



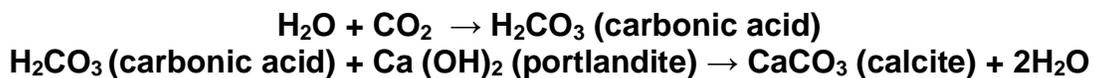
# Carbonation of Concrete and Oxidation of Embedded Steel



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

Do you have a structure that is exhibiting signs of distress, such as spalling concrete with exposed and corroding reinforcing steel? There can be several factors leading to this condition. 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 ( $\text{Ca}(\text{OH})_2$ ) within the cement paste is gradually converted to calcite ( $\text{CaCO}_3$ ) due to the formation of carbonic acid ( $\text{H}_2\text{CO}_3$ ) from water ( $\text{H}_2\text{O}$ ) and carbon dioxide ( $\text{CO}_2$ ) via the following reactions:



$\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and  $\text{H}_2\text{CO}_3$  are natural components of our atmosphere, and pores within the concrete also contain  $\text{H}_2\text{O}$ . 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  $\text{CO}_2$  and  $\text{H}_2\text{CO}_3$  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.

## 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



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 examinations, petrographic analysis, compressive strength testing, and/or ultrasonic evaluation.

For more information, contact Dr. Christopher R. Kelson, PhD, PG at 315-386-4578 or [CKelson@AtlanticTesting.com](mailto:CKelson@AtlanticTesting.com).

This document is for general informational purposes only and is provided with the understanding that the authors are not herein engaged in rendering professional advice or services. Site specific circumstances make each project unique. As a consequence, information in this document may be incomplete, inaccurate, or inapplicable to particular situations or conditions. Any use of this information should take into account all relevant factors and sources of information applicable to a project. We do not accept responsibility for any omission, inaccuracy, or error in this document, or any action taken in reliance thereon.