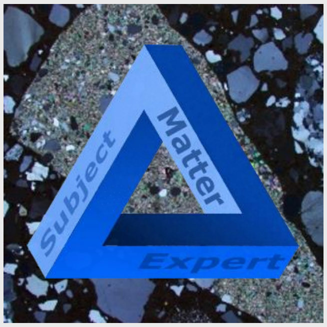
Carbonation of Concrete and Oxidation of Embedded Steel



Dr. Christopher R. Kelson, PhD, PG
Senior Geologist
Atlantic Testing Laboratories

Aging concrete structures, such as parking garages or building foundations, often exhibit signs of distress. Cracking, spalling, delamination, and exposed or corroding reinforcing steel are some common examples. There can be several factors leading to these conditions. In this article, we will discuss carbonation and its effect on concrete and embedded steel over time. We will also highlight common methods for evaluating concrete that can prove helpful in determining mitigation and repair strategies for a structure.

Carbonation of concrete is a natural process in which portlandite ($Ca(OH)_2$) within the cement paste is gradually converted to calcite ($CaCO_3$) due to the formation of carbonic acid (H_2CO_3) from water (H_2O) and carbon dioxide (CO_2) via the following reactions:

$$\mathbf{H_2O + CO_2 \rightarrow H_2CO_3 \text{ (carbonic acid)}}$$
$$\mathbf{H_2CO_3 \text{ (carbonic acid)} + Ca(OH)_2 \text{ (portlandite)} \rightarrow CaCO_3 \text{ (calcite)} + 2H_2O}$$

CO_2, H_2O, and H_2CO_3 are natural components of our atmosphere, and pores within the concrete also contain H_2O. The rate and extent that concrete paste is carbonated is dictated by several factors, including cement type, degree of hydration, and water/cement ratio; the permeability, porosity, and location of the concrete (exterior vs. interior); environmental conditions (e.g., humidity, temperature); and how much surface area of the concrete is exposed to those environmental conditions. The rate of carbonation for a dense (less permeable) concrete made with a low water/cement ratio is generally more gradual than a less dense (more permeable) concrete made using a high water/cement ratio. Cracks and fractures within the concrete expedite the rate of carbonation by allowing CO_2 and H_2CO_3 to penetrate the concrete more easily. Over time, and at a decreasing rate, the carbonation front gradually extends progressively deeper into the concrete from the exposed surface.

The process of carbonation physiochemically alters cement paste by decreasing its permeability and lowering its pH. The decrease in permeability renders the concrete less susceptible to the infiltration of solutions which may contain chemicals detrimental to the concrete such as deicers, acids, chlorides, and salts. Carbonation also tends to increase the compressive and tensile strength of concrete. However, carbonation lowers the pH of cement paste from ~13 to ~9 which nullifies the passivity layer that surrounds and protects embedded steel items (e.g., reinforcement, pipes, conduits) from exposure to oxygen and water. Removal of the passivity layer renders embedded steel items susceptible to oxidation and corrosion due to the formation of secondary products such as iron oxide (rust) which causes the surrounding concrete to expand, crack, and ultimately fail.

If you have concrete that is deteriorated or failing, ATL can assist in evaluating the impact of carbonation and effects from other potential causes of deterioration by performing visual and physical examinations, ultrasonic evaluation, petrographic analysis, chloride testing, and compressive strength testing.

For more information, contact Dr. Christopher Kelson, PhD, PG at [315-386-4578](tel:315-386-4578), info@atlantictesting.com, or visit AtlanticTesting.com.

ASSOCIATED SERVICES

[ASTM C856 Petrographic Examination of Hardened Concrete]()

[ASTM C457 Determination of the Air-Void System in Hardened Concrete]()

[ASTM C295 Petrographic Examination of Aggregates for Concrete]()

[Petrographic and Microanalytical Identification of Rocks, Minerals, and Construction Materials]()

OFFICES