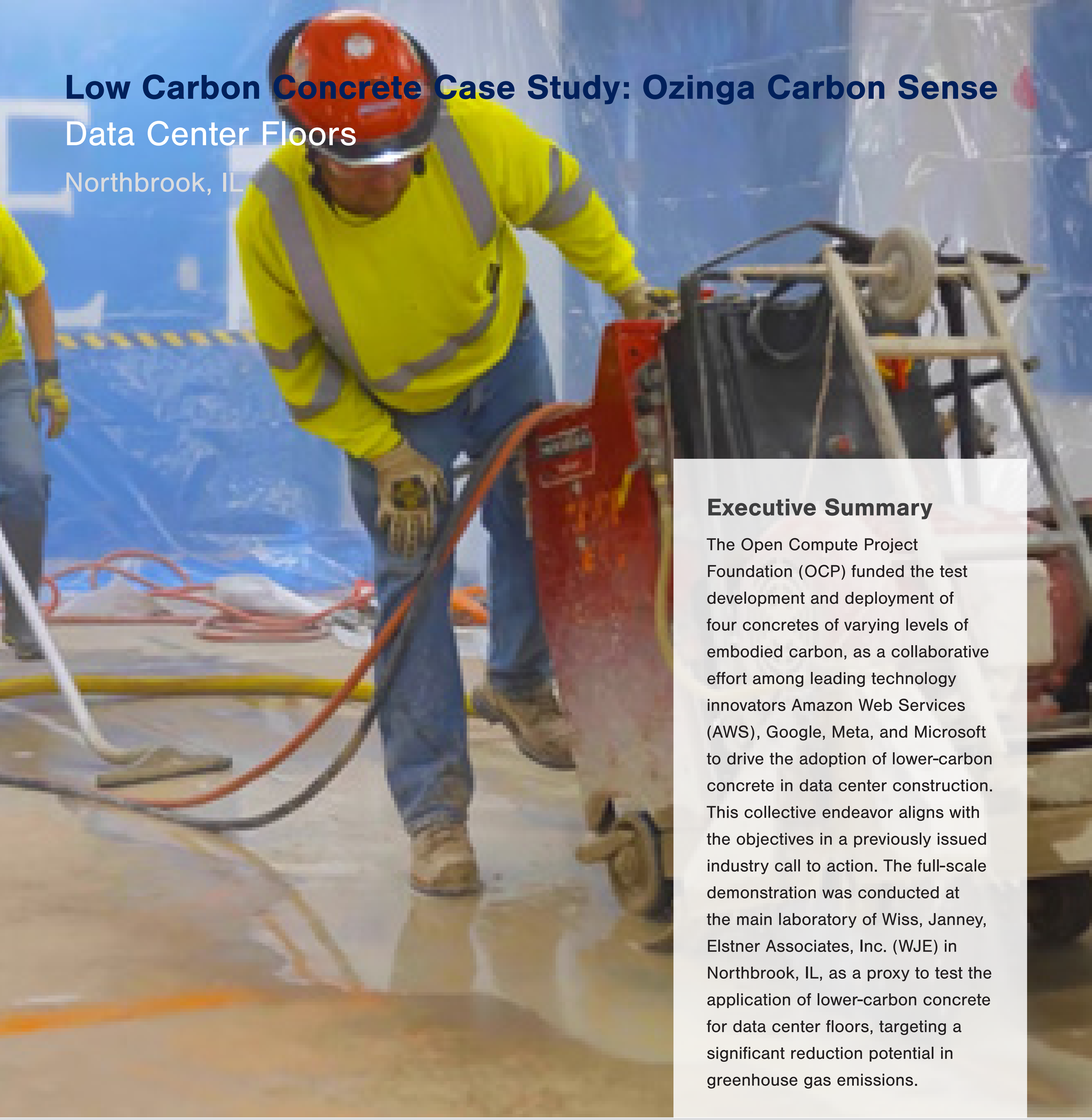
Low Carbon Concrete Case Study: Ozinga Carbon Sense

Data Center Floors

Northbrook, IL



Executive Summary

The Open Compute Project Foundation (OCP) funded the test development and deployment of four concretes of varying levels of embodied carbon, as a collaborative effort among leading technology innovators Amazon Web Services (AWS), Google, Meta, and Microsoft to drive the adoption of lower-carbon concrete in data center construction. This collective endeavor aligns with the objectives in a previously issued industry call to action. The full-scale demonstration was conducted at the main laboratory of Wiss, Janney, Elstner Associates, Inc. (WJE) in Northbrook, IL, as a proxy to test the application of lower-carbon concrete for data center floors, targeting a significant reduction potential in greenhouse gas emissions.

Project Team

OPEN Compute Project® · WJE · OZINGA · CLAYCO

EXACT · GIATEC · wavelogix · Davies-Crooks Associates · climateworks FOUNDATION

INSIGHTS

Ozinga Carbon Sense

ASTM C595 and C1157 Cements

35-60% GWP Reduction

6570-10680 psi @ 28 days

6870-11100 psi @ 56 days

Project Goal

Test four (4) different lower-carbon concrete mixtures that may be incorporated into data center slab-on-grade construction. Compare global warming potential (GWP), workability, appearance, abrasion resistance and strength. Also, measure and compare concrete strength using four (4) different measuring techniques.

Abstract

The Open Compute Project Foundation (OCP) engaged Wiss, Janney, Elstner Associates Inc. (WJE) to test four different lower-carbon concrete mixes, placed within a WJE annex building, for their potential use as a data center floor. The baseline mixture used an ASTM C595 Type IL cement that is common to the Great Lakes Midwest region. Mixture 2 was a blend of this same cement, but with a significant replacement with blast furnace slag as a supplementary cementitious material. Mixture 3 was a blend of this same cement, but with a partial replacement with an Ozinga CarbonSense branded ASTM C1157 performance hydraulic cement. Mixture 4 was a full Ozinga CarbonSense ASTM C1157 cement mixture. The Ozinga CarbonSense cement has previously been used in foundations and other less finish critical applications, but it is yet to be used at large scale, or in data center and warehouse floors with a high finish quality requirement, given perceived and technical implementation risks.

TYPICAL PLACEMENT/DESIGN CRITERIA
(SAME FOR EACH MIXTURE)

Placement

Interior Slab-on-Grade, 7-inches thick, 18 ft x 22 ft.

Each slab placement includes ½ with #4 rebar at 16” o.c. each way, and ½ with no rebar. No fibers were used within any mixture.

Design Criteria

Strength f'c: 4.0ksi @ 28 days

Maximum *w/cm* Ratio: 0.50

Shrinkage: 0.040%

Maximum Aggregate Size: 3/4”

Air Content: Maximum 3%

Exposure Criteria: F0, S0, W0, C0

Delivery: Truck, then pumped through a 4" hose

Slump: 5-9”

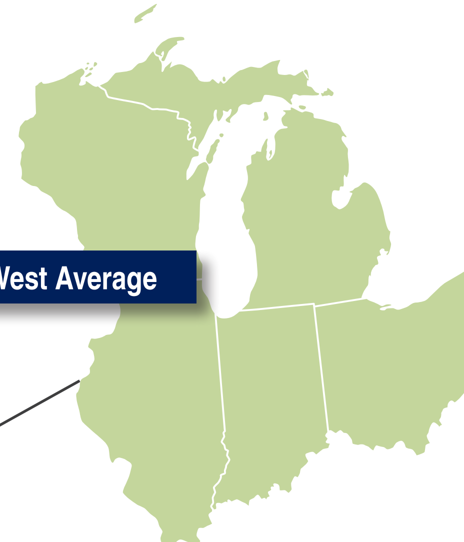
Constituent	Units	Mix 1	Mix 2	Mix 3	Mix 4
Type IL Cement	lbs/yd³	517	295	130	0
Slag Cement	lbs/yd³	0	196	0	0
C1157 Cement	lbs/yd³	0	0	475	750
Fine Aggregate	lbs/yd³	1445	1440	1430	1320
Coarse Aggregate, #67	lbs/yd³	1401	1443	1435	1324
Coarse Aggregate, #4	lbs/yd³	469	483	480	443
Water	lbs/yd³	259	246	212	255
W/CM (incl. admixtures)	n/a	0.50	0.50	0.35	0.37

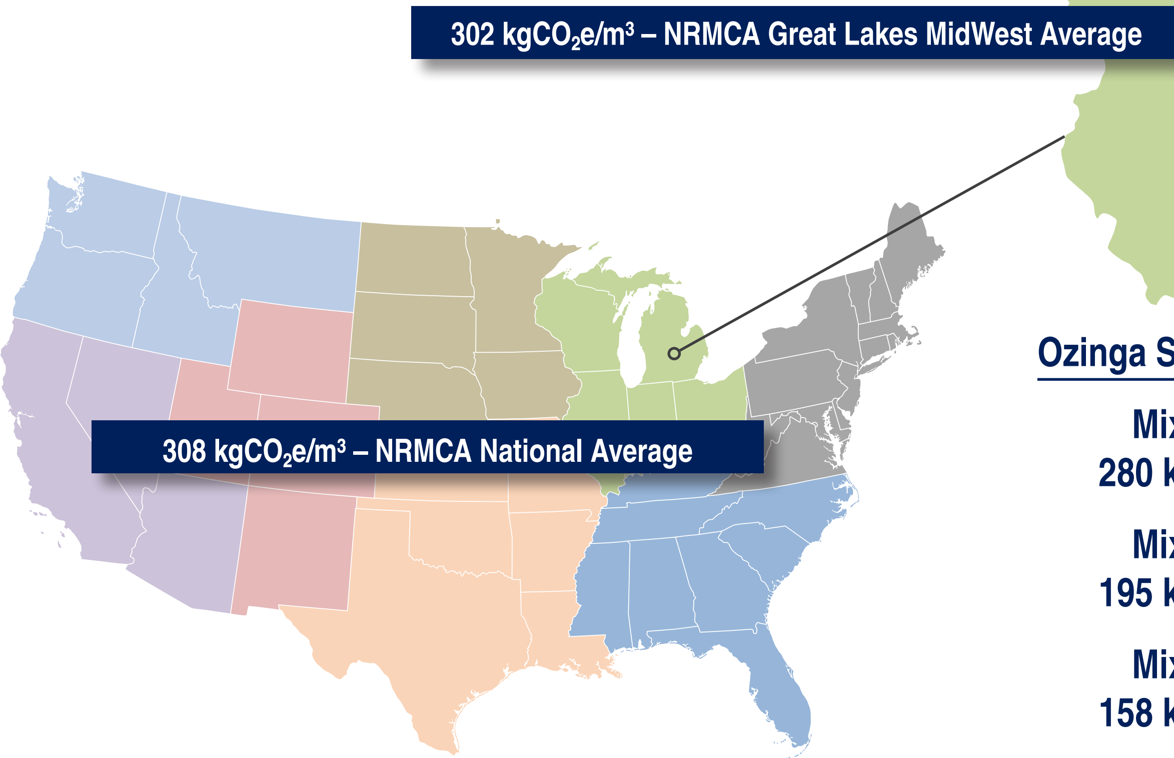
*Concrete Mixture Designs Tested**

All placements of lower-carbon concrete were made via pump to the inside WJE’s Annex II in Northbrook, IL. Finishing was completed by crews from the Concrete Strategies Group of Clayco Construction. The larger WJE testing report provides more extensive mixture specific criteria, including testing performed that is not reported within this case study summary.

GWP Comparison Between Mixtures

NRMCA Industry Average EPD, v3.2, 2022 I 4000 psi Concrete:





Ozinga Supplied EPDs

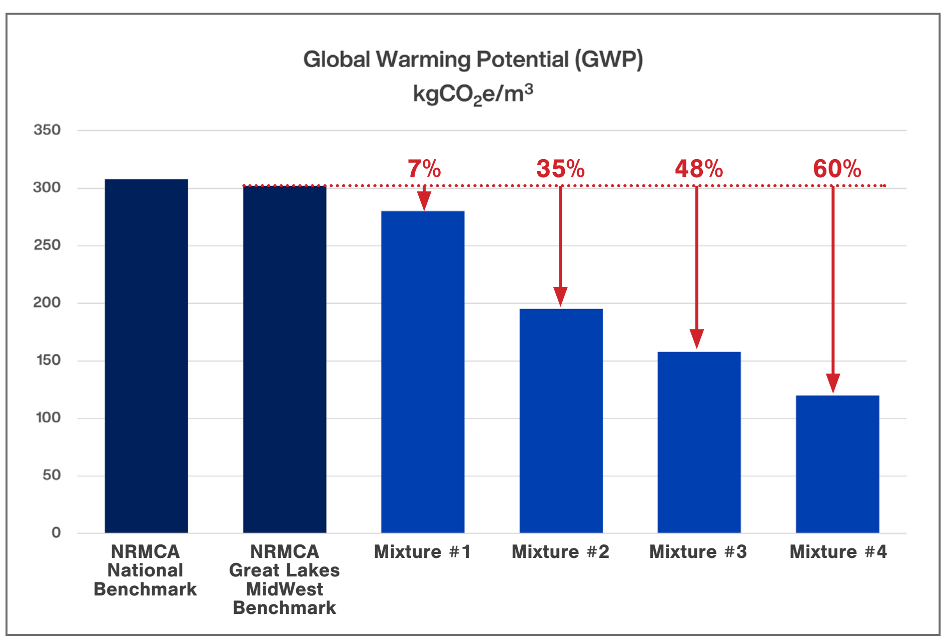
Mixture #1
280 $kgCO_2e/m^3$

Mixture #2
195 $kgCO_2e/m^3$

Mixture #3
158 $kgCO_2e/m^3$

Mixture #4
120 $kgCO_2e/m^3$

GWP ($kgCO_2e/m^3$) Reductions From the NRMCA 4000psi Great Lakes Mid-West Region:



Mixture #1

ASTM C595 Type 1L Cement, No Slag

Design Mixture GWP

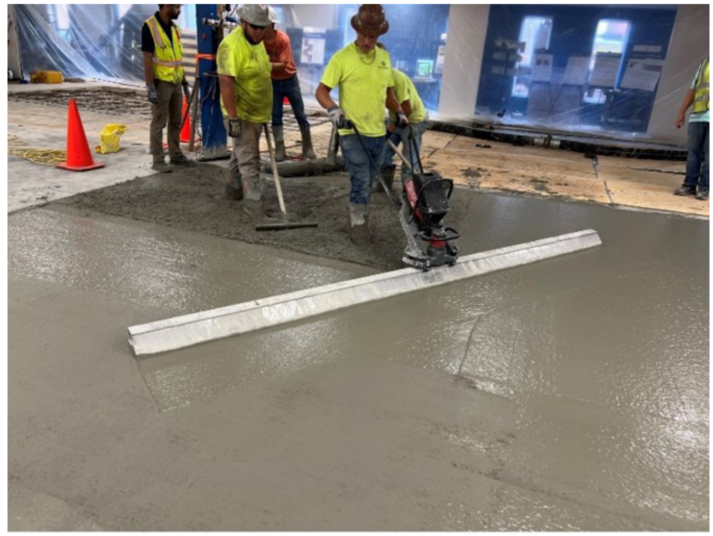
280 $kgCO_2e/m^3$

Contractor and Finisher Comments

Finished about as expected. Initial strike-off was completed with a vibratory screed, followed by hand consolidation as needed. This was followed by power floating and power troweling. Standard procedures used for hard-trowel slab-on-grade construction. Lithium silicate harder was applied, similar to the other slabs.

Mixture #2

ASTM C595 Type 1L Cement, with 40% Slag Replacement



Placement of Mixture #2 showing the finishing sequencing

Design Mixture GWP

195 kgCO_2e/m^3

Contractor and Finisher Comments

Mix 2 was definitely the crowd's favorite. The mix pumped well, placed well and finished well. Overall, it was easy to get into place and it machined/finished the best of the four mixtures placed. Lithium silicate harder was applied, similar to the other slabs.

Mixture #3

ASTM C595 Type 1L Cement with 80% ASTM C1157 Cement Replacement

Placement of Mixture #3 showing the gas-powered walk-behind trowel finisher in use

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Design Mixture GWP

158 $kgCO_2e/m^3$

Contractor and Finisher Comments

Mixture 3 had placement difficulties due in part to delivery truck delays getting to the site. It set up faster because of this, complicating the finishing process. Once mixture 3 stopped moving, it was difficult to get it moving again. The vibra-screed had little to no effect, so we used a gas-powered walk-behind trowel at high throttle, and then ran the screed over it again. Lithium silicate harder was applied, similar to the other slabs.

Mixture #4

100% ASTM C1157 Cement

Todd Nelson from WJE (right) discussing the slab surface with Scott Kelly from Ozinga, who supplied the concrete. Final slab coloring became a constant light grey.

Design Mixture GWP

120 $kgCO_2e/m^3$

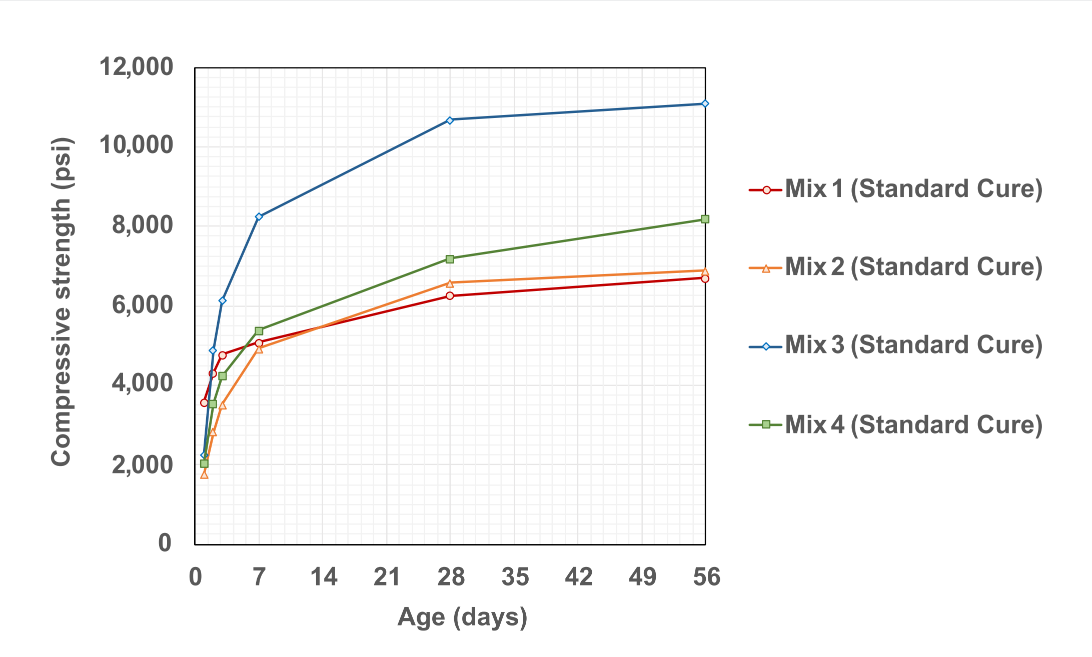
Contractor and Finisher Comments

Mixture 4 pumped fairly well, but once out of the hose it was difficult to move. The mixture did respond slightly to a vibra-screed and minimally to a backpack vibrator. This required more manual labor to complete than a “normal” pour. Once the concrete was in place, it machined and worked with hand tools nicely, but it did not develop quite the “shine” that you would expect out of a normal mixture and it took longer to get to final set.

Lithium silicate surface hardener was applied, similar to the other slabs. While abrasion resistance was the best of the slabs, this mixture had the largest coloration difference from the baseline mix following the placement of lithium silicate.

Summary

Compressive Strength Over Time



Summary of Abrasion Resistance Testing per BS EN 13892-4

	Mix 1 Control	Mix 2 40% SC	Mix 3 C1157& Type IL	Mix 4 C1157
Date Cast	August 1, 2024	August 1, 2024	July 31, 2024	July 31, 2024
Date of BS EN 13891-4 Testing	September 27, 2024	September 27, 2024	September 26, 2024	September 26, 2024
Age at Test	57 Days	57 Days	57 Days	57 Days
Mean Depth of Wear (mm):				
Test 1	0.00	0.01	0.02	0.00
Test 2	0.03	0.00	0.02	0.00
Test 3	0.19	0.03	0.01	0.00
Test Average Area (mm)	**0.073**	**0.013**	**0.017**	**0.000**

Notable was the impact from a change of the water/cement ratio used to the strength gain of the mixtures, as well as the enhanced strength properties from the mixture #3 blend. While abrasion resistance was acceptable from all of the slabs, mixture #1 showed the worst and mixture #4 the best abrasion resistance. Further test findings can be found at the larger WJE testing report.

Testing Method Comparison of Early Strength Gains

Three methods for predicting early slab concrete strengths were also evaluated.

Method #1: Match Cure
Use of 'Exact' temperature match curing chambers for cylinders, used in combination with an 'Exact' maturity probe placed within each slab, and ASTM C39 cylinder sets.

Method #2: Standard Cure
Cylinders went directly into a wet cure room, maintained per ASTM C31, with ASTM C39 cylinder tests.

Method #3: Field Cure
Field cured cylinders, with ASTM C39 cylinder tests.

Method #4: Maturity Meters
GiaTech Smart Rock wireless probes were placed within each slab, calibrated per ASTM C1074, with lab cure data and cylinders.

Method #5: Rebel Sensors from Wavelogix
A circular disk acoustical resonance sensor is cast into the slab and is connected by wire to data loggers, which communicate with a remote server for artificial intelligence (AI) data processing. It's use is per the AASHTO T 412-24 standard.

Typical instrumentation setup, including two Smart Rock maturity probes (white), one EXACT (match cure) chamber control probe (silver), and two REBEL sensors (black) on either side of the temperature probes. Sensor data loggers where placed on a column within the middle of all four slab pours.

Placement of sensors and data loggers

Cast cylinders

Field cure cylinders

Match cure chamber

Standard cure room at WJE laboratory

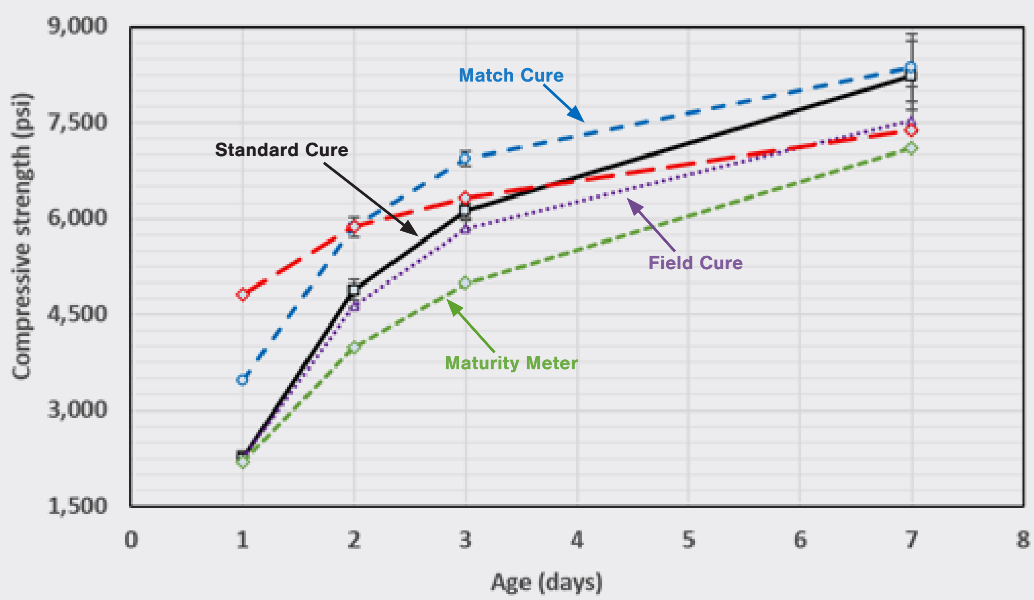
Compression testing

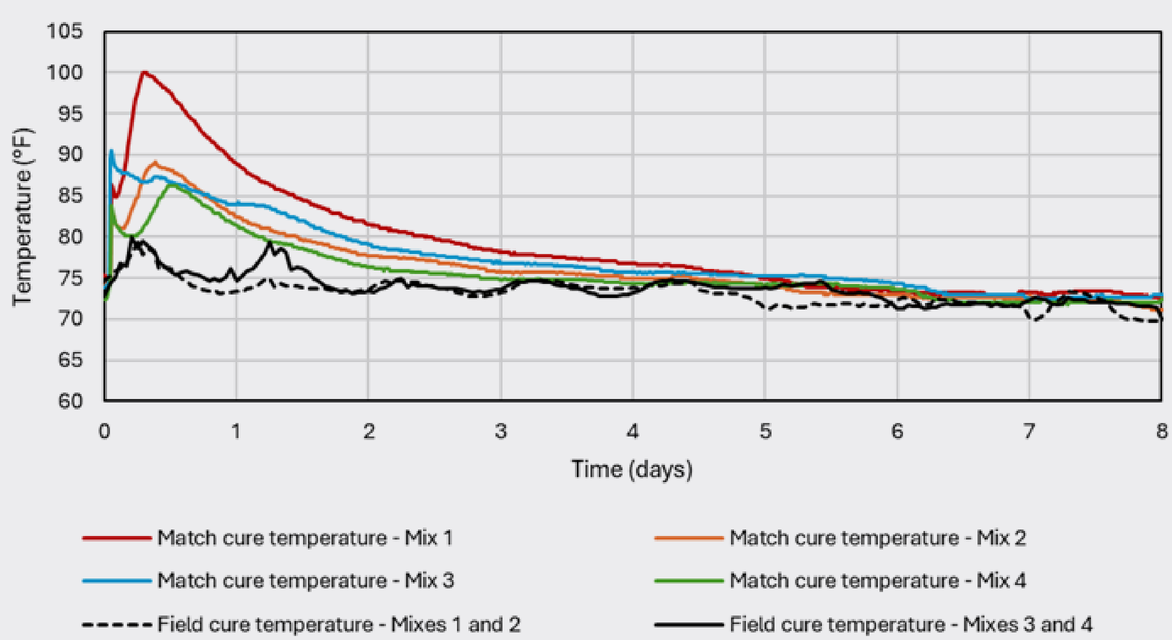
All testing occurred at WJE's laboratory Annex II in Northbrook, IL., the same facility where the four slabs were cast. The cylinders were end ground, with compression testing to ASTM C39.

Findings

From the early date concrete strength testing methods considered:

Sample of Mixture #3 Comparisons (For Reference*)





*WJE testing report provides more extensive and further mixture specific break, maturity sensor, Rebel sensor, and other test data and summary findings.

Comparative Testing Method Observations

Observation #1

Match cured, standard cured, and field cured cylinders were the most consistent data sets, with match cured cylinders breaking highest and the field cured cylinders breaking the lowest. Variations between day 2 to day 7 were 0% to 26%, with the average variation being 9%. The field cured cylinders were kept at room temperature, given the slabs were poured inside of an existing facility. Larger field cured strength variations should be expected from outside conditions due to temperature and humidity swings, sunlight, and construction site conditions.

Observation #2

Maturity meter predictions followed the ASTM C1074 calibration standard, and predicted on average strengths lower than the field cured cylinders (conservative). Variations between match cured cylinders and maturity meters day 2 to day 7 were 10% to 65%, with the average variation being 32% lower for the maturity meters. Note field calibration of maturity meters (a sometimes-attempted industry practice) is not approved by ASTM C1074, nor a proper use of maturity meters.

Observation #3

Rebel sensor predictions varied from the match cured cylinders by 0% to 47%, prior to post-process AI corrections. Their inconsistency was attributed to the limited data sets that the Wavelogix AI algorithm was working from for these newer materials, which will improve as their database of break data expands. After post-processing of the data, backward looking alignments with the match cured cylinders were 0 to 16%, with the average variation being 4%.

Observation #4

The match cured cylinders provided the highest breaking, and the most reliable data from this study due to their more accurate temperature matched curing of cylinders.

Lower carbon concrete regional workshop where findings were shared with industry.

Observation #5

The rebel sensors showed promise for an early non-destructive testing approach but they do not yet calibrate to reliable findings without cylinders being taken in parallel. Growing their database of break data over time, and further system refinements with calibrations for different mix types will improve their ability to accurately predict material strengths.

Observation #6

Variation exists between currently used methods for predicting early concrete strengths, even when performed in best case laboratory conditions.

WJE testing team

Take Aways

All four slabs represent crack-free successful slab-on-grade placements, with mixture #4 providing a 60% GWP reduction from the NRMCA Great Lakes MidWest average. The client preference for aesthetics was the mixture #2 floor finish, though mixture #4 achieved the highest abrasion resistance.

Variation exists between currently used methods for measuring early concrete strengths, even when performed in best case laboratory conditions. Consistent use of one approach on a project, after calibration with multiple cylinder breaks from temperature matched cured cylinders with ground ends, coupled with careful attention to cylinder casting and testing, is recommended as the best-of-class approach.

The match cured cylinders provided the highest breaking and the most reliable early strength data. Of the testing methods evaluated, matched cured cylinders bring the most opportunities for reducing testing variability, mixture optimization, and carbon and cost reductions...today.

Next Steps

- Share findings in Structure Magazine Article – Low-carbon concrete mixes from a contractor's perspective.
- Share findings and data from this study on the WJE website for open industry collaboration.
- Publish this case study summary as part of the ClimateWorks Lower Carbon Concrete Initiative.

Click or scan the QR Code here to view the complete WJE testing report.

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