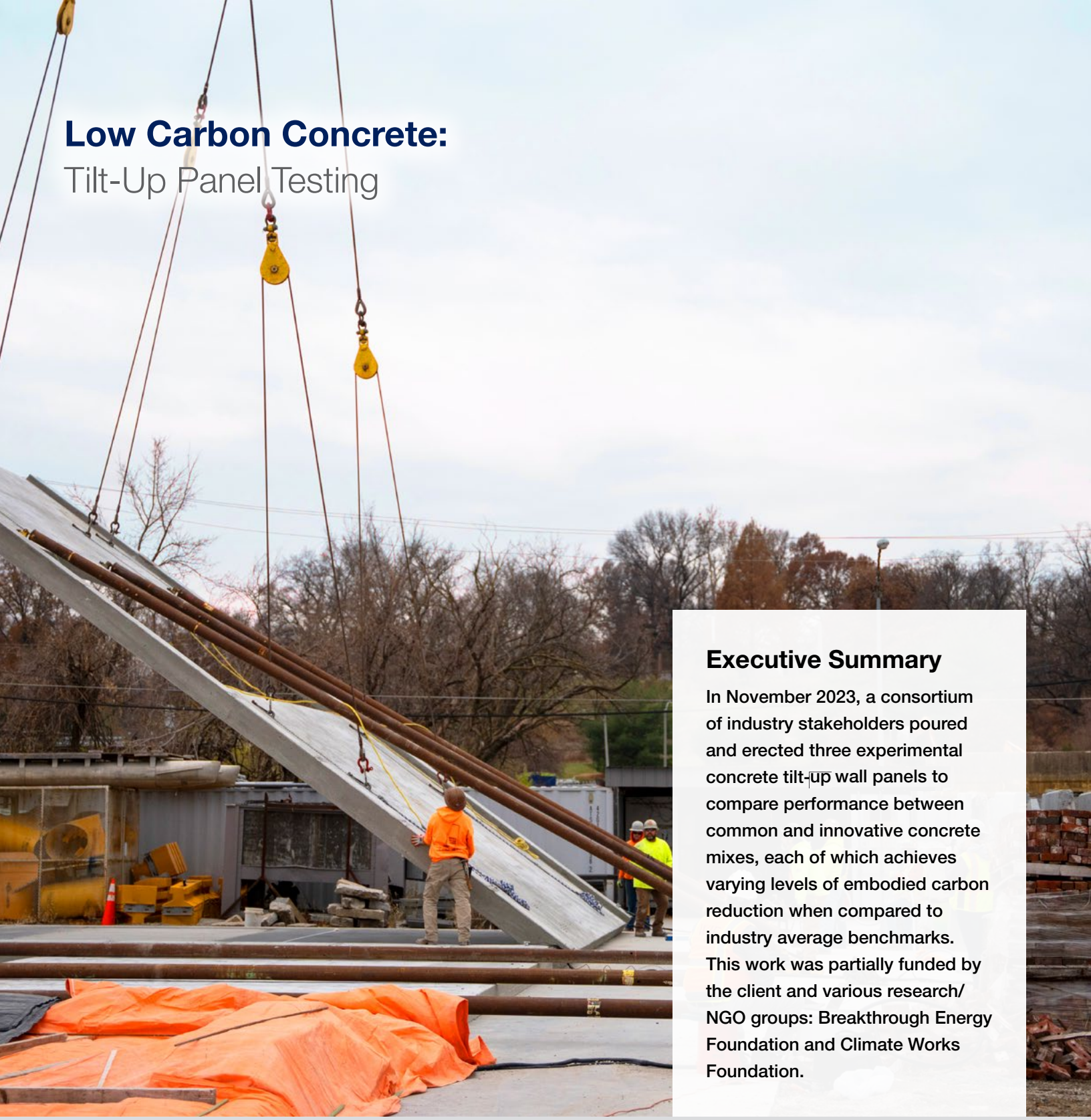
Low Carbon Concrete:
Tilt-Up Panel Testing



Executive Summary

In November 2023, a consortium of industry stakeholders poured and erected three experimental concrete tilt-up wall panels to compare performance between common and innovative concrete mixes, each of which achieves varying levels of embodied carbon reduction when compared to industry average benchmarks.
This work was partially funded by the client and various research/ NGO groups: Breakthrough Energy Foundation and Climate Works Foundation.

Project Team

CLAYCO
THE ART & SCIENCE OF BUILDING

CONCRETE STRATEGIES
MORE TO THE POUR

WJE

OZINGA

SCI ENGINEERING, INC.

KIENSTRA

Breakthrough Energy

climateworks FOUNDATION

INSIGHTS

Ozinga Carbon Sense

ASTM C595 and C1157 Cements

39-64% GWP Reduction

5000psi+ @ 28 days

Project Goal

Prove the applicability of low carbon concrete mixes for use in fast-track tilt-wall construction.

Tilt-wall construction is typically schedule-driven; the use of high early-strength concrete mixes to facilitate “tilting”, or erecting, of the wall panels within an aggressive construction schedule is often necessary. Wall panels are typically tilted 5-7 days after pouring, but sometimes as early as 3 days. Conversely, the use of Supplementary Cementitious Materials (SCMs) in low-carbon concrete mix design can extend the traditional strength gain curve of traditional Portland cement mixes. Many innovative mix designs are in early prototype phase, but are years away from availability at scale. This effort aims to ascertain the applicability of currently available low-carbon mixes which can be immediately put into use.

Abstract

Three full-size panels were to be poured and erected using various mix designs and carbon footprint reductions (as shown in Table 1). Panels would be poured and erected in Concrete Strategies’ St. Louis testing yard in November 2023. The 28-day design strength of all three panels was 5,000 psi. Performance and Exposure criteria for all mixes was F0, C1, S0. No added air entrainment was included in the test panels, based upon an assumed panel use for a climate not subject to freeze/thaw or consistent water saturation. This also eliminated a variable that may have clouded the comparative testing information being studied between the mixes. A third-party lifting analysis provided dual erection criteria of compressive and flexural strength (as shown in Table 2). A testing plan (Table 4 - see next page) to verify this criteria was agreed upon by all team members. In addition to meeting criteria for erection, comments from on-site placement and finishing crews was to be collected to provide critical feedback regarding mix pumping, placing, and finishing.

TABLE 1 - CONCRETE MIXES CONSIDERED: F’C=2.5 KSI @ 3 DAYS / 5KSI @ 28 DAYS

	Cement Type	Embodied Carbon Reduction
Baseline	NRMCA V3.2, Great Lakes Region	Baseline
Panel 1	100% type 1L cement, Holcim St. Genevieve Plant	25%*
Panel 2	Blended cement - 25% blast furnace slag, 75% type 1L cement, Holcim St. Genevieve Plant	39%
Panel 3	Proprietary Ozinga blended 1157 cement mix 1	64%

**Holcim St. Genevieve cement represents a significant reduction from NRMCA.*

TABLE 2 - LIFTING CRITERIA

Compressive Strength	2,500 psi	(50% f’c)
Flexural Strength	500 psi	(10% f’c)

TABLE 3 - MIX DESIGNS

Constituent	Description or Source	Units	Mix 1 - 1L St. Gen	Mix 2 - 25%	Mix 3 - C1157
Type IL Cement	St. Genevieve, MO	lbs/yd^3	564	423	--
Slag Cement	Holcim, Chicago, IL	lbs/yd^3	--	141	--
C1157 Cement	Ozinga	lbs/yd^3	--	--	750
Coarse Aggregate	Bluff City Materials, Alton, IL	lbs/yd^3	1775	1780	1740
Fine Aggregate	Madison County Sand, Collinsville, IL	lbs/yd^3	1420	1400	1240
Water	N/A	lbs/yd^3	271	271	237
High-Range Water Reducer	ADVACAST 600, GCP	fl. oz.	26	26	30
Workability Enhancing Admixture	ADVA XT, GCP	fl. oz.	--	--	22
Rheology Modifying Mixture	V-MAR F100, GCP	fl. oz.	--	--	45
Accelerating Admixture	OZ Set	fl. oz.	--	--	262.5
Target Air Content	--	%	1.5	1.5	1.5
W/CM (not including admixtures)	--	--	0.48	0.48	0.32
W/CM (including admixtures)	--	--	0.48	0.48	0.34

Mix Data & Testing Plan

SCI labs in St. Louis collected a number of cylinder and beam samples. Some were lab-cured and others were cured with the panels on site. Onsite and laboratory testing included:

- Compression (ASTM C39)
- Flexural Strength (ASTM C78 third-point)
- Air content (ASTM C231)
- Slump (ASTM C143)
- Bleed Potential (ASTM C2329)
- Modulus of Elasticity (ASTM C469)
- Drying Shrinkage (ASTM C157
- Maturity (ASTM C1074
- ...and more. Full testing results can be found within the WJE testing report link at the end of this summary.

TABLE 4

	TESTING DAYS						
	1	2	3	5†	7†	14	28*
Field-cured Cylinders	X	X	X	X	X	X	X
Lab-cured Cylinders					X		X
Field-cured Beams (Panels 1 & 2)		X	X		X		X
Field-cured Beams (Panel 3)		X	X	X	X		X

***Note:** All 28 day actions & testing were performed on day 29 (12/26) due to the holiday. †**Note:** Panel 3 only.*

Placing, Finishing

All three mixes were pumped 150', with a 4" line hose. They were all able to be placed and finished, although panel three was finished as the sun was setting and temperature was dropping.

Weather Data

Day	Temperature Range	Weather
1 (Pour)	36-24°F*	Cloudy/Sun
2	60-32°F	Cloudy/Sun
3	55-42°F	Light Rain
4	57-44°F	Light Rain
5	43-41°F	Cloudy
6	53-41°F	Cloudy
7	48-39°F	Rain

**Actual on site temperatures were measured as low as 19° the evening of the pour.*

Field Observations

Comments from placement and finishing crews were gathered. All comments are in comparison to Panel 1 and considers Panel 1 as standard.

Panel 2:

"25% mix acted similar to standard. Placed, finished and cured the same. Less cracking than straight cement."

"25% was not bad – placed and finished like straight cement."

"25% mix gave the crew a bit extra time to finish, which was good. Still set and finished within a reasonable time."

"A bit sticky and harder to finish."

Panel 3:

"Very dry mix"

"Once you used the VibraStrike, it finished well. You need to keep it moving."

"Finished well – final product looked good. Difficult to pour, move around and place."

"Seemed to set up hard on top but was soft underneath. Top inch was hard but you could put a dent in it."

"Seemed to be about a 4" slump. Would need 6" slump at least to place and finish. Hard to move around."

Placing crew working on Panel 2.

Cylinder Samples

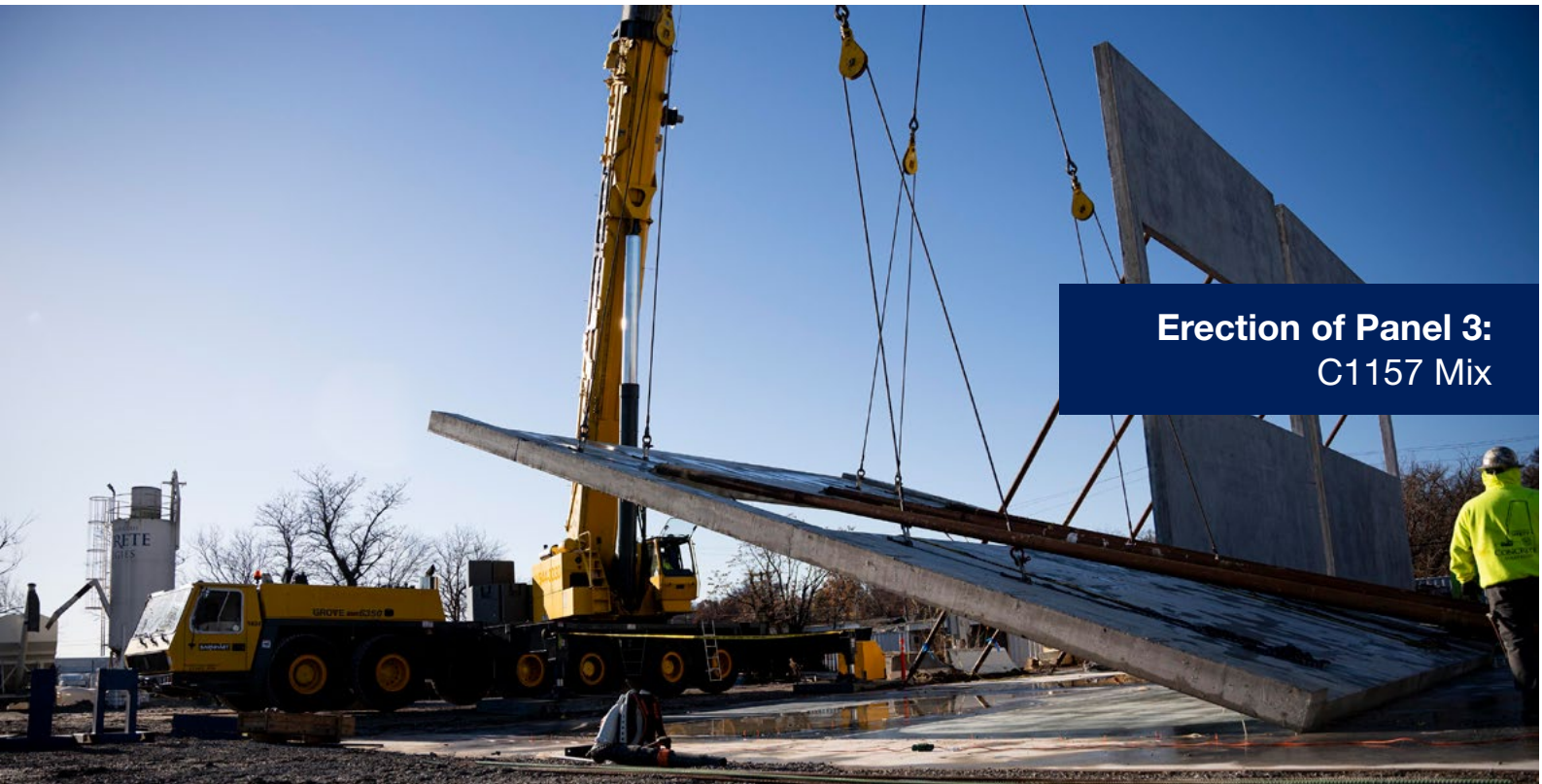
Placing novel 1157 mix for Panel 3.

Panel Lifting & Erection Criteria Verification

Panels 1 and 2 attained adequate compressive and flexural strength to facilitate erection on day 3. Although panel 3 demonstrated adequate strength gain on day 3 with trial batch cylinders at room temperature, the cold temperatures during the pour, and for the 3 days of curing after, retarded the strength gain for this specific mix. Panel 3 attained strength on day 7 and was erected on day 8. Strength gain for panel 3 was verified with dual criteria of in-situ maturity sensors and panel cores.

Erection of Panel 1 and 2 occurred on day 3.

Cores were taken from each panel to verify in-situ compressive strength.



Erection of Panel 3:
C1157 Mix

Takeaways

Panels 1 and 2 represented successful high-early tilt-up wall panel placements. Panel 2 was approximately 40% embodied carbon reduction versus the NRMCA 3.2 baseline. Both mixes can be implemented successfully on construction sites in all weather conditions and gain adequate strength to facilitate 3-day erection.

Panel 3 didn't meet high-early strength targets, largely due to the cold temperatures and the mix's lower internal heat generation for curing, compared to mixes within panels 1 and 2. Panel 3 strength was achieved, just at a slower rate.

Further testing will be conducted to understand the impacts of temperature on the lowest carbon C1157 mix, including when and where its lower internal heat gain will be a benefit and not a detriment to the C1157 mix's use.

Next Steps

- Incorporation of Ozinga C1157 mix at Midwest site for foundations
- C1157 Slab on Grade mockup at Midwest site
- Further testing with client in August 2024 focusing on calcined clay blends as well as additional blends with the original Ozinga C1157 cement
- Structure Magazine Article – Low-Carbon concrete mixes from a Contractor's perspective

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

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