Repair and Strengthening of Reinforced Concrete Slab-Column Connections

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Summary

Seven 2/3-scale interior slab-column connections were tested to quantify the effects of earthquake damage, and the efficiency of different rehabilitation techniques on repairing seismic damaged slab-column connections and improving two-way shear strength of deficient connections. Three alternatives for rehabilitating slab-column connections were experimentally evaluated: (i) installation of steel collars, (ii) installation of external Carbon Fiber Reinforced Polymers (CFRP) stirrups, and (iii) application of well-anchored CFRP sheets. All three techniques increased the connection strength and improved the residual capacity after punching failure.

Keywords: Anchors, CFRP stirrups, CFRP sheets, Punching shear, Repair, Seismic-damaged, Slab-column connections, Steel collars, Strengthening, Two-way shear.

1. Introduction

The use of flat-plate structural systems (consisting of slabs with a uniform thickness that are supported directly on columns without any beams, drop panels, or column capitals) was common for office and residential construction in the mid 20th century. The floor slabs in these structures can be categorized as lightly reinforced (i.e. $\rho = 0.5\%$) and the slab-column connections do not have the appropriate reinforcement details for seismic resistance. Flat-plate structural systems may be prone to shear failure at slab-column connections during or after strong ground motions, and under heavy gravity loads. In many cases, these brittle shear failures initiated a progressive collapse of structures. Therefore, rehabilitation of connections with insufficient two-way shear strength is important.

The objectives of this paper are (i) to present results from an experimental study on the behavior of deficient, damaged, and repaired 2/3-scale slab-column connections, and (ii) to compare the effectiveness of some relatively new rehabilitation techniques (e.g. adding carbon fiber reinforced polymer (CFRP) stirrups at the critical section and attaching CFRP sheets to top surface of the slab to increase the flexural capacity of the slab at the critical section) with a traditional technique (e.g. adding a steel collar to the column beneath the slab to increase the critical shear area).

2. Experimental Program

Seven two-third-scale specimens representing interior slab-column connections were tested. Two specimens served as control specimens to provide information on the two-way shear strength of undamaged and unstrengthened specimens. One of them was reinforced with 0.5% steel in the column strip to represent typical older slab-column connections and the other one had a concentration of reinforcement of 1.0% steel within a width of (c+3h) to represent typical modern connections. After punching shear failure, the epoxy was poured to restore the continuity and the

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steel collars were installed (Fig. 1). Subsequently, the two control specimens were re-tested to study the effectiveness of rehabilitation using the steel collars. The third specimen was subjected to reversed cyclic lateral loads up to failure. The fourth specimen (with 0.5% steel) was subjected to reversed cyclic lateral loads up to 1.25% drift and then was subjected to gradually increasing gravity load up to failure to study the effect of earthquake damage on the punching shear strength. The fifth and sixth specimens were subjected to reversed cyclic lateral loads up to 1.25% drift, then were repaired by the installation of CFRP stirrups and by the installation of well-anchored CFRP sheets (Fig. 1), respectively, before being subjected to gradually increasing gravity loads up to failure to study the effectiveness of repair methods. The seventh specimen (with 1.0% steel within a width of (c+3h)) was subjected to the same loading history as the fourth specimen.

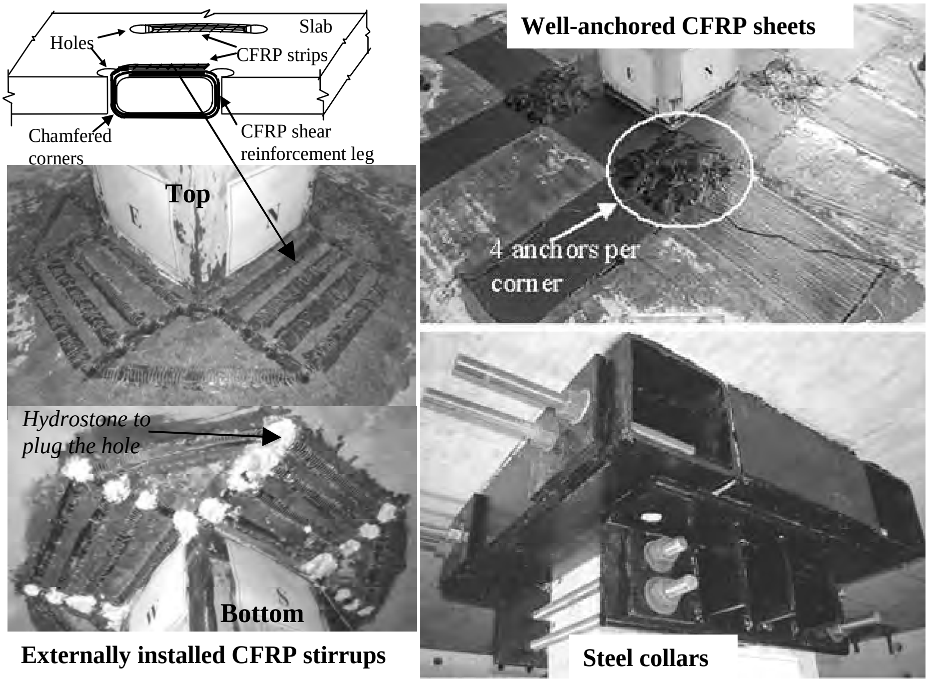

Fig. 1: Different rehabilitation techniques for slab-column connections

3. Conclusions

From the tests conducted, it was found that the two-way shear strength was more sensitive to the slab top reinforcement ratio within (c+3h) region than to the seismic damage in the connection region. The connections with about 0.5% top reinforcement ratio within the ($c+3h$) region, which is typical in the older flat-plate structures, had about 60% of the two-way shear capacity estimated using ACI 318 expressions. The three rehabilitation techniques increased the connection strength and improved the residual capacity after punching failure. The externally installed CFRP stirrups and the steel collars were effective to increase the critical shear parameter and thus increasing the two-way shear strength of the connections. The CFRP sheets did not change the location of the failure surface but limited the width of flexural cracks (that occurred due to simulated seismic displacements) so that the area of concrete resisting shear was maintained and the connection was able to carry more load before a punching shear failure occurred.