Current Status of Coated Reinforcing Steel

By David McDonald, Ph.D., P.E., FACI

Coated reinforcing steel is widely used to provide corrosion protection to reinforced concrete against the effects of deicing and marine salts and carbonation. In North America, approximately 10 percent of all reinforcing is coated. Coated reinforcing steel utilizes the existing reinforcing bar stock and is available in sizes from 0.375 to 2.25 inches and in strengths from 40 to 80 ksi.

Due to the relatively low cost of coating technologies, distributed manufacturing is possible. Over 35 epoxy coating facilities are currently certified by the Concrete Reinforcing Steel Institute (CRSI) and many galvanizing plants are available.

Types of Products

ASTM recognizes the following types of coated bars, wire and welded-wire reinforcement:

- Epoxy-coated (ASTM A775, A884, A934)
- Galvanized (ASTM A767)
- Dual-coated (ASTM A1055)
- Vinyl-coated (ASTM A933)

Epoxy-coated reinforcing steel is the most widely used coated bar in North America. It is manufactured by passing cleaned and heated steel through a cloud of epoxy powder. This powder is drawn to the bar surface by electrostatic forces where it fuses, forming a continuous coating layer.

Most manufacturing plants in North America are certified by CRSI, which randomly inspects manufacturing facilities to ensure that they have processes, staff and equipment to produce high quality materials. ASTM standards have developed during the past 40 years by including thicker coatings and appropriate surface cleanliness and roughness properties.

Vinyl-coated bars are coated in a similar manner to that of epoxy-coated bars, except that the coating material consists of a vinyl polymer. However, these bars have not found significant commercial utilization.

Dual-coated bars are manufactured by spraying prepared reinforcing steel with a zinc alloy, then coating the bars with an epoxy, in a similar manner to that of epoxy-coated reinforcing steel. Several agencies have chosen to use these bars in standard specifications, including Florida and Vermont. Demonstration projects are also being conducted in many states.

Galvanized reinforcing steel is manufactured by placing properly prepared reinforcing bars into molten zinc. The finished product consists of various zinc-iron and zinc layers. Several plants outside North America use a process that applies zinc alloy coatings to reinforcing steel in a continuous process, and an ASTM specification for this process is under development.

Stainless steel clad reinforcing bars have been utilized in concrete structures, but these are not currently commercially available. Laboratory work has also been conducted on ceramic-coated reinforcing bars, but as of yet have not been utilized in concrete structures.

CRSI recently produced a *Specialty and Corrosion-Resistant Product Guide*, which is a useful reference for available reinforcing products.

Research

Significant research has been conducted on the effectiveness of coated reinforcing steel. It is recognized that a weakness of coated reinforcing steel is damage to the coating. Generally, research on these products has been conducted using bars that are damaged prior to placement in concrete. In comparing the two leading types of coating, laboratory research has found that epoxy-coated reinforcing steel performs better than galvanized reinforcing bars when subjected to deicing salts. Notwithstanding, both types of coated bars perform better than uncoated reinforcing steel.

Field studies in Bermuda found good performance of galvanized steel (Kinstler, 1999); however, mixed conclusions were reached in Iowa when it was compared with epoxy-coated reinforcing steel (Kraus, et al., 2014). This may be largely due to the effects of steel and concrete chemistry on the formation of passivating layers in these materials. The continuously processed galvanizing product has not been extensively used, and it is too early to determine how this product performs compared with other products.

Field and laboratory research on A1055 dual-coated bars is limited, but preliminary data shows improved performance compared with other products (Accardi, 2010) due to protection provided by the zinc to the underlying steel at coating damage locations. Several agencies, including Florida and Vermont Departments of Transportation permit use of the dual-coated bars under certain circumstances and many other agencies have demonstration projects using this product.

In the 1980s, concerns were raised regarding the performance of epoxy-coated steel in Florida; however, these performance concerns were isolated to certain structures where poor concrete and poorly applied reinforcing bar coatings were used (Sagüés, et al., 2009). The studies also found that the observed corrosion distress was isolated to less than 10 bridges out of the 300 bridges in Florida containing epoxy-coated reinforcing in their substructures. The majority of these structures are predicted to have a 100-year design life.

The observations of distress in Florida in the 1980s prompted review of coated materials by

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other agencies. Recent reports from New York, Michigan and Nebraska DOTs on the performance of epoxy-coated reinforcing steel all indicate substantial long-term benefits (Agrawal, 2006; Boatman, 2010; Hatami, 2012). For example, statistical analyses by Boatman on almost 1800 Michigan bridges estimated the life of bridges using uncoated bars would be 35 years compared with 70+ years for decks containing epoxy-coated reinforcing.

Bond of coated reinforcing in concrete is as important as the type of coating material, and this has been extensively researched. The governing conclusion is organic coatings do not adhere to concrete as well as metallic coatings. Most design codes provide for increased development length for organic-coated reinforcing steel including epoxy-coated, dual-coated, and vinyl-coated bars.

Future Directions

Future research on organic coatings will focus on increased toughness, surface adhesion to steel and flexibility. These systems are largely based upon epoxy materials that are currently available to the steel pipeline industry and include use of multiple coats of epoxy materials that have different flexibility and abrasion properties. The ongoing research of metallic coatings will expand to various types of passive materials and ceramic coatings, for their durability and low cost of the raw materials.

Future research on coated bars will also focus on the long-term field performance of these products, as it is difficult to determine product life from short-term laboratory tests. Several studies have been conducted using state bridge inventory data and statistical methods, such as Markov Analysis, to determine the life of coated reinforcing compared with that of uncoated bars. Other studies are being conducted as part of the current FHWA Long Term Bridge Project, which includes extensive evaluation of decks around the country. Additional data is also being collected as bridges age. This is particularly true for epoxy-coated reinforcing bars as the oldest bridges containing epoxy-coated bars are only 40 years of age and very few have deteriorated in that time.▪

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