Production of Prestressed Concrete Piles Using Stainless Steel Strand

by Dr. Krista Brown

Although stainless steel strand is not a new technology, it has rarely been used for precast, prestressed concrete components in transportation structures. There are rumors and misconceptions about special requirements and equipment needed for its incorporation into the prestressed concrete fabrication process. This article focuses on the production process of full-size prestressed concrete piles using stainless steel strand. The article "Structural Design Using Stainless Steel Strands" in this issue of *ASPIRE*® addresses designing prestressed concrete components using stainless steel strand.

Background

According to Mark Bucci, bridge design manager at the Louisiana Department of Transportation and Development (LaDOTD), the use of noncarbon steel strand in the precast, prestressed concrete piles on one of three bridges on the Bayou Thunder Overflow Project is an effort to increase the service life of the structure from 50 to 100 years. Corrosion-resistant strand (stainless steel or carbon fiber reinforced polymer) was specified for the forty-two 24-in.-square, 78-ft-long prestressed concrete piles on one of the three bridges of the project. Low-permeability concrete was used in these piles to limit saltwater and chloride intrusion and new detailing for the pile tip and head was also incorporated. The cost of the piles with the stainless steel strands and other detailing measures to increase service life was more than 200% higher than that of piles using conventional carbon steel strands. The result was a $590,000 increase to the cost of the project.

Gulf Coast Pre-Stress (GCP) in Pass Christian, Miss., bid the project based on the stainless steel option and was awarded the contract to produce the piles. GCP then began the journey to fabricate the first prestressed concrete piles using stainless steel strand to be used in an LaDOTD structure.

Materials

For the project, LaDOTD specified that the 7-wire, ½-in.-diameter stainless steel strand meet the chemical requirements of ASTM A276 and the mechanical and dimensional requirements of ASTM A416. Stainless steel alloy 2205 meets these requirements. In addition to the material testing certificates provided by the strand supplier, LaDOTD performed its own tests on strand samples that GCP took from the strand packs for this project.

Compared with its carbon steel counterpart, 2205 stainless steel strand has a lower tensile strength and a lower elastic modulus, as shown in the table below. The stainless steel strands were also stressed to a lower fraction of the tensile strength (70% instead of 75%) as designed by LaDOTD, so the force in each strand was reduced. Therefore, to achieve the same level of precompression in the piles, twenty-eight ½-in.-diameter stainless steel strands were required instead of the 24 carbon steel strands typically used in a 24-in.-square pile. Another reason to increase the number of strands by four was to keep the strand pattern symmetrical. It should be noted that the LaDOTD design for the piles was based on a 240 ksi ultimate strength for the stainless steel strands, which was lower than the 250 ksi for the strands that were used. To obtain the LaDOTD specified prestressing force, the strand was stressed to a fraction slightly less than 70% of the tensile strength.

Comparison of Material Properties for Types of Strands

Strand Material	Minimum Tensile Strength f_{pu}, ksi	Elastic Modulus E, ksi
2205 Stainless Steel Grade 250[a]	250	25,500
1080 Carbon Steel Grade 270[b]	270	28,600

[a]Reference: Sumiden Wire mill certificate.
[b]Data from: www.sumidenwire.com/products/pc-strand

Strand was not the only item in the concrete piles that was stainless steel. LaDOTD specified that the W4.5 wire spirals be Type 304 or 316 annealed stainless steel. The tie wire, the strand used for lift loops, and the reinforcing bar template that GCP uses to ensure strand placement in the middle of the long piles, were also required to be stainless steel.

In 2016, LaDOTD introduced performance-based concrete specifications[1] that included low-permeability concrete mixtures. GCP had already received approval for a 6-ksi concrete mixture with a minimum surface resistivity of 22 kohm-cm at 28 days. The concrete mixture did not require any modifications because of the stainless steel strand.

Long Lead Times for Materials

Stainless steel strand is not a stock item, especially when domestically produced strand is required, as on this project. Currently, suppliers only produce the strand when a sufficient number of orders have been placed to warrant production. Sumiden Wire was willing to guarantee delivery within six months for the ½-in.-diameter stainless steel strand, which is produced in its Dickson, Tenn., facility. Lead times for the stainless wire for the spirals and preformed tie wire were six and two weeks, respectively.

Production

In November 2017, GCP cast the 78-ft-long, 24-in.-square prestressed concrete piles. In the typical production cycle, four piles were cast in each of two adjacent 420-ft-long casting beds, for a total of eight piles. The use of the stainless steel strand did not require GCP to change

The 24-in.-square, 78-ft-long concrete piles prestressed with stainless steel strand were bunked at the lifting points while work was performed for the corrosion-resistant detail at the ends. All Photos: Krista Brown.

its normal procedures for the following:

- Storage and handling of stainless steel strand and wire for spirals.
- Forming of spirals from stainless steel wire, which is a semiautomated process.
- Cleaning and maintenance of strand chucks at the live and dead ends of the strand. The chucks were the same as used with conventional strand.
- Tensioning and de-tensioning, including calculation of strand elongations.

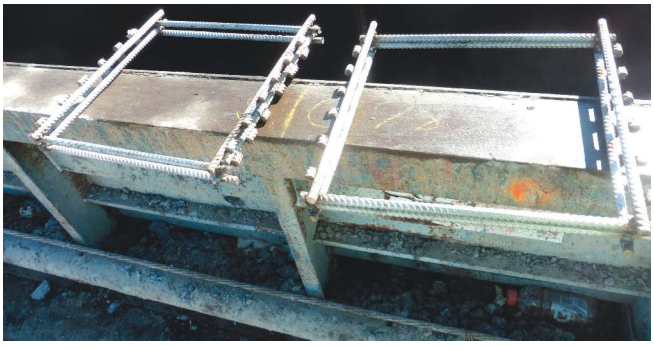
Quality control tasks were also not altered for fabrication using stainless steel strand. As with other LaDOTD precast concrete projects produced at the GCP facility, Volkert Inc. performed inspection duties under contract for LaDOTD.

The following items, although not directly attributable to the use of stainless steel strand, were notable differences from typical pile production at GCP:

- The 28-strand pattern was not typical for a 24-in.-square pile produced at its plant, and GCP did not want to modify the thick stressing plates at the dead and live ends. Inside the beds, GCP had sufficient room to install a steel rendering plate at each end to redirect the ½-in.-diameter stainless steel strand into the required pattern. Because this plate was not cast into the pile, it was not required to be stainless steel.
- Because all embedded steel items needed to be stainless steel, the reinforcing bars used to make templates to hold the strand in place in the middle of the pile also needed to be stainless steel. The longer lead time for stainless steel bar was almost overlooked.
- Workers reported that, as compared with carbon steel strand, more oxygen was needed in the gas mixture for the flame-cutting process during de-tensioning.
- The new pile end detail for the 100-year service life required the strands to be cut 2 in. below the pile head and tip. This led GCP to create a 2-in.-deep recess using a customized wood header

A custom header to separate the piles in the casting bed was fashioned to form the 2-in.-deep recess for strand. This formwork was challenging to make and remove.

Stainless steel preformed wire ties were used to tie the spirals to the strand. Workers reported that the stainless steel ties required more effort to tie than their carbon steel counterpart.



Gulf Coast Pre-Stress typically uses a template made from reinforcing bars to keep strands in position in the middle of long piles. For this project, the template had to be stainless steel.

No modifications to the tensioning procedure were necessary for the stainless steel strand.

The normal de-tensioning procedure was used, but workers reported that more oxygen was needed in the gas mixture to flame-cut the stainless steel strand than carbon steel strand.

The Louisiana Department of Transportation and Development (LaDOTD) required a new corrosion-resistant detail for both ends of the piles to attain a 100-year service life. The detail required that the stainless steel strands be recessed 2 in. at each end and the recess be filled with cementitious grout.

(bulkhead). The complicated shape was needed so that the strand could be saw-cut at the base of the recess. Constructing the wood form took extra hours, and removing it and cutting the strands flush were labor intensive endeavors. Afterward, the recess was formed and grouted.

- After the initial tensioning of each stainless steel strand to 3 kips, the strands were carefully examined for any notches before the tensioning process continued to the required 26 kips.
- The stainless steel preformed tie wire required more effort, and therefore more time, than the comparable carbon steel tie wire when tying the spirals to the strand, according to Dusty Carver, GCP superintendent.

Controlling Material Costs During Production

Material costs were a special concern during production because of the use of stainless steel. Stainless steel is more expensive than carbon steel, and, more importantly, the long lead times for orders of stainless steel materials meant that a shortage of any of the stainless steel items could have severe consequences for the schedule. Care was therefore taken to ensure that the quantities of stainless steel strand and spiral wire ordered were sufficient to allow for the possible remake of a pile. Also, strand used for the lift loops for the initial casting of piles needed to be cut from the virgin strand packs. Thereafter, the leftover strand at the dead and live ends of the beds could be used for the lift loops.

Specific material-handling and inventory-control procedures were adopted for the precious stainless steel preformed tie wires. According to Ben Spruill, vice president at GCP, these measures were so successful that they may become standard practices at the plant for other items.

Summary

The production process for precast concrete piles prestressed with stainless steel strand was not markedly different from that using conventional carbon steel strand. "We thought it would be more problematic," said Spruill. "Most things were regular SOP [standard operating procedure], but a lot more attention" was placed on this project. Long lead times for the stainless steel materials, especially the strand, were the greatest challenge.

Acknowledgments

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Reference

1. Louisiana Department of Transportation and Development (LaDOTD). 2016. *Louisiana Standard Specifications for Roads and Bridges*, 2016 ed. Baton Rouge, LA: LaDOTD.

EDITOR'S NOTE

See concrete connections on p. 44 for links to resources for designing using stainless steel strand.