



SOLUTIONS FOR THE BUILT WORLD

Forensic Investigation of West Des Moines Street Projects



Thomas Van Dam, Ph.D., P.E.
Principal

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IA Better Concrete Conference - 2025

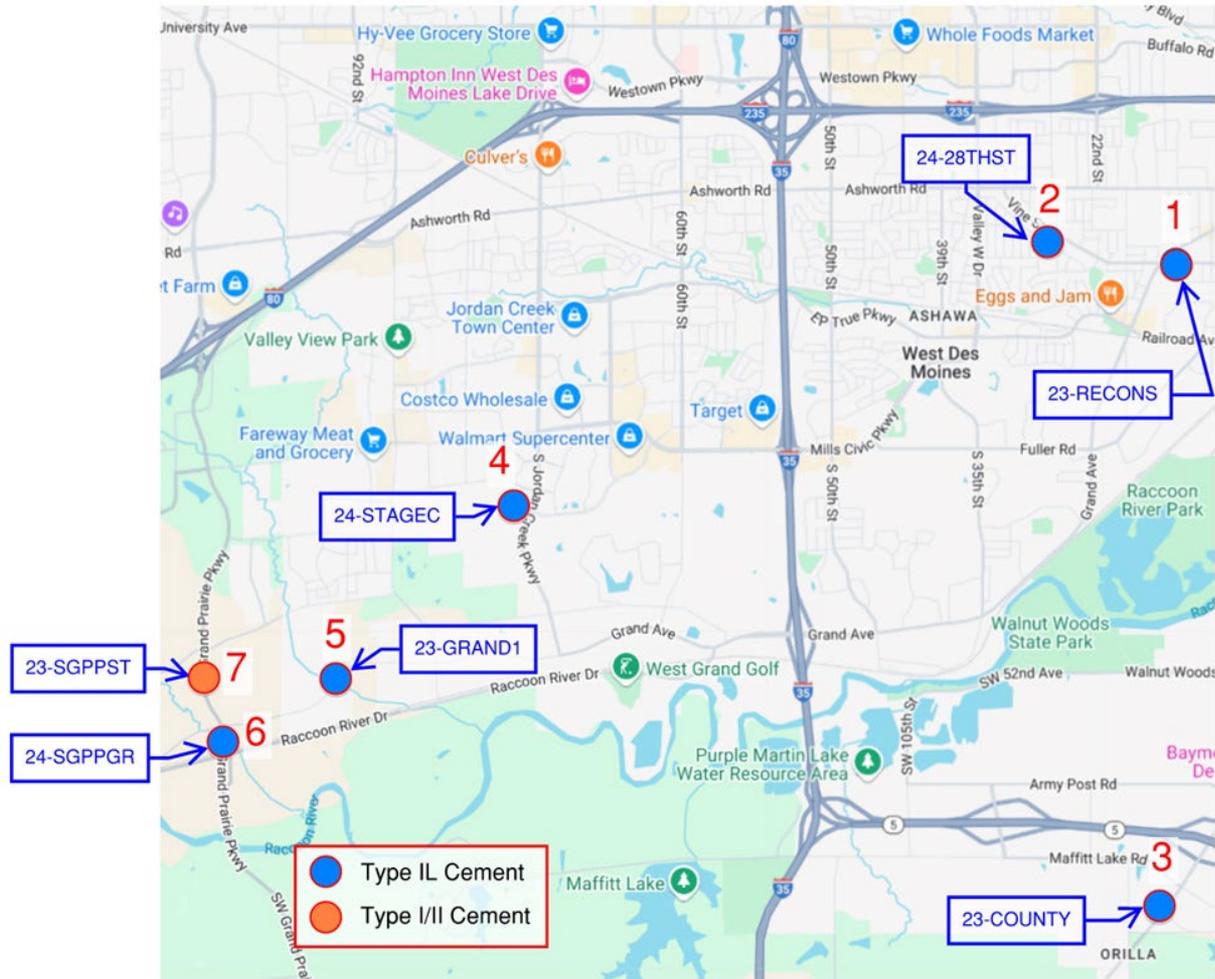
Acknowledgements and Caveat

- This project is funded through the National Center for Concrete Pavement Technology at Iowa State University
 - Managed by Leif Wathne
- The City of West Des Moines and the Iowa Ready Mixed Concrete Association/Iowa Concrete Pavement Association have provided invaluable assistance
- The investigation is not complete and thus this is a preliminary presentation of results
 - Still formulating causation and mitigation strategies
 - Conclusions may be amended

Project Summary

- Seven projects were selected from a list of 21 constructed in 2023 and 2024
 - Six had reported surface and/or strength issues and one project was selected as a control
- Have mixture information on 6 of the 7 projects
 - All made with Type IL cement from at least 3 sources
 - All used fly ash between 20% and 25% (at least 4 sources)
 - All appear to have using a mid-range water-reducer
 - Formulation unclear

Project No.	City Project No.	Location Description	Location ID	Year of construction	Reported strength issues ^[1]	Reported surface defects ^[1]
1	0510-001-2023	2023 Street Reconstruction Program (Incl Vine St)	23-RECONS	2023	Yes	Yes
2	0510-001-2024	2024 Street Reconstruction Program 28th St	24-28THST	2024	No	No
3	0510-077-2021	SE County Line Road Veterans to Orilla Rd	23-COUNTY	2023	No	Yes
4	0510-018-2023	Stagecoach Drive S. 78th St to S. 81st St	24-STAGEC	2024	Yes	Yes
5	0510-009-2021	Grand Ave - S 88th St to S GPP	23-GRAND1	2023	Yes	No
6	0510-014-2021	S Grand Prairie Pkwy Grand Ave to Raccoon River Dr	24-SGPPGR	2024	Yes	No
7	0510-012-2021	S. Grand Prairie Parkway Stagecoach Dr to Booneville RD	23-SGPPST	2022	Yes	No



Mix Design Information

- Information is incomplete
 - No information on Project No. 3
- Information is confusing
 - Batch tickets not always matching mix submittal
- There is a lot of information
 - Will not be able to do a complete analysis under this SOW

Example: Project No. 1

#722 - SUDAS C-SUD DOT

ORDERED: 6.00 DELIVERED: 6.00 SLUMP: 3.50

SIGNED BY:

NOTES:

3 slump, 0 water added

MAX WATER ALLOWED: 169.20 gl WATER ADDED ALLOWED ON SITE: 27.62 gl
 [AT PLANT] W/C RATIO: 0.35 WATER ADDED: 0.00 gl TEMPER WATER: 0.00 gl TOTAL AGGR WATER: 45.58 gl
 BATCHED WATER: 96.00 gl LOAD TIME: 10:48:47
 [ON SITE] W/C RATIO: 0.35 WATER ADDED: 0.00 gl (0.00) DISCHARGE TIME: 12:26:04

SSD Weights per Cubic Yard				
Materials	Sp. Gravity	Weight	Abs. Vol. Ft. ³	% of Total Cementitious
Monarch Cement Type II	3.08	440 lbs.	2.29	20.0
NMC flyash Chillicothe	2.75	110 lbs.	0.64	0.0
NewCem GGBFS	0.00	0 lbs.	0.00	-
Martin Marietta Ames D-57	2.68	1667 lbs.	9.97	-
Martin Marietta Ames 3/8 Chips	2.68	0 lbs.	0.00	-
Hallett Materials-Hoveland	2.66	1375 lbs.	8.29	-
Total Water	1.00	245 lbs.	3.93	-
SA-50	-	5.5 oz	1.89	-
400-NC	-	16.5 oz.	-	-
Super Plasticizer	-	-	-	-
Superset	-	-	-	-
KB-1200	-	-	-	-
			27.00	

	SUDAS C-SIPSI
Design Strength	550 lb.
Total Cementitious	0.445
Water/Cementitious Ratio	4.00 in.
Target Slump	7.00 %
Target Air Content	45.39 %
% Fine Aggregate to Total Aggregate, by volume	142.12 pcf
Theoretical Unit Weight	27.00 cu. ft.
Yield	

Excess water added may cause low strength, pop-outs, and/or surface scaling. We do not make any guarantee to prevent sand pop-outs or surface scaling. We recommend a wet burlap cure followed by pressure washing. Although there is no guarantee, sand can be imported to reduce the risk of pop-outs.

	DESIGN	TARGET	ACTUAL	% VAR	% MOISTURE
LIMESTONE	1431 lb	8698 lb	8620 lb	-0.90%	1.3% (110.62)
HALLETT	1176 lb	7289 lb	7240 lb	-0.67%	3.3% (231.29)
CHIPS	497 lb	3021 lb	3000 lb	-0.70%	1.3% (38.50)
CEMENT	449 lb	2694 lb	2680 lb	-0.52%	
FLYASH	112 lb	672 lb	665 lb	-1.04%	
KB-1200 M.R.	23.72 oz	142 oz	142 oz	0.00%	
SA-50	6 oz	54 oz	53 oz	-1.85%	
WATER	28.2 gl	96 gl	96 gl	0.00%	

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SA-50	-	5.5 oz	1.89	-
400-NC	-	16.5 oz.	-	-
Super Plasticizer	-	-	-	-
Superset	-	-	-	-
KB-1200	-	-	-	-
			27.00	

Design Strength	SUDAS C-SIPSI
Total Cementitious	550 lb.
Water/Cementitious Ratio	0.445
Target Slump	4.00 in.
Target Air Content	7.00 %
% Fine Aggregate to Total Aggregate, by volume	45.39 %
Theoretical Unit Weight	142.12 pcf
Yield	27.00 cu. ft.

Excess water added may cause low strength, pop-outs, and/or surface scaling. We do not make any guarantee to prevent sand pop-outs or surface scaling. We recommend a wet burlap cure followed by pressure washing. Although there is no guarantee, sand can be imported to reduce the risk of pop-outs.

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SA-50	6 oz	54 oz	53 oz	-1.85%	
WATER	28.2 gl	96 gl	96 gl	0.00%	

Cement increased from 400 pcy to 449 pcy
 WR from 400 NC Type A/D to KB-1200 Type A/F

Field Conditions

- Overall, the projects are not “bad”, but there are concerning trends
 - Other than the really bad part of Project No. 1, which was BAD
 - Minor scaling, evidence of abrasion, minor joint spalling/deterioration
 - City feels something seems a bit off
- 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



Bad



Good

Representative Conditions: Project No. 3



Bad



Good

Representative Conditions: Project No. 5



Bad



Good

Other Conditions



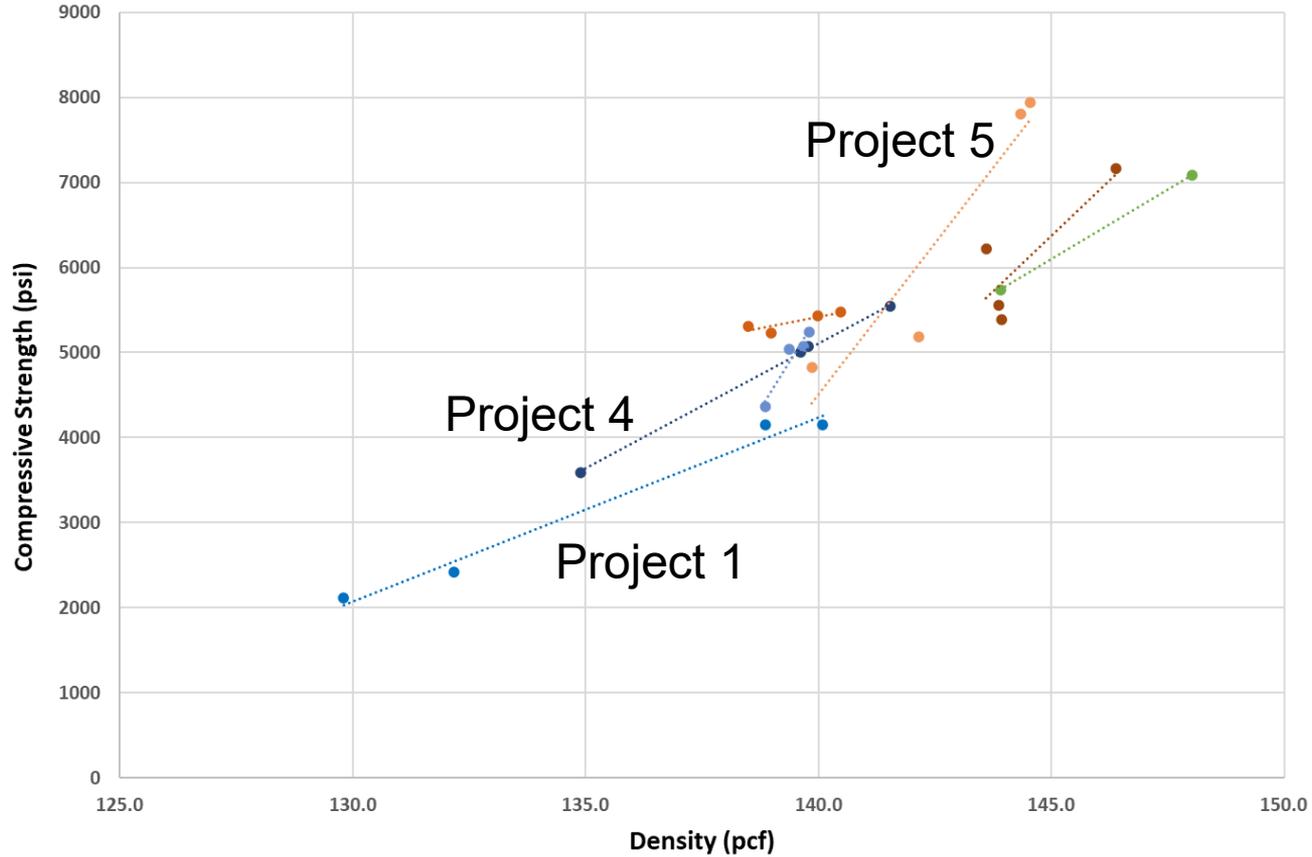
Laboratory Testing – Compressive Strength

Project No.	Area	Sample ID	Unit Wt. (lb/ft ³)	Compressive Strength (psi)
1	"Bad"	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	"Bad"	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	"Bad"	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

Laboratory Testing – Compressive Strength

Project No.	Area	Sample ID	Unit Wt. (lb/ft ³)	Compressive Strength (psi)
5	"Bad"	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	"Bad"	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	"Bad"	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 vs Density



Optical Microscopy – General Observations

- Concrete is compositionally similar, containing crushed limestone and cherty limestone coarse aggregate and siliceous and calcareous fine aggregate in an air-entrained, portland cement and fly ash paste
 - Projects Nos. 5 and 7 also have quartzite coarse aggregate
 - Some fine aggregate particles are alkali-silica reactive
- The paste varied in hardness and dark grey veneers were frequently observed at the interface of the coarse aggregate particles with the paste in all examined cores
 - Indicative of retempering and/or incomplete initial mixing

Reactive Aggregates and Veneers



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 II cement
 - May also be crusher fines from the coarse aggregate
 - Seems to be concentrated with fly ash in some cases

Project No. 3: Air is Highly Irregular

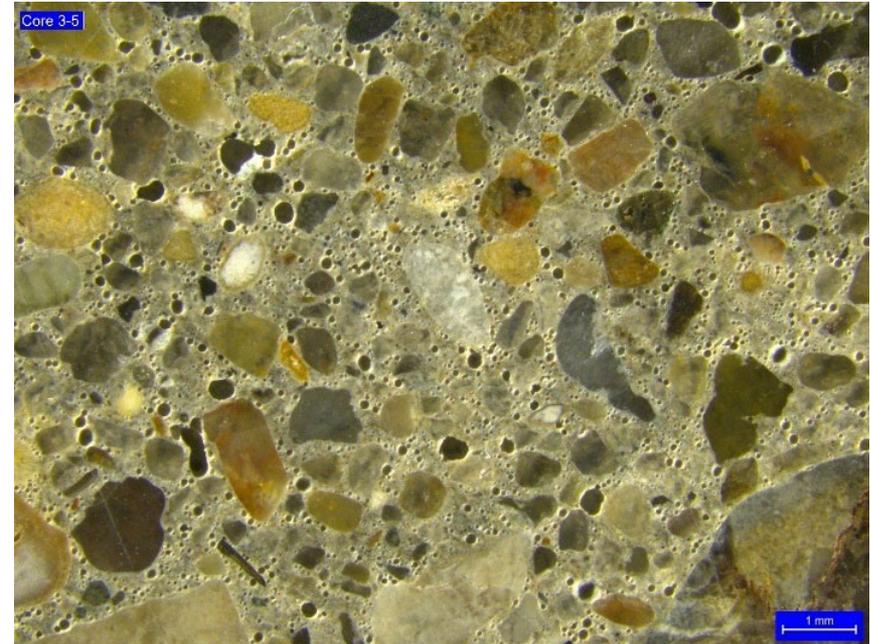
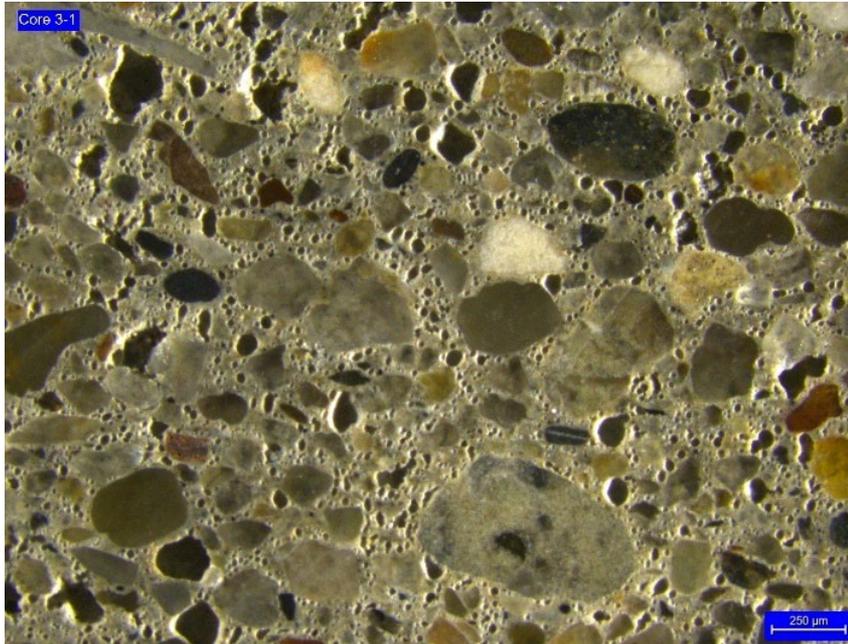
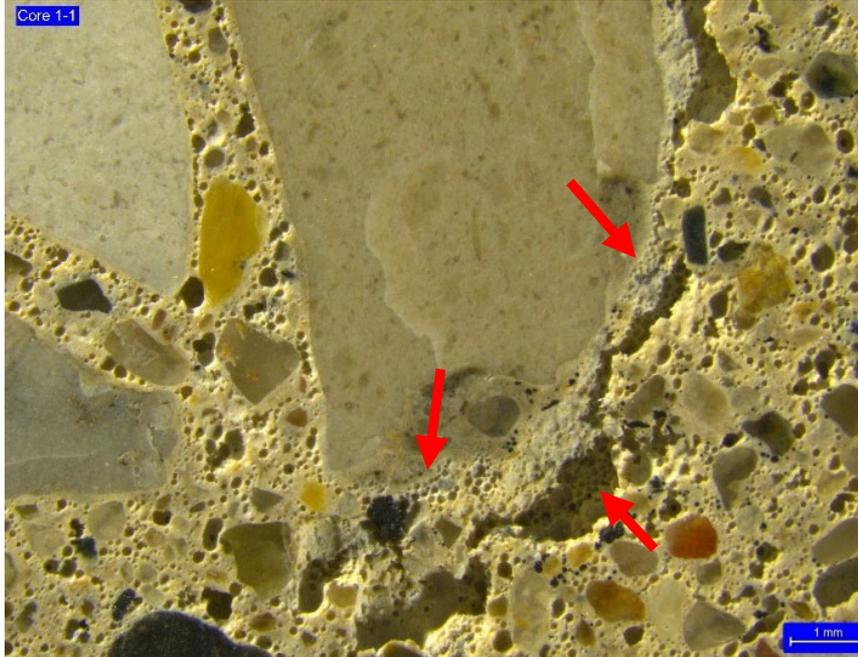


Figure 1. Typical air-void system in Core 3-1 (left) and Core 3-5 (right); images taken at the same magnification for comparison.

Air-Void Chains, Clustering, and Water Gain Voids

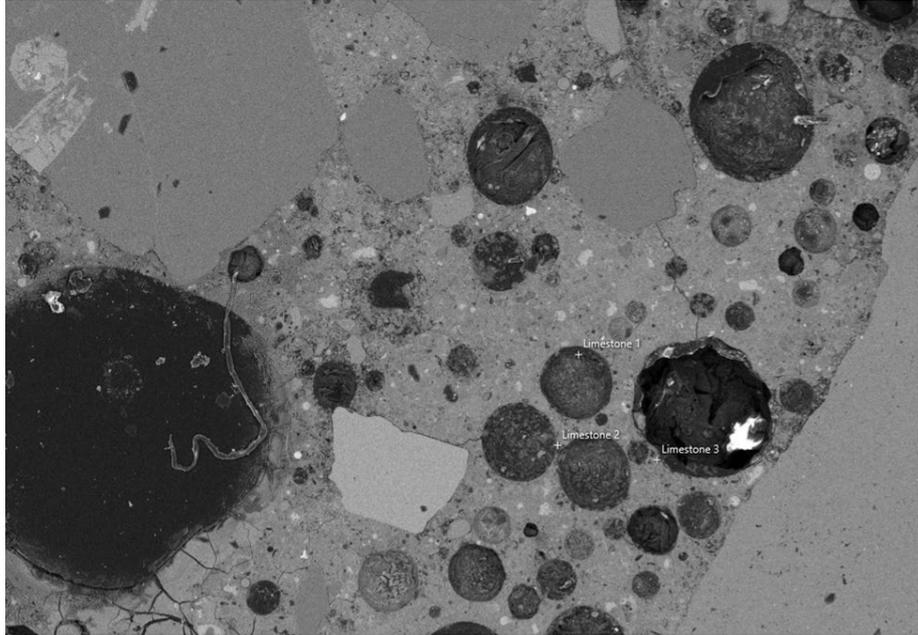


Results of ASTM C457 Air-Void Analysis

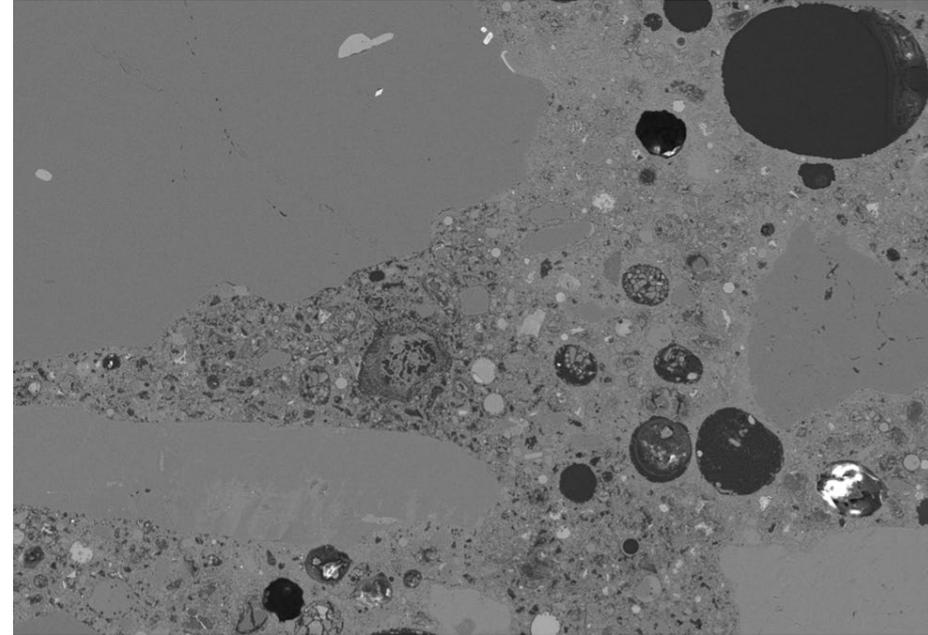
Constituent	Core 1-1	Core 1-8	Core 2-3	Core 3-5	Core 4-1	Core 5-3	Core 6-4	Core 7-3
Air (%)	18.5	10.2	5.3	6.6	9.3	8.8	8.2	7.1
Paste (%)	21.4	25.2	20.1	21.2	24.0	24.2	22.6	22.0
Fine Aggregate (%)	26.4	28.2	27.6	30.4	32.8	32.5	29.0	33.7
Coarse Aggregate (%)	33.7	36.3	47.1	41.8	33.9	34.5	40.2	37.3
Total 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

SEM Is A Work in Progress

200x



500x



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 difficult in finishing and larger compaction voids throughout the thickness suggests the concrete was losing workability at the time of placement

Core 1-1: Near Surface



Figure 1. Near-surface of Core 1-1 contained an incipient spall (arrows).

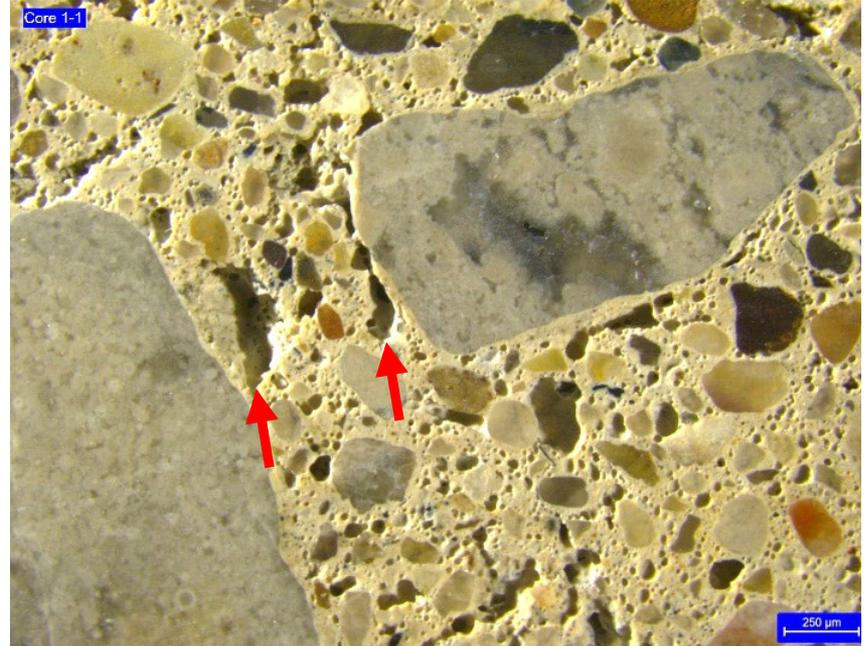


Figure 2. Vertically oriented water gain voids (arrows) near-surface of Core 1-1.

Surface Coating and Curing Compound



Figure 1. Discontinuous white material (arrows) along the top surface of Core 2-3 may represent a topically applied curing compound or sealer; pictured in thin section under oblique (reflected) light.

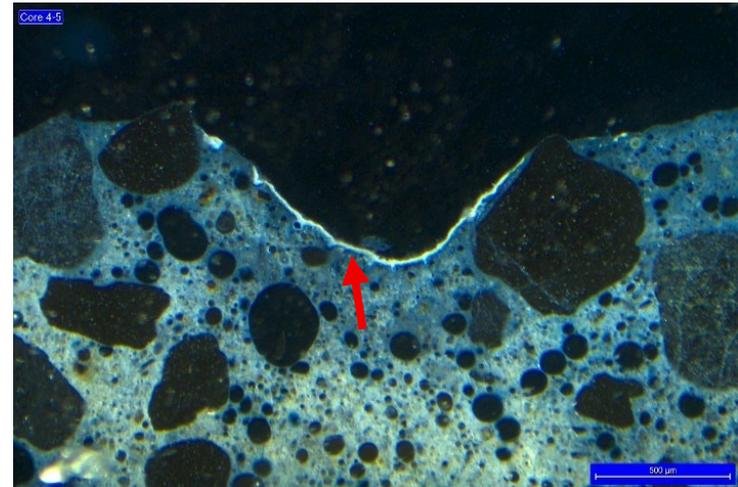


Figure 2. Discontinuous white material (arrow) along the top surface of Core 4-5 represents a possible curing compound or sealer; pictured in thin section under oblique (reflected) light.

Core 3-1: Air at Surface is Scary



Figure 1. Abundant entrained air voids observed on the as-received top surface of Core 3-1.



Figure 2. Abundant air voids lining aggregate sockets from aggregates plucked from the surface in Core 3-1.

Project 4 – Air-Void System at Depth

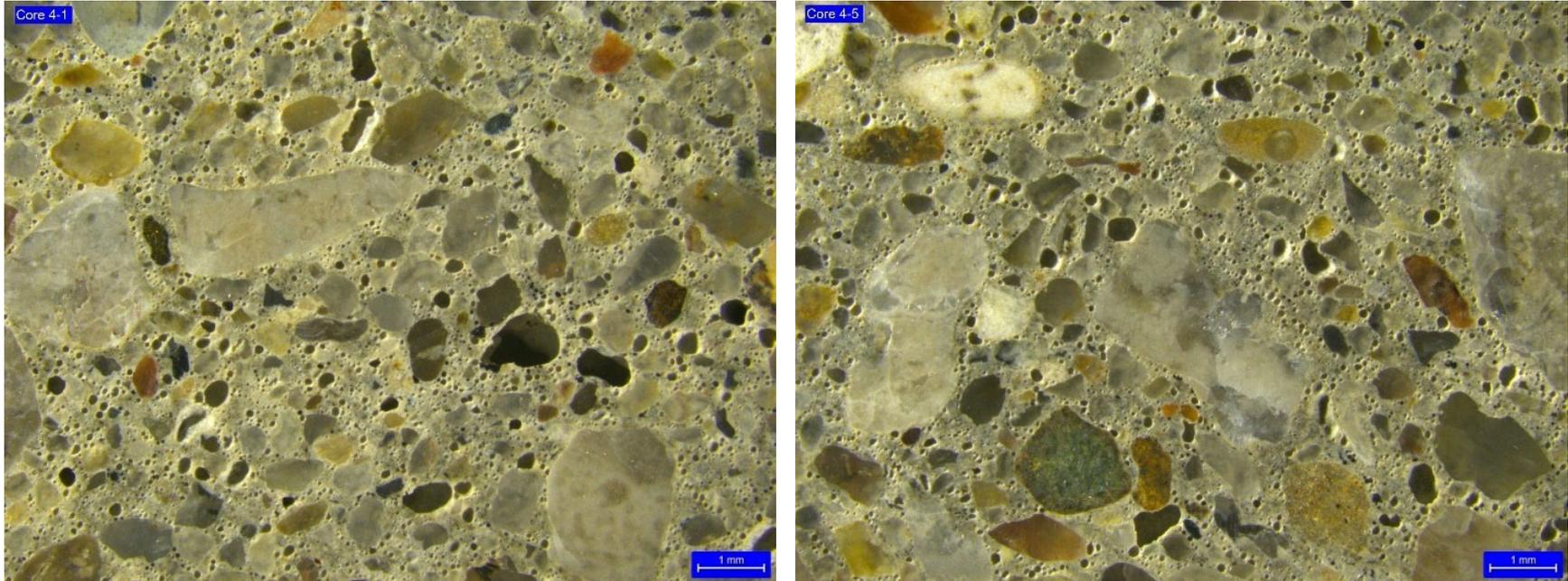


Figure 1. Typical air-void system of Core 4-1 (left) and Core 4-5 (right); images are taken at the same magnification for comparison.

Core 7-3: Near-Surface Air Void Clustering

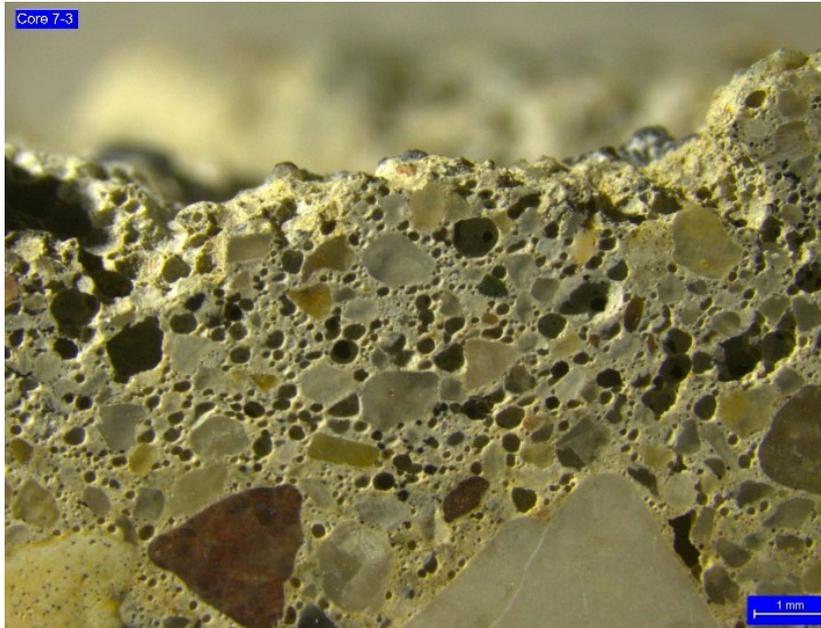
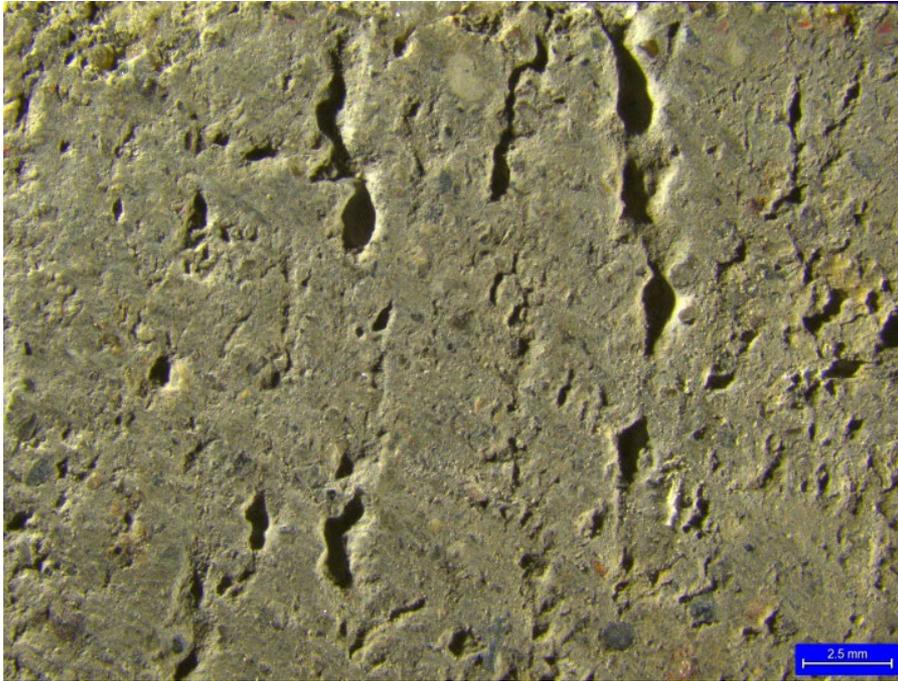


Figure 1. Increased air content along the surface of Core 7-3.



Figure 1. Air void cluster along the spalled surface in Core 7-3.

Workability Issues



Summary

- This work is preliminary and more work is needed
- Evidence of retempering in all concrete
 - Veneers present in all cores evaluated
 - With a few exceptions, the paste-aggregate bond is good
 - Air-void systems are irregular with lots of air and clustering and chains
- Evidence that workability was a challenge on some projects impacting consolidation and finishing

Summary

- It is believed that the combination of Type IL cement, water-reducing admixtures, and retempering has not been kind to the air-void system and uniformity of the paste
 - Dense zones of paste with little air
 - Seeing some floccing of limestone and fly ash particles
- Finishing and curing has had a role in the weak surface
 - Surfaces often had different characteristics than bulk concrete
 - Seems that even within a project, the way the concrete was finished and cured varied

Thank You & Questions

Thomas Van Dam, Ph.D., P.E., FACI

Principal

Wiss, Janney, Elstner Associates, Inc.

Engineers | Architects | Materials Scientists

330 Pfingsten Road, Northbrook, Illinois 60062

tel 847.272.7400 | fax 847.291.9599

direct 847.753.6345 | mobile 775.527.2524

www.wje.com

tvandam@wje.com