FAQs*

Reported by ACI Committee 364, Rehabilitation. FAQs and responses have passed through ACI's full consensus process, including review by the TAC Repair and Rehabilitation Committee, which oversees and coordinates issues related to repair and rehabilitation for the Institute.

FREQUENTLY ASKED QUESTION:

A reinforced concrete façade has been investigated and the concrete has been found to be carbonated to an average depth of 1.5 in. (38 mm). Given a concrete cover of 2 in. (51 mm), should remedial measures be considered to arrest further carbonation in the concrete? If not, what are the implications for the future performance of the façade?

SIGNIFICANCE:

When concrete or any other cement-based material in contact with the embedded reinforcing steel is carbonated, the steel surface is depassivated. Therefore, the reinforcing steel is no longer protected from corrosion. Corrosion may then commence when moisture and oxygen gain access to the steel surface.

ANSWER:

The decision to protect the concrete façade should be based on the expected life of the building. Remedial measures to protect the reinforcing steel should be considered if the intent is to prolong the remaining service life of the façade. At early ages, steel reinforcement is protected from corrosion by the high alkalinity of the surrounding cement paste. The protective passive layer is stable and adherent in this range of alkalinity. However, alkalis in concrete eventually react with acidic components of the atmosphere, particularly carbon dioxide (CO_2). As a result, the alkalinity of the concrete is progressively reduced by converting the calcium hydroxide to calcium carbonate. This conversion reduces the pH value of the concrete below 10, thus reducing the concrete's protective ability. This reaction of carbon dioxide with the products of cement hydration is defined as carbonation.

The carbonation is not a linear function, the rate changes with time and depth. The natural process of carbonation in good quality concrete is very slow—on average about 0.04 in. (1 mm) a year.[1] Thus, after 35 years, the depth of carbonation in the concrete façade can be estimated at approximately 1.5 in. (38 mm). Given this rate, carbonation in the remaining 0.5 in. (13 mm) of concrete cover will take about 12 years.

The rate of carbonation is mainly influenced by the permeability and the calcium content of the concrete as well as the ambient atmospheric conditions: amount of carbon dioxide, relative humidity, and temperature. Concrete carbonates more rapidly in a hot climate than in a moderate climate.

*Frequently Asked Questions

Carbonation has an adverse effect on the degree of concrete alkalinity and its ability to protect the reinforcement. Physical effects of carbonation within the concrete are usually positive—carbonation of mature concrete densifies its structure, increases strength, and reduces permeability. However, carbonation increases shrinkage of concrete that is fully matured, which can cause additional cracking.

If cracking is present in the concrete façade, carbonation may be substantially deeper in localized areas. Cracks in the concrete allow carbon dioxide easy access through the concrete cover, and the carbonation occurs. The active coefficient of carbon dioxide diffusion in a concrete crack 0.008 in. (0.2 mm) wide is about three orders of magnitude (1000 times) higher than in average-quality crack-free concrete.[2] Cracked areas should be included in tests to determine the depth of carbonation.

Methods such as coatings or sealers will help to protect reinforcing steel by reducing the ingress of moisture into the concrete. The corrosion process can be stopped by incorporating cathodic protection.

Selection of carbonation remediation measures for the building façade is complicated by the fact that long-term performance data are lacking for most commercially available systems. Nevertheless, there are benefits for using one of the commercially available anti-carbonation systems. Most of these systems are elastomeric and, if detailed properly, have the capacity to bridge small moving cracks. The following factors should be considered:

- The rate of vapor transmission through the exterior wall;
- The amount of moisture in the façade;
- The breathability of the protective system; and
- The temperature gradient between the concrete surface and ambient air while the protective coating is curing. If the concrete temperature is below that of the dewpoint of the surrounding air, moisture will condense on the concrete surface.

If the concrete cover adjacent to cracks is completely carbonated, then it is too late to protect against carbonation. Therefore, access of moisture and oxygen to the reinforcement should be minimized. This access can be minimized by sealing or injecting cracks, provided corrosion of the reinforcing is not present. Additional guidance on carbonation of concrete is available in ACI 201.2R-01.[3]

References:

1. Vaysburd, A. M.; Sabnis, G. M.; and Emmons, P. H., "Concrete Carbonation—A Fresh Look," *Indian Concrete Journal*, V. 67, No. 5, May 1997, pp. 215-220.

2. Alekseev, S. N., and Rosenthal, N. K., *Resistance of Reinforced Concrete in Industrial Environment*, Moscow, Stroyisdat, 1976.

3. ACI Committee 201, "Guide to Durable Concrete (ACI 201.2R-01)," American Concrete Institute, Farmington Hills, Mich., 41 pp.