WHITE PAPER

Incorporating CarbonCure into Concrete Specifications: A Guidebook for Architectural and Engineering Firms

Did you know that nearly 50% of the carbon emissions from new construction over the next 4 decades will come from embodied carbon? Embodied carbon is the carbon footprint of construction that comes from the manufacturing of the building materials through the construction practices. In other words, it is the carbon footprint of a building before it begins operations.

As the most abundant man-made material on the planet, concrete is one of the biggest contributors to embodied carbon, alongside steel and wood. The manufacturing of cement - the key ingredient In concrete - is responsible for about 7% of global carbon dioxide (CO_2) emissions. The good news is that there are many solutions available today that structural engineers, architects, builders and building owners can use to reduce that impact, while maintaining concrete performance.

CarbonCure is leading a mission to reduce 500 million tonnes of CO_2 emissions annually from the cement and concrete sector. In order to achieve this mission, it is critical that designers and builders adopt concrete specification practices that enable sustainable innovation.

This guidebook provides a few step-by-step suggestions on how to incorporate sustainability best practices, including CarbonCure's CO_2 mineralization solution, into concrete specifications.

Part One: Understanding Concrete's Carbon Impact

Concrete is composed of 5 basic constituents:

1. Cement/cementing materials
2. Coarse aggregates (eg. rock)
3. Fine aggregates (eg. sand)
4. Water
5. Admixtures (chemicals designed to deliver specific performance or handling improvements)

While cement is typically 10-20% of the concrete's volume by weight, it is responsible for over 80% of the concrete's carbon footprint. Ordinary Portland Cement has a carbon-intensive manufacturing process. Cement is produced by mining limestone (calcium carbonate) and other raw materials from a quarry, and then processing those materials in a very hot kiln (> 1300C/2400F). At this temperature, the calcium carbonate bond breaks into two components: i) calcium oxide, which becomes the precursor to cement and ii) carbon dioxide, which is released into the atmosphere as a waste byproduct.

Roughly half of cement's carbon footprint is generated by the combustion process of cement manufacturing (ie: the heating and energy required to break the calcium carbonate bond), while the other half of the carbon footprint comes from the calcination reaction, in which CO_2 is a waste byproduct.

Aggregates may contribute slightly to concrete's carbon footprint, especially if the aggregates are not locally sourced (however most aggregate sourcing is fairly local).

The most effective way to reduce the carbon impact of concrete is to reduce the amount of cement used in that concrete, while ensuring concrete performance (such as strength, slump, shrinkage, etc...) is maintained.

Supplementary Cementitious Materials, such as slag (a byproduct of steel manufacturing), fly ash (a coal byproduct) and metakaolin are the most commonly used materials to reduce cement content in concrete mixes. These materials aid the cement hydration reaction but are significantly less carbon intensive than ordinary portland cement.

The average carbon emission factor for cementing materials is:

- Cement (OPC): 0.922 tonnes CO_2 emitted per tonne of cement
- Fly Ash: 0.14 tonnes CO_2 emitted per tonne of fly ash
- Slag: 0.07 tonnes CO_2 emitted per tonne of slag

Key Takeaway: The most effective way to reduce the carbon impact of concrete is to reduce the amount of cement used in that concrete, while ensuring concrete performance is maintained.

Part Two: Measuring Concrete's Carbon Impact Through Environmental Product Declarations

The carbon impact of concrete products across North America varies wildly. It's essential that we understand the carbon footprint for the actual concrete available within that region.

The standard measurement for the carbon footprint of building products is called the Global Warming Potential (GWP) of a product. In concrete, GWP is measured in kilograms of carbon dioxide emitted per cubic yard or cubic meter of concrete - denoted as $kgCO_2e$/cy or cm.

The GWP of a building material can be calculated and documented using Environmental Product Declarations (EPDs). An EPD will provide the GWP of a building product, along with other environmental impact measurements. An EPD is similar to a nutrition label on a food product, except it denotes the environmental impact of a specific building material.

Not all EPDs are created equally. An Industry Average EPD provides the average GWP of building products meeting similar specification requirements. In regards to concrete, the National Ready Mix Concrete Association published its Industry Average EPD for Ready Mix Concrete. This EPD provides the average GWP value for concrete mixes meeting specific strength requirements with varied mix constituents.

Product-Specific EPDs are known as Type III EPDs. These EPDs provide information on the actual GWP of specific concrete products. In order to accurately measure the embodied carbon impact of a construction project, it's important to request Type III EPDs for each unique concrete mix or batch whenever possible.

Even among Type III EPDs, some EPDs will provide greater data certainty than others. For example, an EPD might calculate the GWP value of a concrete mix by using a CO_2 emissions factor of 0.922 - this is the industry average amount of tonnes of CO_2 emitted per tonne of cement produced. However, some cement operations are more carbon efficient than others and may have smaller or larger CO_2 emissions factors than that average. A high quality EPD will measure the actual carbon footprint of the raw materials used within that particular batch of concrete. The carbon footprint will factor in granular details such as fuels used in manufacturing, raw material extraction, shipping mileage, and the transportation method for the raw materials.

Key Takeaway: Require product-specific (Type III) Environmental Product Declarations (EPDs) in order to accurately measure the carbon footprint of concrete, known as GWP ($kgCO2_e$/cy).

Part Three: Best Practices for Reducing the GWP of Concrete

One of the most impactful methods to reduce the GWP of concrete is to maximize the optimization of concrete mix designs with cement replacements.

The following excerpt from the NRMCA Industry Average EPD demonstrates the difference that just SCMs can make on the concrete's GWP. This chart shows the GWP of a 3001-4000 psi mix design, with varying SCM content. To clarify, the column heading 3001-4000-00-FA/SL refers to a 3001-4000 psi mix with 0% fly ash or slag (a straight cement mix) while 3001-4000-50-FA/SL refers to the same psi mix with 50% fly ash or slag content. The corresponding GWP value provides the kgCO_2e/cy of concrete for each mix design.

Summary Results (A1-A3): 3001-4000 psi (20.7-27.6 MPa) RMC product mix design, per cubic yard

		Minimum	Maximum	3001-4000-00-FA/SL	3001-4000-20-FA	3001-4000-30-FA	3001-4000-40-FA	3001-4000-30-SL	3001-4000-40-SL	3001-4000-50-SL	3001-4000-50-FA/SL
Core Mandatory Impact Indicators											
GWP	kg CO_2e	199.70	326.27	326.27	279.43	254.11	227.39	250.52	225.27	200.02	199.70

The table above clearly demonstrates that the concrete's carbon footprint can be significantly reduced by using 50% supplementary cementitious materials (GWP of 199.7) compared to 100% straight cement (GWP of 326.27) - a 39% reduction in GWP value.

Concrete specifications can significantly impact the GWP of concrete without intending to. Limitations on the amount of SCM allowed in a concrete mix design, or incorporating new sustainable technologies has a drastic impact on the ability of concrete producers to reduce the GWP of their concrete mix designs.. Many concrete specifications will include maximum limits on SCM content (for example: max 20% fly ash), and may not provide a process, allowance, or incentive to producers to bring forward optimized mix designs that address project sustainability goals.

Summary

1. Require product-specific (Type III) Environmental Product Declarations during the concrete supplier selection stage.

2. Review the Global Warming Potential (GWP, measured in kgCO_2e/cubic yard or cubic meter of concrete) of the submitted concrete mix designs. Consider using any of the following bid strategies:
   a. Award concrete supply to the lowest GWP mix
   b. Create a GWP cap and prohibit suppliers who exceed that cap
   c. Create an 'acceptable price premium' metric to incorporate GWP values into the selection process for lowest bid. For example, allow up to a 10% material cost premium for the concrete mix with the lowest GWP.

3. Remove unnecessary prescriptive specifications. Consider the following:
   a. Eliminate minimum cement content requirements
   b. Eliminate maximum supplementary cementitious materials requirements
   c. Review maximum water/cementitious ratio requirements and ensure the requirements are appropriate for the performance characteristics and exposure class of the concrete. Avoid "over-design", which tends to occur when the maximum water/cementitious ratio requirement is too stringent for the application.

4. Incorporate specification language that allows or prefers the use of CO_2 mineralization, if available, pending concrete performance requirements are met.

There's no prescriptive one-size fits all mix design for low carbon concrete, but there IS a one-size fits all strategy:

1. Use Performance Specs
2. Require EPDs
3. Specifically Allow innovative materials like CarbonCure
4. Use GWP information in procurement decision making