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Strengthening of RC Column with Externally Bonded Steel Bars

A.Agalya
M.Tech student, Department of Civil Engineering
B.S. Abdur Rahman Crescent Institute of Science & Technology
Chennai, India

A. Manivannan
Assistant Professor, Department of Civil Engineering
B.S. Abdur Rahman Crescent Institute of Science & Technology
Chennai, India

M. Sriranjani
M.Tech student, Department of Civil Engineering
B.S. Abdur Rahman Crescent Institute of Science & Technology
Chennai, India

M. Shahid Maqdoom Taj
M.Tech student, Department of Civil Engineering
B.S. Abdur Rahman Crescent Institute of Science & Technology
Chennai, India

Abstract:- Strengthening of reinforced concrete column in the existing building is necessary, as the failure of columns collapses the whole structure. As a retrofitting technique, the use of steel bars in the column is almost un-covered in the literature. This project focuses on the effectiveness of the technique of providing steel bars externally in order to strengthen the column. Two types of strengthening is carried out in the columns by removing the cover of the reinforced concrete column. Type1 column is strengthened by welding the steel bars at the corners of the stirrups along the main reinforcement and Type2 is by welding the steel bars at the centres of the stirrups along the main reinforcement. The experimental investigation showed that the load bearing capacity of the columns is improved to 25% and 35% under axial compression and the technique is found to be effective. An analytical study is carried out to analyse the deflection behaviour of the strengthened columns. Also, a theoretical study is conducted and the results are compared with the experimental work which showed an increase in percentage of strength.

Keywords:- *Retrofitingt; steel bars; welding.*

I. INTRODUCTION

In recent years, structural rehabilitation of deteriorated buildings is one of the major issues. There is an increasing demand in the construction industry to repair, strengthen and to upgrade the existing concrete structures. The damage is due to the ageing, poor maintenance, corrosion, poor design and environmental degradation. In India, most of the reinforced concrete structures are susceptible to damage during earthquake as they are designed for gravity loading as per IS 456:2000. During a severe earthquake, these structures may undergo an inelastic deformation which leads to collapse. Such buildings which are designed for gravity loading need to be strengthened for its better strength and stability. By adopting the retrofitting techniques, the axial strength, the bending strength and the stiffness can be increased for the existing columns.

Recent earthquakes have revealed an urgent need to meet the requirements of current seismic design codes, which leads to the development of retrofitting techniques for the existing buildings. Most of the reinforced concrete buildings constructed in India are vulnerable to damage due to the ageing, corrosion and natural hazards. The available techniques to retrofit a column are jacketing, span shortening, steel bracing, plate bonding, section enlargement, near surface mounted bars, FRP strengthening, etc. FRP wrapping is one of the most commonly used retrofitting techniques in the recent years which are found to be effective. All these techniques are very effective but it also leads to some demerits such as corrosion, high cost and difficulty in erection. As there are many available techniques to retrofit a damaged structure, but, still the cost and the simplicity is one of the main reasons to develop a new technique. To overcome the cost and erection problems, there is a need for the simple and effective retrofitting technique. In accordance with the simple and cost effective technique, the present study is conducted by bonding steel bars externally to the longitudinal reinforcement. The retrofitting of column improves the axial strength, bending strength and the stiffness of the original column.

The present study investigates the behaviour and the strengthening effects of the reinforced concrete column which is retrofitted by providing steel bars which are welded to the stirrups along the internal main reinforcement of the concrete column.

II. NEED FOR THE STUDY

In the present days, the deterioration of the reinforced concrete buildings is one of the key problems to be faced. As there are many available techniques to retrofit a damaged structure, but, still the cost and the simplicity is one of the main reasons to develop a new technique. In accordance with the simple and cost effective technique, the present study is conducted by welding steel bars to the stirrups along the internal main reinforcement. The retrofitting of column improves the axial strength, bending strength and the stiffness of the original column.

III. SCOPE AND OBJECTIVES OF THE STUDY

- To investigate the strength improvement of the columns by means of load carrying capacity.
- To study the load deflection characteristics and ductility under axial compression.

- To understand the crack pattern and the failure modes of the columns with different configurations.

IV. METHODOLOGY

The specimens were casted and preloaded with 25% of its ultimate load carrying capacity. The preloaded columns were retrofitted by removing the cover portion of the specimens. As a process of retrofitting, the steel bars are welded to the corners and centers of the stirrups on all the four sides of the specimen along the longitudinal reinforcement.

A. Process of Retrofitting

- *Type1 Columns* – By removing the concrete cover of the columns, the additional steel bars are welded to the corners of the stirrups on all the four sides along the main reinforcement.
- *Type2 Columns* – By removing the concrete cover of the columns, the additional steel bars are welded to the centers of the stirrups on all the four sides along the main reinforcement.

The cross-section of the type1 and type2 columns is shown in the fig.1.

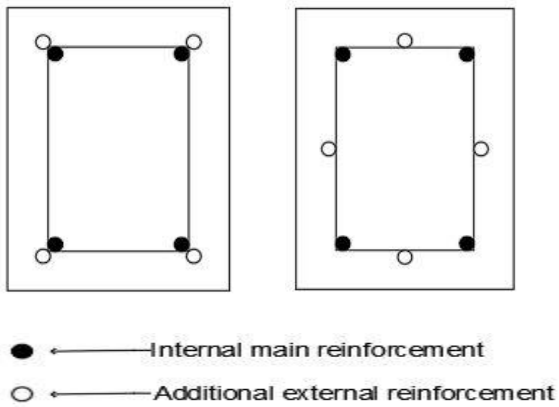

Fig 1:- Cross-section of type-1 & type-2 columns

V. EXPERIMENTAL WORK

A. Specimen Description

The reinforced concrete columns of size 160mm x 160mm with a height of 700mm of six numbers were casted and cured for 28 days. The casted columns were reinforced with 4no's of 12mm diameter bars and the stirrups of 5no's of 8mm diameter bars are placed at 140mm c/c. A clear cover of 40mm is provided in all the sides. All the specimen identifications are listed in the table.1

Specimen id	Description
CC1,CC2	Control concrete column (no extra rods)
RC1,RC2 (Type1)	Retrofitted concrete column with 12mm diameter bars welded at the corners of the main reinforcement
RC3,RC4 (Type2)	Retrofitted concrete column with 12mm diameter bars welded at the centers of the main reinforcement

Table 1. Specimen details

B. Retrofitting of Specimens

All the specimens were preloaded with an axial load of 10tonnes which is 25% of its ultimate load carrying capacity. The columns are then retrofitted with 4no's of 12mm diameter bars. The steel bars are welded to the stirrups with a fillet weld of 3mm thickness. The fig.2 & 3 shows the retrofitting to the finishing up of the specimens.

Fig 2:- Column cover removed and steel rods welded for retrofitting

Fig 3:- Finished up specimens after retrofitting by providing covers

VI. ANALYTICAL WORK

A finite element model of the reinforced concrete column is modeled by using ANSYS Workbench method. To analyze the deflection behaviour of the retrofitted specimens, the ansys modeling is done.

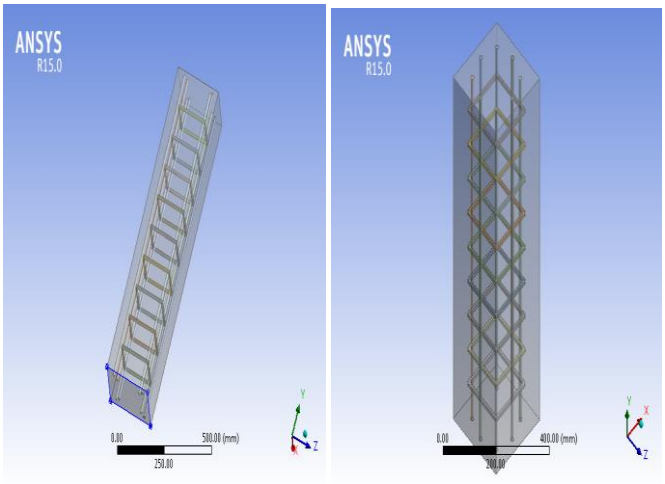

Fig 4:- Modelling of Type1 & Type2 specimens

VII. THEORETICAL STUDY

The columns are designed for the ultimate loading recommended as per IS: 456-2000.

Minimum eccentricity = length / 500 + dimension /30 < 20mm

As per IS 456: 2000, the design load carrying capacity of the column is calculated using:

$$P_u = 0.4f_{ck}A_g + (0.67f_y - 0.4f_{ck})\,A_{sc}$$

Where P_u is the load bearing capacity of column, f_{ck} is the characteristic strength of compression of concrete, Ag is the gross cross sectional area of concrete, f_y is the yield strength of the concrete, A_{sc} is the area of steel in concrete.

VIII. RESULTS AND DISCUSSION

After the application of axial compression loading from the Universal testing machine on the specimens, the results observed at different stages of loading are shown in the table 2.

A. Failure Modes and Crack Pattern

Column id	Initial crack load (kN)	Ultimate load (kN)	Deflection (mm)
CC1	76	430	2.3
CC2	66	417	2.26
RC1	120	521	4.01
RC2	138	538	4.18
RC3	154	592	2.20
RC4	146	580	2.04

Table 2. Experimental results at various stages of loading

The failure mode and crack pattern for control and the retrofitted reinforced concrete columns are shown in fig. 5 to 7. The control columns were crushed at the top due to axial compression. In retrofitted columns, when the load is applied, initial cracks developed at the top of the columns. On further loading, the spalling of the cover of the column leads to failure.

Fig 5:- Failure of convention columns

Fig 6:- Failure of type1 columns

Fig 7:- Failure of type2 columns

B. Load Deflection Behaviour

The load and deflection for all the column specimens has been clearly observed and the values were recorded. According to the results obtained, the columns in which the steel bars welded to the centre of the stirrups (type2) had higher load bearing capacity in comparison to the columns where the steel bars are welded at the corners of the stirrups (type1) and the conventional concrete column. Hence, the type2 column shows

the better behaviour than the type1 and conventional columns in accordance with its higher load carrying capacity.

For various stages of loading, the deflections were observed and the graph is plotted by taking the average values of control columns (CC1 & CC2), type1 retrofitted columns (RC1 & RC2) and type-2 retrofitted columns (RC3 & RC4).

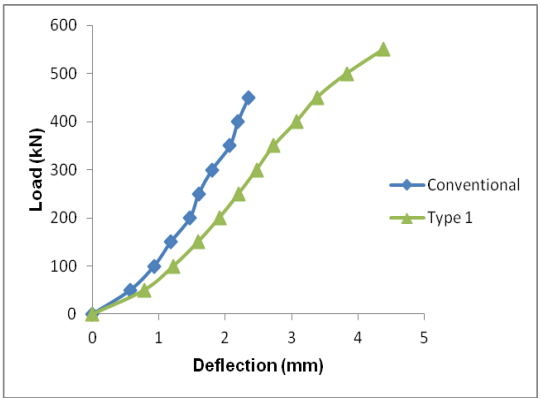

Fig 8:- Load-Deflection for convention and type1 column

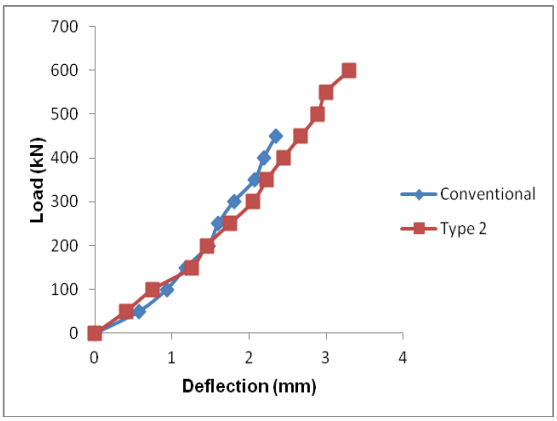

Fig 9:- Load-Deflection for convention and type2 column

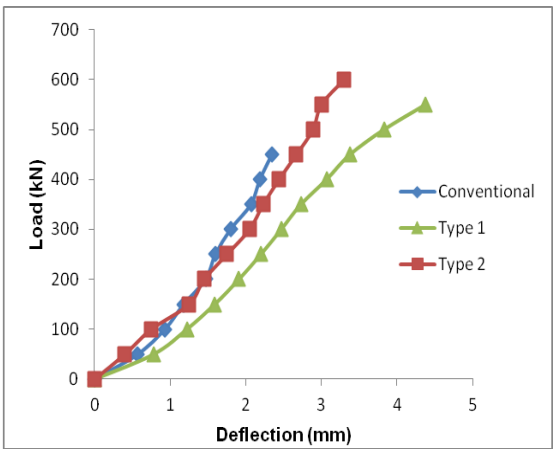

Fig 10:- Load-Deflection for all specimens

C. Analytical Results

From the strengthened columns modeled in ANSYS, the load of 500kN is applied on the type1 and the type2 columns and the deflection behaviour is studied. The figure 11 and 12 represents the deflection behaviour of the retrofitted columns.

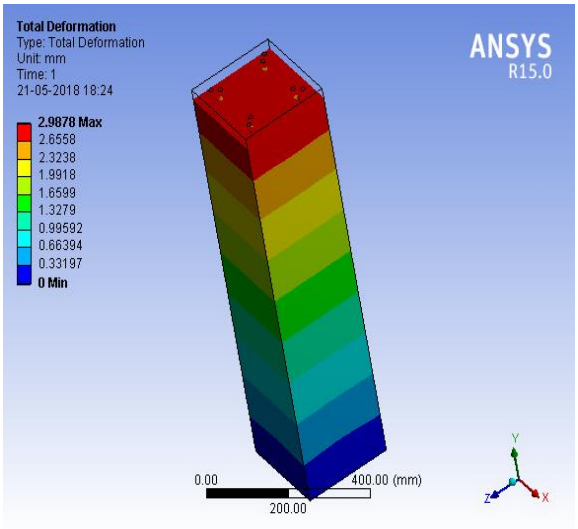

Fig 11:- Deflection of type1 column

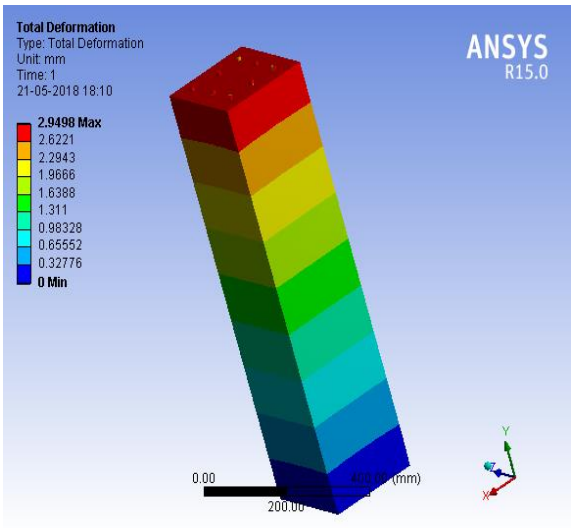

Fig 12:- Deflection of type2 column

D. Comparison of Experimental Theoretical And Results

The experimental results obtained are compared with the theoretical results drawn to determine the percentage increase in the load bearing capacity of the columns. The table 3 shows the comparison of the experimental and the theoretical results.

Column id	Ultimate load (kN)		% increase in ultimate load
	Theoretical	Experimental	
Convention	360	424	18
Type1	510	530	4
Type2	510	585	15

Table 3:- Comparison of experimental and theoretical results

IX. CONCLUSIONS

- The reinforced concrete columns welded with steel bars at the centre of the stirrups on all the sides along the main reinforcement is found be effective in load carrying capacity.

- The ultimate load bearing capacity of type1 and the type2 column is 25% and 38% more than the conventional concrete. The type-2 column shows 10.5% improvable in load bearing capacity compared with the type1 column.
- From the theoretical results, it is found that the ultimate load bearing capacity of the experimentally tested columns shows increase in strength compared to the theoretical results. The type2 column shows better improvement in strength than the type1 column.
- Due to the higher load bearing capacity and lesser deflection, the type2 columns with steel bars welded at the centre of the stirrups can be suitable for the extreme loading conditions.
- Failure mode and the crack pattern of the conventional columns are similar to that of the type1 and type2 columns in case of crushing. In addition to crushing, the type1 and type2 columns lead to failure by spalling of the concrete covers.

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