COLUMN RETROFIT BY PLASTIC HINGE RELOCATION USING ADVANCED COMPOSITE MATERIALS

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ABSTRACT

Advanced composite materials composed of carbon and glass fiber reinforced polymers, have been used to retrofit reinforced concrete columns for over two decades. The original testing of these systems started in the late 1980’s and continues to the present day. The first tests, performed at the University of California at San Diego under the guidance of Professor Nigel Priestley, were focused on the use of unidirectional composites that were oriented in the transverse direction. The goal of many of the these tests was to essentially supplement the existing transverse reinforcement in order to change what would have been a premature shear failure into a flexural, ductile mode of failure. Effectively, these tests were forcing the columns to fail in the upper and/or lower hinge regions, while increasing the displacement ductility and preventing premature shear or lap splice failure (Paulay and Priestley 1992; Priestley et al. 1996). Similar testing was then performed at various universities (e.g. University of California at Irvine, University of Nevada, Reno, University of Southern California, University of Canterbury Christchurch, New Zealand and the University of Toronto) in order to validate both the glass and the carbon fiber reinforced polymers for this type of application. The structural testing then turned to the validation of these advanced composites to provide the same performance on noncircular columns, including rectangular, diamond, flare and even square shapes with re-entrant corners. Some of these column cross sections require the use of advanced composite anchors in order to achieve the same performance goals. All of these tests concluded that once the longitudinal steel had buckled or fractured, the column repair was no longer feasible. This is due to the fact that inelastic strain capacity of the buckled bars is severely diminished.

Exciting new research has been conducted in order to challenge this assumption by relocating the plastic hinge to a location above the damaged region. In order to achieve this goal it is essential to supplement both the existing transverse and longitudinal steel reinforcement. By increasing the flexural strength of the damaged region it can be possible to force a secondary plastic hinge to form above the original hinge region. It is important to note that in order to increase the flexural strength of the section, it is necessary to develop the vertically oriented composite material into the spread footing. It was only due to the previous development of the Tyfo® fiber anchor systems that this was possible. By embedding these anchors into the footings and splaying them onto the vertically oriented sheets, it was possible to develop the required tension forces into the footing and effectively increase flexural strength of the section. This retrofit can then relocate the hinge where the longitudinal reinforcement has a higher reserve strain capacity. The practical application of this research would be to take a column that has been severely damaged in a seismic event and be able to get it back into service without the need to demolish the structure.

The testing conducted at North Carolina State University consisted of three large-scale reinforced concrete column specimens 2.4m high and 600mm in diameter (Rutledge 2012). The first column contained buckled but not fractured longitudinal reinforcement and was repaired with the goal to increase the flexural strength of the damaged hinge region while also adding confinement to the new, target hinge region above. This additional confinement was provided based on the assumption that the new hinge region will need to accommodate an increase in curvature. The second specimen also contained buckled bars but no ruptured bars. This specimen was repaired to increase the flexural strength of the original hinge region but it did not include additional confinement of the new hinge region. The third column contained both buckled and ruptured longitudinal reinforcing bars and was repaired in the same manner as the second specimen. The goal for all of the specimens was to achieve the same strength and displacement capacity of the undamaged column while relocating the plastic hinge region to a location above the original hinge. The peak displacements and hinge locations can be seen in Figure 1. This presentation will briefly review the early testing and original design goals related to advanced composite strengthening of columns and then
it will review the testing completed at North Carolina State University and discuss the conclusions and implications for the design of severely damaged reinforced concrete columns.

![Images of testing specimens](a) Specimen 1; (b) Specimen 2; (c) Specimen 3

Figure 1: Maximum displacement: (a) Specimen 1; (b) Specimen 2; (c) Specimen 3

REFERENCES

