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Structural Performance of Jacketing in Reinforced Concrete Columns: A Brief Survey

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Abstract - *Most of the reinforced concrete (RC) residential buildings situated in earthquake prone areas are not seismically designed. To prevent disaster due to future earthquakes, these deficit structures need to be retrofitted. The present thesis discusses about the structural behavior and gain in strength of RC column re strengthened by using three retrofitting techniques: RC jacketing, fiber reinforced polymer (FRP) wrapping and steel jacketing. The objective of this study is to discuss the difference in structure behavior of RCC column after retrofitting by, RC jacket, three different types of CFRP and steel jacketing by comparing their demand-capacity ratio (DCR) and inter-story drifts. In this study, a typical G+1 RC residential structure located in North-East region of India (seismic Zone-V according to IS1893:2016) is modeled numerically and analyzed linear dynamically. All the real parameters corresponding to this location such as soil type, topology, seismic zone etc. are considered. IS 875 (part-1 and part2):1987 has been referred for application of loads and IS1893(part-1):2016 forseismic analysis. RC columns that are seismically deficit are then retrofitted with RC jacketing, CFRP andsteel jacketing and the comparative study on their behavior against earthquake is done. RC jacket is designed according to IS 456 and IS 15988, CFRP is designed according to ACI440.2R-17 and steel jacket based on existing literatures. CFRP was found to be more efficient among all three retrofitting techniques for enhancement of capacity of RC column. RC jacking gave best results for reduction in inter-story drift ratios of structure*

***Key Words*: Retrofitting design, RC jacketing, FRP wrapping, steel jacketing, Response Spectrum Analysis**.

1. INTRODUCTION

Almost everyone has heard of concrete and knows that it is a material that is used in the construction of various structures such as multi-story buildings, flyovers, and bridges, and that concrete is nothing more than a mixture of binding material, fine aggregates, and coarse aggregates mixed with the appropriate amount of water. Reinforced cement concrete (RCC) is a versatile material that is widely employed in most projects around the world. However, its performance during earthquakes or seismic forces has raised a number of concerns in the minds of many researchers. Earthquakes can cause reinforced concrete structures to collapse, resulting in the loss of lives as well as massive economic losses. The majority of structures in India cannot withstand even minor seismic or earthquake loading. It is critical for RC constructions to have the lateral resistance capacity against brittle breakdown during seismic activity. Buildings that are not earthquake resistant and were built using non-seismic codes of practice are vulnerable to seismic excitations. Because RC buildings are expensive to reconstruct and demolish, upgrading a small portion of structural components and the building can be a viable method for assuring the safety of structure and people.

1.1 RC Jacketing

RC-jacketing is mostly used process for strengthening of reinforced concrete columns. It has been studied by a number of researchers for its effectiveness in strengthening weak structures and restoring their load carrying capacity. According to a statistical study conducted to investigate the ways utilized to strengthen various concrete structures damaged by an earthquake in 1985, RC-jacketing was often used as a reinforcing strategy. When it comes to the structural qualities of RC jacketing, this method can increase stiffness while improving strength and ductility. It improves the overall behavior of that structure while also increasing the strength and ductility of the target part. It was also proved that via RC jacketing, a strong beam weak column may be transformed into a weak beam strong column. Furthermore, the RC-Jacketing method can boost a damaged column's strength by three times its original value. A similar study on RC frames discovered that the lateral strength was five times that of the original frame. The RC-Jacketing technique, on the other hand, is simple and requires extreme caution when it comes to surface drying; otherwise, the jacket can split.

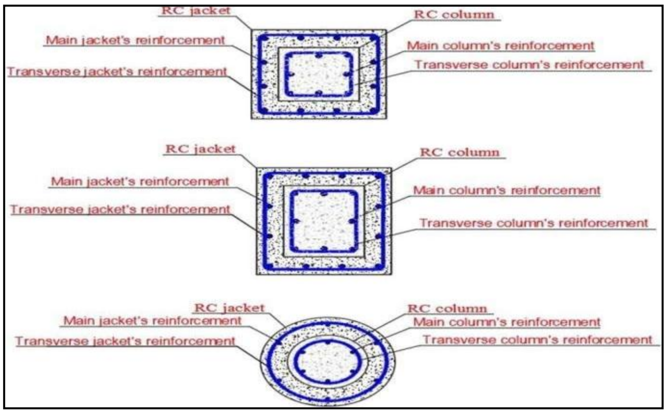

Fig -1: RC jacketed RC column with different cross-section

1.2 Fiber Reinforced Polymer (FRP)

In recent years, Fiber Reinforced Polymer (FRP) has gained popularity for retrofitting or reinforcing reinforced concrete structural parts. It's a composite material consisting a polymer matrix and natural or synthetic fibers. Carbon, aramid, glass, basalt, and a variety of other fibers, including paper, wood, asbestos, and natural fibers, have all been employed. As previously stated, aramid fibers, a type of synthetic fiber, are employed in this experimental study.Despite of the fact that there are a few researches evaluating the confinement efficiency of various FRPs on reinforced concrete columns on the basis of serviceability and strength. This thesis focuses on the application of Carbon Fiber Reinforced Polymers (CFRP) to improve the compression behavior of preloaded RC columns.

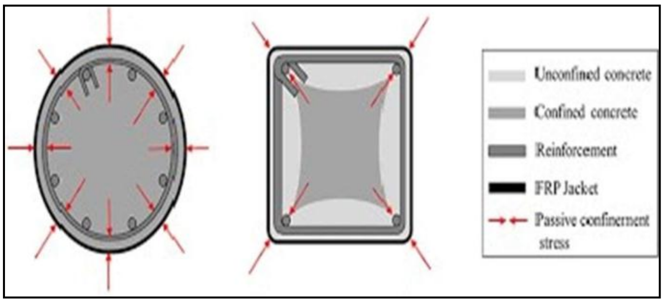

Fig -2: A RCC column with FRP laminates

2. Methodology

1. Strength related checks of each component of the structure will be performed manually as per guidelines provided in IS 1893 (Part 1):2016.

2. The entire structure to be modeled in ETABS 2018 as per the actual site conditions,i.e. soil type, loads, earthquake zone, building architecture and etc.

3. Loads on the structure will be applied as per IS 875:1987 and seismic analysis as per IS 1893(part-1):2016..

4. The model will be then analyzed linear dynamically (RSA) for the defined load combinations for the checks and optimizations of the structural member.

5. The critical members will be then modified individually in order to obtain the required strength under the action of seismic loads.

6. Comparison of the results of all three retrofitting methods.

3.Literature Review

Ghobarah A. et al (1997) presented an experimental study of failure modes of non- ductile RC columns re-strengthened with the use of rectangular flat steel jackets. Expansion anchor bolts were used to secure the jacket to the column. The study's goal was to determine how effective this type of jacketing is at improving column seismic performance. Under cyclic loading, three large scale columns were tested. It was discovered that strengthening columns with steel jackets and expansion anchor bolts improved their cyclic behavior

Sakino K. et al (2000) offered a report (based on several studies done in Japan), on theseismic behavior of the square reinforced concrete columns retrofitted using steel jackets. The load bearing and deformation capabilities of the retrofitted RC columns are the focus of their report. The main items studied in this report are: (1) stress-strain curve model for concrete confined by the steel jacket, (2) methods to evaluate shear strength and ultimate bending strength of the retrofitted reinforced concrete columns, and (3) a design formula for prediction of the deformation capacity of retrofitted columns.

Kaliyaperumal G. et al (2009) studied the influence of jacketing on the performance and flexural strength of RC columns. Slant shear tests were first performed to investigate the interaction between the old and new concrete. Second, column specimens were put to the test to see how strong they were. Third, the ductility (or energy absorption) and energy dissipation of beam-column joint sub-assemblage specimens were investigated. Analytical studies were conducted in order to forecast thetrial outcomes. The moment versus curvature curves and the axial load versus momentinteraction curves for the retrofitted RC columns were predicted using lamellar technique and a simplified technique of analysis.

Mohsen S. et al (2013) (based on Lam and Tang model) worked for the verification ofthe the model of FRP confined columns in SAP2000, which calculates the material parameters of wrapped reinforced concrete columns. The technique for modelling andassigning specializations is given in context, and the analysis results have been compared to literature to determine the dependability of analysis. For FRP confined RCcolumns with and without reference to ACI-440 regulations for the rectangular and thecircular section, the allowed range of difference according to SAP2000 (2009) guideline is controlled. An investigation of the performance of FRP wrapped columns revealed that yield is comparable to that of the typical RC columns, but ductility and post-yield are different.

Tarabia A.M. et al (2014) conducted an experimental study on ten column's specimensthat are axially loaded till failure. The major goals of his work were to investigate the behavior and effectiveness of RC square columns reinforced with steel strips and angles(steel cage). The key researched parameters in his paper were the spacing of strips, grout material between column sides and steel angles, size of the steel angle, and the connection between the steel cage and the head of specimen.

4. Result Of Analysis Of Retrofitting Building

RC clowmns selected for retrofitting have been designed as described in last chapter and then modelled and analyzed linear dynamically on computer software. Columns are been retrofitted using all three methods by referring the standard codes as specifiedin last chapter. Results of DCR of particular columns obtained after analysis has been tabulated in this section.

- DCR (demand capacity ratio) of column is calculated for every individual loadcombination used for design. The load combination having maximum value ofDCR is critical load combination.

- For calculation of DCR, all the loads acting on column are evaluated. Vertical loads include DL, SIDL and LL. Lateral loads are seismic loads in both X and Y directions. Base shear (calculated in section 3.4) is then distributed on each floor with respect to proportion of weight of that floor. These distributed base shear are lateral earthquake forces in X and Y directions.

- All these loads are then substituted in load combinations for calculation of thatload demand of column. Ratio of this demand and capacity is termed as DCR

Table -1: DCR of columns wrapped with CFRP-1

Col. No.	Unique name	Floor	Existing DCR	No. of layersof	DCR after wrapping
C6	33	1st	9.201	13	1.073
C6	35	Terrace	6.919	6	1.202
C7	17	1st	7.008	14	1.062
C7	19	Terrace	5.805	10	.0971
C10	41	1st	6.465	25	.669
C10	43	Terrace	4.978	6	1.205
C12	65	1st	9.094	21	0.726
C12	67	Terrace	6.133	6	1.085
C15	61	1st	9.08	17	0.85
C15	63	Terrace	6.073	7	1.031
C19	53	1st	8.805	20	0.668
C19	55	Terrace	6.385	6	1.072

Table -2: DCR of columns wrapped with CFRP-2

Col. No.	Unique name	Floor	Existing DCR	No. of layersof	DCR after wrapping
C6	33	1st	9.201	18	1.084
C6	35	Terrace	6.919	5	1.692
C7	17	1st	7.008	20	1.06
C7	19	Terrace	5.805	8	1.397
C10	41	1st	6.465	36	0.66
C10	43	Terrace	4.978	2	2.309
C12	65	1st	9.094	31	0.733
C12	67	Terrace	6.133	9	0.805
C15	61	1st	9.08	15	1.167
C15	63	Terrace	6.073	8	0.178
C19	53	1st	8.805	29	0.661
C19	55	Terrace	6.385	8	1.11

Table 3: DCR of columns wrapped with CFRP-HM60

Col.No.	Unique name	Floor	Existing DCR	No. of layersof	DCR after wrapping
C6	33	1st	9.201	12	1.125
C6	35	Terrace	6.919	4	1.566
C7	17	1st	7.008	13	1.119
C7	19	Terrace	5.805	6	1.312
C10	41	1st	6.465	24	0.689
C10	43	Terrace	4.978	2	1.707
C12	65	1st	9.094	21	0.739
C12	67	Terrace	6.133	6	1.095
C15	61	1st	9.08	10	1.213
C15	63	Terrace	6.073	5	1.278
C19	53	1st	8.805	19	0.699
C19	55	Terrace	6.385	6	1.075

3. CONCLUSIONS

Based on the of results obtained by linear dynamic analysis of retrofitting techniques of RC column, following conclusions can be made-

- RC jacketing it is observed to be more effective than FRP and steel jacketing forenhancement of stiffness

- CFRP proved to be best of all the three in reduction of DCR of columns

- Inter-storey drift of RC structure has been reduced effectively just by restrengthening of six out of nineteen columns.
- Inter-storey drift of structure can be reduced to satisfy criteria of IS codes (0.004 times of storey height) by restrengthening of key frame members.
- RC jacket increases the dead load on columns below and effects nearby area duringexecution.
- RC jacket increases crossection area resulting in increasing of self weigth of structure, hence the adjacent columns also get effected by its increased load. Therefore, this increased load should be considered during its design.

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