Raising the Reinforcing Bar: Introducing Textured Epoxy Coating

Textured epoxy coating has the potential to significantly improve bridge life spans

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A new approach to coating steel reinforcing bar has the potential to change a core aspect of concrete bridge construction. Known as textured epoxy coating (TEC), this novel technology is the subject of a newly approved specification: ASTM A1124, *Standard Specification for Textured Epoxy-Coated Steel Reinforcing Bars*.[1] The standard covers surface preparation, material application, coating thickness, and testing, among other requirements. As a secondary coating, TEC provides added protection for epoxy-coated reinforcing bar (ECR), commonly referred to as "green bar," which is the industry's leading corrosion-protection solution.

The application of TEC to reinforcing steel bars is a two-step, but nearly simultaneous, process in which bars pass through two powdered-coating application steps in a row. Uncoated bars are first blasted to remove surface contamination. Then the bars are heated before passing through the ECR application booth. There, a powdered fusion-bonded epoxy coating is sprayed onto the heated bar and immediately melts into a liquid coating that flows over every surface. The heated bar then moves through the TEC application booth, where a high-performance, textured fusion-bonded epoxy coating is sprayed over the first coating layer. As this textured powder melts and flows over the bar surface, it covalently bonds with the ECR layer, creating a monolithic coating despite the application taking place in two steps. The thickness and roughness of the applied coating material will vary depending on the parameters of the reinforcing bar usage as defined in the ASTM A1124 specification.[1]

In corrosion resistance, bond strength, and damage tolerance, TEC offers significant improvements over both ECR and uncoated reinforcing bar (black bar).[2–6] While various factors influence a bridge's life span, TEC has the potential to extend asset life, making a strong case for its cost-effective use to benefit taxpayer-funded infrastructure projects. Preventing structural deterioration can delay the need for bridge replacement or extend required maintenance cycles, often resulting in substantial cost savings and avoiding the environmental impacts of construction and maintenance projects. TEC also offers sustainability advantages because it is made with repurposed, "upcycled" materials that might otherwise go to a landfill. In addition, TEC may enable the use of alternative cementitious technologies, as concrete ingredients to date have typically been limited to those that do not corrode uncoated reinforcement.

Globally, most reinforcing bars remain uncoated, owing to the expense and various drawbacks associated with ECR (these drawbacks are discussed later). Applied to a green bar, TEC adds an extra layer of protection to ECR and increases an asset's durability. Recent research shows that TEC presents an opportunity to harness the benefits of coating reinforcing bar, while enhancing outcomes for concrete projects.[2–6]

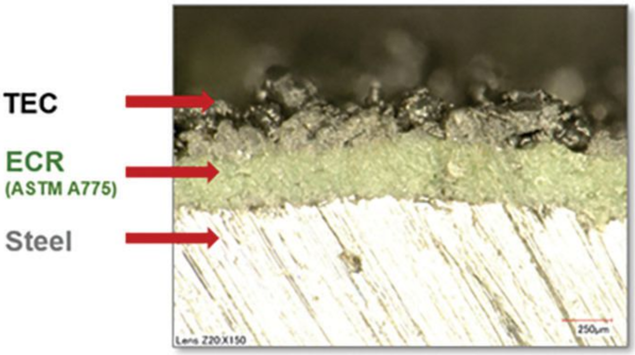
Improving Corrosion Resistance

The interface of reinforcing bar to concrete is critical. While ECR offers a layer of corrosion protection for the uncoated bar, its smooth surface reduces the bond interaction between the concrete and the steel reinforcement.

When a TEC is applied along with an epoxy coating, there are multiple benefits. The two layers cure together and covalently bond, creating a

Textured epoxy-coated reinforcing bar (left) and uncoated reinforcing bar (right) have comparable rib texture and bond strength. All Photos: The Sherwin-Williams Company.

Textured epoxy coating applied to reinforcing bar adds an extra layer of protection and durability to assets by improving bond strength, corrosion resistance, and damage tolerance.



This closeup view of a reinforcing steel bar cross section shows how the textured epoxy coating (TEC) and the epoxy-coated reinforcement (ECR) covalently bond to form a monolithic coating from the substrate to the air interface with a stratification of properties. The base ECR layer provides corrosion protection to the steel substrate, while the top TEC layer delivers damage resistance and enhanced concrete-bonding characteristics.

monolithic coating from the substrate to the air interface. The results are an enhanced barrier and durability properties that further improve the corrosion resistance and damage tolerance of the reinforcement. The resulting texture also reestablishes the desired bond interaction between the steel and concrete.

Bond Strength Comparison

In use since the 1970s, ECR provides long-term corrosion protection, creating a proven barrier to oxygen, electrolytes, and other deleterious substances. Yet, there are some well-documented drawbacks associated with the use of ECR. For example, the powdered fusion-bonded epoxy coating cures to a hard surface that smooths out the ribs on reinforcing bars. This smoother surface reduces the rough surface profile and reduces the bond strength with concrete by approximately 15% as compared with that of uncoated black bar.[7] To compensate, engineers must use longer development and splice lengths than what is required with black bar. On a project, this approach can add significant cost, weight, and reinforcement congestion.

Compared with ECR, black bar offers better interaction and bond with concrete. However, it is susceptible to corrosion. Corrosion-resistant TEC establishes a lasting connection with concrete with bond strength that is similar to that of black bar, allowing comparable reinforcing bar splice and development lengths. TEC, which adds texture, not only enhances the interaction with the concrete but also increases the available surface area for bonding by introducing texture through proprietary resin technology. This re-creates deformations on the reinforcing bar surface, establishing a more pronounced anchor profile on the reinforcing bar.

Research on Bond Strength

Sherwin-Williams has been involved in the development of TEC for 15 years. Since 2019, they have tested the technology in concert with studies at research universities. While testing will continue through 2027, available results paint a clear picture.[2–6]

At the University of Minnesota, researchers performed tests of reinforced concrete lap splice beams using uncoated reinforcing bars, ECR, and TEC bars. The results of this research have not yet been published, but the following preliminary observations are offered. In ECR tests, the concrete separated cleanly from the coated reinforcing bar, indicating weaker adhesion. Reinforcing bar coated with TEC showed the best adhesion—better than uncoated black bar—with researchers needing to chisel off concrete to inspect the reinforcing bars underneath.

In beam-end experiments at the University of Kansas,[2] the reinforcing bars with TEC showed approximately 20% better bond strength than ECR. The splice strength of TEC bars also averaged 1.05 times that of uncoated bars, indicating that TEC bars have a comparable, if not better, bond than uncoated bars.

According to a Wisconsin Department of Transportation study,[3] TEC can reduce reinforcing bar splice lengths by 10% and 60%, compared with black bar and ECR, respectively. In a related study at Clemson University,[4] researchers compared flexural cracking (vertical cracks formed from tension and bending). Concrete with ECR resulted in fewer but larger cracks when compared with TEC bars, which had cracks that were smaller and finer.

At the University of Illinois,[5] ASTM A944-10[8] microcracking testing of concrete specimens with the TEC bars showed that cracks were about half as wide as those with ECR, with a total crack area that was 33% smaller. Flexural tests demonstrated TEC reinforcing bar, compared with ECR, had substantially better slip resistance of up to 74%. On the heels of the university's testing, the Illinois Department of Transportation continues to broaden the research for implementation of TEC as a promising innovation for bridge construction projects.[6]

Damage Tolerance

TEC offers enhanced durability and chip resistance compared with ECR, contributing to better corrosion resistance by minimizing areas where steel might be exposed before being covered in concrete.

In unpublished damage-tolerance tests performed by Sherwin-Williams, in which technicians dropped reinforcing bars on gravel to mimic potential impacts at a construction site, ECR was more easily damaged than reinforcing bar coated with the TEC. The matrix of the TEC material is a molecular-level composite that provides more durability than the coating on an ECR.

If TEC is damaged, repairs can be performed as specified in the ASTM A775 specification,[9] as well as ASTM A1124.[1] Field repair is prescribed in the specification and involves using an approved spray-applied or brush-and-roll-applied liquid touchup material.

Concrete Evidence

The new ASTM A1124 specification uses several approved test methods to assess the corrosion resistance, bond strength, and damage tolerance of different coatings. These standards set the stage for establishing and documenting acceptance criteria that can be applied when specifying TEC bars. To create this standard, independent laboratories conducted the following tests on both TEC and alternative materials:

- **Relative bond strength:** ASTM A944[8] bond-strength testing, as well as lap-splice testing
- **Damage tolerance:** Durability testing covering impact resistance (ASTM G14[10]), chipping resistance (ASTM D3170[11]), abrasion resistance (ASTM D4060[12]), and flexibility (ASTM A775 A1.3.5[9])
- **Corrosion resistance:** ASTM A775[9] testing, including tests for chemical resistance (ASTM G20[13]), cathodic disbonding (ASTM G8[14]), salt spray resistance (ASTM B117[15]), and chloride permeability (ASTM A775 A1.3.4[9])

Concrete Plan

With ASTM A1124 in place, further independent testing and product evaluations by the International Code Council will evaluate TEC effectiveness and help with adoption by the American Association of State Highway and Transportation Officials. State departments of transportation can gain confidence in the material and follow suit as leading oranizations adopt guidance on the use of TEC technology for bridges. In addition, independent testing could eventually lead to code adoption in the American Concrete Institute's *Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)*.[7] The concrete industry will then have the data and support to adopt TEC and realize the increased bond strength, damage tolerance, and corrosion resistance—not to mention the reduced costs and longer asset lives—the coatings offer as compared with ECR and black bar.

To demonstrate this technology, Sherwin-Williams is constructing their headquarters in Cleveland, Ohio, using TEC reinforcing bars. It will be the first commercial building to use TEC bars.

References

1. ASTM International. 2023. *Standard Specification for Textured Epoxy-Coated Steel Reinforcing Bars*. ASTM A1124/A1124M-23. West Conshohocken, PA: ASTM International.
2. Aryal, A. M., K. Truman, D. Darwin, et al. 2023. *Bond Strength of Textured Epoxy-Coated Bars*. Structural Engineering and Engineering Materials, SM Report no. 151. Lawrence: University of Kansas Center for Research.
3. Ross, B. E., A. Poursaee, M. Mueller, et al. 2020. Proceedings from the 2020 American Concrete Institute Virtual Conference.
4. Murphy, A. 2021. "Comparison of Flexural Cracking in Reinforced Concrete Beams with Different Bar Coatings." MS thesis, Clemson University.
5. Andrawes, B., E. A. P. Claros, and Z. Zhang. 2022. *Bond Characteristics and Experimental Behavior of Textured Epoxy-Coated Rebars Used in Concrete Bridge Decks*. University of Illinois Urbana-Champaign, FHWA-ICT-22-001. Urbana: Illinois Center for Transportation. https://doi.org/10.36501/0197-9191/22-001.
6. Illinois Department of Transportation (IDOT). 2022. "Setting the Bar for Longer-Lasting Bridges." IDOT Blog. https://idot.illinois.gov/news/stronger-bridges.html.
7. American Concrete Institute (ACI) Committee 318. 2019. *Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)*. Farmington Hills, MI: ACI.
8. ASTM International. 2010. *Standard Test Method for Comparing Bond Strength of Steel Reinforcing Bars to Concrete Using Beam-End Specimens*. ASTM A944-10. West Conshohocken, PA: ASTM International.
9. ASTM International. 2019. *Standard Specification for Epoxy-Coated Steel Reinforcing Bars*. ASTM A775/A775M-19. West Conshohocken, PA: ASTM International.
10. ASTM International. 2018. *Standard Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test)*. ASTM G14-04(2018). West Conshohocken, PA: ASTM International.
11. ASTM International. 2022. *Standard Test Method for Chipping Resistance of Coatings*. ASTM D3170/D3170M-14(2022). West Conshohocken, PA: ASTM International.
12. ASTM International. 2019. *Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser*. ASTM D4060-19. West Conshohocken, PA: ASTM International.
13. ASTM International. 2010. *Standard Test Method for Chemical Resistance of Pipeline Coatings*. ASTM G20-10. West Conshohocken, PA: ASTM International.
14. ASTM International. 2019. *Standard Test Methods for Cathodic Disbonding of Pipeline Coatings*. ASTM G8-96(2019). West Conshohocken, PA: ASTM International.
15. ASTM International. 2019. *Standard Practice for Operating Salt Spray (Fog) Apparatus*. ASTM B117-19. West Conshohocken, PA: ASTM International.

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