# Seismic Analysis of Multi-Story Building with underneath Satellite Bus Stop Having Service Soft Storey and Moment Transfer Beams

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*Abstract*— Generally RC framed high rise structures are designed without regards to structural action of masonry infill walls present. Masonry infill walls are widely used as partitions. They are considered as non- structural elements. RC frame building with open first storey is known as soft storey, a similar soft storey effect can also appear, at intermediate storey level if a storey used as a service storey. The soft storey located in the lower part of the high rise building especially the first storey is very undesirable as it attracts severely large seismic forces. In satellite bus stops the ground soft story is of double height than the normal buildings and have sufficiently larger spans for movement of buses, so the effect will be more. At the same time, the soft storey located in the upper part of the high rise building does not significantly affect the performance compared to the performance of the fully infill frame.

***Key words:*** Satellite Bus Stop, Multi-Story Building

## I. Introduction

### A. *General*

A large portion of India is susceptible to damaging levels of seismic hazards. Hence, it is necessary to take in to account the seismic load for the design of high-rise structure. The different lateral load resisting systems used in high-rise building are: 1. Bare frame 2. Shear wall frame. In tall building the lateral loads due to earthquake are a matter of concern. These lateral forces can produce critical stresses in the structure, induce undesirable stresses in the structure, induce undesirable vibrations or cause excessive lateral sway of the structure. Today's tall buildings are becoming slenderer and leading to the possibility of more sway in comparison with earlier high-rise buildings.

In satellite bus stops due to slender columns and larger spans columns buckles easily and the effect during shorter earthquake will be severe, so to minimize the whole effect of soft storey at ground, and upper storey level of building different types of shear walls need to use.

## II. Description of Structural Model

In the present study 10 different models of 21 storey having 5 bays of 11m in X-direction and 12 bays of 6m in Y-direction and 2m cantilever beams on all 4 sides of the building. And a storey height of 7m in bottom soft storey, 3m in intermediate soft storey (11$^{th}$ storey) and 3.65m in remaining all storeys.

| Data | Values |
|---|---|
| Zone | V |
| Soil strength | Medium |
| Response reduction factor | 1 |
| E for M25 concrete | 25X10$^6$ KN/m$^2$ |
| E of brick masonry | 3500X10$^6$ KN/m$^2$ |
| Density of brick masonry | 20 KN/m$^3$ |
| **Grade of concrete** | |
| For beams and slabs | M25 |
| For columns and shear walls | M35 |
| **Loads** | |
| Floor finishes | 2 KN/m$^2$ |
| Imposed load | 4 KN/m$^2$ |
| **Slab thickness** | |
| Storey 1 to 5 | 0.150m |
| Storey 6 to 21 | 0.120m |
| **Column size** | |
| Storey 1 to 5 | 0.8mX1.5m |
| Storey 6 to 21 | 0.6mX1.2m |
| **Beam size** | |
| Main beams | 0.3mX0.9m |
| Moment transfer beams | 0.3mX0.45m |
| Edge beams | 0.23mX0.45m |
| Thickness of masonry wall | 0.23m |
| Thickness of concrete wall | 0.20m |

Table 1: Description of structural model.

## III. Models for Analysis

A total of 10 models being analyzed by equivalent static method(ESA), response spectrum method (RSA), and Time history analysis (THA) using ETABS2015.

- Model1: bare frame model with added masses of masonry infill loads.
- Model2: model has complete diagonal struts (which replace brick infill) except ground soft storey.
- Model3: same as model2 but no diagonal struts in intermediate soft storey (11$^{th}$ storey) also.
- Model4: building model is same as model3 Further, L-type shear wall is provided in all 4 corners up to top storey of length equal to one bay.
- Model5: building model is same as model 4 but having shear wall up to intermediate soft storey only.
- Model6: building model is same as model 3 and having swastika-type of shear wall is provided in 4 corners.
- Model7: building model is same as model3 and having U-shape shear walls provided in 4 corners.
- Model8: building model is same as model3 and having C-shape shear walls in 4 corners (as shown in Fig. below).
- Model9: building model is same as model3 and having H-type shear walls in 4 corners.
- Model10: building model is same as model3 and having I-type shear walls in 4 corners.

 

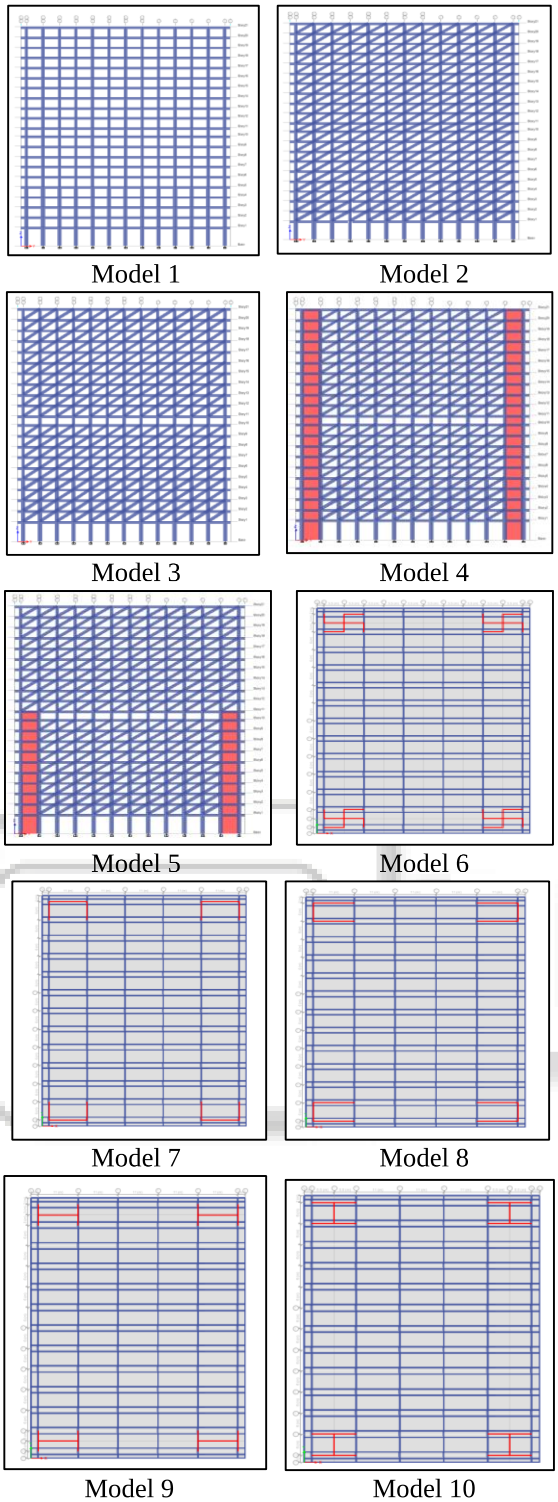


Fig. 1: Models

## IV. RESULTS AND DISCUSSIONS

| Fundamental Time Period | |
|---|---|
| Model | Time in sec |
| 1 | 9.252 |
| 2 | 1.155 |
| 3 | 1.182 |
| 4 | 0.763 |
| 5 | 0.815 |
| 6 | 0.754 |
| 7 | 0.813 |
| 8 | 0.722 |
| 9 | 0.802 |
| 10 | 0.729 |

Table 2: Fundamental Time period for various models.

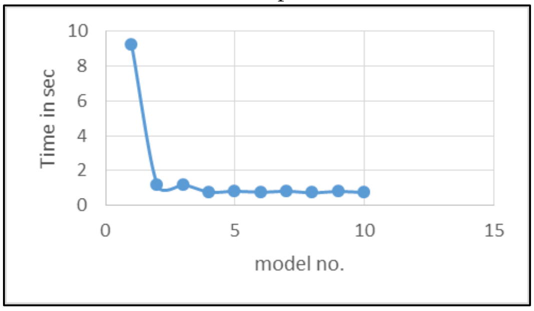


Fig. 2: Time period v/s model no. of all models.

| Model | Base shear in KN | | |
|---|---|---|---|
| | ESA | RSA | THA |
| 1 | 12927.61 | 10661.164 | 13077.741 |
| 2 | 49336.74 | 49072.106 | 221496 |
| 3 | 47825.73 | 46890.863 | 205426.99 |
| 4 | 75083.6 | 63929.878 | 230062.2 |
| 5 | 69865.67 | 63464.002 | 250958.06 |
| 6 | 76948.25 | 69429.127 | 237980.8 |
| 7 | 70794.53 | 64558.748 | 253649.78 |
| 8 | 79932.22 | 72037.182 | 208151.34 |
| 9 | 72268.19 | 65567.798 | 250041.14 |
| 10 | 79312.93 | 71183.924 | 215230.48 |

Table 3: Comparison of highest values of seismic base shear between ESA, RSA and THA in X-directions.

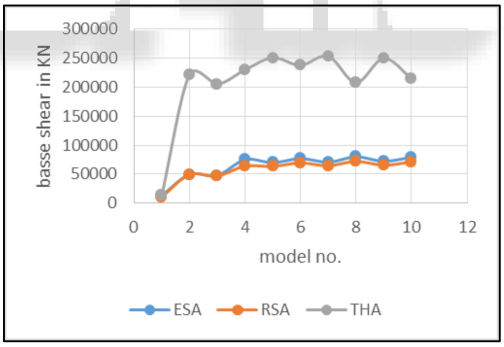


Fig. 3: Base shear v/s model in x-direction.

| Model | Base shear in KN | | |
|---|---|---|---|
| | ESA | RSA | THA |
| 1 | 17794.55 | 16229.32 | 40818.91 |
| 2 | 78739.04 | 77390.08 | 218233 |
| 3 | 76164.92 | 73342.99 | 230269.2 |
| 4 | 92652.83 | 87741.38 | 203520.4 |
| 5 | 88589.64 | 85258.49 | 213375.4 |
| 6 | 94947.46 | 90913.47 | 205984 |
| 7 | 97679.06 | 91085.11 | 215252.9 |
| 8 | 91235.33 | 88733.93 | 220831.9 |
| 9 | 97056.18 | 90668.04 | 210323.9 |
| 10 | 89259.72 | 87541.63 | 216419.9 |

 

Table 4: Comparison of highest values of seismic base shear between ESA, RSA and THA in Y-directions.

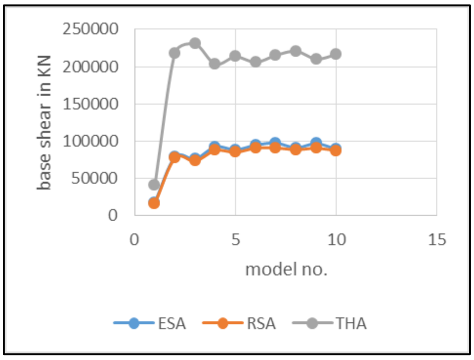


Fig. 4: Base shear v/s model in Y-direction.

| model | Maximum drift in m | | |
|---|---|---|---|
| | ESA | RSA | THA |
| 1 | 0.009081 | 0.008194 | 0.008067 |
| 2 | 0.001626 | 0.00168 | 0.007264 |
| 3 | 0.001577 | 0.001629 | 0.006819 |
| 4 | 0.000992 | 0.000839 | 0.00306 |
| 5 | 0.000934 | 0.000785 | 0.00301 |
| 6 | 0.000935 | 0.000935 | 0.002704 |
| 7 | 0.000929 | 0.000791 | 0.003038 |
| 8 | 0.000881 | 0.000723 | 0.001869 |
| 9 | 0.000905 | 0.000773 | 0.003033 |
| 10 | 0.000885 | 0.000727 | 0.002003 |

Table 5: Comparison of highest value of drift between ESA, RSA and THA. In X-direction.

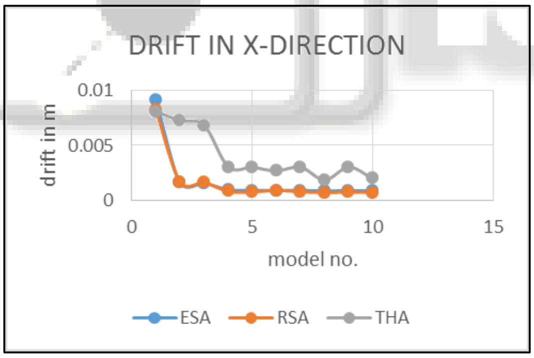


Fig. 5: drift v/s model in X-direction.

| model | Maximum drift in m | | |
|---|---|---|---|
| | ESA | RSA | THA |
| 1 | 0.001171 | 0.001008 | 0.002644 |
| 2 | 0.000926 | 0.000959 | 0.002559 |
| 3 | 0.000895 | 0.000926 | 0.002867 |
| 4 | 0.000693 | 0.000678 | 0.0018 |
| 5 | 0.000737 | 0.000727 | 0.001607 |
| 6 | 0.000704 | 0.000704 | 0.001536 |
| 7 | 0.000637 | 0.000622 | 0.00133 |
| 8 | 0.000756 | 0.000741 | 0.001724 |
| 9 | 0.000642 | 0.000627 | 0.00134 |
| 10 | 0.000785 | 0.000766 | 0.001645 |

Table 6: Comparison of highest value of drift between ESA, RSA and THA. In Y-direction.

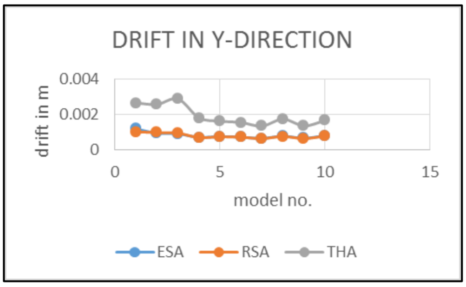


Fig. 6: Drift v/s model in Y-direction.

| model | Maximum Displacement in mm | | |
|---|---|---|---|
| | ESA | RSA | THA |
| 1 | 504.897 | 422.607 | 335.783 |
| 2 | 22.705 | 19.529 | 87.105 |
| 3 | 24.006 | 20.529 | 91.421 |
| 4 | 20.463 | 18.752 | 63.324 |
| 5 | 20.095 | 16.666 | 61.227 |
| 6 | 18.953 | 15.999 | 51.957 |
| 7 | 19.599 | 16.323 | 59.753 |
| 8 | 18.413 | 15.562 | 38.488 |
| 9 | 19.486 | 16.328 | 58.864 |
| 10 | 18.729 | 15.889 | 41.654 |

Table 7: Comparison of highest displacement value between ESA, RSA and THA. In X-direction

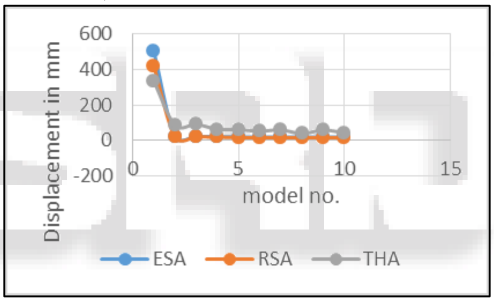


Fig. 7: Displacement v/s model in X-direction.

| model | Maximum Displacement in mm | | |
|---|---|---|---|
| | ESA | RSA | THA |
| 1 | 66.654 | 52.468 | 134.641 |
| 2 | 16.342 | 12.688 | 37.403 |
| 3 | 17.036 | 13.253 | 44.374 |
| 4 | 14.587 | 12.333 | 21 |
| 5 | 15.152 | 12.611 | 24.399 |
| 6 | 14.074 | 11.749 | 23.757 |
| 7 | 14.205 | 11.97 | 27.663 |
| 8 | 14.332 | 11.91 | 24.935 |
| 9 | 14.407 | 12.143 | 24.723 |
| 10 | 14.473 | 12.062 | 23.034 |

Table 8: Comparison of highest displacement value between ESA, RSA and THA. In Y-direction

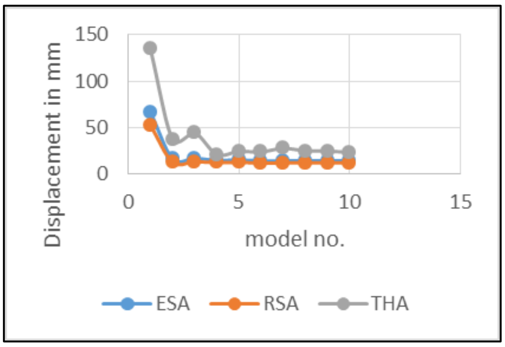


Fig. 8: Displacement v/s model in Y-direction.

| model | Maximum ACCELERATION | | | |
|---|---|---|---|---|
| | RSA | | THA | |
| | X | Y | X | Y |
| 1 | 350.27 | 463.28 | 823.61 | 1082.07 |
| 2 | 650.55 | 1099.96 | 3150.56 | 3162.36 |
| 3 | 658.88 | 1098.62 | 3134.25 | 3816.47 |
| 4 | 1511.27 | 1390.98 | 5219.53 | 3603.41 |
| 5 | 1094.08 | 1297.88 | 4190.48 | 2673.36 |
| 6 | 1216.08 | 1324.13 | 3995.66 | 3203.14 |
| 7 | 1066.46 | 1454.48 | 4260.99 | 3381.44 |
| 8 | 1278.71 | 1255.54 | 3010.11 | 2760.36 |
| 9 | 1100.7 | 1441.16 | 4372.25 | 3365.76 |
| 10 | 1286.5 | 1213.74 | 3242.53 | 2762.36 |

Table 9: Comparison of highest acceleration value between ESA, RSA and THA. In both X and Y-direction.

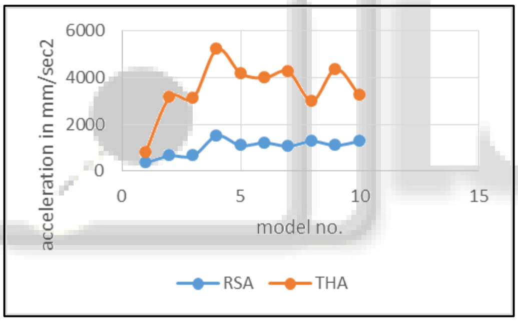


Fig. 9: Acceleration v/s model in X-direction.

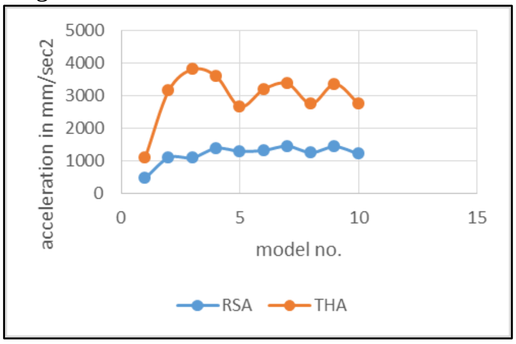


Fig. 10: Acceleration v/s model in Y-direction.

Table 2 shows fundamental time period of all 10 models obtained by the ETAB analysis. Time period is reduced for model 2 about 8 times the model 1. This can be avoided by adding masonry infill and shear walls in the models. As we compare model 3 is increased by 2.33% than that of model 2. For models with shear walls i.e., model 4 to 10 times period is reduced by 35.44%, 31.05%, 36.21%, 31.22%, 38.92%, 32.15%, 38.32% respectively as compared with model3.

Table 3 and 4 shows the comparison of seismic base shear values between ESA, RSA and THA. In ESA and RSA model 8(with C-type shear wall) shows highest base shear in X-direction, and in THA model 7(with U-type shear wall) giving highest base shear. And in Y-direction model 7 has highest base shear in ESA and RSA. As we compare to all 3 methods THA giving higher values, so by the values comparing to model 1 we can say for design purpose considering only bare frame model will lead to underestimation of base shear values.

Table 5 and 6 shows the maximum drift values for all models in X and Y direction.in which model 8 is showing less drift compare to all models in X-direction in all 3 methods and in Y-direction model 7 showing less drift in all 3 methods of analysis.

Table 7 and 8 shows maximum joint displacement in X and Y direction in all 3 methods. In which model 1 is showing highest displacement in X direction because of slender columns this effect can be reduced by providing shear walls in X-direction. The masonry infill also giving good results comparing to bare frame. By comparing all the models in model 8 there is less displacement in X-direction by all three methods of analysis. And in Y direction model 6 giving less displacement by all 3 methods. So by comparing the results all the models giving very much nearer values so providing any type of shear wall will be manageable in our convenience.

Table 9 shows maximum acceleration in X and Y direction by RSA and THA for all models. By comparing the values model 4 has maximum acceleration in x-direction in both the methods. And in y-direction model 7 by RSA and model 4 by THA has highest storey acceleration.

## V. Conclusions

1) The bare frame model has highest time period comparing to all models.
2) When the model added with infill and shear walls the time period decreased very much. So for design purpose we should consider the infill and shear walls.
3) By comparing model 2 and 3 the time period increased because of intermediate soft story, we can make the structure more flexible by adding soft storeys.
4) Model 8 is giving least value of time period by comparing all models.
5) The storey drifts are within the limits compare as specified by IS 1893(part-I):2002.
6) Base shear is increased 4 times by adding infills and 6 times by adding shear walls as compared with bare frame model.
7) By adding any type of shear wall the displacement is controlled very much.
8) By providing shear walls in our convenience we can eliminate the soft storey effect.
9) THA giving highest value of all parameters compare to other analysis.
10) By providing shear walls in corners significantly improves all parameters.
11) The aim of providing moment transfer beam is to eliminate the floating columns. Because cumulative loads on floating column increase the first beam size enormously.

12) In satellite bus stops we can extend the columns in Y-direction only because the movement of buses is in parallel to Y-direction, the clear width will be decreased.
13) The main beams are actually in x- direction so the clear height will be decreased, so we are making the main beams in shorter span and secondary beams in larger span so the beam height will be decreased.
14) By using moment transfer beams we can decrease the column height.
15) Moment is transferred from X-axis to Y-axis.

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