

Seismic Analysis of Multistoried Building on Sloping Ground with Ground , Middle & Top Soft Story

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Abstract : The hilly region are more prone to seismic activity. Due to scarcity of plain ground on hilly regions building are required to be constructed on sloping ground Earthquake has a high potential to cause a wide spread damage in densely populated areas which causes heavy loss of human life and high economic losses. This cause of damage is due to lack of knowledge of engineers and hence resulting in improper design of structures. Hence, it is necessary to ensure adequacy of the structures against horizontal earthquake effects. The static & dynamic analysis is carried out using the parameters like fundamental time period, storey displacement and base shear has been studied for buildings of different angles. As per codal provisions , a soft story is defined as the story in which the stiffness is less than 70% of the story above or below , in soft story building a story is kept open for the purpose vehicle parking , shops , for service etc., . This paper highlights the importance of explicitly recognizing the presence of the open storey in the analysis of the building , for that purpose modeling of G+16 story regular building is done , software like ETABS & SAP 2000 have been used and the results are compared .

IndexTerms – EQX , EQY , RSX , RSY , GMT soft story , shear wall , sloping ground.

I. INTRODUCTION

INDIA is having the record of disastrous earthquake , which left behind loss of many lives & intense damage to assets and financial system .Analysis of structure in hill region is rather different than that of a level ground , since the column of sloped building rests @ different level . The term earthquake may be describe as any quite unstable waves which can be either natural or initiated by humans that generate unstable waves. Earthquakes are caused normally by rupture of geologic faults. Mass destruction of the low and high rise buildings in the recent earthquakes leads to the need of investigation especially in a developing country like INDIA . Structure subjected to seismic/earthquake forces are always vulnerable to damage and if it occurs on a sloped building as on hills which is at some inclination to the ground the chances of damage increases , The economic growth and rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density in the hilly region has increased enormously. Therefore, there is popular and pressing demand for the construction of multi-storey buildings on hill slope in and around the cities. A soft story is characterized by vertical discontinuity in stiffness. When an individual storey in a building is made taller and more open in construction it is called soft storey . From the past earthquake it has been observed that a building with discontinuity in the stiffness and mass subjected to concentration of forces and deformations at the point of discontinuity which may leads to the failure of members at the junction and collapse of building. Most economical way to eliminate the failure of soft storey is by adding shear walls to the tall buildings. 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 behaviour of the building.

II. OBJECTIVES

- To make out the effect of infill in frame when subjected to seismic loading .
- To know the behavior of the building with ground , middle and top soft-storey .
- To study the Seismic response of soft story structure with shear wall .
- To match up to results of ETABS 2016 with SAP 2000 .

III. METHODOLOGY

The building has five bays in X direction with spacing of 6m and nine bays in Y direction with spacing of 4m. The plan dimension 30 m × 36 m. Typical Story height is 3.0 m for each floor including intermediate soft storey the height of ground and top soft storey is different. In the top storey swimming pool is modelled . . Following data is used in the analysis of the RC frame building models. Thickness of masonry wall (tw) = 0.23m, $E_{\text{masonry}} = 3500000 \text{ kN/m}^2$ Density of brick masonry 20 kN/m^3 thickness of slab (ts) = 0.15m Density of Reinforced Concrete 25 kN/m^3 , Beam dimension 230 x 600 mm , Thickness of shear wall 0.20m, grade of concrete used M35 Poisson's Ratio of concrete 0.2, Floor finishes 1.0 kN/m^2 , Imposed loads 3.5 kN/m^2 , Roof live 1.5 kN/m^2 , water pressure = 24.525 kN/m^2 Zone –V, Zone factor (Table2 of IS 1893-2002) – 0.36, Importance factor, I (Table 6 of IS 1893-2002) – 1.0, Response reduction factor, R (Table 7 of IS 1893-2002) – 5.00, Soil type (figure 2 of IS 1893-2002) – Type II (Medium soil) .

Models considered for analysis are

Model 1 Bare frame model , however masses of brick masonry infill walls (230 mm thick) are included .

Model 2 Building has full brick masonry infill of 230 mm thick in all the story .

Model 3 Building has no brick masonry infill in ground , middle and top story and has full brick masonry infill of 230 mm thick in rest of story .

Model 4 Building model is same as model 3 further , L shaped shear wall is provided at corners .

Model 5 building model is same as model 3 further , C shaped shear wall is provided at corners .

These models are analysis for 6 degree 12 degree and 18 degree ground slope

Models in ETABS

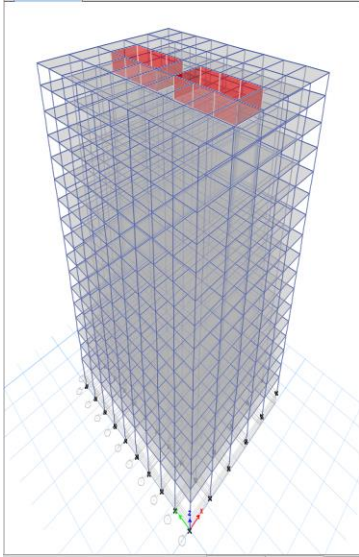


Figure 1: Bare frame

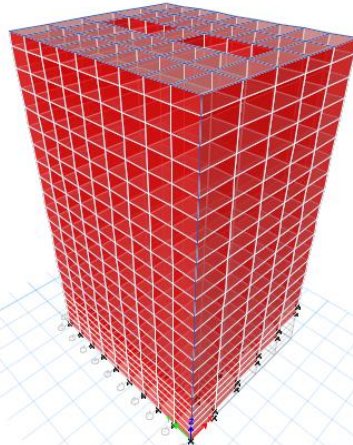


Figure 2: Full infill

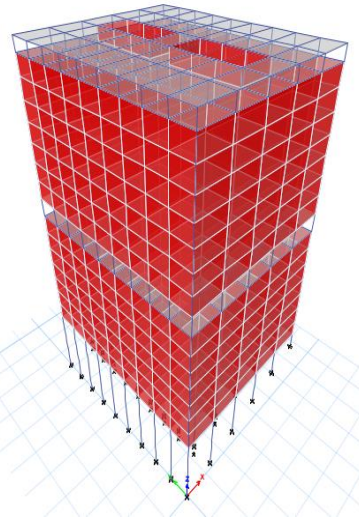


Figure 3: GMT soft story

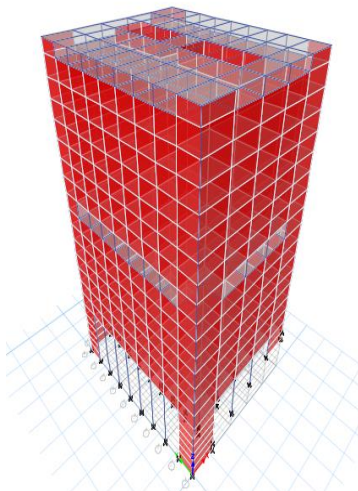


Figure 4: GMT SS & L type shear wall

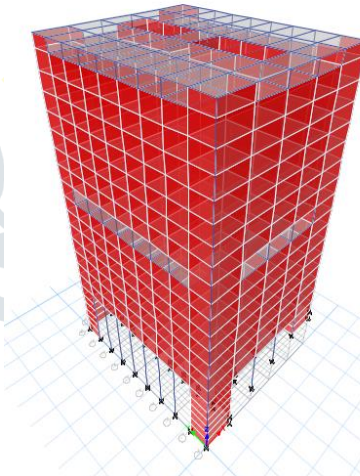


Figure 5: GMT SS & C type shear wall

Models in SAP 2000

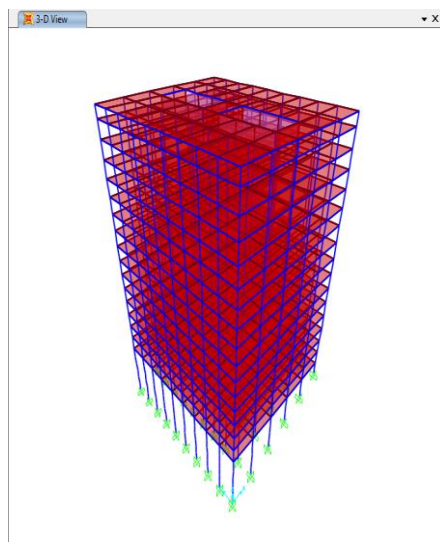


Figure 6: Bare frame

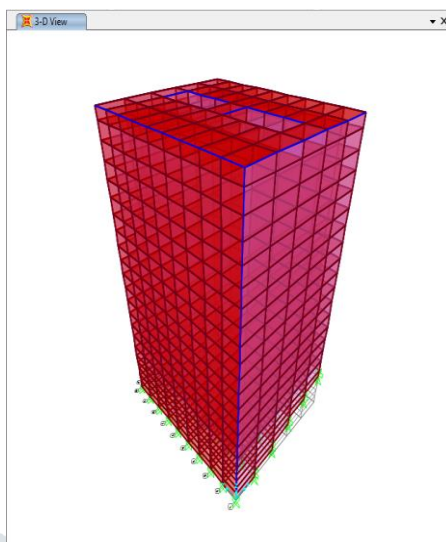


Figure 7: Full infill

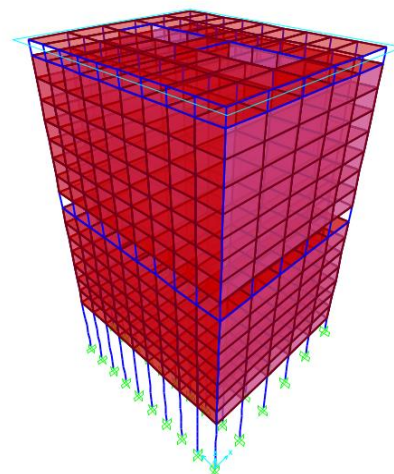


Figure 8: GMT soft story

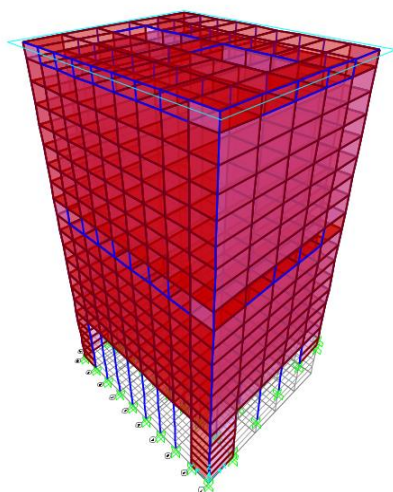


Figure 9: GMT SS & L type shear wall

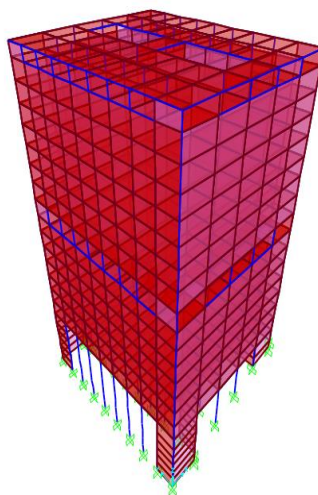


Figure 10: GMT SS & C type shear wall

IV. ANALYSIS

The analysis of building is carried out using ETABS and SAP 2000, equivalent static method and response spectrum method were used, as both methods attempt to quantitatively estimate force due to an earthquake on a structure in terms of set of static forces.

Equivalent lateral force – seismic analysis of most of the structures are still carried out on the basis of lateral force assumed to be equivalent to the actual (dynamic) loading. This method is usually conservative for low to medium height building with a regular conformation.

Response spectrum analysis is a linear dynamic statistical analysis method which measures the contribution from each natural mode of vibration to indicate the likely maximum seismic response of an essentially elastic structure. Computer analysis can be used to determine these modes for a structure. Following are the types of combination methods in response spectrum method

- absolute - peak values are added together.
- square root of the sum of the squares (SRSS).
- complete quadratic combination (CQC) - a method that is an improvement on SRSS for closely spaced modes.

V. RESULTS AND DISCUSSION

5.1 TIME PERIOD

Table shows the time period of the building. Thus it can be clearly seen that, presence of brick infill wall and shear wall considerably reduces the time period of building.

Table 5.1(a) Time Period for bare frame

| Models | Time Period ETABS | Time Period SAP2000 |
|----------------------|-------------------|---------------------|
| 0 degree bare frame | 2.115 | 2.131827 |
| 6 degree bare frame | 2.16 | 2.177733 |
| 12 degree bare frame | 2.18 | 2.197263 |
| 18 degree bare frame | 2.19 | 2.207461 |

Figure 11 Time Period for bare frame Vs model

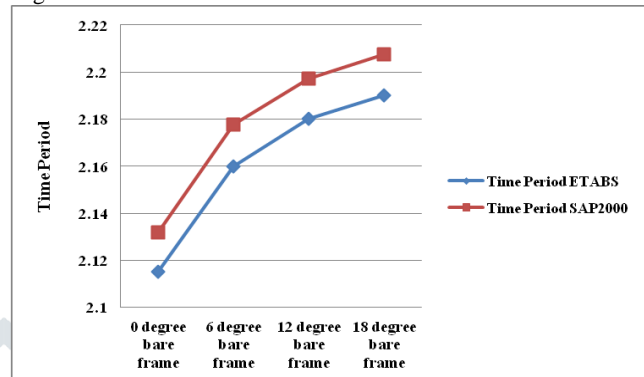


Table 5.1(b) Time Period for full infill

| Models | Time Period ETABS | Time Period SAP2000 |
|-----------------------|-------------------|---------------------|
| 0 degree full infill | 0.57 | 0.594783 |
| 6 degree full infill | 0.587 | 0.612203 |
| 12 degree full infill | 0.608718 | 0.627968 |
| 18 degree full infill | 0.631718 | 0.642991 |

Figure 12 Time Period for full infill Vs model

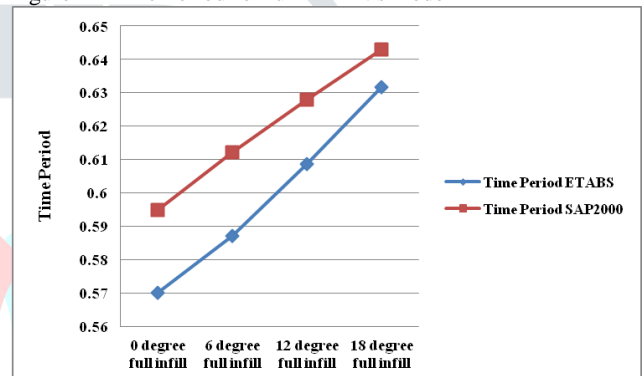


Table 5.1(c) Time Period for GMT soft story

| Models | Time Period ETABS | Time Period SAP2000 |
|---------------------------|-------------------|---------------------|
| 0 degree gmt soft story | 0.614 | 0.643508 |
| 6 degree gmt soft story | 0.655 | 0.685138 |
| 12 degree gmt soft storey | 0.706 | 0.735397 |
| 18 degree gmt soft story | 0.758 | 0.787085 |

Figure 13 Period for GMT soft story Vs model

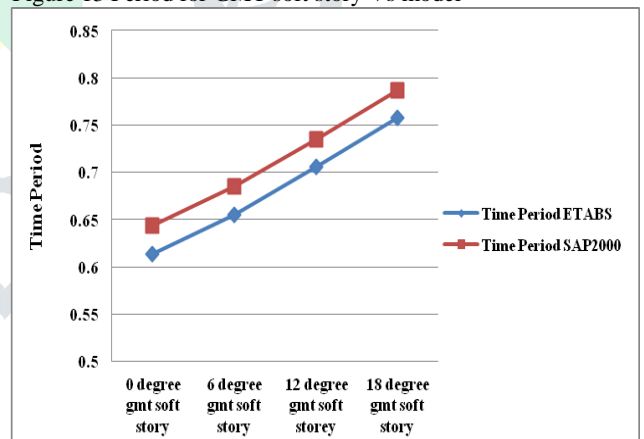


Table 5.1(d) Time Period for GMT ss & L type sw

| Models | Time Period ETABS | Time Period SAP2000 |
|------------------------------|-------------------|---------------------|
| 0 degree gmt ss & L type sw | 0.564 | 0.588456 |
| 6 degree gmt ss & L type sw | 0.591 | 0.61615 |
| 12 degree gmt ss & L type sw | 0.615 | 0.640531 |
| 18 degree gmt ss & L type sw | 0.636 | 0.661754 |

Figure 14 Time Period for GMT ss & L type sw Vs model

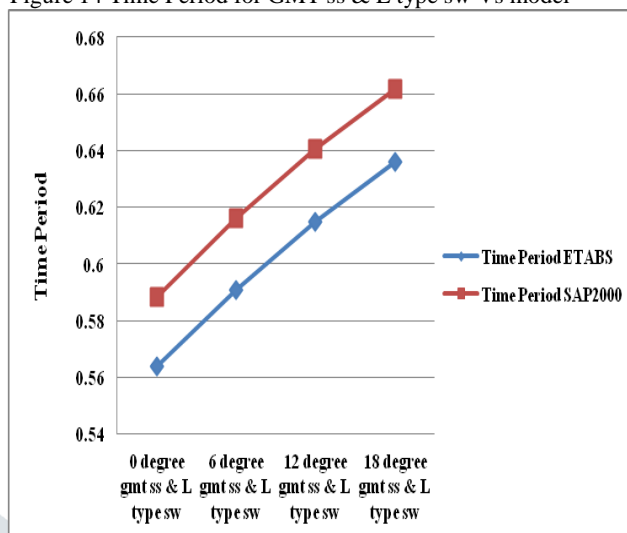


Table 5.1(e) Time Period for GMT ss & C type sw

| Models | Time Period ETABS | Time Period SAP2000 |
|------------------------------|-------------------|---------------------|
| 0 degree gmt ss & C type sw | 0.54 | 0.561555 |
| 6 degree gmt ss & C type sw | 0.563 | 0.586022 |
| 12 degree gmt ss & C type sw | 0.5845 | 0.608529 |
| 18 degree gmt ss & C type sw | 0.6051 | 0.629054 |

Figure 15 Time Period for GMT ss & C type sw Vs model

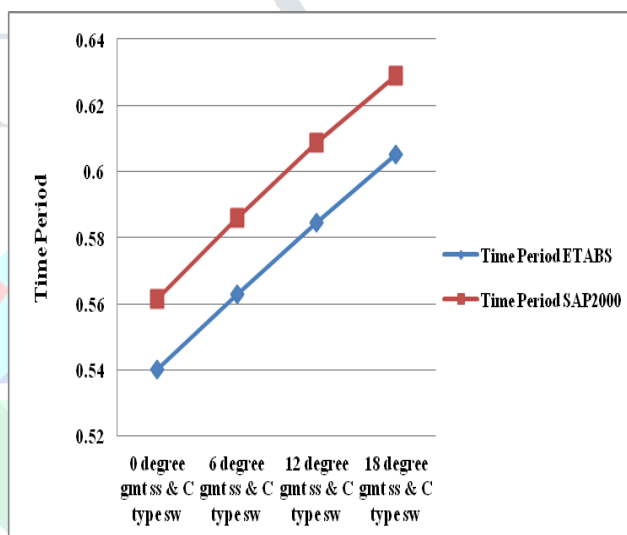


Table 5.1(f) % increase in time period of ETABS with respect to SAP 2000

| bare frame | full infill | gmt soft story | gmt ss & L type shear wall | gmt ss & C type shear wall |
|-------------|-------------|----------------|----------------------------|----------------------------|
| 0.795602837 | 4.347895 | 4.80586319 | 4.33617 | 3.991666667 |
| 0.820972222 | 4.293526 | 4.60122137 | 4.255499 | 4.089165187 |
| 0.791880734 | 3.162384 | 4.16388102 | 4.151382 | 4.111035073 |
| 0.797305936 | 1.784499 | 3.83707124 | 4.049371 | 3.958684515 |

5.2 Story Displacement

The maximum displacements at roof level with respect to ground are presented in Tables for Equivalent static and Response spectrum method. For better comparability the displacement for each model along the two directions of ground motion are plotted in graphs as shown in Figures . The floor displacement will be maximum at the top floor, gradually reducing down the height of the building to an almost negligible displacement at the lowest basement floor. Buildings resting on sloping ground has more displacement compared to buildings on Plain ground and the presence of Shear wall reduces the lateral displacement considerable by both Equivalent static and Response spectrum analysis.

Table 5.2(a) max story displacement bare frame

| Model | EQX ETABS | EQX SAP2000 | EQY ETABS | EQY SAP2000 |
|----------------------|--------------|----------------|--------------|----------------|
| 0 degree bare frame | 53.717 | 54.23167 | 46.472 | 46.9182 |
| 6 degree bare frame | 54.098 | 54.39862 | 47.306 | 47.56251 |
| 12 degree bare frame | 53.563 | 53.7643 | 47.367 | 47.53824 |
| 18 degree bare frame | 52.974 | 53.08452 | 47.306 | 47.39776 |

Figure 16 max story displacement bare frame Vs model

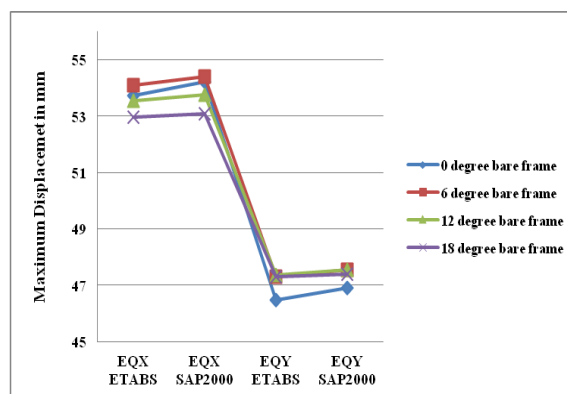


Table 5.2(b) max story displacement bare frame

| Model | RSX ETABS | RSX SAP2000 | RSY ETABS | RSY SAP2000 |
|----------------------|--------------|----------------|--------------|----------------|
| 0 degree bare frame | 41.787 | 41.90662 | 36.849 | 37.00106 |
| 6 degree bare frame | 42.422 | 42.27246 | 41.066 | 38.67805 |
| 12 degree bare frame | 42.827 | 43.09476 | 41.255 | 41.64087 |
| 18 degree bare frame | 43.197 | 43.43618 | 40.589 | 40.93949 |

Figure 17 max story displacement bare frame Vs model

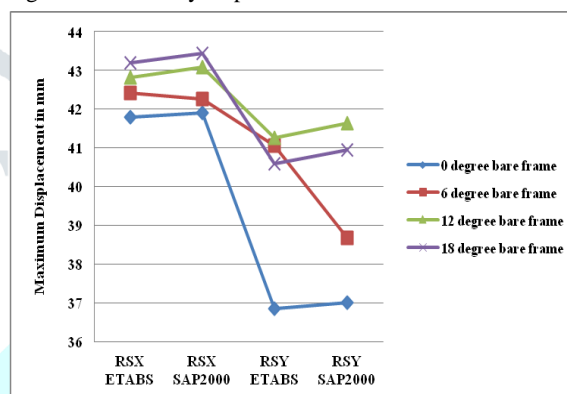


Table 5.2(c) max story displacement full infill

| Model | EQX ETABS | EQX SAP2000 | EQY ETABS | EQY SAP2000 |
|-----------------------|--------------|----------------|--------------|----------------|
| 0 degree full infill | 12.977 | 13.55078 | 14.463 | 14.90256 |
| 6 degree full infill | 13.857 | 14.17908 | 15.157 | 15.49085 |
| 12 degree full infill | 14.717 | 14.28575 | 16.72 | 15.73753 |
| 18 degree full infill | 14.414 | 14.39103 | 15.763 | 15.97448 |

Figure 18 max story displacement full infill Vs model

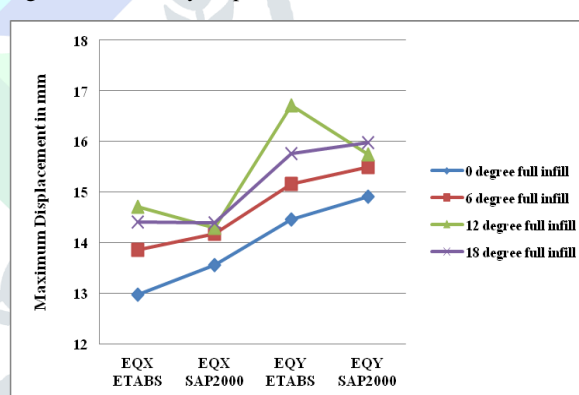


Table 5.2(d) max story displacement full infill

| Model | RSX ETABS | RSX SAP2000 | RSY ETABS | RSY SAP2000 |
|-----------------------|--------------|----------------|--------------|----------------|
| 0 degree full infill | 11.215 | 11.83549 | 12.496 | 12.92937 |
| 6 degree full infill | 12.157 | 12.57437 | 13.681 | 14.02749 |
| 12 degree full infill | 13.281 | 12.87641 | 16.117 | 14.81461 |
| 18 degree full infill | 13.078 | 13.19261 | 15.346 | 15.5608 |

Figure 19 max story displacement full infill Vs model

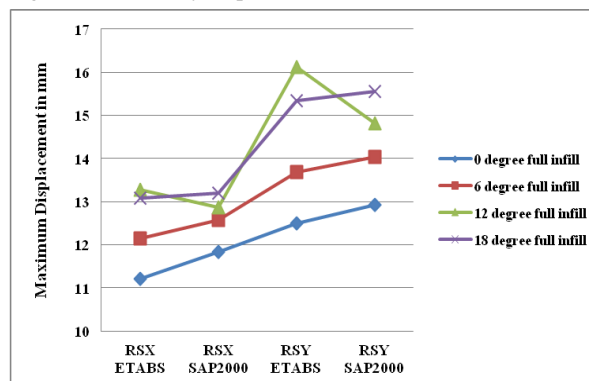


Table 5.2(e) max story displacement GMT soft storey

| Model | EQX ETABS | EQX SAP2000 | EQY ETABS | EQY SAP2000 |
|--------------------------|--------------|----------------|--------------|----------------|
| 0 degree gmt soft story | 14.293 | 14.61285 | 15.274 | 15.87088 |
| 6 degree gmt soft story | 14.617 | 14.88671 | 16.114 | 16.67098 |
| 12 degree gmt soft story | 15.766 | 14.96081 | 17.121 | 17.26336 |
| 18 degree gmt soft story | 14.794 | 15.00983 | 17.248 | 17.76839 |

Figure 20 max story displacement GMT soft storey Vs model

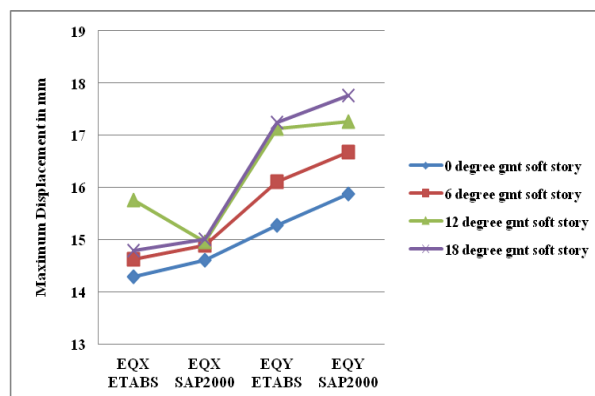


Table 5.2(f) max story displacement GMT soft storey

| Model | RSX ETABS | RSX SAP2000 | RSY ETABS | RSY SAP2000 |
|--------------------------|--------------|----------------|--------------|----------------|
| 0 degree gmt soft story | 12.272 | 12.63385 | 13.131 | 13.68306 |
| 6 degree gmt soft story | 12.63 | 12.94307 | 15.556 | 16.01755 |
| 12 degree gmt soft story | 14.046 | 13.17141 | 17.75 | 18.17675 |
| 18 degree gmt soft story | 13.139 | 13.41252 | 19.277 | 19.70681 |

Figure 21 max story displacement GMT soft storey Vs model

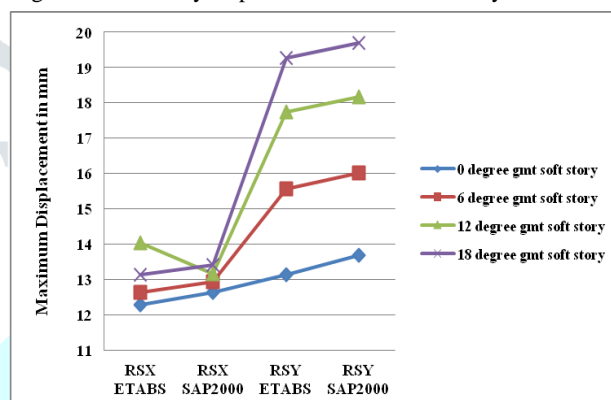


Table 5.2(g) max story displacement GMT & L type sw

| Model | EQX ETABS | EQX SAP2000 | EQY ETABS | EQY SAP2000 |
|------------------------------|--------------|----------------|--------------|----------------|
| 0 degree gmt ss & L type sw | 12.214 | 12.78773 | 14.204 | 14.70028 |
| 6 degree gmt ss & L type sw | 13.023 | 13.56926 | 14.774 | 15.22175 |
| 12 degree gmt ss & L type sw | 14.665 | 13.65053 | 16.376 | 15.53039 |
| 18 degree gmt ss & L type sw | 13.52 | 13.66898 | 15.373 | 15.7767 |

Figure 22 max story displacement GMT & L type sw Vs model

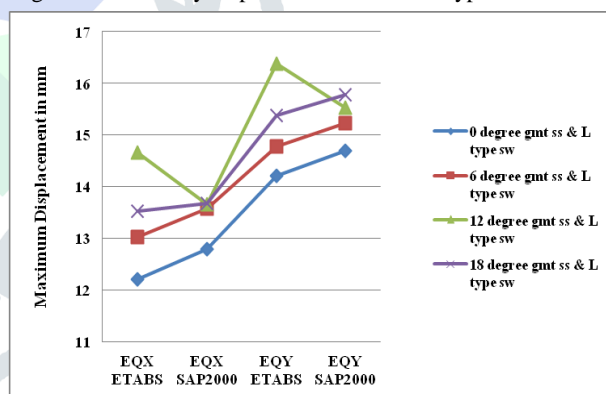


Table 5.2(h) max story displacement GMT & L type sw

| Model | RSX ETABS | RSX SAP2000 | RSY ETABS | RSY SAP2000 |
|------------------------------|--------------|----------------|--------------|----------------|
| 0 degree gmt ss & L type sw | 10.542 | 11.13458 | 12.283 | 12.74587 |
| 6 degree gmt ss & L type sw | 11.365 | 11.93979 | 13.318 | 13.73476 |
| 12 degree gmt ss & L type sw | 12.878 | 12.18967 | 15.6 | 14.59886 |
| 18 degree gmt ss & L type sw | 12.18 | 12.40661 | 15.018 | 15.38957 |

Figure 23 max story displacement GMT & L type sw Vs model

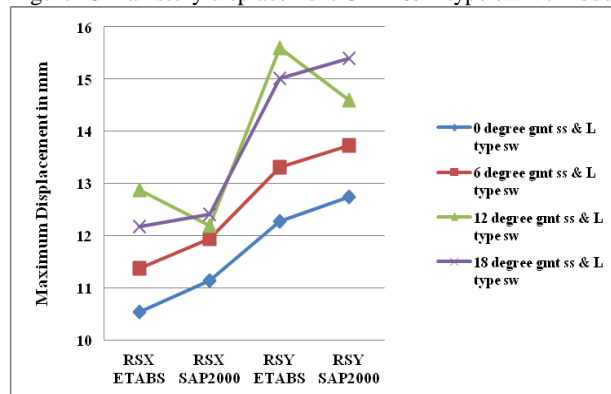


Table 5.2(i) max story displacement GMT & C type sw

| Model | EQX ETABS | EQX SAP2000 | EQY ETABS | EQY SAP2000 |
|------------------------------|--------------|----------------|--------------|----------------|
| 0 degree gmt ss & C type sw | 12.036 | 12.59625 | 13.679 | 14.25062 |
| 6 degree gmt ss & C type sw | 12.842 | 13.37404 | 14.318 | 14.7327 |
| 12 degree gmt ss & C type sw | 13.498 | 13.56863 | 15.105 | 15.00856 |
| 18 degree gmt ss & C type sw | 13.446 | 13.58939 | 14.86 | 15.23475 |

Figure 24 max story displacement GMT & C type sw Vs model

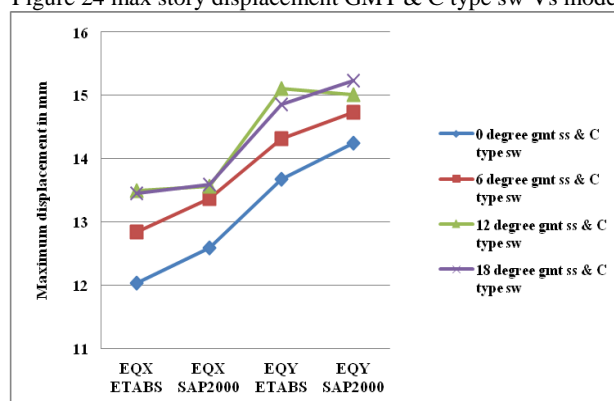


Table 5.2(j) max story displacement GMT & C type sw

| Model | RSX ETABS | RSX SAP2000 | RSY ETABS | RSY SAP2000 |
|------------------------------|--------------|----------------|--------------|----------------|
| 0 degree gmt ss & C type sw | 10.385 | 10.96045 | 11.882 | 12.42284 |
| 6 degree gmt ss & C type sw | 11.203 | 11.76175 | 13.029 | 13.42581 |
| 12 degree gmt ss & C type sw | 11.961 | 12.11372 | 14.207 | 14.28512 |
| 18 degree gmt ss & C type sw | 12.113 | 12.33219 | 14.707 | 15.06296 |

Figure 25 max story displacement GMT & C type sw Vs model

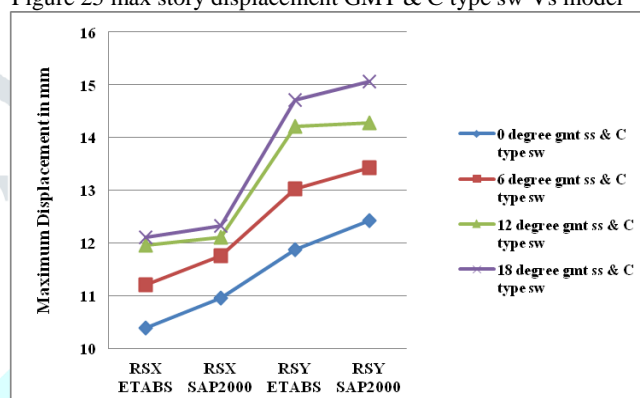


Table 5.2(k) % ↑ or ↓ values for ETABS EQX wrt SAP2000

| Model | 0 degree | 6 degree | 12 degree | 18 degree |
|----------------------------|----------|----------|-----------|-----------|
| Bare Frame | 0.958114 | 0.555701 | 0.375819 | 0.208631 |
| Full infill | 4.421515 | 2.324334 | -2.93028 | -0.15936 |
| GMT soft story | 2.237809 | 1.845146 | -5.10713 | 1.458902 |
| GMT soft story & L type sw | 4.697315 | 4.194594 | -6.91763 | 1.101923 |
| GMT soft story & C type sw | 4.654786 | 4.142992 | 0.523263 | 1.066414 |

Table 5.2(l) % ↑ or ↓ values for ETABS EQY wrt SAP2000

| Model | 0 degree | 6 degree | 12 degree | 18 degree |
|----------------------------|----------|----------|-----------|-----------|
| Bare Frame | 0.960148 | 0.542227 | 0.361518 | 0.193971 |
| Full infill | 3.039203 | 2.202593 | -5.87602 | 1.341623 |
| GMT soft story | 3.907817 | 3.456485 | 0.831493 | 3.017103 |
| GMT soft story & L type sw | 3.493945 | 3.030648 | -5.16372 | 2.626033 |
| GMT soft story & C type sw | 4.178814 | 2.896375 | -0.63846 | 2.521871 |

Table 5.2(m)% ↑ or ↓ values for ETABS RSX wrt SAP2000

| Model | 0 degree | 6 degree | 12 degree | 18 degree |
|----------------------------|----------|----------|-----------|-----------|
| Bare Frame | 0.286261 | -0.35251 | 0.625213 | 0.553696 |
| Full infill | 5.532679 | 3.433166 | -3.04638 | 0.876357 |
| GMT soft story | 2.948582 | 2.478781 | -6.22661 | 2.081741 |
| GMT soft story & L type sw | 5.621135 | 5.057545 | -5.34501 | 1.860509 |
| GMT soft story & C type sw | 5.541165 | 4.987503 | 1.276816 | 1.809543 |

Table 5.2(n)% ↑ or ↓ values for ETABS RSY wrt SAP2000

| Model | 0 degree | 6 degree | 12 degree | 18 degree |
|----------------------------|----------|----------|-----------|-----------|
| Bare Frame | 0.412657 | -5.81491 | 0.935329 | 0.86351 |
| Full infill | 3.46807 | 2.532637 | -8.08085 | 1.399713 |
| GMT soft story | 4.204249 | 2.967022 | 2.404225 | 2.229652 |
| GMT soft story & L type sw | 3.768379 | 3.129299 | -6.41756 | 2.474164 |
| GMT soft story & C type sw | 4.551759 | 3.045591 | 0.54987 | 2.420344 |

5.3 Base Shear

The base shear for Equivalent static method (V_b) and the Response spectrum method (VB) as per IS 1893: 2002(Part I) for various building models are listed in the tables below. Results are compared between ETABS and SAP 2000 .

Table 5.3(a) Base Shear bare frame

| Model | Base Shear EQX ETABS | Base Shear EQX SAP2000 | Base Shear EQY ETABS | Base Shear EQY SAP2000 |
|----------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree bare frame | 6643.912 | 6667.044 | 7700.076 | 7772.794 |
| 6 degree bare frame | 6663.194 | 6699.984 | 7607.591 | 7648.283 |
| 12 degree bare frame | 6680.663 | 6705.207 | 7500.284 | 7526.507 |
| 18 degree bare frame | 6728.484 | 6741.501 | 7457.94 | 7471.013 |

Figure 26 Base Shear bare frame Vs model

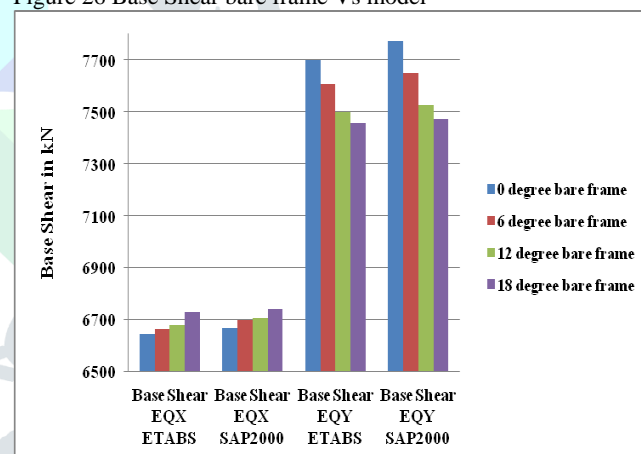


Table 5.3(b) Base Shear bare frame

| Model | Base Shear RSX ETABS | Base Shear RSX SAP2000 | Base Shear RSY ETABS | Base Shear RSY SAP2000 |
|----------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree bare frame | 6744.346 | 6786.704 | 7899.696 | 7923.337 |
| 6 degree bare frame | 6791.985 | 6829.749 | 7751.604 | 7796.415 |
| 12 degree bare frame | 6809.557 | 6835.074 | 7645.271 | 7672.281 |
| 18 degree bare frame | 6858.755 | 6872.071 | 7602.092 | 7615.712 |

Figure 27 Base Shear bare frame Vs model

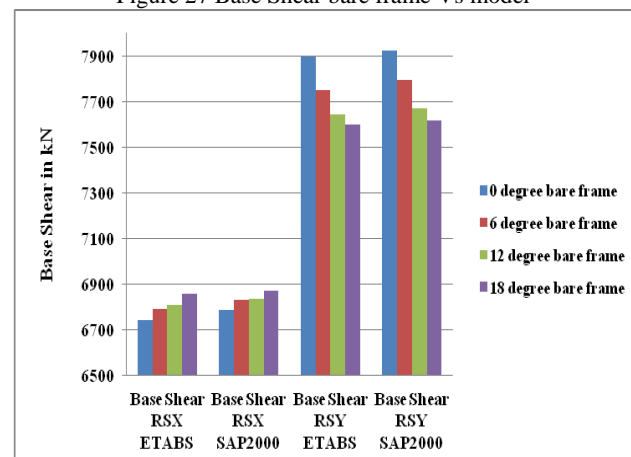


Table 5.3(c) Base Shear full infill

| Model | Base Shear EQX ETABS | Base Shear EQX SAP2000 | Base Shear EQY ETABS | Base Shear EQY SAP2000 |
|-----------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree full infill | 28232.57 | 28683.42 | 26945.45 | 26234.4 |
| 6 degree full infill | 29605.65 | 29482.76 | 27456.43 | 26503.1 |
| 12 degree full infill | 33701.49 | 33350.24 | 30649.24 | 29311.1 |
| 18 degree full infill | 30162.34 | 29312.17 | 27344.9 | 26178.76 |

Figure 28 Base Shear full infill Vs model

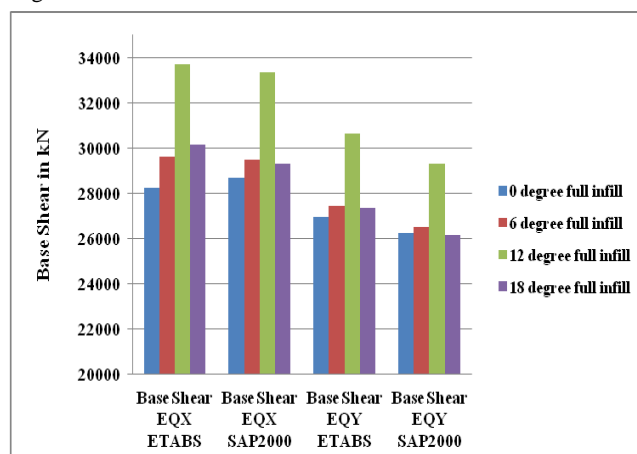


Table 5.3(d) Base Shear full infill

| Model | Base Shear RSX ETABS | Base Shear RSX SAP2000 | Base Shear RSY ETABS | Base Shear RSY SAP2000 |
|-----------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree full infill | 28781.01 | 29238.96 | 27470.91 | 26742.5 |
| 6 degree full infill | 30177.96 | 30053.79 | 27987.08 | 27016.41 |
| 12 degree full infill | 34353.27 | 34018.7 | 31241.09 | 30520.7 |
| 18 degree full infill | 30744.88 | 29879.89 | 27872.69 | 26685.78 |

Figure 29 Base Shear full infill Vs model

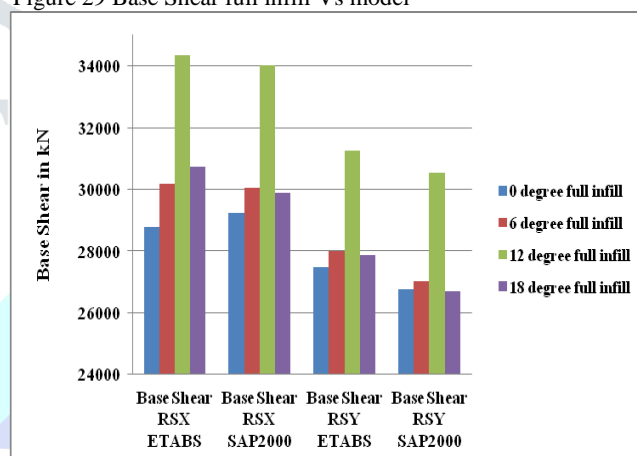


Table 5.3(e) Base Shear GMT soft story

| Model | Base Shear EQX ETABS | Base Shear EQX SAP2000 | Base Shear EQY ETABS | Base Shear EQY SAP2000 |
|--------------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree gmt soft story | 25816.23 | 25484.73 | 23724.04 | 23022.7 |
| 6 degree gmt soft story | 24985.19 | 24596.95 | 22763.84 | 22051.51 |
| 12 degree gmt soft story | 24266.19 | 23874.58 | 21363.78 | 20737.98 |
| 18 degree gmt soft story | 23830.77 | 23425.83 | 20111.83 | 19564.78 |

Figure 30 Base Shear GMT soft story Vs model

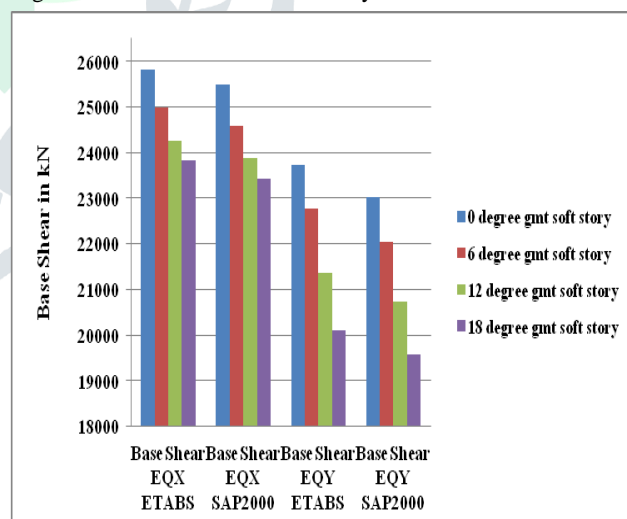


Table 5.3(f) Base Shear GMT soft story

| Model | Base Shear RSX ETABS | Base Shear RSX SAP2000 | Base Shear RSY ETABS | Base Shear RSY SAP2000 |
|--------------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree gmt soft story | 26315.23 | 25978.31 | 24182.91 | 23468.61 |
| 6 degree gmt soft story | 25469.04 | 25073.35 | 23204.14 | 22478.61 |
| 12 degree gmt soft story | 24735.61 | 24336.98 | 21776.73 | 21139.63 |
| 18 degree gmt soft story | 24292.12 | 23879.54 | 20499.82 | 19943.71 |

Figure 31 Base Shear GMT soft story Vs model

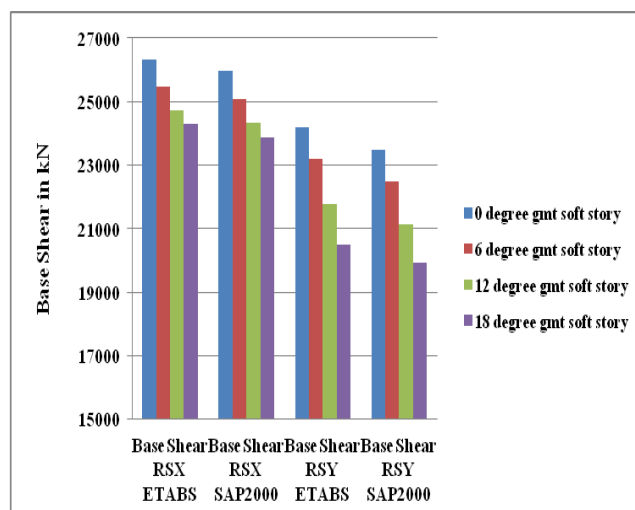


Table 5.3(g) Base Shear GMT soft story & L type sw

| Model | Base Shear EQX ETABS | Base Shear EQX SAP2000 | Base Shear EQY ETABS | Base Shear EQY SAP2000 |
|------------------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree gmt ss & L type sw | 26974.14 | 27424.98 | 25996.1 | 25353.11 |
| 6 degree gmt ss & L type sw | 27670.73 | 28008.77 | 25454.91 | 24729 |
| 12 degree gmt ss & L type sw | 28003.87 | 27519.53 | 24753.76 | 24031.41 |
| 18 degree gmt ss & L type sw | 27638.84 | 27157.36 | 24233.82 | 23506.79 |

Figure 32 Base Shear GMT soft story & L type sw Vs model

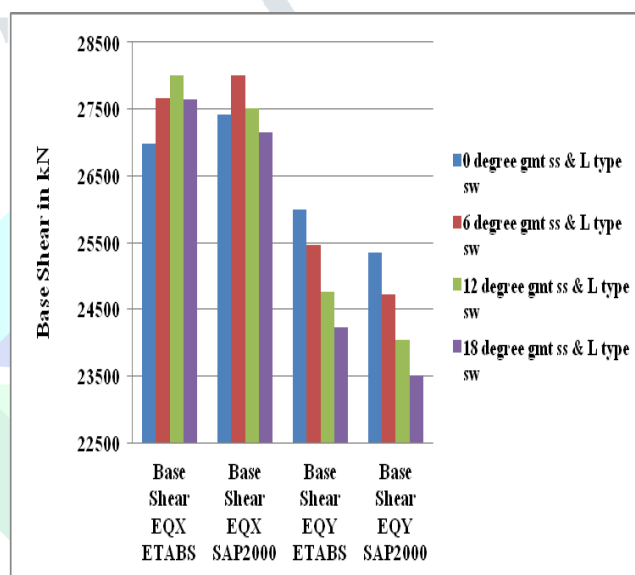


Table 5.3(h) Base Shear GMT soft story & L type sw

| Model | Base Shear RSX ETABS | Base Shear RSX SAP2000 | Base Shear RSY ETABS | Base Shear RSY SAP2000 |
|------------------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree gmt ss & L type sw | 27496.22 | 27956.15 | 26499.01 | 25844.15 |
| 6 degree gmt ss & L type sw | 28205.18 | 28551.25 | 25946.46 | 25207.95 |
| 12 degree gmt ss & L type sw | 28544.31 | 28764.41 | 25232.78 | 24496.85 |
| 18 degree gmt ss & L type sw | 28172.41 | 27683.35 | 24702.91 | 23962.07 |

Figure 33 Base Shear GMT soft story & L type sw Vs model

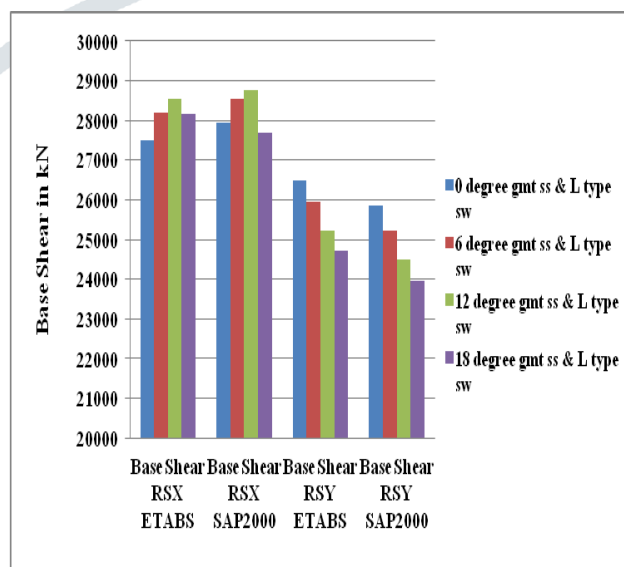


Table 5.3(i) Base Shear GMT soft story & C type sw

| Model | Base Shear EQX ETABS | Base Shear EQX SAP2000 | Base Shear EQY ETABS | Base Shear EQY SAP2000 |
|------------------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree gmt ss & C type sw | 27050.53 | 27501.37 | 27050.53 | 26641.62 |
| 6 degree gmt ss & C type sw | 27771.06 | 28106.84 | 26819.51 | 26091.38 |
| 12 degree gmt ss & C type sw | 32054.64 | 32858.32 | 25577.12 | 25391.19 |
| 18 degree gmt ss & C type sw | 27996.26 | 27506.29 | 24988.19 | 24829.99 |

Figure 34 Base Shear GMT soft story & C type sw Vs model

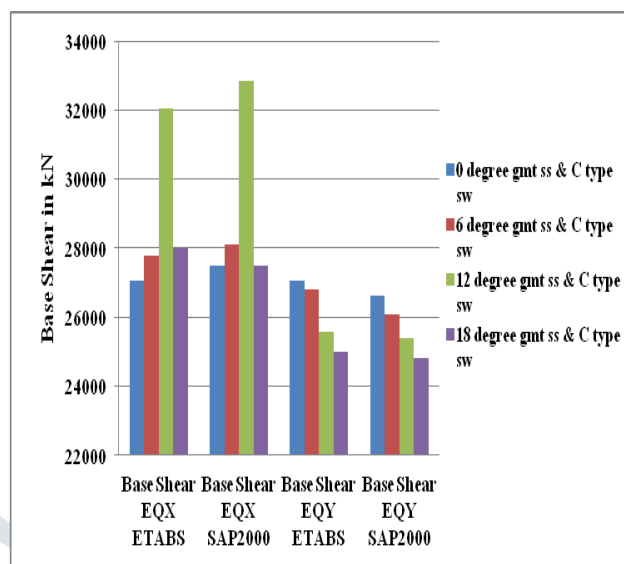


Table 5.3(j) Base Shear GMT soft story & C type sw

| Model | Base Shear RSX ETABS | Base Shear RSX SAP2000 | Base Shear RSY ETABS | Base Shear RSY SAP2000 |
|------------------------------|----------------------------|------------------------------|----------------------------|------------------------------|
| 0 degree gmt ss & C type sw | 27575.01 | 28034.02 | 27574.27 | 27157.62 |
| 6 degree gmt ss & C type sw | 28308.41 | 28651.21 | 27337.53 | 26596.71 |
| 12 degree gmt ss & C type sw | 32674.69 | 33397.88 | 26336.86 | 25882.97 |
| 18 degree gmt ss & C type sw | 28537.52 | 28039.04 | 26083.16 | 25310.9 |

Figure 35 Base Shear GMT soft story & C type sw Vs model

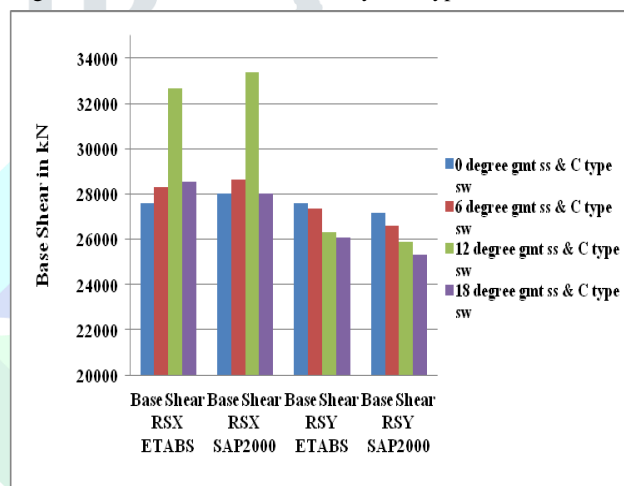


Table 5.3(k) % ↑ or ↓ values for ETABS EQX wrt SAP2000

| Model | 0 degree | 6 degree | 12 degree | 18 degree |
|----------------------------|----------|----------|-----------|-----------|
| Bare Frame | 0.348168 | 0.552138 | 0.367389 | 0.193461 |
| Full infill | 1.596914 | -0.41509 | -1.04224 | -2.81865 |
| GMT soft story | -1.28408 | -1.55388 | -1.61381 | -1.69923 |
| GMT soft story & L type sw | 1.671379 | 1.221652 | -1.72955 | -1.74204 |
| GMT soft story & C type sw | 1.666659 | 1.2091 | 2.507219 | -1.75013 |

Table 4.3(l) % ↑ or ↓ values for ETABS EQY wrt SAP2000

| Model | 0 degree | 6 degree | 12 degree | 18 degree |
|----------------------------|----------|----------|-----------|-----------|
| Bare Frame | 0.94438 | 0.534887 | 0.349627 | 0.17529 |
| Full infill | -2.63885 | -3.47216 | -4.36598 | -4.26456 |
| GMT soft story | -2.95624 | -3.12922 | -2.92926 | -2.72004 |
| GMT soft story & L type sw | -2.47341 | -2.85175 | -2.91814 | -3.00006 |
| GMT soft story & C type sw | -1.51165 | -2.71493 | -0.72694 | -0.6331 |

Table 5.3(m) % ↑ or ↓ values for ETABS RSX wrt SAP2000

| Model | 0 degree | 6 degree | 12 degree | 18 degree |
|----------------------------|-----------|-----------|-----------|-----------|
| Bare Frame | 0.628052 | 0.556008 | 0.374723 | 0.194146 |
| Full infill | 1.591153 | -0.41146 | -0.97391 | -2.81344 |
| GMT soft story | -1.28032 | -1.55361 | -1.61156 | -1.69841 |
| GMT soft story & L type sw | 1.672703 | 1.226973 | 0.771082 | -1.73595 |
| GMT soft story & C type sw | 1.6645869 | 1.2109476 | 2.2133033 | -1.746753 |

Table 5.3(n) % ↑ or ↓ values for ETABS RSY wrt SAP2000

| Model | 0 degree | 6 degree | 12 degree | 18 degree |
|----------------------------|----------|-----------|-----------|-----------|
| Bare Frame | 0.299265 | 0.578087 | 0.35329 | 0.179161 |
| Full infill | -2.65157 | -3.46828 | -2.30591 | -4.25833 |
| GMT soft story | -2.95374 | -3.12673 | -2.9256 | -2.71276 |
| GMT soft story & L type sw | -2.47126 | -2.84628 | -2.91656 | -2.999 |
| GMT soft story & C type sw | -1.51101 | -2.709901 | -1.723402 | -2.960761 |

VI. Conclusions

Fundamental time period decreases when effect of masonry infill and shear wall is considered .

Bare frame model has got highest time period compared to other models & C type shear wall building with soft story has got least value of time period .

Buildings resting on sloping ground have more lateral displacement compared to buildings on Plain ground , as the angle of slope was increased displacement were also reduced , and the presence of Shear wall & infill reduces the lateral displacement of the soft story building .

Bare frame model has got the least base shear compared to other models . Base shear was increased in X direction and decreased in Y direction .

A attempt to compare the results of ETABS with SAP2000 is made , the result obtained for time period max story displacement and maximum storey drift & base shear are nearly same hence modeling & analyzing in either of the structural software can be done .

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