Project Summary
Texas Department of Transportation

0-6306: Shear Strengthening of Large Reinforced Concrete Elements Using Carbon Fiber Reinforced Polymer (CFRP) Sheets

Background

Carbon fiber reinforced polymer (CFRP) materials provide a relatively new option to strengthen or repair concrete elements that have been damaged either by overload or other action such as impact, deterioration, fire, or settlement. CFRP laminates consist of a textile like fabric woven with thin carbon fiber strands that are impregnated with a high strength structural epoxy. When properly installed, the CFRP material possesses a high axial tensile strength in the direction of the carbon fiber strands. CFRP materials offer a light-weight, high-strength, and non-corrosive option when strengthening or rehabilitating a concrete structure. The ability to quickly apply CFRP materials to a concrete element surface with a minimum of disruption to the use of a structure and with virtually no change in the geometry or weight of the element makes CFRP a viable and attractive method for strengthening existing elements.

Without adequate anchorage of CFRP sheets to the concrete surface, premature failures by debonding of the CFRP from the concrete significantly limit the capacity of CFRP strengthening systems. Most of the currently researched CFRP anchorage systems consist of mechanical means to effectively pin the ends of the CFRP laminates to the concrete surface. However, recent research on the use of CFRP materials to anchor CFRP strengthening systems has been reported. CFRP anchors were proven capable of preventing debonding failures of CFRP laminates and developing the full tensile strains of the carbon fiber material.

What the Researchers Did

The objective of the study was to demonstrate the feasibility of using anchored carbon fiber reinforced polymers (CFRP) for shear strengthening of large bridge girders or supporting elements. Particularly, the external U-wrap application of CFRP sheets anchored with CFRP anchors was the focus of the project (Figure 1). Although many tests have been done on small elements to show the efficiency of CFRP anchors and sheets, data were needed where large elements are to be strengthened to carry substantial shear forces. Also there has been little work done regarding the effect of creep of polymer materials and anchors in structural elements under sustained or fatigue loads.

Research Performed by:

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An extensive experimental program was undertaken on several full-scale T-beams and I-girders to achieve project objectives. Sixteen tests were conducted under monotonically increasing loading on 24 in.-deep T-beams. Eight monotonic tests were conducted on 48 in.-deep T-beams. Two 24 in.-deep beams were tested under sustained loading and two 24 in.-deep beams were tested under fatigue loading. Finally, four tests were conducted on 54 in.-deep pre-stressed I-girders. Key parameters investigated in the experimental program included: 1) beam shear span to depth ratio, 2) beam depth, 3) beam or girder shape, 4) amount of transverse steel, 5) amount and layout of CFRP sheets, 6) amount and layout of CFRP anchors (including tests without anchorage), and 7) surface preparation.

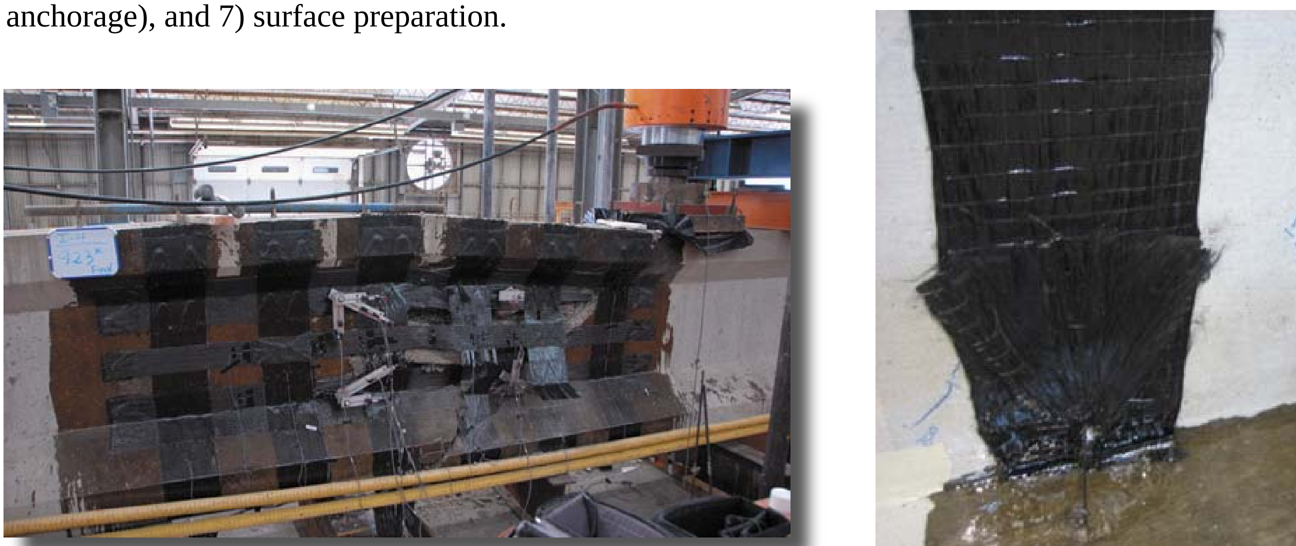

Figure 1: (a) Full-scale bridge I-girder strengthened using anchored CFRP (after testing); (b) CFRP anchor close-up

What They Found

Experiments with un-anchored externally bonded CFRP only showed about a 5% shear strength increase whereas anchored applications showed shear strength increases of up to 50%. CFRP anchors were able to mobilize the full capacity of CFRP sheets leading to large strength gains. Such results demonstrate the effectiveness of anchored CFRP systems in shear strengthening of large reinforced concrete members. Test beams performed well under fatigue and sustained loading.

What This Means

Lab testing demonstrates that anchored CFRP is likely to be a useful tool in maintaining large concrete elements. Field implementation is planned to further develop the methods to be employed.

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