Use of CFRP to Strengthen Lap Splices of Reinforced Concrete Columns

InSung KIM
Graduate Research Assistant
University of Texas at Austin
Austin, USA
insung@mail.utexas.edu

James O. JIRSA
Janet S. Cockrell Centennial Chair in Engineering
University of Texas at Austin
Austin, USA
jirsa@uts.cc.utexas.edu

Oguzhan BAYRAK
Associate Professor
University of Texas at Austin
Austin, USA
bayrak@mail.utexas.edu

Summary

The use of Carbon Fiber Reinforced Polymer (CFRP) materials to repair and strengthen inadequate lap splices in square and rectangular reinforced concrete columns is presented. Four large scale columns (three square columns and one rectangular column) were tested to examine the effectiveness of the rehabilitation methods for improving lap splice behavior. The test results show that a combination of CFRP jackets and CFRP anchors effectively confined the lap splices of the columns. The tensile capacity of the longitudinal bars was developed and the deformation capacity of the columns was considerably improved. The strengthening methods of RC columns using CFRP may provide a solution for improving structures vulnerable to progressive failure.

Keywords: reinforced concrete columns; lap splices; rehabilitation; CFRP; CFRP anchors

1. Introduction

In many reinforced concrete structures built in the 1970's and earlier, lap splices in column longitudinal reinforcement were based on compression loads only. The length of those splices and the amount of transverse reinforcement are inadequate if the lap splices are subjected to different types of loading or if ductility is needed. In extreme loading conditions such as loss of a column support due to terrorist attack or if earthquake or other extreme actions occur, performance of the structure may be inadequate and the structure could be vulnerable to progressive failure. Jacketing of the reinforced concrete columns using CFRP may provide a solution for improving the lap splice behavior. However, CFRP jacketing of square and rectangular reinforced concrete columns is not as efficient as it is for circular columns. Except for lap splices located at the corners of a square or rectangular column, lap splices of bars away from the corner will not be confined effectively by the CFRP jacketing. Limitations of CFRP jacketing due to the shape of columns could be overcome using CFRP anchors.

The intent of this study is to find effective methods of strengthening and repairing inadequate lap splices in square and rectangular reinforced concrete columns using combinations of CFRP jackets and CFRP anchors. Three square columns(460 mm x 460 mm x 2970 mm) and one rectangular column (460 mm x 910 mm x 2970 mm) column were fabricated and rehabilitated using CFRP jackets only or by a combination of CFRP jackets and CFRP anchors. Both damaged and undamaged columns were strengthened and tested. The geometry and loading configuration for the test specimens are provided in Figure 1.

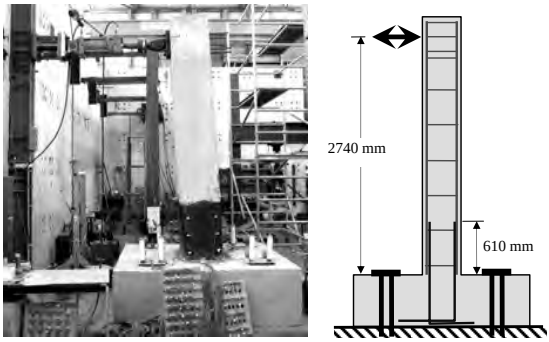

Figure 1: Test column and test setup

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2. Test results

Figure 2 shows drift ratio VS normalized load responses. The lateral load applied to the test columns was normalized using the computed nominal strength of each column. The nominal strength was calculated using design strength of the concrete and reinforcement.

Significant improvement of strength and deformation capacity was observed in all the test columns after rehabilitation with CFRP. This improvement was observed for splices on both damaged and undamaged sides of the column.

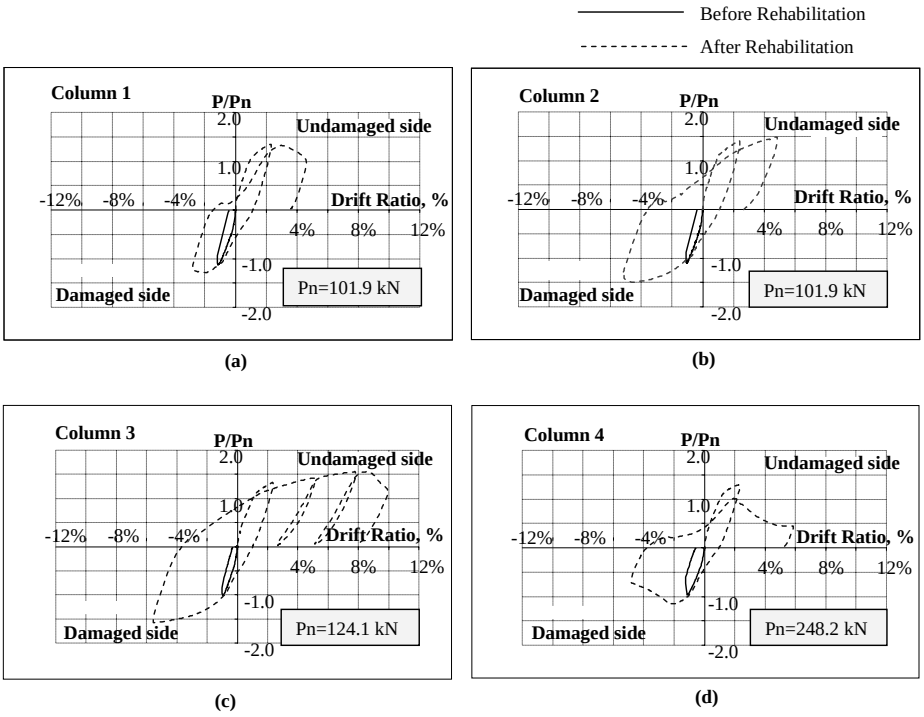

Figure 2 Drift ratio– normalized load response (a) Column 1. (b) Column 2. (C) Column 3. (d) Column 4.

3. Concluding remarks

The results of this study indicate that it is possible to use CFRP jackets and CFRP anchors to rehabilitate inadequate lap splices of longitudinal reinforcement in square and rectangular reinforced concrete columns. A significant increase of strength and deformation capacity was observed after repair or strengthening. Strength and deformation capacity improved more when the column was rehabilitated by a combination of CFRP jackets and anchors than when rehabilitated by a CFRP jacket only. The rehabilitation method was more effective for a square column than for a rectangular column. However, rectangular column showed desirable performance after the rehabilitation.

Additional tests are underway to evaluate performance of CFRP-rehabilitated splices under cyclic loading.