2020 Low Carbon Concrete Sidewalk Pilot

This case study provides information on the City of Portland's first round of low-carbon concrete pilot projects, featuring sidewalk ramps within the City's Bureau of Transportation.

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Carbon Leadership Forum Portland

State of Oregon Department of Environmental Quality

KNIFE RIVER AN MDU RESOURCES COMPANY

CALPORTLAND

Background

The City of Portland's 2016 Sustainable Supply Chain Analysis identified construction services as the top spend category contributing to the City's supply chain greenhouse gas (GHG) emissions. Within construction services, concrete is one of the most GHG-intensive materials typically used on City construction projects. As a result, in 2019, after gathering both internal and external stakeholder input, the City established its Low Carbon Concrete Initiative to reduce the overall carbon intensity of the concrete mixes used on City projects. **The Initiative involves three phases:**

- The first phase, which began in January 2020, requires third-party verified product-specific Type III Environmental Product Declarations (EPDs) for any mix submitted for approval for the City's (Pre)Approved Concrete Mix Design List or for project-specific mixes in use over 50 yd^3. This phase was designed to address the overall lack of existing data on the carbon intensity of concrete mixes typically used on City projects.
- The second phase includes pilot testing different lower-carbon mixes to gather data on how these mixes perform.
- These pilot tests will inform the third phase of the Initiative, establishing maximum global-warming potential (GWP) thresholds for concrete used on City construction projects

This case study provides information on the City's first round of low-carbon concrete pilot projects, featuring sidewalk ramp projects within the City's Bureau of Transportation (PBOT).

Project Overview

In early 2020, the City's Sustainable Procurement Program brought together PBOT, the City's Materials Testing Lab (part of the Bureau of Environmental Services – BES MTL), two minority-owned and/or small-business-certified sidewalk contractors, two concrete producers (Knife River and CalPortland), and the Oregon Department of Environmental Quality's Materials Management Program to test low-carbon concrete mixes on sidewalk ramps. The goal was to understand how the mixes perform, both in terms of technical requirements and workability. Overall, the project involved testing five different lower-carbon concrete mixes against 100% cement mixes at six different sites. Each site involved pouring a 100% cement mix for one sidewalk ramp and a lower-carbon mix for another sidewalk ramp at the same intersection. A total of twelve ramps were involved in the project. The following mixes were tested:

Table 1: Low-Carbon Pilot Test Mixes - Design Strength 3000-3300 PSI						
Supplier A Mixes				**Supplier B Mixes**		
% Cement/SCM[a]	**Lbs Cement / yd3[b]**	**Lbs Slag / yd3[b]**		**% Cement/SCM**	**Lbs Cement / yd3[b]**	**Lbs Slag / yd3[b]**
100% cement	564	0		100% cement	573	0
70% cement/30% slag	400	170		65% cement/35% slag	372	201
60% cement/40% slag	338	226		50% cement/50% slag	287	286
70% cement/30% slag plus Carbon Cure[c] *(tested at two sites)*	400	170				

a-SCM=Supplemental Cementitious Material
b-per the supplier's Design Mix, actual batch levels may vary slightly
c-Carbon Cure is a technology that injects captured recycled CO2 into concrete with the goal of increasing the compressive strength

To test performance, during each pour, BES MTL technicians tested the concrete for entrained air, slump, temperature (ambient and concrete) and collected 10 cylinders that would be used for compressive strength tests according to ASTM C39. Compressive strength tests were subsequently conducted at the 7, 14, 28, and 56-day intervals.

To test workability, at each pour, the concrete finishers were interviewed to assess how they thought each mix performed in terms of how the mix flowed, reacted to vibration, troweled/finished, impacted application time, and affected flashing. To the extent possible, concrete finishers were kept unaware of which mix was which prior to the interviews.

BES MTL technicians will also be conducting post-project visual inspections per ACI 201.1R-08 at 3, 6, and 12-month intervals to add to data regarding concrete performance over time. At the time of publication, only the three and six-month visual inspections have been completed.

Results

Overall, the low-carbon mixes met the City's concrete performance specifications, were well received by the concrete finishers, were cost-neutral or less expensive, and are performing well in in the post-project visual inspections – all while reducing the carbon footprint of an average sidewalk ramp by 23-34%. The main difference between the 100% cement and lower-carbon mixes was the early strength gain, although all mixes achieved the specified compressive strength of 3000 psi by day 14 – well ahead of the 28-day specification.

Figure 1 – Compressive Strength Results

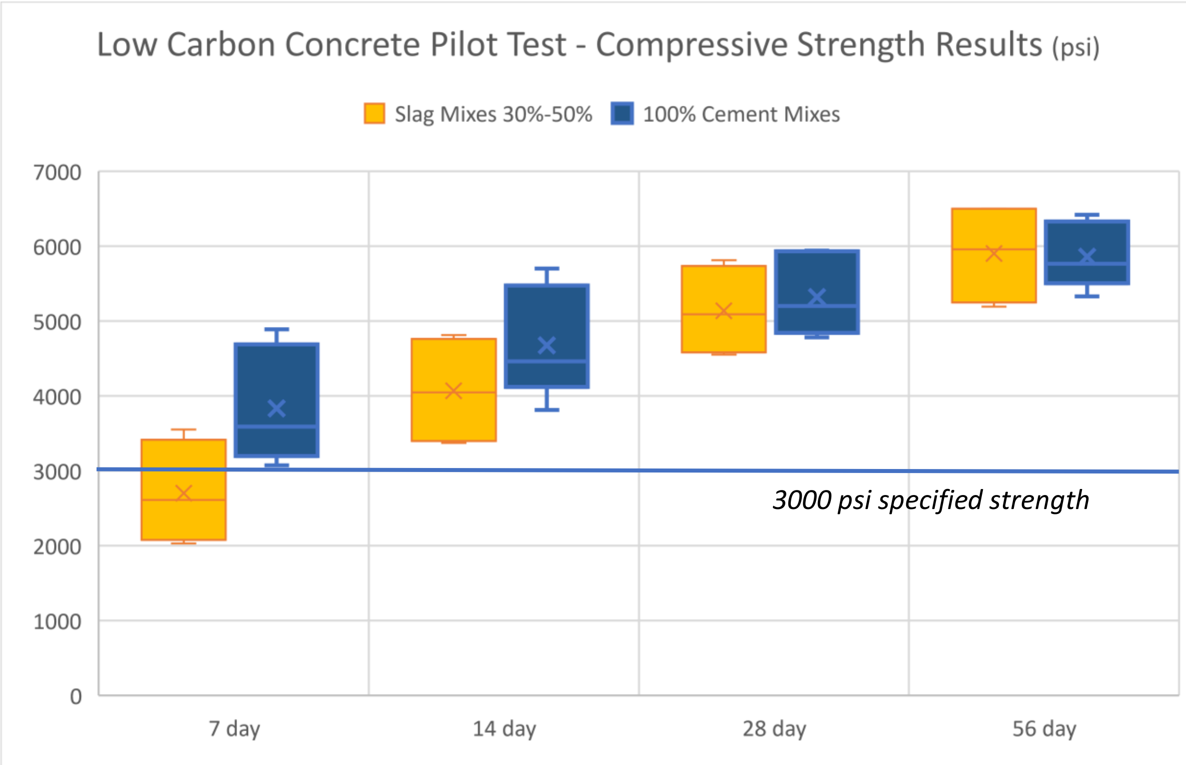
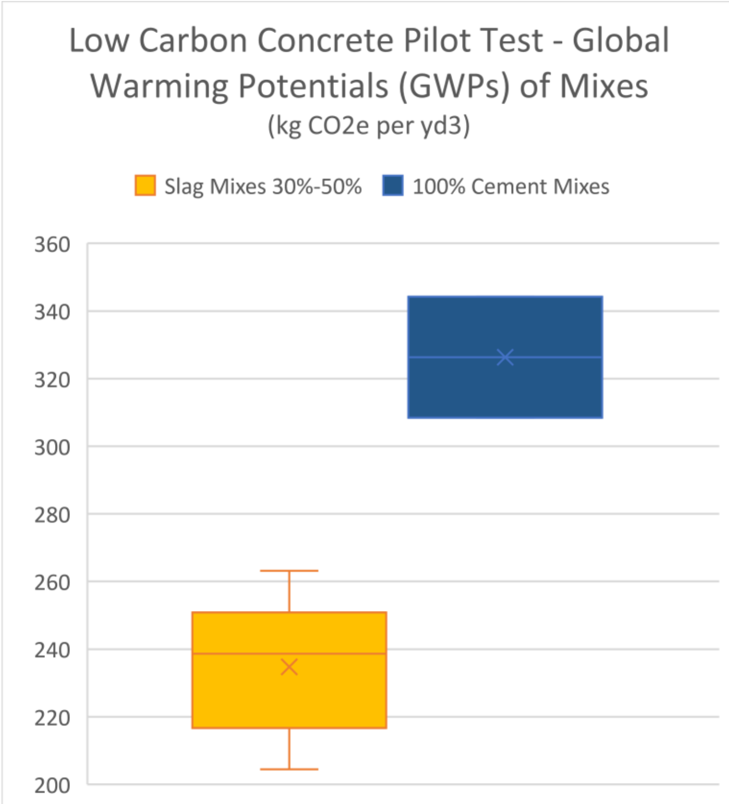


Figure 2 shows that the slag mixes had a considerably lower GWPs than the straight cement mixes. By using less cement and adding slag, GHG reductions ranged from 23-34% compared to the more typical 100% cement mixes. It's important to note that carbon reductions were achieved by reducing cement contents and not by simply increasing slag contents to meet a percent slag target.

In terms of workability, the concrete finisher interviews did not raise any red flags regarding how the lower-carbon concrete mixes performed. Comments ranged from a preference for working the lower-carbon mixes to observing they were not discernable from any other mix. The only issue raised was that for a couple of the lower-carbon mixes, some finishers observed that the set time was longer, but it did not affect overall workflow.

Figure 2 – Global Warming Potentials of Mixes



The three and six-month post-project visual inspections did not reveal performance concerns attributed to a specific mix. The corners were essentially indistinguishable in terms of the presence of cracking, scaling, pop-outs, or other defects.

During this time, PBOT also confirmed with local utility locate firms that they are not aware of any concerns with slag interfering with locate readings, but it may be prudent to test this in future pilot tests.

Photos: (Left) Workers at one of the pilot test sites moving wet concrete. (Above) Site preparation work at one of the pilot test sites.

Discussion

The pilot test results indicate that the lower-carbon concrete mixes meet required performance requirements while significantly reducing the carbon footprint for the application. For this pilot project, the combined use of the lower-carbon concrete mixes resulted in a reduction of 4.5 MT of CO2e compared to using only 100% cement mixes. On average, for a 10.5 yd^3 curb, using these slag mixes reduced the carbon footprint of a curb by 0.89 MT of CO2e. PBOT replaces up to 1,000 curbs a year to make them compliant with the Americans with Disabilities Act. If each of those curbs used 10.5 yd^3 of concrete, and PBOT maximized slag use, PBOT would lower the carbon footprint of the concrete used in a year by 1,211 MT CO2e. This is equivalent to 27% of the CO2e annual emissions associated with the electricity used by PBOT's street lights and traffic signals.[1]

While utilizing SCM mixes such as slag presents a significant opportunity to reduce the carbon intensity of concrete, there is additional potential to further reduce the carbon intensity of these mixes. One observation from this pilot project is that all the mixes were over-designed for the application and thus, present an opportunity to further reduce cement content while still meeting strength requirements.

It's also important to note that outdoor temperatures can have a significant effect on concrete set time and this entire pilot project was conducted in relatively warm weather. In colder weather conditions, we're likely to see slower set times with slag mixes to the extent that it may affect finish time operations, but this can be offset with the use of accelerators.

Lastly, the results from this pilot project support conducting additional pilot tests with other SCMs and for different concrete applications. As this pilot project demonstrated, reducing cement content within concrete mixes is a viable option for reducing embodied carbon of concrete while meeting performance requirements. Insight gained from this pilot project will also be valuable when the City brings together stakeholders in 2021 to develop maximum global-warming potential (GWP) thresholds for concrete used on City construction projects.

Recommendations

Concrete mixes using less cement and supplementing the cement binder with 30%-50% slag, are feasible options for sidewalk applications when seeking lower embodied carbon concrete mixes. Furthermore, should PBOT pursue lower carbon concrete mixes as their standard, the cumulative reduction in CO2e emissions would be significant – and at no added cost to sidewalk projects.

Results also show that sidewalks are a low risk application for other municipalities looking to lower the carbon impacts of their concrete consumption. The best options for other municipalities will depend on local materials and SCM availability. Other municipalities are encouraged to contact their local concrete producer to inquire about low cement/low carbon mixes.

[1] FY18-19 City of Portland total carbon emissions data. https://www.portland.gov/bps/scg/carbon-emissions Accessed 9/11/20.

Disclaimer:
This publication was developed by members of the Carbon Leadership Forum Hub in Portland and the findings presented within are the perspectives of the authors.

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CLF Info:
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