

Problem **Exposed reinforcing steel**

Reinforcing steel is visible on the concrete surface. Exposure may occur in any type of reinforced-concrete structure.



formed it. The advancing ice front in saturated concrete pushes water in front of it. However, the small pores in the concrete resist the flow of water, producing pressure within the concrete. The farther the water must flow before reaching an escape boundary, the higher the pressure. In air-entrained concrete with many small air bub-

Prevention

The keys to preventing corrosion in reinforced concrete are providing adequate concrete cover depth and preventing or slowing chloride entry by using sealers or membranes or by reducing concrete permeability. Another option is changing the corrosion threshold by using a corrosion-inhibiting admixture or epoxy-coated, galvanized, or stainless reinforcing steel.

To prevent freeze-thaw damage, provide good drainage and the proper amount of entrained air in the concrete. Run air tests at the jobsite to make sure the concrete has the air content specified and ordered.

References

ACI 222R-96, "Corrosion of Metals in Concrete," American Concrete Institute, Farmington Hills, Mich., 1996.

ACI 201.2R-92, "Guide to Durable Concrete," ACI, 1992.

T.C. Holland, "Corrosion Protection for Reinforced Concrete," *Concrete Construction*, March 1992, pp. 230-236.

Ken Hover, "Why Is There Air in Concrete," *Concrete Construction*, January 1993, pp. 11-15.

Causes

Exposed reinforcing steel may result from deterioration within the concrete or from errors during construction. Here, we cover the first cause. We'll cover construction errors in another issue.

When concrete deterioration exposes rebar, the problem usually is the result of steel corrosion, freeze-thaw damage, or both.

Corrosion. Corrosion within concrete most often results from the slow buildup of chloride ions at the level of the reinforcing steel. Once the chloride level reaches the corrosion threshold value (about 0.20% by weight of cement for acid-soluble chloride),

protection naturally afforded to the reinforcing steel by the high alkalinity of the concrete is lost, and corrosion begins.

Corrosion is a progressive process that forms different kinds of iron oxide. Each of these iron oxides takes up slightly more volume than the previous form. After all available space within the concrete is filled with corrosion products, stresses begin to develop and ultimately exceed the tensile strength of the concrete. This leads to concrete cracking and the loss of cover concrete, thus exposing the reinforcing steel.

Freezing and thawing. When ice forms in concrete, it occupies 9% more volume than the water that

bubbles, the bubbles provide enough escape boundaries to keep pressures low enough to avoid damage. But in non-air-entrained concrete or concrete with an inadequate air-void system, pressures exceed the concrete's tensile strength, and cracking occurs, followed by disintegration that exposes the steel.

For concrete exposed to freeze-thaw cycles and deicing salts, both corrosion and freezing-induced pressure within the concrete can cause damage. Corrosion can produce small cracks in the cover concrete that can fill with water. When this water freezes, expansion caused by ice formation pops off the concrete.

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