Rehabilitation Of Concrete Structures

Carbon Fiber Reinforced Polymer (CFRP)

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With a staggering demand for their utilization, concrete structures are the most commonly used choice of construction throughout the world. The worldwide production and use of concrete will soon surpass the 10 billion tons-per-year mark. In the United States, concrete production has almost doubled from 220 million cubic yards per year in early 1990s to more than 430 million cubic yards in 2004. This growth will inevitably strain our ability to respond to the increased demand for infrastructure development, and construction delays and material shortages will result in escalating costs. Design for sustainability requires us to rethink the way we extend the service life of structures. We must consider technically feasible structural remediation technologies and life cycle maintenance costs of existing structures as we choose between the rehabilitation of existing structures as opposed to demolishing them for new construction.

From a structural safety perspective, much improvement is needed in construction practices in many areas of the world. For example, approximately 74,000 persons died during the earthquake which struck near the Pakistan-India border on October 8, 2005. In addition about 70,000 have been injured, and more than 3 million people are now homeless. Evaluation of earthquake records indicates that approximately 60% of the deaths in earthquakes in the past 60 years stem from the collapse of unreinforced structures such as masonry walls (Coburn and Spence, 2002). While many structures and wall systems are designed in accordance to standard traditional structural codes, we need to find better alternatives for safer structural systems.

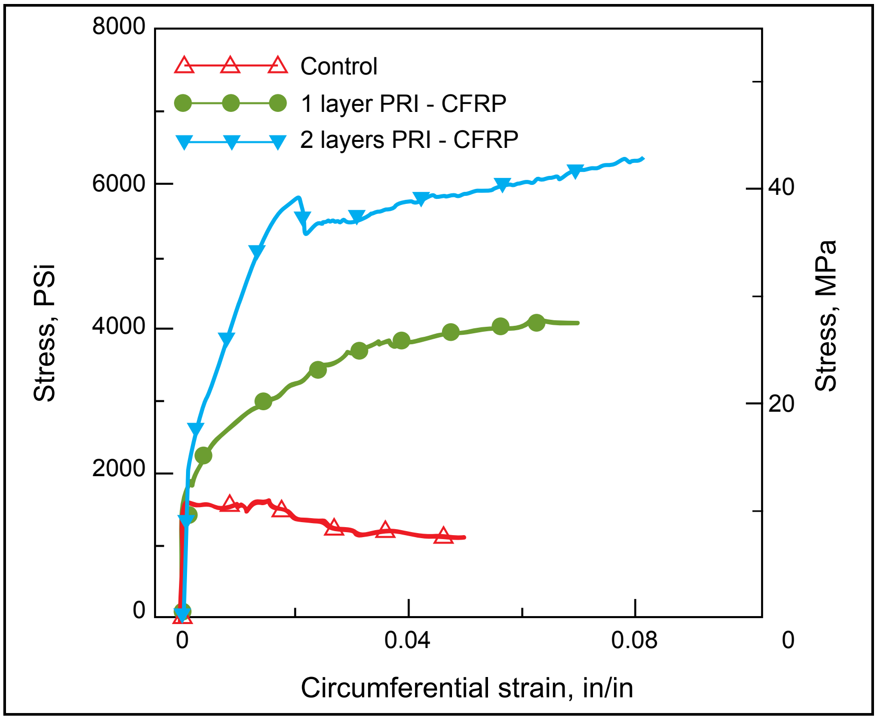

Figure 1: Effect of confinement on the compressive stress-circumferential strain of plain concrete specimens. Courtesy of Ken F. Sweat and Barzin Mobasher, Ira A. Fulton School of Engineering, Arizona State University.

Figure 2: Specimens used in the cyclic load-displacement testing of CFRP Beam – column connection

Both of these issues require modern approaches to the reinforcement of existing structures. One of the reasons for the extensive use of carbon fiber reinforced polymer (CFRP) rehabilitation of cement-based systems is the design versatility which can be tailored for each application. New research programs with carbon fiber systems enable opportunities for development of innovative and cost effective products to address the emerging repair and retrofit markets. By understanding, predicting, and controlling the composite response, we can better address the design and reinforcement of infrastructure systems.

Testing of confined cylinders has long shown that an increase in strength and ductility of the concrete is obtained due to the confining effect of the carbon fiber wrapping. *Figure 1* indicates the benefits of confinement enhancement by means of carbon fiber epoxy systems applied to plain concrete. Note that both the compressive strength and the ductility of the specimen increase significantly due to the confining role of the carbon wrap. This allows for the composite design to be an integral portion of the structural design process; varying constituent materials and processing techniques can be used to achieve performance metrics such as increased ductility, strength, deformation capacity, and prevention of progressive collapse systems.

A majority of the reaction forces of columns and beams in RC structures subjected to strong ground motions concentrate in the joint. Hence, beam-column joints are crucial regions in structures. The beam-column joints that are not detailed, and built in accordance with seismic codes, present a serious hazard to the overall ductility and stability of structures subjected to severe earthquake shocks.

A research project sponsored by KPFF Consulting Engineers and Pipe Reconstruction Inc. (PRI), conducted at Arizona State University, is evaluating the performance and behavior of the reinforced concrete (RC) exterior beam-column joints rehabilitated using (CFRP). The program experimentally and analytically studies the cyclic loads simulating seismic excitation. Half-scaled exterior beam-column joint specimens were prepared. While one of these specimens was designed in accordance with ACI 318-02, the other specimens were designed to be insufficient from view point of joint hoops and main reinforcements of beam and column. Two of these deficient beam-column joints were strengthened using CFRP sheets attached on the concrete. *Figure 2 (see page 17)* shows the specimen used in the cyclic load-displacement testing of CFRP Beam–column connection set up. The actuator applies a cyclic loading history (earthquake) on the tip of the beam portion of the T-shaped specimen (located at the top), while there is a constant axial load of 90 kN applied to the horizontally held column. Results are studied to measure the effectiveness of the carbon wrapping on the ultimate displacement and load carrying capacity in addition to ductility, dissipated, recoverable, and total energy. CFRP wrapping increases the strength and ductility of the joint, in addition to changing the failure location and mode of failure of exterior beam-column joints. The test results are integrated in non-linear structural analysis software for further analysis.

The envelopes of the displacement-cyclic load hysteresis curves are constructed from the cyclic load-displacement curves, and the results of the control and strengthened exterior beam-column joint specimens are compared. Results indicate that the strengthened specimens have higher displacement-cyclic load, responses giving them better properties. The location of the beam failure can be shifted away from the beam-column connection point, and the plastic hinge can form well with in the length of the beam as shown in *Figure 3*.

Results of this study indicate that it is possible to increase the capacity of existing beam column joints through the use of CFRP composites. By increasing the strength, and ductility of the members and the joints connecting these members, it is possible to extend the service life of structures.▪

Figure 3: The failure of the beam column due to hinge formation in the beam section of the connection

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Reference

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