UNIVERSITY of HOUSTON

PROJECT SUMMARY

Texas Department of Transportation

0-6917: Synthesis of Concrete Bridge Piles Prestressed with CFRP Systems

Background

Transportation infrastructure is aging and deteriorating largely due to corrosion of steel reinforcements in concrete including steel prestressing strands. A corrosion-free material for prestressing will create alternatives for bridge engineers to design long-lasting and safer bridges. Otherwise, corrosion may create significant additional maintenance and replacement costs. Furthermore, the loss of area of the prestressing steel may result in lower load-carrying capacity of bridge members, which may eventually lead to structural failure, hence a major concern for public safety.

The Texas Department of Transportation (TxDOT) frequently constructs prestressed concrete piles for use in bridge foundations. Such prestressed concrete piles are built with steel strands that are highly susceptible to environmental degradation and corrosion in harsh environments such as in coastal regions or where deicing chemicals are used. TxDOT currently employs many techniques to combat this structural degradation, but these measures address only the symptom but not the root cause. It would therefore be advantageous to TxDOT to adopt a corrosion-resistant reinforcing material. It was then the aim of this research to assess the feasibility of employing carbon fiber-reinforced polymers (CFRPs) into TxDOT infrastructure through comprehensive literature synthesis, investigations in the field and interviews with design professionals, and a comparative analysis of mechanics and economics.

What the Researchers Did

The Research Team assessed the feasibility of implementing CFRPs in TxDOT infrastructure through:

- A comprehensive literature synthesis of numerous publications in journals and technical reports focusing on similar technology
- Investigations in the field to assess firsthand the effects of pile deterioration and the frequency with which they occur
- Interviews with design professionals and local contractors to more accurately quantify the current maintenance and associated costs of managing the state's numerous bridge piles
- A comparative capacity analysis using widely accepted and well-validated analysis approaches to develop axial load-bending moment interaction diagrams for both CFRP and steel
- A comparative analysis of the cost of implementation and overall maintenance for both CFRP and steel reinforcement.

What They Found

They found that the current investigations indicate that some DOTs are including pilot studies using CFRP in their design of prestressed piles. Most of these studies have limited laboratory tests. Furthermore, there is a lack of comprehensive design specifications and construction procedures to enable transportation engineers to adopt this innovative technology.

In addition, the findings of this study illustrated the feasibility of CFRP adoption when considered over the entire lifespan of a bridge structure, relying on CFRP's excellent environmental durability to mitigate the more expensive upfront costs. Incorporating CFRP

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prestressing strands into bridge piles, especially in aggressive, corrosive environments, has the potential to not only increase the overall lifespan of the structure, but requires far less maintenance, saving a large sum of repair costs and design time. This synthesis study suggests that some important issues must be better understood and quantified, such as additional drivability concerns and splicing information, before the large-scale implementation of CFRP-prestressed piles is undertaken by TxDOT. With literature synthesis, mechanical behavior comparison, and economic comparison completed, the following conclusions were made:

- From the preliminary literature synthesis performed at the beginning of this project and various materials gathered in the completion of its subsequent tasks, CFRP outperforms its steel counterpart in corrosion resistance, axial and limited bending moment capacity, and its overall viability as a suitable structural reinforcement alternative to prestressed-steel. This has been well-validated in numerous peer-reviewed journal articles and DOT publications with reproducible values and full-scale prestressed-CFRP piles being employed in other states. Numerous technical aids have been published for limited design purposes of bridge piles by FDOT and VDOT, and CFRP's economic viability has been reviewed by several literature sources. While important in establishing some guidance in design, these specifications do not address splicing in between individual pile segments, drivability concerns, or any guidance on transverse reinforcement.
- While life-cycle cost analysis shows that the use of CFRP in piles could increase the initial cost of the substructure, it also indicates that there is the potential for significant saving over the life of the bridge.
- The Research Team's final recommendation is that there exist some minor gaps in knowledge regarding CFRP-prestressed piles that should be addressed with additional research before full implementation is recommended.
- The use of CFRP strands for piles may be beneficial in the construction of signature structures that are exposed to salt-water. In those cases a detailed economic analysis should be considered given the implications and consequences of strand corrosion in those types of structures. While other DOTs have developed in-house design specifications for use of CFRP in piles, AASHTO is also developing design specifications for use of CFRP in bridge girders with results and design specifications that could be applicable to piles.

What This Means

Based on the assessment of pile conditions within the State, as confirmed by earlier site reports and interviews of design professionals and contractors, the Research Team suggests prestressed-CFRP to be considered primarily for new construction rather than maintenance and repair. It was determined that the issue of deteriorated bridge piles due to internal steel corrosion was of minor significance to TxDOT budgets, in the proportion to the overall number of repairs made.

The implementation of CFRP-prestressed piles, when restricted to new construction endeavors, would likely result in substantial net benefits to TxDOT and State. The material could be technically and economically feasible to be implemented in some signature structures that are particularly susceptible to corrosion and detailed consideration of this alternative is merited.

For More Information

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