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SEISMIC RETROFITTING OF EXISTING R.C.C. BUILDING WITH SOFT STOREY AND FLOATING COLUMN

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ABSTRACT

Seismic Retrofitting Techniques are required for concrete constructions which are vulnerable to damage and failures by seismic forces. In the past thirty years, moderate to severe earthquakes occurred around the world every year. Such events lead to damage to the concrete structures as well as failures. Thus the aim of this paper is to focus on improving the practice for the evaluation of seismic vulnerability of existing reinforced concrete building and for its seismic retrofitting by means of various innovative techniques such as shear wall and bracings. In this paper, case study of building with floating column and soft storey situated in Pune has been considered for analysis purpose. At site floating column is directly rested on RCC beam, which is not safe structurally. So in our study, we have analysed the existing building with various retrofitting methods mentioned above and proposed the best possible strengthening solution for existing building.

KEYWORDS:*Floating column, bracing, Story Drift, soft story,base shear, ETABS.*

I. INTRODUCTION

Multi-storey buildings in metropolitan cities require open taller first storey for parking of vehicle and/or for retail shopping, large space for meeting room or a banking hall owing to lack of horizontal space and high cost. Due to this functional requirement, the first storey has lesser strength and stiffness as compared to upper stories, which are stiffened by masonry infill walls. This characteristic of building construction creates weak or soft storey problems in multi storey buildings. Increased flexibility of first storey results in extreme deflections, which in turn, leads to concentration of forces at the second storey connections accompanied by large plastic deformation. In addition, most of the energy developed during the earthquake is dissipated by the column of the soft stories. In this process the plastic hinges are formed at the ends of column, which transform the soft stories into a mechanism. In such cases the collapse is unavoidable. Therefore, the soft stories deserve a special consideration in analysis and design. It has been observed from the survey that the damages are due to collapse and buckling of columns especially where parking places are not covered appropriately. On the contrary, the damage is reduced considerably where the parking places are covered adequately. It is recognized that this type of failure results from the combination of several other unfavorable reasons, such as torsion, excessive mass on upper floors, P-Δ effects and lack of ductility in the bottom storey. Figure shows some of the examples of soft storey. The soft storey concept has technical and functional advantages over the conventional construction. First, is the reduction in spectral acceleration and base shear due to increase of natural period of vibration of structure as in a base isolated structure. However, the price of this force reduction is paid in the form of an increase in structural displacement and inter storey drift, thus entailing a significant P-Δ effect, which is threat to the stability of the structure. Secondly taller first storey is sometimes necessitated for parking of vehicles and /or retail shopping, large space for meeting room or banking hall. Due to this, functional requirement, the first storey has lesser stiffness of columns as compared to stiff upper floor rooms, which are generally constructed with masonry infill walls.

Floating column is a vertical member, which at its lower level rests on a beam which is a horizontal member. The beam in turn transfers load to the column below it, thus load transfer path in the discontinuous frame changes from vertical to horizontal. There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. These open spaces may be required for assembly hall or parking purpose. Thus floating column is also an often encountered construction practice, that it should be avoided because it leads to the overload of the beams. The joint between beam and floating column are considered as critical since their stability influence the overall stability of building and failure of beam-column joint in concrete moment resisting frame was identified as one of the leading causes of collapse of such structure.

R.C.C. buildings with column that hang or float on beams at an intermediate storey and do not go all the way to the foundation have discontinuities in the load transfer path. Since balconies are not counted in the Floor space index (FSI) , building having balconies overhanging in the upper stories beyond the footprint area at the ground storey overhangs up to 1.2m to 1.5 m in plan are usually provided on each side of the building. In the upper storey, the perimeter columns of the ground storey are discontinued, and floating columns are provided along the overhanging perimeter of the building. This floating columns rest at the taper overhanging beams without considering the increased vulnerability of the lateral load resisting system due to vertical discontinuity.

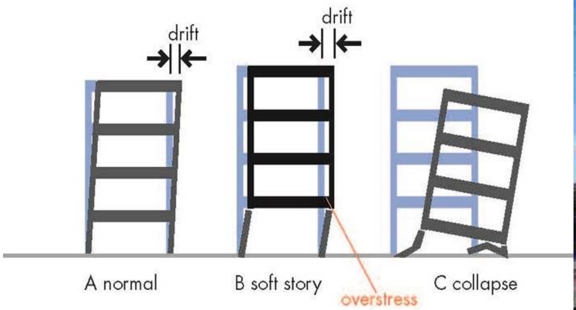


Fig. 1 Soft story failure

Fig. 2 Floating Column building failure

Steel bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. Bracing has been used to stabilize laterally the majority of the world’s tallest building structures as well as one of the major retrofit measures. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear. A bracing system improves the seismic performance of the frame by increasing its lateral stiffness and capacity. Through the addition of the bracing system, load could be transferred out of the frame and into the braces, bypassing the weak columns while increasing strength. Steel braced frames are efficient structural systems for buildings subjected to seismic or wind lateral loadings. Therefore, the use of steel bracing systems for retrofitting reinforced concrete frames with inadequate lateral resistance is attractive.

1.1 Seismic Retrofitting

Seismic Retrofitting Techniques are required for concrete constructions which are vulnerable to damage and failures by seismic forces. In the past thirty years, moderate to severe earthquakes occured around the world every year. Such events lead to damage to the concrete structures as well as failures. Thus the aim is to focus on a few specific procedures which may improve the practice for the evaluation of seismic vulnerability of existing reinforced concrete buildings of more importance and for their seismic retrofitting by means of various innovative techniques such as base isolation and mass reduction. So Seismic Retrofitting is a collection of mitigation technique for Earthquake engineering. It is of utmost importance for historic monuments, areas prone to severe earthquakes and tall or expensive structures.

Seismic Retrofitting of Concrete Structures:

- To ensure the safety and security of a building, employees, structure functionality, machinery and inventory
- Essential to reduce hazard and losses from non-structural elements.
- Concerned with structural improvement to reduce seismic hazard.
- Important buildings must predominantly be strengthened whose services are assumed to be essential just after an earthquake like hospitals.

There are several methods for seismic retrofitting as mentioned below:

- Adding shear wall
- Adding infill wall
- Adding bracing
- Wall thickening
- Mass reduction
- Base isolation

Here in this paper we will be using Shear wall and bracing as seismic retrofitting methods for an existing G+5 building situated in Pune.

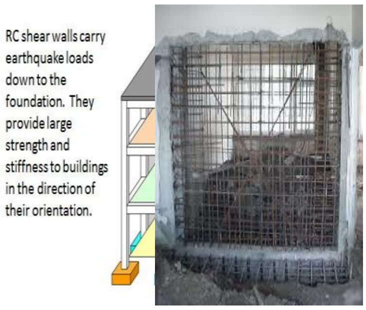


Fig. 3Use of shear walls in RCC building

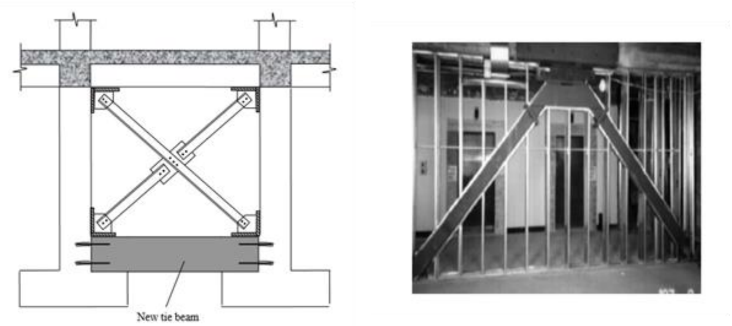


Fig 4: Use of Bracings in RCC building

II. RELATED WORK

Adrian Fredrick C. Dyaa and Andres Winston C. Oretaaa (2015) [1] have studied the Seismic vulnerability assessment of soft story irregular buildings using pushover analysis. Upon analysis of the modelling results for the soft story building, they have concluded that the main cause for soft story buildings to be more susceptible to earthquakes is the localization of seismic forces. Though the total demand on the building is smaller due to the increased height, uneven demands on the areas of the building results to a local hazard. The forces are concentrated on the segment of the building where there is a reduction in stiffness which is at the location of the soft story. This can be observed through the development of the plastic hinges, the story drift of the buildings, as well as the design. These seismic parameters show a localization of seismic demand.

Benavent-Climent and S. Mota-Páez (2017) [2] investigated a solution for the seismic upgrade of existing reinforced concrete frames with open first story and masonry infills at the upper stories. It combines the addition of hysteretic dampers with the strengthening (if necessary) of the columns of the first story. They concluded that the probability of having first story drifts larger that the target drift is very low (13%), and in no case the target drift was exceeded by more than 20%. The maximum shear forces in the upper stories predicted with the proposed formulae coincides approximately with the upper bound of the responses obtained from the time history analyses. The residual drift at the first story is less than 0.05% for 83% of the ground motions.

Seyed Bahram Beheshti Aval et. al. (2017) [3]investigated the efficiency of two types of rehabilitation methods based on economic justify cation that can lead to logical decision making between the retrofitting schemes. Among various rehabilitation methods, concentric chevron bracing (CCB) and cylindrical friction damper (CFD) were selected. The performance assessment procedure of the frames is divided into two distinct phases.They concluded that that the retrofit of a deficient building constructed according to outdated guidelines with brace and cylindrical friction dampers decreases the damage potential at a specific level of seismic intensity for both IO and CP performance levels. Comparing the two retrofitting schemes at the IO level demonstrate significant improvement, but the behavior of the building equipped with CFD has a more substantial effect at the CP level which leads to better seismic performance in terms of collapse probability, mean annual frequency, and expected annual losses. Decreasing the structural period leads to seismic hazard enhancement, and therefore by considering different site hazard characteristics, distinct outcomes will be obtained. In buildings retrofitted with braces at the CP level, when compared with bare frames, the collapse potential increases.

Rahul Ghosh and Rama Debbarma (2017) [4] attempted to evaluate the seismic performance of setback structures resting on plain ground as well as in the slope of a hill, with soft storey configuration. The analysis has been performed in three individual methods, equivalent static force method, response spectrum method and time history method and extreme responses have been recorded for open ground storeyed setback building.Orthogonal movement under unidirectional force has been recorded for the setback buildings. These structures also reflect differential movement of either sides of the structure, as the taller side moves more than the shorter side along the direction of force. Due to the variation of mass, stiffness and geometry of the setback building, the twisting of the structure also takes place. The columns of the setback buildings at the higher level of the slopes are subjected to higher bending moments; so, special measures should be taken during theirdesign and construction.

F. Hejazi et. al.(2011)[5]studied the occurring of soft at the lower level of high rise buildings subjected to earthquake. Also has been tried to investigate on adding of bracing in various arrangements to structure in order to reduce soft story effect on seismic response of building.Result showed that a bracing will only makes a different result for the storey that equipped with bracing. The horizontal and vertical movements of building which bracing installed in most bays are much reduced during earthquake compare with other models. So it shows that the use of bracing is effectively reduced effect of soft story on structure response in earthquake excitation. In the other hand, vulnerability level of existing multi-storied buildings is assess by analysis of different arrangement of bracing on building and it helped for retrofitting of structure on consider level of operation and safety with minimum requirements.

T. M. Prakash et al. (2018) [6] analyzed RCC building with soft story at different location. Linear dynamic analysis (Response spectrum analysis) in ETABS software was carried out. Different seismic parameters like time period, story shear, story displacement and story drift were checked. For that, G+14 (Reinforced cement concrete) RCC model was selected. Comparison of single soft storey at different locations in the building was developed and it was found that the earthquake response was maximum in the model with soft storey at ground floor and minimum in the model with soft storey at the top floor. From this one can say that the top soft storey will absorb more energy which results in the reduction of Earthquake response of the building. Story shear is around 30% more in soft story case as compared to without soft story and story drift is around 50% more as compared to without soft story case.

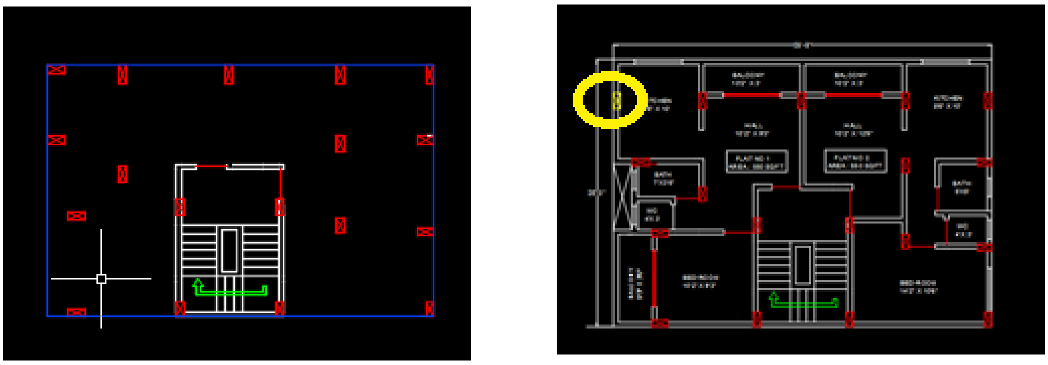
Objectives of investigation:

1. To perform the equivalent static analysis on existing building at Pune.
2. To check the strength of existing building by comparing design results with actual results.
3. To assess the best suitable retrofitting method by adding shear wall and bracing in existing building.

III. MODELLING

- No of stories: S+4
- Story height: 3.65m at stilt, 3.048 above
- Reponses reduction factor:5
- Importance Factor:1

- Soil Type: Medium
- Time period as per : 0.09*h/sqroot(d) as per IS:1893 2016

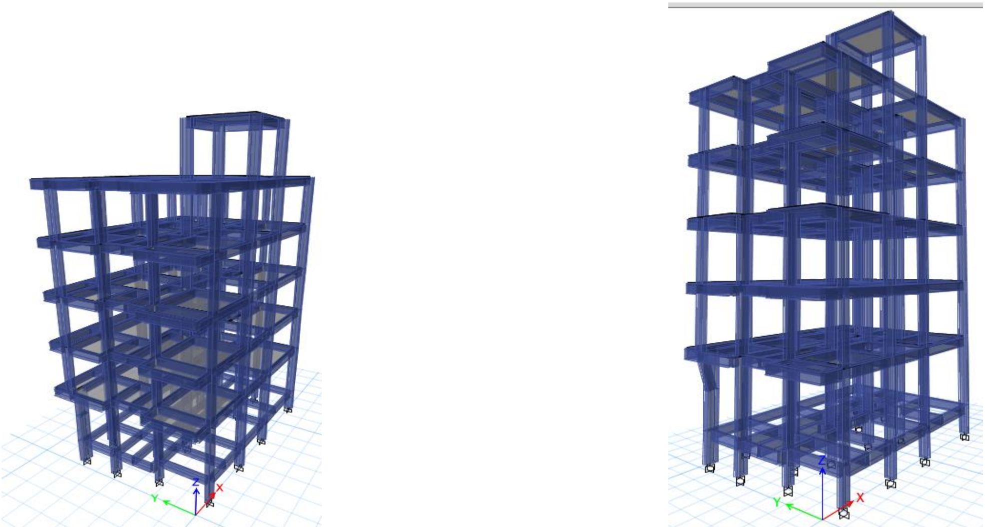


(a) (b)

Fig. 5: Plan of building in AutoCAD (a) stilt floor (b) ground floor

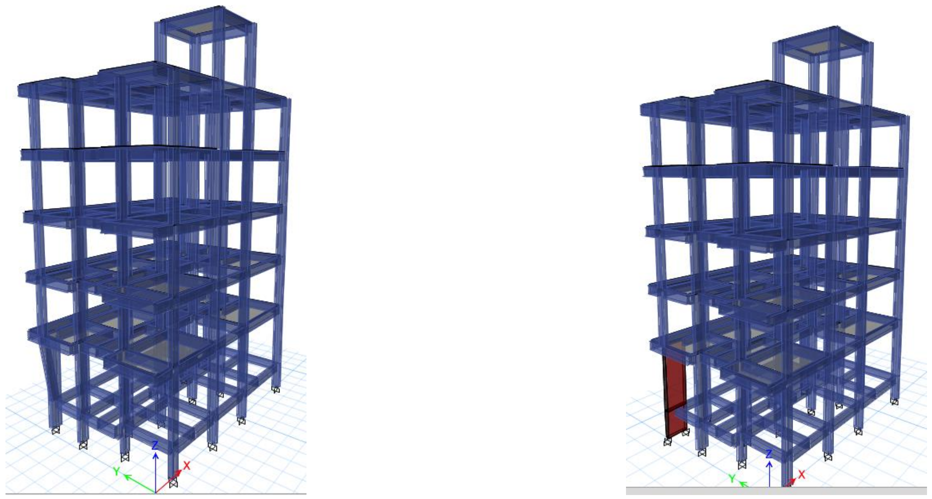
IV. RESULTS AND DISCUSSIONS

All models are first analysed by equivalent static analysis and results of story drift, maximum lateral displacement, base shear has been compared for performance of the structure. Also design and analysis of floating column area has been compared for performance of the structure.



(a) (b)

Fig. 6: Plan of building in AutoCAD (a) Building with soft story and floating column at corner and Floating column directly supported on beam (b) Building with soft story and floating column at corner and Floating column with bracing connected at middle of lower story column



(a) (b)

Fig. 7: Plan of building in AutoCAD (a) Building with soft story and floating column at corner and Floating column with bracing connected at bottom oflower story column (b) Building with soft story and floating column at corner and with shear wall

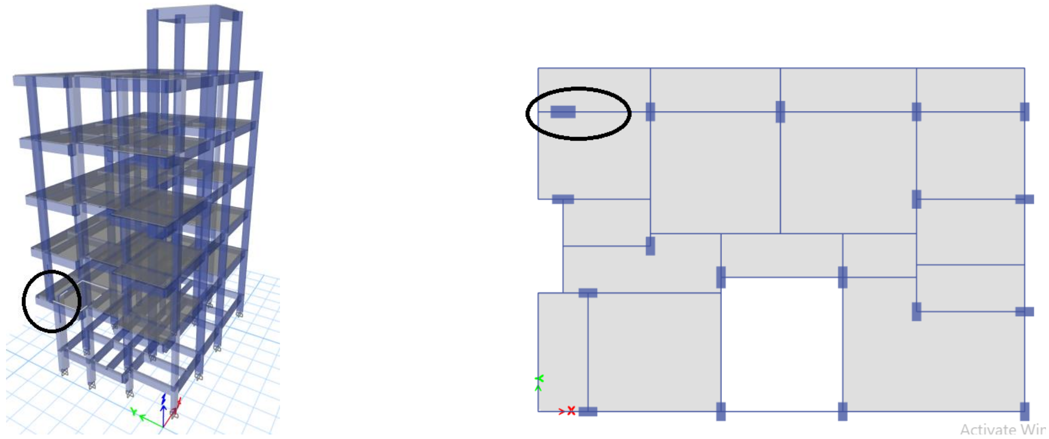


Fig. 8:area of the building considered for analysis in all cases

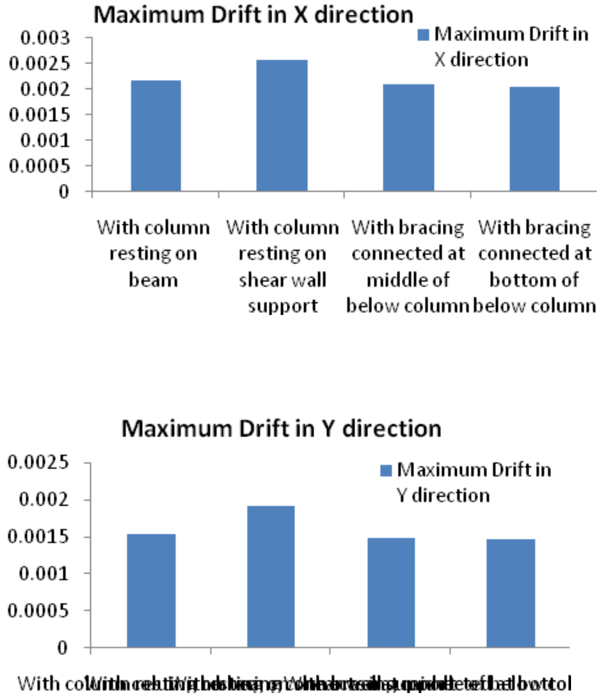


Fig. 9 Variation of maximum story drift for various cases in X & Y direction

From Figure 9 it is found out that, the value of maximum story drift in X direction increases to around 17-18% with shear wall case as compared to floating column resting directly on beam and decreases by 4-5% by using bracing with floating column. Similar results were observed in Y direction also.

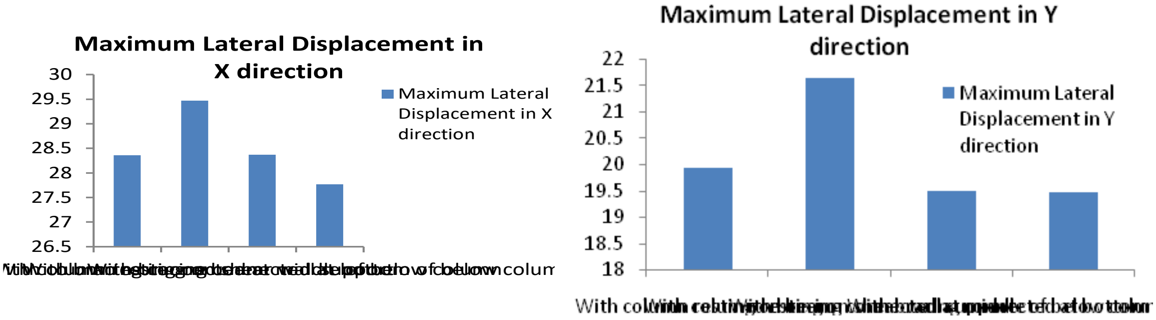


Fig. 10 Variation of maximum lateral displacement for various cases in X & Y direction

From Figure 10 it is found out that, the value of maximum lateral displacement in X direction increases to around 4-5 % with shear wall case as compared to floating column resting directly on beam and decreases by 2-3% by using bracing with floating column. Similar results were observed in Y direction also.

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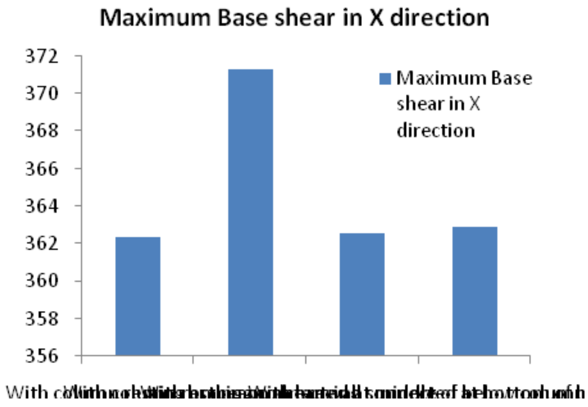


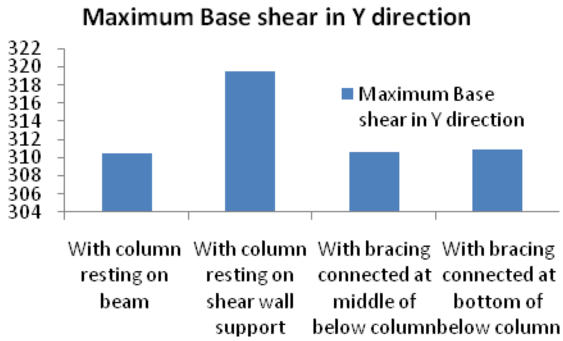
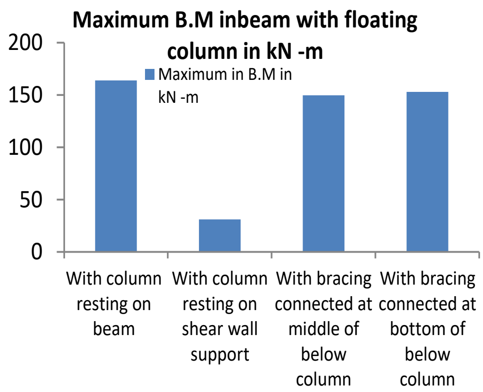


Fig. 11 Variation of base shear for various cases in X & Y direction

From Figure 11 it is found out that, the value of base shear doesn't change much for all cases, there is a slight increase in base shear due to increase in seismic weight of the structure.



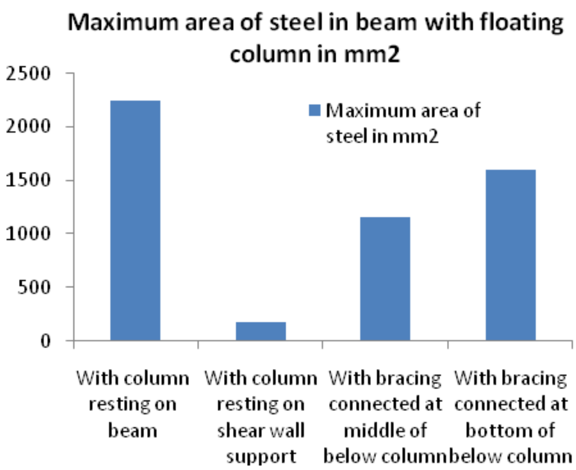
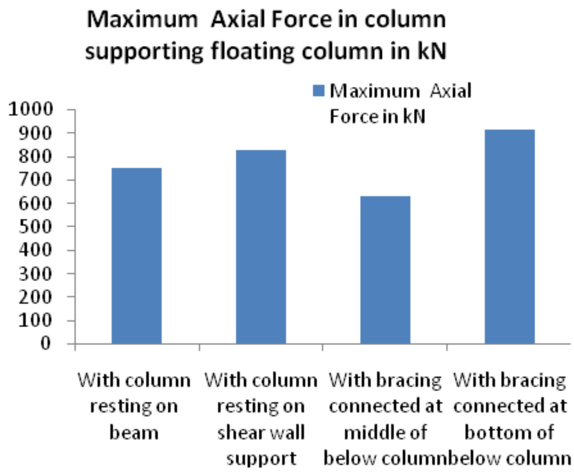


Fig.12 Variation of Maximum Moments and area of steel in beam with floating column

From Figure 12 it is found out that, the value of maximum moment in beam with floating column is maximum when floating column is directly resting on beam case as moment of floating column is directly transferredthrough beam and also area of steel required in that is maximum and is failing in design.



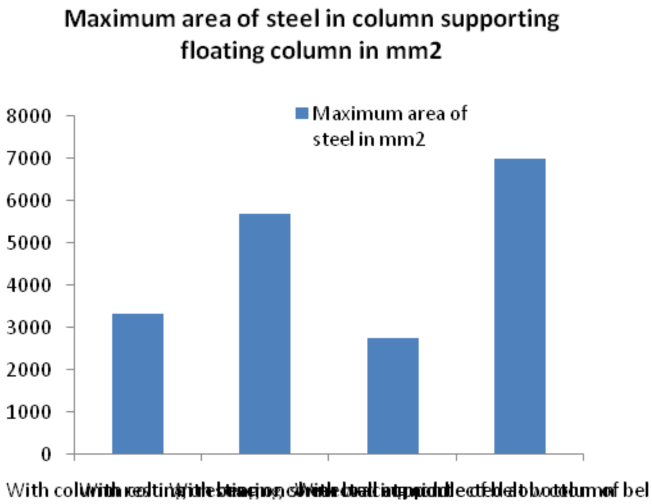


Fig.13 Variation of Maximum axial force and area of steel in column supporting floating column

From Figure 13 it is found out that, the value of maximum axial force in column supporting floating column is maximum when floating column is when floating column is connected to base of bottom column through bracings case as moment of floating column is directly transferredthrough bracing in column below and also area of steel required in that is maximum in this case.

V. CONCLUSION

After studying the existing building with different retrofitting methods, we concluded that strengthening of existing building after construction is a complex procedure, we need comprehensive analytical study as well site execution to increase the strength of existing structure. Use of bracing from floating column to mid of column below decreases the drift and lateral displacement of the building and area of steel in below column is less as compared to other cases. Alsoafter adding a shear wall at that location supporting floating column which can take all the load of above structure there will be no loads on beams.But adding shear wall will be costly as compared to bracing, also constructing foundation for that shear wall would be very tedious job. So best possible solution for seismic retrofitting of existing building will be use of bracing from floating column to mid of column below.

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