EFFECT OF SHEAR WALL IN HIGH-RISE BUILDING SUBJECTED TO DYNAMIC LOADING.

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ABSTRACT: *To avoid the damages from horizontal forces such as seismic forces and wind forces, the provision of a lateral force resisting system in the structure is essential. Lateral forces develop high stresses, produce sway movement or cause vibration, which leads to structural failure and therefore, it is crucial for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral loads. Shear walls offer effective means of providing in-plane lateral force resistance, typically to the wind and seismic loads in multi-story buildings. Shear wall systems have high plane stiffness and strength which can be utilized to resist large horizontal loads and support gravity loads simultaneously, making them advantageous in many structural engineering applications. Since the incorporation of shear walls in multi-storey buildings has now become a requirement, it is necessary to determine the most effective and accurate location of shear walls. When the mass center and hardness center coincide with each other, the distance of the shear wall from the mass center plays a significant role in the shear contribution of the shear wall. This paper presents the response of a building with different positioning of the shear wall using Response Spectrum Analysis and Wind load Analysis. Five different models of RCC buildings, one with no shear wall and the other four models with different positioning of the shear wall, subjected to earthquake load and wind load has been studied. The performance of each storey of a 20-storey building is evaluated for different combinations of loads applied. The analysis is done by structural finite element analysis method using SAP2000 software.*

Keywords: Shear walls, lateral load, High-rise buildings, Response spectrum analysis, Finite element method.

1. INTRODUCTION

Several researchers have studied the performance of lateral force resisting systems, i.e., steel bracing, outrigger, masonry and shear wall and compared parameters such as maximum lateral displacement, maximum storey drift, maximum base shear, storey shear and storey drift. These studies have concluded that shear walls provide the most effective earthquakes resistance design (Somasekharaiah et al, 2016, Kevadkar and Kodag, 2013). Shear walls are vertically-oriented wide concrete beams constructed that carry earthquake loads downwards to the foundation to resist the lateral displacement of a building and are usually provided along both length and the width of buildings. Conventional RCC (Reinforced Cement Concrete) buildings resist lateral load up to an extent, primarily by flexure. However, various structural parameters exceed the limit and deform substantially which makes the conventional method comparatively less effective than shear walls. Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces the lateral sway of the building and in turn, the damage to the structure. Generally, the thickness of an RCC shear wall is in the range of 150mm- 400mm and incurs a lower construction cost compared to conventional RCC buildings. Further, shear walls deform substantially prior failure and provide satisfactory warning during failure.

2. LITERATURE REVIEW

The inclusion of shear walls adds stiffness to structure and aids in reducing lateral drift under seismic loads. Important aspects concerning the design of shear walls are its placement in structure and the cross-section (i.e. Width to thickness ratio) keeping in view torsional stresses, economy and ductility of the structure. Jamal Ali at el, 2015 conducted a study a using ETABS software by varying the location and cross section of shear wall for the Stock Exchange Building, Islamabad, Pakistan. In this study analysed the maximum lateral drift, storey drift, base shear forces and time period of the structure parameters of 4 instances with varying the location of the shear wall. In addition, for each location, the thickness of the shear wall was varied (12 in, 9 in and 6in) and the parameters were compared. It was concluded that the original location with a 6in thick shear wall was more economical and ductile than existing 12in thick wall keeping in view the allowable lateral drift and base shear forces.

A similar study was carried out by Damam, 2015 that studied the effectiveness of RCC shear wall of four different models: the first model was a bare frame system and the other three types were frames having different locations of the shear wall. An earthquake load was applied to G+10 storey building located in different zones and the performance of building was evaluated in terms of lateral displacements of each storey. The analysis is done by structural finite element analysis method using SAP2000 software and concluded that the least deflection was observed at the corner type shear wall and it reduces the shear force and bending moment of the building. Elastic and elasto-plastic analyses were performed using both STAAD Pro 2004 and SAP 2000 software packages by Anshuman et al, 2011. Shear forces, bending moment and storey drift were computed for a building of fifteen stories located in zone IV in both cases and location of the shear wall was established based upon the results.

Further, Romy Mohan et al, 2011 conducted a Dynamic Analysis of RCC buildings for six different types of shear walls with variation in shape to study their effectiveness in resisting lateral forces. This paper also deals with the effect of the variation of the building height on the structural response of the shear wall. Koichiro, et al, 2001, investigated the effect of shear wall location in rigid frames on the dynamic behaviour of a roof structure due to vertical and horizontal earthquake motion. Large horizontal stiffness difference between the side frames is caused by the shear wall location which results in large vertical vibration of the roof & large shear at the side bearings. The study has carried out the earthquake response analysis of gabled and flat beams supported by bearing structures.

3. METHODOLOGY

A geometrically symmetrical building structure has been considered for this study with asymmetric loading. Its behaviour has been studied with various positions of shear wall.

3.1 Model Description:

- The complete description of the methods followed in modelling of the required buildings for the present work is stated.
- In the present work, 3D models of three different types of structural systems are simulated to study and compare the performance of the structures subjected to earthquake and wind forces on structures.
- Type of support for the building is a fixed support.
- All the models have the same structural plan dimensions.
- The shear wall is modelled using shell elements.
- The grade of concrete considered for all columns is C30, for the shear wall it is C25 and C25 for slabs and beams.
- The structure proposed for this project is a high-rise residential building of G+19 floors.

3.2 Building modelling and analysis

For analysis, G+ 19 storeys and plan area is 25m*30m. The storey height of each floor is 3.2m including the ground Floor. There are 5 bays in building in both X and Y direction. C25 & C30 grade concrete and Fe415 structural steel is used. The building is fixed at the base. All the properties of the building are mentioned below:

- Size of Beam in all direction: 450*600 mm
- Size of column: 450*600 mm
- Thickness of shear Wall: 150 mm
- Thickness of slab: 150 mm
- Thickness of external and internal Wall: 225mm
- Partition Wall: 4.5KN/m^2 uniformly applied in slab.
- Floor Finish: 1KN/m
- Importance Factor: 1
- Type of soil**:** medium

Five Models are considered for analysis and are indicated below:

Model 1: Building without shear wall.
Model 2: Building with corner shear wall
Model 3: Building with shear core
Model 4: Building with shear wall each side on middle
Model 5: Building with C shape shear wall

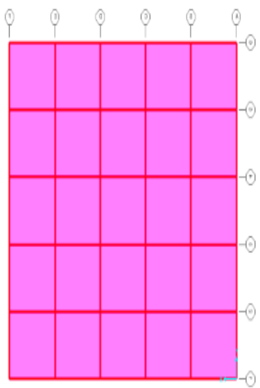
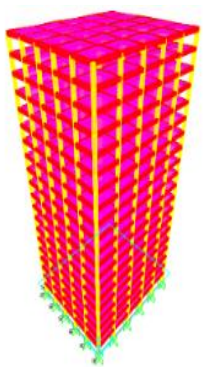
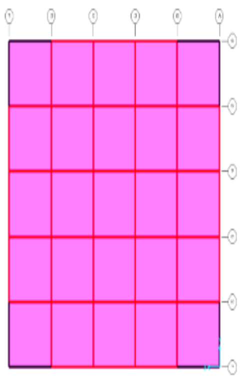
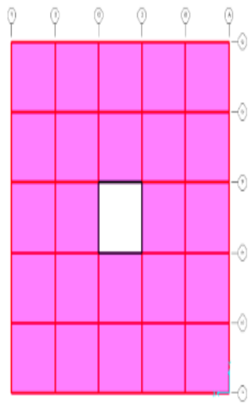





Figure1. Model 1

Figure2. Model 2



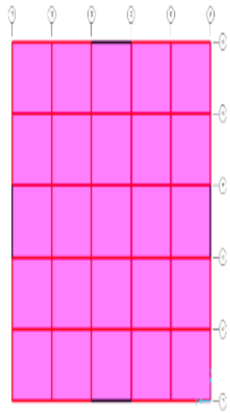


Figure3. Model 3

Figure4. Model 4

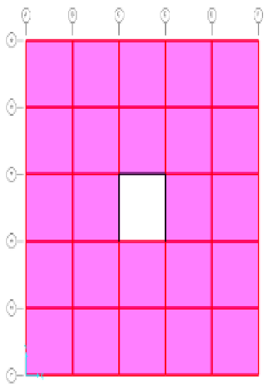


Figure5. Model 5

Two sets of models, one with shear wall and one without shear wall have been analysed. Various positions of the shear wall as shown in Model 2 to 5 have been considered. Analysis of building is performed according to the response Spectrum analysis and wind analysis is in SAB2000. Deflection, Storey Drift, Fundamental period of Vibration Parameters were studied.

Loads

A building is subjected to the following loads during its service life.

1) Dead Load (D.L): The dead loads in a building compromise of the weight of all the walls, partition walls, floors and shall include the weight of all the other permanent constructions in the building.

2) Live Load(L.L): Live loads are also called the superimposed loads and include all the moving or variable loads, due to people or occupants, their furniture, temporary stores, machinery etc. Live loads on floors compromise of all loads other than the dead loads.

3) Earthquake Load (EQ): EQ load acts on the structure during an earthquake. It will act horizontally on the structure. It is also called as a seismic force

The following load combinations are considered as per Eurocodes and the model is analysed for critical load condition

Combination 1: 1.35D.L + 1.5L.L
Combination 2: 0.9.D.L +1.5W.L
Combination 3: 1.35D.L +1.5W.L
Combination 4: 1.35D.L+1.5W.L+1.05L.L
Combination 5: 1.35D.L + 1.5L.L + 0.9W.L
Combination 6: 1.35D.L+0.9W.L
Combination 7: D.L+0.3L.L+EQX+0.3EQY
Combination 8: D.L+0.3L.L+EQX-0.3EQY
Combination 9: 1.35D.L+1.5L.L+1.5EQX
Combination10: 1.35D.L+1.5L.L-1.5EQX
Combination11: 1.35D.L+1.5L.L+1.5EQY
Combination12: 1.35D.L+1.5L.L-1.5EQY
Combination13: 1.35D.L+1.5EQX
Combination 14: 1.35D.L+1.5EQY

For asserting the simplest yet reliable method for analysis, the combined action of DL, LL, EQX &WL forces are considered i.e.1.35D.L+1.5L.L+1.5EQX, 1.35D.L + 1.5W.L + 1.05L.L.

4. RESULTS AND DISCUSSION

4.1 Fundamental Time period

The time period for all the models are shown in figure 6.

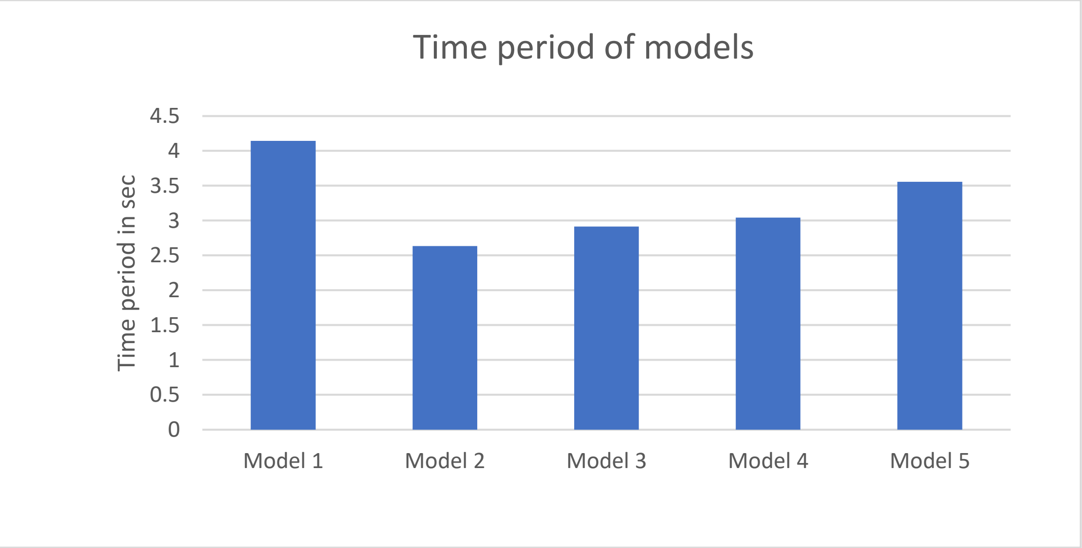


Figure 6. The time period of models

The time period of the structure increases with the increase in mass as shown in Figure 6. Time period decreases when the shear wall is provided and is minimum for shear walls on the outer edges of the structure. Therefore, Model 2 has the least fundamental period of vibration among all the models.

4.2 Lateral Displacement

The magnitude of displacement due to wind load is higher than that of seismic loads. Structures with shear wall have lesser top storey displacement than those without shear wall and displacement is minimum when the shear wall is provided at the edge of the building shown in Figure 3. Also, the presence of shear wall reduces the difference in positive and negative direction loading behaviour of mass asymmetric buildings.

Lateral Displacement of the top storey of different models for various load combinations using Wind and Response Spectrum Analysis is shown in the table below

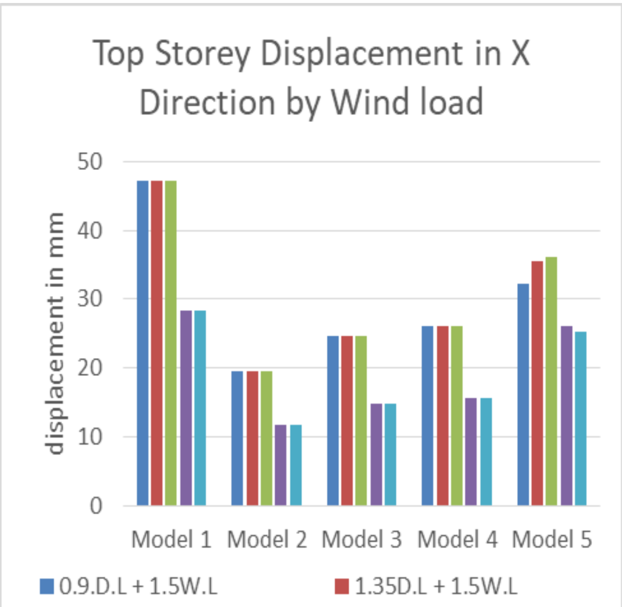
Table 1: Top storey displacement for wind analysis

Load Combination	Top Storey Displacement in X- Direction (mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
0.9.D.L + 1.5W.L	47.28	19.52	24.61	26.00	32.26
1.35D.L + 1.5W.L	47.28	19.52	24.61	26.00	35.57
1.35D.L + 1.5W.L + 1.05L.L	47.28	19.52	24.61	26.00	36.15
1.35D.L + 1.5L.L + 0.9W.L	28.37	11.71	14.76	15.60	26.14
1.35D.L + 0.9W.L	28.37	11.71	14.76	15.60	25.31

Table 2: Top storey displacement for seismic analysis

Load Combination	Top Storey Displacement in X- Direction (mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
D.L+0.3L.L+EQX+0.3EQY	28.41	15.00	27.29	25.53	27.95
D.L+0.3L.L+EQX-0.3EQY	28.41	15.00	27.29	25.53	27.95
1.35D.L+1.5L.L+1.5EQX	41.09	21.41	39.00	36.48	39.94
1.35D.L+1.5L.L-1.5EQX	41.09	21.41	39.00	36.48	39.94
1.35D.L+1.5EQX	37.59	19.92	36.14	33.82	37.00

Comparison of Lateral displacement of the top storey when the building is only subjected to Lateral forces as obtained in Wind and Response Spectrum Analysis is shown in the charts below.



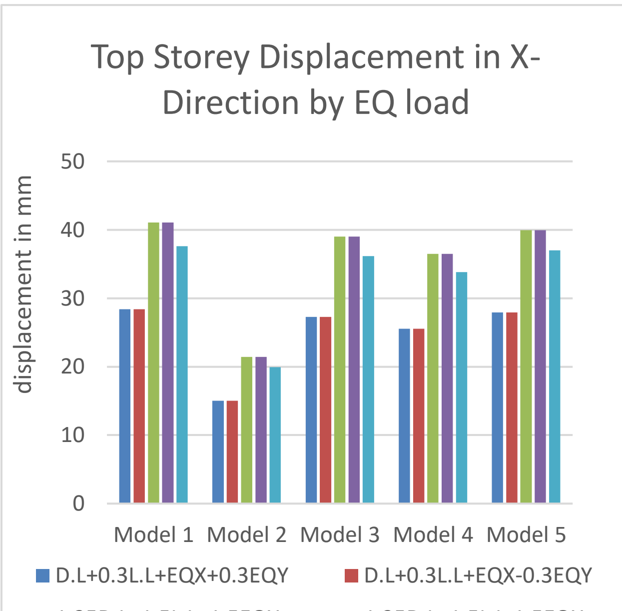


Figure7. Comparison of Lateral displacement of top storey

Lateral displacement is Maximum for Model 1 and Minimum for Model 2 compared to other models in wind static method. Wind static method of analysis gave higher values of lateral displacement in all the building models. Lateral displacement is maximum for Model 1 and minimum for Model 2 compared to other models in the response spectrum method. Wind static method of analysis gave a higher value of lateral displacement in all the building models compared to the response spectrum method of analysis.

4.3 Displacement results by wind and earthquake load

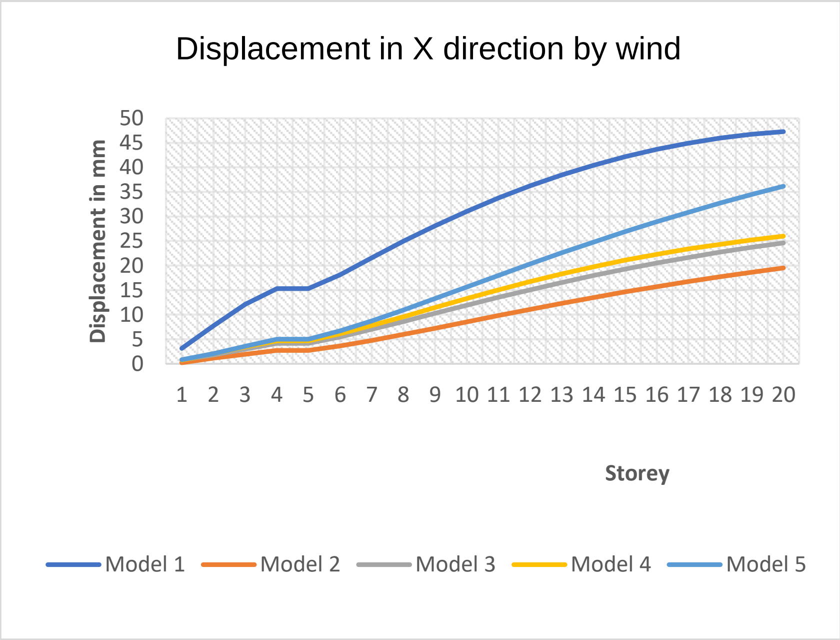


Figure 8. Storey displacement by wind load

When considering the variation of displacement storey to storey, Model 1 indicates significantly higher displacements and Model 2 has the least displacement variation.

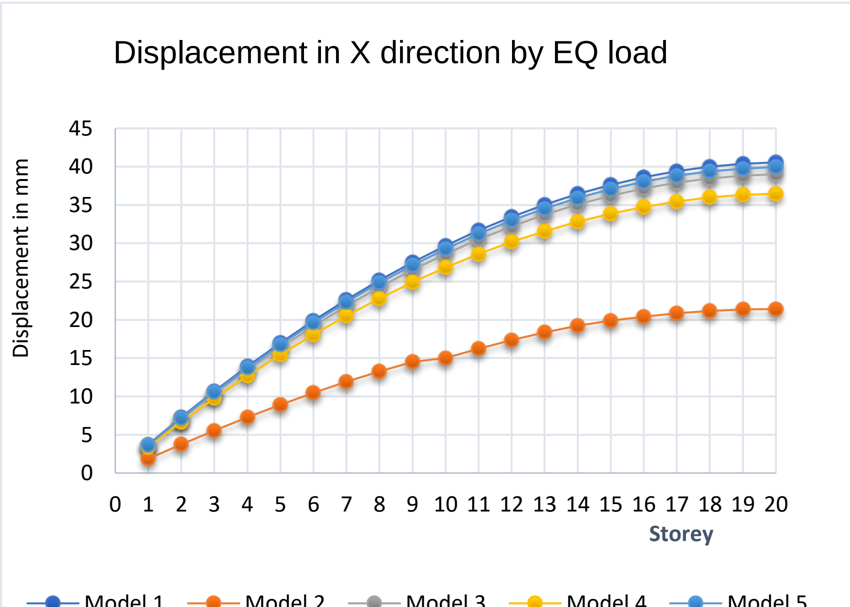


Figure9: Storey displacement by EQ load

The displacement is minimum in model 2 as compared to other models in both cases. The maximum displacement occurred in model 1 which is a frame structure with no shear wall. Model 1 experienced higher displacement in both cases.

4.3 Storey drift

Story drift is the displacement of one level relative to the other level above or below. In the software utilised, the value of story drift is given as a ratio. Story drift ratio is the difference between the displacement of two stories by the height of one storey. The storey drift of all five models in X direction using wind static and response spectrum method is shown in the figure below.

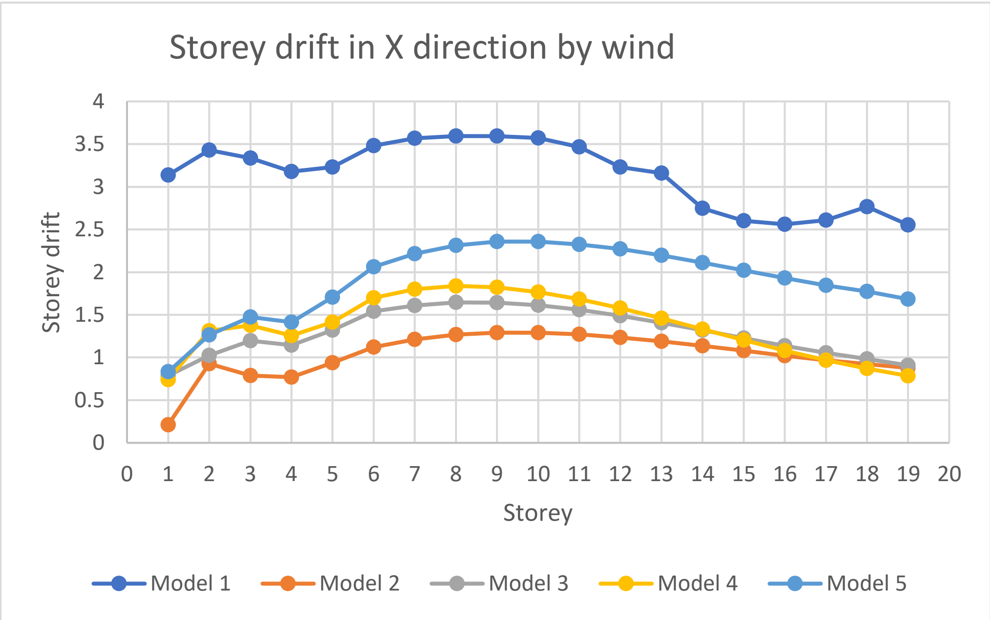


Figure 10: Storey drift in X direction by wind

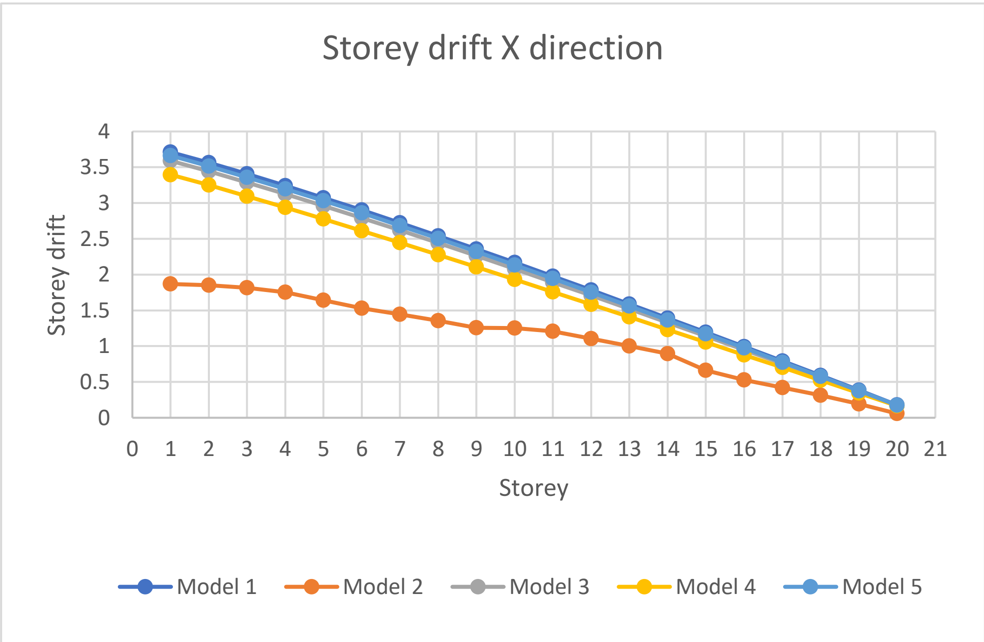


Figure11: Storey drift in X direction by EQ load

The Storey Drift is minimum in Model 2 compared to other models. Maximum Storey Drift occurred in model 1 which is frame structure with no shear wall. Maximum storey drift values obtained for Model 1 in both wind and EQ loads.

.5. CONCLUSION

Carefully evaluating seismic and wind hazard is essential before the construction of high-rise structures. Based on the above analytical study carried out on 5 models, it is evident that buildings with shear walls are efficient compared to conventional frames when subjected to lateral loads, in terms of minimizing earthquake damage in structural and non-structural elements.

The following deductions are made from the obtained results:

- From the above response spectrum and wind load analysis it is observed that the corner type shear wall (Model 2) has least deflection as compared to all other models.
- Substantial differences in lateral displacements are perceived for both wind load and seismic load. However, the worst condition is observed for wind load.
- Fundamental Period of vibration was lower For Model 2 having shear walls along the corner edges and higher time period was observed in Model 1 having no shear wall in the building.
- Storey drift is highly influenced by the presence of the shear wall in the building. Model 2 showed a lower value of storey drift in comparison to other models. The value of storey drift obtained for wind analysis was found to be more than that of the storey drift obtained from Response spectrum analysis.
- Building Model 2 is the safest model considering all conditions
- The frame with shear walls clearly provides more safety to the designers and although it proves to be slightly costly, they are extremely effective in terms of structural stability.

6. REFERENCE

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