Epoxy-Coated Prestressing Steel Strand

Three types of surface finish are available for epoxy-coated strands (from left): smooth, for unbonded applications; fine grit; and coarse grit. The latter two are for bonded applications. Note individual coating of each wire. Photo: Sumiden Wire Products Corporation.

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Prestressed concrete was introduced in the 1950s and is now widely recognized as a durable and superior construction method for many structural applications, including bridges of all sizes and types, wind towers, and single-story and high-rise buildings. To further increase the service life of prestressed concrete structures, owners, design engineers, and contractors want cost-effective and reliable methods to prevent premature corrosion of the reinforcing steel. Carbon fiber, stainless steel, and epoxy coatings have all been successfully used to help eliminate or significantly reduce the risk of premature reinforcing steel corrosion. This article focuses on the development and success of epoxy-coated prestressing steel strand (as specified in ASTM A882).

History

Epoxy-coated strand was first developed in the early 1980s by Florida Wire and Cable with the help of a grant from the Federal Highway Administration. When the product was initially developed, the epoxy coating was only applied to the outside of the strand. Field experience with this first-generation epoxy-coated product soon proved this coating practice had a serious flaw: water could enter the strand from the exposed ends and migrate through the unfilled interstitial spaces between the wires. When this was recognized, the epoxy-coating process was redesigned to remove this vulnerability by filling the interstitial spaces with the epoxy-coating material in addition to applying the coating on the outside of the strand.

In the following years, the technology for making epoxy-coated strand was further refined and improved, with advancements made in the uniformity of coating thickness, coating adhesion, and other characteristics of the product. For example, when the coating was initially developed for bonded applications, sand was impregnated on the epoxy coating to enhance the bond performance. This coarse-grit finish was effective at developing bond, but it proved to be problematic for thin members because resulting transfer lengths were very short. The coarse grit (sand) epoxy-coated strand was also abrasive to handle and caused unwanted wear when it rubbed against tooling, as it would when passing through the holes in prestressing form bulkheads. To address these issues, fine-grit epoxy-coated strand was developed using aluminum oxide impregnated on the epoxy surface. The fine-grit finish on the epoxy-coated strand resolved the handling and wear concerns associated with the coarse-grit finish, and its transfer length is similar to bare strand. Currently, three types of surface finish are available: smooth, for unbonded applications; fine grit; and coarse grit–the latter are both for bonded applications. Epoxy-coated prestressing strands are available in the same diameter ranges as uncoated steel strands.

Distinctive Characteristics

Although epoxy-coated prestressing steel strand has been available in the U.S. market since the 1980s, many in the prestressed concrete community are not familiar with this product. When first hearing about epoxy-coated strand, many people may associate this product with its distant cousin, epoxy-coated reinforcing bars. While this association is understandable, there are significant differences between the two products.

One of the primary differences between the two products is the surface preparation prior to epoxy coating. Surface preparation for an epoxy-coated reinforcing bar primarily consists of a shot-blast process to remove the mill scale remaining after the steel hot-rolling manufacturing process, a subsequent cleaning and removal of the shot blast media and related debris, and a heating process at ~450°F; then, the epoxy coating is applied.

For epoxy-coated strand, the mill scale is removed from the hot-rolled wire rod before the production of the individual wires. Next, the descaled wire rod is cold-drawn through a series of dies, which ensures the wire surface is uniform and free of any loose debris. During the stranding process, the individual wires are stranded and then heated to over 700°F, burning off a large portion of any remaining surface contaminants. This heated strand is rapidly cooled in a water bath, which also acts as another cleaning process. Prior to epoxy coating, the bare strand is passed through an acid-cleaning operation, a subsequent water rinse, and a heating process at ~400°F. After all of these processing and cleaning steps, the 15-

Bite-through wedges, which have longer teeth, must be used when tensioning epoxy-coated prestressing steel strand. Coated strand at left shows how the teeth have penetrated the coating to engage the surface of the strand. Photo: Sumiden Wire Products Corporation.

to 45-mil epoxy coating is finally applied. When epoxy-coated prestressing steel strand is coated, each individual wire is coated as well as the overall strand surface. The strand is untwisted and then retwisted during the epoxy coating process to ensure that all surfaces of the wires are covered and the interstitial spaces are filled. As a result, if the coating is damaged in the field, only the wires with damage have been exposed to potential corrosion. Additionally, because of the superior adhesion of the coating, corrosion does not migrate or travel along the strand if the epoxy is damaged and bare steel wire is exposed. Only the exposed surfaces can corrode, and the adjacent epoxy coating does not blister or soften. This remarkable adhesion property has been confirmed in 3000-hour salt fog tests with the strand tensioned at 70% of its guaranteed ultimate tensile strength.

The tensioning properties of epoxy-coated strand are essentially the same as those of traditional bare strand, but there are slight differences in handling and care. For example, bite-through wedges must be used when tensioning the epoxy-coated strand, unless the user elects to strip off the epoxy in the gripping sections. Also, the epoxy-coated strand is delivered on wooden spools, whereas conventional bare prestressing steel strand is delivered with reel-less packaging; therefore, a different payout device must be used when working with epoxy-coated strand.

The epoxy coating on epoxy-coated strand is both durable and ductile. If the coating were to become damaged, a two-part epoxy-patching compound is available for repairs of any size. The patching process can be easily performed in the field with a small applicator and heat gun. The resultant patch has the same adhesion and elongation properties as the original epoxy coating. The coating material is also specially engineered to exceed the elongation demands needed in both the longitudinal direction and when bending the strand in radii as tight as 32 times the nominal strand diameter.

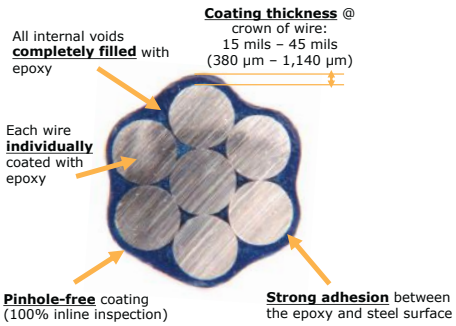
Applications for Bridges and Other Transportation Structures

Since the early 1990s, over 700 projects in Asia, primarily in Japan and South Korea, have successfully used epoxy-coated prestressing steel strand in bridge construction for applications such as external tendons for segmental bridges, transverse tendons, internal tendons, and extradosed/stay cable tendons. Epoxy-coated strand has also been used for ground anchors and mine roof bolts. In the United States, epoxy-coated strand has been successfully used in pretensioned concrete girders, piling, and deck panels; post-tensioned stay cables; ground anchors; and several other specialty applications.

One of the largest U.S. pretensioned concrete projects using epoxy-coated strand was the widening of the San Mateo Bridge, crossing San Francisco Bay between Hayward and Foster City, Calif. The total length of this section of the San Mateo Bridge is 4.9 miles and consists of 2160 bulb-tee girders, 826 piles, and 18,293 deck panels (see article in the January-February 2005 issue of the *PCI Journal*). Epoxy-coated strand was selected for all prestressed concrete elements because this structure is very close to the water level with all elements within the marine splash zone and the owner set the objective of achieving a 125-year service life. The bridge was completed in 2002, within budget and on schedule, and has performed as designed without any corrosion concerns.

The U.S. prestressed concrete industry has used epoxy-coated strand in a variety of pretensioned applications, including bridge decks, piling, and girders. Precast concrete H-columns for highway sound walls are a new pretensioned concrete application in areas where deicing salts are frequently used. Another market application is ground anchors and tiebacks where corrosion can be a significant concern.

To date, the most prominent application for epoxy-coated prestressing steel strand in the United States has been cable-stayed bridges. Two iconic cable-stayed bridges using epoxy-coated strand are the Penobscot Narrows Bridge near Bucksport, Maine, and the Veterans Glass City Skyway Bridge in Toledo, Ohio. Two additional signature cable-stayed bridges currently under construction are using a combined total of over 5000 tons of epoxy-coated strand: the Harbor Bridge in Corpus Christi, Tex., and the Houston Ship Channel Bridge in Houston, Tex.



Cross section of an epoxy-coated strand showing the complete coating of each wire. Photo: Sumiden Wire Products Corporation.

Owners are now demanding 100-year-plus service lives for many of their key infrastructure projects. Epoxy-coated prestressing steel strand provides a viable and cost-effective option to meet this challenging durability standard.

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EDITOR'S NOTE

ASTM A882 is listed as "Withdrawn" by ASTM as of this writing. This standard is in the process of being revised and will become active again once it passes the ASTM balloting process.

When the San Mateo Bridge was widened, epoxy-coated strand was used in the prestressed concrete of its 2160 bulb-tee girders, 826 piles, and 18,293 deck panels. Photo: Balfour Beatty Construction.