Reducing the Carbon Footprint of Concrete
Reducing the Carbon Footprint of Concrete

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Learning Objectives

By the end of this presentation, participants will be able to:

1. Understand the impact of embodied carbon from the built environment and describe the means through which cement manufacturing contributes to embodied carbon.

2. Utilize assessment and reporting resources such as Environmental Product Declarations (EPDs) to evaluate the environmental impact of building materials.

3. Explore the innovative method of CO$_2$ mineralization as a means to reduce embodied carbon in concrete production, and describe the method's impact on the fresh and hardened properties of concrete.

4. Embrace best practices in concrete design to reduce the carbon impact of concrete, and empower concrete producers to adopt lower carbon solutions while ensuring concrete performance requirements are maintained.
Carbon Definitions

**Embodied Carbon**
The emissions from manufacturing, transportation, and installation of building materials.

**Operational Carbon**
The emissions from a building’s energy consumption.
Global CO$_2$ Challenge

Global Temperature Projections for various RCP Scenarios

Source: Reproduced with permission from Architecture 2030: Adapted from IPCC Fifth Assessment Report, 2013. Representative Concentration Pathways (RCP), temperature projections for SHES scenarios and the RCPs.
Global CO$_2$ Challenge

Global Temperature Projections for various RCP Scenarios

- **RCP8.5**: Business-as-usual, 2.2 trillion tons carbon
- **RCP6.0**: emissions peak 2080, 1.6 trillion tons carbon
- **RCP4.5**: emissions peak 2040-50, 1.3 trillion tons carbon
- **RCP2.6 (1.5°C)**: 0.53 trillion tons carbon, zero CO$_2$ emissions -2050

Source: Reproduced with permission from Architecture 2030: Adapted from IPCC Fifth Assessment Report, 2013. Representative Concentration Pathways (RCPs), temperature projections for INDC scenarios and the RCPs.
Global CO₂ Emissions by Sector

- 30% Industry
- 28% Building Operations
- 11% Building Materials and Construction
- 22% Transportation
- 9% Other


Reducing the Carbon Footprint of Concrete
Decoupling of Operational Emissions

Efforts by designers to create more efficient and sustainable buildings are having an impact.

But what about the emissions associated with building materials?
Did you know?

The world’s building stock is expected to double by the year 2060. This means we’re building an entire New York City every month for the next 40 years.
Did you know?

Of that new construction, embodied carbon is expected to account for nearly 50% of the buildings’ total carbon emissions.
Time Value of CO$_2$ - New Buildings
“If we do not achieve a **65% reduction** in total global emissions **by 2030**, we will have lost the opportunity to meet the 1.5-2 ℃ warming threshold and **climate change will become irreversible**. The immediate focus for embodied carbon reductions must therefore be on the **next decade**.”
Structural Engineers 2050

Source: SE2050
Through our Advancing Net Zero project, and in partnership with European Climate Foundation, Children’s Investment Fund Foundation, C40 Cities and Ramboll, World GBC is developing a ‘call to action’ report focusing on embodied carbon emissions, and the systemic changes needed to achieve full decarbonisation across the global buildings sector.

World Green Building Council
New Emphasis on Embodied Carbon

Green buildings certification systems now address embodied carbon

LEED BD+C: New Construction l v4.1 - LEED v4.1

Building Life-Cycle Impact Reduction

Possible 5 points

2 points
Demonstrated impact reduction of at least 5% in Global Warming Potential and 2 other impact categories.

3 points
Demonstrated impact reduction of at least 10% in Global Warming Potential and 2 other impact categories.

4 points
Demonstrated impact reduction of 20% in Global Warming Potential, at least 10% in 2 other impact categories, and building reuse and/or use of salvaged materials.

Materials & Resources
Focuses on minimizing embodied environmental impacts to support a life-cycle approach that improves performance.

Option 4:
Whole Building Life Cycle Assessment (1-4 points)
Conduct a life cycle assessment and show a 10% impact reduction in embodied CO₂ emissions + 2 other impact categories shown on an Environmental Product Declaration.
Environmental Product Declarations

Independently-verified documents based on international standards that report the environmental impacts of a product.

<table>
<thead>
<tr>
<th>Environmental Facts</th>
<th>Impact</th>
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</thead>
<tbody>
<tr>
<td>Functional unit = 1 yd³ of concrete</td>
<td></td>
</tr>
<tr>
<td>Primary Energy Demand (BTU)</td>
<td>9.3x10⁵</td>
</tr>
<tr>
<td>Global Warming Potential (lb CO₂ eq)</td>
<td>360</td>
</tr>
<tr>
<td>Acidification Potential (lb H+ eq)</td>
<td>40</td>
</tr>
<tr>
<td>Eutrophication Potential (lb N eq)</td>
<td>0.4</td>
</tr>
<tr>
<td>Ozone Depletion Potential (lb CFC-11 eq)</td>
<td>1.98x10⁻⁵</td>
</tr>
<tr>
<td>Smog Potential (lb O₃ eq)</td>
<td>21</td>
</tr>
</tbody>
</table>
New Tools for Increased Transparency

Embodied Carbon in Construction Calculator (EC3) Tool

Material Quantity Estimate \( \times \) Embodied Carbon Per Material EPDs = Embodied Carbon (EC) Building Estimate

Source: Skanska USA; Carbon Leadership Forum
Concrete is the most abundant man-made material in the world.

As a result, cement production creates ~7% of the world’s CO₂ emissions and is one of the largest contributors to embodied carbon in the built environment.

*Source:* Architecture 2030
Cement makes up only **12%** of the weight of concrete, but is responsible for **95%** of the CO$_2$ footprint.
Cement Demand Projection

Cement demand expected to grow 12 to 23% by 2050.

-IEA, Cement Sustainability Initiative
Concrete is a low impact material.

Concrete on its own has low CO₂ emissions and embodied energy for every kilogram produced (though cement is higher).
IEA Technology Roadmap

Pathway for reducing emissions in the cement and concrete sector

- 48% of emissions reductions must come from carbon capture and utilization strategies
- 37% of reductions must come from reduced clinker to cement ratios
What is CarbonCure?

CO$_2$ Utilization in Concrete

CarbonCure’s technology beneficially repurposes carbon dioxide to reduce the carbon footprint of concrete without compromising concrete performance.
CarbonCure Concrete Impact

- Operating at **400 Concrete Plants**
- Used in **13,000,000+ yd³ of concrete**
- Resulting in **120,000 tonnes CO₂ saved**
- Compliance with **ASTM C494 Type S**
Award-Winning Innovation

Strategic Partners

Amazon

THE Paris PLEDGE Early

Breakthrough Energy VENTURES

Mission Innovation

accelerating the clean energy revolution
CO₂ Supply

CO₂ is captured and distributed to concrete plants by industrial gas suppliers.

Collection
CO₂ is collected from large emitters

Purification
The gas is purified by industrial suppliers

Delivery
The CO₂ is delivered to concrete plants by industrial gas suppliers

Storage
The CO₂ is stored at concrete plants in pressurized tanks
How it Works: Technology

Seamless retrofit technology that operates with no disruption to normal batching procedures

Installation
- CarbonCure equipment installed into existing concrete plans

Integration
- CarbonCure software integrates seamlessly with the batching software

Injection
- The equipment injects a precise automated dosage of CO₂ into concrete as it mixes
What Happens When CO₂ is Injected?

- CO₂ mineralization occurs
- CO₂ converts into CaCO₃ (solid limestone)
Cement Manufacturing Process

1 ton cement = 0.922 ton CO₂
(2021 EPD for US Portland Cement)

CaCO₃ + Heat (calcination reaction) → CaO

Limestone (Calcium carbonate)

CO₂
Converting CO$_2$ to a Mineral

Limestone (Calcium carbonate) + Heat (+) calcination reaction → CaO → Cement

Add aggregate, water & admixtures → Concrete
Converting CO$_2$ to a Mineral

Limestone (Calcium carbonate) → Heat (+) calcination reaction → CaO → Cement

CO$_2$ mineralization reaction → CO$_2$ Mineralized Concrete

Add aggregate, water & admixtures
Converting CO$_2$ to a Mineral

Nano-calcium carbonate particles act as nucleation sites for hydration. Compressive strength benefits can arise from this interaction.

Carbonate product formed about 400 nm dimension
Compressive Strength Gain

Conclusion: The formation of a calcium carbonate nanomaterial improves the compressive strength of ready mix concrete.

Mix Adjustment Opportunities

Conclusion: CarbonCure enables concrete producers to reduce cement content without sacrificing strength. Source: “Ready Mix Technology Trial Results” (2015).
CO₂ has a Neutral Impact on...

**Fresh Properties**
- Setting time
- Workability/slump
- Concrete pumping
- Air content
- Temperature
- Finishing

**Hardened Properties**
- Freeze-thaw
- pH
- Density
- Durability
- Color
- Texture

Note: Peer reviewed papers are available to support the above information at carboncure.com.
Trial Results

- Desired strength levels were achieved
- ZERO complaints from customer base on finishability, set time and overall performance
- Customers had no idea anything was different
CarbonCure for Ready Mix

How Much CO₂ Can Be Saved?

15-30 lbs CO₂ saved per yd³

- CO₂ saved = CO₂ mineralized + CO₂ avoided by reducing cement
- Avg. 5% reduction in GWP (stackable carbon benefit with SCMs)
Reference Project:

725 Ponce
360,000 sq ft commercial office in Atlanta, GA

“Uzun+Case, with input from Thomas Concrete, specified the CarbonCure Technology to reduce the carbon footprint of 725 Ponce. We’re proud to have saved 1.5 million pounds of CO₂ while maintaining our high-quality standards for concrete.”

Rob Weilacher
Engineer of Record, Uzun+Case

Supplier: Thomas Concrete
Concrete Usage: 48,000 yd³ of concrete made with CarbonCure
CO₂ Savings: 1.5 million lbs
CO₂ Savings Equivalent: 888 acres of forest absorbing CO₂ for a year
Reference Project:

Kapolei Interchange - Honolulu, HI
Concrete paving, Department of Transportation highway

“I am pleased to see HDOT moving ahead with CarbonCure, local concrete companies, and Hawaii Gas to reduce the levels of carbon dioxide emitted during the construction process.”

David Ige
Governor of The State of Hawai’i

Supplier:
Island Ready Mix

Owner:
Hawaii Department of Transportation

Project Size:
19,000 square feet

CO₂ Savings Equivalent:
30,000 lbs
LinkedIn is proud to support environmental consciousness in the built environment. The design of our new headquarters campus incorporates sustainable concrete solutions, including CarbonCure Technologies through our local concrete experts, Central Concrete.

Jennifer Mitchell
Senior Project Manager, GWS Design + Build Team at LinkedIn
Amazon HQ2 - Arlington, VA

“We are excited to invest in CarbonCure, a company producing stronger, more sustainable concrete, which will help Amazon and other companies meet The Climate Pledge, a commitment to be net-zero carbon by 2040. We are looking forward to lowering the carbon footprint of many of our buildings by using CarbonCure concrete, including in Amazon’s HQ2 building in Virginia.”

Kara Hurst
Vice President of Sustainability at Amazon

Concrete Supplier:
Miller & Long

Estimated CO₂ savings:
1,144 tonnes (1,261 tons)

Structural Engineer:
Thornton Tomasetti

Estimated Completion:
2022
How can you help reduce concrete’s carbon impact?

Communicate your commitment to embodied carbon reduction throughout the supply chain *early* and *often*.

Design strengths for what you *need*.

Use *supplementary cementitious materials* and/or *low-carbon cement*.

Remove unnecessary prescriptive concrete specs.

Consider *performance*-based concrete specs.

Specify and/or approve *CO$_2$ mineralized concrete*.
The unexpected

Construction materials are a major contributor to climate change. Here's one company with a clever approach to embedding carbon dioxide in concrete.
## Barriers to Innovation: Specs

Prescriptive specs may result in unnecessary limitations to sustainability improvements

### Prescriptive Spec

- Minimum cement/cementitious requirement
- Maximum supplementary cementitious content
- Maximum water/cement ratio

### Performance Spec

Consider

- Specify strength (eliminate minimum cement requirement)
- Specify strength (eliminate maximum SCM requirement)
- Use only when appropriate for exposure class and performance requirement
What’s next for us? Reclaimed WashWater Technology

- **Stabilize** returned cementitious solids in RW slurry tank using CO\(_2\)

- **Recycle** stabilized solids back into concrete production (replacing virgin cementitious)

- **Reduce** offsite waste streams, helping producers achieve *net zero discharge* operation
Questions?
Reducing the Carbon Footprint of Concrete
Build for the Future. Build with CarbonCure.

A building or infrastructure project may save as much CO₂ as 100s if not 1000s of acres of trees absorb over a year.

Who knew that building with concrete could be like planting trees?

www.carboncure.com
@CarbonCure
CarbonCure-Technologies
CarbonCure.Technologies

Simply better concrete.