Seismic Analysis of a Multi-Storeyed Building with Bottom Rigid Storey along with Intermediate and Top Soft Storey using Floating Columns

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Abstract— The G+20 multi storey irregular building is taken for present study. This building is modeled and analyzed by using ETABS V9.7.4. Assuming the material property as linear and nonlinear. The performance of the building is studied by comparing the base shear, displacement, storey drift in different analysis. Multi-storey buildings with open (soft) ground floor are inherently vulnerable to collapse due to earthquake load, even then their construction is still widespread in the developing nations. An investigation has been performed to study the behavior of the columns at ground level of multi-storey buildings with soft ground floor as satellite bus stop and moment transfer beams in all storey subjected to earthquake loading. The structural action of masonry infill panels of upper floors has also been taken into account by modeling them as diagonal struts. Shear wall is one of the most commonly used lateral load resisting in high rise building. In this study building is modeled with different shapes of shear wall with top and bottom soft storey.

Key words: Soft Storey, Equivalent Diagonal Strut, Floating Columns, Shear Wall

I. INTRODUCTION

Earthquakes are natural hazards under which disasters are mainly caused by damage or collapse of buildings. Objective of seismic analysis is stated as the structure should be able to endure minor shaking intensity without sustaining any damage, thus leaving the structure serviceable after the event. Lateral forces can produce the critical stresses in a structure and in addition cause lateral sway of the structure. Many buildings constructed in recent times have a special feature that the ground stories are left open for the purpose of parking, reception etc. Such buildings are often called open ground storey buildings or buildings on stilts. The strength demand on the column in the first storey for these building is large, upper stories move almost together as a single block and most of the horizontal displacement of the building occurs in the soft ground storey. Reinforced concrete building can adequately resist both horizontal and vertical load. Whenever there is requirement for a multistory building to resist higher value of seismic forces, lateral load resisting system such as shear wall should be introduced in a building. Vertical plate like RC wall introduced in building in addition to beam, column and slab are called shear wall. Shear walls are incorporated in building to resist lateral forces and support the gravity loads. RC shear wall has high in plane stiffness. Positioning of shear wall has influence on the overall behavior of the building. For effective and efficient performance of building it is essential to position shear wall in an ideal location. Many researchers have investigated on changing position of shear wall location to determine parameter like storey shear, time period, storey acceleration and displacement. This analysis is done by using ETABS 2015.

II. DESCRIPTION OF STRUCTURAL MODEL

In the present study 9 different models of 21 storey which is having 6 bays of 10m in x- direction and 15 bays of 10 m in y direction with the plan dimension of 60m X 150m and a storey height of 10m, 2m and 3m of storey 1, storey 11 and 21 and remaining all storey respectively. Following type of structure such as bare frame, both ground and intermediate floor as soft storey are considered, L, Box, swastika and I pattern shear wall are provided at corner of the plan. Providing equivalent diagonal strut of 300 mm width in place of masonry infill panel. The building is considered in zone 5 and medium strength soil. Modulus of elasticity of brick masonry is $3500x10^3 kN/m^2$ density of brick masonry is$20kN/m^3$, grade of concrete(for beams and slabs) is 25 N/mm^2, grade of concrete(for columns and shear walls) is 30 N/mm^2, floor finishes is $1kN/m^2$, imposed loads is 3.5 KN/ m^2, wall load of 12kN/m2 .Slab thickness of 0.150m and thickness of slab of 0.150 .Column size of 1.2mx1.5m , floating column of .3mx.3m in x –direction , beam at first storey of .6mx1.2m and rest of the beams as .4mx.6m. Beam size, From storey 1to storey7= 0.4m x 0.8 m, thickness of slab = 0.23m thickness of concrete wall= 0.23m.

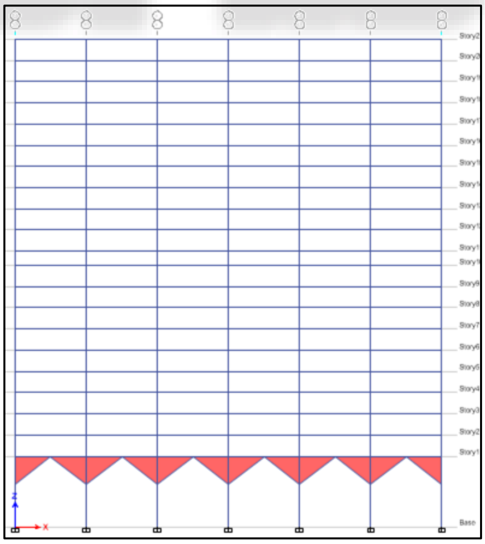


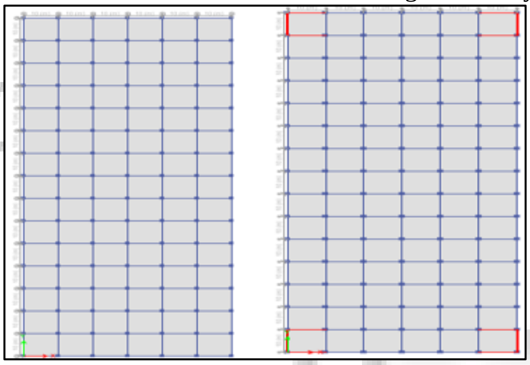
Fig. 1: Structural Model

The above figure shows how beams and columns in the ground storey are connected by the use of a triangular reinforced concrete wall in order to provide extra stability and increase the resistance against seismic forces.

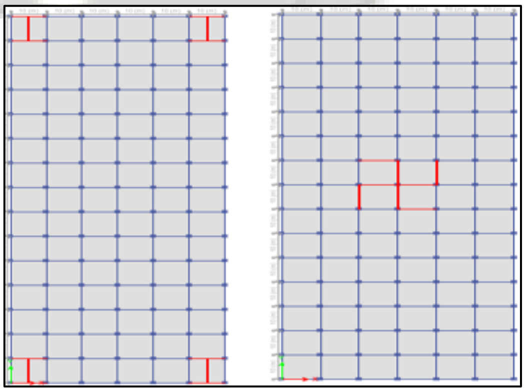
III. MODEL CONSIDERED FOR ANALYSIS

Following 9 models are analyzed by equivalent static method response spectrum method using ETABS software.

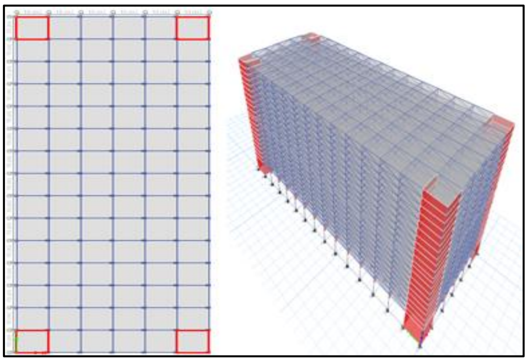
- Model 1: Bare frame model, however masses of brick masonry infill walls (230mm thick) are included in the model.
- Model 2: Building model is same as model 1 with C-type shear wall at corners.
- Model 3: Building model is same as model 1 with H-type shear at the corners.
- Model 4: Building model is same as model 1 with Swastik-type shear wall at corners.
- Model 5: Building model is same as model 1 with BOX-type shear wall at corners.
- Model 6: Building model is same as model 2 with full diagonal strut that replaces brick masonry infill of 230mm thick in all the stories excluding soft storey.
- Model 7: Building model is same as model 3 with full diagonal strut that replaces brick masonry infill of 230mm thick in all the stories excluding soft storey.
- Model 8: Building model is same as model 4 with full diagonal strut that replaces brick masonry infill of 230mm thick in all the stories excluding soft storey.
- Model 9: Building model is same as model 5with full diagonal strut that replaces brick masonry infill of 230mm thick in all the stories excluding soft storey.



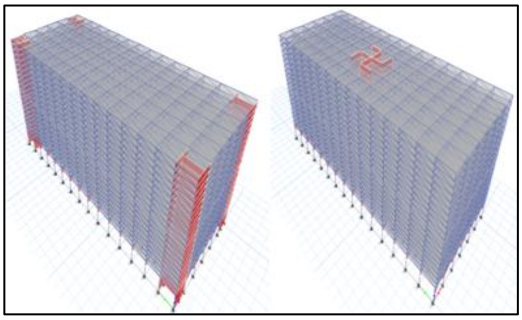
Model1 Model 2



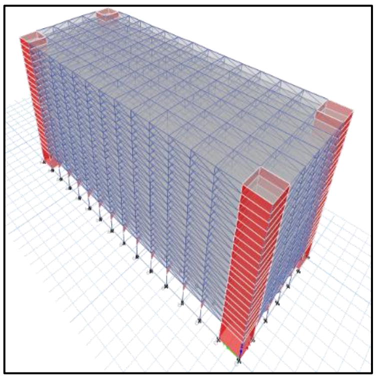
Model 3 Model 4



Model 5 Model 6



Model 7 Model 8



Model 9

Fig. 2: Models

IV. Results and Discussion

A. Time Period

When the ground shakes, the base of a building moves with respect to the ground, and the building swings back and forth. The building will oscillate back-and-forth horizontally and after some time come back to the original position these oscillations are periodic. The time taken (in seconds) for each complete cycle of oscillation (i.e., one complete back-and-forth motion) is the same and is called Fundamental Natural Period T of the building.

Fundamental time period in Sec	
Model No.	Time in Sec
1	4.616
2	2.333
3	2.239
4	3.664
5	2.273
6	1.614
7	1.536
8	1.741
9	1.392

Table 1: Fundamental time period for various models

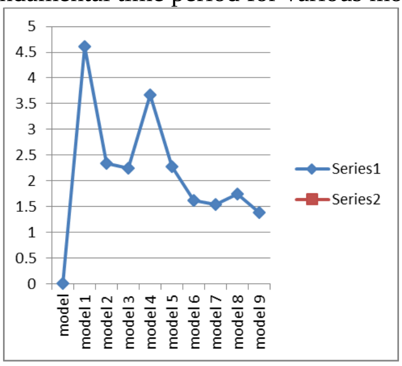


Fig. 3: Chart 1 Time period vs Model No. of all models.

– Note: The results are showing in only X- direction of building, because there is less percentage of variation observed in all results of both direction.

B. Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure

Base Shear (KN)		
Model No.	RSA	THA
1	21116.84	51029.17
2	40022.51	121209
3	39649.06	113377
4	38646.6	101519
5	49293.82	151083
6	55154.2	103523
7	51765.93	94590.74
8	41918.28	107124
9	42981.64	128471

Table 2: Comparison of highest values of seismic base shear between RSA and THA by table and graph above.

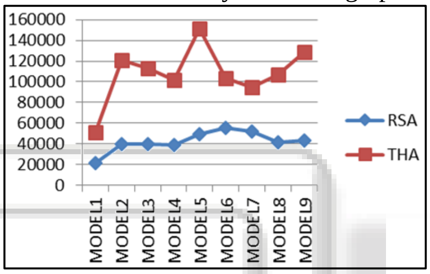


Fig. 4: Graph of different models.

C. Storey Drift

It is nothing but the difference between storey displacements of one storey with respect to the other storey. As per codes its value should not exceed the limit of 0.004 of height of the storey. Its value is usually maximum at mid stories.

Story Drift		
Model No.	RSA	THA
1	0.001918	0.003942
2	0.00097	0.002748
3	0.001	0.002876
4	0.000977	0.002564
5	0.00097	0.002703
6	0.001002	0.002145
7	0.000803	0.002067
8	0.000762	0.001913
9	0.000642	0.001869

Table 3: Comparison of highest values storey drift of all models between ESA and RSA by table and graph.

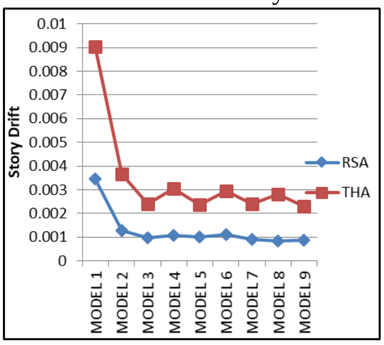


Fig. 5: Drift Vs Models in x-direction

D. Storey Displacement

It is the important factor, when the structure is affected by seismic forces and wind force. It mainly depends on the height of the structure and tall structures are more flexible for lateral loads. Displacement values will be higher at the top storey and less at bottom storey.

Story Displacement(mm)		
Model No.	RSA	THA
1	89.5	139.2
2	50.3	108.1
3	48.2	113.5
4	47.5	115.5
5	50.1	110.9
6	48.3	78
7	40.2	68.1
8	37.6	78.8
9	32.9	92.5

Table 4: Comparison of highest values of storey displacement between RSA and THA by table and graph.

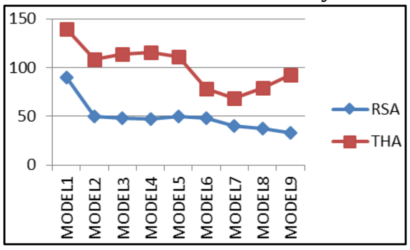


Fig. 6: Chart 4. Displacement vs Models in x- direction

Table 1 shows the time period is obtained by ETABS analysis, Model1 has highest time period. For models with shear walls i.e. model 2, 3, 4 and 5 the value of time period has reduced considerably. For models with only shear wall i.e. 2, 3, 4 and 5, model with Box type shear wall at the corners has found to be least. Now the models with shear wall and equivalent diagonal strut the time period has decreased considerably. Similarly for model with Box type shear wall and equivalent strut, time period is found to be least. When infill panel is modeled as diagonal strut, models are giving good result. This is shown in chart 1. Table 2 shows comparison of seismic base shear between RSA and THA in which time history analysis results shows higher values compare to response spectrum method. Model 7 (Box type shear wall at corner with equivalent diagonal strut) yields the highest base shear value from all models in case of RSA and Model 6 shows highest value of base shear in case of THA. Therefore it has been found that calculation of earthquake forces by considering building by ordinary frame will leads to underestimation of base shear. Table 3 shows the comparison of the highest drift values of all the model by two method of analysis, from that it can be seen that the storey drift in all storey for models (with shear wall) has lower values as compare to that for bare frame model without shear wall. Hence it can be concluded that providing shear wall at the corners in X and Y direction significantly reduces the drifts in the storey. Model 8with Swastik type of shear wall yields considerable lesser drift than other types of shear walls by RSA and Model 9 yields lowest value in case of THA this is shown in chart3. Table 4 shows the comparison of the highest displacement values of all the model by two method of analysis, from that it can be seen that the storey displacement in all storey for models (with shear wall) has lower values as compare to that for model (with without shear wall). Model 8 with Swastik type of shear wall yield considerable lesser displacement by RSA analysis and Model 9 by THA analysis. This is shown in chart 4.

V. CONCLUSIONS

1) Fundamental time period decreases when the effect of masonry infill wall and concrete shear wall is considered.
2) The RC frame model 1(bare frame) having highest value of time period compared to model with shear wall and diagonal strut.
3) As the number of soft stories increases the fundamental time period also increase, therefore existence of soft story can make the structure very much flexible.
4) The time period obtained for model with shear wall (Box type shear wall) has got least value as compared with bare frame model.
5) The storey drifts are found within the limit as specified by the code IS 1893(Part-1):2002.
6) Swastik shaped shear wall shows considerably lesser storey drift in x-direction and y-direction by RSA and I shaped shear wall by THA.
7) Considerable amount of reduction in storey displacement observed by introduction of any type of shear wall.
8) Model with Swastik and I shaped shear wall shows considerably lesser storey displacement in x-direction and y-direction direction respectively.
9) As we add shear wall of I and Swastik at the corners of the building in x direction, the effect of soft ground and top soft story got reduced.
10) The soft story effect is less at intermediate location of the building. A service storey of lesser height can be safer for building at higher level.
11) Providing shear wall at corners in X and Y direction significantly improves all parameters.
12) The soft story effect can be optimized by using the shear walls at corners without effecting the functional aspect of the building.
13) Consideration of stiffness of masonry infill and shear wall greatly influences the overall.
14) The soft story effect is less at intermediate location of the building compared to soft story at the top.
15) Floating columns can be placed wherever required so that partition can be provided and the effect of wind load can be minimised.
16) The seismic analysis of RC frames should be done by considering the infill walls in the analysis. For modeling the infill wall the equivalent diagonal strut method can be effectively used.
17) All models with different type of shear wall and models with shear wall with diagonal strut are giving good results compared bare frame model. So it is recommended to use any type of shear wall depending on the site condition and the convenience of designer.
18) By making the bottom storey rigid as shown in Fig1 it has provided considerable stability and improved its resistance against seismic forces.
19) Providing top soft storey with swimming pool has considerably increased storey displacement.

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