Investigation of West Des Moines Pavements Constructed with Type IL Cement

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Federal Highway Administration

Background

- The Iowa market transitioned from ASTM C150 Type I/II cements to ASTM C595 Type IL cements rapidly
  - Started mid-2021 and by 2022 the entire cement market was Type IL
- For the most part, Type IL was simply substituted in concrete mixtures Type I/II as a 1:1 replacement
  - Transition happened so quickly that some mix designs, and even batch tickets, still listed Type I/II
- Local agencies in Iowa often employ the Iowa Statewide Urban Design and Specifications (SUDAS) for their concrete pavement projects
  - C-SUD: optimized aggs, lower paste (550-560#), lower w/cm (.42), higher SCM substitution allowed

Background

- The City of West Des Moines observed some issues with concrete pavements constructed in 2022 through 2024
  - Lower reported strength
  - Weak surfaces (i.e., wear/ abrasion and scaling)
  - Questions raised about the role of change to Type IL cement

Background

- CP Tech engaged with FHWA to fund a study of WDM pavements
    - **DETERMINE, TO THE DEGREE POSSIBLE, THE CAUSE(S) OF THESE ISSUE AND TO DEVELOP STRATEGIES TO MITIGATE THEIR OCCURRENCE IN THE FUTURE**
- **Led by WJE (Dr. Van Dam)** with support from **AP Tech** and **Sutter Engineering**
- The City of West Des Moines and Iowa Concrete Paving Association have provided invaluable assistance
- This is the second phase of study, and additional studies may be conducted

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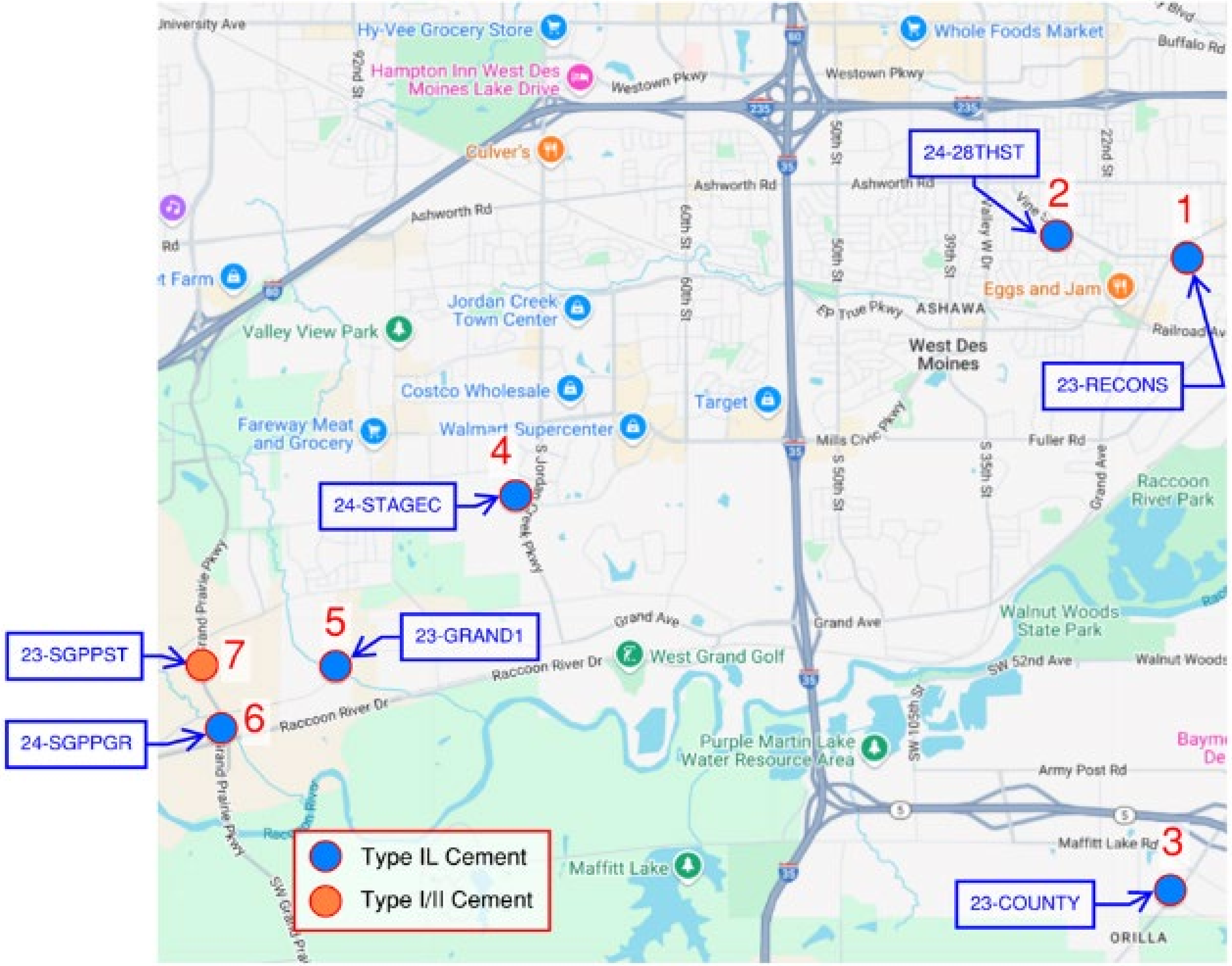
Study Summary

- Seven projects were selected from a list of 21 constructed in 2022, 2023 and 2024
- Six had reported surface and/or strength issues and one project was selected as a control (#2)
- All made with Type IL cement from at least 3 sources
- All used fly ash between 20% and 25% (at least 4 sources)
- All coarse aggregate sourced from same limestone quarry



Study Summary

- Concrete produced by three (3) different ready-mix suppliers and placed by three (3) different contractors
- **Majority were truck-mixed**
- Largely slipformed
- Areas were selected from each project to represent “good” and “bad” parts of the project (except for control)
  - Detailed visual assessment
  - Laboratory testing

Representative Conditions: Project No. 1

poor

Good

Representative Conditions: Project No. 5

Poor

Good

Other Observations

Visual Assessment

- Overall, the projects are not 'bad', but there are concerning trends
  - Other than the really bad part of Project No. 1, which already has been removed…
  - Minor scaling, evidence of abrasion, minor joint spalling/deterioration
  - City feels something seems a bit 'off' compared to past projects
- 'Poor' areas are largely isolated…does this point to 'means and methods' versus universally a materials issue?

NOTE: Records review is tricky! Incomplete information. Some mix submittals were in error or evolved. Batch tickets do not always match mix submittal

Sampling and Testing

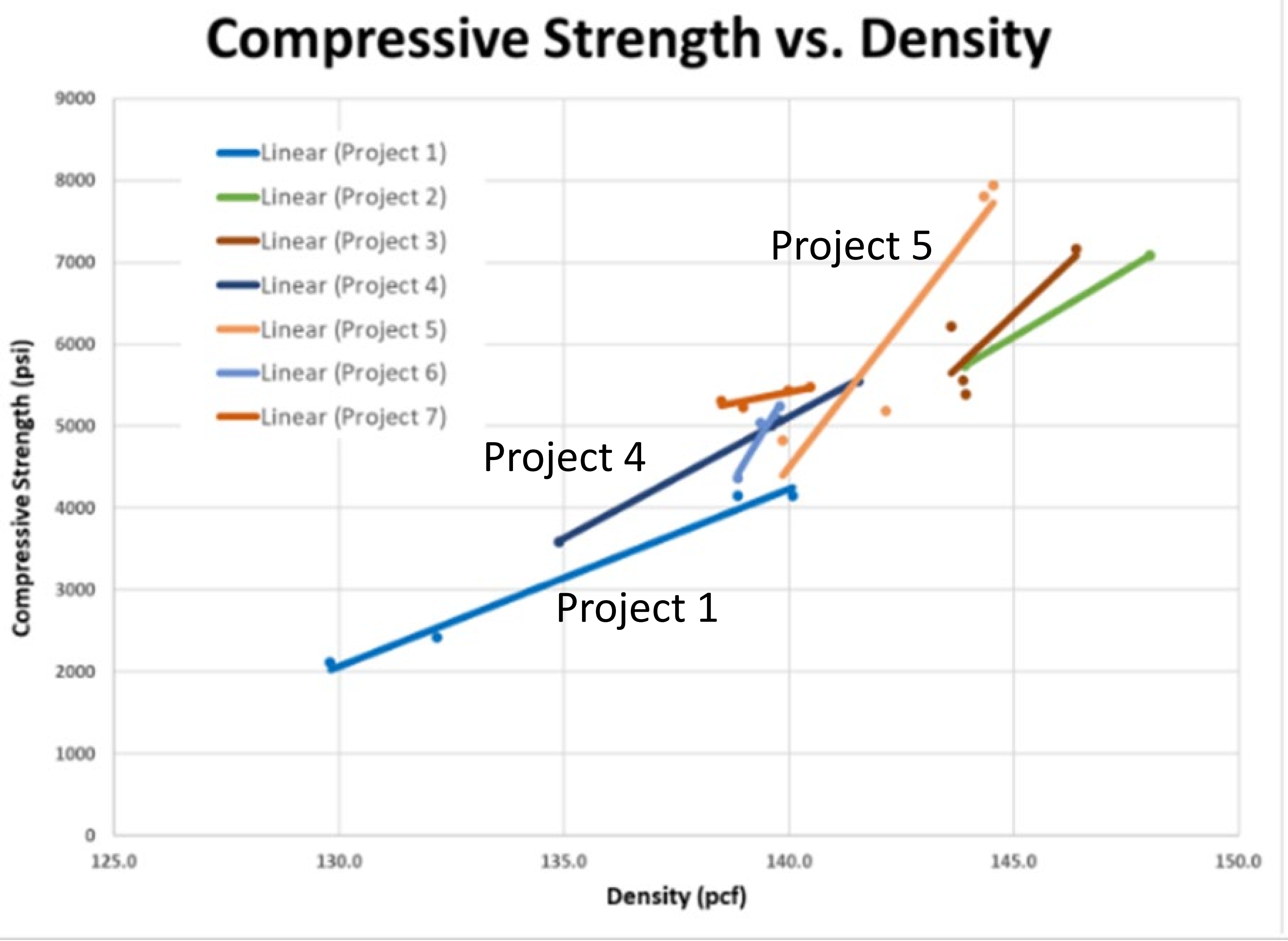
- Eight cores were extracted from each of the six projects with issues (four cores from "poor" area and four cores from "good" area
  - Only four cores obtained from Project 2, which is the control
- The density and compressive strength was determined from two of the four cores in each combination of project/condition
- The other two cores were evaluated petrographically

Density and Compressive Strength

Project No.	Area	Sample ID	Unit Wt. (lb/ft³)	Compressive Strength (psi)
1	“Poor”	1-3	129.8	2,110
		1-4	132.2	2,410
	“Good”	1-6	140.1	4,140
		1-7	138.9	4,150
2 (Control)	“Good”	2-1	143.9	5,740
		2-2	148.0	7,090
3	Poor”	3-3	143.9	5,560
		3-4	143.9	5,390
	“Good”	3-6	146.4	7,160
		3-7	143.6	6,220
4	Poor”	4-2	139.8	5,070
		4-3	134.9	3,590
	“Good”	4-6	139.6	5,010
		4-7	141.5	5,540

Density and Compressive Strength

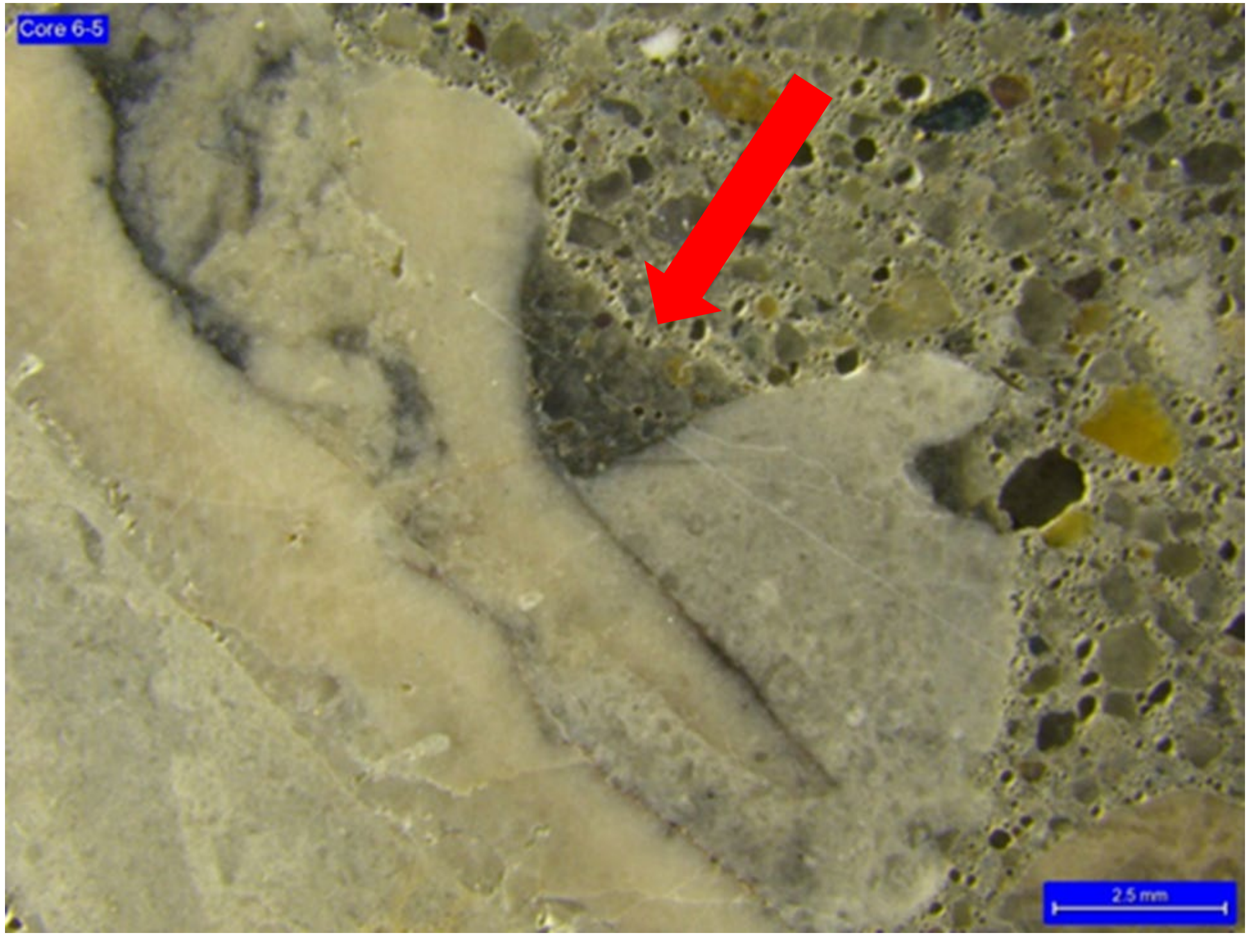
Project No.	Area	Sample ID	Unit Wt. (lb/ft³)	Compressive Strength (psi)
5	Poor”	5-2	139.9	4,820
		5-4	142.2	5,190
	“Good”	5-5	144.5	7,940
		5-7	144.3	7,810
6	Poor”	6-1	138.9	4,360
		6-3	139.7	5,070
	“Good”	6-6	139.8	5,240
		6-8	139.4	5,040
7	Poor”	7-1	140.5	5,480
		7-2	140.0	5,430
	“Good”	7-5	139.0	5,230
		7-6	138.5	5,310



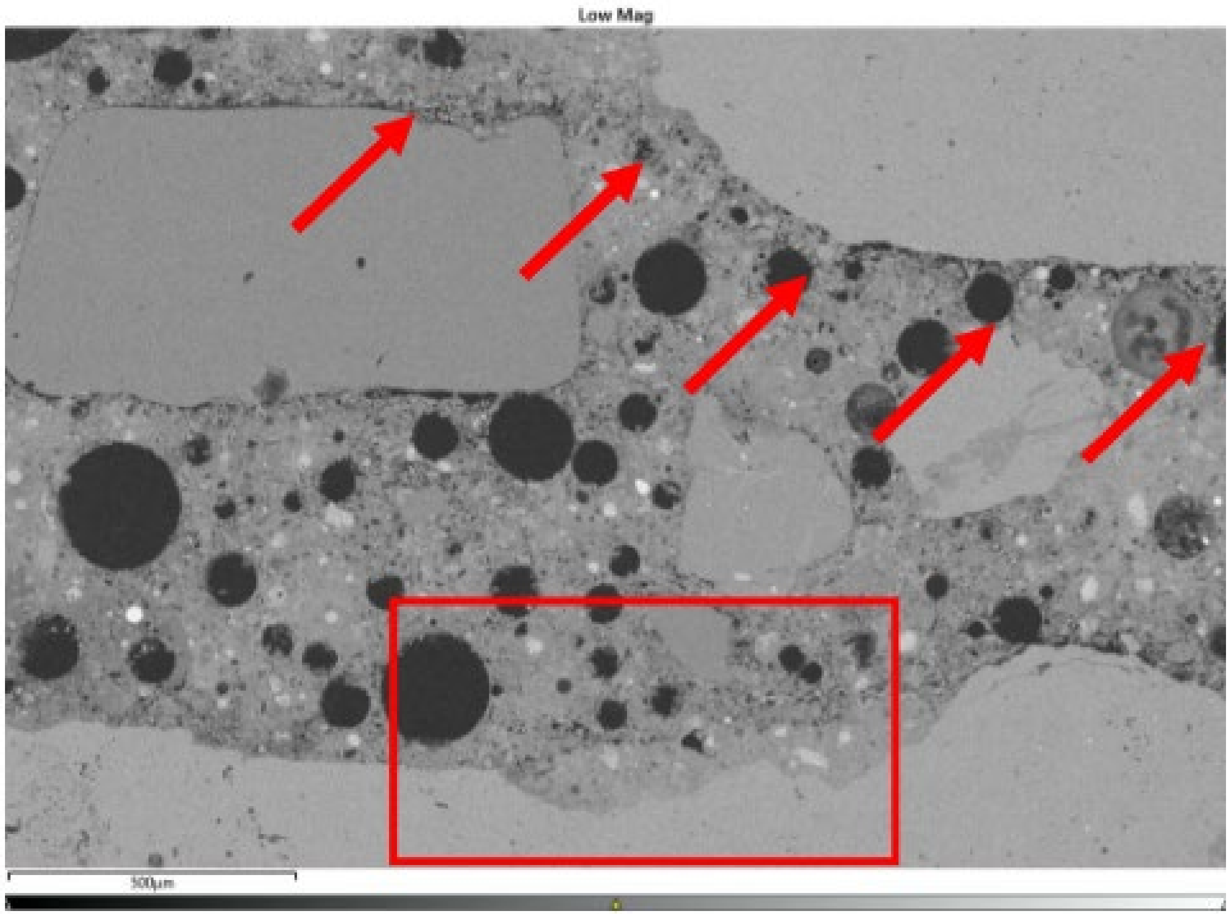
Compressive Strength vs. Density
Linear (Project 1)
Linear (Project 2)
Linear (Project 3)
Linear (Project 4)
Linear (Project 5)
Linear (Project 6)
Linear (Project 7)
Project 5
Project 4
Project 1
Compressive Strength (psi)
Density (pcf)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
125.0
130.0
135.0
140.0
145.0
150.0

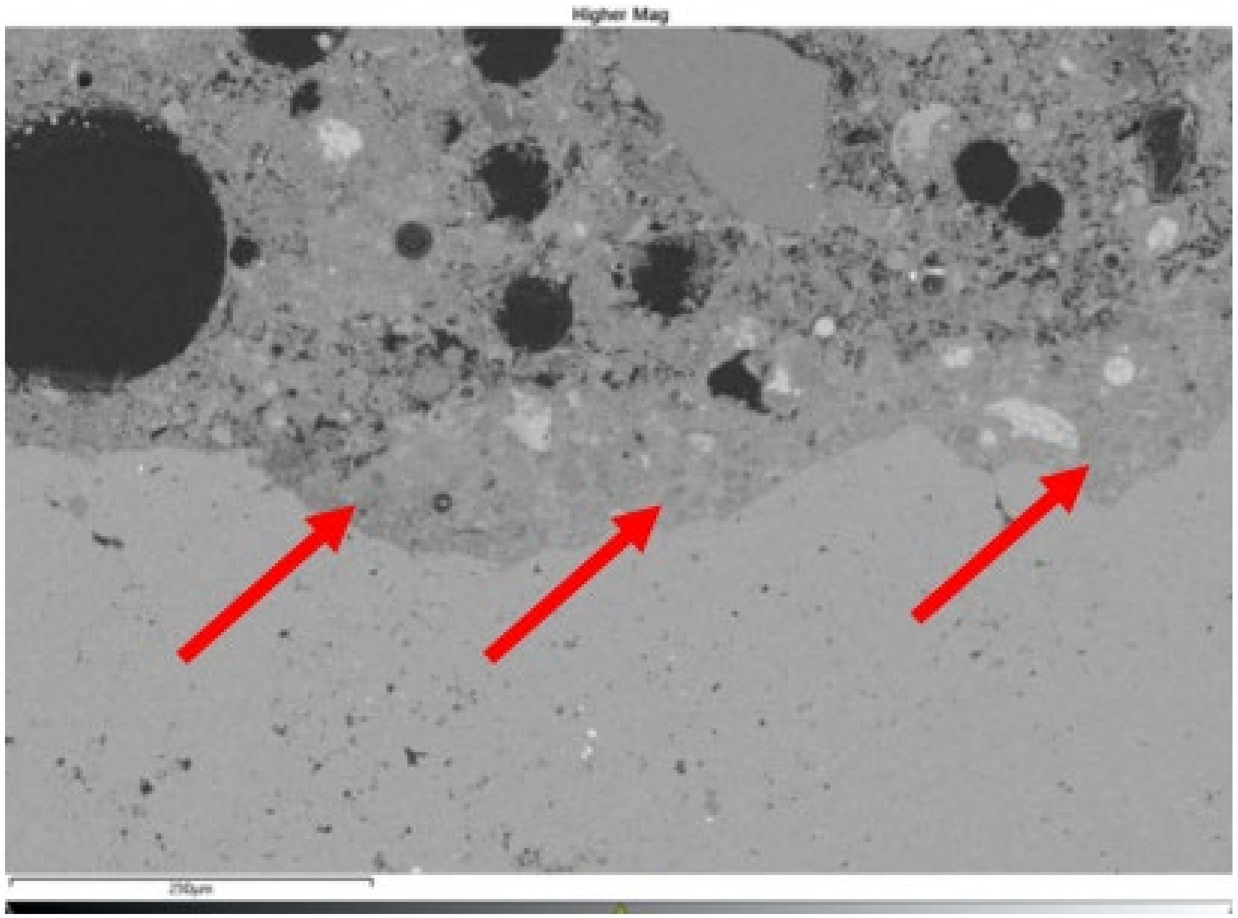
Optical Microscopy – General Observations

- Samples are compositionally similar, containing crushed limestone in an air-entrained, portland limestone cement and fly ash paste
- Dark grey veneers were frequently observed at the interface of the coarse aggregate particles with the paste in all examined cores
  - Indicative of incomplete initial mixing and/or late addition of water



SEM Micrographs - Veeners

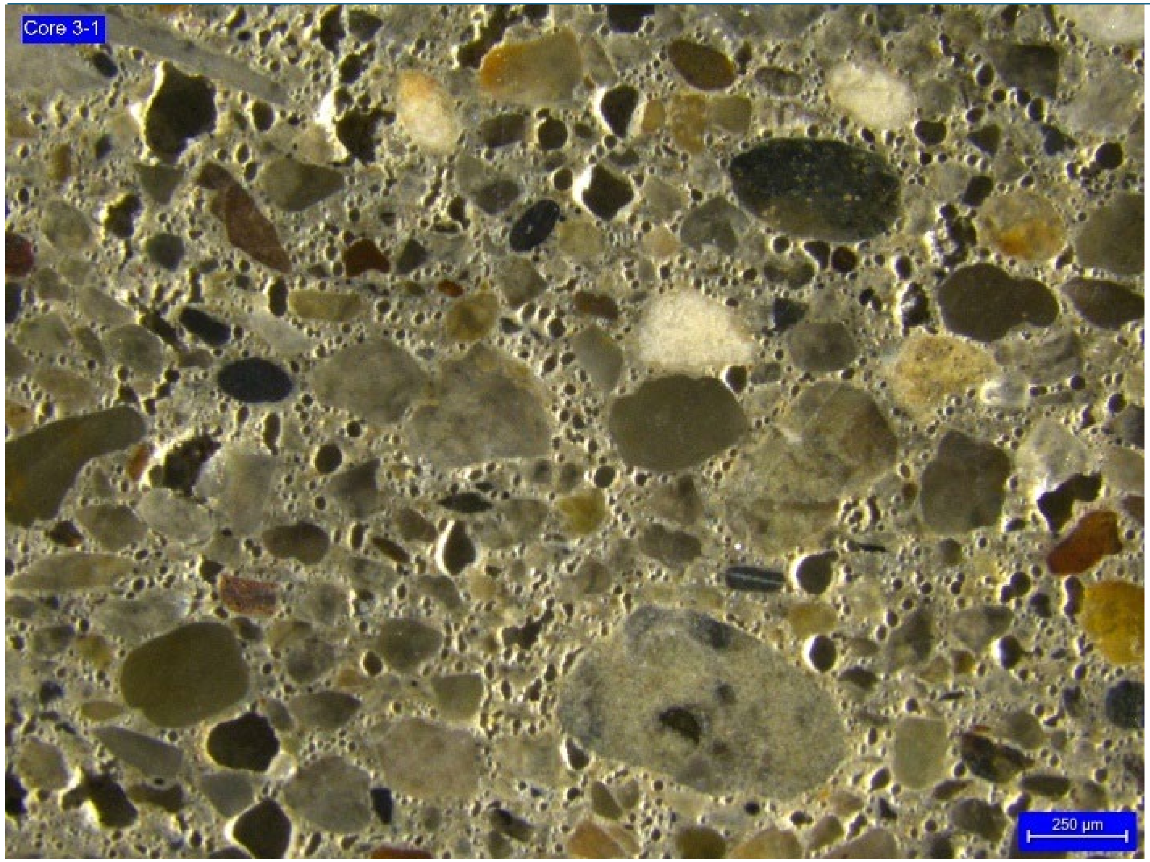


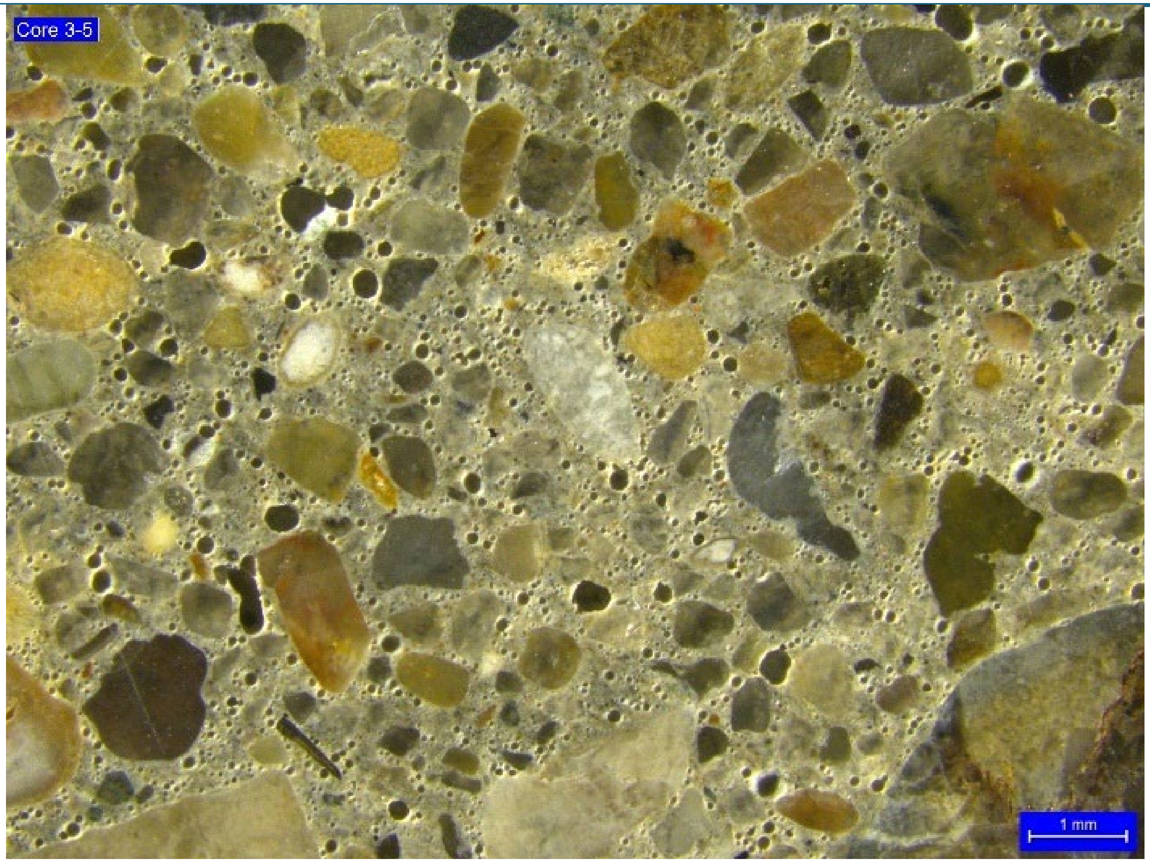


Optical Microscopy – General Observations

- Voids consist of small to coarse spherical entrained air and irregular water gain voids
  - Air void chains and clusters were frequently observed in all examined cores
  - The volume of air voids varied significantly between the examined cores and was often high
- Cement-sized and finer limestone fines in the paste
  - Expected for Type IL cement
  - Crusher fines from the limestone coarse and intermediate aggregate likely contributing

Air Void System is Irregular





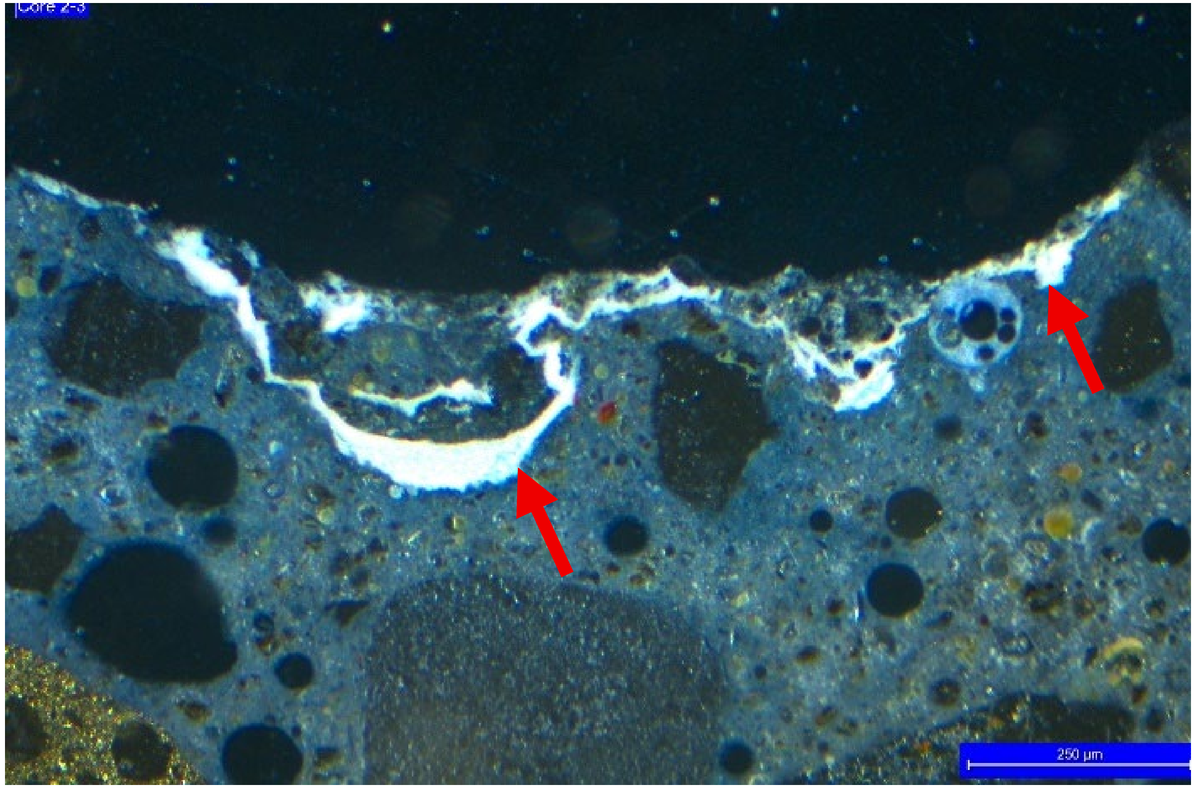
Results of ASTM C457 Air-Void Analysis

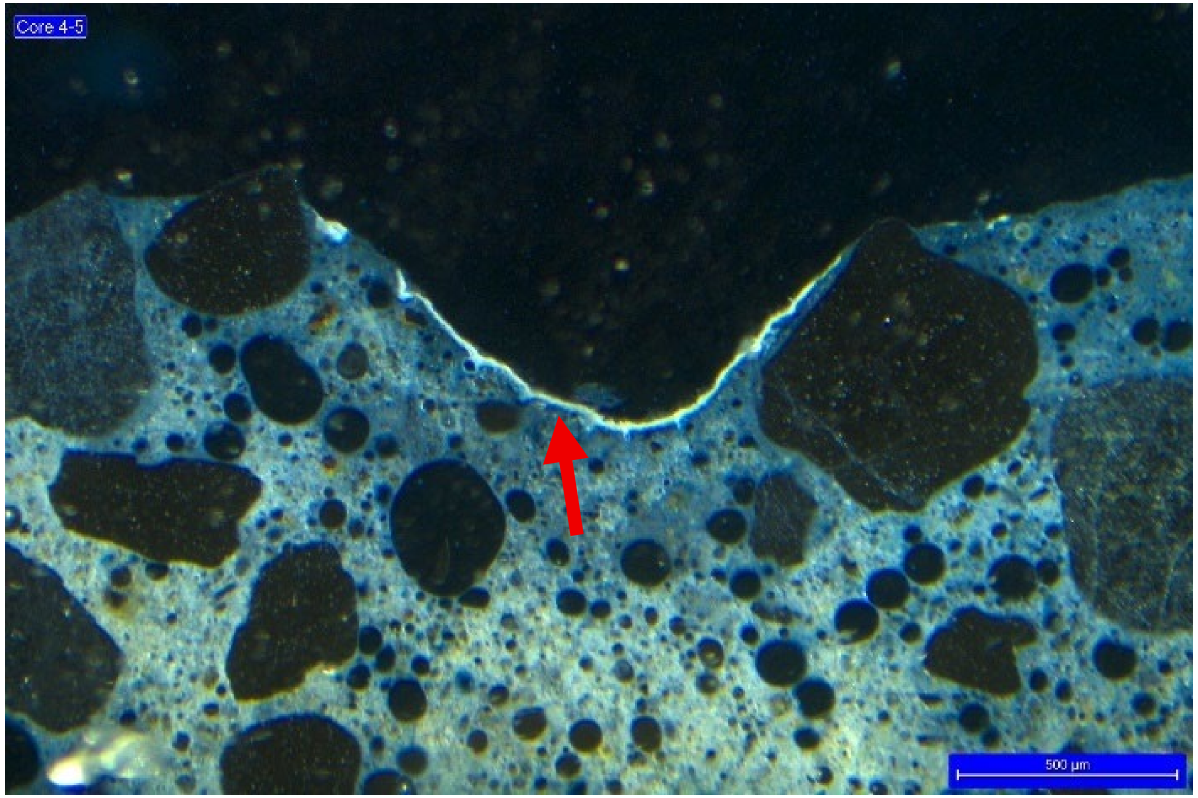
Constituent	Core 1-1	Core 1-8	Core 2-3	Core 3-5	Core 4-1	Core 5-3	Core 6-4	Core 7-3
Air (%)	18.5	10.2	5.3	6.6	9.3	8.8	8.2	7.1
Paste (%)	21.4	25.2	20.1	21.2	24.0	24.2	22.6	22.0
Fine Aggregate (%)	26.4	28.2	27.6	30.4	32.8	32.5	29.0	33.7
Coarse Aggregate (%)	33.7	36.3	47.1	41.8	33.9	34.5	40.2	37.3
Total Aggregate (%)	60.1	64.5	74.7	72.2	66.7	67.0	69.2	71.0
Paste/Air Ratio	1.2	2.5	3.8	3.2	2.6	2.8	2.8	3.1
Void Frequency	26.4	11.4	8.3	11.5	13.6	11.3	14.8	0.21
Average Chord Length (inch)	0.007	0.009	0.006	0.006	0.007	0.008	0.006	0.006
Specific Surface (in^2/in^3)	572	447	632	697	587	512	728	723
Spacing Factor (inch)	0.002	0.006	0.006	0.005	0.004	0.005	0.004	0.004
Measured Unit Weight (pcf)	131.5	141.1	147.6	144.4	140.0	142.5	141.0	143.1

Other Observations

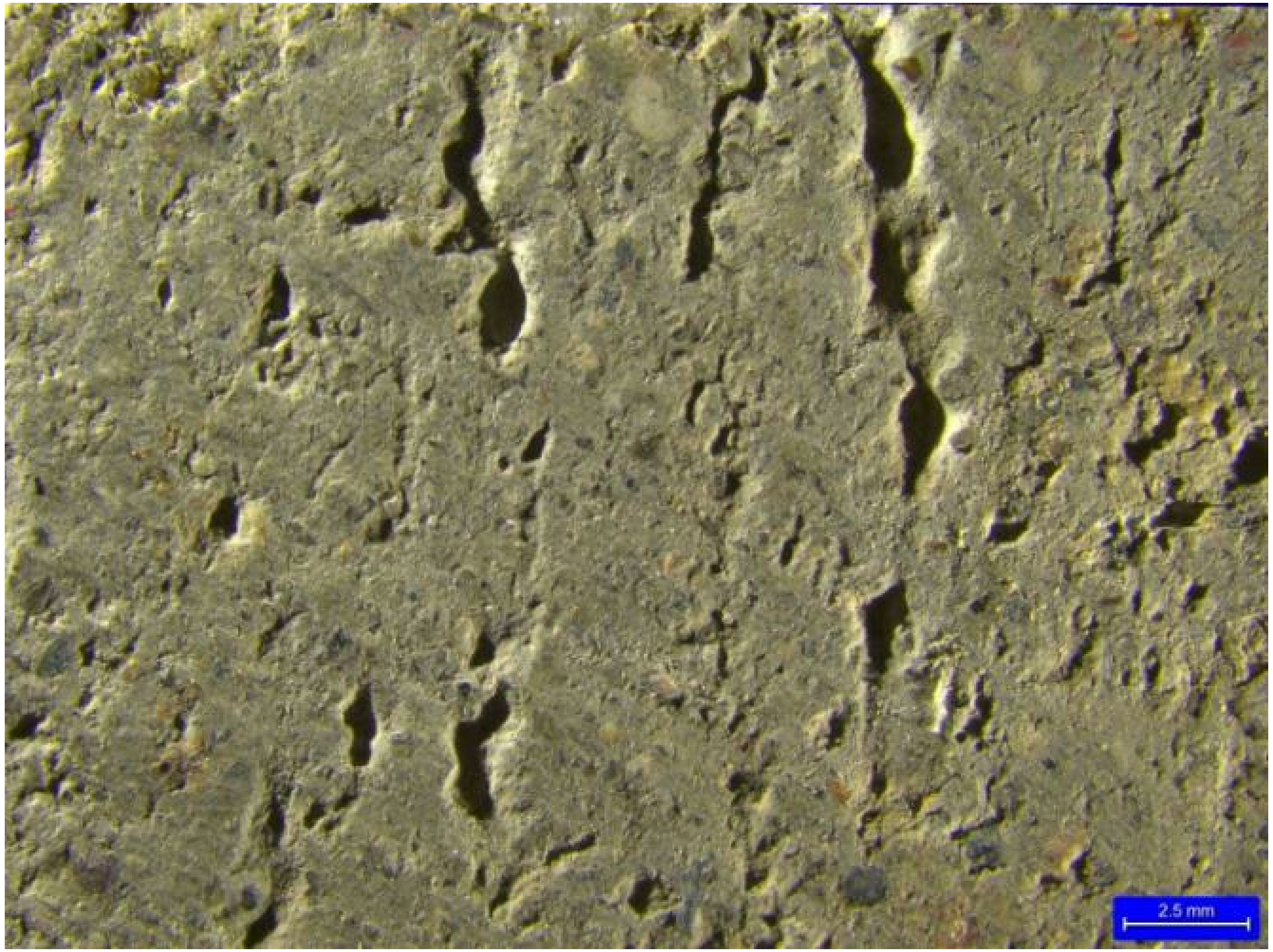
- Near surface regions often had higher w/cm and less air than bulk concrete
  - More often observed in “poor” areas
  - Observed microcracking often observed more in “poor” areas
- Evidence of curing compound not always observed, and at times only observed in the “good” areas
- Textural features on the surface of some cores suggest difficultly in finishing and loss of workability at the time of placement

Surface Coating and Curing Compound





Workability Issues Also Observed



Key Takeaways

- With regards to strength, even within the same project, it can be highly variable
  - Strongly linked to the density, which is linked to air content
  - Overall, the air was high, and in some cases, too high
  - With a few exceptions, the paste-aggregate bond is good
- Evidence of poor initial mixing or late retempering in all concrete
  - Dense veneers with little to no air present in all cores evaluated
  - Air-void systems are often irregular with evidence of clustering and chains
  - There is evidence of limestone dust along aggregate boundaries
    - Very likely from the limestone aggregate (…dusty aggregate)

Key Takeaways

- Evidence that workability was a challenge on some projects impacting consolidation and finishing
- Finishing and poor curing has had a role in the weak surface
  - Surfaces often had different characteristics than bulk concrete as a result of finishing practices and poor curing
  - Finished in bleed water and in one case, the “poor” section had been rained on

What was found…

In areas where distresses were present

- Variable and high air content
- Evidence of inadequate mixing
- Evidence of late retempering
- Evidence of finishing trouble
- Evidence of inconsistent curing

Why now…?

- Probable that evidence of poor mixing is evident in I/II mixtures… but distresses not as common
- It’s the RESPONSE to different bleed and setting behavior that is causing increased occurrence of distress - additional water, retempering, surface water, etc.
- Lack of proper finishing and curing practices exacerbate distresses

Recommendations

Get a handle on the air

- Target less air…perhaps 5% to 8% (instead of 6% to 10%)
- Start measuring **unit weight** in addition to air tests, just prior to placement at point of discharge (after last addition of water)

Recommendations

Improve mixture uniformity

- Concrete mixture proportioning testing (trial batching) should be conducted any time a change in material occurs
  - Add box test and potentially tests for bleeding and set time (modeling haul time & expected placement temp)
- Consider test strips (mock-ups) using means and methods for production and construction

Recommendations

Improve mixture uniformity (continued)

- Focus on moisture management during production
  - Concrete should be batched at the plant close to target w/cm (practice of holding back significant water for low slump, truck-mixed concrete should stop – may lead to excessive site water being added, spins up air)
  - When necessary, site water should be monitored by qualified personnel, so it is mixed properly, and re-tested

Recommendations

- Emphasize best practices for finishing
  - In general, Type IL will have a slower bleeding rate, discourage addition of water to surface
- Enforce best practices for curing (initial and final)
  - Apply final cure as soon as soon as finishing is complete
  - Ensure cure meets specifications
  - Monitor evaporation rate
  - Consider evaporation retarders
- Educate field personnel about changes and proper way to respond

Closing Thoughts…

- Lots of information!
- Rigor
- Context is important!
  - Scaling is not new
  - Workforce
  - Optimized mixes
  - Bulk of concrete is good

Closing Thoughts (cont.)

- Nothing in this work suggests that there is something “wrong” with Type IL cement
  - It does suggest that it is different, and that changes that were once relatively unimportant may now be consequential
- Concrete made with Type IL will behave and finish differently and these difference <u>must</u> be acknowledged and addressed
  - Do more mixture proportioning and consider test strips
  - Educate workforce to be more observant and responsive to differences
- Things appear to be “better” this past year, with fewer challenges noted. (Adjusted practice? IL blends optimized?)

Closing Thoughts (cont.)

- Additional guidance on the way…
  - Finishing
  - Trial batching

QUESTIONS?

Report published soon on
www.CPTechCenter.org

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