TECHNICAL NOTE
Impact of CO_2 Utilization on Concrete Pore Solution pH

Concrete Carbonation

Concrete can be subjected to two distinct types of carbonation. The first is weathering carbonation, which concerns mature concrete reacting over an extended period of time when it is exposed to carbon dioxide in the atmosphere. The second is treatment through carbon dioxide utilization, which involves using carbon dioxide in the production of concrete wherein the reaction occurs at very early ages on fresh concrete. CarbonCure Technologies uses early age carbonation to sequester CO_2 into concrete. The following document examines the impact that the carbon dioxide utilization approach has on pore solution pH.

Pore Solution Alkalinity

Weathering carbonation, or atmospheric carbonation, occurs in concrete when calcium compounds react with carbon dioxide (CO_2) from the atmosphere and water (H_2O) in the concrete pores. The carbon dioxide reacts mainly with calcium hydroxide (typically 25 – 50 % by weight of the cement paste) to form solid calcium carbonate ($CaCO_3$).

The depletion of calcium hydroxide will cause the concrete pore solution pH to drop below 13, potentially as low as 8 for fully carbonated concrete. Concrete with ferrous reinforcement requires a high pH to ensure the stability of the protective passive layer on the surface of the reinforcement. A drop in the pH level can cause the passive layer to deteriorate, thereby making the reinforcement susceptible to harmful corrosion. This is a particular issue if the reinforcement is exposed to aggressive agents such as chloride ions. The corrosion products occupy a greater volume than the original ferrous reinforcement and, in a hardened, mature microstructure, can create internal stresses that cause cracking of the concrete cover.

Exposure conditions, primarily the relative humidity, can have a significant effect on the depth of carbonation and the amount of CO_2 absorbed over time. In general, carbonation only occurs when the relative humidity is between 40 and 90%. If the relative humidity is too low then there is insufficient water in the pores for CO_2 to dissolve to form the carbonic acid needed to react with the calcium compounds. If the humidity is too high then the CO_2 pore network is full of water and ingress of the carbon dioxide is inhibited. When the relative humidity is in a moderate range the conditions are ideal to promote a greater carbonation depth and thus a higher CO_2 absorption.

Carbon dioxide utilization uses a carbonation reaction during the early hydration of the cement. This carbonation approach can involve calcium that, on balance, would otherwise have hydrated to form calcium hydroxide and contribute to high pH. However, the early age carbonation does not hinder

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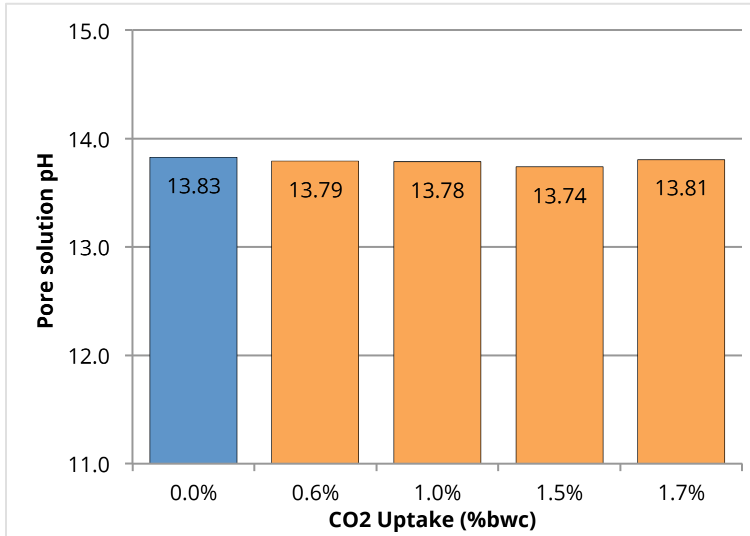
the long-term development of the concrete microstructure as the concrete matures. Therefore, calcium hydroxide will develop during later hydration and the pore solution pH development continues as normal once the carbonation application ends.

Research conducted by CarbonCure Technologies (at right) has shown that an carbon dioxide utilization process has a minimal effect on the pH of the pore solution of mature concrete. Paste samples were created with varying levels of carbonation (expressed as CO_2 content by weight of cement) that were achieved through a carbon dioxide injection during mixing. The paste was then cast into cylindrical specimens and moist cured. The pore solution was extracted at 28 days and the pH was measured. The impact was minimal and suggests no risk of depassivation of ferrous reinforcement.



Pore solution pH of carbonated paste samples

Context

The widely held notion that "carbonation is deleterious for concrete" is specifically rooted in the harmful effects of weathering carbonation on mature hydrated microstructures. Conversely, early age carbonation involves different chemical reactions affecting an immature microstructure. The attendant material and environmental benefits of the carbon dioxide-cement interaction can be leveraged with a carefully considered carbonation approach.

CarbonCure Technologies focuses on using early age carbonation to sequester CO_2 in the cement paste to produce better concrete. While concrete carbonation has long been only considered to negatively impact concrete as a building material, the use of CO_2 now enables the development of a 'green' concrete building material.

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