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# Seismic Evaluation of R.C. Framed High Rise Structural System with the Effect of Ground and Intermediate Soft Storey

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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. 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. To study the effect of masonry infill and different soft storey level, 12 Models of R C framed building were analyzed with two types of shear walls when subjected to earthquake loading. The results of bare frame and other building models have been compared. It is observed that, models with Swastika and L shape shear wall with central core wall are showing efficient performance and hence reducing the effect of soft storey.**

## 1. INTRODUCTION

**T**all buildings are the most complex built structures since there are many conflicting requirements and complex building systems to integrate. Today's tall buildings are becoming more and more slender, leading to the possibility of more sway in comparison with earlier high-rise buildings. Thus the impact of wind and seismic forces acting on them becomes an important aspect of the design. Improving the structural systems of tall buildings can control their dynamic response

In the present practice of structural design in India, masonry infill panels are treated as non- structural element and their strength and stiffness contribution are neglected. In fact the presence of infill wall changes the behavior of the frame action in to truss action, thus changing the lateral load transfer mechanism. Performance of buildings in the past earthquakes clearly illustrates that the presence of infill walls has significant structural implications. Therefore, we cannot simply neglect the structural contribution of infill walls particularly in seismic regions where, the frame–infill interaction may cause significant increase in both stiffness and strength of the frame in spite of the presence of openings.

Reinforced concrete (RC) structural walls, conventionally known as shear walls are effective in resisting lateral loads imposed by wind or earthquakes. They provide substantial strength and stiffness as well as the deformation capacity (capacity to dissipate energy) needed for tall structures to meet seismic demand. It has become increasingly common to combine the moment resisting framed structure for resisting gravity loads and the RC shear walls for resisting lateral loads in tall building structures. The consequence of the presence of a soft storey either in the ground storey or in the upper storey, may lead to a dangerous sway mechanism in the soft storey due to formation of plastic hinges at the top and bottom end of the columns, as these columns are subjected to relatively large cyclic deformations.

The main Objectives of the present study is

1. To know the effect of infills in the frame.
2. To know the effect of ground and intermediate soft storey.
3. How different types of shear walls reduces the effect of soft storey and how it can enhance the seismic performance of tall R.C buildings.

## 2. DESCRIPTION OF STRUCTURAL MODEL

For the study 12 different models of twenty one (21) storey building are considered the building has seven bays in X direction and five bays in Y direction with the plan dimension 28 m × 20 m and a storey height of 3.5 m each in all the floors except 11$^{th}$ storey, height of 11$^{th}$ storey is 2m. The building is kept symmetric in both orthogonal directions in plan to avoid torsional response. The orientation and size of column is kept same throughout the height of the structure. The building is considered to be located in seismic zone V. The building is founded on medium strength soil through isolated footing under the columns. Elastic moduli of concrete and masonry are taken as 27386 MPa and 3500 MPa respectively and their poisons ratio as 0.20 and 0.15 respectively Response reduction factor for the special moment resisting frame has taken as 5.0 (assuming ductile detailing). The unit weights of concrete and masonry are taken as 25.0 KN/m$^3$ and 20.0 KN/m$^3$ respectively the floor finish on the floors is 1.5 KN/m$^2$. The live load on floor is taken as 3.5 KN/m$^2$. In seismic weight calculations, 50 % of the floor live loads are considered. Thickness of slab, shear wall and masonry infill wall as 0.120m, 0.25 m and 0.23m respectively.

## 3. MODEL CONSIDERED FOR ANALYSIS

Following twelve (12) models are analyzed as special moment resisting frame using equivalent static analysis, response spectrum analysis and Pushover analysis.

**Model 1**: Building modeled as bare frame. However, masses of the walls are included.
**Model 2**: Building has full brick masonry infill of 230mm thick in all the stories including ground storey and intermediate storey.
**Model 3**: Building has no brick masonry in fill in ground storey and has full brick masonry infill of 230mm thick in upper stories.
**Model 4**: Building has no brick masonry infill in intermediate storey (11th storey) and has full brick masonry infill in rest of the storeys.
**Model 5**: Building has no brick masonry infill in ground storey, intermediate storey (11th storey) and has full brick masonry infill in rest of all storeys.
**Model 6**: Building has no brick masonry infill in ground and intermediate storey. Further, shear of swastika shape (250mm thick) is provided at corners.
**Model 7**: Building model is same as in model 6 and a concrete core (250mm thick) is provided at the centre.
**Model 8**: Buidling model is same as in model 7, but the position of corner swastika shear wall has been changed.
**Model 9**: Building model is same as in model 7.further, an opening in core wall at each storey is provided.
**Model 10**: Building model is same as model 5.further, L shaped shear wall (250mm thick) is provided in both x and y direction.
**Model 11**: Building model is same as model 10 and a core wall (250mm thick) is provided at the centre.
**Model 12**: Building model is same as model 11. Further, an opening in core wall at each storey is provided.

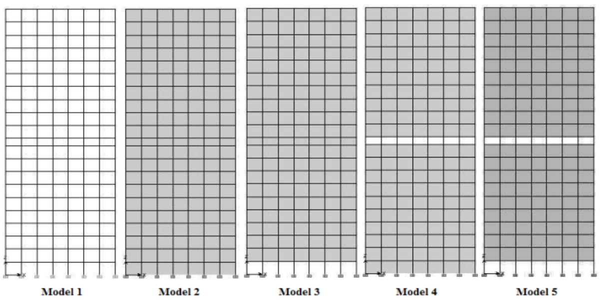


Fig 1 Elevation of different building models

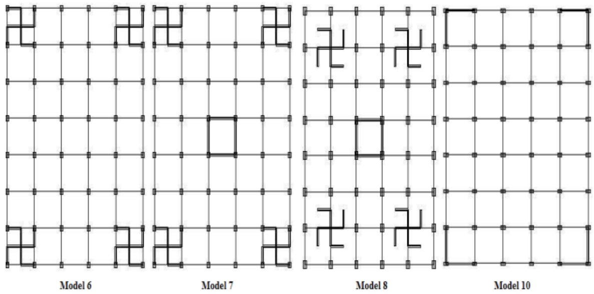


Fig 2 Plan of different building models

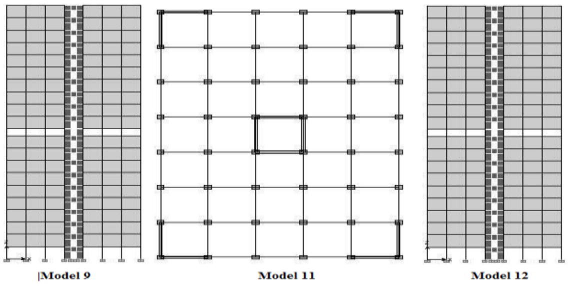


Fig 3 Plan and elevation of different building models

## 4. MODELING OF FRAME MEMBERS, MASONRY INFILL AND SHEAR WALL

The frame elements are modelled as beam elements. The masonry infill is modelled as quadrilateral shell element (with in-plane stiffness) of uniform thickness of 0.23mm. The slab is modelled as rigid (in-plane) diaphragm. The shear walls are modelled with Mid-Pier frame.

## 5. FUNDAMENTAL TIME PERIOD

Table 1 Comparison of time period between IS code method and using ETABS and SAP2000 software for various models.

| Fundamental time period(Sec) | | | | | | |
|---|---|---|---|---|---|---|
| | Is Code 1893-2002 | | Etabs Analysis | | Sap2000 Analysis | |
| Model No | Long | Tran | Long | Tran | Long | Tran |
| 1 | 1.85 | 1.85 | 2.72 | 2.72 | 2.77 | 2.77 |
| 2 | 1.23 | 1.45 | 1.15 | 1.15 | 1.12 | 1.12 |
| 3 | 1.23 | 1.45 | 1.30 | 1.30 | 1.33 | 1.33 |
| 4 | 1.23 | 1.45 | 1.17 | 1.17 | 1.21 | 1.21 |
| 5 | 1.23 | 1.45 | 1.31 | 1.31 | 1.33 | 1.33 |
| 6 | 1.23 | 1.45 | 0.99 | 0.99 | 1.04 | 1.04 |
| 7 | 1.23 | 1.45 | 0.97 | 0.97 | 1.02 | 1.02 |
| 8 | 1.23 | 1.45 | 1.03 | 1.03 | 1.07 | 1.07 |
| 9 | 1.23 | 1.45 | 0.97 | 0.97 | 1.01 | 1.01 |
| 10 | 1.23 | 1.45 | 1.04 | 1.04 | 1.07 | 1.07 |
| 11 | 1.23 | 1.45 | 1.00 | 1.00 | 1.04 | 1.04 |
| 12 | 1.23 | 1.45 | 1.00 | 1.00 | 1.04 | 1.04 |

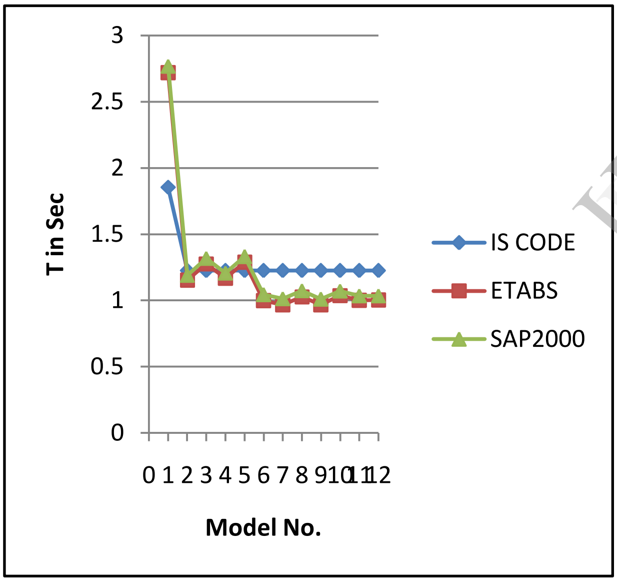


Figure 4 Model Vs Time period for different building models along longitudinal direction

## 6. COMPARISON OF BASE SHEAR

Table 2 Comparison of Base shear with IS code, Equivalent static analysis and response spectrum analysis for various building models.

| Model No | Base Shear (KN) | | | | | |
|---|---|---|---|---|---|---|
| | Is Code 1893-2002 | | Linear Static Analysis (Etabs) | | Response Spectrum Analysis (Etabs) | |
| | Long | Tran | Long | Tran | Long | Tran |
| 1 | 9695.1 | 9695.1 | 11585.2 | 11585.2 | 10345.5 | 8605.9 |
| 2 | 14689.5 | 12412.7 | 28111.8 | 28111.8 | 23754.1 | 20247.6 |
| 3 | 14558.3 | 12301.7 | 27820.9 | 27820.9 | 23415.7 | 19849.5 |
| 4 | 14562.8 | 12305.5 | 27779.4 | 27779.4 | 23199.5 | 19819.9 |
| 5 | 14431.5 | 12194.6 | 27488.5 | 27488.5 | 22977.5 | 19536.5 |
| 6 | 15358.7 | 12978.1 | 29103.3 | 29103.3 | 27953.8 | 23498.6 |
| 7 | 15400.8 | 13013.7 | 28903.6 | 28903.6 | 28371.0 | 23908.3 |
| 8 | 14368.2 | 12141.1 | 28545.5 | 28545.5 | 27102.1 | 22445.6 |
| 9 | 15362.2 | 12981 | 28833.6 | 28833.6 | 28274.6 | 23860.6 |
| 10 | 14515.7 | 12265.8 | 27565.3 | 27565.3 | 25957.0 | 21987.2 |
| 11 | 14557.8 | 12301.4 | 27329.8 | 27329.8 | 26301.3 | 22107.6 |
| 12 | 14631.7 | 12363.8 | 27295.7 | 27295.7 | 26213.6 | 22057.6 |

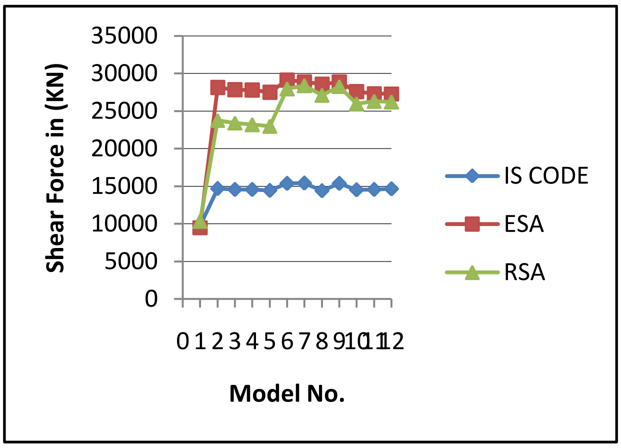


Figure 5 Comparison of base shear with IS code method, ESA and RSA for various building model

## 7. STOREY DRIFT

Table 3 Storey Drifts for various building models along Longitudinal direction

| | Storey Drift(mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | Model 9 | Model 10 | Model 11 | Model 12 |
| **Storey** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** |
| 21 | 0.499 | 0.550 | 0.551 | 0.549 | 0.552 | 0.349 | 0.342 | 0.402 | 0.347 | 0.391 | 0.385 | 0.395 |
| 20 | 0.674 | 0.586 | 0.586 | 0.585 | 0.587 | 0.374 | 0.364 | 0.425 | 0.372 | 0.419 | 0.409 | 0.420 |
| 19 | 0.862 | 0.628 | 0.621 | 0.622 | 0.621 | 0.402 | 0.390 | 0.450 | 0.398 | 0.449 | 0.436 | 0.446 |
| 18 | 1.029 | 0.654 | 0.652 | 0.653 | 0.650 | 0.432 | 0.415 | 0.476 | 0.424 | 0.476 | 0.461 | 0.471 |
| 17 | 1.167 | 0.682 | 0.678 | 0.681 | 0.678 | 0.459 | 0.440 | 0.500 | 0.447 | 0.502 | 0.484 | 0.493 |
| 16 | 1.282 | 0.704 | 0.700 | 0.704 | 0.699 | 0.484 | 0.462 | 0.520 | 0.469 | 0.524 | 0.503 | 0.512 |
| 15 | 1.373 | 0.721 | 0.716 | 0.720 | 0.716 | 0.504 | 0.481 | 0.538 | 0.487 | 0.542 | 0.520 | 0.527 |
| 14 | 1.446 | 0.732 | 0.728 | 0.732 | 0.728 | 0.524 | 0.499 | 0.553 | 0.504 | 0.558 | 0.535 | 0.541 |
| 13 | 1.490 | 0.738 | 0.734 | 0.736 | 0.732 | 0.542 | 0.514 | 0.564 | 0.514 | 0.571 | 0.546 | 0.546 |
| 12 | 1.464 | 0.743 | 0.737 | 0.778 | 0.771 | 0.570 | 0.537 | 0.586 | 0.542 | 0.599 | 0.568 | 0.574 |
| 11 | 1.304 | 0.712 | 0.708 | 1.065 | 1.047 | 0.672 | 0.616 | 0.662 | 0.629 | 0.738 | 0.667 | 0.687 |
| 10 | 1.554 | 0.737 | 0.731 | 0.763 | 0.758 | 0.577 | 0.542 | 0.585 | 0.544 | 0.602 | 0.567 | 0.569 |
| 9 | 1.683 | 0.721 | 0.717 | 0.711 | 0.707 | 0.556 | 0.524 | 0.562 | 0.525 | 0.573 | 0.544 | 0.545 |
| 8 | 1.744 | 0.705 | 0.700 | 0.695 | 0.691 | 0.548 | 0.515 | 0.549 | 0.516 | 0.562 | 0.532 | 0.533 |
| 7 | 1.788 | 0.684 | 0.680 | 0.672 | 0.669 | 0.538 | 0.503 | 0.535 | 0.504 | 0.549 | 0.517 | 0.518 |
| 6 | 1.827 | 0.656 | 0.654 | 0.646 | 0.644 | 0.522 | 0.487 | 0.515 | 0.489 | 0.530 | 0.498 | 0.500 |
| 5 | 1.862 | 0.624 | 0.624 | 0.615 | 0.614 | 0.502 | 0.466 | 0.489 | 0.469 | 0.509 | 0.475 | 0.477 |
| 4 | 1.884 | 0.585 | 0.589 | 0.577 | 0.580 | 0.474 | 0.438 | 0.458 | 0.440 | 0.482 | 0.446 | 0.449 |
| 3 | 1.864 | 0.540 | 0.542 | 0.532 | 0.534 | 0.434 | 0.398 | 0.416 | 0.401 | 0.444 | 0.408 | 0.412 |
| 2 | 1.693 | 0.491 | 0.582 | 0.488 | 0.574 | 0.390 | 0.350 | 0.372 | 0.356 | 0.416 | 0.368 | 0.399 |
| 1 | 0.950 | 0.376 | 1.196 | 0.371 | 1.181 | 0.357 | 0.298 | 0.315 | 0.307 | 0.479 | 0.370 | 0.389 |



## 8. STOREY DISPLACEMENT

Table 4 Storey Displacement for various building models along longitudinal direction

| | Storey Displacement (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | Model 9 | Model 10 | Model 11 | Model 12 |
| **Storey** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** | **Ux** |
| 21 | 93.23 | 45.55 | 48.28 | 46.13 | 48.75 | 34.05 | 32.05 | 35.1 | 32.18 | 36.49 | 34.34 | 34.56 |
| 20 | 91.67 | 43.65 | 46.38 | 44.23 | 46.85 | 32.86 | 30.88 | 33.71 | 31.01 | 35.14 | 33.00 | 33.23 |
| 19 | 89.67 | 41.63 | 44.37 | 42.22 | 44.85 | 31.58 | 29.63 | 32.25 | 29.77 | 33.70 | 31.59 | 31.82 |
| 18 | 87.12 | 39.50 | 42.25 | 40.09 | 42.73 | 30.21 | 28.3 | 30.71 | 28.44 | 32.16 | 30.10 | 30.32 |
| 17 | 84.27 | 37.30 | 40.04 | 37.86 | 40.53 | 28.75 | 26.89 | 29.08 | 27.03 | 30.54 | 28.52 | 28.74 |
| 16 | 80.93 | 34.97 | 37.75 | 35.55 | 38.24 | 27.2 | 25.39 | 27.38 | 25.54 | 28.83 | 26.87 | 27.08 |
| 15 | 77.23 | 32.57 | 35.39 | 33.17 | 35.88 | 25.57 | 23.83 | 25.6 | 23.97 | 27.05 | 25.15 | 25.36 |
| 14 | 73.19 | 30.12 | 32.98 | 30.72 | 33.48 | 23.86 | 22.19 | 23.77 | 22.33 | 25.20 | 23.37 | 23.58 |
| 13 | 68.86 | 27.63 | 30.53 | 28.24 | 31.03 | 22.08 | 20.49 | 21.89 | 20.63 | 23.30 | 21.55 | 21.75 |
| 12 | 64.32 | 25.12 | 28.06 | 25.74 | 28.56 | 20.24 | 18.74 | 19.96 | 18.88 | 21.35 | 19.68 | 19.88 |
| 11 | 59.77 | 22.59 | 25.57 | 23.09 | 25.96 | 18.29 | 16.9 | 17.95 | 17.02 | 19.30 | 17.73 | 17.91 |
| 10 | 57.40 | 21.20 | 24.20 | 21.01 | 23.94 | 16.98 | 15.69 | 16.65 | 15.79 | 17.86 | 16.42 | 16.56 |
| 9 | 52.38 | 18.68 | 21.72 | 18.4 | 21.38 | 15.00 | 13.83 | 14.64 | 13.92 | 15.80 | 14.47 | 14.61 |
| 8 | 46.8 | 16.20 | 19.28 | 15.96 | 18.99 | 13.08 | 12.02 | 12.7 | 12.12 | 13.83 | 12.59 | 12.73 |
| 7 | 41.05 | 13.77 | 16.89 | 13.57 | 16.63 | 11.19 | 10.24 | 10.79 | 10.33 | 11.88 | 10.75 | 10.89 |
| 6 | 35.00 | 11.41 | 14.56 | 11.24 | 14.34 | 9.34 | 8.50 | 8.94 | 8.57 | 9.987 | 8.963 | 9.08 |
| 5 | 28.75 | 9.14 | 12.31 | 9.00 | 12.13 | 7.52 | 6.81 | 7.15 | 6.88 | 8.143 | 7.23 | 7.35 |
| 4 | 22.32 | 6.96 | 10.15 | 6.87 | 10.01 | 5.77 | 5.18 | 5.45 | 5.26 | 6.37 | 5.57 | 5.69 |
| 3 | 15.76 | 4.92 | 8.11 | 4.86 | 8.002 | 4.13 | 3.66 | 3.85 | 3.73 | 4.69 | 4.01 | 4.12 |
| 2 | 9.25 | 3.03 | 6.22 | 2.99 | 6.142 | 2.6 | 2.271 | 2.40 | 2.33 | 3.15 | 2.59 | 2.68 |
| 1 | 3.33 | 1.31 | 4.18 | 1.3 | 4.137 | 1.25 | 1.046 | 1.10 | 1.08 | 1.68 | 1.30 | 1.36 |

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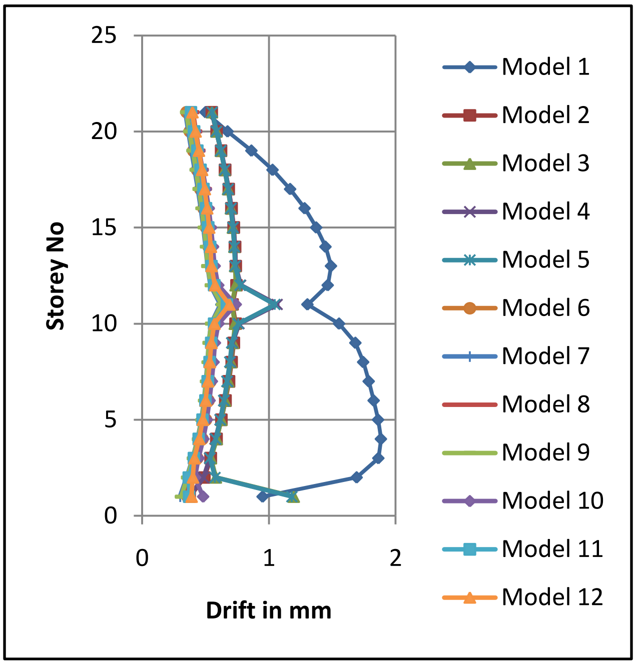


Figure 6 Comparison of storey drift for different building models along longitudinal direction

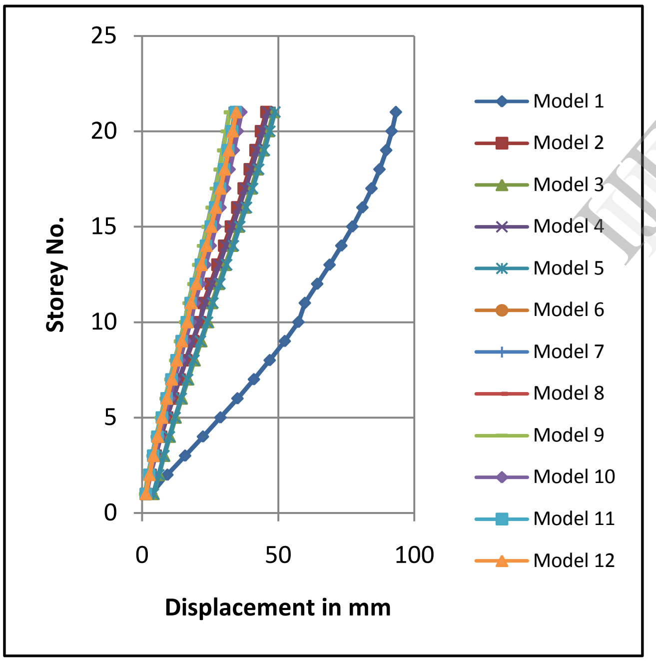


Figure 7 Comparison of storey Displacement for different building models along longitudinal direction

## 9. Comparison of seismic base shear by ETABS and Sap2000

Table 5 Comparison of seismic base shear by static analysis with ETABS and Sap2000

| Base shear (KN) | | | | |
|---|---|---|---|---|
| **Model no** | **Equivalent Static Analysis (ETABS)** | | **Equivalent Static Analysis (SAP2000)** | |
| | **Long** | **Tran** | **Long** | **Tran** |
| **1** | 11585.2 | 11585.2 | 11820.1 | 9694.0 |
| **2** | 28111.8 | 28111.8 | 29658.4 | 24723.2 |
| **3** | 27820.9 | 27820.9 | 27306.2 | 21872.0 |
| **4** | 27779.4 | 27779.4 | 28992.8 | 24102.7 |
| **5** | 27488.5 | 27488.5 | 26749.8 | 21410.2 |
| **6** | 29103.3 | 29103.3 | 34194.9 | 28875.3 |
| **7** | 28903.6 | 28903.6 | 35383.6 | 29730.7 |
| **8** | 28545.5 | 28545.5 | 33804.4 | 27809.3 |
| **9** | 28833.6 | 28833.6 | 34939.9 | 29543.5 |
| **10** | 27565.3 | 27565.3 | 31665.6 | 26633.9 |
| **11** | 27329.8 | 27329.8 | 32662.7 | 27343.5 |
| | | | | |
| **12** | 27295.7 | 27295.7 | 32360.5 | 27273.3 |



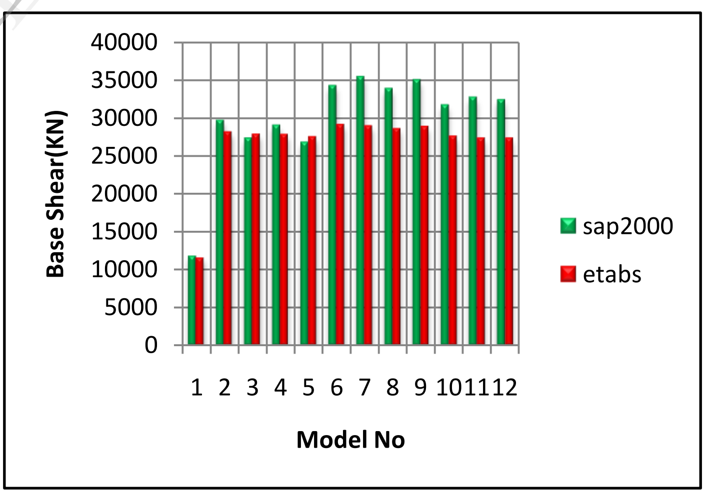


Figure 8 Model Vs Base shear for different models along longitudinal direction

Table 6 Comparison of seismic base shear by Response spectrum analysis with ETABS and Sap2000

| Base shear (KN) | | | | |
|---|---|---|---|---|
| Model no | Response Spectrum Analysis (ETABS) | | Response Spectrum Analysis (SAP2000) | |
| | Long | Tran | Long | Tran |
| 1 | 10345.5 | 8605.9 | 10508.3 | 8756.4 |
| 2 | 23754.1 | 20247.6 | 23404.4 | 20347.9 |
| 3 | 23415.7 | 19849.5 | 23351.6 | 20012.3 |
| 4 | 23199.5 | 19819.9 | 22837.2 | 19913.6 |
| 5 | 22977.5 | 19536.5 | 22900.0 | 19695.4 |
| 6 | 27953.8 | 23498.6 | 27177.2 | 23383.4 |
| 7 | 28371.0 | 23908.3 | 27730.0 | 23633.3 |
| 8 | 27102.1 | 22445.6 | 26780.8 | 22545.5 |
| 9 | 28274.6 | 23860.6 | 27465.0 | 23458.2 |
| 10 | 25957.0 | 21987.2 | 25654.5 | 22056.1 |
| 11 | 26301.3 | 22107.6 | 25988.9 | 22155.7 |
| 12 | 26213.6 | 22057.6 | 25881.4 | 22107.9 |

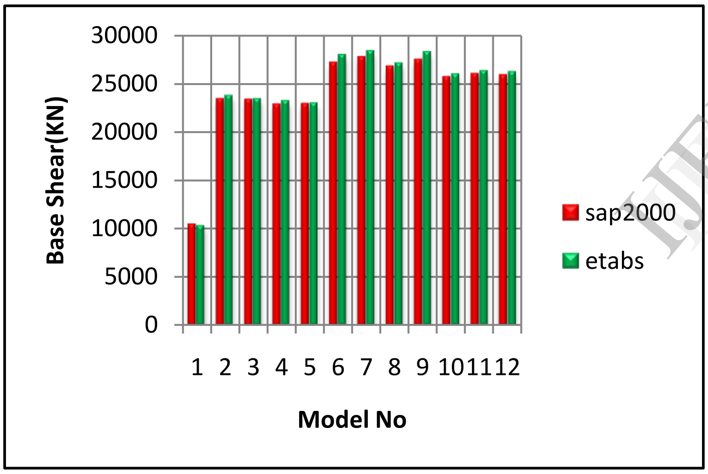


Figure 9 Model Vs Base shear for different models along longitudinal direction

## 10. RESULTS AND DISCUSSIONS

Table 1 shows natural time period for bare frame model from ETABS is 46.64% more than the IS code method. When the structural action of masonry infill is taken the fundamental natural time got reduced 58% when compare with bare frame model, time period of structure increases when soft storey is at ground level and get decreases as it moves up. Thus it can be clearly understand that from table 1 and fig 4, presence of brick infill and concrete walls considerably reduces the time period of building.

Seismic base shear obtained by I S code procedure are considerable less as compared with Base shear obtained by ETABS (ESA) analysis and both showing linear variation for different building models.RSA procedure showing a non-linear variation of base shear for different building models(refer table 2, fig 5).

When masonry infill stiffness taken into consideration, Model 2 (full brick infill) shows considerable reduction in storey drift, For model 3(Ground soft storey), the storey drift is increased by 68.56%, for model 5 Storey drift is increased in ground and 11$^{th}$ soft storey by 68.16%, 32.0% as compared with model 2.model 7 is showing highest reduction in drift value of about 67% (refer table 3, fig 6).Hence provision of shear wall in swastika and L shape with core central wall considerably reduce the effect of soft storeys.

Model 1(bare frame) model shows highest storey displacement values in all different building models model 2 (full brick infill) shows considerable reduction in storey displacement with a maximum reduction of 62.2% compared with model 1 and model 7 shows 70.0% reduction in displacement value compared with model 1 (refer table 4, fig 7).Thus it can be concluded that addition of infill and concrete shear wall act as drift and displacement controlled elements in RC buildings.

Time period calculated by ETABS and SAP2000 are quite same (Refer table1).comparing the values of base shear between ETABS and SAP2000, for static analysis sap2000 is giving some higher results and for response spectrum analysis both structural programs are giving approximately same results for different building models( Refer table 5 and 6). Hence modelling and analysis can easily be done in either of the program. Due to space restriction comparison of Storey drifts and displacements has not been presented in the paper.



## 11. CONCLUSION

- Fundamental time period decreases when the stiffness of masonry infill and concrete shear wall is considered.
- For masonry infill and concrete shear wall models, IS-1893 2002 gives same fundamental time period, therefore software like ETABS and SAP2000 must be use to calculate the time period of the structure.
- As the number of soft stories increases, the fundamental time period of the structure is also increases hence existence soft stories can make the structure to be flexible in nature.
- Seismic base shear considerably more for masonry infill and shear wall models as compared with bare frame model and storey drifts and joint displacements considerably reduces, Hence consideration of masonry infill and shear wall will increases strength and stiffness of structure when subjected to lateral seismic loading..
- As we add shear wall in Swastika and L shaped at the corners of building in x and y direction with a concrete core wall at the centre, the effect of soft ground and soft intermediate storey got reduced. Hence shear wall in the form of swastika and L shape can be a good solution to minimize the effect of soft storeys and can

allow parking facilities in ground and in intermediate soft stories.

- Models with openings in core wall in each storey level, has no effect on over all behavior.
- A service storey of lesser height can be safer at higher altitude in a tall building as long as it is properly managed.
- A comparison is done between ETABS and SAP2000.Approximately both software are giving the same results for lateral load analysis. Hence modeling and analysis can easily be done in either of the program.

## 12. REFERENCE

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