Engineering Technical Note

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Frequently Asked Questions (FAQ) about Epoxy-Coated Reinforcing Bars

Introduction

CRSI routinely receives inquiries concerning various aspects of reinforcing bars, and reinforced concrete design and construction. This *Technical Note* presents a collection of typical questions that are asked regarding epoxy-coated reinforcing bars. Most of these questions come from licensed design professionals (LDPs), namely engineers and architects, field personnel (inspectors, code enforcement personnel, and contractors), and state DOTs.

Epoxy-coated reinforcing steel is defined by ASTM A775/A775M *Standard Specification for Epoxy-Coated Steel Reinforcing Bars* as reinforcing bars with protective epoxy coating applied by the electrostatic spray method. Additionally ASTM A934/A934M *Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars* covers deformed and plain steel reinforcing bars which prior to surface preparation are prefabricated and then coated with a protective fusion-bonded epoxy coating by electrostatic spray or other suitable method.

Epoxy-coated reinforcing bars are the most commonly used corrosion-resistant reinforcing bar reinforced concrete projects due to corrosion-resistance, and cost. Figure 1 shows one example of the use of epoxy-coated reinforcing bars on a bridge deck on I-294 near Chicago.

Specific frequently asked questions (FAQ) and responses are provided below.

Basic Material Characteristics

What Standards govern epoxy-coated reinforcing bars?

Epoxy-coated reinforcing steel bars should be specified according to ASTM A775/A775M *Standard Specification for Epoxy-Coated Steel Reinforcing Bars* or ASTM A934/A934M *Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars.* ASTM D3963 *Standard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars* covers the fabrication and field installation of epoxy-coated reinforcing steel.

What reinforcing bars do the ASTM standards permit to be coated?

ASTM A775/775M and ASTM A934/A934M permit bars meeting ASTM A615/A615M *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*, A706/A706M *Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement* and A996/A996M *Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement* to be coated. Bars meeting ASTM A615/A615 M are available in strength grades of 40, 60, 75 and 80 [280, 420, 520, 550]. Bars meeting ASTM A706/A706M are available in strength grades of 60 and 80 [420 and 550]. Bars meeting ASTM 996/A996M are not as readily available as the other two steel types, but Type R bars are available in strength grades of 50and 60 [350 and 420], while Type A bars are available in strength grades of 40 and 60 [280 and 420].

What are the available sizes of epoxy-coated steel reinforcing bars?

Epoxy-coated reinforcing bars are available in all of the U.S. conventional bar sizes and the metric sizes used in Canada. U.S. bar sizes are #3 through #11, #14, and #18. Metric sizes in Canada are 10M, 15M, 20M, 25M, 30M, 35M, 45M, and 55M.

How are the types of epoxy-coated reinforcing bars identified?

While there is no requirement for the color of coatings used for either ASTM A775/A775M or ASTM A934/A934M bars, in general, a green color coating is used to identify bars that meet ASTM A775/A775M while a purple or gray color coating is used to identify bars that meet ASTM A934/A934M. Typical bar markings on the steel are readily visible on the epoxy-coated bars through the coating. ASTM A775/A775M and A934/A934M require that the identification of all steel reinforcing bars be maintained throughout the coating and fabrication processes to the point of shipment.

Do epoxy-coated reinforcing bars have the same weight per foot as normal "black" carbon reinforcing steel bars?

Yes, epoxy-coated reinforcing bars have the same weight per foot as normal "black" carbon reinforcing steel bars.

What is a fusion-bonded coating?

Fusion bonding refers to the process used to apply the coating the reinforcing steel. The steel is cleaned and the surface heated to 400° to 450°F and then passed through an electrostatic spray containing fine epoxy powder. The powder is attracted to the bars based upon electrostatic forces. When the epoxy encounters the heated bars it melts and fuses forming a thermosetting polymer. The resultant coating is significantly more uniform in thickness than could be achieved other methods, such as coating or dipping.

Availability and Cost

How is the epoxy-coated reinforcing bar available?

Epoxy-coated reinforcing bars are readily available from over 35 CRSI Certified Manufacturing Plants throughout North America. A listing of certified plants may be found at http://www.crsi.org/index.cfm/certification/plant. Approximately 10 percent of

all reinforcing steel is epoxy-coated and the most commonly available product is Grade 60 in both ASTM A615/A615M and A706/A706M coated according to ASTM A775/A775M.

What is the availability of epoxy-coated reinforcing bar? What are the lead times necessary to order and get the bar fabricated?

Epoxy-coated reinforcing bar is readily available from over 35 different CRSI Certified manufacturing plants. Purchasers are encouraged to inquire with a local fabricator about lead times for specific grades, sizes, and quantities early in the project schedule. For the most current CRSI certified Epoxy-Coated Steel Reinforcing Bar Manufacturers please see www.crsi.org under the Certification tab.

What is the cost of epoxy-coated reinforcing bar compared with normal "black" bar or other corrosion resistant bars on the market?

As a trade organization, CRSI does not comment on costs and costs will vary by location and with the price of uncoated reinforcing steel. Manufacturers or suppliers should be contacted for current pricing information.

Where can I purchase Epoxy-Coated Steel Reinforcing Bar?

Epoxy-coated steel reinforcing bars are produced and inventoried nationwide. Currently, over 35 plants are certified under the CRSI Fusion-Bonded Epoxy Coating Applicator Plant Certification Program.

Is Epoxy-Coated Steel Reinforcing Bar environmentally friendly?

Epoxy-Coated Steel Reinforcing Bar have the following sustainable attributes:

- Manufactured using reinforcing bars that are made using almost 100% recycled steel
- Can be readily recycled after use
- Manufacture using low amounts of energy compared with other systems
- The coating process produces no VOCs during manufacture or use
- Structures that use epoxy-coated steel reinforcing bar are more durable that those that do not
- Epoxy-coated bars are locally available

Engineering Design Issues

What are the yield and tensile strengths of epoxy-coated reinforcing bars?

Bars meeting ASTM A615/A615 M are available in strength grades of 40, 60, 75 and 80 ksi [280, 420, 520 and 550]. Bars meeting ASTM A706/A706M are available in strength grades of 60 and 80 ksi [420 and 550]. Bars meeting ASTM 996/A996M are not as readily available as the other two steel types, but these are available in strength grades of 40, 50, and 60 [280, 350 and 420].

Are there any special design guidelines for epoxy-coated reinforcing bars in ACI 318 or AASHTO?

ACI 318 *Building Code Requirements for Structural Concrete* and AASHTO *LRFD Bridge Design Specifications* generally treat epoxy-coated reinforcing bars the same as carbon steel reinforcing bars in terms of structural design except that additional development length is generally required.

Can epoxy-coated reinforcing bars be mixed with other reinforcing steel bars?

Epoxy-coated bars can be used in structures with other reinforcing steel bars; however, when using epoxy-coated reinforcing steel in decks it is recommended that all the deck steel is coated as this will reduce the overall rate of corrosion if the coating is damaged.

In piers, the use of epoxy-coated reinforcing steel should be continued into an area above the splash zone to minimize corrosion risks.

Can the clear cover distance to epoxy-coated bars be reduced? Will this translate into a savings in the concrete weight material cost?

The AASHTO *LRFD Bridge Design Specifications* permits a reduction in concrete cover when epoxy-coated reinforcing steel is used, while the ACI 318 *Building Code Requirements for Structural Concrete* does not permit a reduction in concrete cover when epoxy-coated reinforcing steel is used.

Is development length increased of epoxy coated rebar?

The development length is the length of bar embedded in concrete required to obtain yield of the steel. This value is increased for epoxy-coated reinforcement as the coating could reduce the bond to the concrete by 15%.The increased development length has been well established by testing and is included in design codes such as ACI 318 *Building Code Requirements for Structural Concrete* and AASHTO *LRFD Bridge Design Specifications*.

What is the effect of damage on the bar performance?

Epoxy-coated reinforcing steel without damage will perform better than bars with undamaged coatings; however, field and laboratory data has shown that even bars with damage perform significantly better than uncoated bars. Essentially all tests evaluating epoxy-coated reinforcing steel are conducted using bars with deliberate damage to simulate worst-case situations.

Do epoxy-coatings degrade in concrete?

Epoxy-coatings are stable in high pH materials and do not degrade in concrete. Coated bars removed from bridges in West Virginia after 35 years were examined using scanning electron microscopy (SEM). These bars did not exhibit surface cracking. Some discontinued formulations of epoxy coatings developed surface crazing prior to placement into concrete, while modern epoxy formulations do not.

Is it better to lap splice or mechanically couple epoxy-coated reinforcing bars?

Epoxy-coated reinforcing steel may be spliced using either lap splices or mechanical couplers. Use of the particular method depends on many factors and this will likely become an economic decision. For the smaller bar sizes, the "extra" length of epoxy-coated steel bar to facilitate the splice requirements will likely be cheaper than the selected coupler. For the larger bar sizes, the coupler becomes more economical than the "extra" length of bar used to make the splice. A mechanical coupler may, however, be a better alternative given job specific constructability conditions, congestion issues, and/or spacing requirements. ACI 318 *Building Code Requirements for Structural Concrete* or AASHTO *LRFD Bridge Design Specifications* provisions may also influence this decision.

What types of couplers are available?

Many mechanical couplers are commercially available in standard size threaded couplers. Some of these are coated with epoxy-coating, while others are uncoated and protected using a water-proof sleeve at the jobsite. As with any coupler, test data should be utilized to determine suitability of available products.

Are there any issues to using couplers with epoxy-coated steel bars?

When couplers are used, they should be inspected for any coating damage prior to placement of concrete. If damage is observed, the steel should be lightly cleaned to remove any surface corrosion and coated with an approved two-part epoxy coating, formulated for use with epoxy-coated reinforcing steel.

Fabrication

What shapes can epoxy-coated reinforcing bars be bent?

Epoxy-coated reinforcing steel meeting ASTM A775/A775M can be fabricated into the entire array of standard bend shapes found in the CRSI *Manual of Standard Practice* (2009) and ACI 315 *Details and Detailing of Concrete Reinforcement (*1999). The bars are bent to the same diameters as conventional carbon steel reinforcing bars.

Bars meeting ASTM A934/A934M should only be bent after coating with the permission of the engineer and any damage to the coating should be repaired using a two-part epoxy repair material.

Fabrication of epoxy-coated reinforcing bars uses the same process as for carbon reinforcing steel bars except the bending pins are covered with a polymer outer wrap. However, the contact surfaces of equipment used to fabricate or handle stainless steel bars should be protected using plastic or other material to protect the bars against damage.

Do sheared ends of epoxy coated bars need to be coated after shearing?

All exposed steel should be coated using a two-part epoxy. Generally, end coating is conducted as part of standard fabrication practices.

Construction Handling

Are there any special handling requirements for epoxy-coated reinforcing steel?

The fabrication and field handling of epoxy-coated reinforcing steel is covered by ASTM D3963 and in the Appendixes of ASTM A775/A775M or A934/A934M. Further information is also found in the CRSI Publication *Specialty and Corrosion-Resistant Steel Reinforcement: A Product Guide* and from the Epoxy Interest Group of CRSI (www.epoxyinterestgroup.org).

Recommendations include:

- When lifting individual bars or bundles of epoxy-coated reinforcing bars, spreader bars or strong backs with multiple pick-up points shall be used to minimize sags.
- Synthetic or padded slings should be used and at no time should epoxy-coated reinforcing bars be lifted using bare chains or cables.
- Bundles of epoxy-coated reinforcing bars should be stored off the ground on suitable materials, such as timber cribbing.
- Epoxy-coated reinforcing bars should be stored separately from uncoated carbon steel reinforcing bars to prevent abrasion of coating.
- During storage and shipping, all contact points (e.g. trailers, storage racks) should be wood or plastic-lined.
- Epoxy-coated reinforcing bars should be covered using opaque polyethylene sheeting or other suitable opaque material if they are to be stored outdoors for more than two months.
- Epoxy-coated bars should be protected against coating damage through appropriate lifting, handling, placing and concrete placement operations.
- During placement, bars should be lifted and set in place.
- Epoxy-coated reinforcing bars should not be dragged into place and other materials shall not be dragged across placed epoxy-coated reinforcing bars.
- Movement of personnel and materials across the epoxy-coated bars should be minimized.

- Prior to concrete placement, epoxy-coated bars should be inspected and damaged coating repaired with a two-part epoxy material meeting ASTM A775/A775M or A934/A934M.
- Plastic-headed vibrators should be used to consolidate the concrete.

Additional information may be found at www.epoxyinterestgroup.org

Do I need to use special accessories (e.g., supports, ties, etc.) if I am using epoxy-coated reinforcing bar?

When placing coated steel reinforcing bars, all wire bar supports, spacers, and tying wire should be coated with dielectric material, for example, an epoxy-coated or plastic coated material compatible with concrete.

Are there any storage issues on the project site that could impact the use of epoxy-coated reinforcing bar?

Epoxy-coated reinforcing steel should be stored separately from carbon steel to prevent damage. Stored bars should be elevated off the ground on timber dunnage.

Can I weld epoxy-coated reinforcing steel?

According to the CRSI Manual of Standard Practice reinforcing steel should be welded according to the American Welding Society, AWS D1.4/D1.4M *Structural Welding Code – Reinforcing Steel*. If the steel used for the coated bars meets ASTM A706/A706M, the bars are intended for welding without preheating and therefore should be specified for applications that require an appreciable amount of welding.

ASTM A615/A615M reinforcing bars can be welded, but may require preheating the bars up to 500° F. After completion of the welding on epoxy-coated bars, the damaged

areas shall be repaired using patch materials meeting ASTM A775/A775M or A934/A934M.

How long can epoxy coated rebar be exposed to UV light before damage is done to the epoxy material?

ASTM D3963 requires that: *"Placed coated bars shall be covered with opaque polyethylene or similar protective material if cumulative environmental exposure of the coated bars, including previously uncovered storage time, of greater than two months prior to concrete embedment is expected."*

The provision for two-months of exposure was developed from testing conducted by C-SHRP where bars were left exposed and then tested. (See: http://www.cshrp.org/products/outdoor.pdf) It is known that extended exposure is often unforeseen and that bars may be exposed for longer periods than that suggested by ASTM D3963. Fusion-bonded epoxy coatings may undergo surface discoloration and chalking from exposure. Should extended exposures occur, it is strongly recommended that the bars be carefully inspected and any site of damage or localized corrosion be repaired following ASTM D3963 using a two-part epoxy, recommended for use on epoxy-coated steel reinforcing.

Coating Repair

Will a small area of damaged epoxy coating increase the rate of corrosion or focus the corrosion to the area of damaged coating?

Field evaluations of epoxy-coated reinforcing steel has shown that if corrosion does occur , it could cause bond loss of the coating to the steel, if an actual cathodic/anodic cell were to develop. Focused corrosion in the area of damage that may compromise the structural performance does not generally occur.

Can a "Rebar Green" pressurized spray can to repair epoxy coated rebar?

The epoxy-coating reinforcing steel industry does not recommend use of 1-part spray coating materials to repair damaged areas or sheared ends of bars. These coatings generally cannot be applied to adequate thicknesses and tend to be more porous than two-part materials.

What is the appropriate method of repairing or touching up epoxy coated rebar?

The process for repairing damaged coating on epoxy-coated reinforcing steel involves cleaning any corrosion off the bars at the damage site using a wire brush followed by application of a two-part epoxy repair material, typically using a paint brush.

When doing a spall repair or concrete patch on an existing concrete structure, what is the best way to repair the existing epoxy coated reinforcing bar?

If epoxy-coated reinforcing steel is exposed during concrete repair, the exposed areas of steel on the coated bars should be field coated or new bars spliced into the repaired area to minimize the ability of those bar sections to become cathodic to the adjacent steel in concrete. While field coating will provide less protection than plant coated reinforcing, the addition of the field coating will provide additional protection. Generally the concrete used in repair areas is better than that of the existing structure.

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Note: References listed above were used in the development of this document. Because these documents are updated on a frequent basis, the year has generally been omitted in the text for clarity. The licensed design professional is referred to the respective organization for the latest revisions and applicable year of adoption.

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Figure 1 – Epoxy-coated reinforcing steel bar used in the deck of a bridge structure located in Illinois. (Photo Courtesy of the Epoxy Interest Group of CRSI)