Ask Dr. Galv

Q One of my customers is specifying hot-dip galvanized rebar for a new bridge. However, he is concerned about possible reactions between the zinc coating and the concrete. Are there any problems that can arise from such reactions, and is there anything special we can do to limit these reactions?

A The reactions between galvanized reinforcement bars and concrete are only of concern during the initial curing stages of the concrete. The initial stages of curing include the time when the concrete mix is still wet. During this time the pH of the concrete is very alkaline with a pH of approximately 12.5. The wet concrete reacts with the zinc to form hydroxyzincates ($Ca[Zn(OH)_3] \times 2\ H_2O$), which protects the zinc from further corrosion, but can evolve hydrogen gas. Excessive hydrogen evolution during curing results in a more tenuous interface between the galvanized steel and the concrete, thus reducing the bond strength. Using concrete mixes with extremely high pH's may increase these reactions to unacceptable levels. Wet concrete mixes with a pH of over 13.3 have shown to significantly increase the reactions between concrete and galvanized rebar and should be avoided if possible without chromates.

The reactions that occur during the initial curing phases of the concrete can be limited by the use of chromate. Chromating the galvanized steel has shown to limit the reaction between the concrete and the zinc, thus reducing the amount of hydrogen evolved. Chromate can either be applied to the rebar directly after galvanizing by dipping, or small chromate additions can be made to the concrete mix. The amount of chromate that is added to the concrete remains in question. One study suggests that as little as 20 ppm of chromate will limit the reactions. However, it may prove beneficial to provide excess chromate (100 ppm) to ensure that the reactions between the galvanized rebar and concrete are limited.

After the initial curing stages of the concrete, the reactions between the concrete and the galvanized steel cease. Once the concrete has hardened, the only access that corrosive compounds have to the galvanized rebar is through the pores of the concrete matrix. This allows the galvanized rebar to provide protection for many years.

Beyond providing long-term corrosion protection, galvanized rebar poses many other chemical advantages over black rebar. The corrosion products of steel occupy a much larger volume than the metal from which they originate. The voluminous corrosion products of black steel exert a tensile stress on the surrounding concrete. Over time, these corrosion products build up pressure on the surrounding concrete. When the pressure exceeds the tensile strength of the concrete, cracking and spalling of the concrete occurs. The cracking of the concrete creates passageways that allow further corrosive media, such as chloride salts, to enter and cause further corrosion of the rebar. While the corrosion products of zinc also occupy a larger volume than its parent metal, they have been shown to disperse into the surrounding concrete matrix, unlike black rebar's. Increased pressure due to these corrosion products is not as substantial as with black rebar and is less likely to cause cracking of the concrete.

Laboratory studies have shown that other concrete design factors affect the corrosion rate of zinc. Slightly higher corrosion rates are seen as the water-to-cement ratio of the concrete increases. Also, a thicker concrete-cover above the galvanized rebar has shown to reduce its potential of reacting with carbonation reaction products, such as calcium carbonate, that may permeate into the concrete matrix.

If damaged, galvanized rebar should not be repaired using compounds that contain aluminum. Aluminum is not stable in concrete and may cause other reactions with concrete.

I hope this answer provides "concrete" evidence that galvanized rebar, when used correctly, will protect your customer's bridge for generations.

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