Low-Carbon Concrete: Type 1L + Slag Mixes for Retaining Walls and Other Park Infrastructure

This case study provides information on the use of low-carbon concrete at one of Portland Parks & Recreation's playground improvement projects.

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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. Part of the Initiative involves documenting how lower-carbon mixes perform. This case study provides information on the use of Type 1L cement and slag for various park infrastructure elements associated with a Portland Parks & Recreation playground improvement project. Associated concrete infrastructure elements highlighted in this case study include: retaining walls, wall footings, pedestrian/bike paths, and concrete stairs.

Project Overview

The most common type of cement used in concrete mixes has historically been Type I/II Portland Cement. However, with current efforts to reduce the carbon footprint of concrete, the concrete industry is beginning to transition more to Portland Limestone Cement (PLC), also referred to as Type 1L cement. Type 1L cement has a lower carbon footprint than Type I/II cement (see the side bar on Type 1L cement for more info), thus using Type 1L cement is one strategy to reduce the carbon intensity of concrete mixes. Mixes with both Type 1L cement and a supplemental cementitious material (SCM), such as slag, can reduce the carbon intensity of a concrete mix even further. This case study documents the use of Type 1L + slag concrete mixes for various concrete infrastructure elements associated with a Portland Parks & Recreation playground improvement project. In documenting its use for these applications, this case study aims to help familiarize more stakeholders with the use of Type 1L mixes.

Type 1L Cement

As per ASTM C595, the term portland-limestone cement (PLC or Type 1L) refers to a hydraulic cement in which the limestone content is more than 5% but less than or equal to 15% by mass of the blended cement.

In other words, with Type 1L cement, up to 15% raw (uncalcined) limestone is ground with calcined clinker. Type 1L has a lower global warming potential (GWP) due to the reduction in clinker use.

The Mixes

Table 1 summarizes the type of mix used by application for this project.

Table 1: Low-Carbon Type 1L + Slag Mixes

Application	Design Strength (PSI @ 28 days)	% Cement/SCM[a]	Lbs Cement / yd3[b]	Lbs Slag / yd3[b]
Walk/Bike Paths	3500	70% Type 1L cement/30% slag, 1 1/2"	395	169
Wall Footings & Concrete Stairs	3500	70% Type 1L cement/30% slag, 3/4"	362	155
Retaining Wall	4500	70% Type 1L cement/30% slag, 1"	494	212

a-SCM=Supplemental Cementitious Material

b-per the supplier's Design Mix, actual batch levels may vary slightly

The use of the Type 1L + slag mixes for this project was not specifically due to a low-embodied carbon requirement, but rather a result of the concrete contractor choosing to use these mixes because they like working with these mixes. In this case, the concrete supplier for the project had already switched all its mixes from Type I/II cement to Type 1L cement. According to a representative of the concrete supplier, when they switched from Type I/II to Type 1L cement for their mixes, for the most part, none of their customers noticed a difference. These comments align with studies conducted by Oregon State University that confirm Type 1L can be a direct substitute for Type I/II cement.[1]

Findings

Both mix design submittals and project-specific compression test results confirm that the Type 1L + slag mixes used on the project met the City's concrete performance specifications. Yet, as further detailed in Table 2, they were significantly less carbon intensive compared to average concrete mixes (available in Oregon) of the same strength class. As mentioned earlier, the concrete contractors have had no issues using the Type 1L + slag mixes, and actually prefer using these mixes. And while slag can slightly increase set times and slow early strength compared to non-slag mixes[2], when asked about this, the concrete contractor said they have not had to change their approach or procedures to specifically accommodate these 30% slag mixes, even under different weather conditions. In the case of this project, the highlighted concrete elements were poured at different times of year, including summer, autumn and winter.

Table 2: Embodied Carbon Comparison (as measured by global warming potential - GWP)

Mix Reference	Mix Description	GWP/yd³	% Less Embodied Carbon Against Applicable Oregon Average
PP&R Project - Walk/ Bike Paths	3500psi, 70% Type 1L cement/30% slag (1 1/2" aggregate)	180.59	41% reduction
PP&R Project - Wall Footings and Stairs	3500psi, 70% Type 1L cement/30% slag (3/4" aggregate)	167.17	46% reduction
PP&R Project - Retaining Wall	4500psi, 70% Type 1L cement/30% slag	222.62	40% reduction
EC3 Tool[a]	3500psi concrete mix (Oregon region)	308[b]	n/a
EC3 Tool[a]	4500psi concrete mix (Oregon region)	370[b]	n/a

a-Embodied Carbon in Construction Calculator (EC3) is a free database of construction EPDs and matching building impact calculator for use in design and material procurement. (EPD = Environmental Product Declaration).
b-Average GWPs of referenced mix strength (psi by day 28) among applicable EPDs published in the EC3 tool. https://www.buildingtransparency.org/, accessed 2/15/22.

[1] Weiss et al. (2021), *"CALTRANS: Impact of the Use of Portland-Limestone Cement on Concrete Performance as Plain or Reinforced Material."* Oregon State University. https://ir.library.oregonstate.edu/concern/articles/7h149x67f?locale=en
[2] City of Portland Low-Carbon Concrete Initiative 2020 Sidewalk Pilot Project Case Study, October 2020. https://www.portland.gov/sites/default/files/2020/concretecasestudy_copsidewalks_final.pdf.

Conclusions

This case study provides evidence that there are low-embodied carbon mixes available on the market today that can be used for various concrete infrastructure elements within a park application, and with no change to a contractor's typical installation procedures.

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