Seismic Analysis of Multi-Storeyed Building with Bottom Rigid Story and Intermediate Service Soft Storey having Floating Columns

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Abstract— Multi-storeyed 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-storeyed buildings with soft ground floor as satellite bus stop and floating columns in the upper stories subjected to earthquake loading. The structural action of masonry infill panels of upper floors has also been taken into account by modelling 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 modelled with different shapes of shear wall with intermediate and bottom soft storey. Static and dynamic analysis is carried out by using ETABS 2015. The comparison of these models for different parameters like Storey shear and storey displacement is carried out.

Key words: Soft Storey, Equivalent Strut Width, Floating Column, 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 Multistorey 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 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 in place of masonry infill panel. The building is considered in zone 5 and medium strength soil. Response reduction factor is 5 Young's modulus of (M30) concrete is27.386x106kN/m² modulus of elasticity of brick masonry is 3500x10³kN/m² density of brick masonry is20kN/m³, grade of concrete (for beams and slabs) is25 N/mm², grade of concrete (for columns and shearwalls) is 30 N/mm², floor finishes is 1kN/m², imposed loads is 3.5 KN/m², slab thickness of 0.150mm Column size of 1.2mx1.5m, floating column size 0.3mx0.3m. beam at fisrt storey of 0.4mx1.2m and rest of the beams as 0.4mx0.8m. Beam size, thickness of concrete wall= 0.23m.

III. Model Considered for Analysis

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

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

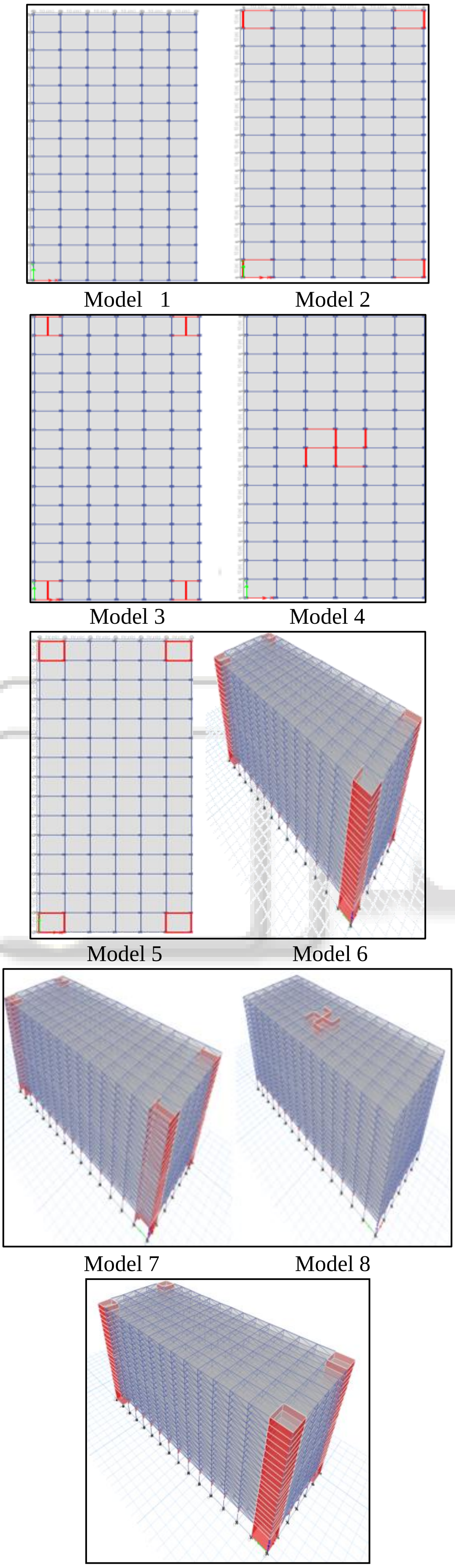

Fig. 1: Models

IV. RESULTS AND DISCUSSION

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

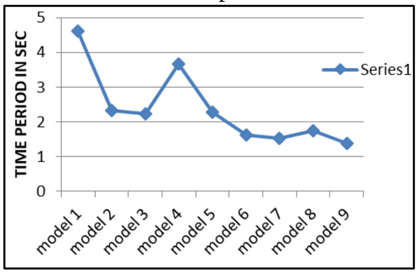

Fig. 2: Chart 1. Time period Vs Model No. of all models.

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.

Base Shear in kN		
Model No.	ESA	RSA
1	16682.8	21116.84
2	31936.1	40022.51
3	31364.1	39649.06
4	35015.3	38686.6
5	37632.2	49293.82
6	47007.4	55154.2
7	46805.5	51765.93
8	49422.7	41918.28
9	48919.5	42981.64

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

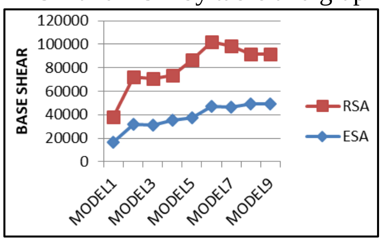

Fig. 3: Graph of different models.

Story Drift		
Model No.	ESA	RSA
1	0.00245	0.001918
2	0.00116	0.00097
3	0.001194	0.001
4	0.001503	0.000977
5	0.001162	0.00097
6	0.001044	0.001002
7	0.000938	0.000803
8	0.00113	0.000762
9	0.000948	0.000642

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

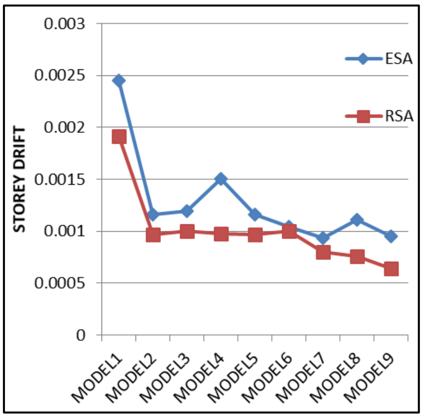

Fig. 4: Drift Vs Models in x-direction

Story Displacement in mm		
Model No.	ESA	RSA
1	101	89.5
2	58.8	50.3
3	60.4	48.2
4	75.1	47.5
5	60.4	50.1
6	53.9	48.3
7	49.1	40.2
8	55.5	37.6
9	49.6	32.9

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

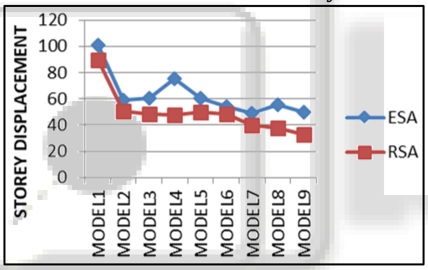

Fig. 5: Chart 4. Displacement vs Models in x- direction

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, 3,4and 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 ESA and RSA in which response spectrum analysis results shows higher values compare to equivalent static method. Model 7 (C type shear wall at corner with equivalent diagonal strut) yields the highest base shear value from all models in case of ESA and RSA along x-direction .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 storeys. Model 7 with Box type of shear wall yields considerable lesser drift than other types of shear walls. 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 7 with I type shear wall yield considerable lesser displacement by ESA analysis and Model by RSA analysis. This is shown in chart 4.

V. Conclusion

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) I shaped shear wall shows considerably lesser storey drift in x-direction and y-direction by ESA and box shaped shear wall by RSA.
7) Considerable amount of reduction in storey displacement observed by introduction of any type of shear wall.
8) Box and I shaped shear wall shows considerably lesser storey displacement in x-direction and y-direction direction respectively.
9) 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.
10) Providing shear wall at corners in X and Y direction significantly improves all parameters.
11) The soft story effect can be optimized by using the shear walls at corners without effecting the functional aspect of the building.
12) Consideration of stiffness of masonry infill and shear wall greatly influences the overall.
13) 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.
14) 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.
15) By using floating columns, we need to increase the depth of beam in shorter span and are quite usefull
16) They are used in places where less obstruction is preferred like auditoriums etc.
17) The load from column acts as point load on beam and column is considered to be hinged on designing.

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