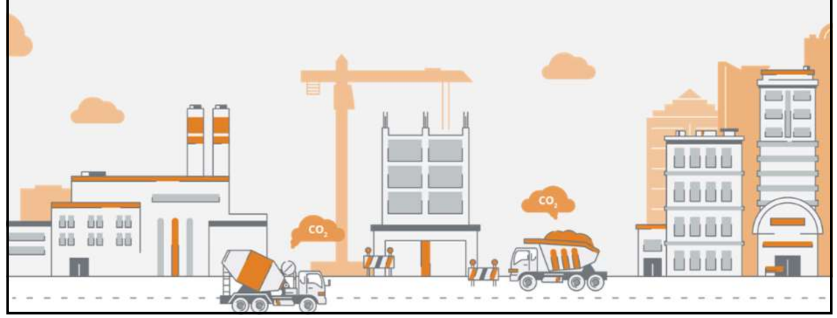
Carbon Dioxide Mineralization in Concrete

SEAN MONKMAN
SVP of Technology Development
CarbonCure Technologies

CARBON CURE

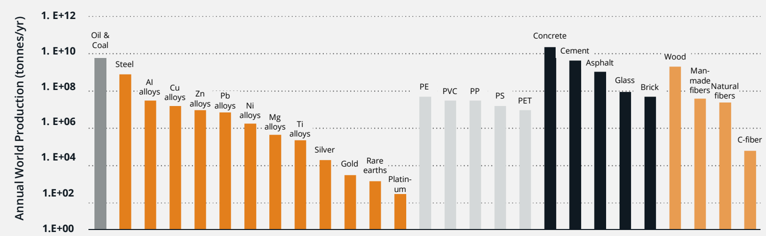
What is Embodied Carbon?

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.

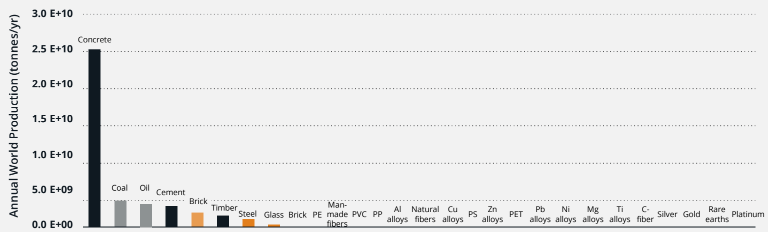
Scale of material production



Source: *"27 Materials on Which Industrialized Society Depends"*
Adapted from Ashby (2013) Materials and the environment, eco-informed material choice. ISBN 978-0-12-385971-6

Scale of material production

Linear scale and sorted

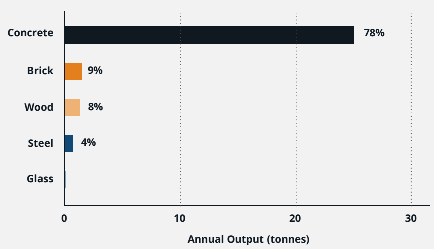


Source: *"27 Materials on Which Industrialized Society Depends"*
Adapted from Ashby (2013) Materials and the environment, eco-informed material choice. ISBN 978-0-12-385971-6

Scale of concrete production

Source: *"27 Materials on Which Industrialized Society Depends"*
Adapted from Ashby (2013) Materials and the environment, eco-informed material choice. ISBN 978-0-12-385971-6

Building materials



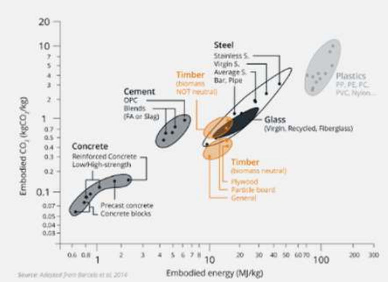
The environmental discussion of concrete *often ignores the scale*.

Concrete is used because it is low-cost, locally-produced, resilient, recyclable and versatile.

Adapted from Ashby (2020) Materials and the environment, eco-informed material choice. ISBN 9780128215265

Concrete: Low Carbon & Energy Footprint

Embodied emissions and energy for construction materials

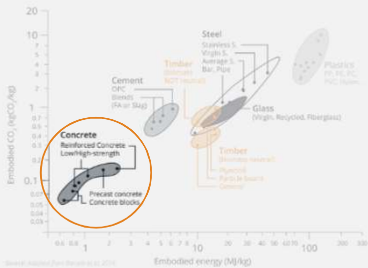


- Cradle-to-gate analysis – includes process emissions, fuel emissions and transport emissions.

Source: Barcelo et al. Cement and carbon emissions. Mater Struct 47, 1055–1065 (2014). doi: 10.1617/s11527-013-0114-5

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

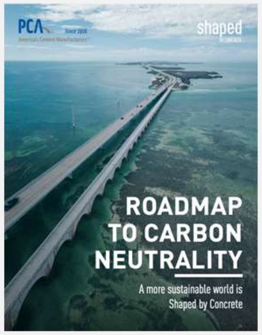
Source: Barcelo et al. Cement and carbon emissions. Mater Struct 47, 1055–1065 (2014). doi: 10.1617/s11527-013-0114-5

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



What is CarbonCure?

CarbonCure's technology beneficially repurposes carbon dioxide (CO_2) to **reduce the carbon footprint of concrete** without impacting performance.

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 CO_2 saved**

Which is equivalent to **159,000+ acres of trees absorbing CO_2 for a year**

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

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

CarbonCure engineers install the proprietary equipment into existing concrete plans

Integration

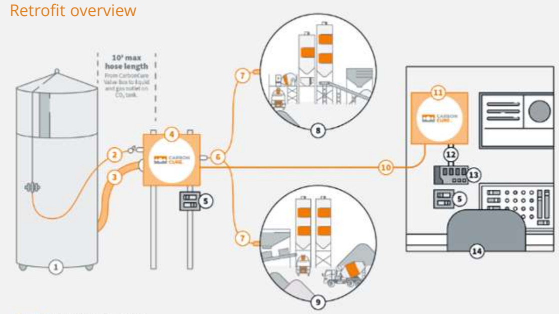
The CarbonCure software integrates seamlessly with the plant's batching software

Injection

The equipment injects a precise automated dosage of CO_2 snow into concrete as it mixes

CarbonCure for Ready Mix

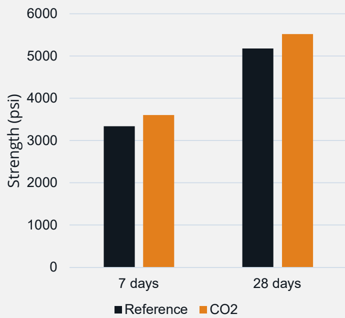
Retrofit overview



1. **Bulk CO_2 Tank** Sized according to anticipated CO_2 usage
2. **Gas CO_2 Transfer Line**
3. **Liquid CO_2 Transfer Line**
4. **CarbonCure Valve Box**
5. **120 VAC Electrical Supply** (5A breaker)
6. **CO_2 Snow Discharge Hoses** 60' max hose length
7. **CO_2 Snow Discharge Nozzles** Mounted to inject inside central mixer or in loading area for dry batch
8. **Ready Mix Plant Central Mixer**
9. **Dry Batch Loading Area**
10. **Communication Cable** Variable Length
11. **CarbonCure Control Box**
12. **18AWG Comm Wires**
13. **Batching Junction Box** Open admixture feed card and pulse card
14. **Control Room**

Orange: Supplied by CarbonCure
Black: Supplied by Concrete Producer
Gray: Supplied by Gas Company

Hawkeye Ready Mix



- Design strength 4500 psi
- 564 pcy binder comprising 68% cement, 17% slag, 15% fly ash
- Dose of 0.2% CO_2
- 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

CarbonCure producer since July 2020

47,800+ yd³
CarbonCure concrete produced

11,148
truckloads delivered

501 tonnes
CO_2 savings achieved

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

XPRIZE CARBON | nrg cosia

Demonstration of this technology won us the global NRG COSIA Carbon XPRIZE competition

Concrete Wash Water

NRCMA benchmark water numbers scaled to one load

Concrete production

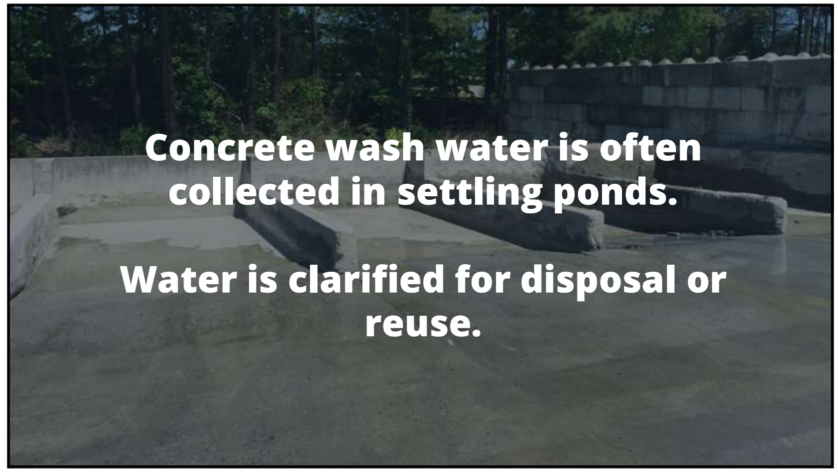
Batch with **275 gal** of potable water → **Batching and Mixing** → → Ship 10 yd³ concrete

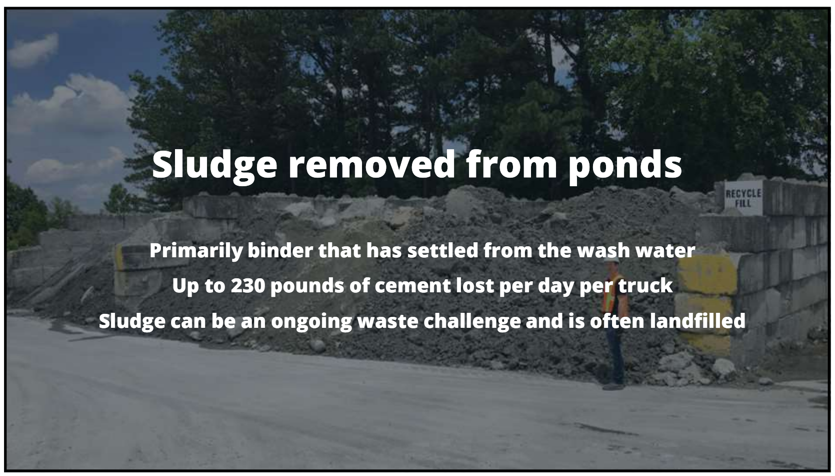
Wash water generation

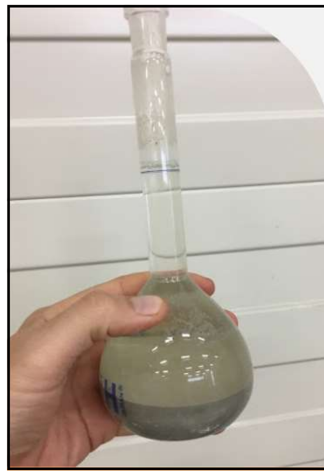
Concrete truck returns → ; Wash with **254 gal** of water → → **Wash Water** → Produce 254 gal wash water, including cementitious sludge

Wash water is a **waste product from concrete production** and presents an ongoing **logistical, material and economic challenge for producers**.

CARBON CURE







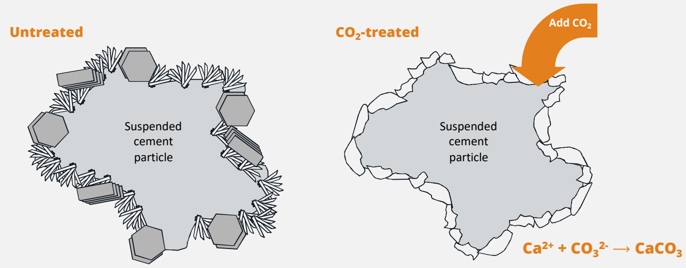
Recycling Concrete Wash Water as Mix Water

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

24

CO_2 Beneficiation of Wash Water



Hydration products develop and increase with time.

Carbonation products form and arrest hydration

Benefits of CO_2 Treated Reclaimed Water

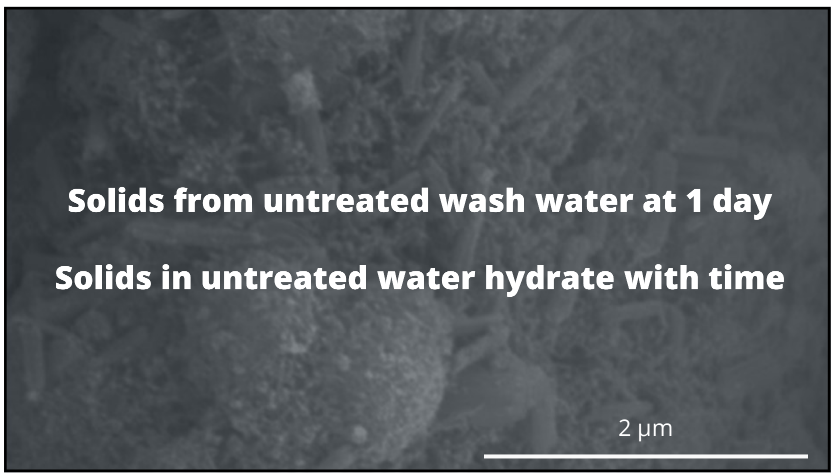
Performance

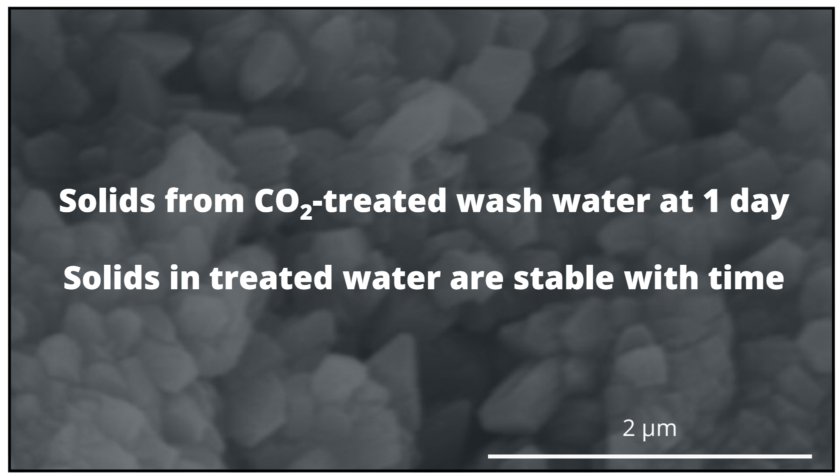
- Reduced set acceleration
- Compressive strength increase
- Greatly reduced variability with water age

Producer

- Makes water demand more consistent
- Reduced or avoided waste streams, landfilling
- Reduced dilution and fresh water
- Mineralized CO_2 is permanently stored

Materials and Structures 54 (2021)
doi:10.1617/s11527-021-01642-9





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

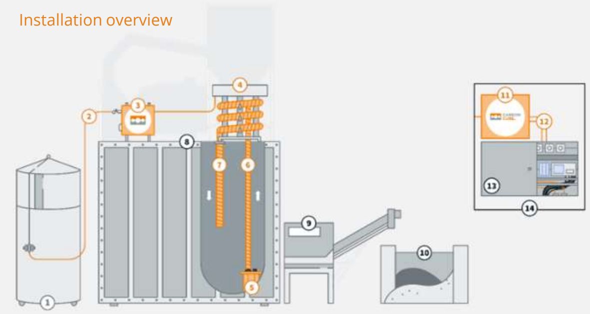
ECONOMIC VALUE
Reduced demand for virgin cement
Reduced waste management costs

ENVIRONMENTAL VALUE
Carbon footprint reduction
Potential net zero discharge operations

CARBON CURE Better Concrete Conference – Ames IA – 10 Nov 2021 29

CarbonCure for Reclaimed water

Installation overview



1. CO_2 Tank — Sized according to anticipated CO_2 usage
2. Gas CO2 Transfer Line
3. CarbonCure Valve Box
4. Reclaimed Water Treatment System
5. Slurry Pump
6. Slurry Infeed Pipe
7. Treated Slurry Return
8. Reclaimed Water Slurry Tank
9. Aggregate Reclaimer
10. Reclaimed Aggregate
11. CarbonCure Control Box
12. Process Monitoring Sensors
13. Reclaimer Control Panel
14. Reclaimer Control Room

Orange: Supplied by CarbonCure
Black: Supplied by Concrete Producer
Grey: Supplied by CO_2 Supplier

CARBON CURE Better Concrete Conference – Ames IA – 10 Nov 2021 30

TRIO Ready Mix, Victoria, BC, Canada

TRIO Ready Mix, Victoria, BC, Canada

CARBON CURE Better Concrete Conference – Ames IA – 10 Nov 2021 32

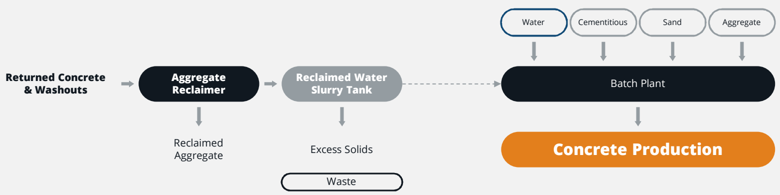
Early results

- Mineralizing hundreds of kg CO_2 per day
- Slurry recycled as 20 to 60% of the mix water
- Solids at 0.8 replacement for virgin binder

CARBON CURE

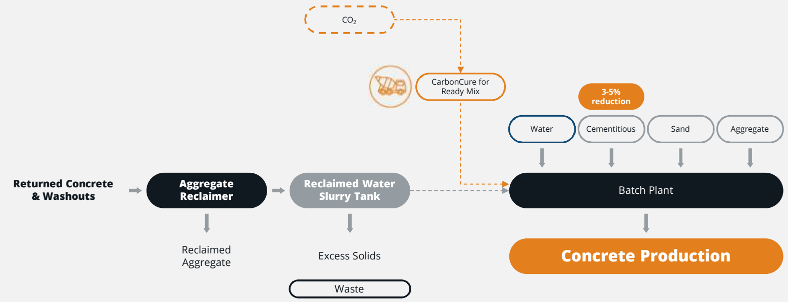
Concrete Production

Before CarbonCure



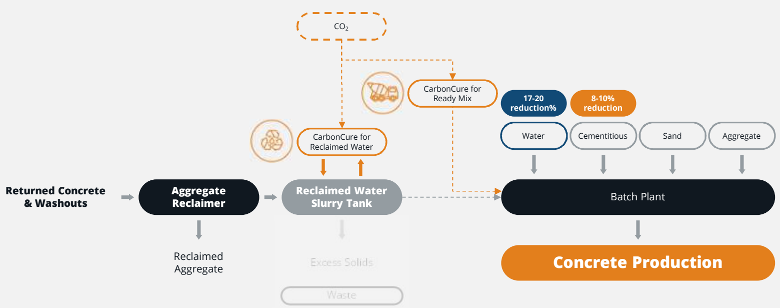
Concrete Production

Current approach with CarbonCure for Ready Mix

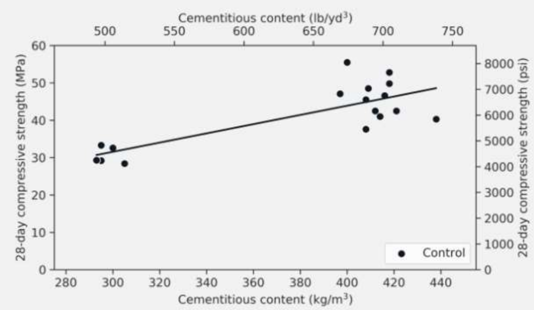


Concrete Production

Stacked Benefit: CarbonCure for Ready Mix & Reclaimed Water



Cement Replacement Opportunities

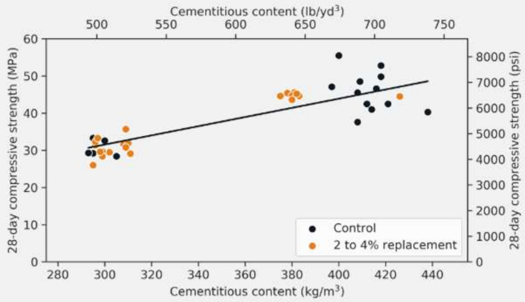


Control: <1% increase in cementitious solids due to Reclaimed Water usage

n = 17

Source: Commercial optimization trials, TRIO Ready-Mix, Victoria, BC (2021).

Cement Replacement Opportunities



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

n = 17

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

n = 21

No change in strength

Source: Commercial optimization trials, TRIO Ready-Mix, Victoria, BC (2021).

CO_2 Supply

CO_2 is captured and distributed to concrete plants by industrial gas suppliers

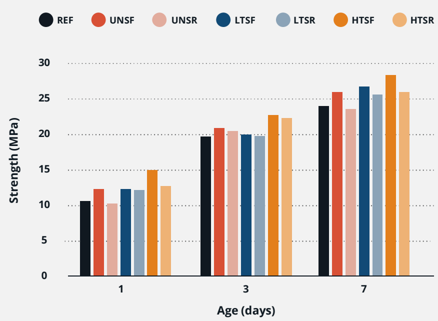
Collection. CO_2 is collected from large emitters.

Purification. The gas is purified by industrial suppliers.

Delivery. The CO_2 is delivered to concrete plants by industrial gas suppliers.

Storage. The CO_2 is stored at concrete plants in pressurized tanks.

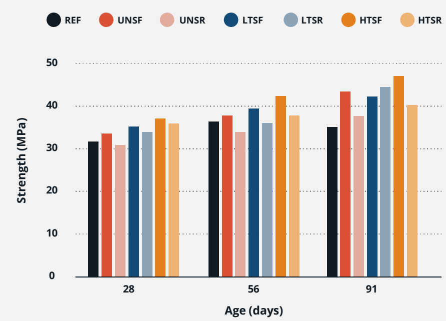
PERFORMANCE – Early Strength



Study completed

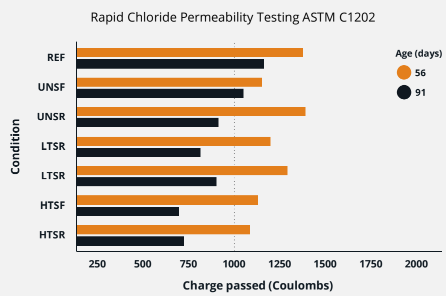
REF – potable water
UNS – untreated slurry
LTS – CO_2 treated slurry, low uptake
HTS - CO_2 treated slurry, low uptake
*F – full cement loading
*R – reduced cement loading

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

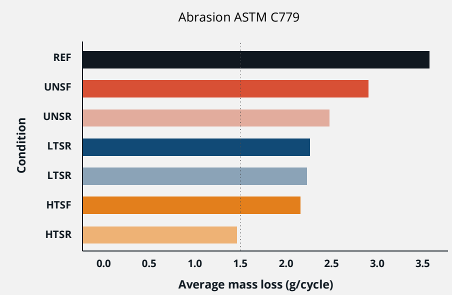


Study completed

REF – potable water
UNS – untreated slurry
LTS – CO_2 treated slurry, low uptake
HTS - CO_2 treated slurry, low uptake
*F – full cement loading
*R – reduced cement loading

CARBON CURE. Better Concrete Conference – Ames IA – 10 Nov 2021 45

DURABILITY – Abrasion



- Validated compressive strength, flexural, G109, abrasion, RCPT, resistivity, diffusion, shrinkage
- Forthcoming submission to *Cement and Concrete Composites*

CARBON CURE. Better Concrete Conference – Ames IA – 10 Nov 2021 46

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**

47

Thank You

Sean Monkman
SVP Technology Development
smonkman@carboncure.com

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

CARBON CURE.
Simply better concrete.