Measuring and Reducing Embodied Carbon in Concrete

106 11TH AVENUE BUILDING
OLYMPIA, WA

MATERIALS AS A PATH TO GREENHOUSE GAS REDUCTION

For its new 106 11th Avenue office building, the State of Washington challenged the Sellen design-build team to deliver a new model of office efficiency and sustainability. In addition to reducing greenhouse gases (GHG) from building operations by 71%, the team focused on minimizing the embodied carbon in concrete as a complementary path to reduce overall greenhouse gas emissions.

By redesigning the concrete mixes for this project and producing Environmental Product Declarations (EPD) for almost all mixes, this project reduced the overall embodied carbon in concrete by 27%, compared to similar mixes in the Pacific Northwest. Compared to national averages, this project reduced the overall embodied GHG from concrete by 31%. **The maximum GHG reduction for a specific mix used in this project was 58%, as compared to the national average.*** By optimizing the 12,024 cubic yards of concrete placed in this project, it saved 1,386 metric tons of GHG as compared to the national average of similar strength mixes; this is the equivalent of not driving 3.4 million car miles.

See the following pages for more in-depth information on how the project team reduced the embodied carbon in concrete for the 106 11th Avenue project.

PROJECT INFORMATION

- **Name:** 106 11th Avenue, State Office Building
- **Owner:** State of Washington, Department of Enterprise Services
- **Design-Builder:** Sellen Construction
- **Concrete Supplier:** Cal Portland
- **Structural Engineer:** KPFF
- **Architect:** ZGF Architects

*Greenhouse gas reductions in this case study are relative to data in the NRMCA Member National and Regional Life Cycle Assessment Benchmark (Industry Average) Report - Version 2.0, published by Athena Sustainable Materials Institute.

Sellen

CONCRETE DECISIONS

The requirement to limit overall building height to below the elevation of the capitol dome necessitated a thin floor structure and led the team to post-tensioned concrete decks as the preferred structural system. The raw materials of concrete were available locally, which helped minimize transportation emissions; however, the greater challenge was to reduce the emissions associated with the cement content during concrete production.

Through a series of iterative meetings with concrete producer Cal Portland, Sellen and KPFF Structural Engineers identified structural requirements, constructability needs, and GHG reduction goals for the concrete mixes. To reduce the quantity of cement – the greatest source of embodied GHG in concrete – the materials engineer proposed mixes with supplementary cementitious materials (SCMs) such as Ground Granulated Blast Furnace Slag (slag). The maximum percentage of SCMs used in this project's mixes was 50%.

MEASURE, DISCLOSE, DELIVER

While the SCM percentage is often cited as a proxy for sustainability, a higher SCM replacement percentage does not always guarantee a lower carbon intensity mix. A more accurate measure of impact is an Environmental Product Declaration (EPD), which is a standardized report that uses the technique of life-cycle assessment (LCA) to quantitatively measure the environmental impacts of materials or products. The measured impacts are defined by the product category rule (PCR) and include: global warming potential, ozone depletion potential, acidification potential (in land and water), eutrophication (excessive nutrients in water bodies), and photochemical smog creation potential.

As part of its design-build competition package, Sellen proposed creating new EPDs for this project's concrete mixes as a way to measure the team's efforts to reduce embodied GHG impacts from the business-as-usual condition. This project was the first publically funded project in Washington that required EPD data for concrete mixes — 99.7% of this project's concrete has EPD data, providing a clear and quantifiable picture of the project's embodied greenhouse reduction amounts.

As a result of this project, Cal Portland produced EPDs not only for the 106 11th Avenue building, but also for 90 of its commonly used mixes in its Duwamish (Seattle), DuPont and Tumwater, WA plants. This has been catalytic for Washington's concrete industry: prior to this project there were five EPDs available for mixes in Washington State; today the number of EPDs for concrete produced in Washington exceeds 2,000.

EDPs are one tool in a growing movement for quantifying and disclosing the environmental and health impacts of building materials and products. The industry is at the outset of this movement with large companies often leading the way through investing in the rigorous EPD process. Currently the majority of EPDs for Washington-produced concrete are available through two of the largest suppliers. While software models, available on a licensing basis, exist to generate large numbers of third-party verified EPDs, this still requires an investment of time and money to set up and maintain. This initial investment may be a barrier for smaller suppliers and companies to deliver EPDs.

SCHEDULE, NOT TECHNOLOGY, IS THE CHALLENGE

By reducing the amount of cement per cubic yard and replacing it with SCMs and admixtures, some Washington State concrete manufacturers have the technical expertise to significantly decrease the embodied GHGs in concrete while exceeding the required ultimate required strength. Although the technology exists, the key challenge is satisfying the demands of the construction schedule and the need to quickly reach early strengths to enable the safe removal of formwork, reducing the time required for the form-pour-strip cycle to maximize the reuse of the formwork.

Structural systems such as post-tensioned (PT) slabs are especially time sensitive – the ideal scenario is to be able to stress the slabs and strip forms within three days after a pour, so a new level can be formed, poured, reach initial strength and stripped all within a seven-day cycle. Again, reuse of formwork is a major cost factor in this process. In these cases, the need for achieving initial strength often leads to mixes with higher amounts of cement per cubic yard, or “hotter” mixes. The higher percentage of cement accelerates initial strength, but also increases the heat of hydration, a chemical reaction that can produce high temperatures during the curing process. Other technology and admixtures are being developed that may be able to address this need in a different manner; however, the cost is still high.

At the 106 11th Avenue project, the mixes used for PT decks had to serve competing needs: reduce embodied GHG while quickly attaining initial strengths to remove the formwork and enable a one-week pour cycle. Even with these constraints, the mixes used for the PT slabs achieved moderate GHG reductions -- 28% less GHG than comparable strength mixes in the Pacific Northwest.

In other cases, such as thick mat slabs and footings, there is less urgency to reach an early strength within a few days. In fact, the engineer will often specify a longer period, such as 56 or 90 days for reaching full strength; these elements will receive loads long after the needed strength is reached. These situations are not on the schedule’s critical path and are good opportunities to consider “leaner” mixes with less cement per cubic yard and SCMs that work in concert with other ingredients to achieve the required ultimate strength and help control the heat of hydration.

In this project, the footings achieved GHG reductions of 55% compared to similar strength Pacific Northwest mixes.

In short, not all structural elements have the same schedule urgency; ones not on the critical path are the best candidates for lower carbon solutions that may result in a longer curing time than a conventional concrete mix.

TRANSPARENCY AND THE MARKET DEMAND

There is growing interest by some members of the design, construction and manufacturing communities to move toward increased disclosure of health and environmental impacts of materials and building products. The current version of LEED puts a new emphasis on disclosure and rewards manufacturers and projects for selecting products that disclose material ingredients and/or impacts and optimize their products.

Some manufacturers have made considerable investment to produce EPDs and or optimize products. Feedback from manufacturers have noted that they are looking for project teams and owners to consistently specify EPDs, lower carbon concrete or recycled aggregate so that they have financial justification to continue these initiatives. Large owners, either public or private, have a powerful opportunity to drive change through their project requirements, specifications and the material procurement. As more owners demand quantified performance, the market is likely to deliver.

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