Innovations Deserving Exploratory Analysis Programs

NCHRP IDEA Program

Enhanced Performance Zinc Coating for Steel in Concrete

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Final Report for NCHRP IDEA Project 174

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Enhanced Performance Zinc Coating for Steel in Concrete IDEA Program Final ReportContract Number: NCHRP-174

1 IDEA PRODUCT 1.1 INTRODUCTION

Current and future designs for bridges and other reinforced concrete structures exposed to deicing or marine chlorides requires improved corrosion resistance of the reinforcing steels in combination with higher quality concrete. Several stainless steel alloys are believed to have good performance, but the material costs are several times that of conventional black steel. In addition, though only the outer surface of the steel needs protection, the entire bar is made of alloys using premium raw materials.

A more sustainable approach considering initial material costs would be to use black steel with a protective coating, such as in hot-dipped galvanized (HDG) or epoxy-coated bars (ECR). If these bars provide enhanced corrosion protection, there can be a reduction in the overall life cycle cost versus black steel or stainless steel, using holistic approaches addressing the overall performance of the bar as a function of concrete properties and concrete cover over the bars, as performed in life-cycle modeling. These bars are subjected to mechanical damage in placement and in use to due to cyclic loading of the concrete and the development of cracking. The potential for hydrogen embrittlement and coating application temperature limits the use of hot-dipped galvanized coating on some higher strength reinforcing bars that are desired for more efficient designs. Epoxy-coated reinforcement requires longer embedment lengths, and its lower bond might offset the use of higher strength steel bars.

1.2 PRODUCT

The product that was the focus of investigation is a reinforcing bar with a thermal zinc diffusion (TZD) coating, with and without a supplemental organic coating. This TZD coating should have excellent bond to the steel as does the HDG coating, but is applied at lower temperatures than hot-dip galvanizing. This allows TZD coatings to be applied to higher strength steels without negative effects on the strength properties. It has a more porous surface than hot-dipped galvanized so that it should have a better bond to the concrete and is an excellent substrate for paint. The coating is significantly thinner using less zinc.

1.3 POTENTIAL IMPACT ON TRANSPORTATION PRACTICE

TZD-coated reinforcement will have a significantly lower initial cost than stainless steel reinforcement, and can be applied to all strength grades of steel, allowing for potential additional savings where the designer can use higher tensile strengths to reduce the amount of reinforcing bars needed. When used with higher strength bars and lower permeability concrete, TZD could potentially lower the overall upfront and service life costs for bridges versus alternative reinforcing bar options.

2 CONCEPT AND INNOVATION

A process of applying zinc to steel via thermal diffusion has been developed by Distek, NA, and has been in commercial use since 1993. The bars in this study were produced in the United States and coated in Michigan. The coating deposition temperatures (700–780°F) are lower than that in hot-dip galvanizing (840°F), but zinc-iron intermetallic phases form resulting in a metallurgical alloy bond between the zinc overlay and the steel substrate. The process results in a metallurgical conversion of the exterior surface into a porous zinc/iron alloy. The thermal diffusion process provides a very uniform coating that retains the original geometry of the part, as can be seen in Figure 1. It is hard and wear- resistant, and can withstand the rough handling and storage conditions generally expected in the field, as well as exhibiting ductility in bending and forming. Also, the thermal process is not susceptible to hydrogen embrittlement. Tests comparing the performance in severe salt environments with and without abrasion show a 5 to 10 times improvement in performance with the TZD-coated steel versus HDG steel. Steel coated by this method is covered by ASTM A 1059 Standard Specification for Zinc Alloy Thermo-Diffusion Coatings (TDC) on Steel Fasteners, Hardware, and Other Products. Bars can be produced in lengths of 60 ft.

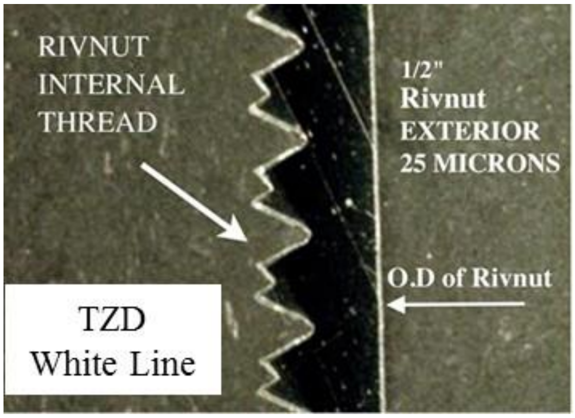

FIGURE 1 Example of how TZD coating maintains the original geometry. Cross section of the nut shows that the internal threads are coated and maintain the thread geometry with a 25-micron coating (bright surface).

Applying TZD to reinforcing bars is a recent application for this technology. The coating is not as thick as the zinc coating in HDG reinforcing bars, which helps to reduce cost and should help in workability. It has excellent abrasion resistance, based on current uses on chains used by the U.S. Navy, and the surface porosity should improve reinforcement bond to the concrete. The higher porosity should be beneficial for a two-component coating where the top coat would be an organic coating.

As noted earlier, the coating is very uniform even over ribs in the bars and is a low-temperature process. This could potentially be applied to higher strength reinforcement. This could potentially result in improved cracking behavior and a reduction in the cross-sectional requirements for the steel. The TZD coating applied to higher strength (grades 75 to 100) reinforcing bars could provide cost savings (less steel required), offsetting the initial upfront cost of the bars, where designs allow for reducing the required reinforcement for higher tensile strength reinforcement.

Summary:

The advantages to considering the use of TZD and TZE are:

- Equal to or lower cost than HDG at better performance
- Improved bond, potentially reducing crack width and migration of chlorides to bottom matt bars under surface cracks.
- Improved welding
- Low application temperatures which allow it to be applied to higher strength reinforcing bars to increase strenrgth

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