Kimley»Horn

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Low-Carbon Concrete
Implementation Guide

By: Marta Gappy, EIT and Jake Panter, PE

Background

The building industry is looking for ways to reduce carbon emissions both in their operations and construction processes. This implementation guide was developed for owners, developers, engineers, and contractors to assist in the understanding of an easy way to reduce carbon emissions in the construction process through alternative materials in concretes. **The following document will define what a low-carbon concrete is and provide ways to implement this material into your projects.**

What is Low-Carbon Concrete?

Concrete is the world's second most consumed material, behind water[1]. Globally, concrete is responsible for 8% of carbon dioxide (CO2) emissions, with cement being responsible for about 90% of those emissions[2]. There are many ways the concrete industry is working to reduce CO2 emissions, including more efficient design, improved mixes, and recycling post-concrete use. **Currently, improved mixes are the most widely utilized way to reduce CO2 emissions.** One effective technique is the use of Low-Carbon Concrete (LCC), achieved by replacing Ordinary Portland Cement (OPC) with Supplementary Cementitious Materials (SCMs). Supplementary Cementitious Materials include:

- **Slag** - the byproduct of steel production from the blast furnace
- **Fly Ash** - a byproduct of the combustion of coal
- **Recycled Glass** - glass that is crushed to a fine enough powder to replace cement
- **Other Alternative Materials**

LCC can be evaluated based on its Environmental Product Declaration (EPD), and more specifically its Global Warming Potential (GWP) that is represented on the EPD. See page 6 for an evaluation of two separate EPDs using Ordinary Portland Cement and one using a high volume of SCMs to produce a low-carbon concrete. LCC will vary based on the compressive strength of the material, but a baseline GWP for a 4,000 psi concrete might be around 300-350 kg CO2 eq/cubic yard. LCC can be below 200 kg CO2 eq/cubic yard.

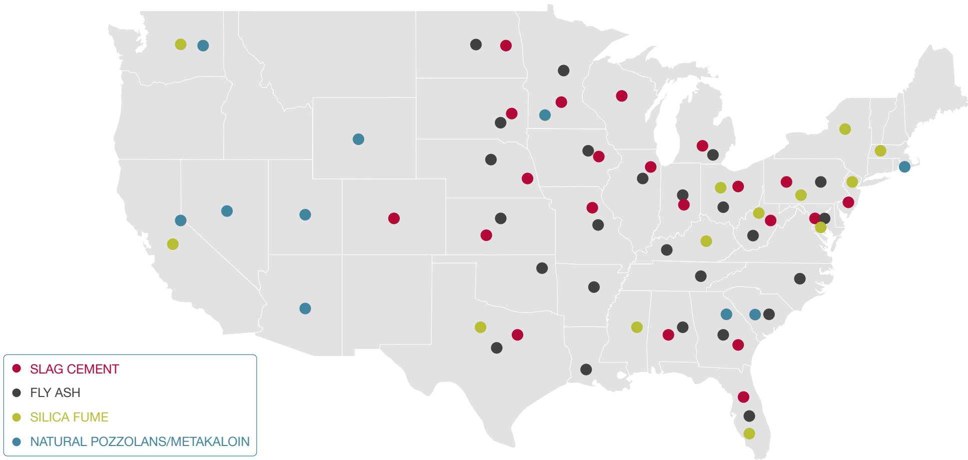
1. Architecture 2030, "The Emissions Impact of Concrete."
2. Suraneni, "Emerging Approaches for Reducing Concrete CO2 Emissions."

How can I incorporate Low-Carbon Concrete into my project?

Determine your carbon reduction goals for the project. What is your goal for carbon reduction for site elements, specifically your pavements? What is the maximum GWP you are aiming to achieve in your mixes?

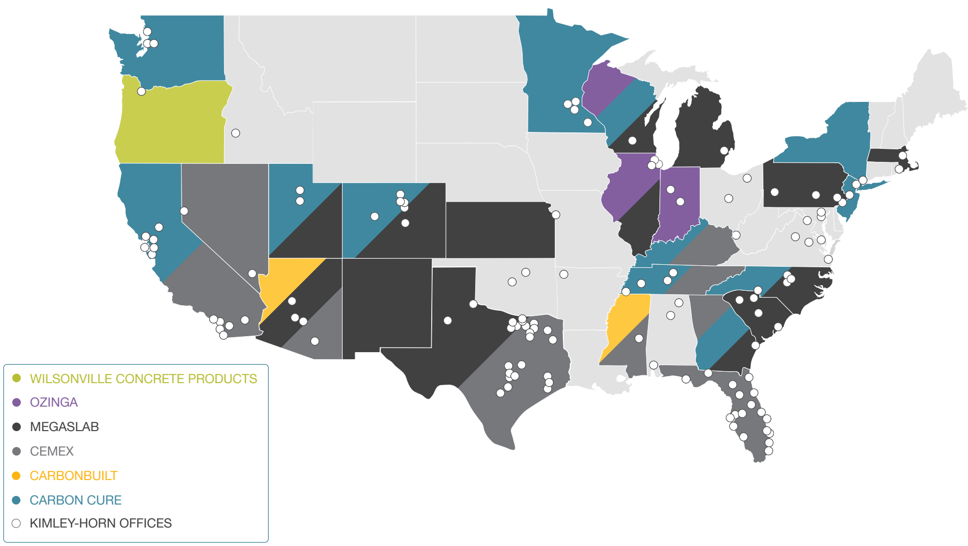
- Have your consultant reach out to a local supplier to determine if their mixes are a good fit for the project. Ask questions like:
  - What is the lowest global warming potential concrete mix your plant has produced? Can you provide EPDs as proof?
  - What Supplementary Cementitious Materials (SCMs) do you have available that we can incorporate into a LCC mix? Do you have experience with low-carbon mixes?
  - Work with consultants, contractors, and material suppliers to develop a LCC mix standard.

Supplementary Cementitious Materials By State



The map below shows concrete mix consultants and Kimley-Horn offices so you can identify potential partners for your future LCC design projects.

Low-Carbon Concrete Suppliers by State



What are common misconceptions for Low-Carbon Concrete?

Low-Carbon Concrete costs more than standard OPC concrete.

Depending on material availability and technologies that are used in the mix, suppliers should be able to produce a mix that is comparable in costs. In most cases, LCC is equal or even less costly when using SCMs in place of OPC.

There is not enough information on Low-Carbon Concrete and how it fits into existing standards.

While LCC can vary in what types of SCMs are used, there continues to be more information about their strength and durability. Owner standards can be updated to require LCC producers to work with third-party testing facilities to verify their project meets and/or exceeds standards such as ASTM C1157. Reporting and educating on LCC's ability to meet strength standards is incredibly important for widespread implementation. Reporting and considering Environmental Product Declarations (EPDs), which standardize a material's sustainability through its lifecycle, in the design stage of a project can also normalize the use of sustainable materials, such as LCC.

Kimley-Horn recommends engaging with the local material suppliers early in the process to understand material availability and how best to meet the goals of the project. Setting Carbon Reduction goals with the project team early on can get everyone on the same page to incorporate into designs. At a minimum, GWP maximums should be coordinated with your design consultants to put into the contract documents. Collaboration with consultants, contractors, and suppliers early will be critical to incorporate low carbon materials successfully.

Low-Carbon Concrete cannot meet the same strength requirements as standard OPC concrete.

Not only can LCC be poured just like traditional concrete, but using SCMs to replace cement in concrete mixes can actually improve the strength. For example, using Silica Fume can increase the strength of concrete. Others like Fly Ash and Slag still meet the strength demands but have slower initial strength gains[3]. These slower strength gains should be taken into account and coordinated with contractors early in the process so that schedules are not delayed.

Due to changing industries, Slag and Fly Ash demand is outpacing the supply.

Due to the decline of coal and iron ore industries, there is worry that the two main SCMs: Slag sources (byproduct of iron or steel production) and Fly Ash (residue from coal combustion) sources will not be as widely available for use in LCC. While there is truth in the declining availability and increasing demand of these SCMs, SCM suppliers, such as, Eco Materials, are looking for new ways to provide Slag and Fly Ash nationally, such as, Fly Ash Harvesting. This method uses stockpiled Fly Ash from coal combustion in the 1980s and 1990s[4]. There are also other emerging alternatives to Slag and Fly Ash, such as, Calcined Clay, Silica Fume, and Limestone Powder[5].

3. Sutter, "Supplementary Cementitious Materials."
4. EcoMaterial Technologies, "Harvested Fly Ash."
5. Harbi, "Low-Carbon Concrete Routemap."

Kimley-Horn Case Studies

To demonstrate the practical application of the concepts explored in this implementation guide, we present two real-world case studies.

Porsche Campus Expansion

Atlanta, GA

The track at Porsche Cars North America's Experience Center in Atlanta allows customers the opportunity to give sports cars an intense workout. Kimley-Horn provided a wide array of services on this 33-acre expansion, including incorporation of low-carbon concrete into construction. This innovative approach resulted in an overall reduction of 20% in emissions compared to a standard concrete mix.

Porsche OPD Campus Expansion

Indianapolis International Airport (IND) Runway 5R-23L and Taxiway

Indianapolis, IN

Kimley-Horn worked with the Indianapolis airport to reduce their carbon emissions by incorporating supplementary cementitious materials like Slag and Fly Ash as well as CarbonCure technology into their concrete mix. This reduced the carbon emissions of the concrete significantly. To date, this project is the only airfield project awarded Institute for Sustainable Infrastructure Envison Platinum Award.

Indianapolis International Airport

EPD Evaluation

The tables below offer a comparison between two types of concrete mixes: low-carbon concrete and ordinary or traditional concrete that does not utilize Supplementary Cementitious Materials (SCMs). When evaluating the Environmental Product Declaration (EPD), it is important to consider the potential harmful impacts of the materials used on the environment. The lower the values for these impacts, the more sustainable the concrete mix becomes.

Low-Carbon Concrete

ENVIRONMENTAL IMPACTS

Compressive strength: 4000 PSI at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	**213**
Ozone Depletion Potential (kg CFC 11-eq)	**6.84E-6**
Acidification Potential (kg SO_2-eq)	**0.79**
Eutrophication Potential (kg N-eq)	**0.30**
Photochemical Smog Creation Potential (kg O_3-eq)	**14.1**
Abiotic Depletion, non-fossil (kg Sb-eq)	**4.00E-5**
Abiotic Depletion, fossil (MJ)	**468**
Total Waste Disposed (kg)	**60.0**
Consumption of Freshwater (m^3)	**3.32**

Product Components: crushed aggregate (ASTM C33), Portland cement (ASTM C150), natural aggregate (ASTM C33), slag cement (ASTM C989), fly ash (ASTM C618), batch water (ASTM C1602), admixture (ASTM C494)

Ordinary or Traditional Concrete

ENVIRONMENTAL IMPACTS

Compressive strength: 4000 PSI at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	**459**
Ozone Depletion Potential (kg CFC 11-eq)	**1.09E-6**
Acidification Potential (kg SO_2-eq)	**1.04**
Eutrophication Potential (kg N-eq)	**0.56**
Photochemical Smog Creation Potential (kg O_3-eq)	**20.3**
Abiotic Depletion, non-fossil (kg Sb-eq)	**9.65E-5**
Abiotic Depletion, fossil (MJ)	**566**
Total Waste Disposed (kg)	**148**
Consumption of Freshwater (m^3)	**3.46**

Product Components: crushed aggregate (ASTM C33), Portland cement (ASTM C150), batch water (ASTM C1602), admixture (ASTM C494)

Global Warming Potential – the CO2 emitted from production. The lower this number is, the more sustainable the material.

Ozone Depletion Potential – potential impact of substances that contribute to ozone depletion.

Acidification Potential – potential impact of substances including nitrogen oxides, sulfur oxides, and additional acidic materials.

Eutrophication Potential – the material's contribution to excess richness of nutrients in a body of water.

Photochemical Ozone Creation Potential – potential for smog formation.

Abiotic Depletion, non-fossil – the depletion of non-renewable materials.

Abiotic Depletion, fossil – the depletion of fossil fuel materials.

Total Waste Disposed – total waste produced through production of the material.

Consumption of Freshwater – amount of water consumed during production.

Meet the Experts

Marta Gappy, EIT

Marta Gappy specializes in asset and pavement management. Marta graduated with her degree in environmental engineering from Michigan State University, sparking her involvement in sustainable building. Her experience with low-carbon concrete includes developing guidance documents and reviewing client specifications for incorporation and consulting on low-carbon concrete and SCM suppliers.

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Jake Panter, PE

Jake Panter has twelve years of experience working with site pavements on new developments and pavement management of existing facilities. Jake became involved in low-carbon materials during the pandemic as Environmental Product Declarations became more available on projects. His experience with low-carbon concrete includes developing guidance documents and reviewing client specifications for incorporation, consulting on low-carbon mixes to make decisions between suppliers, and reporting emissions of construction materials through documentation including Life Cycle Assessments.

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