Carbon Dioxide Mineralization in Concrete

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What is Embodied Carbon?
Embodied carbon is the emissions from manufacturing, transportation, and installation of building materials through to the construction of the building.

Concrete is the most abundant man-made material in the world.

Scale of material production

The environmental discussion of concrete often ignores the scale. Concrete is used because it is low-cost, locally-produced, resilient, recyclable and versatile.
**Concrete: Low Carbon & Energy Footprint**

Embodied emissions and energy for construction materials

- Cradle-to-gate analysis – includes process emissions, fuel emissions and transport emissions.
- On a unit basis, concrete has very low embodied impacts


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**Embodied Carbon Reduction**

Stakeholders across the value chain

- Cement Producers
- Concrete producers
- Structural engineers
- Construction companies
- Governments

See PCA Roadmap to Carbon Neutrality cement.org/sustainability/roadmap-to-carbon-neutrality

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**Where We Are**

As of November 2021

- Available in 400+ concrete plants, 6 continents
- Used in 14,100,000+ yd³ of concrete
- Resulting in 126,000+ tonnes CO₂ saved
- Which is equivalent to 159,000+ acres of trees absorbing CO₂ for a year

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**What is CarbonCure?**

CarbonCure’s technology beneficially repurposes carbon dioxide (CO₂) to reduce the carbon footprint of concrete without impacting performance.
Complementary Concrete Technologies

Retrofit technology that operates with no disruption to normal batching procedures

CarbonCure for Ready Mix
CarbonCure for Precast
CarbonCure for Reclaimed Water

CarbonCure for Ready Mix

Retrofit technology that operates with no disruption to normal batching procedures

Installation
Integration
Injection

The equipment injects a precise automated dosage of CO₂ snow into concrete as it mixes

CarbonCure engineers install the proprietary equipment into existing concrete plants
The CarbonCure software integrates seamlessly with the plant’s batching software

Better Concrete Conference – Ames IA – 10 Nov 2021

Complementary Concrete Technologies

Retrofit technology that operates with no disruption to normal batching procedures

CarbonCure for Ready Mix
CarbonCure for Precast
CarbonCure for Reclaimed Water

CarbonCure for Ready Mix

Retrofit overview

Better Concrete Conference – Ames IA – 10 Nov 2021
Hawkeye Ready Mix

- Design strength 4500 psi
- 564 pcy binder comprising 68% cement, 17% slag, 15% fly ash
- Dose of 0.2% CO₂
- No impact on air
- No impact on slump
- Strength improved 8% at 7 days and 7% at 28 days

Case Study: Iowa City Ready Mix

- 47,800+ yd³ CarbonCure concrete produced
- 11,148 truckloads delivered
- 501 tonnes CO₂ savings achieved

Complementary Concrete Technologies

Retrofit technology that operates with no disruption to normal batching procedures

Concrete Wash Water

NRCA benchmark water numbers scaled to one load

Concrete production
- Batch with 275 gal of potable water
- Batching and mixing
- Ship 10 yd³ concrete

Wash water generation
- Concrete truck returns
- Wash with 254 gal of water
- Wash Water
- Produce 254 gal wash water, including cementitious sludge
Wash water is a **waste product from concrete production** and presents an ongoing logistical, material and economic challenge for producers.

Concrete wash water is often collected in settling ponds. Water is clarified for disposal or reuse.

Sludge removed from ponds

- Primarily binder that has settled from the wash water
- Up to 230 pounds of cement lost per day per truck

Sludge can be an ongoing waste challenge and is often landfilled.

**Recycling Concrete Wash Water as Mix Water**

**Challenges**
- Day-to-day variability
- Strong set acceleration
- Increased water demand
- Outcomes change with both the water age and composition
- **Headaches for producers**
- If practiced, dilution is the solution
**CO₂ Beneficiation of Wash Water**

- **Untreated**
  - Suspended cement particle
  - Hydration products develop and increase with time.

- **CO₂-treated**
  - Suspended cement particle
  - Carbonation products form and arrest hydration
  - \( \text{Ca}^{2+} + \text{CO}_2 \rightarrow \text{CaCO}_3 \)

**Benefits of CO₂ Treated Reclaimed Water**

**Performance**
- Reduced set acceleration
- Compressive strength increase
- Greatly reduced variability with water age

**Producer**
- Makes water demand more consistent
- Reduced or avoided waste streams, landfilling
- Reduced dilution and fresh water
- Mineralized CO₂ is permanently stored

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**Solids from untreated wash water at 1 day**

**Solids in untreated water hydrate with time**

**Solids from CO₂-treated wash water at 1 day**

**Solids in treated water are stable with time**

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CarbonCure for Reclaimed water
Unlocking value from reclaimed water from concrete production

CONVERT WASTES TO VALUE
Reducing the use of virgin materials and minimizing wastes generated from returned concrete

ECONOMIC VALUE
- Reduced demand for virgin cement
- Reduced waste management costs

ENVIRONMENTAL VALUE
- Carbon footprint reduction
- Potential net zero discharge operations

CarbonCure for Reclaimed water
Installation overview

TRIO Ready Mix, Victoria, BC, Canada

Control Box
Early results

- Mineralizing hundreds of kg CO₂ per day
- Slurry recycled as 20 to 60% of the mix water
- Solids at 0.8 replacement for virgin binder
Concrete Production

Before CarbonCure

Concrete Production

Current approach with CarbonCure for Ready Mix

Concrete Production

Stacked Benefit: CarbonCure for Ready Mix & Reclaimed Water

Cement Replacement Opportunities

Control: <1% increase in cementitious solids due to Reclaimed Water usage
n = 17

Cement Replacement Opportunities

Data collected where the slurry solids replaced 2 to 4% of the virgin cement


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.

PERFORMANCE – Early Strength

Study completed

REF – potable water
UNS – untreated slurry
LTS – CO₂ treated slurry, low uptake
HTS – CO₂ treated slurry, low uptake
*F – full cement loading
*R – reduced cement loading

PERFORMANCE – Later strength

- Compressive strength improved 12 to 17% at 28 days at full cement loading
- Compressive strength improved 7 to 14% if proportional replacement of virgin cement with slurry solids
- Consistent strength improvements through 91 days
**DURABILITY – RCPT**

Rapid Chloride Permeability Testing ASTM C1202

<table>
<thead>
<tr>
<th>Condition</th>
<th>REF</th>
<th>UNSF</th>
<th>UNSR</th>
<th>LTSF</th>
<th>LTSR</th>
<th>HTSF</th>
<th>HTSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (days)</td>
<td>94</td>
<td>91</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Charge passed (Coulombs)</td>
<td>250</td>
<td>500</td>
<td>750</td>
<td>1000</td>
<td>1250</td>
<td>1500</td>
<td>1750</td>
</tr>
</tbody>
</table>

Study completed

REF – potable water
UNSF – untreated slurry
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**DURABILITY – Abrasion**

Abrasion ASTM C779

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<th>LTSF</th>
<th>LTSR</th>
<th>HTSF</th>
<th>HTSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average mass loss (g/cycle)</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
<td>2.0</td>
<td>2.5</td>
<td>3.0</td>
<td>3.5</td>
</tr>
</tbody>
</table>

- Validated compressive strength, flexural, GT09, abrasion, RCPT, resistivity, diffusion, shrinkage
- Forthcoming submission to *Cement and Concrete Composites*

**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 CO₂ mineralized concrete

**Thank You**

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Simply better concrete.