

Seismic Evaluation of RC Unsymmetrical Building with Floating Columns & Soft storey Considering Different Configuration

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ABSTRACT: Open first story and Floating columns are typical features in the modern multi-storey constructions in urban India. This paper deals with the study of architectural drawing and the framing drawing of the building having Floating columns & Soft storey. Existing commercial building comprising of G+ 7 structures has been selected for carrying out the project work. The building was modelled as per plan and the plan was remodified in different ways so that total twelve models are carried out in this study. In the present work, the recommendations such as the effect of Infill, Bracings and Shear wall are introduced in the building in order to improve the seismic performance. The structural action of masonry infill panels have been taken into account by modelling them as diagonal struts. Equivalent static and response spectrum methods are used for analysis by ETABS 15.2.0 software. The structure was assumed to be situated in earthquake Zone III & V on a medium soil (type II). The parameters evaluated were displacement, storey drift, storey shear, and storey stiffness of all models are compared and significant co-relationship between these values are established with graphs.

KEYWORDS: Floating column, Soft storey, Infill, Bracings, Shear wall, Equivalent diagonal strut, Equivalent static analysis, Response spectrum analysis, ETABS.

I. INTRODUCTION

Conventional Civil Engineering structures are designed on the basis of strength and stiffness criteria. In case of earthquake forces the demand is for ductility. Larger is the capacity of the structure to deform plastically without collapse, more is the resulting ductility and the energy dissipation. This causes reduction in effective earthquake forces [1]. The behaviour of a building during earthquakes depends mainly on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building. Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey [2].

Floating Column: A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which ends (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam which is a horizontal member as shown in figure 1. The beams in turn transfer the load to other columns below it. Such columns where the load was considered as point load. This is being provided more space in ground floor for a) Accommodation of parking or ground lobbies b) For architectural beauty c) To increase floor space index [3].

Soft Storey: Open ground storey (stilt floor) used in most severely damaged or, collapsed RC buildings, introduced 'severe irregularity of sudden change of stiffness' between the ground storey and upper storeys since they had infilled brick walls which increase the lateral stiffness of the frame by a factor of three to four times. Such a building is called a building with 'soft' ground storey (buildings on stilts or with open plinth), in which the dynamic ductility demand during the probable earthquake gets concentrated in the soft storey and the upper storeys tend to remain elastic. Hence

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whereas the 'soft storey' is severely strained causing its total collapse, much smaller damages occurs in the upper storeys, if at all.

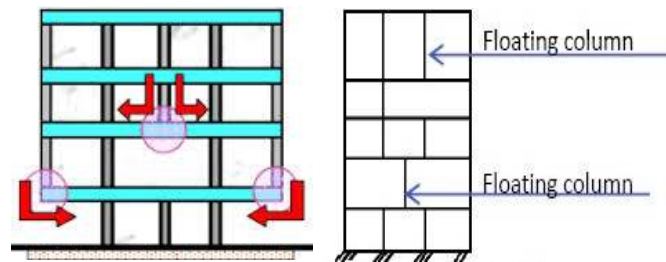


Fig 1: Floating column or Hanging column in a building [4]

When irregular features such as floating columns and soft storey are included in buildings, a considerably higher level of engineering effort is required in the structural design and these kinds of discontinuous members are endangered in seismic regions. But those structures cannot be demolished, rather study can be done to strengthen the structure or some remedial features can be suggested. The stiffness of these columns can be increased by retrofitting or these may be provided with masonry infill, bracing or shear wall to decrease the lateral deformation.

For present study, the building with soft storey & floating columns is provided with Infill, Lateral bracings, Shear wall. Linear analysis was carried out for this study (Equivalent static & Response spectrum) using ETABS 15.2.0. The results were tabulated for lateral displacement, storey drift, storey shear and storey stiffness.

II. RELATED WORK

A.P. Mundada et al., [5] dealt with the study of architectural drawing and the framing drawing of the building having floating columns. In this study an existing G+7 residential building is selected for the equivalent static analysis of load distribution on floating columns and various effects due to it are presented using staad pro v8i. Thus the main objective of this paper is to find the various analytical properties of the structure and also understand a very systematic and economical design of the structure.

Pratyush Malaviya., et al., [6] made a comparative study of effect of floating columns on the cost analysis of a structure designed on staad pro v8i. The conclusion is made that in the framed structure with no floating columns, the nodal displacements is minimum with uniform distribution of stresses at all beams and columns and these are the most economical one and at a particular case (all the outer columns (Y direction) in ground floor) there is maximum requirement of concrete and steel. This type of building is frequently used so as to avoid any external facility for parking of vehicles; so the analysis shows that it is not advisable to propose such structures.

Srikanth.M.K et al., [7] studied the importance of explicitly recognizing the presence of the floating column in the analysis of building and also along with floating column some complexities were considered for ten storey building at different alternative location and for lower and higher zones. It is concluded that, the displacement of the building increases from lower zones to higher zones, similarly for drift, because it is correlated with the displacement. Storey shear will be more for lower floors, then the higher floors due to the reduction in weight.

Prerna Nautiyal et al., [8] investigated the effect of the floating column under earthquake excitation for different soil conditions and a linear dynamic analysis is done for the 2D frame of the multi-storey building with and without floating column to achieve the response of the frame for safer and economical design of the structure under such excitations.

III. OBJECTIVES AND METHODOLOGY

Objectives: My research project aims at doing seismic evaluation for an existing reinforced concrete building using linear analysis method. Taking the results into consideration, objective is: (a) To study the effects of Floating column & Soft storey in structural behaviour of high rise building. (b) To Model the multi-storey building with and without floating column & Soft storey using ETABS 15.2.0. (c) To study the modeling of infill as equivalent diagonal

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strut.(d)To carry out Static (ESA) and Dynamic analyses (RSA) for different cases of unsymmetrical building.(e)To compare the multi-storey building with and without floating column, when the floating columns are present at ground floor and different location.(f)To observe the structural performance of the soft storey structure (with and without floating column) having equivalent diagonal strut, bracings, shear wall when subjected to lateral loads.(g)To study the structural response of building in different seismic zones (Zone 3 & Zone 5).(h)To study the structural response of the building models with respect to following aspects –storey displacement, storey shear, storey drift, storey stiffness .Generally these buildings with floating columns are usually designed for gravity loads and are safe under gravity loads but are not designed for earthquake loads. So these buildings are unsafe in seismic prone areas .Hence this study aims to create awareness about these issues in earthquake resistant design of multi-storeyed buildings with floating columns.

Methodology:The methodology worked out to achieve the above-mentioned objectives is as follows:(i) Review the existing literature and Indian design code provision for designing the building.(ii) Select an existing building model for the case study.(iii)The plan is remodified by selecting some of the ground floor columns considered as floating column.(iv) Model the selected BF building with and without floating column.(v) To improve the seismic performance the building with floating column and soft storey is recommending some design recommendations such as infill, bracings and shear wall.(vi) Linear analysis of the building models and a comparative study on the results obtained from the analyses.(vii) Observations of results and discussions.

IV. STRUCTURAL MODELLING AND ANALYSIS

One of the major purposes of this work was to test a real life structure under various loads. The building considered is a commercial building having G+7 stories. The original structure is detailed according to new conforming seismic detailing practice as per IS 13920 and Earthquake loads are considered as per IS1893 (part 1):2002.The plan layout for all the building models is same as shown in figure 2.Study has been done on twelve different models of an 8 storey building with special moment resisting frames in two orthogonal directions.

Table 1: Details of Building

MEMBER DIMENSIONS		
Slab Thickness		150mm
Beams		230x300mm , 230x600mm
Columns		300x600mm
Brick infill wall thickness		230mm
Shear wall thickness		200mm
Typical storey height		4m
LOADS		
Unit weight of concrete		25kN/m ³
Unit weight of brick infill		20kN/m ³
Dead load		Self-weight of the structure
Live load	On Floors	4 kN/m ²
	On Roof	1.5 kN/m ²
Floor finish		1kN/m ²
MATERIAL PROPERTIES		
Characteristic strength of concrete, f_{ck}		25 Mpa
Yield stress for steel, f_y		415 Mpa
Modulus of Elasticity of steel, E_s		2 X 10 ⁵ Mpa
Modulus of Elasticity of concrete, E_c		27386.13 Mpa
Type Of Frame		Special Moment Resisting frame
Type Of Building		Commercial

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Diagonal Strut and Model details: The geometric and material properties of the equivalent diagonal strut are required for conventional braced frame analysis to determine the increased stiffness of the infilled frame. The geometric properties are of effective width and the thickness of strut. The infills are modelled by single equivalent diagonal strut approach and its thickness is equal to infill wall thickness. The ends of strut are pin connected to frame and make it moment releases at it ends, to avoid the transfer of moment from frame to strut. The width of the diagonal strut given as,

$$W = 0.175(\lambda'h)^{-0.4} d'$$

$$d' = \sqrt{L^2 + h^2}$$

Where,

$$\text{Contact length parameter } (\lambda') = 4 \sqrt{\frac{E_i t \sin(2\theta)}{4E_s I_c h}}$$

To study the effect of various loads in various Earthquake zone, the building was modelled as per plan and the plan was remodified in different ways and also randomly some of the ground floor columns are considered as floating column as shown in fig 2(c). The discontinuity has been provided at the ground floor only because it has already been observed in previous research studies that floating column caused adverse effects when discontinued at ground floor. In all the models floating columns(5 numbers) are located in ground floor and various features are included in each model in order for earthquake resistant design. The ground floor of the all models were considered as soft storey.

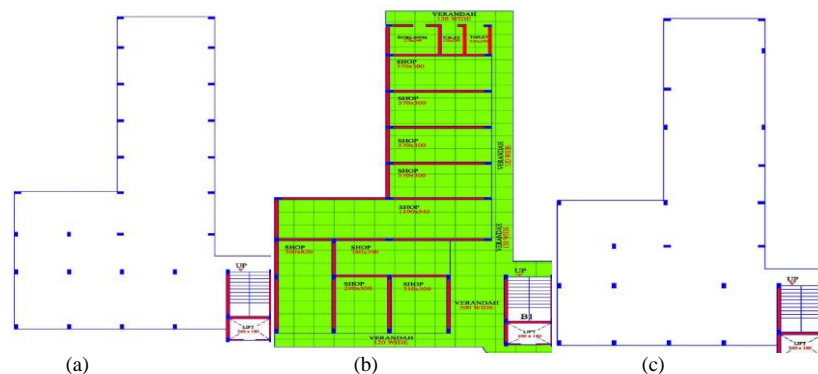


Fig 2: Typical Plan of the Building to be analysed
(a) Ground floor (b) Floors above (1st-8th) (c) Building with floating column in ground floor

The models are developed by progressive addition of various features. Each model is described in following:

- 1) MODEL 1: Building model is same as the floor plan, but there is no infill (considered as bare frame)
- 2) MODEL 2: Building model is same as model 1, with floating columns and soft storey at Ground floor.
- 3) MODEL 3: Building model is same as model 1, with soft storey at ground floor, has full brick masonry infill in the form of diagonal strut.
- 4) MODEL 4: Building model is same as model 2, with floating columns and soft storey at Ground floor, has full brick masonry infill in the form of diagonal strut.
- 5) MODEL 5: Building model is same as model 4, brick masonry infill in the form of diagonal strut provided on the specific corners of outer face of ground floor.
- 6) MODEL 6: Building model is same as model 4, X – Bracings are provided on the specific corners of outer face.
- 7) MODEL 7: Building model is same as model 4, Shear wall is provided on the specific corners of outer face
- 8) MODEL 8: Building model is same as model 4, brick masonry infill in the form of diagonal strut provided on the location of floating columns
- 9) MODEL 9: Building model is same as model 4, X – Bracings are provided on the location of floating columns.
- 10) MODEL 10: Building model is same as model 4, Shear wall is provided on the location of floating columns.

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- 11) MODEL 11: Building model is same as model 1, located in ZONE V.
- 12) MODEL 12: Building model is same as model 2, located in ZONE V.

The configuration of infill, bracings and shear wall for (Model 5 to model 10) are shown in figure 3. For model 5, model 6, model 7, infill bracings and shear wall provided on all possible corners as shown in figure while for model 8, model 9, model 10, they are provided on the floating column locations as shown in figure below:

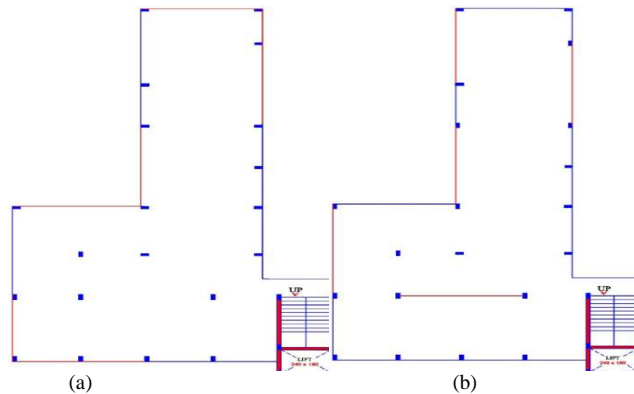


Fig 3: Configuration of building models
(a) Building Model 5,6,7 (b) Building Model 8,9,10

V. RESULTS AND DISCUSSIONS

Equivalent static analysis (ESA) and Response spectrum analysis (RSA) has been performed for each model in ETABS 15.2.0 software. From the obtained results below charts has been drawn in X direction. Similar variation is observed on Y direction.

4.1. Lateral Displacement

The lateral displacement profiles of the various models for the ESA and RSA performed in this study are shown in Figures below:

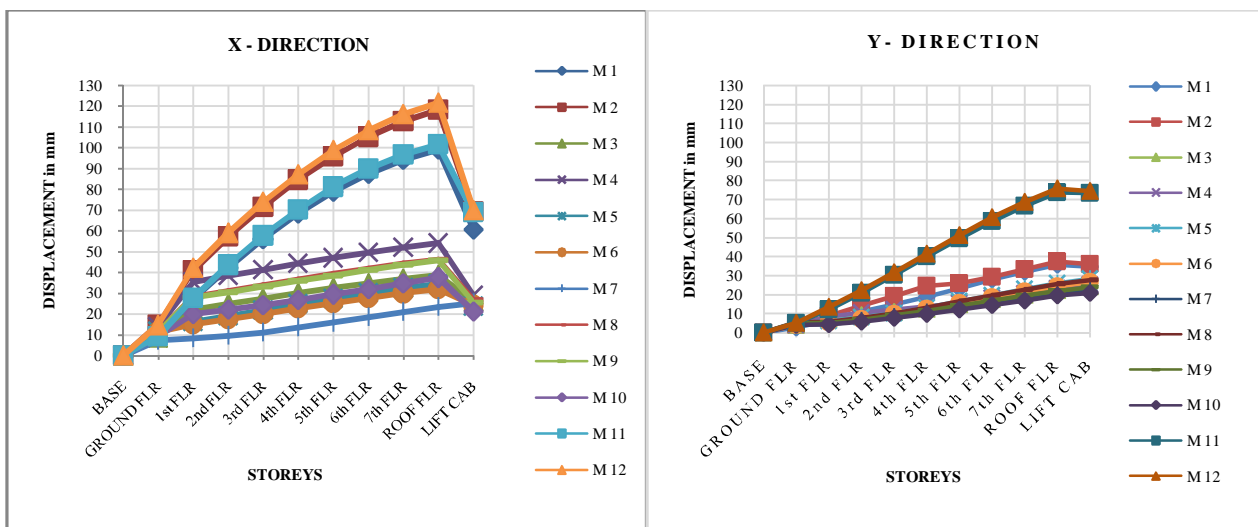


Fig 4: Comparison of Displacement in X & Y direction due to lateral loads in ESA

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Storey displacement is the lateral movement of the structure caused by lateral force. The deflected shape of a structure is most important and most clearly visible point of comparison for any structure. The maximum displacements of building in different stories in both X and Y directions for all models have been compared. No other parameter of comparison can give a better idea of behavior of the structure than comparison of storey displacement.

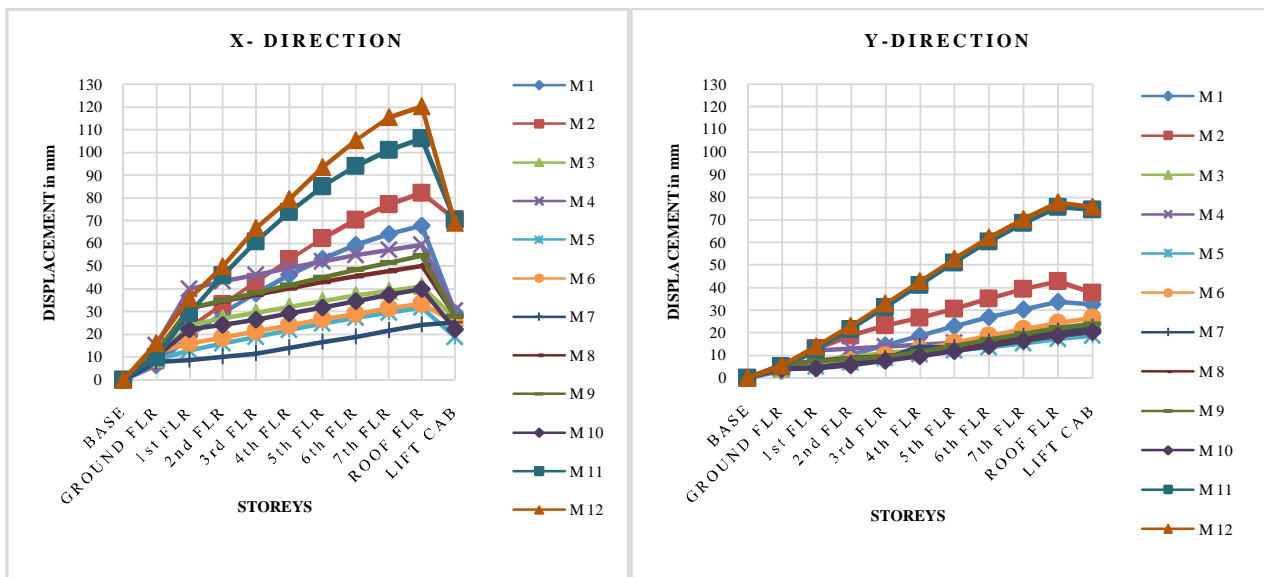


Fig 5: Comparison of Displacement in X & Y direction due to lateral loads in RSA

4.2.Storey Drift

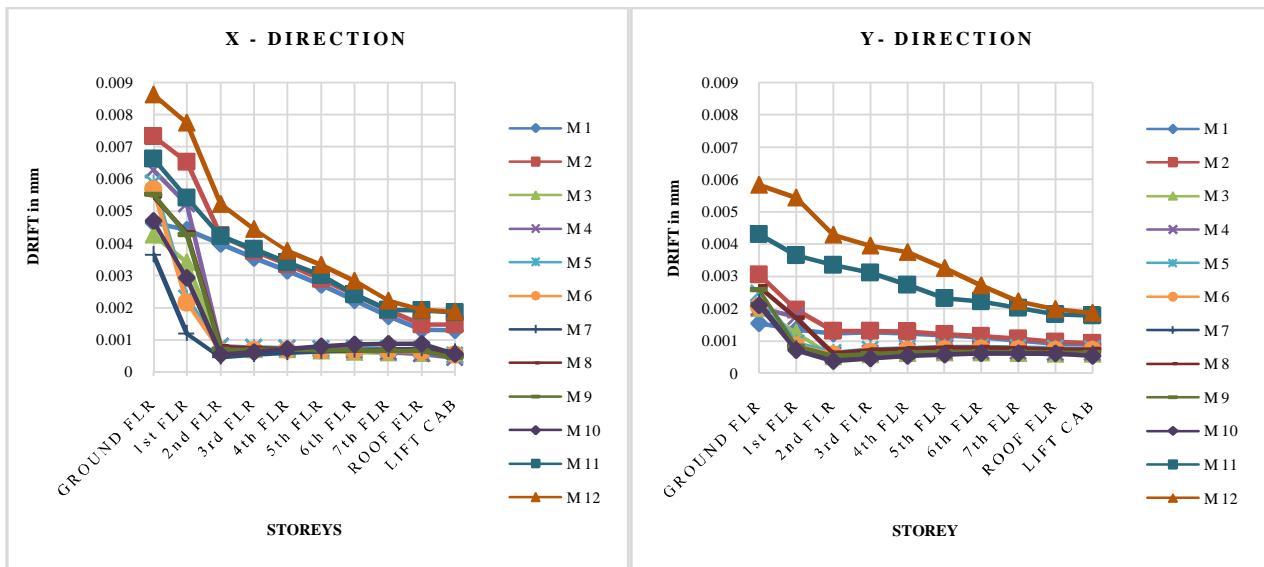


Fig 6: Comparison of Storey Drift in X & Y direction of the different models in ESA

Story drift is the displacement of one level relative to the other level above or below. Damage to non-structural components of buildings depends on drift. First of all consider model 1 “Bare Frame (G+7)” because, it is a basic or

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traditional structure in which no other element are included or considered in structure for improving the performance of the building, so the results of the Bare frame (G+7) can compare with the results of the other models. The storey drifts at each floor height of the model 1 (i.e. Bare Frame (G+7)) with all load combination get from software, from this result understand the load combination shows the maximum storey drift. So here storey drift of that maximum load combinations in all models can be considered as a benchmark to state the comparative statement.

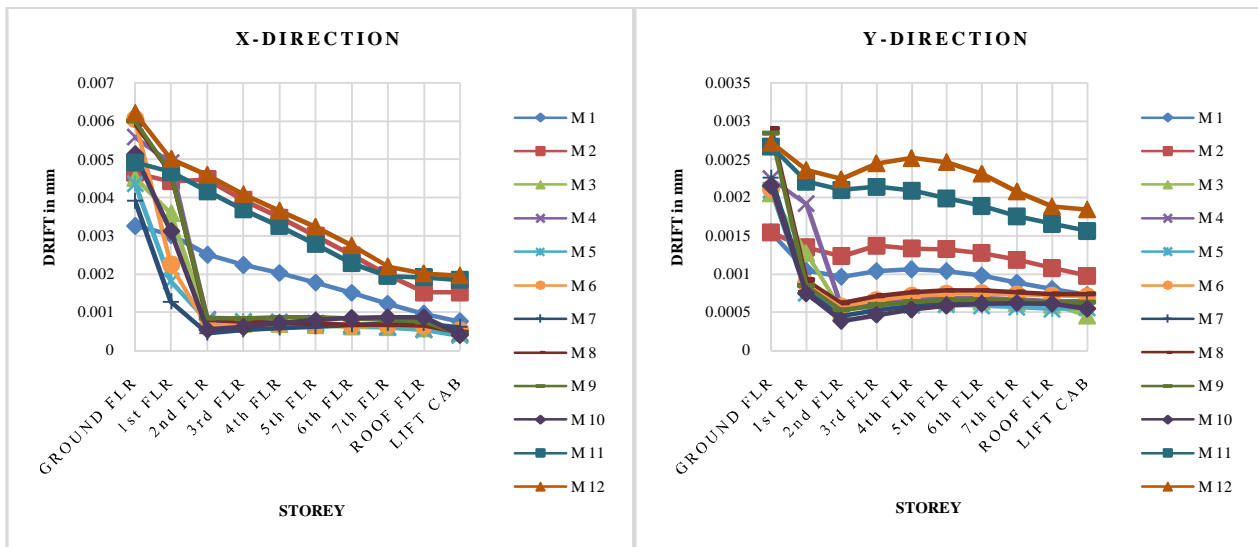


Fig 7: Comparison of Storey Drift in X & Y direction of the different models in RSA

4.3. Storey Shear

Storey shear is the distribution of design base shear along height of the structure. Storey shear depends on stiffness in the frame. The infill as equivalent diagonal strut have significance influence on shear. The struts resist the lateral seismic forces through axial compression along the strut. Shear induced at the base of building during earthquake is called base shear which depends on the seismic mass and stiffness of building.

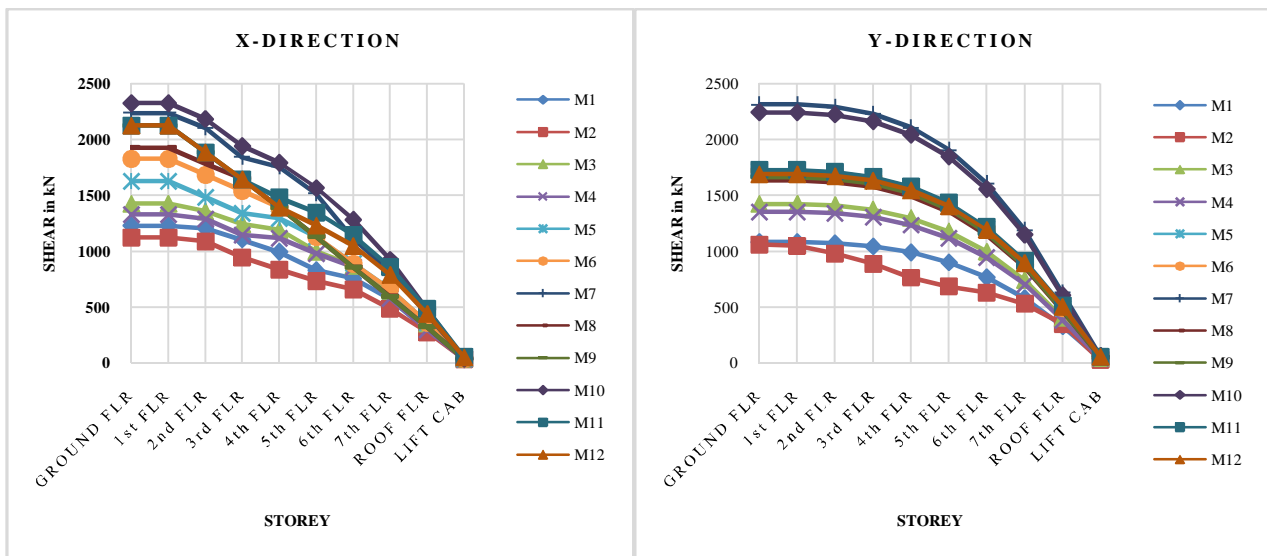


Fig 8: Comparison of Storey shear of all models in X & Y direction in ESA

Storey shear is minimum for bare frame models as the mass is less, and shear is maximum for building with shear wall. The shear increases also by the introduction of infill and bracings too. Due to the introduction of floating columns in the building, the value of shear decreases due to the increase of natural period of vibration of structure. Also, the mass of concrete in column is less for floating column building as compared to normal building (NB), so this further decreases the base shear.

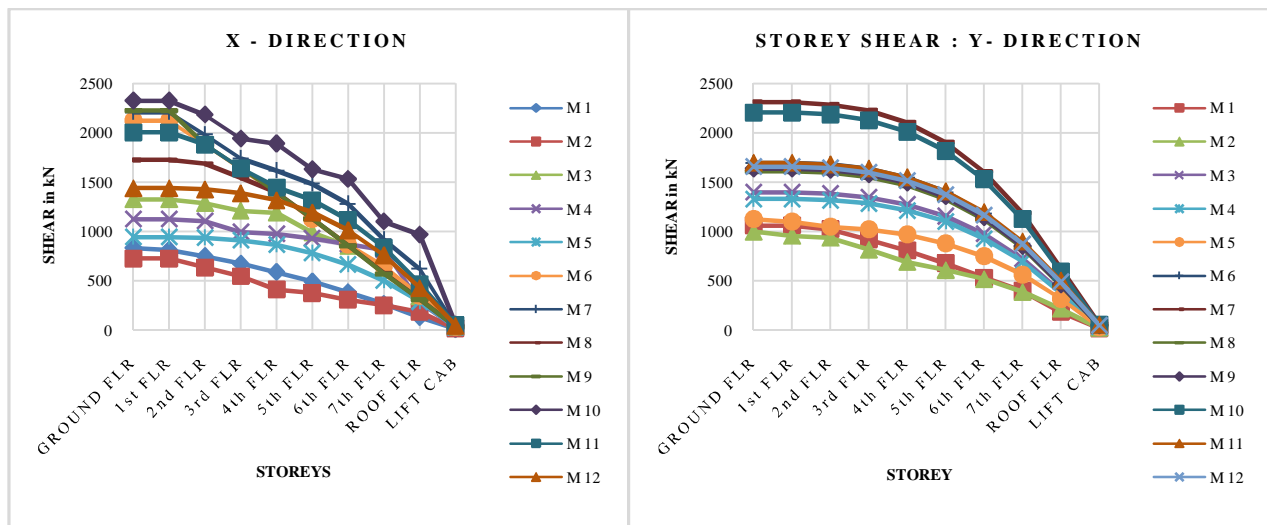


Fig 9: Comparison of Storey shear of all models in X & Y direction in RSA

4.4. Storey Stiffness

The storey stiffness is defined as the magnitude of the force couple required at the floor levels adjoining the storey to produce a unit lateral translation within the storey, letting all the other floors to move freely. The stiffness of twelve models in X & Y directions for both analysis are shown in figures below:

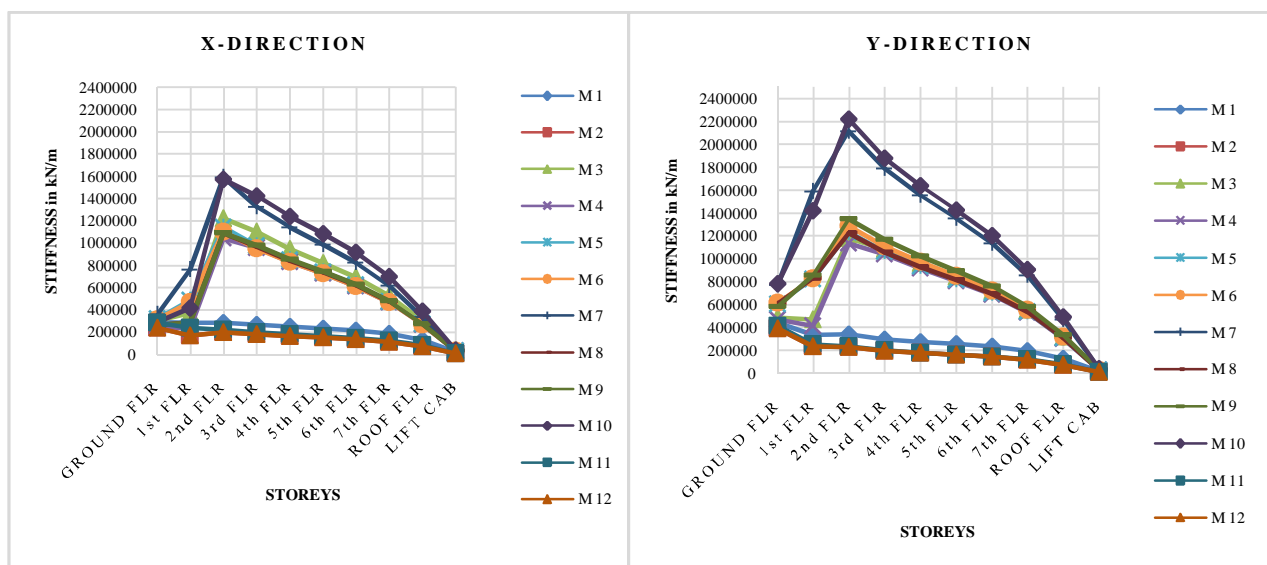


Fig 10: Comparison of Storey Stiffness in X & Y direction of different models in ESA

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Except BF models all other models shows a reduction in the stiffness values in ground and first floor after that it reach a particular value from second floor and gradually decreases. This is due to the presence of floating column and soft storey in ground floor. The BF models shows a constant variation in stiffness. For the building models at hand, the storey stiffness of the first and second storeys are comparatively less compared to other storeys except bare frame building models. The stiffness irregularity in building models with soft first storey is evident that they are weak storeys. Here, stiffness is more for building having shear wall configurations.

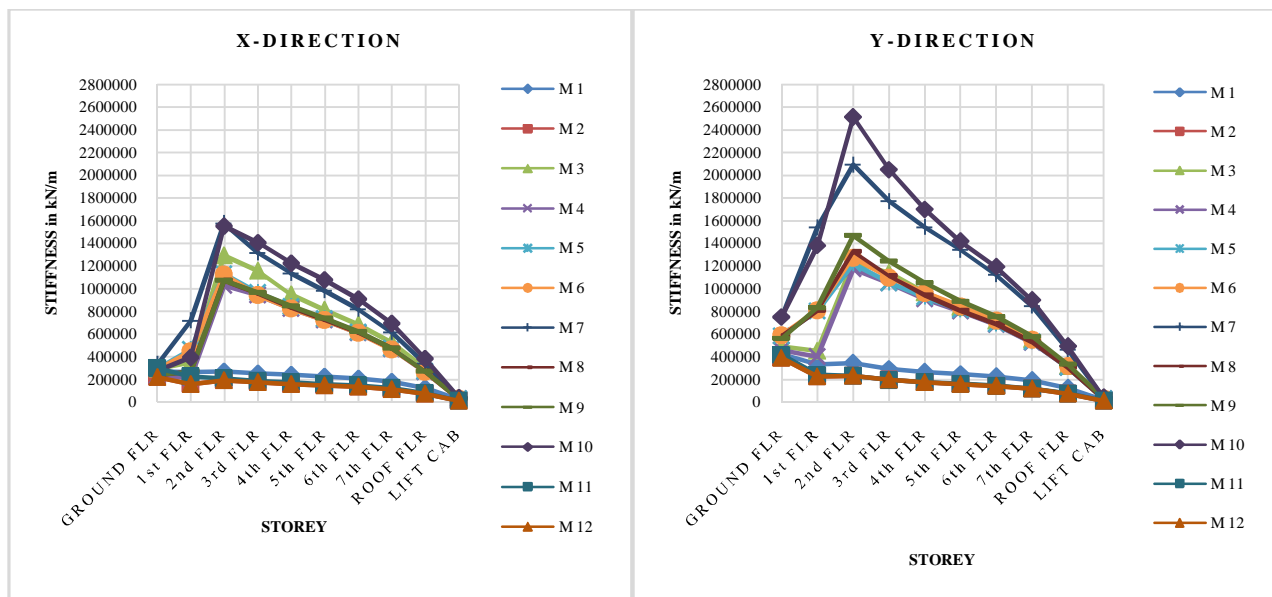


Fig 11: Comparison of Storey Stiffness in X & Y direction of different models in RSA

VI. CONCLUSION

Following conclusions have been made on the basis of analysis and results:

1. Floating column building shows poor performance during earthquake.
2. RC frame buildings with open first storeys are known to perform poorly during in strong earthquake shaking. The drift and the strength demands in the first storey columns are very large for buildings with soft ground storeys. It is not very easy to provide such capacities in the columns of the first storey. Thus, it is clear that such buildings will exhibit poor performance during a strong shaking. This hazardous feature of Indian RC frame buildings needs to be recognized immediately, and necessary measures taken to improve the performance of the building.
3. The displacement of building increases from lower zones to higher zones, because the magnitude of intensity will be more for higher zones, similarly for drift, because it is correlated with the displacement. In all models the displacement values are less for lower zones and it goes on increases for higher zones in ESA and RSA methods.
4. The storey displacements increase when floating columns are introduced in the building, which proves that buildings with floating columns in ground floor are more vulnerable during earthquake. It was also observed that deflections increase marginally in that storey where floating columns are located.
5. Out of all the models, by using ESA & RSA methods to evaluate storey drift, multi-storey building with shear walls has performed exceedingly well when compared with normal multi-storey building, building with bracings and masonry infill walls. Drift is more severe in ground floor due to vertical irregularity
6. Storey shear reduces due to presence of floating column in building as the mass is less for building with floating column. Storey shear will be more for lower floors than the higher floors due to the reduction in weight when we go from bottom to top floors. And with this if we reduce the stiffness of upper floors automatically there will be a reduction in weight on those floors so in the top floors the storey shear will be less compared to bottom stories.

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7. The building with shear wall configuration shows more stiffness compared to other models. Nevertheless building with masonry infill as equivalent diagonal strut, bracings also shows good performance. Except BF models all other models show a reduction in the stiffness values in ground and first floor after that it reaches second floor and gradually decreases. This is due to the presence of floating column and soft storey in ground floor. The BF models show a constant variation in stiffness.
8. The recommendations such as shear walls, infill walls, bracings are considered in the modelling and analysis and observed that they can also be designed as an earthquake resistant up to an extent, such that on introduction of floating columns in the RC frames increases the time period of bare frames due to decrease in the stiffness.
9. On comparison of the results obtained for each model, it is observed that the building with shear wall are much preferable when compared with other recommendations.

Though floating columns are of more interest to architects for construction of multi-storey buildings in urban areas which are not as reliable as the conventional structures. The failure of storeys having floating columns can have a serious effect on progressive collapse of the building. Hence, floating columns should be avoided as far as possible in seismic regions and if they are unavoidable, then the structure should be strengthened by adopting some remedial features such as infill, bracings and shear wall etc. The analysis also proves that irregularities are harmful for the structures and it is important to have simpler and regular shapes of frames as well as uniform load distribution around the building especially in seismic zone areas. Therefore, as far as possible irregularities in a building must be avoided. But, if irregularities have to be introduced for any reason, they must be designed properly following the conditions of IS 1893-part-1: 2002 and IS-456: 2000, and joints should be made ductile as per IS 13920:1993. Now a days, complex shaped buildings are getting popular, but they carry a risk of sustaining damages during earthquakes. Therefore, such buildings should be designed properly taking care of their dynamic behaviour.

VII. SCOPE FOR FUTURE WORK

1. The applicability of the procedure of taller structure and structure with large time periods needs to be investigated.
2. In this work column size has been kept constant throughout the building height. One may go for the variation of sizes for the different levels as per the actual design consideration.
3. Nonlinear analysis need to be carried out for all the models.
4. The reactions at footing level is to be investigated and modified for the present study
5. An experimental investigation and verification can be done with small scale model on a shake table under simulated motions.
6. Design and estimation of building is necessary for checking the cost effectiveness of these measures used for improving the seismic performance of structure.

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