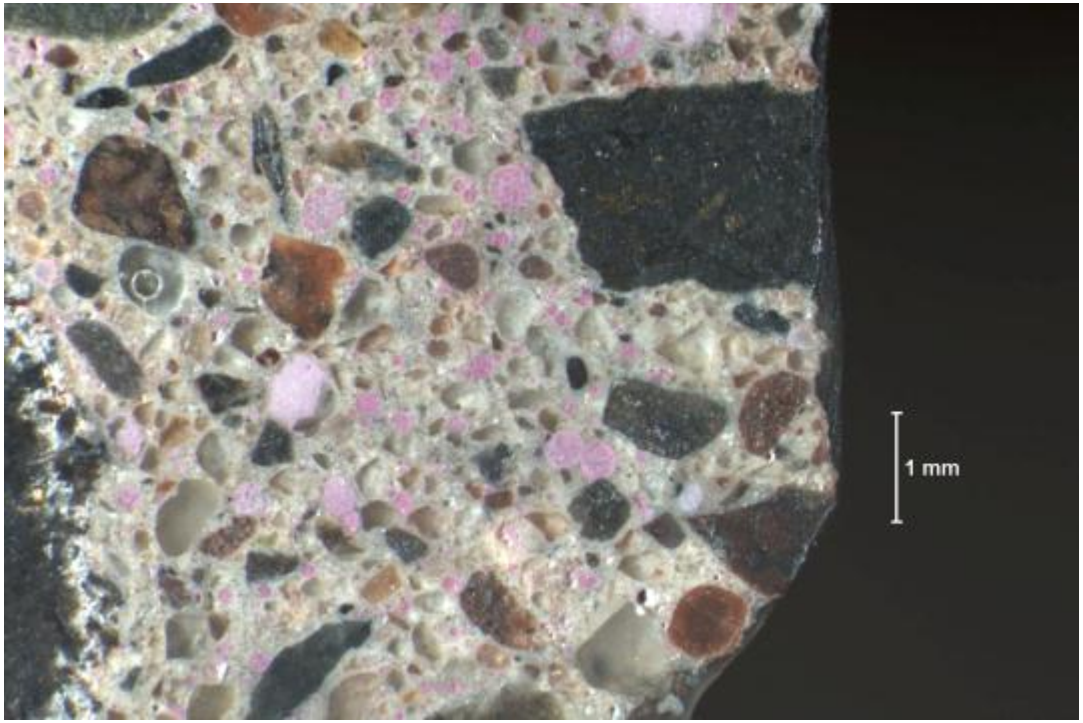


Comparison of best fit lines to Fick's 2nd Law – chloride penetration more pronounced at Site 2 as compared to Site 4.

Field Studies

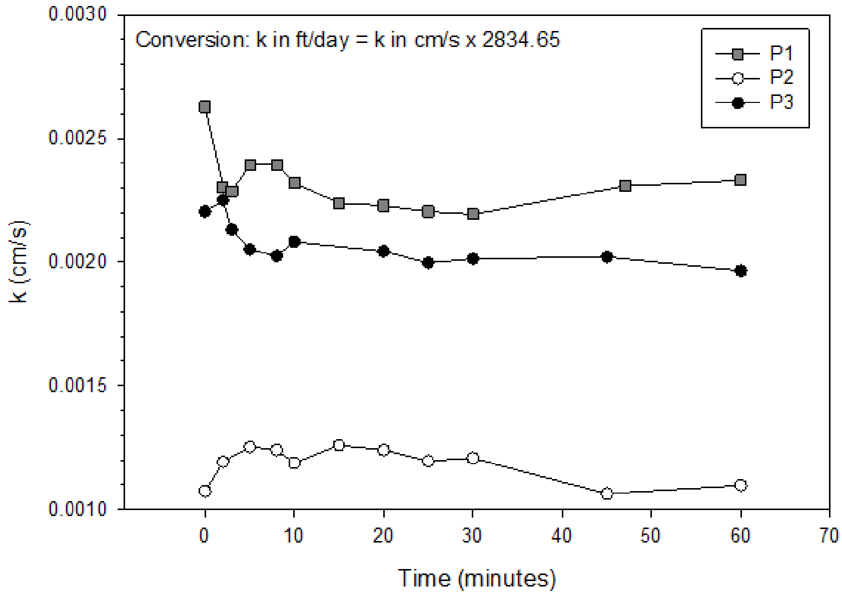
- Other Observations
  - Compromised air-void systems due to ettringite in-filling





Field Studies

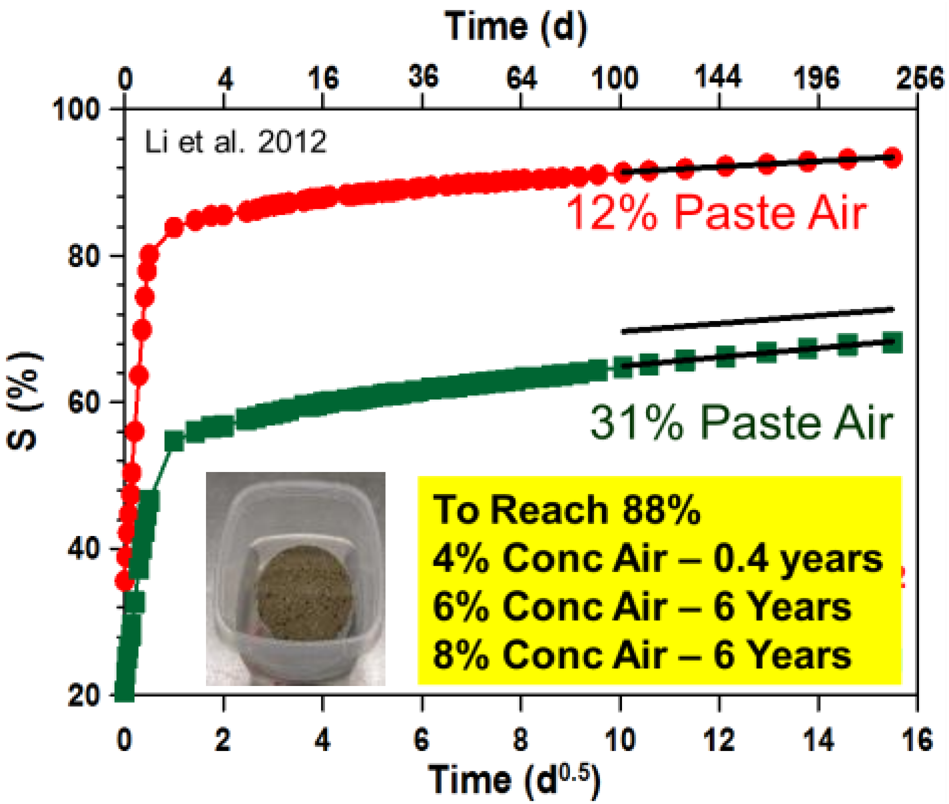
- Other Observations
  - Base layer drainage

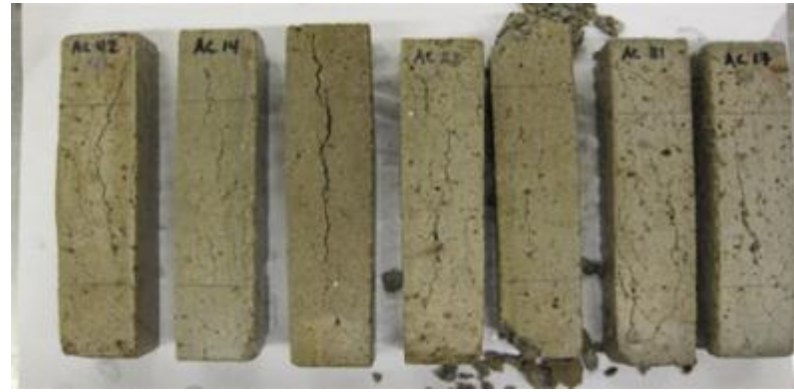


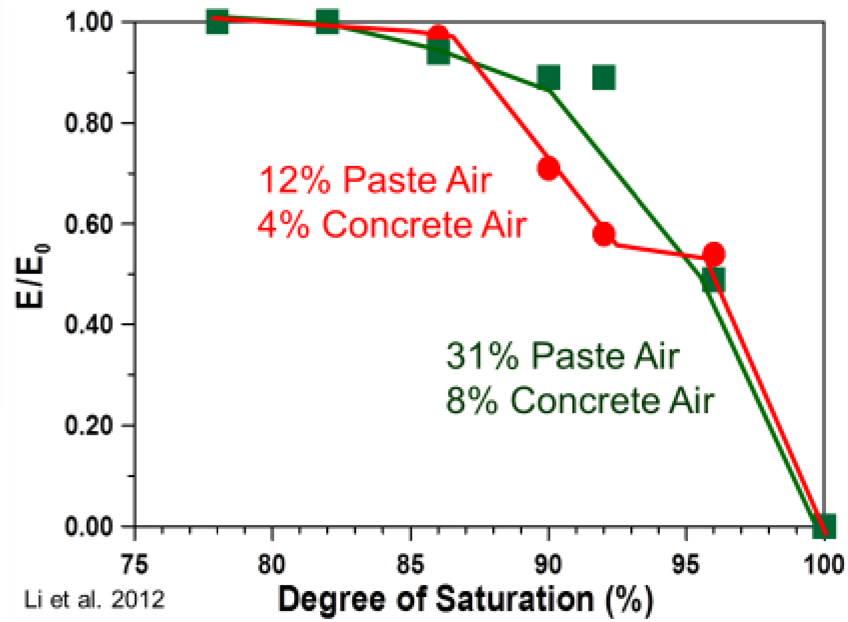
Research on Mechanisms

- A conceptual model will be shown to relate the rate of water absorption to degree of saturation
- When concrete reaches a critical degree of saturation its freeze thaw behavior is compromised
- Salts have slower absorption; however they alter drying with a higher degree of saturation
- Sealers may be able to be used to keep out water but how do they perform in FT

Freeze-Thaw Damage and the Degree of Saturation

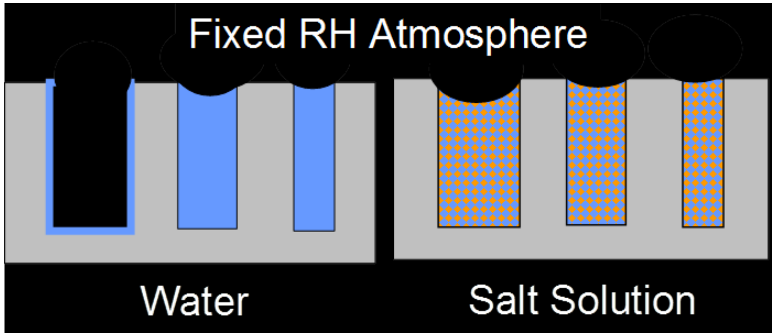


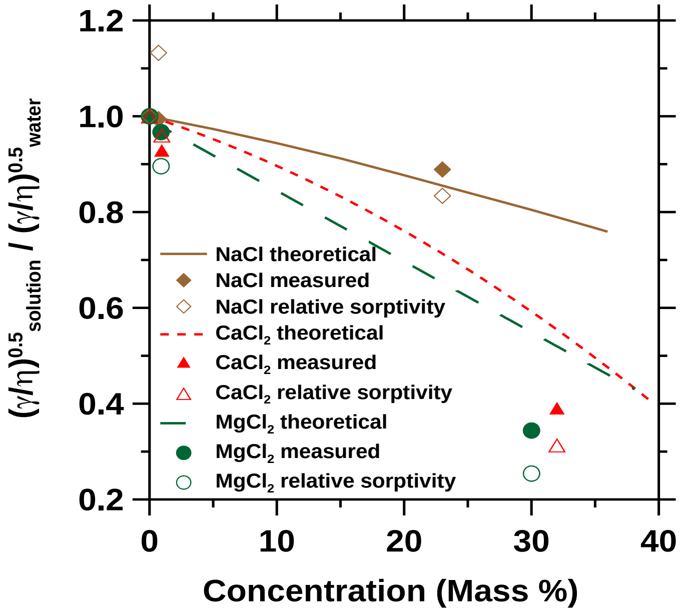


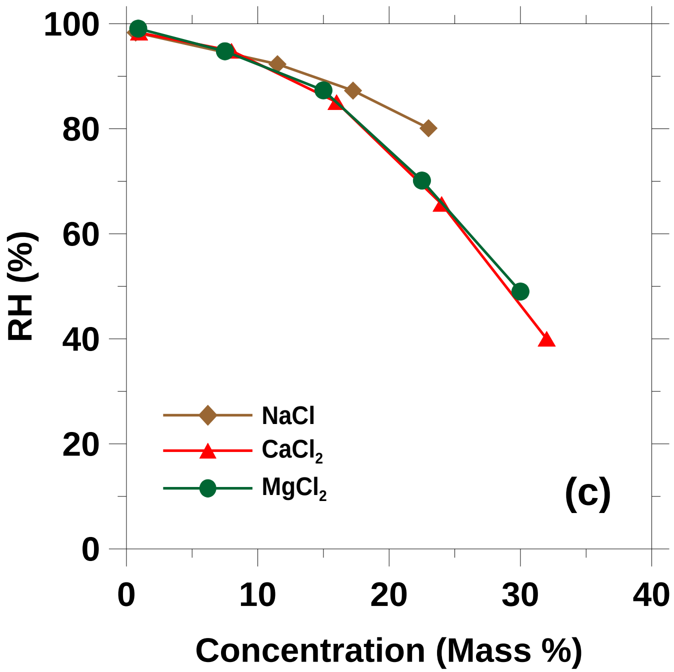


Salt Water Solutions are not the Same as Water

- Slower abs. with salt solns.
- Different phase diagram
- Different equilibrium RH

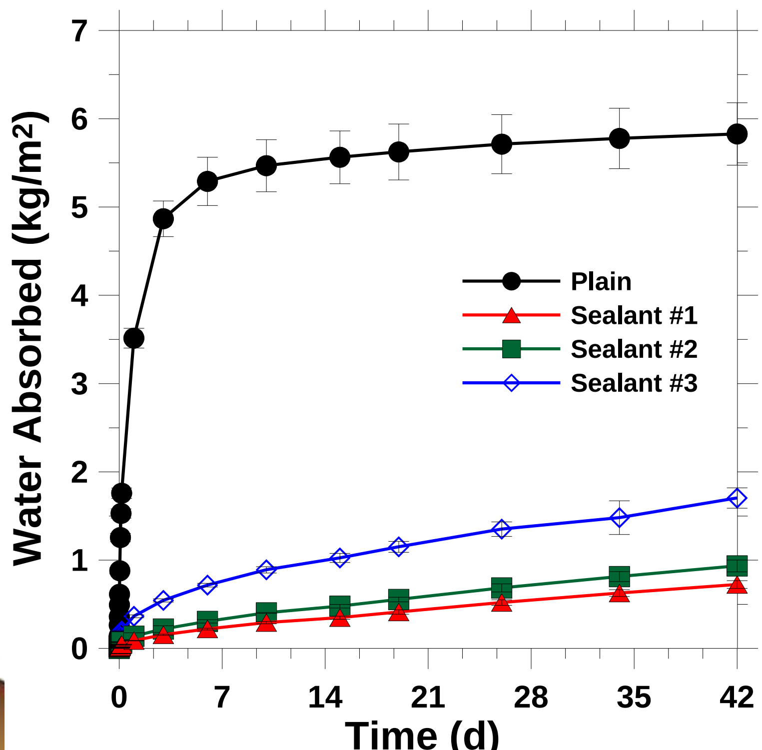


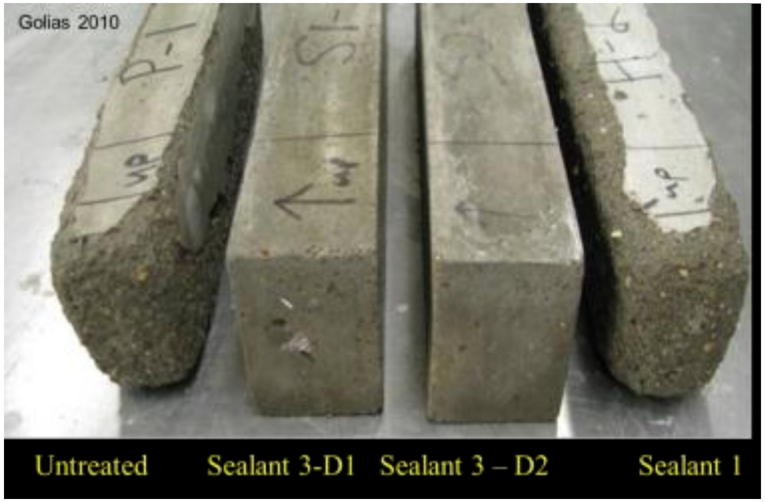


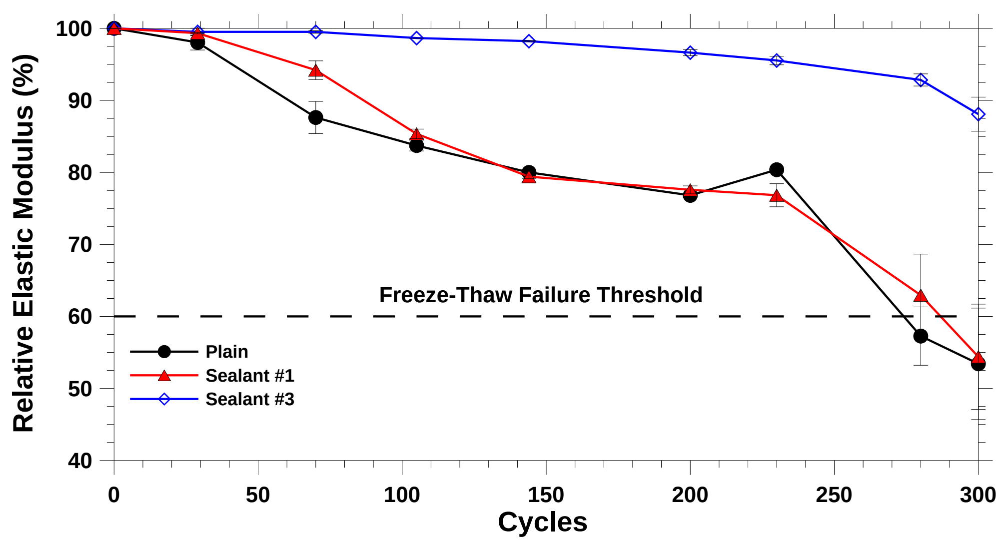


Can We Use Concrete Sealers/Pore Blockers to Reduce Saturation

- Sealers can keep out water
- FT behavior differs – new test in development







Observations

- Absorption to saturation, then damage is instantaneous
- Proper air only delays the rate of saturation
- Salts have slower absorption & alter drying
- Recent investigations of sorption important
- Sealers appear to work but discrepancies are noticed with temperature (working hypothesis)

Conclusions

- Multiple factors are at the root of the problem
  - Materials
  - Design
  - Construction
- What worked in the past is not working now
  - Deicing practices have changed the game
  - New materials require new specifications and construction practices

Conclusions

- New maintenance practices must be examined
  - Sealants
- Marginal concrete will not survive
  - Need low permeability
  - Need good air-void systems
  - Need high quality aggregates
  - Need thoughtful deicing practices

Questions?

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