CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

0-6783: Use of Carbon Fiber Reinforced Polymer (CFRP) with CFRP Anchors for Shear-Strengthening and Design Recommendations/Quality Control Procedures for CFRP Anchors

Background

The objective of the study was to demonstrate the feasibility of using bi-directional layouts of CFRP for shear strengthening of bridge girders. In a previous project (0-6306), it was demonstrated that uni-directional CFRP strips and CFRP anchors could be used to improve the shear strength of reinforced concrete elements. Tests of I-beams with both uni-directional and bi-directional CFRP strips indicated that the use of bi-directional strips led to improved shear capacity. Because the data on the bi-directional layout of CFRP was limited, additional work was needed to understand the behavior and design of CFRP strips and anchors for bridge elements subjected to large shear forces. Since the anchor installation is a key element of the strengthening technique, there is a need for quality control procedures to make sure that the materials are used properly and the installation meets the design requirements. The information obtained from this project provides needed guidance that will enable TxDOT to design strengthening projects using CFRP materials and to develop quality control procedures to assess workmanship in the field.

What the Researchers Did

The project consisted of a number of different experimental studies to assess the behavior of reinforced concrete elements strengthened using CFRP materials. Those studies included the following:

- **Panel Tests:** Small concrete panels that provided a relatively inexpensive way to assess the role of uni-directional and bi-directional strips in controlling the cracking and strength of the panels.
- **T-Beam Tests:** A series of T-Beams was tested with uni-directional and bi-directional layouts of CFRP strips and anchors to assess the role of the CFRP in strengthening the T-Beam and in controlling diagonal shear cracking.
- **Pile Cap Girder Tests:** A series of large beams with square cross-sections were tested with different layouts of CFRP strips to assess their potential for strengthening pile cap girders. The layouts included continuous wraps around the beam and anchored U-wraps where beams seated on the pile cap girder would preclude continuous wrapping. These tests also provided a means of assessing the performance of anchors in zones of flexural tension or compression

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- **Anchor Design and Quality Control Tests:** Small beam tests were used to study the geometry of CFRP anchors that is needed to make sure that the anchor is stronger than the strip being anchored. The ease of anchor installation was also assessed using the beam tests. The use of the same type of test was assessed to be a reliable means of quality assurance for field use. The use of non-destructive tests (NDT) was assessed to determine whether such procedures could be used to check field installation and workmanship.

What They Found

The use of CFRP was shown to be a feasible and reliable method for shear strengthening of reinforced concrete bridge elements. The tests demonstrated that the use of anchors permits higher design values and makes better use of the inherent strength of carbon fiber. The data obtained was used to develop design and detailing recommendations for CFRP anchors and for the CFRP shear reinforcement. Since there are currently no design guidelines for anchored CFRP strips, these recommendations provide guidance in the use of CFRP materials for strengthening transportation structures. Because the quality of workmanship in the field is critical for the strengthened element to perform as designed, the recommendations for quality assurance tests represent another advance where there are currently no such procedures available.

What This Means

The findings from this project coupled with the findings from an earlier project (0-6306) provide a means for developing TxDOT design requirements for strengthening with CFRP materials. The recommendations for quality assurance tests provide TxDOT with procedures that can be used in the field to qualify the workers and to check anchor designs if new materials or different anchor geometry is proposed. These procedures are vital for the design and construction of strengthening and repair systems for extending the service life of aging, damaged, or inadequate bridge structures. Such capability is extremely important as the demand grows for more and improved roads and bridges in the state of Texas.

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