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Seismic Analysis and Retrofitting of an Existing Structure

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Abstract
Few years ago, people were constructing the structures without any future and not according to the codes. Now a day's people need additional floors without demolishing the existing structures for convenient requirement like residential purpose /commercial purpose. Urban sprawl is a main problem in India. This describes the expansion of human populations in the urban areas. When the generation population is increased instantly they require space to live, and even for the commercial purpose also they require and now a days purchasing a land in the urban areas is too costly like Bengaluru, Hyderbad, Mumbai, Chennai etc…. So instead of purchasing land, an additional floor is added to existing building to live space for residential or for commercial purpose.
This project was carried out to explore a concept for renovation of apartment blocks. The aim of the project was to develop an economical and efficient concept for renovating, expanding and adding floors to existing apartment blocks. Present study is focused on soil structure interaction and effect of seismic loads and study of different retrofitting techniques for finding out the optimized solution for any structure which require retrofitting. The G+6 storied structure is acquired for analysis and the method adopted is linear static method and comparison of the parameters such as story drift, story displacement and story shear were carried out for the different retrofitted structures at different soil conditions. Steel jacketing method, column jacketing method, steel bracings methods are the few retrofitting techniques adopted in this study. The software used for the purposes of analysis is ETABS

Keywords: *ETABS, linear static analysis, retrofitting techniques, soil conditions, steel jacketing method, RC column jacketing method, steel bracings method.*

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I. INTRODUCTION

A number of reasons may necessitate the need to retrofit existing structures. It may be rehabilitation of a structure damaged by seismic loads or other causes, or the strengthening of an undamaged structure made necessary by revisions in structural design or loading codes of practice. The deterioration in RC structures can be due to environmental effects like reduction of strength with ageing, corrosion of steel, temperature variations, freezing-thawing effects. Earthquake around the world is one of the reasons responsible for destruction to life and property in large numbers. In order to mitigate such hazards, it is important to incorporate norms that will enhance the seismic performance of the structure.

RETROFITTING is the process of addition of new features to older buildings, heritage structures, bridges etc……. It increases the strength, resistivity and overall lifespan of the structure.

As total reconstruction (or) replacement of an existing structure will be cost effective. Hence retrofitting is one of the effective ways to strengthen the existing RC structure.

A number of methods can be used to retrofit concrete structures. Retrofitting may be carried out on basis by extra adding load-resisting elements such as steel frames, steel bracings to an existing structure. Or it can be performed on local basis by retrofitting the existing structural elements such as column, beam

The goal of retrofitting is to improve seismic performance and correct deficiencies by increasing strength, stiffness, and to create a more sustainable environment within the context of an existing urban form

Retrofitting is one of the best options to make an existing inadequate building safe against future environmental effects like earthquake. Now-a-days, retrofitting has become increasingly important as structures lose their strength in due course of time, some structures are important in view of public, social or past importance.

1.1 CLASSIFICATION OF RETROFIT TECHNIQUES:

1) Local retrofit strategies.
2) Global retrofit strategies.

- Local retrofit strategies: to avoid failure of the components, and also thereby enhance the overall performance of the structure.

Example: concrete jacketing, steel jacketing, fibre-reinforced polymer (FRP) sheet wrapping.

- Global retrofit strategies: to provide increased lateral stiffness and strength to the building as a whole. And, to ensure that a total collapse of the building does not occur.

Example: addition of infill walls, addition of shear walls, addition of steel braces.

1.1.1 TECHNIQUES OF RETROFITTING:

1.1.2 RC JACKETING OF COLUMNS:

RC jacketing has been used extensively for strengthening and repairing deficient and damaged RC columns, respectively. In traditional reinforced concrete jacketing, the section of the column is enlarged by casting a new reinforced concrete/mortar section over a part or the entire length of the column.

1.1.3 STEEL JACKETING:

confining RC columns in steel jackets is also an effective method to increase basic strength capacity. Steel jacketing not only provides enough confinement but also prevents deterioration of shell concrete, which is the main reason of bond failure and buckling of longitudinal bars

1.1.4 STEEL BRACINGS:

Bracings provides an excellent approach for strengthening and stiffening existing buildings for lateral forces.

1.2 OBJECTIVES:

- To study seismic response of building under different soil conditions.
- The present study mainly concentrates on the addition of floors to an existing structure.
- To introduce different retrofit techniques to the structure which fails after adding the floors
- To analyse the responds of building after introducing retrofitting.
- To compare the different parameters among different retrofit techniques at different soil conditions

1.3 SCOPE:

- To ensure the safety and security of a building, employees, structure functionality, machinery and inventory.
- Essential to reduce hazard and losses from structural elements.
- Predominantly concerned with structural improvement to reduce seismic hazard.

II. METHODOLOGY:

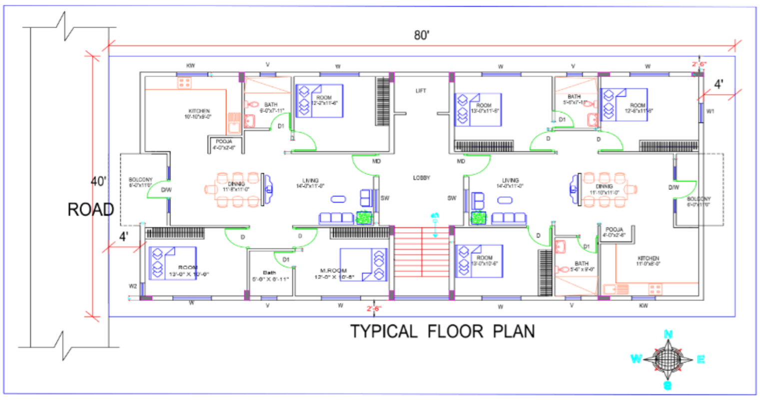


Figure 1: Existing typical floor plan.

2.1: Existing typical floor plan developed in AUTOCAD: A design of R.C building of G+6 Storey frame work is taken up. The site is located in Bangalore under Earthquake Zone II as per IS 1893:2002 (Part 1). The total area of the land is 3200 sq. ft. and built-up area is 2635 sq. ft. The size of the building is 24x12m (80'x40'). The number of columns is 24. The floor height of rooms is 3.2 m. Access is given to floors by staircase and lift. The fig.1 above shows a typical floor plan of two houses in a single floor.

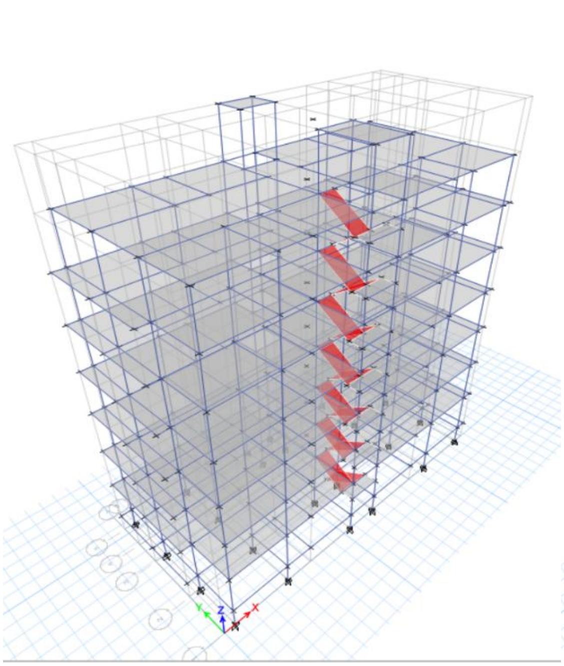


Figure 2: G+6 existing building

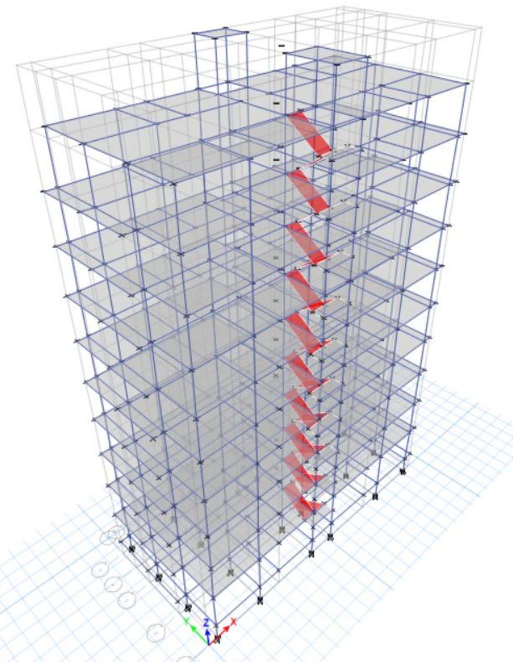


Figure 3: Addition of 3 floors to an existing

2.1: MODELLING AND ANALYSIS IN ETABS:

- In this present study, existing structure is modeled as a 3-diminesional frame at different soil conditions using ETABS, figure 2 shows 3D model of an existing structure.
- Figure 3 shows 3D model of 3 floors added on an existing building.
- The present study is carried out to understand the retrofitting techniques.

2.2: LOADS ON THE STRUCTURE:

1) DEAD LOAD: The dead loads are taken from IS 875 Part 1(Dead Loads). The dead loads comprise the weights of walls, partitions, floor finishes, false ceilings, false floors and other permanent constructions in the buildings.

2) LIVE LOAD: The live loads are taken from IS 875 Part II(Live Loads).

3) SEISMIC LOAD: Seismic design shall be done in accordance with IS: 1893:2002. The building is situated in earthquake zone II.

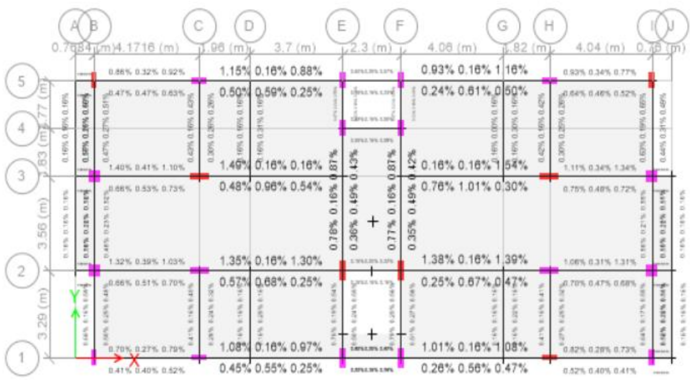


Figure 4. G+9 building members when subjected to seismic loads at **MEDIUM SOIL**

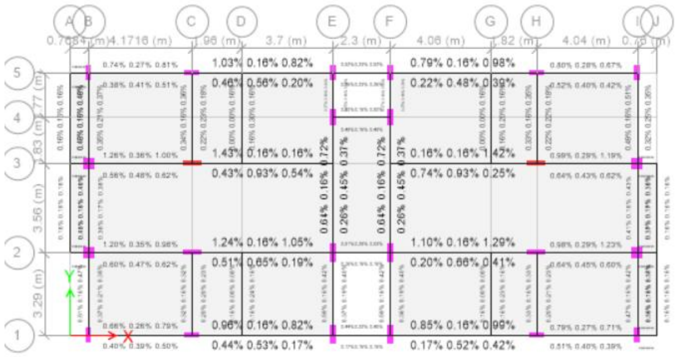


Figure 5: G+9 building members failing when subjected to seismic loads at **HARD SOIL.**

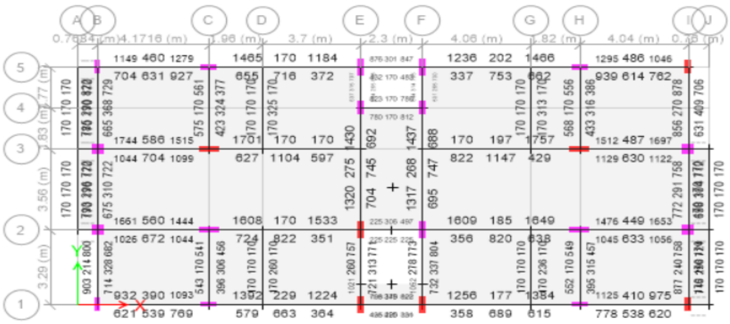


Figure 6: G+9 building members failing when subjected to seismic loads at **SOFT SOIL.**

The above fig4, fig5, fig6, shows the column failures when additional floors are applied on an existing structure, and to failure columns RETROFITTING is done. It has been observed that a greater number of columns fail in case of structure situated at soft soil when compared to medium soil and hard soil.

2.3 BUILDING RETROFITTED BY RC COLUMN JACKETING METHOD:

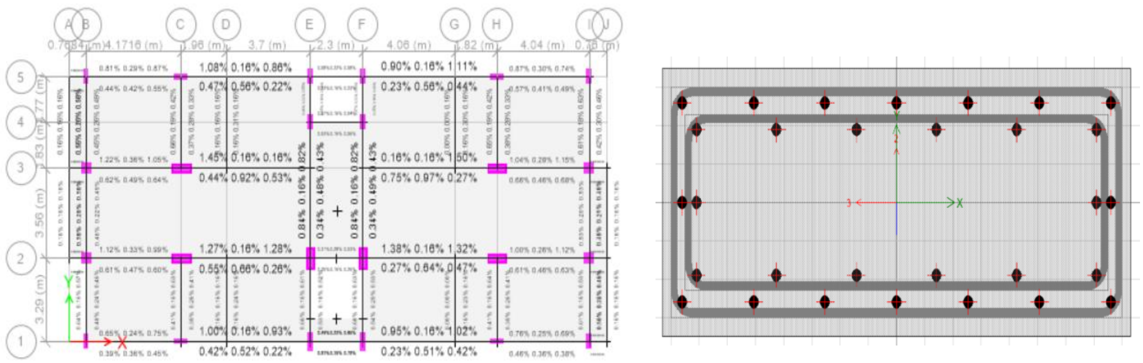


Figure 7: All members are safe with RC column jacketing technique

2.4 Design of RC column jacketing using IS 15988:2013

The first details of existing column are as follows:

- Height of the column:3200mm.
- Cross-section=230*750mm.
- Grade of concrete= 20 N/mm^2.
- Grade of steel= 500 N/mm^2.
- Load, P_u = 3114.1156kN.
- Reinforcement provided (pt) = 1.39%

$$Ast= \frac{pt*b*d}{100} = \frac{1.39*230*750}{100} = 2397.75mm^2$$

Providing 14 no of 16mm dia bars

$=14*\frac{3.14*(16*16)}{4}$

$=2815.232mm^2$.

$= 2815.232mm^2 > 2397.75mm^2$

Procedure:

Pu= 0.4*fck*Ac+0.67*fy*Asc

According to the provision provided in 8.5.1.2(a) of IS 15988:2013, concrete strength shall be at least 5 Mpa greater than the strength of an existing concrete.

Thus, taking value of fck= 30 N/ mm^2 and assuming Asc= 0.8% Ac.

3114.11*10^3 = (0.4)(30) Ac +0.67*500*0.8Ac

3114.11*10^3 = 10Ac +2.68Ac

Ac = 3114.11x10^3/12.68

Ac= 245592.27 mm^2.

Assuming cross sectional details as:

B=300mm, D=245592.27/300

D=818.64mm.

Jacketing details of cross section:

B=(300-230)/2=40mm.

D=(850-750)/2=50mm.

However, according to the code specified above, minimum jacket thickness shall be 100mm as per IS 15988:2013

Thus, new size of column:

B= 230+100+100=430mm=450mm

D=750+100+100=950mm.

New concrete area = 450*950= 427500>245592 mm

Area of steel, As= 0.8% *450 * 950=3420 mm^2

But according to IS 15988: 2013, As=(4/3)*A's

As=(4/3)*3420=4566 mm^2

Assuming 20mm dia bars

Thus, number of bars, N=4566*4/3.142*20^2

Provide 16 no of 20mm dia bars for jacketed section.

Therefore, revised jacketed section will be 450mmx950mm.

Design of lateral ties: As per IS 15988:2013, minimum diameter of ties shall be 8mm and not less than one-third of the longitudinal bar diameter.

Diameter of bar= 1/3 dia of largest longitudinal bar=1/3*20=6.66mm…..take 8mm

Spacing of ties= $s=\frac{fy*d2}{sqrt(fck)tj}$

Where fy= yield strength of steel, fck= cube strength of concrete.

d= dia of stirrup, and t= thickness of jacket

$S=\frac{500*20*20}{sqrt(30)200}$ =180mm.

Provide 8mm dia bars @ 200mm c/c.

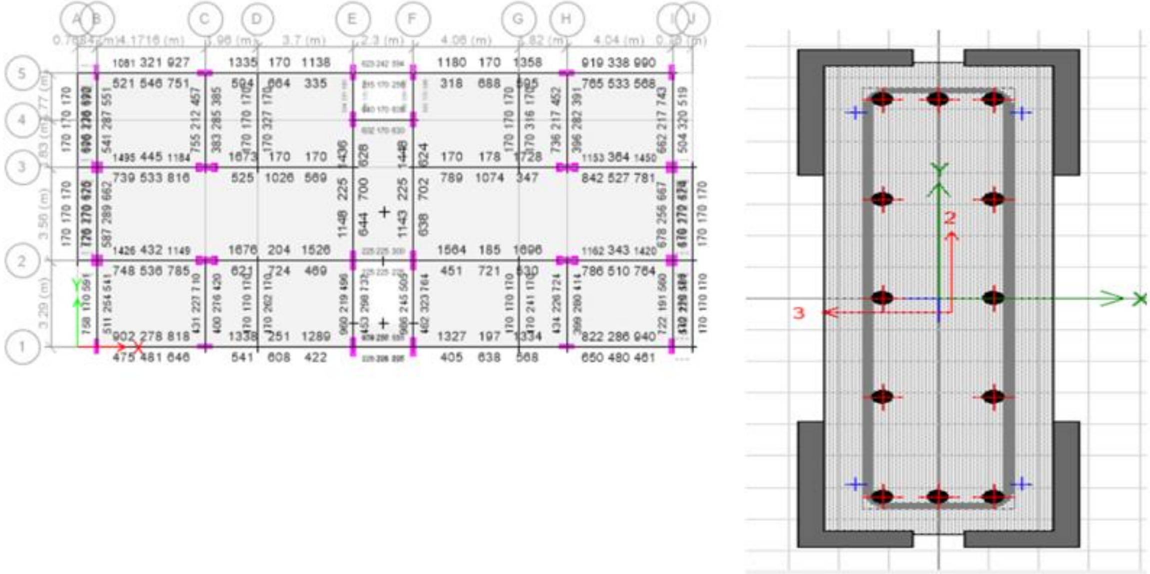


Figure 8: All members are safe with steel jacketing technique.

❖ Grade of steel used in steel jacketing: Fe345

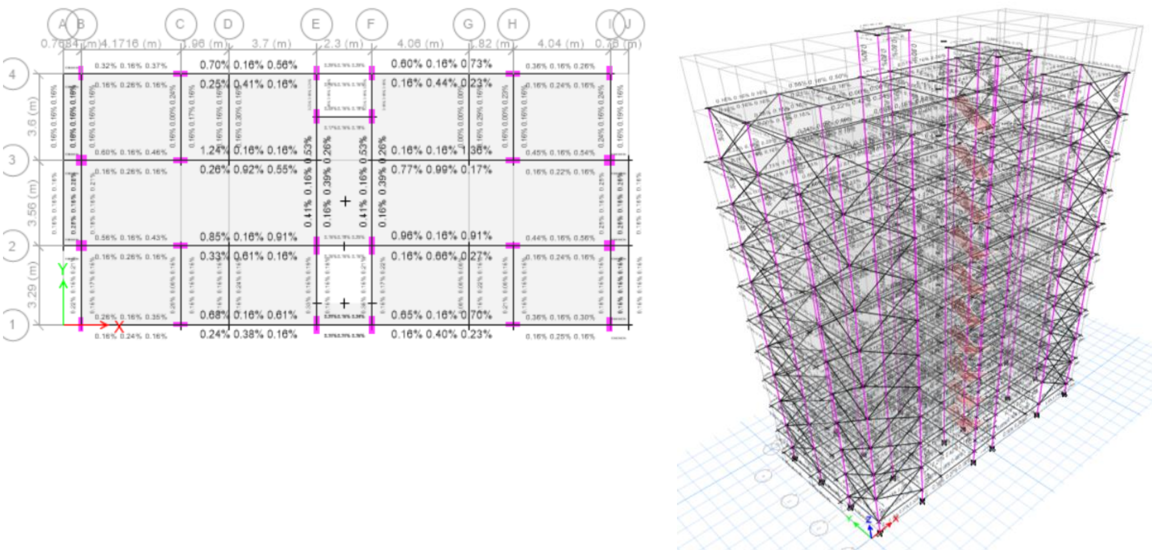


Figure9: All members are safe with steel bracings technique.

III. RESULTS AND DISCUSSIONS:

GRAPHICAL REPRESENTATION:

STOREY DISPLACEMENT:

Story displacement is defined as total displacement of any storey with respect to ground. Maximum allowable displacement is calculated from IS:1893-2002, maximum permissible storey displacement is limited to H/500.

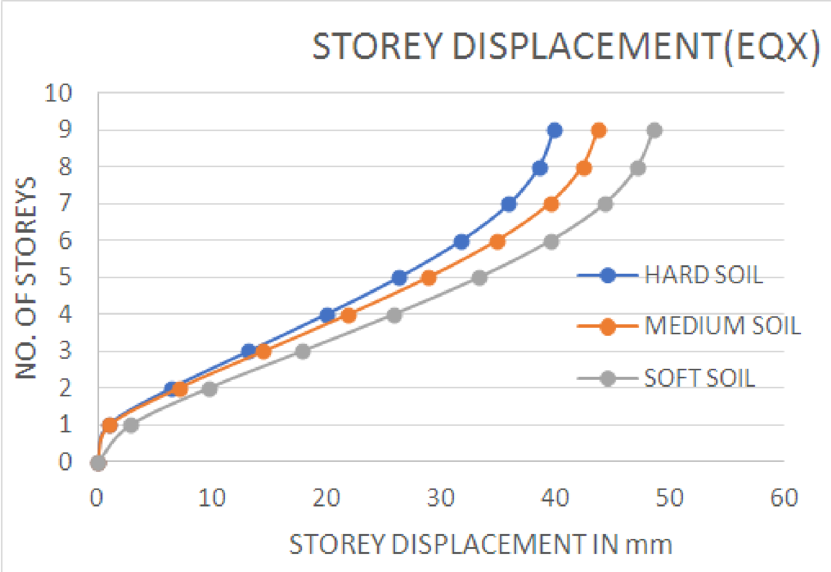
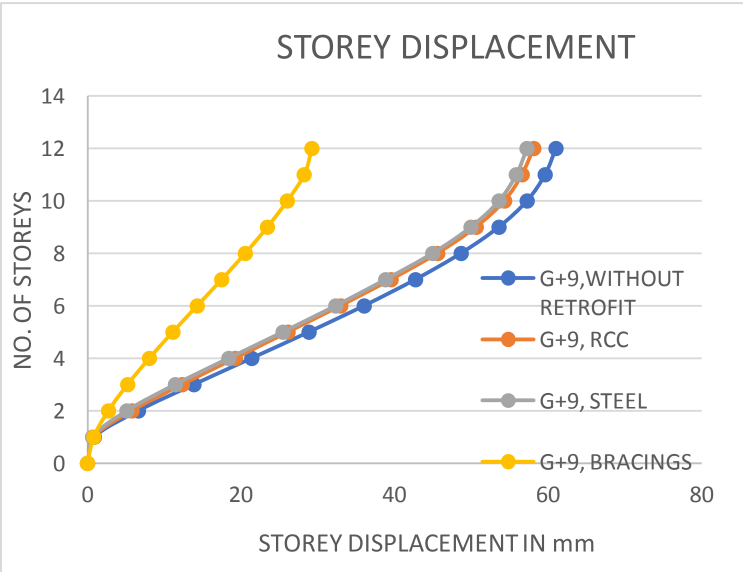


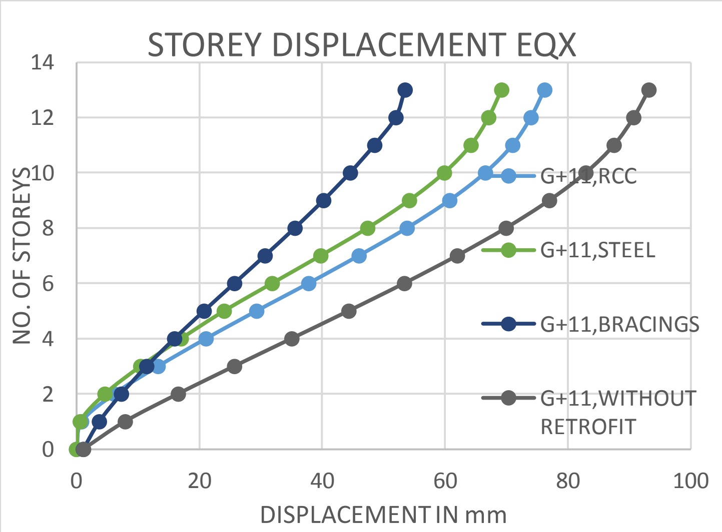
Fig10: no. of storeys v/s displacement at different soil conditions

Graph shows storey v/s displacement under three altered condition of soil, it was observed that the displacement of the fixed base model at the roof is 39.847mm, 43.826mm and 48.564mm for hard soil condition, medium soil condition and soft soil condition respectively. it clearly shows that structure at soft soil shows more displacement when compared it with medium soil and hard soil.



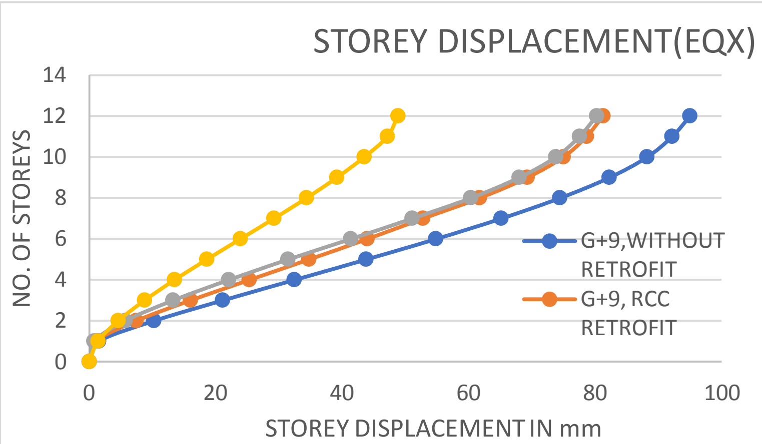
Graph shows storey v/s displacement, It was observed that the displacement of the fixed base model at the roof is 61.017mm, 58.127mm, 57.238mm and 29.22mm for the structure without retrofit and structures with RC column jacketing, steel jacketing and bracings respectively at hard soil. it clearly shows that structure without retrofit shows more displacement when compared it with other structures with retrofit. it clearly shows that structure with bracings shows lesser deflection when compared to structure with RC column jacketing method and steel retrofitting method.

Fig11: no. of storeys v/s displacement for different retrofitting methods at hard soil



Graph shows storey v/s displacement, It was observed that the displacement of the fixed base model at the roof is 77.694mm, 70.074mm, 67.636mm and 39.23mm for the structure without retrofit and structures with RC column jacketing, steel jacketing and bracings respectively at medium soil. It shows that structure with bracings shows lesser deflection when compared to structure with RC column jacketing method and steel retrofitting method. Structure without retrofit shows displacement more than the permissible limit. i.e.,77,694mm<73mm.

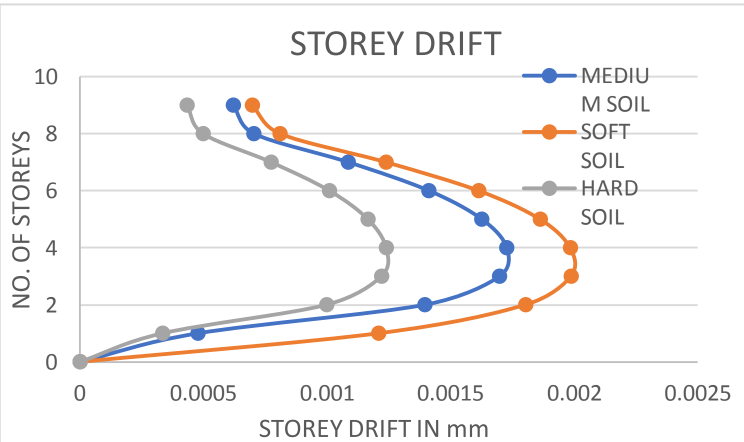
Fig12: no. of storeys v/s displacement for different retrofitting methods at medium soil.



graph shows storey v/s displacement, It was observed that the displacement of the fixed base model at the roof is 94.926mm, 80.19mm, 48.797mm and 48.797mm for the structure without retrofit and structures with RC column jacketing, steel jacketing and bracings respectively at soft soil. It shows that structure with bracings shows lesser deflection when compared to structure with RC column jacketing method and steel retrofitting method.

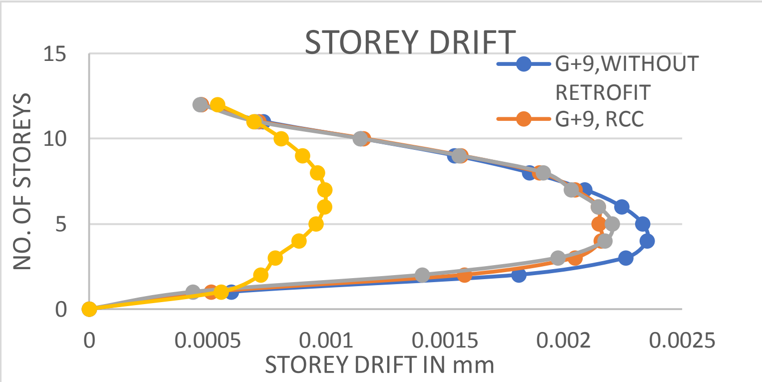
Fig13: no. of storeys v/s displacement for different retrofitting methods at soft soil.

STOREY DRIFT: It is defined as ratio of displacement of two consecutive floors to height of that floor. Maximum permissible storey drift is limited to 0.004h, as per IS code: 1893:2002.



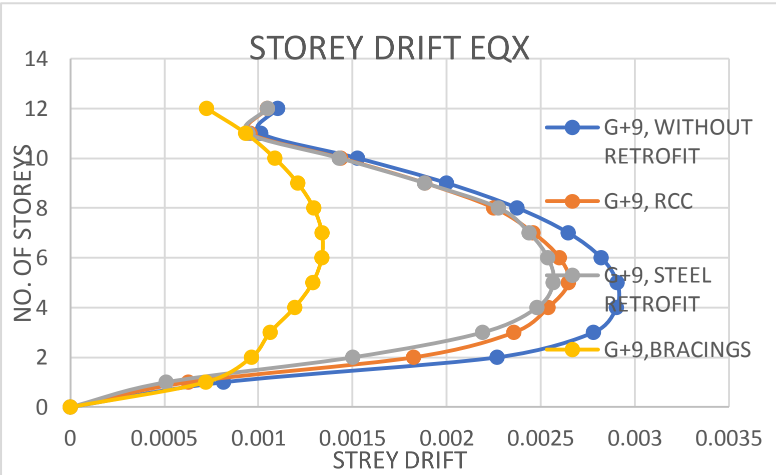
From the figure, storey v/s drift, it clearly shows that structure at soft soil shows more drift when compared it with medium soil and hard soil.it has been observed that at the 3rd storey maximum drift 0.002327mm and 0.002115mm is observed at medium and hard soil respectively. Whereas in soft soil the maximum drift 0.00252mmis observed at 2nd storey.

Fig14: no. of storeys v/s drift at different soil conditions.



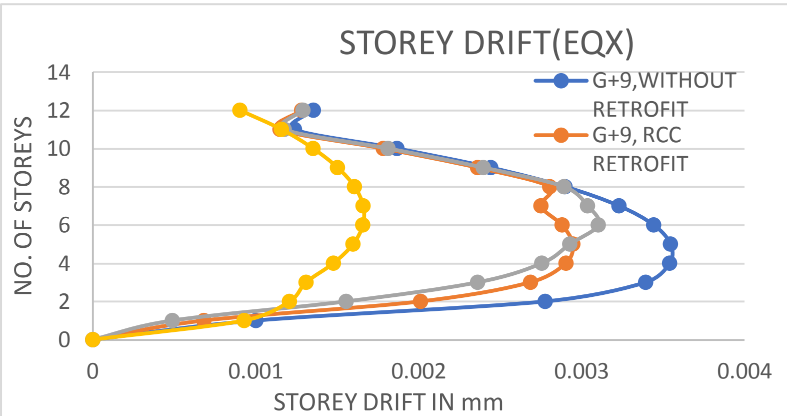
From the figure i.e., storey v/s drift at hard soil, it clearly shows that structure with bracings shows lesser drift when compared to structure with RC column jacketing method and steel retrofitting method. The structure without retrofit shows maximum drift of 0.002352mm at 3rd storey.

Fig15: no. of storeys v/s drift for different retrofitting methods at hard soil.



From the figure i.e., storey v/s drift at medium soil, it clearly shows that structure with bracings shows lesser drift when compared to structure with RC column jacketing method and steel retrofitting method. The structure without retrofit shows maximum drift of 0.002906mm at 4th storey.

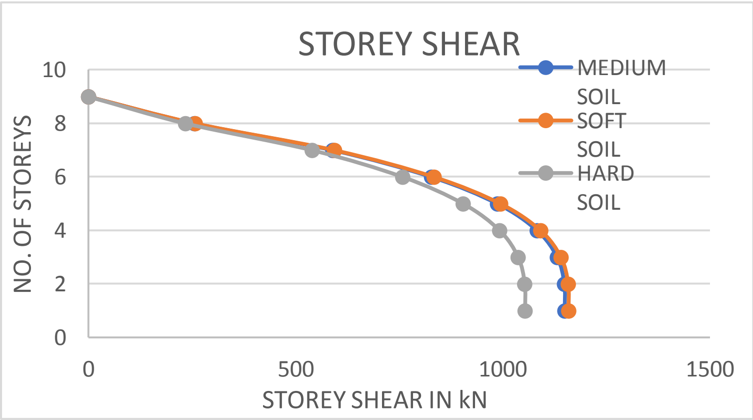
Fig16: no. of storeys v/s drift for different retrofitting methods at medium soil.



From the figure i.e., storey v/s drift at soft soil, it clearly shows that structure with bracings shows lesser drift when compared to structure with RC column jacketing method and steel retrofitting method. The structure without retrofit shows maximum drift of 0.003546mm at 4th storey.

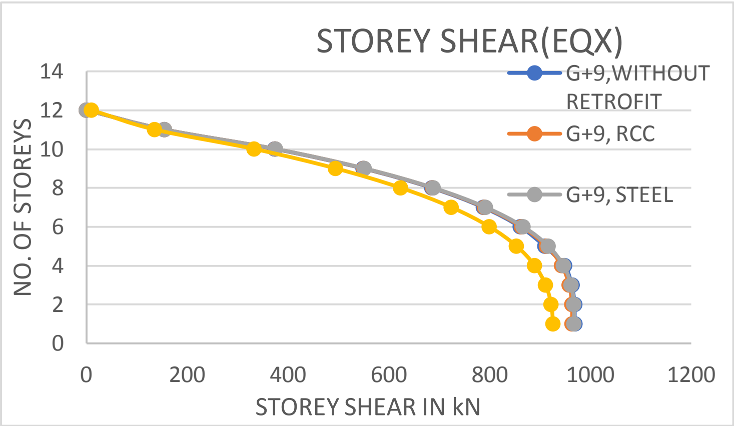
Fig17: no. of storeys v/s drift for different retrofitting methods at soft soil.

Storey shear: The storey shear is defined as lateral forces acting on a storey due to the forces such as seismic and wind force. It is calculated for each storey, changes from minimum at the top to maximum at the bottom of the building.



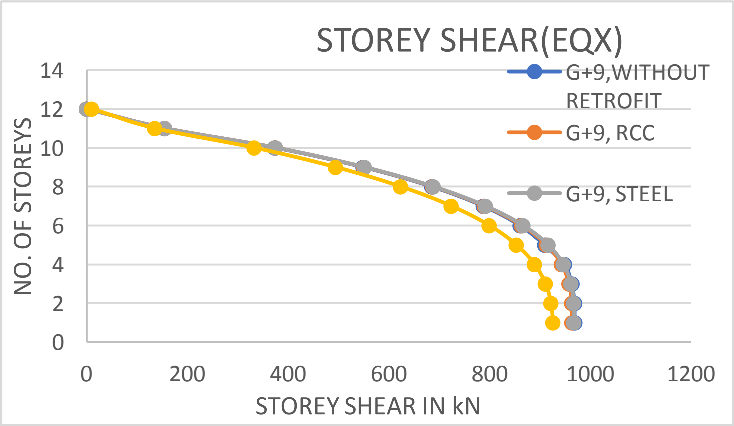
From the figure i.e., storey v/s shear, it clearly shows that structure at hard soil shows lesser shear when compared it with medium soil and soft soil.

Fig18: no. of storeys v/s storey shear at different soil conditions.



From the figure i.e., storey v/s shear at hard soil, it shows that structure with different retrofit techniques shows almost similar storey shear.

Fig19: no. of storeys v/s storey shear for different retrofitting methods at hard soil.



From the figure i.e., storey v/s shear at medium soil, it shows that structure without retrofit shows more storey shear when compare to structures with retrofit.

Fig20: no. of storeys v/s storey shear for different retrofitting methods at medium soil.

From the figure i.e., storey v/s shear at soft soil, it shows that structure with different retrofit techniques shows almost similar storey shear.

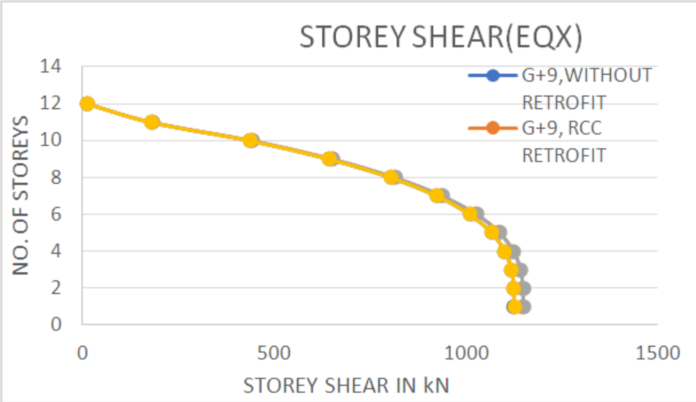


Fig21: no. of storeys v/s storey shear for different retrofitting methods at soft soil.

IV. CONCLUSION:

The study attempt is made on weakening points of structure, when additional floors are constructed above on an existing building at different soil types, column failures when additional floor load is applied on existing structure. The analysis is made on existing building on ZONE II and soil type I, soil type II, soil type III. Due to the increase of load on the existing structure, the columns of the building got weaken so, columns retrofitting technique is adopted to regain its strength.

The following are the conclusion taken before and after retrofitting

- The storey displacement, storey drift and storey shear were maximum for the building at soft soil compared to the buildings located at the hard and medium soil.
- There is a sudden failure of structural members when additional floors are added.
- The structure without retrofit shows more storey displacement, storey drift and storey shear.
- Different retrofit techniques such as RC column jacketing method, steel jacketing method and bracing methods are adopted in this project.
- Slabs are parallel to earthquake, they need not to be strengthened.
- Retrofitting technique enhances the axial load and moment carrying capacity in structural members. After retrofitting storey displacement, storey drifts are reduced.
- From completing the project, it was concluded that BRACINGS METHOD was chosen as the most appropriate technique which enhances the axial load and moment carrying capacity in the structural members
- The analysis of the structure before and after retrofitting evidently showed that the retrofitting technique complimented in strengthening of the structure. It showed that retrofitting aims in strengthening a structure to satisfy the requirements of the current codes for seismic design.
- From completing the project, it was concluded that seismic retrofitting provides existing structures with more resistance to seismic activity due to earthquakes.

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