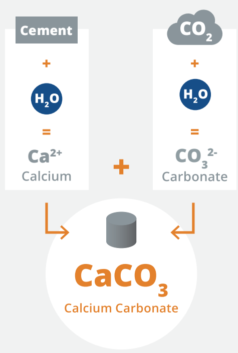
CarbonCure Ready Mix Durability FAQ

What is CarbonCure Ready Mix?

CarbonCure Ready Mix enables concrete producers to reduce the carbon footprint of their concrete mixes without compromising on quality or performance. Using an approach known as ***CO_2 utilization,*** CarbonCure introduces captured carbon dioxide (CO_2) to freshly mixed concrete, where it converts to a solid mineral (calcium carbonate). The addition of CO_2 can improve the compressive strength of concrete without impacting other fresh or hardened properties of concrete, enabling the use of less cementitious materials while achieving equivalent performance.

CO_2 Mineralization in Concrete



CO_2 utilization vs. atmospheric carbonation

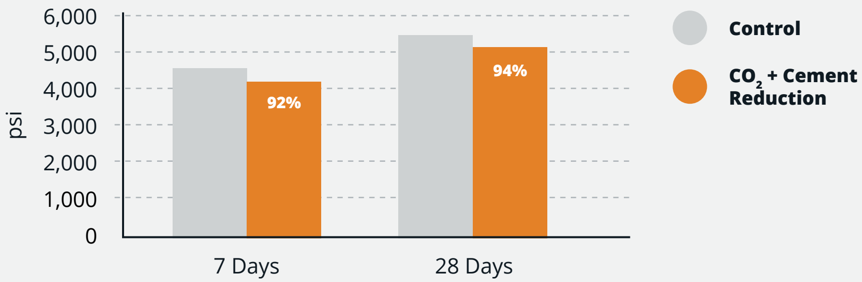
CarbonCure Ready Mix involves the introduction of CO_2 into concrete as it is being batched and mixed. The CO_2 is mineralized in a chemical reaction that occurs alongside the earliest stages of the cement hydration. Subsequent hydration and phase development continue as normal after the CO_2 is added. The introduced CO_2 converts to a solid $CaCO_3$ mineral.

The mineralization reaction central to CO_2 utilization takes place within the first few minutes of hydration, whereas weathering (atmospheric) carbonation takes place in concrete in service over long time scales (e.g., months and years). The latter reaction sees CO_2 from the atmosphere react with cement hydration phases present in mature concrete which compromises durability. The CO_2 utilization process involves a reaction between deliberately added CO_2 and the earliest forming hydration phases and/or clinker phases in concrete that is in the fresh state. The in-situ development of calcium carbonate during can improve the concrete performance. without experiencing the negative effects of atmospheric carbonation.

What is the impact of CarbonCure on the strength of concrete?

Compressive Strength

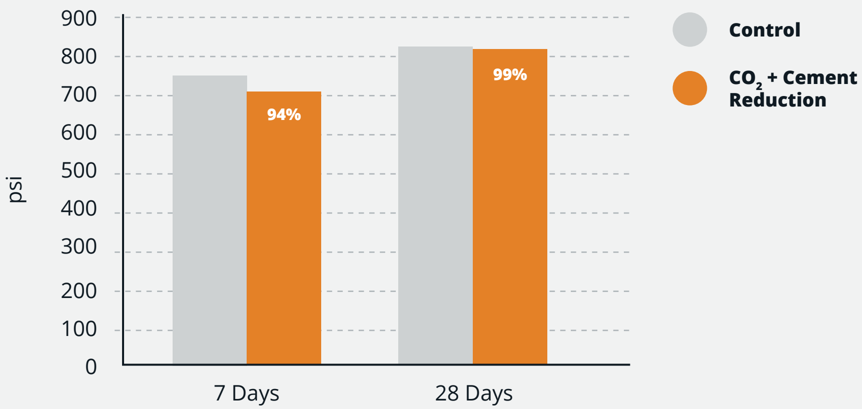
CarbonCure Ready Mix has been observed to provide concrete compressive strength improvements on the order of up to 10% through and beyond 28 days. The improvement can be leveraged to support a reduction of cementitious materials in the mix design without compromising on strength performance.



ASTM C39 test results showing a sample comparison of the compressive strength profile of a 4,000 psi CarbonCure mix with a cement reduction versus a control mix made without CO_2 or cement reduction.

Flexural Strength

The flexural strength of concrete is unaffected by the CO_2 addition. A 4,000 psi CarbonCure concrete mix with a cement reduction demonstrates comparable flexural strength in comparison to a control mix after 28 days.



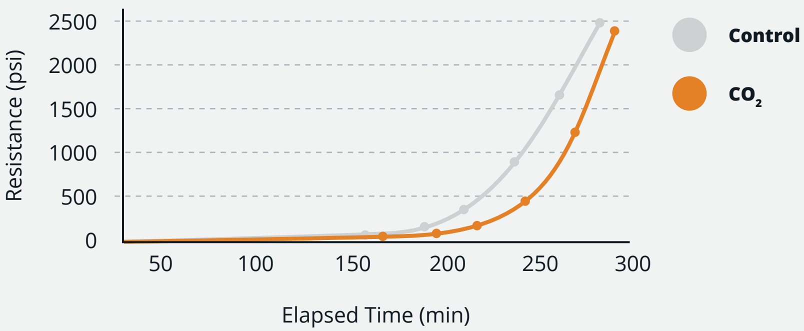
ASTM C78 test results comparing the flexural strength of a 4,000 psi CarbonCure mix with a reduction in cement versus a control mix without CO_2 or cement reduction. After 28 days, the flexural strength is equivalent with the reduced cement mix, indicating that the added CO_2 had no impact on flexural strength.

Frequently Asked Durability Questions

How does CarbonCure influence fresh concrete properties?

Set Time

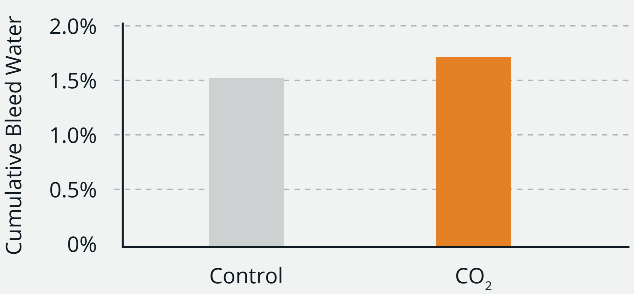
The addition of CO_2 to concrete mixes does not impart any significant change to the concrete set time relative to a control mix as measured by ASTM C403.



ASTM C403 test results comparing the set time of a 4,000 psi CarbonCure mix with a reduction in cement versus a control mix without CO_2 or cement reduction. The CarbonCure mix set within 10 minutes of the control mix, indicating a neutral effect on set time.

Bleed Rate

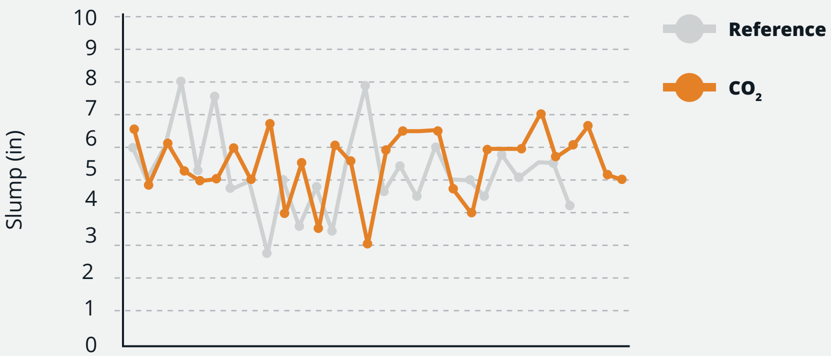
The addition of CO_2 to concrete mixes does not impart any change to the bleed rate of a concrete mix as measured by ASTM C232.



ASTM C232 test results comparing the bleed rate of a 4,000 psi CarbonCure mix with a cement reduction versus an unmodified control mix. The CarbonCure mix demonstrates an equivalent water bleed rate indicating that the CO_2 has a neutral effect.

Workability

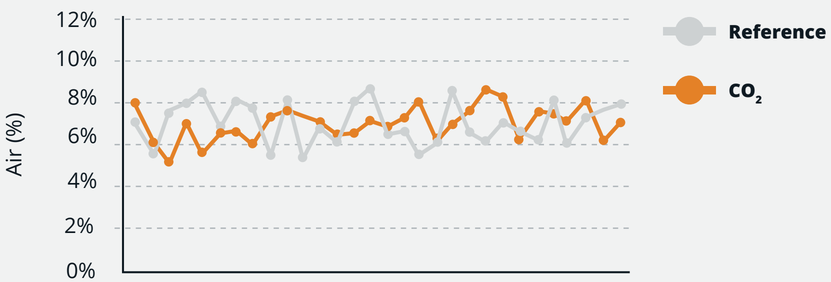
Concrete produced using CarbonCure with a cement reduction maintains desired workability. The CO_2 addition impacts neither the effectiveness of the plasticizing admixtures, the amount of workability, nor the batch-to-batch consistency of the workability.



The slump of concrete produced with CO_2 and a cement reduction is identical to and within the control limits of reference concrete samples.

Air Content

Concrete produced using CarbonCure with a cement reduction maintains desired air content. The CO_2 addition impacts neither the amount of air nor the batch-to-batch consistency of the air.

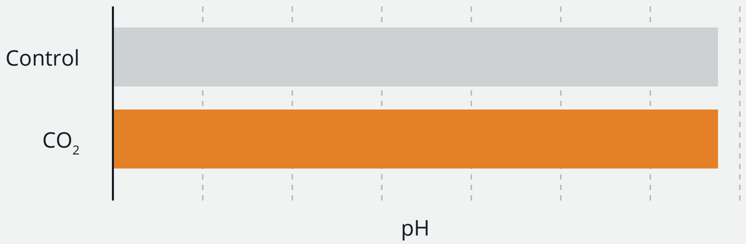


The air content of concrete produced with CO_2 and a cement reduction is identical to and within the control limits of reference concrete samples.

How does CarbonCure influence hardened concrete properties?

pH

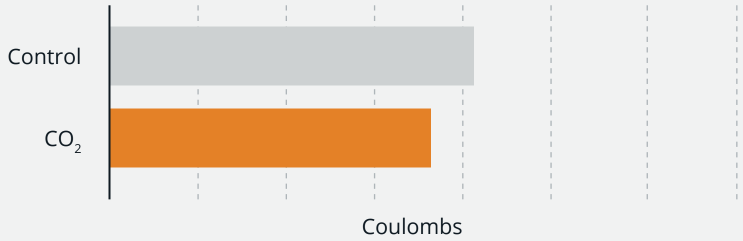
The pore solution pH of concrete produced with CO_2 is equivalent to that of conventionally produced concrete. CO_2 introduced to concrete mixes through the CarbonCure process rapidly converts to calcium carbonate, and there is therefore no reduction in the formation of calcium hydroxide during later hydration that would lead to reduced pore solution alkalinity and pH levels.



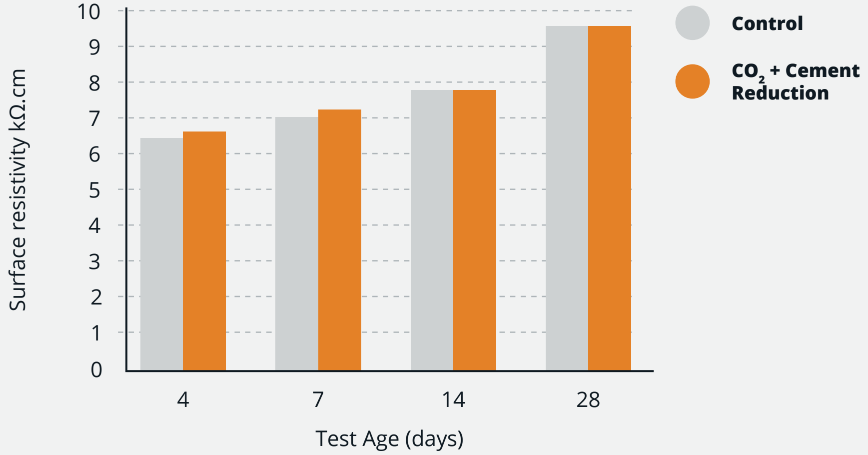
Pore solution pH at 56 days is unchanged by the addition of CO_2.

Chloride Ion Penetrability – RCPT and Surface Resistivity

Concrete samples dosed with CO_2 and a cement reduction, as tested according to ASTM C1202 and AASHTO T358, demonstrated resistance to chloride ion penetration that was equivalent to control concrete mixes.



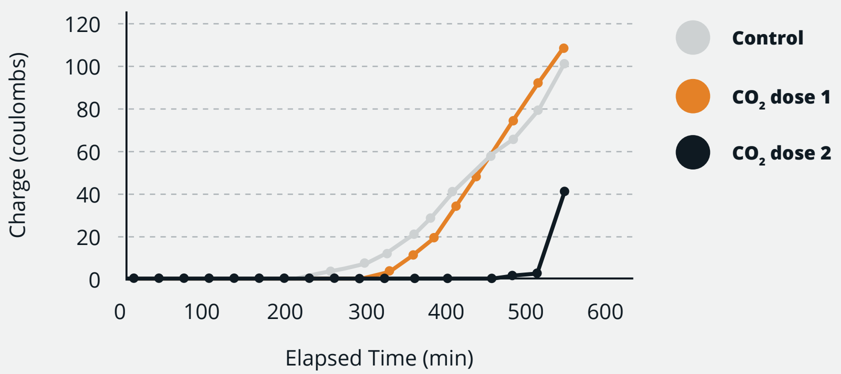
Rapid chloride permeability test (ASTM C1202) results at 28 days show that the performance of concrete produced with CO_2 is equivalent to that of a control concrete sample. A charge passed > 4,000 coulombs is considered to indicate high chloride penetrability while when between 2,000 – 4,000 coulombs it indicates moderate chloride penetrability.



Surface resistivity (AASHTO T358) results show that the performance of concrete produced with CO_2 and a cement reduction is equivalent to that of a concrete sample.

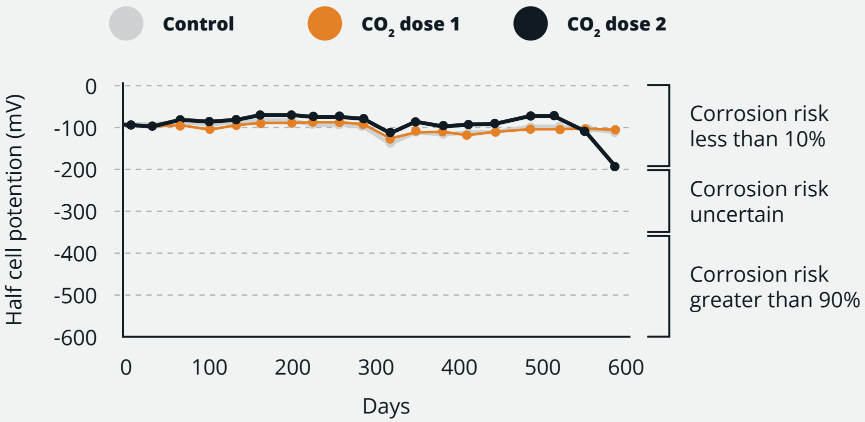
Corrosion Testing

The corrosion performance of reinforced concrete dosed with CO_2 has been examined through testing under ASTM G019 and ASTMC876 (half cell potential). The results indicate that the addition of CO_2 does not affect the corrosion performance of reinforcing steel.



Total Corrosion (ASTM G109) results show that the performance of concrete produced with CO_2 is comparable or better than that of a control concrete mix.

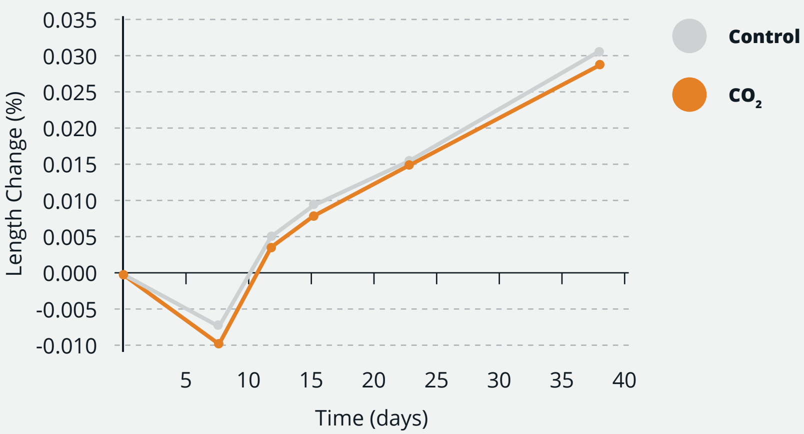
CARBON CURE



Half cell potential (ASTM C876) results show that the performance of concrete produced with CO_2 is comparable to that of a control concrete mix.

Drying Shrinkage

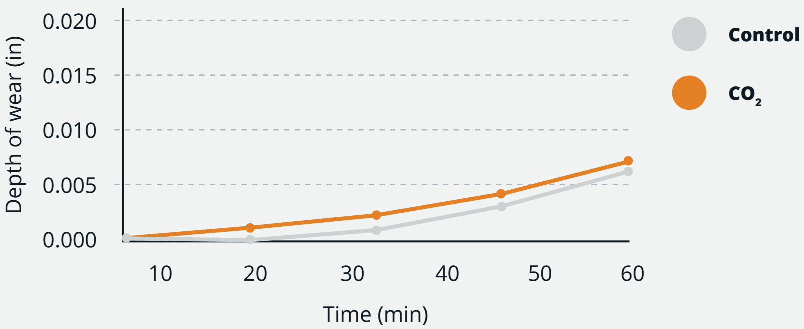
The addition of CO_2 to concrete mixes does not impart any change to the drying shrinkage relative to a control concrete mix as measured by ASTM C157.



ASTM C157 test results comparing the drying shrinkage of a 4,000 psi CarbonCure mix with a cement reduction versus an unmodified control mix. The CarbonCure mix demonstrates a potential reduction in drying shrinkage versus the control mix, indicating a neutral to positive effect.

Abrasion Resistance

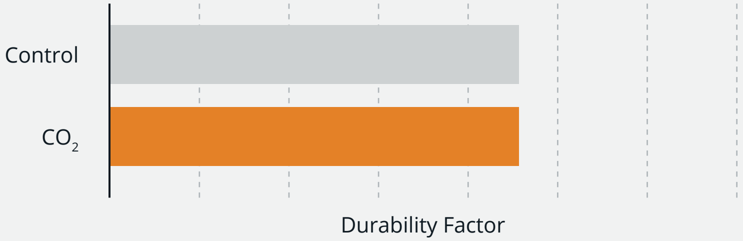
The impact of the CO_2 addition on abrasion resistance has been examined according to ASTM C779. Concrete samples produced with CO_2 and a reduced cement content demonstrate equivalent abrasion resistance to control samples.



ASTM C779 Procedure B test results comparing the abrasion resistance of the finished surface of a 4,000 psi CarbonCure mix with a cement reduction versus an unmodified control mix. After 48 days, the final depth of wear of the CarbonCure mix was within 0.001 inches, indicating a neutral effect.

Freeze-Thaw

The impact of the CO_2 addition on the freeze-thaw durability has been examined according to ASTM C666. Concrete samples produced with CO_2 and a reduced cement content demonstrate equivalent freeze-thaw resistance to control concrete samples.



Freeze-thaw durability of concrete produced with CO_2 and a cement reduction is equivalent to that of a control sample.

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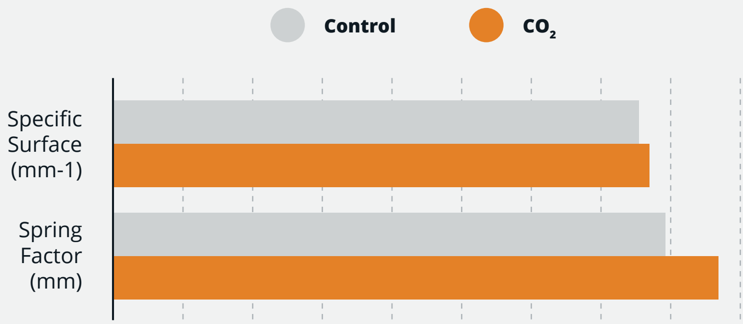
Hardened Air

The impact of the CO_2 addition on the hardened air void characteristics of air entrained concrete has been examined according to ASTM C457. The addition of CO_2 does not impact the effectiveness of air entraining admixtures.



Hardened air void characteristics of concrete produced with CO_2 is equivalent to that of a control concrete mix. For air-entrained concrete designed in accordance with ACI 201.2R and ACI 211.1, the specific surface is usually in the range of 25 to 45 mm^{-1} and then spacing factor is usually in the range of 0.1 to 0.2 mm.

What mix design adjustments are made for a CarbonCure concrete mix?

Cement Reduction

Strength improvements attributable to the CO_2 addition can be leveraged to create a more efficient or optimized concrete mix. Often the adjustment involves a reduction in the cement content of the mix by 4% to 6%. Where the concrete mixes contain supplementary cementitious materials, the total cementitious content is reduced (rather than just a reduction of the cement). For example, if the cementitious materials used in a concrete mix is 20% fly ash and 80% cement, and the use of CO_2 enables a reduction of 20 pounds per cubic yard of cementitious material, the adjusted mix would have 4 pounds less of fly ash and 16 pounds less of cement in keeping with the original ratio of cement to fly ash.

Water to Cement Ratio

Where CarbonCure concrete mixes achieve a reduction in the cementitious material content, the water to cement ratio is necessarily affected as the total volume of water remains unchanged. Typical adjustments to the CarbonCure mixes may see the water to cement ratio increase by 0.02 relative to the equivalent control mix.

Volume and Yield

A reduction in the binder loading achieved by using CarbonCure can serve to reduce the volume of the concrete mix. The volume of concrete supplied is maintained by increasing the amount of fine aggregate by a volume equivalent to that of the removed binder. Alternatively, a cement reduction can be paired with maintaining the paste volume by a replacing it with another binder or filler (e.g., fly ash, slag, limestone, etc.) that has a lower carbon footprint. The total volume of concrete delivered remains unchanged in either case.

Admixture Loading

Where admixtures are dosed on the basis of cement, a reduced cement loading may reduce the quantity of admixtures required to achieve the same performance outcome.

Can CarbonCure be used with other materials, technologies, and approaches to reducing the carbon footprint of concrete?

CarbonCure has been used in thousands of different concrete mixes around the world. Concrete mixes made with traditional Ordinary Portland Cement and commonly used supplementary cementitious materials like fly ash and blast furnace slag are being placed every day.

Comprehensive testing and customer feedback have indicated that CarbonCure is compatible with commonly used admixtures available on the market. The CO_2 addition has not been associated with any performance changes for plasticizing, high-range water reducing, air-entraining or set accelerating admixtures. These admixtures have been regularly used in concrete made with CarbonCure.

How can I use CarbonCure on my project?

Regulations, codes, and standards that govern the purchasing of concrete often rely on the use of prescriptive specifications which set specific limits on how concrete can be made. Although these specifications do not directly restrict the use of CO_2, they can inadvertently create barriers by using requirements that prevent innovation by concrete producers. Common restrictions include:

- Mandated minimum cement requirements
- Overly strict water to cement ratio requirements

Adapting any specifications that you use that set these requirements is critical to empowering innovation and achieving lower carbon concrete products. Consider recommendations for performance-based specifications provided by the National Ready Mixed Concrete Association and guidance provided by Structural Engineers 2050.