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Retrofitting Of Reinforced Concrete Column by Steel Jacketing

Abhishek Jodawat[1], Arihant Parekh[1], Bhushan Marathe[1], Ketan Pawar[1], Sunny Patwa[1], Yash Sahu[1], Indrajeet Jain[2]
([1].Stutents And [2] Asst. Professor, Department Of Civil Engineering, Sinhgad Institute Of Technology And Science, SPPU, Pune-41)

ABSTRACT
Reinforced concrete structures often require strengthening to increase their capacity to sustain additional loads, due to change in use that resulted in additional live loads, deterioration of the load carrying elements, design errors, construction problems during erection, aging of structure itself or upgrading to confirm to current code requirements. 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.
The experimental study was carried out on RC column on designed and detailed using IS 456:2000 provisions. The concrete mix design being performed after conducting numerous material test and cube test to validate expected strength as per specified grade of concrete. The trial testing conducted to estimate load at 1st crack and failure load for normal RC column with capturing displacement using dial gauges at regular load increment in UTM. The loading conditions are decided based on failure load to induce cracks in column under 85% loading of the failure one. In all fifteen specimen casted and tested with three samples for failure load estimation, three samples each for plate jacketing & angle battening system and three samples each for plate jacketing & angle battening with column preloaded to 85% of its failure load. The angle batten system proves to be better compared to full plate retrofitting in terms of load carrying capacity and enhancing confinement effect.
Keywords: Axially loaded column, Retrofitting, steel jacketing, epoxy resign, Cracks

I. INTRODUCTION

Throughout the world many existing reinforced concrete structures, constructed prior to up to date earthquake resistant design procedures, suffer from the inability to supply adequate ductility during earthquakes. Particularly, brittle columns without adequate transverse reinforcement may cause a total collapse of this type of structure due to lack of sufficient deformation capacity. Retrofit of this type of column by means afforming an additional jacket layer may supply the required transverse reinforcement and enhance the seismic performance by providing additional ductility, and reducing the seismic force demand.

The different types of retrofitting techniques used and applied depending on the suitability, applicability, the type of damage to be repair, type of resistance required, whether the damage is local or global and extent of strengthening possible from existing state of stress.

The purpose of this paper is to conduct experimental study on Reinforced concrete column to evaluate performance of steel plate jacketing and angle batten systems in strengthening or increasing load carrying capacity of members. In this study the behavior of strengthened reinforced concrete columns by steel jacketing techniques is studied experimentally and the behavior of retrofitted column is compared with undamaged reinforced concrete column and also with preloaded column with 85% of failure load with retrofitting done to it.

II. EXPERIMENTAL STUDY ON RC COLUMN STRENGTHENING

2.1 Introduction

The material used in construction has to satisfy bear minimum strength and criteria as per the Indian Standard code of practice for Plain and Reinforced concrete design (IS 456:2000) Further the relevance of specific IS codes have been extracted wherever necessary for different materials and procedures to obtain material character and parameters required for mix design. The mix design being performed to achieve target strength of specific grade of concrete to be prepared using basic ingredient in specific proportion. The numerous tests were conducted for cement, fine aggregates, coarse aggregate and water to figure out material properties.

The RC structures are subjected to deterioration and degradation due to aging, extreme loading, workability and climatic conditions. The 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. The experimentation involves casting of specimen, trial testing to decide the fate of loading condition, bonding between steel-concrete and fabrication of retrofitting or strengthening technique to be employed. The instrumentation also plays the vital role in evaluation of responses parameters.

2.2 Materials test

The basic ingredients for concrete is Cement, fine aggregates, coarse aggregate reinforcement steel bars are used in casting of columns. The various tests are performed on above mentioned ingredients or components to satisfy code requirement. Table 2.1 provides proportion for M25 grade mix.

Table 2.1 Proportion of M25 Grade Mix

Cement	River sand	Coarse Aggregate (20mm)	Coarse Aggregate (10mm)	Water
382.2 kg/m3	662 kg/m3	756.6 kg/m3	504.4 kg/m3	191.6 kg/m3
1	1.73	1.97	1.32	0.05

2.3 Cube testing

The RC column are casted in four stages with proper standards and to ensure the required or target strength is achieved the cubes are casted. The standard cubes of 150x150x150 are casted during each stage. The three samples are taken to figure out average strength. The cubes are cured in water bath for 28 days period.

The cube strength is estimated using results obtained from cube testing for each casting stage. The Table 2.2 shows compressive strength and average strength after 28 days. The average strength achieved is satisfactory as it is well above desired grade of M25 and strength is closer to target strength which is considered in mix design calculations.

Table 2.2 Compressive Strength of cubes

Compressive strength (MPa) at age 28 days			Average Compressive Strength (MPa)
1	2	3	
28.70	27.55	28.88	28.37
31.11	30.22	30.22	30.51
28.44	30.02	29.77	29.41
29.33	28.70	28.00	28.67

2.4 Specimen Details of Column

Table 2.3 Specimen Details of Column

Specimen	Details
Column size (mm)	200×250×1450
Grade of concrete	M25
Grade of steel	Fe415
Longitudinal Reinforcement	4 nos of 12mm diameter bars
Lateral Reinforcement	8mm diameter bars @190mm spacing

2.5 Testing of retrofitted specimen

The retrofitted specimens are tested under axial loading for the angle battening system and full plate system for the loading case of 85% and intact cases and also for original columns. The specimens are loaded till failure to estimate strengthening effects on carrying capacity.

2.6 Summary

The material testing performed on different constituents with detailed mix design adhering to standard and specification as per IS standard. The target strength of concrete was achieved with strict supervision and quality control to meet the desired strength i.e. M 25 grade of concrete. Cube testing verified the compressive strength of concrete necessary for M25 grade. The ultimate load capacity was found using IS 456 provisions for short axial column.

The crushing of concrete observed when strain reaches failure limits. The crack initiates dominantly at corners and upper 200mm height from top of column and propagates further downwards. The cracking and crushing is observed on shorter side first and then subsequently on longer side. The load carrying capacity of the specimen is enhanced after retrofitting on intact specimen while for preloaded specimen the strength regain is at least up to ultimate failure capacity of RC column.

III. RESULTS AND DISCUSSION

3.1 Introduction

In this chapter, experimental results of angle battening and full plate jacketing for different loading conditions adopted are discussed. Average load capacity of retrofitted specimen and original specimen is given in Table 3.1. Also summary of Failure Load Displacement data for all specimen is given in Table 3.2.

3.2 Average load capacity of retrofitted specimen & summary of Failure Load Displacement data for all specimen

Table 3.1 Average load capacity of retrofitted specimen

Specimen Type	1	2	3	Average
Original specimen with angle batten	1042.61	1079.54	1156.06	1092.73
Original specimen with plate	1014.89	986.43	965.61	985.97
85% damage specimen with angle batten	967.83	916.15	937.48	940.49
85% damage specimen with plate	868.62	849.58	848.05	855.42
Original Specimen	785.14	828.20	801.17	804.16

Table 3.2 Summary of Failure Load Displacement data for all specimen

Sr. No.	Specimen Type	Failure Load (kN)	A.D. (mm)	L.D. (150 - 200) (mm)	L.D. (750 - 200) (mm)	L.D. (750 - 250) (mm)
1	column 1	785.14	4.38	6.12	1.88	1.78
2	column 2	828.50	4.24	6.50	1.84	1.60
3	column 3	801.17	4.31	6.24	1.63	1.66
4	OCRAB1	1042.61	3.43	5.15	2.08	1.95
5	OCRAB 2	1156.06	3.70	5.61	2.64	2.57
6	OCRAB 3	1079.54	3.58	5.03	2.70	2.57
7	OCRP 1	1014.89	4.17	5.32	2.42	2.02
8	OCRP2	986.43	3.99	5.14	2.17	1.94
9	OCRP3	965.61	3.97	5.12	2.24	1.83
10	85% PLCRAB 1	967.83	4.65	5.89	2.16	2.01
11	85% PLCRAB 2	916.15	4.80	5.80	2.23	2.16
12	85% PLCRAB 3	937.48	4.26	5.47	1.98	1.92
13	85% PLCRP1	868.62	4.70	5.78	2.25	2.07
14	85% PLCRP 2	849.58	4.38	5.49	2.13	2.10
15	85% PLCRP 3	848.05	4.48	5.50	2.05	1.90

Where,
OCRAB-Original Column Retrofitted with Angle Battening
OCRP-Original Column Retrofitted with Plate
PLCRAB-Preloaded Column Retrofitted with Angle Battening
PLCRP-Preloaded Column Retrofitted with Plate
AD-Axial Displacement
LD-Lateral Displacement

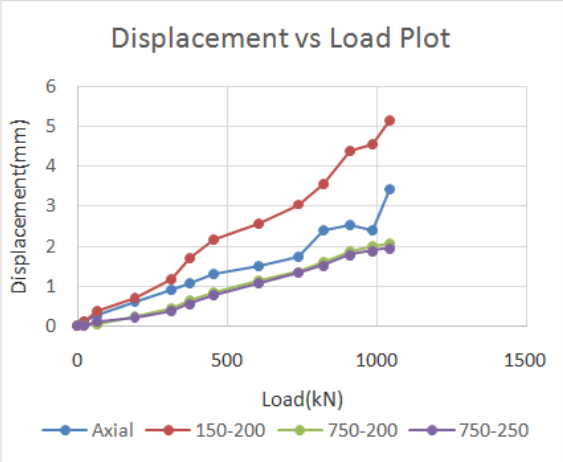

Fig. 3.1 Load displacement curve for original Specimen 1 retrofitted with Angle Batten System.

3.3 Summary

The load deformation curves for axial, lateral at mid height and at 150 mm from top are plotted for various specimen tested with different loading conditions and retrofitting systems to predict and compare the behavior of normal RC column to retrofitted RC column. A sample graph is shown in Fig. 3.1. The angle batten system showed higher strength gain with better confining effect than the thin plate system. The retrofitting system provides lateral confinement, which helps to prevent bulging, early crushing with increase in load carrying capacity in comparison to normal RC column.

IV. CONCLUSIONS

4.1 Summary and conclusions

The present study was undertaken to investigate the behavior of RC columns and also of RC columns retrofitted with steel jacketing systems either with angle batten or full plate systems. The performance of normal RC columns and retrofitted RC columns under axial load for different specimen. The performance and behavior of different specimen are assessed and analyzed with experimental study. The experimental study has showed that strength regain for intact and preloaded specimen. The preloaded specimen is loaded 85% of failure load. The following conclusions are derived as follows:

1. The strength enhancement for retrofitted specimen compared to normal RC column for different loading condition and structural systems are;

a. The increment in strength for intact specimen retrofitted with angle batten and full plate system are 32% and 22% respectively.

b. The strength is increased for 85% loaded specimen retrofitted with angle batten and full plate system are 16% and 6% respectively.

2. The confinement effect observed as there is decrement in internal deflection for retrofitted specimen compared to normal RC column for different loading condition and structural systems are;

a. The decrement in lateral deflection for original specimen retrofitted with angle batten and full plate system are 16% and 17% respectively.

b. The lateral deflection is increased for 85% loaded specimen retrofitted with angle batten and full plate system are 9% and 11% respectively.

3. The increment in axial deflection for retrofitted specimen compared to normal RC column for different loading condition and structural systems are

a. The decrement in axial deflection for original specimen retrofitted with angle batten and full plate system are 16% & 6% respectively.

b. The axial deflection is increased for 85% loaded specimen retrofitted with angle batten and full plate system are 7% & 6% respectively.

4. The angle batten system proves to be better compared to full plate retrofitting in terms of load carrying capacity and enhancing confinement effect.

5. The crack filler helps to bind crack portion forming strong bond while bonding chemical helps in confining and adhering effect so that composite section have monolithic behavior.

6. The retrofitted specimen shows higher ductility compare to normal RC column as it shows enhanced behavior after yield displacement or yielding.

4.2 Scope of future work

1. The advance instrumentation scheme can be deploy to capture the response of structure in scientific manner.

2. The experimentation can be performed for eccentric loading as in case of accidental load, the load may not be purely axial.

3. The parametric study can be performed to figure out optimum batten spacing in case of angle batten and optimum length required in case of plate bonding system.

4. The parametric study can be performed to estimate optimum size and thickness of angle and batten in case of angle batten and optimum thickness required in case of plate bonding system.

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