# Trial Batching and Demonstration of Lower Carbon Concrete (LCC)

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# When are trial batches and demonstrations needed?

- Higher replacements rates of SCMs than typically used
- Implementation of new SCMs
- New binders: $LC^3$, ASTM C1157, ASTM C595 (new blends), etc.
- Application specific:
  - SCC, Mass Concrete, and UHPC
  - Long service life (>50 years)
  - Long placement and/or transient times
  - Unique placement and/or finishing procedures

# Trial Batching and Demonstration of LCC

- Project funded by Hyperscalers: Google, Meta, Microsoft, and Amazon
- Goal: Demonstrate the use of lower carbon concrete for the construction of slabs used for the construction of data centers
- Full-scale slab-on-ground panels constructed utilizing four concrete mixtures with varying degrees of GWP using new binder
- How does this relate to pavements/bridges?
- Extensive trial batching and field data collection to understand performance and constructability of the mixes.
- Demonstration performed on WJE's campus in Northbrook, IL

# Why Demonstrate Slab Construction?

- One of the most difficult applications to implement innovative materials
- Final finish procedures are guided by experience and empirical knowledge
  - Densified/polished surface is not easy
  - Timing and intensity is guided by experience
- Slabs are a very important part of data center construction

# Concrete Mixture Development

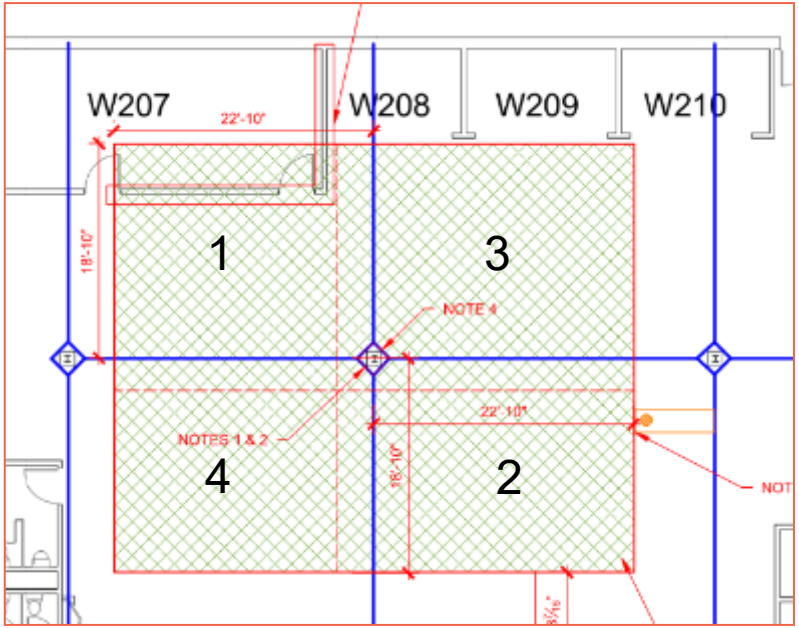
- **Mixture #1 – Control:** Mixture typically used in datacenter applications for SOG using an ASTM C595 Type IL w/o SCMs
- **Mixture #2 – 40% Slag Cement:** Replace 40% of the Type IL with slag cement ~ **37%** reduction in embodied carbon
- **Mixture #3: PLC/ASTM C1157:** Replace 80% of Type IL with ASTM C1157 cement ~ **49%** embodied carbon reduction
- **Mixture #4 – ASTM C1157:** Replace 100% of Type IL with ASTM C1157 cement ~ **61%** embodied carbon reduction

# Concrete Mixtures

| Constituent | Units | Mix 1 | Mix 2 | Mix 3 | Mix 4 |
|---|---|---|---|---|---|
| Type IL Cement | lbs/yd$^3$ | 517 | 295 | 130 | 0 |
| Slag Cement | lbs/yd$^3$ | 0 | 196 | 0 | 0 |
| C1157 cement | lbs/yd$^3$ | 0 | 0 | 475 | 750 |
| Fine aggregate | lbs/yd$^3$ | 1445 | 1440 | 1430 | 1320 |
| Coarse aggregate, #67 | lbs/yd$^3$ | 1401 | 1443 | 1435 | 1324 |
| Coarse aggregate, #4 | lbs/yd$^3$ | 469 | 483 | 480 | 443 |
| Water | lbs/yd$^3$ | 259 | 246 | 212 | 255 |
| W/CM (incl. admixtures) | na | 0.50 | 0.50 | 0.35 | 0.37 |
| GWP | kg $CO_2$e/yd$^3$ | 214 | 149 | 121 | 92 |
| Reduction from Benchmark* | % | 9% | 37% | 49% | 61% |

*236 kg $CO_2$E/yd$^3$ - NRMCA National Average for 4000 psi, 2022 Athena, V 3.2

# Site Location – 255 Melvin Drive, Northbrook, IL

# Laboratory Trial Batching

- Fresh concrete properties
  - Slump (6 to 8 in), air content (<3.0% ), unit weight, and temperature (ASTM C1064)
- Setting time (ASTM C403), heat of hydration (ASTM C1702), bleeding potential (ASTM C232), and slump life
- Constructability: pumpability, placeability, and finishability
- Hardened concrete properties
  - Compressive strength (ASTM C39), flexural strength (ASTM C78), drying and shrinkage (ASTM C157), and many others

# Laboratory Results: Fresh Properties

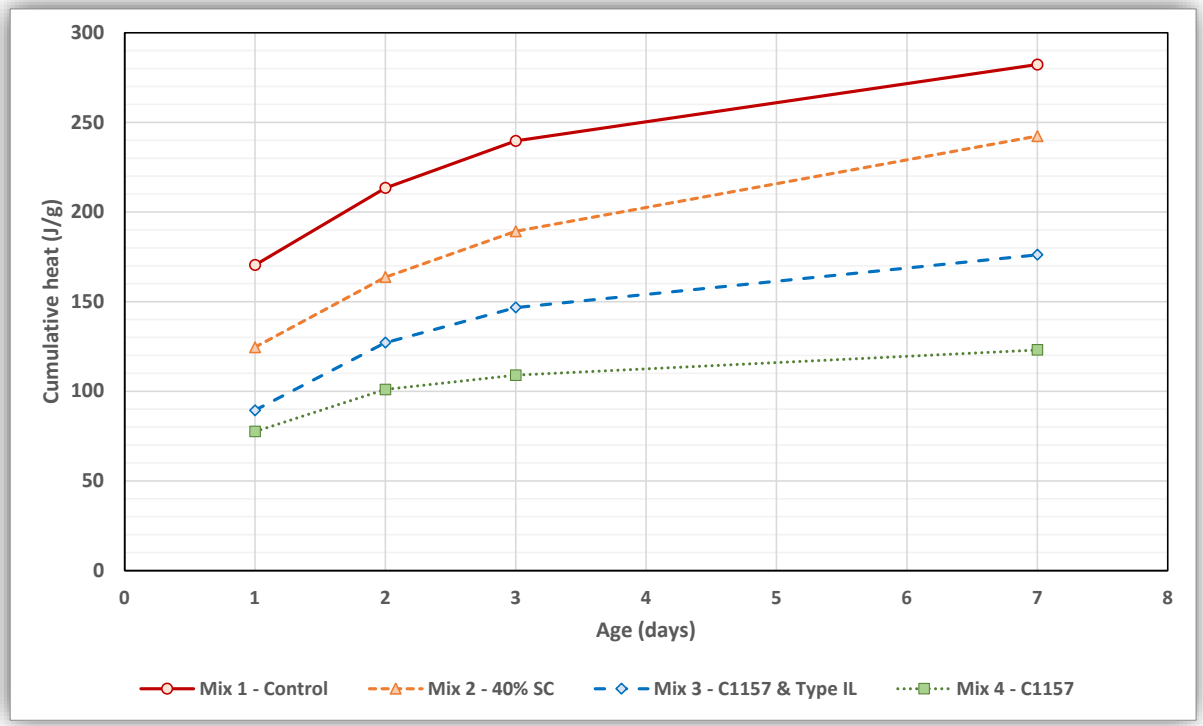
| Batch ID | Slump (in.) | Air Content (%) | Density ($lb/ft^3$) | Temp (F) |
|---|---|---|---|---|
| Mix 1-1 | 7.5 | 1.6 | 149.6 | 77.3 |
| Mix 1-2 | 8 | 1.9 | 149.1 | 76.9 |
| Mix 2-1 | 8 | 1.7 | 150.3 | 75.2 |
| Mix 2-2 | 6.5 | 1.9 | 150.3 | 75.9 |
| Mix 3-1 | 8.25 | 2.3 | 151.5 | 78.6 |
| Mix 3-2 | 6.5 | 2.5 | 151.2 | 78.6 |
| Mix 3-3 | 8.25 | 2.1 | 151.6 | 76.1 |
| Mix 4-1 | 8.25 | 2 | 149.6 | 75.3 |
| Mix 4-2 | 6.25 | 2.2 | 150 | 77.3 |
| Mix 4-2 | 8.25 | 2 | 150.7 | 75.2 |

# Laboratory Results: Setting Time

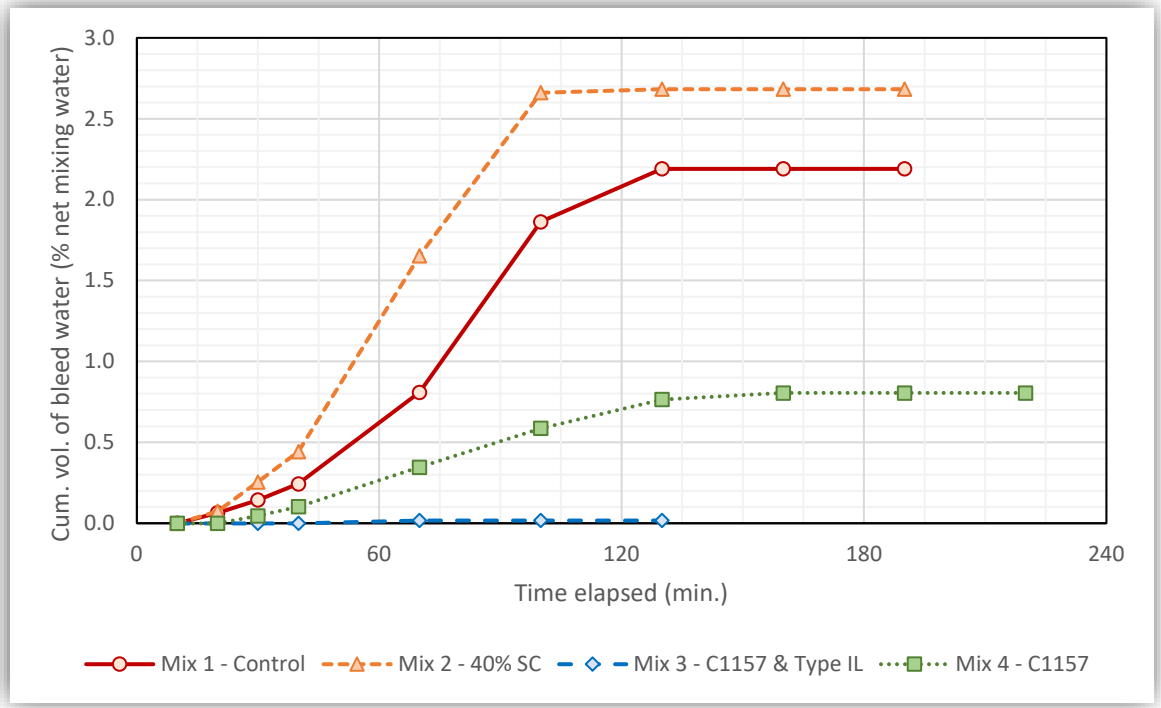
| Setting | Mix 1 | Mix 2 | Mix 3 | Mix 4 |
|---|---|---|---|---|
| Initial Set | 3:25 | 3:15 | 1:50 | 3:40 |
| Final Set | 4:30 | 4:55 | 3:20 | 9:40 |

- Potential Challenges:
  1. Initial set of Mix 3
  2. Final set of Mix 4

# Laboratory Results: Total Heat Generated (J/g)



# Laboratory Results: Bleeding

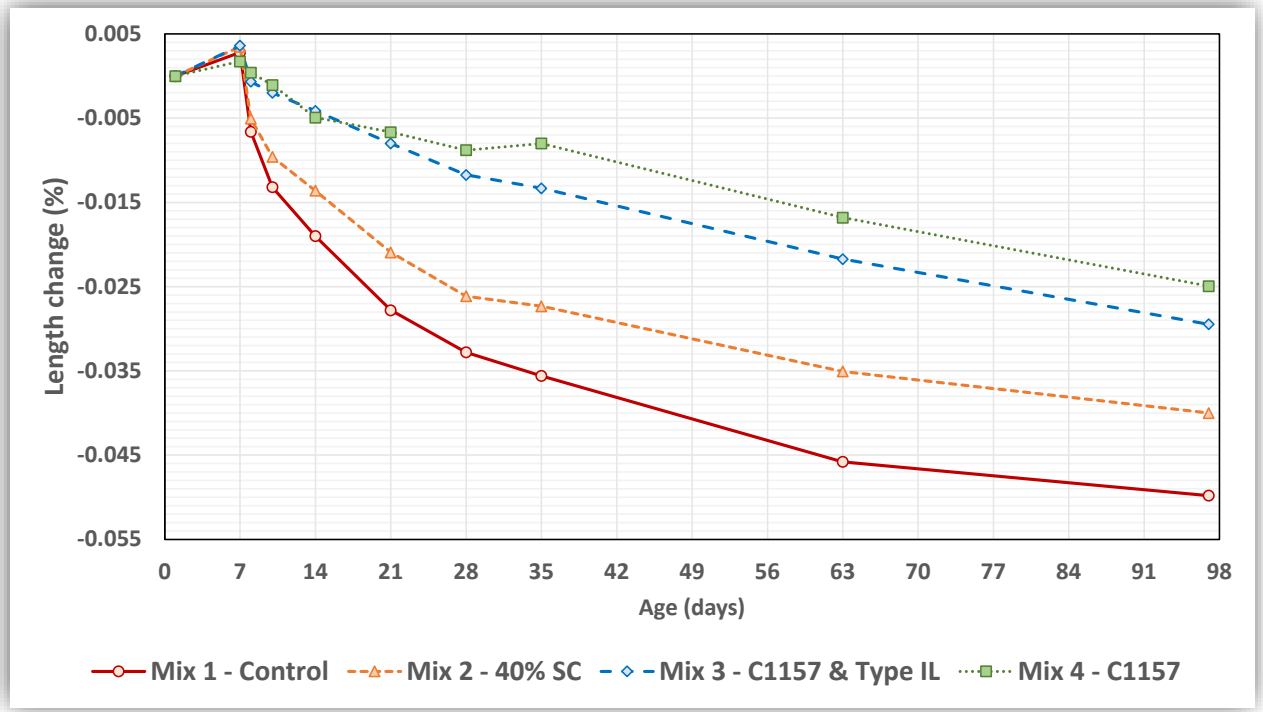


# Laboratory Results: Compressive Strength

| Age | Mix 1 | Mix 2 | Mix 3 | Mix 4 |
|---|---|---|---|---|
| 1 day | 2,230 | 1,370 | 1,270 | 1,310 |
| 2 day | 3,250 | 2,380 | 3,240 | 2,540 |
| 3 day | 3,950 | 3,010 | 4,800 | 3,070 |
| 7 day | 4,540 | 4,510 | 6,600 | 3,410 |
| 28 day | 5,870 | 5,750 | 8,100 | 4,140 |
| 56 day | 5,920 | 6,300 | 8,600 | 4,470 |
| 90 day | 6,130 | 6,760 | 8,460 | 4,690 |

- Design strength of 4,000 psi at 28 days

# Laboratory Results: Drying Shrinkage



# Summary of Trial Batching

- All mixes met Hyperscalers' requirements of plastic properties, compressive strength, and drying shrinkage
- All mixes were judged to be pumpable and placeable
- Potential challenges related to the following:
  1. Bleed – Mix 3 and 4 have little to no bleed
  2. Screeding – Will be difficult with Mix 3 and Mix 4, energy and timing
  3. Delay in finishing expected for Mix 4, setting characteristics
  4. Final Finishing may be difficult with Mix 3 and 4

# Construction of the Slabs

- Contractor: Concrete Strategies
- Concrete Supplier: Ozinga Ready Mix
- Field Evaluations and QC: WJE

# Standard Construction Practices


Pump Hopper

Pumping Concrete

# Screeding and Floating

Screeding

Bull Floating

# Challenges: Screeding

Screeding – Mix 3

Screeding – Mix 4

# And Final Finishing

Power Floating

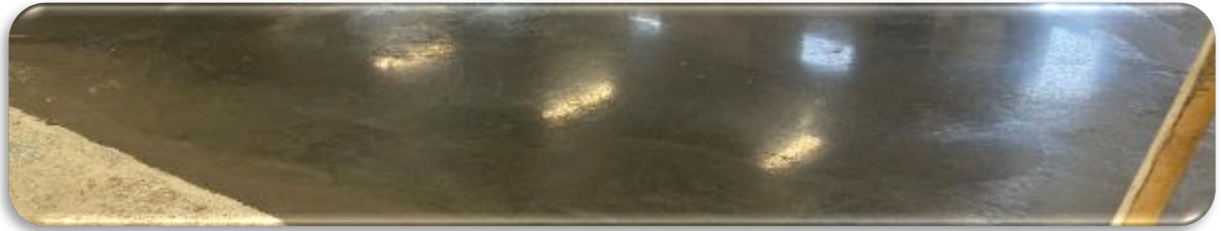

Power Troweling

# Challenges: Finishing


Finishing – Mix 3

Finishing – Mix 4

Mix 1



Mix 2

Mix 3

Mix 4

# Field Evaluations – Quality Control Testing

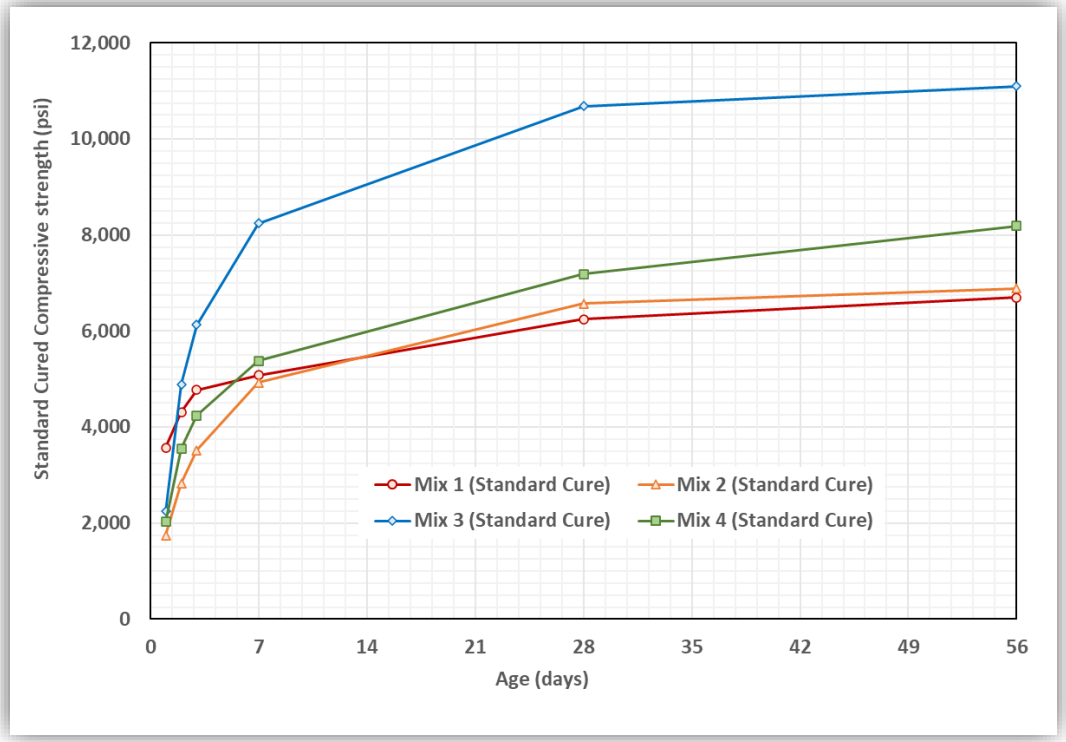
1. Compressive strength cylinders ~ 70 cylinders per mix
    1. Standard Cure – moist cured per ASTM C31
    2. Field Cure – cured next to the slab in the same environment
    3. Match Cure – cured in an environmental chamber that matches the temperature of the slab

Standard Cure

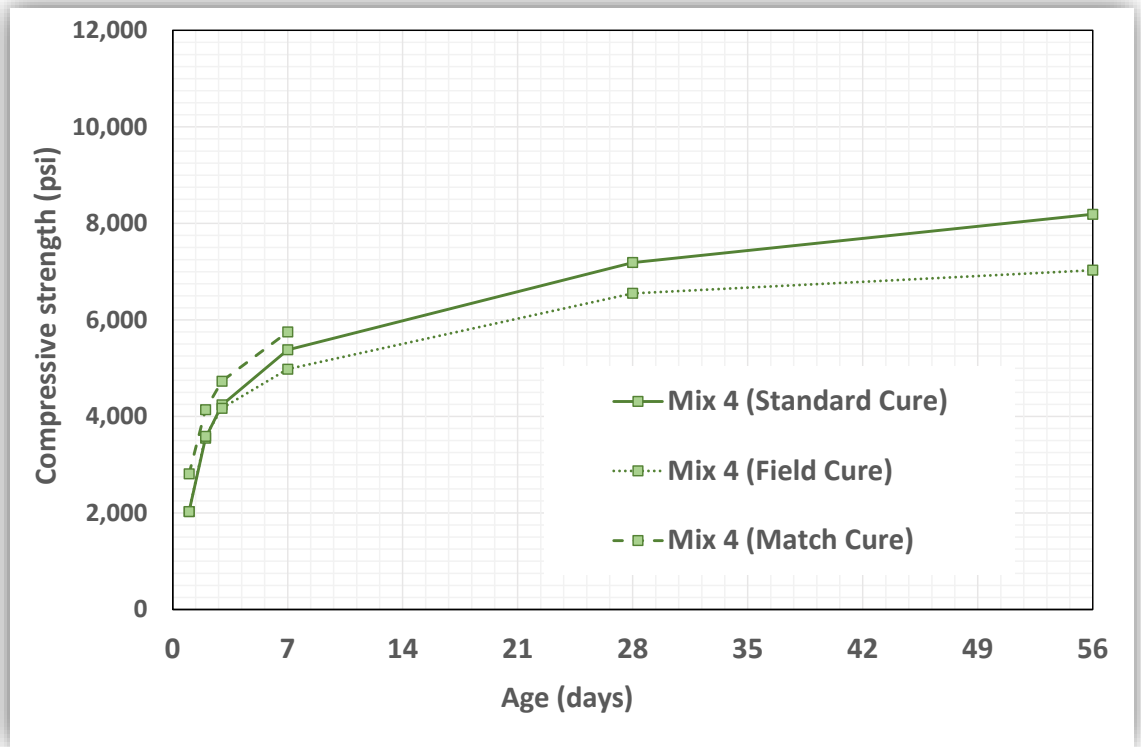
Field Cure


Match Cure

# Field Evaluations: Compressive Strength



# Field Evaluations: Compressive Strength



# Takeaways

- Casting for the ASTM C1157 based concretes were not ideal, but all mixtures could be pumped, placed, and finished
  - Mix #2 (40% slag cement mixture) performed the best: constructability
  - Mix #3 and #4 (ASTM C1157 mixture) were difficult to screed and finish
- Mix 2 has since been implemented on datacenter slabs
- Based on the trial batching and project demonstration, constructability issues with Mix 3 were addressed with mix modifications
- Subsequent modifications of Mix 3 were successfully implemented on:
  - MNROAD pavement research - 2025
  - Datacenter foundations, grade beams, and slabs

# Thanks!

## Questions?

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