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Behavior of reinforced concrete columns strengthened by steel jacket

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Abstract RC columns often need strengthening to increase their capacity to sustain the applied load. This research investigates the behavior of RC columns strengthened using steel jacket technique. Three variables were considered; shape of main strengthening system (using angles, C-sections and plates), size and number of batten plates. Behavior and failure load of the strengthened columns were experimentally investigated on seven specimens divided into two un-strengthened specimen and five strengthened ones. A finite element model was developed to study the behavior of these columns. The model was verified and tuned using the experimental results. The research demonstrated that the different strengthening schemes have a major impact on the column capacity. The size of the batten plates had significant effect on the failure load for specimens strengthened with angles, whereas the number of batten plates was more effective for specimens strengthened with C-channels. Then, by using finite element (F.E) package ANSYS 12.0 [1] their behavior was investigated, analyzed and verified. Test result showed a good match between both experimental tests and F.E models.

Introduction

Reinforced concrete structures often require strengthening to increase their capacity to sustain loads. This strengthening may be necessary due to change in use that resulted in additional live loads (like change in use of the facility from residential to public or storage), deterioration of the load carrying elements, design errors, construction problems during erection, aging of structure itself or upgrading to confirm to current code requirements (seismic for example). These situations may require additional concrete elements or the entire concrete structure to be strengthened, repaired or retrofitted. Common methods for strengthening columns include concrete jacketing, fiber reinforced polymer (FRP) jacketing and steel jacketing. All these methods have been shown to effectively increase the axial load capacity of columns.

Julio Garzón-Rocaet et al. [2] presented the results of a series of experimental tests on full-scale specimens strengthened with steel caging including simulation of the beam-column

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joint under combined bending and axial loads. Capitals were applied to all the specimens to connect the caging with the beam-column joint either by chemical anchors or steel bars. It was observed that steel caging increases both the failure load and ductility of the strengthened columns.

Khair Al-Deen Isam Bsisu [3] performed an experimental and theoretical study on 20 square reinforced concrete columns retrofitted with steel jacket technique. All tested specimens were tested under concentric axial loading. The author concluded that retrofitting square reinforced concrete columns with full steel jackets enhanced the compressive strength more than double the strength of the original column without retrofitting. Also, confinement of reinforced concrete columns with steel jackets enhanced the ductility of the column.

Pasala Nagaprasad et al. [4] presented a rational design method to proportion the steel cage considering its confinement effect on the concrete column. An experimental study was carried out to verify the effectiveness of the proposed design method and detailing of steel cage battens within potential plastic hinge regions. The author concluded that the performance of deficient RC columns under combined axial and cyclic lateral loading can be greatly improved by steel caging technique without using any binder material in the gap between concrete column and steel angles. The proposed design method was found effective and reasonably accurate. Detailing of end battens of the steel cage located in the potential plastic hinge region played an important role in improving the column overall behavior under lateral loads. The increase in width of end battens significantly enhanced the plastic rotational capacity and its resistance to lateral loads; however, it had a minor effect on the overall energy dissipation potential.

Rosario Montuori et al. [5] presented a theoretical model to predict the moment curvature behavior of RC columns confined by angles and battens and the validation of the proposed model by results from experimental testing on 13 specimens tested under axial force. It was concluded that theoretical model showed a good ability to predict the behavior of columns strengthened with angles and battens in terms of both deformation and resistance.

The objective of this research program is to determine the effect of the following parameters on the behavior of strengthened RC column: shape of main strengthening system (using angles, C-sections and plates), size, and number of confining batten plates. A comparison is made between the experimental test results and analytical results obtained through the finite element program ANSYS 12.0 [1].

Experimental testing

In order to investigate the effect of the above mentioned parameters on the behavior of strengthened RC column, an experimental program was carried out to test seven RC columns with concrete compressive strength of f_{cu} = 34 N/mm^2.

Test specimens

All tested columns were 200 × 200 mm in cross-section with 1200 mm height .The specimens were divided into two groups: the first group includes two control specimens without strengthening and second group includes five specimens strengthened with different steel jacket configurations. Vertical steel elements (angles, channel and plates) were chosen to have the same total horizontal cross sectional area. Table 1 gives the reinforced concrete column data for all specimens while Table 2 gives strengthening details for each specimen. Fig. 1 shows specimens' dimensions and steel jacket configuration while Fig. 2 shows the strengthened specimens after casting and jacket erection.

Concrete mix and casting

The concrete mix used for grade 34 Mpa is shown in Table 3. The concrete mixture used was prepared from ordinary Portland cement, natural sand and crushed natural dolomite aggregate with maximum nominal size of 10 mm. The test specimens were vertically cast in wooden forms stiffened by battens to maintain the form and shape.

Test procedure

The specimens were placed in the testing machine between the jack head and the steel frame. The strain gages, load cell and linear voltage displacement transducer (LVDT) were all connected to the data acquisition system attached to the computer. The load was monitored by a load cell of 5000 kN capacity and transmitted to the reinforced concrete column through steel plates to provide uniform bearing surfaces. Fig. 3 shows a schematic view of the test setup. A controlled data acquisition system was used to continuously record readings of the electrical load cell, the two dial gauges of 0.01 mm accuracy (LVDT instruments) that measure the column horizontal deformations in two perpendicular directions, the reinforcement strain gages and also the steel jacket

Table 1 Reinforced concrete column data for all specimens.

Specimen	f_{cu} (N/mm^2)	Dimensions (mm)	RFT		
			Long bars		Stirrups
			Type	f_y (N/mm^2)	
Col.00 (2 specimens) Col.01.L.3P Col.02.L.6P Col.03.C.3P Col.04.C.6P Col.05.Pl	34	200 × 200 × 1200	4 Φ 12 mm @ corners	360 N/mm^2	6 φ 8/m'