Problem Carbonation

Reaction between carbon dioxide and a hydroxide or oxide to form carbonate, especially in cement paste, mortar, or concrete

Causes

There continues to be a great deal of confusion about concrete carbonation, probably because the subject itself is confusing. Carbonation can occur while the concrete is plastic or after it has hardened. While similar reactions are taking place, their effects are very different.

Carbonation in the plastic state usually develops during cold-weather construction. Typically, the structure has been closed in, but the central heating plant has not yet been installed. When installing the floor slab, the contractor will often choose to heat the interior of the structure with combustion heaters that are not vented to the outside. Current practice is to use propane-fired heaters. The heaters produce a great deal of carbon dioxide as part of the products of combustion. Carbon dioxide, or CO_2, being a relatively heavy gas, tends to settle down to the floor. Carbon dioxide is also fairly soluble in water, and it enters the mix water readily.

Carbon dioxide by itself is not reactive, but when it enters the mix water and goes into solution, it becomes carbonic acid. This reacts with the calcium hydroxide in the mix water, which is necessary for the development of strength in the cement paste, to form insoluble calcium carbonate. If this reaction is carried far enough, no calcium hydroxide is left in solution to react with the silica and alumina to form the hydrates that give concrete its strength. Typically, the result is a soft layer that can be removed with finger pressure. It is normally only about 1/8 inch thick, but that is the surface that was to resist traffic, and it has lost that ability. The repair is never easy or economical.

Prevention

To avoid this unfortunate situation, provide a means of exhausting the combustion products to the outside, usually by forcing them through a long, mostly horizontal, chimney that acts as a large radiator. The cost of fuel will increase somewhat, but it will be infinitesimal compared with the cost of repairing a carbonated surface.

Remediation

The contractor has only two possible choices for rectifying this problem—both expensive. The first is to remove the soft layer and replace it with a polymeric mortar. The second is to remove and replace the entire slab. Which one is more economical must be determined on a case-by-case basis.

After the concrete has hardened, carbonation actually benefits strength development. Ancient mortars depended on the reaction of burned limestone and carbon dioxide for their strength. However, if carbonation proceeds to the depth of the reinforcing steel, it can instigate corrosion by destroying what is called *the passive layer*. The passive layer consists of a tight, thin layer of iron oxide that prevents further corrosion until carbonation or leaching has reduced the pH enough to make the layer unstable. Chloride ions also have this effect, but they are much more aggressive, and they assist in the development of an electrochemical cell. But that's another story.

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Modern oil- or propane-fired heaters can be vented to avoid carbonation of concrete surfaces.