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FRP-CONCRETE COMPOSITE COLUMN AND PILE JACKET SPLICING (PHASE II)

PROBLEM STATEMENT

Issues of corrosion and deterioration of steel reinforcement have led to the use of fiber reinforced plastics (FRP) in infrastructure. Florida DOT has been in the forefront of using FRP for the repair of existing bridges. A new and innovative use of fiber composites has been introduced by Dr. Mirmiran and Dr. Shahawy that consists of concrete-filled FRP tubes as structural columns, piles and piers. The tube acts as the pour form, protective and confining jacket, shear stirrups, and flexural reinforcement, all at the same time. It further allows removing conventional reinforcement from the column. Feasibility of this method of construction was clearly demonstrated under Phase I of this research project Phase I also resulted in a new model for confined concrete, and new methods of fabricating hybrid beam-columns. Phase II of this research has been focused on several issues including; shear capacity of hybrid FRP-concrete columns, effect of cross-sectional shape on the degree of confinement provided by the FRP shell, effect of length and slenderness of hybrid columns on their strength and ductility, effect of bond between the concrete core and the FRP shell on the strength and ductility, and finally optimization of hybrid columns.

OBJECTIVES

The following objectives were identified for Phase II:

1. Evaluate the shear capacity of hybrid columns and develop methods to increase shear transfer between the tube and the concrete core.
2. Study the effect of cross-sectional shape, length or slenderness of the column, and bond between the tube and the core, on the strength and ductility of hybrid columns.
3. Develop procedures for optimization of hybrid FRP-concrete columns, and perform parametric studies to establish the effects of basic variables on the cost of the system.

FINDINGS

The experimental and analytical studies of Phase II led to several findings as outlined below:

1. Shear tests on a total of 16 hybrid beams indicated that unless shear ribs are provided, hardly any bond would exist naturally between the FRP jacket and the concrete core. As a result, slippage would not allow shear to be transferred at the concrete-FRP interface. The tube, however, still somewhat increases the shear strength of concrete by simply containing the cracked section. With the shear connectors, the slippage problem was corrected, and the tube increased the strength by at least 6 times the shear strength of unjacketed beams of the same cross section. Also, the ribbed FRP tubes proved effective in inhibiting shear failure of the beams.
2. Uniaxial compression tests on a total of 9 composite specimens with square section demonstrated that square sections are not as effective as circular sections in confining the concrete core, as the strength of concrete is increased only marginally and rather independent of the jacket thickness. However, a post-peak ductility can be expected. Failure of the square FRP-encased specimens is accompanied by white patches around the corners, showing stress concentration at the edges. As the corner radius is increased, the confinement effectiveness and the behavior of confined concrete become closer to circular sections. The over-riding parameter in controlling the confinement was shown to be the product of the corner radius and the confining pressure.
3. Uniaxial compression tests on a total of 24 composite columns with various lengths and jacket thicknesses indicated that length-to-diameter ratios of up to 5:1 would not alter the general behavior of confined concrete such as its mode of failure or dilation characteristics. No slenderness effect in the form of buckling was observed during the tests. Further analysis indicated that the maximum eccentricity was within 10-12% of the section width. Noting that ACI 318-95 considers a minimum eccentricity of 10% and a strength reduction of 20% for tied columns, the amount of eccentricity and the strength reductions that were noticed for L/D ratios of 2:1 to 5:1 seemed acceptable. It was therefore, concluded that the 12" cylinders should be considered adequate to represent the confinement of concrete sections. Longer specimens possess an inherent eccentricity that results in lower values of the ultimate load. However, the eccentricity is well within the acceptable range, and does not quality for any slenderness effect.
4. Uniaxial compression tests on a total of 24 composite specimens with and without construction bond and with various jacket thicknesses indicated that the effect of construction bond on confined concrete is not significant, as long as the biaxial stresses in the jacket are considered properly for the bonded specimens.
5. Optimization studies for a variety of jacket thicknesses and core diameters indicated that adding hoop fibers at low axial loads does not increase the capacity of the section. For a specific core diameter, there is only one particular combination of axial and hoop fibers that provides the optimum solution. A penalty function was introduced to determine the significance of weight on the total cost of a hybrid column. When weight becomes a significant factor, the optimum solution shifts to a lower core diameter and higher hoop and axial fiber reinforcement ratios.
6. Acoustic emission (AE) was shown to be an efficient nondestructive evaluation technique for concrete-filled FRP tubes. Of the various AE parameters, AE

energy and number of AE counts both proved to be effective measures for the response of confined concrete. It was shown that while Kaiser effect was not present for hybrid columns even at low levels of axial load, Felicity effect during loading and unloading was apparent as one would expect from fiber composites.

CONCLUSIONS

A series of beam and column tests with a variety of design parameters helped quantity the response of hybrid FRP-concrete columns as related to shear strength, confinement, cross-section, slenderness, and construction bond. It was shown that design of hybrid columns can be optimized for any load combination and core diameter. Finally, effective use of nondestructive methods for FRP-concrete columns was demonstrated. Phase III of this project will focus on field testing of concrete filled FRP piles.

This research project was conducted by Dr. Amir Mirmiran, P.E. at the University of Central Florida. For more information on the project, contact Dr. Mohsen Shahawy P.E., Project Manager, at (850) 414-2966.