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Retrofitting of RC Building Column and Foundation and its Analysis using ETABS

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***Abstract*: Retrofitting is a technique to improve the structural capacities including the strength, stiffness, ductility, stability of a building that is found to be deficient. It can effectively improve the performance of a building. In this paper, an RC building of G+3 will be analyzed and design in E-tabs software. Then the number of floors will increase to 3 numbers above the top floor of existing building so that the building becomes G+6 floors and again it is increased by 2 numbers above the top floor of existing building then it becomes G+8 floors. Because of increment of floors the load on the building will be increased so the existing columns may fail in design the failure of columns may be maximum in bottom storey, so how many number of columns fail the same will rectified by Reinforced Concrete jacketing technique, because of jacketing the column strength will increased and the jacketing will be design to carry the increased load by using IS code (IS 15988:2013) and the jacketing will be done in ETABS software. In the software each failed column will be modeled and the increased area of reinforced column can able to take an increased load so the building can be raised to the above-mentioned floors. Hence columns can be strengthened to carry the increased load safely.**

***Keywords*: Concrete jacketing, Retrofitting, ETABS software, MS–EXCEL, Strengthening, Deflection.**

1. Introduction

Jacketing of columns consists of added concrete with longitudinal and transverse reinforcement around the existing columns. This type of strengthening improves the axial and shear strength of columns while the flexural strength of column and strength of the beam-column joints remain the same. It is also observed that the jacketing of columns is not successful for improving the ductility.

A major advantage of column jacketing is that it improves the lateral load capacity of the building in a reasonably uniform and distributed way and hence avoiding the concentration of stiffness as in the case of shear walls. This is how major strengthening of foundations may be avoided. In addition, the original function of the building can be maintained, as there are no major changes in the original geometry of the building with this technique.

Jacketing of columns is needed when the load carried by the column is increased due to either increasing the number of floors or due to mistakes in the design. Jacketing is practiced when the compressive strength of the concrete or the percent and type of reinforcement are not according to the codes' requirements and also when columns is exposed to an earthquake, an accident such as collisions, fire, explosions. The most common types of jackets are steel jacket, reinforced concrete jacket, fibre reinforced polymer composite jacket, jacket with high tension materials like carbon fibre, glass fibre etc.

External confinement of concrete significantly enhances its strength and ductility, resulting in large energy dissipation capacity. Therefore, confined reinforced concrete (RC) columns possess larger bending moment capacity and ductility, as well as larger axial load carrying capacity than unconfined normal reinforced columns.

In order to prevent loss of human life and property due to earthquakes, the steel jacket retrofit has been investigated in this research, as a method to enhance the axial strength and ductility of square and circular RC column specimens. The present paper is focused on the load carrying capacity and deformation capability of the retrofitted RC column specimens.

2. Literature Review

Yogendra Singh (2003) [1] large number of existing buildings in India is severely deficient against earthquake forces and the number of such buildings is growing very rapidly. This has been highlighted in the past earthquake. Retrofitting of any existing building is a complex task and requires skill, retrofitting of RC buildings is particularly challenging due to complex behavior of the RC composite material. The behavior of the buildings during earthquake depends not only on the size of the members and amount of reinforcement, but to a great extent on the placing and detailing of the reinforcement. The construction practices in India result in severe construction defects, which make the task of retrofitting even more difficult. Step to step procedure given below.

- Setting of goals and performance level of building and estimation of seismic hazard.
- Systematic visual inspection and study of available drawing and documents.
- In situ investigation for strength and degradation of material and preparation of as built drawing.
- Identify deficiencies and scheme for detailed

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investigation.

- Detailed evaluation of strength, ductility, deterioration.
- Design of Retrofitting scheme based on evaluated deficiencies.
- Evaluation of Retrofitted building.

Sudhir k. Jain (2002) [2] In this paper the Concept of pushover analysis that is becoming a famous tool in the profession for design of new structure, seismic evaluation of existing buildings and developing appropriate strategy for seismic retrofitting of structure. It is shown how this Analytical technique can be useful in deciding seismic retrofitting.

Lakshmanan D (2006) [3] In this Pushover analysis of the structures done by SAP 2000.Sap 2000 evaluating the various repair strategies for improvement of the seismic performance of RC structures are given. The behaviors of repaired beams of beam column joints are discussed. It is observed that inherent deficiencies in the detailing of the beam-column joints get reflect even after repair, though the performance factors indicate significant improvement. Two of the logical extensions show that the repair would not be as effective in these cases.

Giuseppe Oliveto and Massimo Marletta (2005) [4] considered the retrofitting of buildings vulnerable to earthquakes and briefly described the main traditional and innovative methods of seismic retrofitting. Among all the methods of seismic retrofitting, particular attention was devoted to the method which was based on stiffness reduction. This method was carried out in practice by application of the concept of springs in series, which lead in fact to base isolation. One of the two springs in series represented the structure and the other represented the base isolation system. The enhanced resistance of the buildings to the design earthquake clearly showed the effectiveness of the method, while a generally improved seismic performance also emerged from the application.

Abhijit Mukherjee and Amit R. Kalyani (2004) [5]. This paper introduces a method of design of structural upgradation using FRC and discusses the design of enhancement of RCC elements with FRC, a strategy of upgradation of RCC frames and use of the developed strategy of upgradation for retrofitting of RCC frames based on Capacity Spectrum Method.

Sarvesh Kumar Jain (2003)6 In this paper main focus on functioning of a building during retrofit work in a progress. Mainly we see conventional method of Retrofitting often requires restricting the use of the building during retrofit. In the paper briefly prevailing retrofit methods without affecting their daily functioning. Their some techniques used which are given below Sheet jacketing Strand jacketing Panel jacketing Dampers Wall type viscous damper.

Pranab Agarwal, Siddhartha Gupta, Ankur Kataria and Pratima Rani Bose (2003) [7] Normally jacketing is provided according to experience. In this paper suggest an effective analytical procedure for the purpose of jacketing. Standard codal provision for column design has utilized to suggest a jacketing solution. The entire procedure has been supported by a C++ program which plots the interaction diagram and gives the final dimensions of the retrofitted member.

Jong-Wha Bai (2003) [8] Studied the Seismic Retrofit for Reinforced Concrete Building Structures and proposed a relatively new paradigm, performance-based design, has also had an impact on seismic retrofitting and rehabilitation.

This concept provides a new approach to design objectives and desired performance levels. As the performance-based design paradigm become more accepted for new structures, seismic retrofitting and rehabilitation methods have been affected by this concept. Consequently, retrofitting procedures could be selected and applied so that the performance objective of the retrofit depends upon the importance of the structure and the desired structural performance during a seismic event with a particular recurrence interval.

Abdullah and Takiguchi (2003) [9] Investigated the square columns using both square and circular ferrocement simultaneously under compressive and cyclic loading. For the study three types of columns were considered Three columns, designated as CJ-AL10-6L, CJAL15- 6L, and CJAL20-6L were tested under different axial loads after being strengthened 13 with circular ferrocement jackets containing six layers of wire mesh. Specimen CJAL15- 6/3L, strengthened with reduced number of layers of wire mesh for the centre portion, was tested to investigate the behavior and strength of the important practical aspect of strengthening RC column with ferrocement. Two reference columns, SJ-AL15-4L and SJAL15-6L, were strengthened with square ferrocement jackets, with four and six layers of wire mesh, respectively, before tested to their failure to study the effects of different shapes of jacketing on lateral load–displacement response.

Each of the reference columns was reinforced with 12 deformed D-6 bars distributed evenly around the perimeter of the column cross-section. Smooth R-2 (diameter ¼ 2mm) bars were used as transverse reinforcement spaced at 50 mm.

Shailesh Agrawal and Ajay Chourasia (2003) [10] performed the nonlinear static analysis of RC building using pushover approach before and after retrofitting.

The comparison of strength parameters and pushover curve indicated that there was increase in ductility. As regards to stiffness of the building, it was seen that it remains more or less same up to linear stage, while in nonlinear stage every point increased both in capacity and the deformation after retrofitting. The strength of the building was correlated with base shear, the net enhancement in strength after retrofitting.

M. C. Griffith and A. V. Pinto (2000) [11] have investigated the specific details of a 4-storey, 3-bay reinforced concrete frame test structure with unreinforced brick masonry (URM) infill walls are described along with estimates of its likely weaknesses with regard to seismic loading. The concrete frame is shown to be essentially a “weak-column strong beam frame” which is likely to exhibit poor post yield hysteretic behavior. Based on the results of an extensive literature review, the building is expected to have maximum lateral deformation capacities corresponding to about 2% lateral drift. The unreinforced masonry infill walls are likely to begin cracking at much smaller lateral drifts, of the order of 0.3%, and to completely lose their load carrying ability by drifts of between 1% and 2%.

Amlan K. Sengupta, V. T. Badri Narayan and A. Ashokan

(2003) [12] In this paper aim to evolve methodologies to assess the seismic vulnerability of reinforced concrete three-ten storey residential and commercial building. Use of local Retrofit Strategies they are given hear Steel Jacketing, Steel Plating, Use of FRP bars Addition of Concrete, Concrete Jacketing It is imperative to have seismic evaluations of a building both for the existing and retrofitted conditions.

N. M. Bhandari and A. K. Dwivedi (2003) [13] In this paper Some materials are described like Epoxy, Steel, Mortar, Quick setting cement mortar, F RP. Some techniques also describe like Shotcrete Jacketing, Mechanical anchorage Inserting new walls, strengthening of existing wall, Masonry arches, Random rubble Masonry.

Kondraivendhan and Pradhan (2009) [14], Studied effect of ferrocement confinement on behavior of concrete. The effect of different grades of concrete confined with ferrocement was studied by keeping all other parameters constant. In this investigation, concrete mixes had been chosen over a wide range of grades of concrete, namely M25, M30, M35, M40, M45, M50 and M55. The M25, M30, M35, M40, M45, M50 and M55 have a characteristic compressive strength of 25N/mm^2, 30 N/mm^2, 35 N/mm^2, 40 N/mm^2, 45 N/mm^2, 50 N/mm^2 and 55 N/mm^2, respectively. A total of 42 cylindrical specimens (21 each for controlled and confined specimens) with a diameter of 150 mm and a height of 900 mm, three replicates for each grade of concrete, were cast. Column specimens of size 150mm x 900mm with different grade of plain cement concrete were casted and then confined with ferrocement. It was found that with the increase in compressive strength of the concrete significantly improved in lower grades of concrete such as M25 which showed 78% increase as compared to higher grade of concrete M55 which resulted in an increase of 45.3%.

Turgay et. Al. (2010) [15] studied the effect and failure mechanisms of large-scale square/rectangular columns wrapped with fiber reinforced polymer (FRP). The experimental research program studied the performance of large-scale square RC columns wrapped with carbon fiber reinforced polymer (CFRP) sheets. Moreover, the research was mainly focused on the investigation of the total effect of longitudinal and transverse reinforcement and FRP jackets on the behavior of concentrically loaded columns. A total of 20 large-scale RC columns were fabricated and tested to failure under axial loading in the structural laboratory.

Three types of columns were primarily considered: unwrapped, fully wrapped, and partially wrapped. Five different test series were conducted: unwrapped (C1); partially wrapped (C2); fully wrapped (C3); partially wrapped with two-layers (C4); and fully wrapped with two14 layers (C5). The dimensions of all the columns were 200 x 200 mm square section and 1000 mm in height. Each column was tested under uniaxial compression using a testing machine with a capacity of 2000 kn. The standard cylinder compressive strength of concrete mix are 18.08 mpa and 19.36 mpa 28 days and 60 days, respectively. All the specimens were subjected to monotonically increasing compression up to the fracture. Fully wrapped specimens with a slenderness ratio of 5:1 fractured at the top or bottom quarters whereas the partially wrapped columns show failure at the ends of confined regions. The partial wrapping with one-layer of CFRP results an increase in ductility and this is much more pronounced for RC columns with eight longitudinal bars. Finally, for all RC columns fully wrapped with one layer of CFRP, transverse reinforcement with a diameter of 12 mm clearly enhances the beneficial effect of CFRP on ductility.

Xiong et. al. (2011) studied the load carrying capacity and ductility of circular concrete columns confined by ferrocement including steel bars (FS) where they are proposed to increase the compressive strength along with the ductility. The behavior of the ferrocement strengthened columns was compared with the bar mat-mortar (BS) and fibre reinforced polymer (FRP) wrapped columns under uniaxial compression. The dimensions of the concrete cylindrical columns were, 105 mm (dia) x 450mm and 150 mm (dia) x 450mm. After wet-curing (24 hrs), the samples were transferred to curing room for 27 days. The specimens with 105 mm (dia) were confined with FS or BS whereas 150mm (dia) with FRP.

The comparative analyses of these samples show that the compressive strength of FS columns was enhanced by 30% than that of BS columns. Due to ferrocement caging along with steel bars specimens showed higher ductility, compressive strength and energy absorbing capacity than BS or FRP strengthened circular columns.

Mourad and Shannag (2012) studied the column specimens for the ultimate load capacity and stressed samples confined with ferrocement using welded wire mesh as the confining material. Ductility of the specimens also increased. In case of stressed samples to a value of 60% and 80% of the ultimate load capacity, the confinement enhanced the ultimate load capacity to 28% and 15% respectively. With the confinement the column specimens failed in a ductile manner as compared to brittle failure of the control specimens

A Obaidat, Y.T., Heyden, S., Dahlblom, O., Abu-Farsakh. "Retrofitting of reinforced concrete beams using composite laminates". Submitted to Construction & Building Materials, 2010. Summary: This paper presents the results of an experimental study to investigate the behavior of structurally damaged full-scale reinforced concrete beams retrofitted with CFRP laminates in shear or in flexure. The main variables considered were the internal reinforcement ratio, position of retrofitting and the length of CFRP. The experimental results, generally, indicate that beams retrofitted in shear and flexure by using CFRP laminates are structurally efficient and are restored to stiffness and strength values nearly equal to or greater than those of the control beams. It was found that the efficiency of the strengthening technique by CFRP in flexure varied depending on the length. The main failure mode in the experimental work was plate deboning in retrofitted beams.

N. F. Grace, G. A. Sayed, A. K. Soliman and K. R. Saleh: "Strengthening Reinforced Beam Using Fiber Reinforced polymer (FRP) Laminates" ACI Structural journal/ September-1999. Summary: This paper present in the various types of fiber reinforced polymer laminates are tested with the 14 simply supported cross section beams. In each beam was strengthened with FRP laminates of initially loaded above its cracking load and tested until failure. The carbon/ glass fiber reinforced polymer (CFRP/GFRP) of strengthening materials were used in externally bonded with beams. The different layers of frp sheet, types of epoxy and strengthening pattern which are examined and to calculate the absorbed energy to total energy, or energy ratio. The proper combination of vertical and horizontal sheets are provided; proper epoxy can lead to a doubling of the ultimate load carrying of the beam. To conclude the behavior of strengthening of beams are exhibits in higher factor of safety in design.

Tarek H. Almusallam and Yousef A. Al-Salloum. "Retrofitting of RC beam and Column joints using FRP Laminates": 2007, presented a procedure for analytical prediction of joint shear strength of interior beam-column joints, strengthened with externally bonded fiber-reinforced polymer sheets. To implement the available formulation for shear capacity prediction, a program was developed. Using this program, shear capacity of the joint and joint shear stress variation at various stages of loading were predicted and compared with experimental observations. It was observed that even a low quantity of FRP can enhance shear capacity of the joint significantly.

Ramakrishnan. V. "Strengthening of RC Beam by using BFRP" 2003 Summary: The researched and find out the basalt fiber may use in concrete. After investigations, the basalt fiber used in concrete for the first time in world.

And also, they find out the beams reinforced with plain basalt bars failed in flexure due to inadequate bond between the steel and concrete. All the actual ultimate moments were much less than the calculated ultimate moments to the steel pullout failure. The beam with fibers exhibited a primary failure in flexure and shear followed by a secondary failure on splitting and also ductile, micro cracks resist bond between all the modified basalt rebar and concrete was extremely good. Ultimate moment good compare with normal concrete. In general, the basalt fibers are suitable for use in reinforced concrete section.

Priti A. Patel, Atul K. Desai, and Jatin A. Desai, “Evaluation of Engineering Properties for Polypropylene Fiber Reinforced Concrete”, 2012 Has studied on the performance of polypropylene fiber reinforced concrete. From the experimental studies properties such as compressive strength, flexural strength, split tensile strength and shear strength of polypropylene fiber reinforced concrete was studied. The fiber volume fraction Vf ranges from 0 to 2%. Conclusions drawn are like the failure modes when fibers are present in concrete are spelling of mortar or bulging in transverse direction. With the increasing fiber content compressive strength was increased. Strength increases ranges from 8 to 16%. PFRP has better crack control. There is increase in the shear strength by 23 to 47%.

3. Research Methodology

A. Need for Present Study

1) To prevent disaster in future earthquakes.
2) Public safety.
3) Structural serviceability.
4) For utility and historic significance.

B. Objectives

1) Public Safety only. The hoal is to protect human life.
2) The main objective of this project is to study and analysing that after Column and Foundation Retrofitting is the existing building is enough strong to withstand the load.
3) No. of columns fail the same will be rectify by reinforced concrete jockeying technique, because of jacketing the column & by using strength will increase.
4) Then in the ETABs Software all fail column will be molded and the increase the area of reinforced column can able to take an increase load so the building can raise to the above mention floors.
5) Hence column can be strengthened to carry the increase loads safely.
6) Structure Survivability
7) Structure functionality

C. Methodology

1) Column Jacketing

After doing the jacketing of columns by increasing the overall area of columns it results in increases the strength in columns and withstand all the upcoming extra loads.

2) Foundation

By using rubber isolator at foundation there is a decrease in displacement and also able to resist the seismic load if acted.

4. Design and Analysis

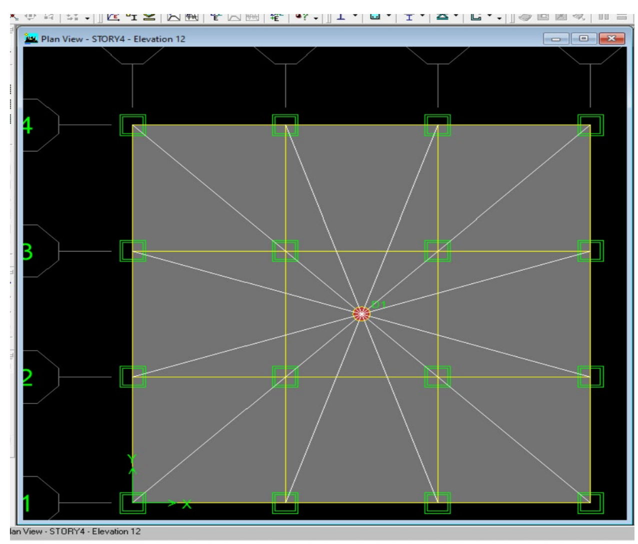


Fig. 1.

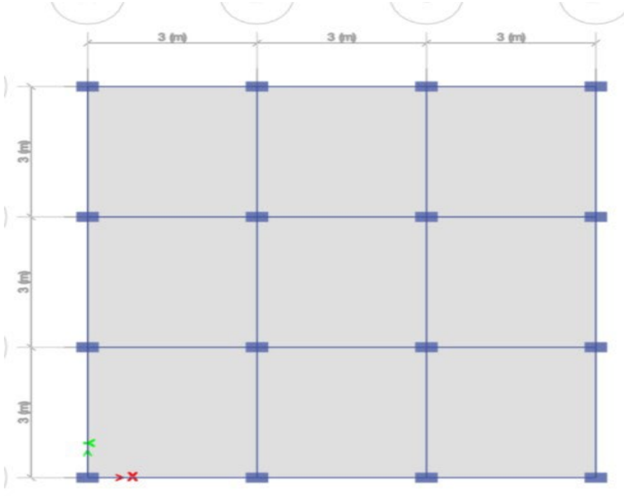


Fig. 2.

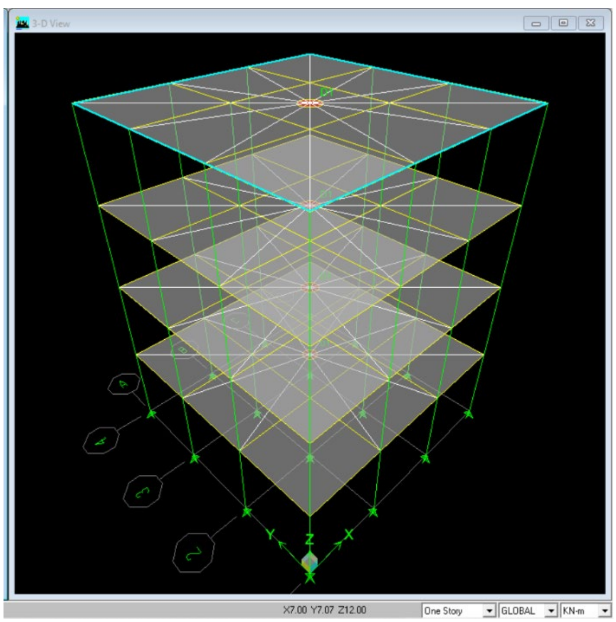


Fig. 3.

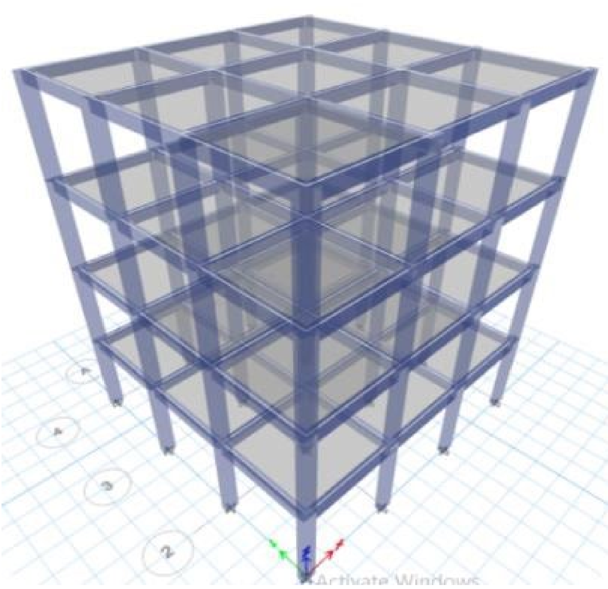


Fig. 4. 3D model

All plan and 3-D design are been considered to design the and analyze the deflection in columns.

Some of the historic monuments, and heritage structures got weak and found large cracks in their building elements.

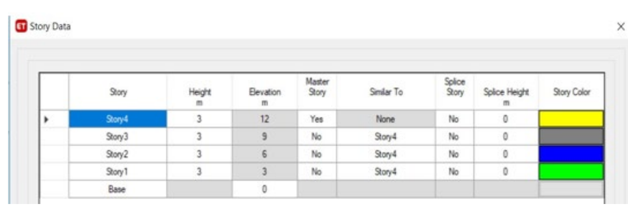

Fig. 5.


Fig. 6.

Table 1
Building parameters

S. No.	Description	Dimension
1	Plan	9mx9m
2	No. of story	4
3	Total height	12 m
4	Beam size	230x300 mm
5	Column size	230x400 mm
6	Depth of slab	150 mm
7	Member load: beam	0.23x0.3x25 = 1.725KN
8	Member load: column	0.23x0.4x25 =2.3KN
9	Basic wind speed of Pune	39 m/s
10	Seismic zone of Pune	Zone III

A. Experimental analysis of building by using ETAB's software


Story Data

Story	Height m	Elevation m	Master Story	Similar To	Splice Story	Splice Height m	Story Color
Story4	3	12	Yes	None	No	0	
Story3	3	9	No	Story4	No	0	
Story2	3	6	No	Story4	No	0	
Story1	3	3	No	Story4	No	0	
Base		0					

Fig. 7.

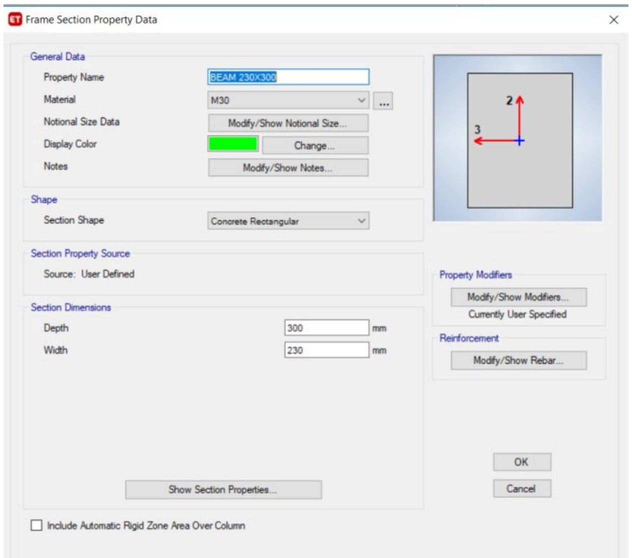


Fig. 8.

B. Loading Details

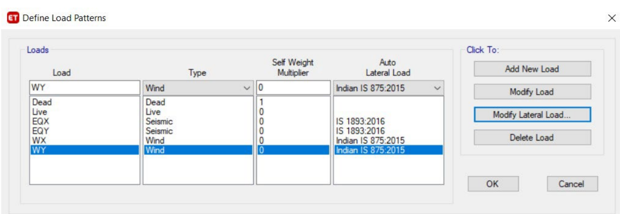


Fig. 9. Load pattern

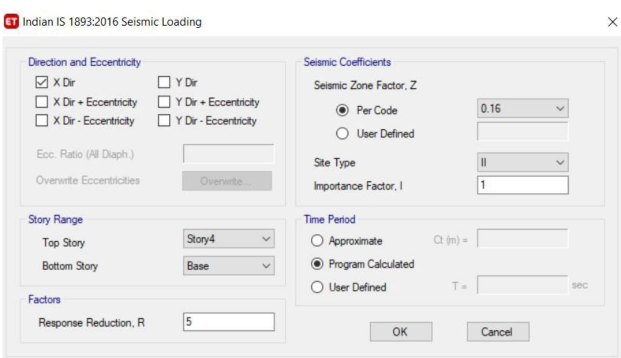


Fig. 9. Seismic load

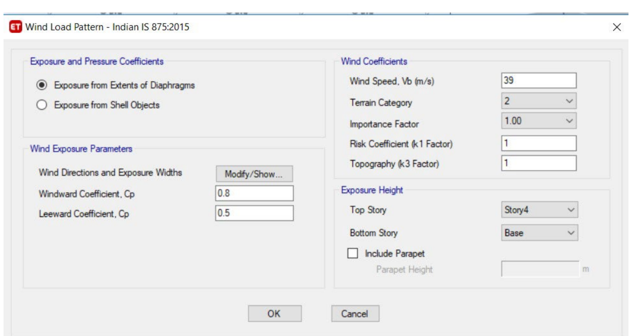


Fig. 10. Wind load

C. Various Loads on the Structure

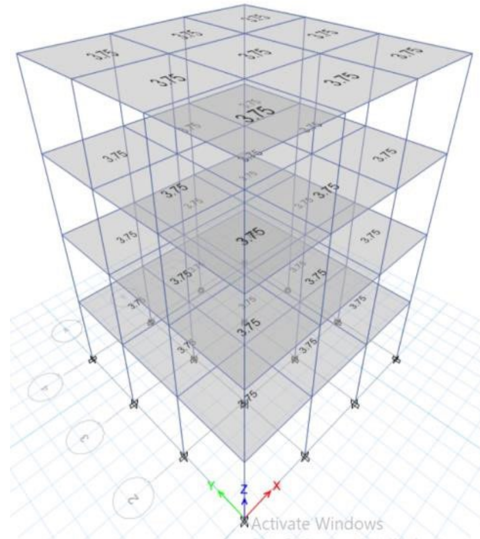


Fig. 11. Dead load

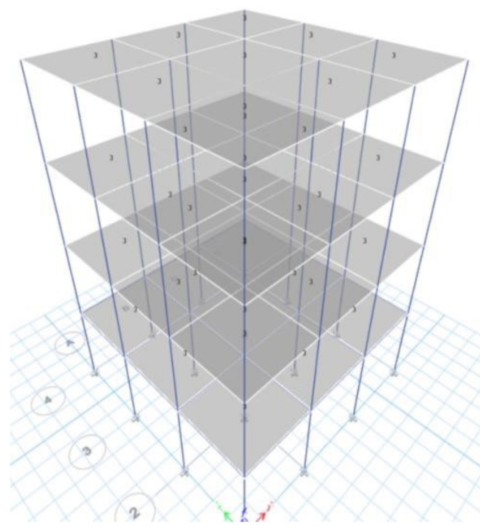


Fig. 12. Live load

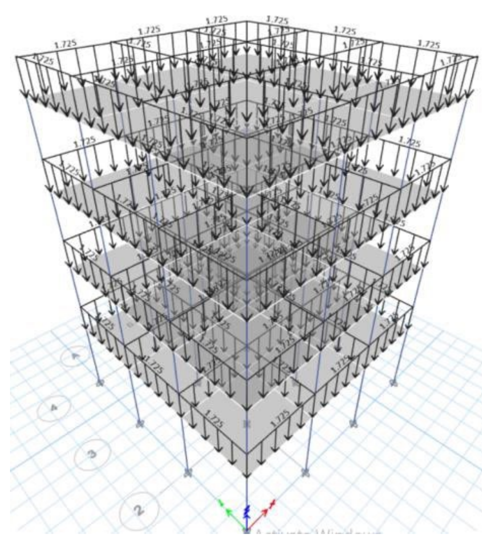


Fig. 13. Member load

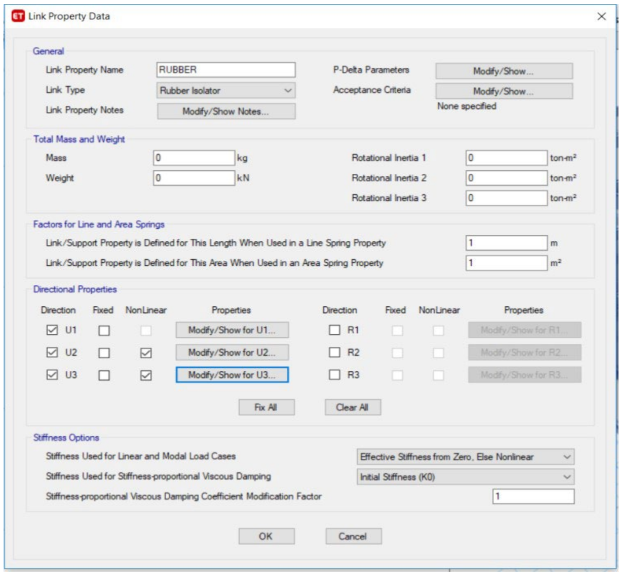


Fig. 14. Rubber isolator

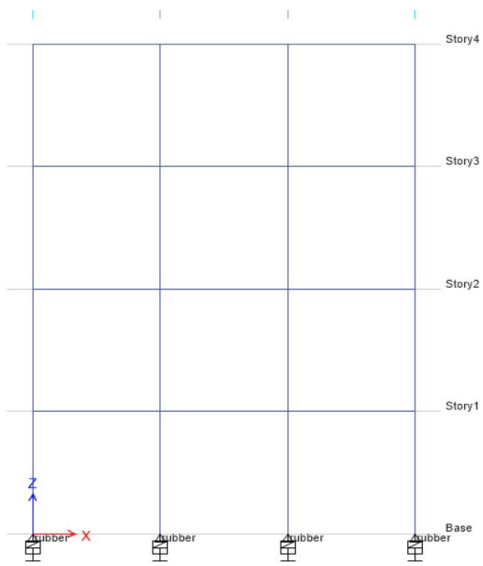


Fig. 15.

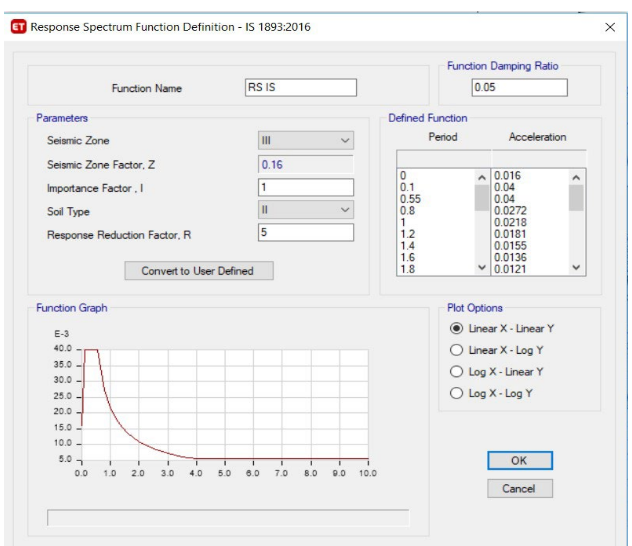


Fig. 16. By response spectrum method

D. Result of Story Drift

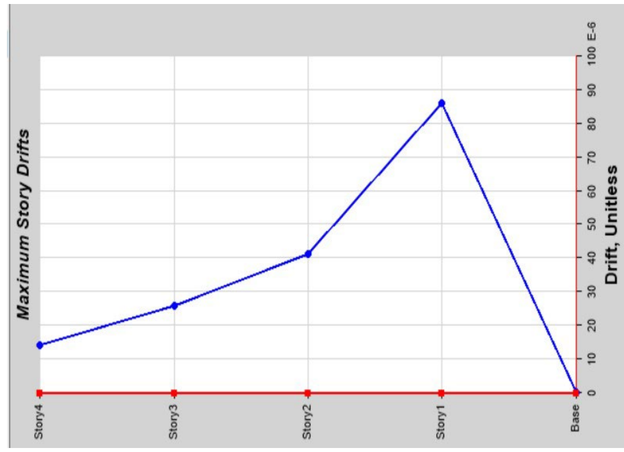


Fig. 17. Story drift with base isolation

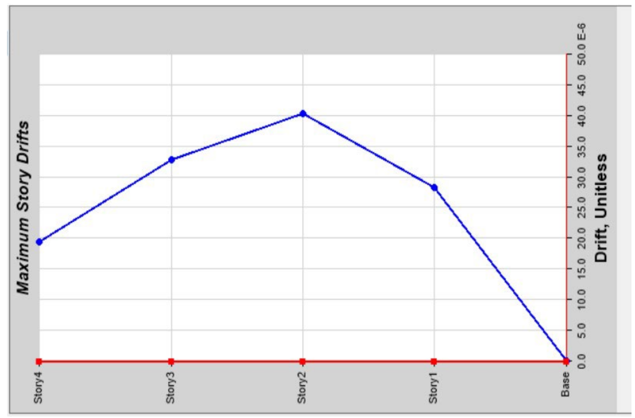


Fig. 18. Story drift without base isolation

E. Stories Displacement

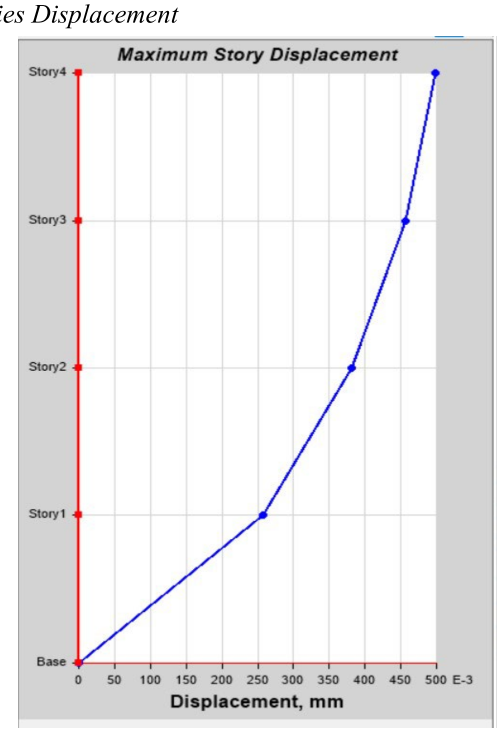


Fig. 19. With base isolation

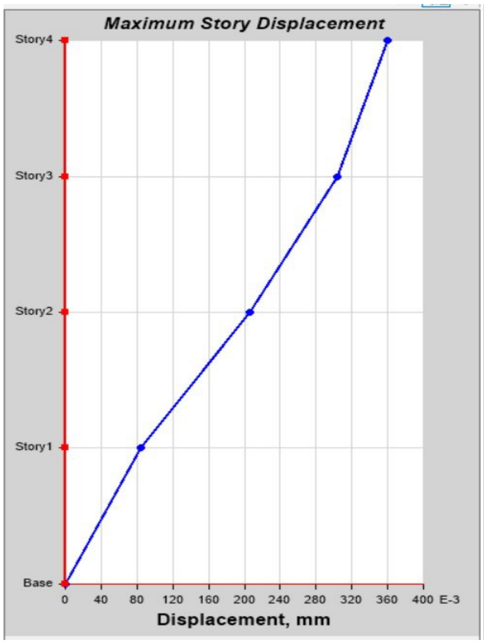


Fig. 20. Without base isolation

5. Conclusion

1. In RC Jacketing, sizes of the sections are increased and the free available usable space becomes less and also huge dead mass is added.
2. In RC Jacketing, drilling of holes in existing column, slab, beams and footings are required which cause further damage to the columns.
3. RC retrofitting technique are significant improvement in Moment resisting capacity, shear strength capacity in Beam and Axial load carrying capacity in column.
4. Building with base isolation is safer than fixed base building in order to withstand earthquake events
5. By using rubber isolator at foundation reduces the story drift and displacement and hence increases the strength.

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