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Seismic Analysis and Comparison of Different Lateral Load Resisting Systems for Rectangle Shape Building for Different Soil Condition

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Abstract — *For earthquake resistant design the normal building should be able to resist minor, moderate, sever shaking. In the circumstances of the building, simple shape configuration building transfer the earthquake force in the direct path to the base while in complex shape building, the load transferring path is indirect which leads to generation of stresses at the corners. Structure designers need to design and build a structure in which the damage to the structure and its structure component by earthquake is minimized. From the past studies and structure designer's researches, they found various lateral load resisting systems; like Shear wall systems, Bracing systems, Flat slab systems, etc. Here 15 Storey Rectangle Shape building is considered for analysis. In present study five different models are used for analysis, I) Bare Frame, II) Moment resisting frame with steel bracings at corners (MFBR), III) Moment resisting frame with RC Shear wall at corners(MFSW), IV) Flat slab with steel bracings at corners(FSBR), V) Flat slab with RC Shear wall at corners(FSSW). All models analyzed for three types of soils, I) Hard Soil, II) Medium Soil, III) Soft Soil as per IS 1893 (Part-1):2002. All the models were analyzed using Finite Element Method based software ETABS 15.0.0 subjected to lateral and gravity loading in accordance with IS provisions. The main parameters considered in this study to compare the seismic performance of different models for linear static analysis are; Top storey displacements, Storey drift ratios, Storey shears and for dynamic analysis are; Torsional moments, Time Period and Response Spectrum.*

Keywords *- ETABS, Rectangle Shape, Lateral Load Resisting Systems, Shear Wall, Bracing, Flat Slab, Lateral Displacement, Base Shear, Storey Drift, Time Period.*

I. INTRODUCTION

In recent era India is fast growing country and population of country is also increasing with higher rate; so it is necessary to develop residential as well as commercial, educational buildings, etc for people. So infrastructure of country is also developing simultaneously. And these fast growing Infrastructures requires vast area for construction purpose. But India is also a country where so many people are connected with activities of agriculture; so we cannot deal with land of agriculture as well as Irrigation (farms, dams, canals, etc). So it is necessary to develop infrastructure without affecting such useful lands. There is only solution of this problem is vertical construction of buildings. But also there are problems with high rise vertical structures. High rise vertical structures are affected by different lateral loads such as; earthquake and winds. In earthquake design the building has to go through regular motion at its base, which leads to inertia force in the building that consecutively causes stresses. India has experienced number of earthquakes that caused large damage to residential and industrial structure. For earthquake resistant design the normal building should be able to resist minor, moderate, sever shaking. In the circumstances of the building, simple shape configuration building transfer the earthquake force in the direct path to the base while in complex shape building the load transferring path is indirect which leads to generation of stresses at the corners. Structure designers need to design and build a structure in which the damage to the structure and its structure component by earthquake is minimized. Behaviour of structure during earthquake motion depends on distribution of weight, stiffness and strength in both horizontal and planes of building. To reduce the effect of earthquake different lateral load resisting systems are used in the building. These can be used for improving seismic response of buildings. Structural design of buildings for seismic loading is primarily concerned with structural safety during major Earthquakes, in tall buildings, it is very important to ensure adequate lateral stiffness to resist lateral load. The provision of lateral load resisting systems in building to achieve rigidity has been found effective and economical.

When buildings are tall, beam, column sizes are quite heavy and steel required is large. So there is lot of congestion at these joint and it is difficult to place and vibrate concrete at these place and displacement is quite heavy. Lateral load resisting systems are usually used in tall building to avoid collapse of buildings.

II. METHODOLOGY

2.1. Preliminary Data For Model Generation

Table 1. Preliminary data for model generation

Shape of buildings	Rectangle Shape
Each bay size	5m
Number of storeys	15
Floor to Floor height	4m for Ground storey & 3m for Other storeys
Beam size	(230x450) mm
Column size (External)	(230X500) mm
Column size (Internal)	(300X300) mm
Slab thickness	150 mm
Drop	250 mm
External wall thickness	230 mm
Internal wall thickness	115 mm
Height of parapet wall	1 m
Thickness of parapet wall	115 mm
Terrace water proofing	1.5 kN/m2
Floor finish	0.6 kN/m2
Live load	3 kN/m2 (As per IS : 875 (Part 2) – 1987, Table-1, Page 7)
Thickness of Shear wall	300 mm (As per IS 13920 : 1993, Clause 9.1, Page 12)
Steel Bracing	ISMB500

2.2. Material Property

Table 2. Material Property

Concrete Grade	M25
Steel reinforcement Main & Secondary	Fe415
Steel for bracing	Fe345
Unit weight of Concrete	25 kN/m3
Unit weight Brick masonry	20 N/m3

2.3. Seismic Data

Table 3. Seismic Data

Seismic Zone	IV (Z=0.24)
Response reduction factor	5
Importance factor	1
Soil condition	Hard, Medium and Soft as per IS 1893 (Part 1) : 2002
Damping	5%

2.4. Load Combinations

Ultimate Limit State Envelope - I

1. 1.5 (DL+LL)
2. 1.5 (DL+LL) + EQX

3. 1.5 (DL+LL) – EQX
4. 1.5 (DL+LL) + EQY
5 1.5 (DL+LL) - EQY
6. 1.5 (DL+EQX)
7. 1.5 (DL-EQX)
8. 1.5 (DL+EQY)
9. 1.5 (DL-EQY)
10. 0.9 DL + 1.5 EQX
11. 0.9 DL – 1.5 EQX
12. 0.9 DL + 1.5 EQY
13. 0.9 DL – 1.5 EQY
14. 1.2 (DL+LL+EQX)
15. 1.2 (DL+LL-EQX)
16. 1.2 (DL+LL+EQY)
17. 1.2 (DL+LL-EQY)

2.5. Load Resisting Systems

1. Bare Frame (Moment resisting frame)
2. Moment resisting frame with Bracings at corners (MRBR)
3. Moment resisting frame with Shear wall at corners (MRSW)
4. Flat slab with Bracings at corners (FSBR)
5. Flat slab with Shear wall at corners (FSSW)

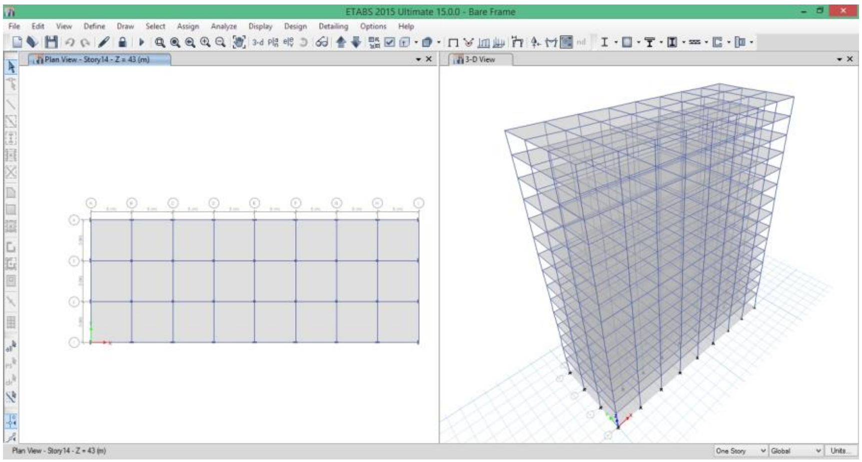


Figure 1. Plan & 3D view of Model-1 (Bare Frame)

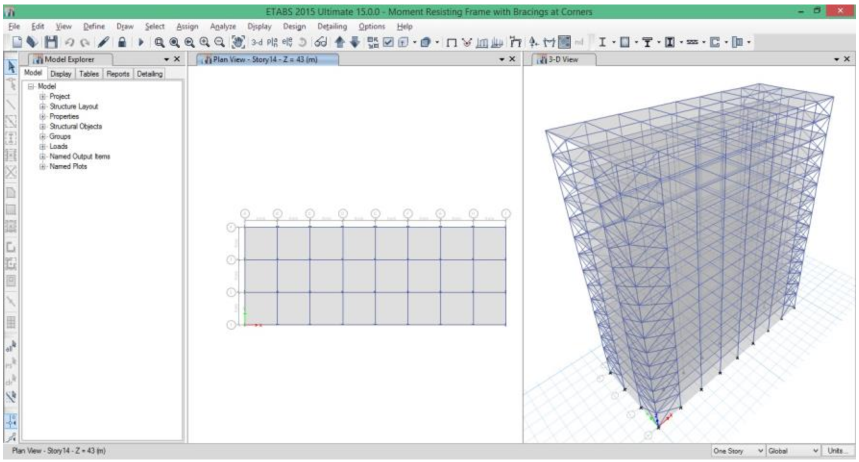


Figure 2. Plan & 3D view of Model-2 (MRBR)

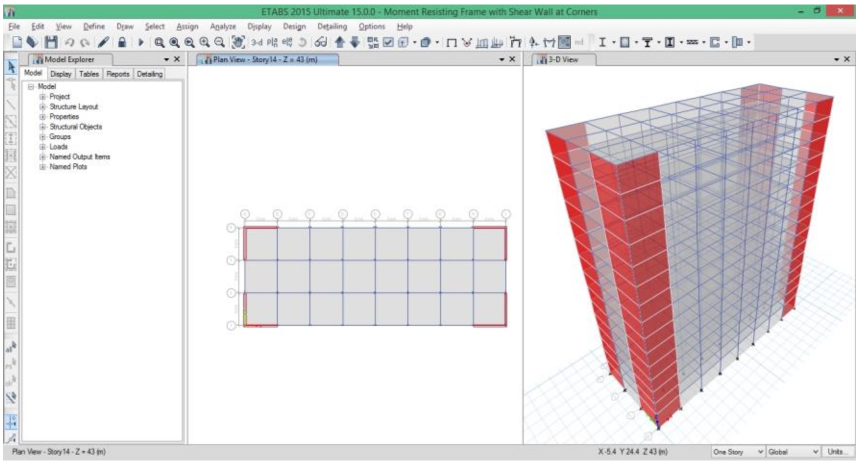


Figure 3. Plan & 3D view of Model-3 (MRSW)

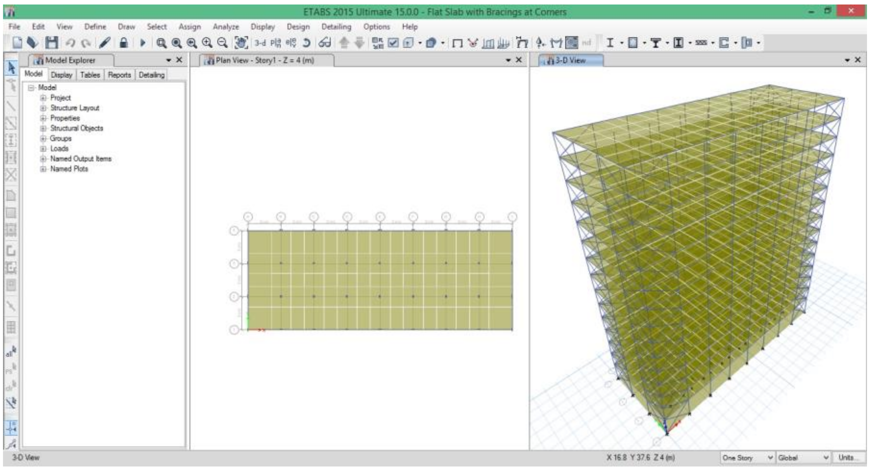


Figure 4. Plan & 3D view of Model-4 (FSBR)

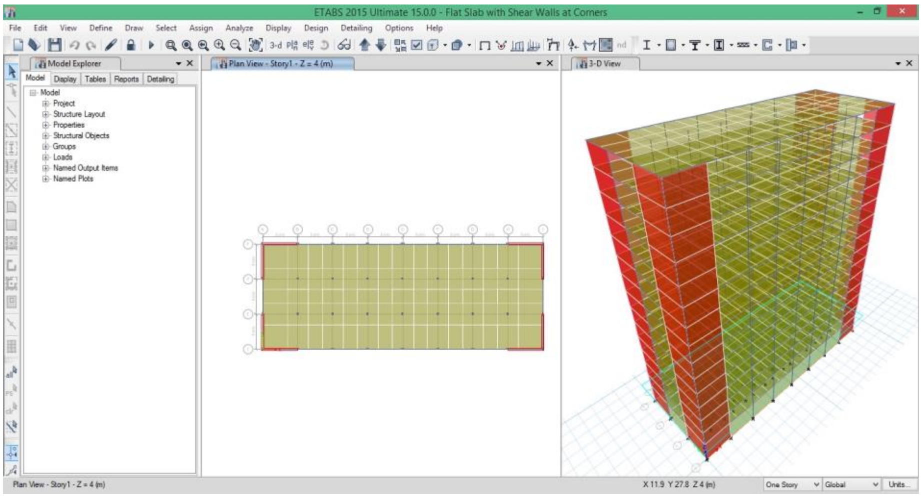


Figure 5. Plan & 3D view of Model-5 (FSSW

III. RESULTS

3.1. Top Storey Displacement

Table 1. Top Storey Displacements In X-Direction

Lateral Load Resisting Systems	Hard Soil		Medium Soil		Soft Soil		Permissible Deflection (mm)
	X	Y	X	Y	X	Y	
1. Bare Frame	155.6	**249.7**	**211.6**	**339.6**	**259.7**	**417**	As per IS 1893 (Part 1) (2002) Clause 7.11.1 Pg.27 **184**
2. MRBR	46.5	50.3	63.2	68.4	77.5	83.9	
3. MRSW	33.6	33.7	45.5	45.9	55.9	56.3	
4. FSBR	47.6	56.6	64.7	76.7	79.4	94	
5. FSSW	32.6	34.1	44.3	46.3	54.4	56.8	

Table 2. Percentage Decrement in Top Storey Displacements

Lateral Load Resisting Systems	Hard Soil		Medium Soil		Soft Soil	
	X	Y	X	Y	X	Y
2. MRBR	70.11 %	79.85 %	70.13 %	79.85 %	70.15 %	79.88 %
3. MRSW	78.40 %	**86.50 %**	78.49 %	**86.48 %**	78.47 %	**86.49 %**
4. FSBR	69.40 %	77.33 %	69.42 %	77.41 %	69.42 %	77.45 %
5. FSSW	79.04 %	86.34 %	79.06 %	86.36 %	79.05 %	86.37 %

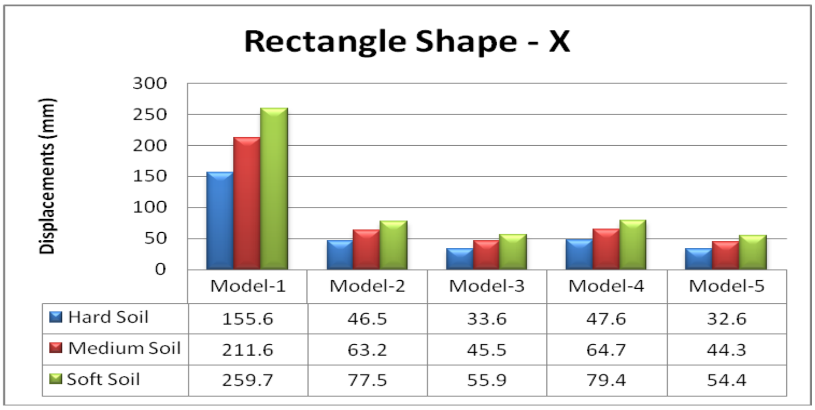
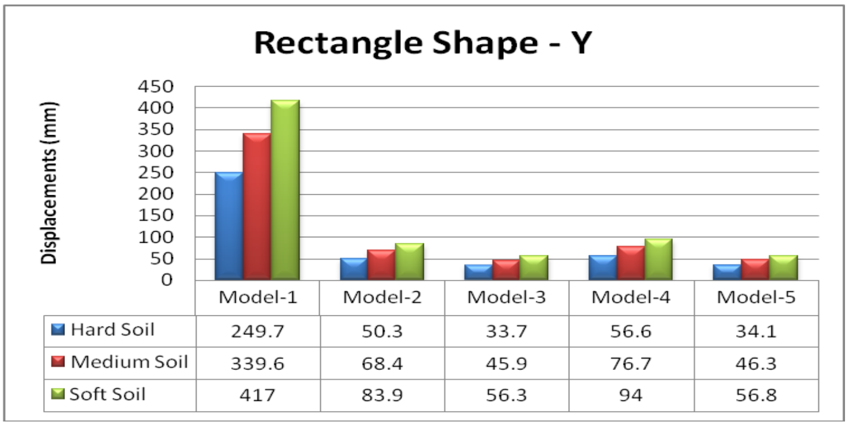


Figure 6. Top Storey Displacements in X-Direction



	Model-1	Model-2	Model-3	Model-4	Model-5
Hard Soil	249.7	50.3	33.7	56.6	34.1
Medium Soil	339.6	68.4	45.9	76.7	46.3
Soft Soil	417	83.9	56.3	94	56.8

Figure 7. Top Storey Displacements in Y-Direction

3.2. Storey Drift

Story drift is the displacement of one level relative to the other level above or below. Software value of story drift is given in ratio.

Story drift ratio = (difference between displacement of two stories / height of one storey).

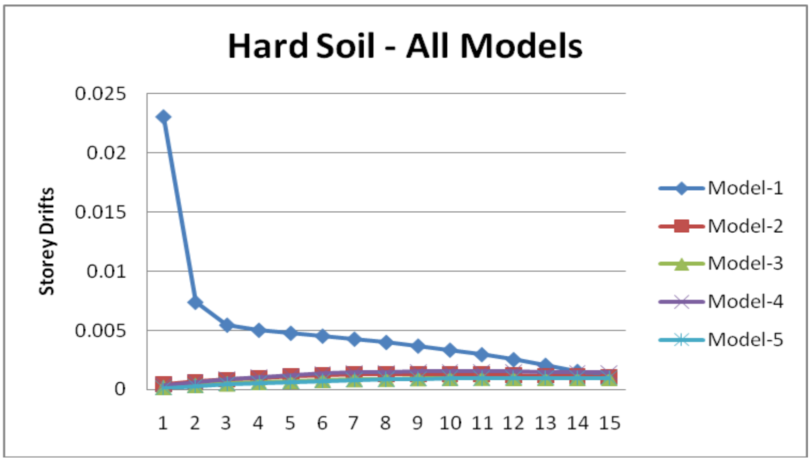


Figure 8. Storey Drifts for Hard Soil (All Models)

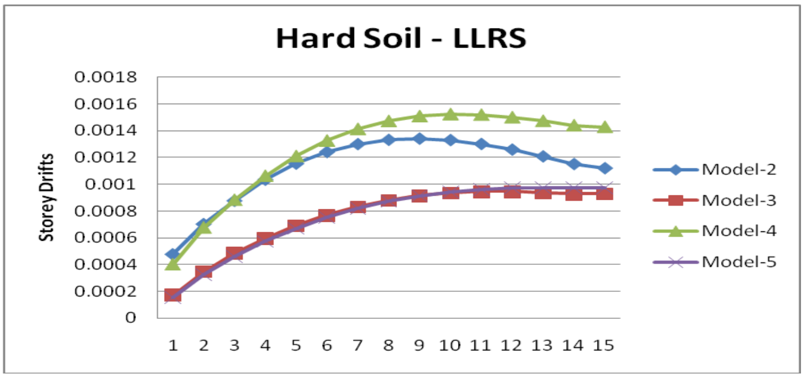


Figure 9. Storey Drifts for Hard Soil (LLRS)

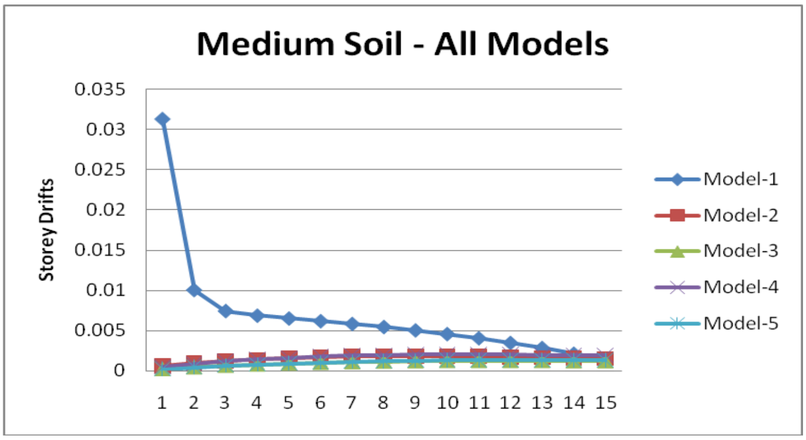


Figure 10. Storey Drifts for Medium Soil (All Models)

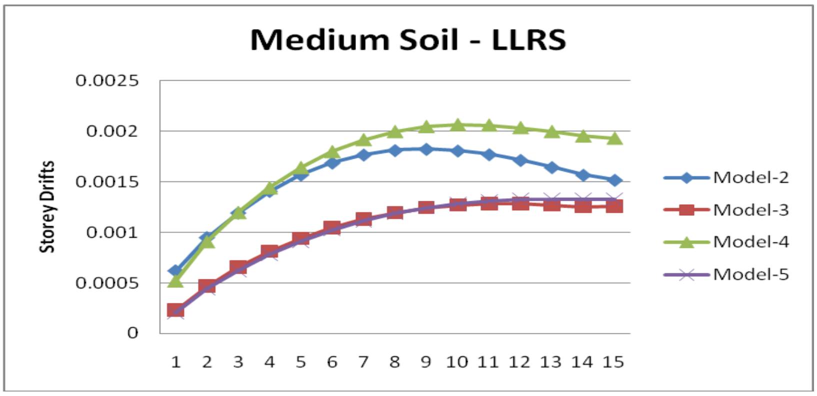


Figure 11. Storey Drifts for Medium Soil (LLRS)

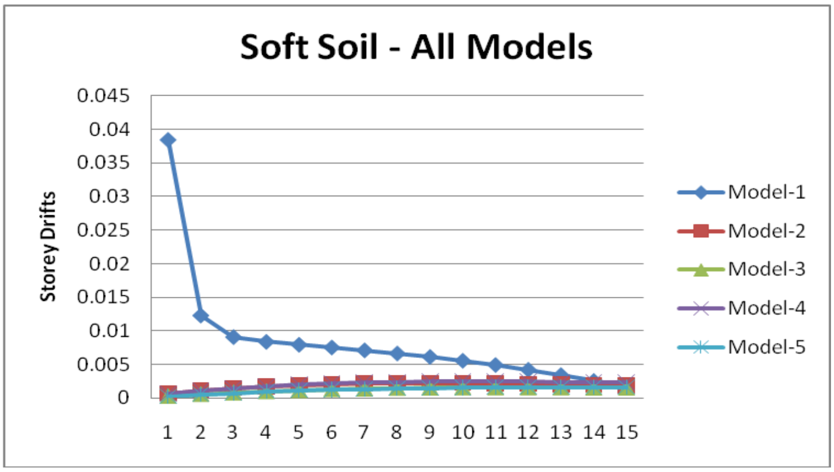


Figure 12. Storey Drifts for Soft Soil (All Models)

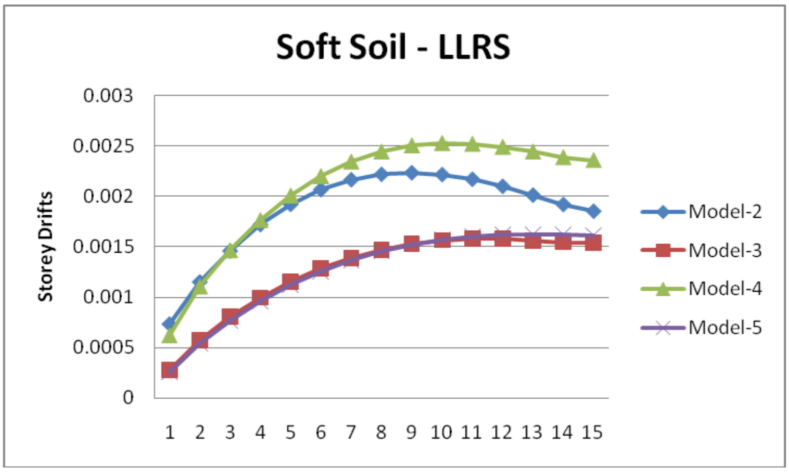


Figure 13. Storey Drifts for Soft Soil (LLRS)

3.3. 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.

Calculation of base shear depends on soil conditions at the site.

The results of base shear in X-direction and Y-direction of various lateral load resisting systems are presented in and respectively.

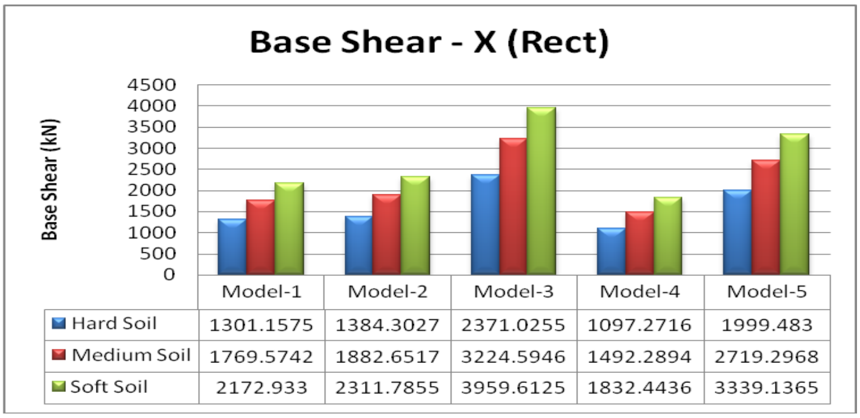


Figure 14. Base Shear in X-Direction

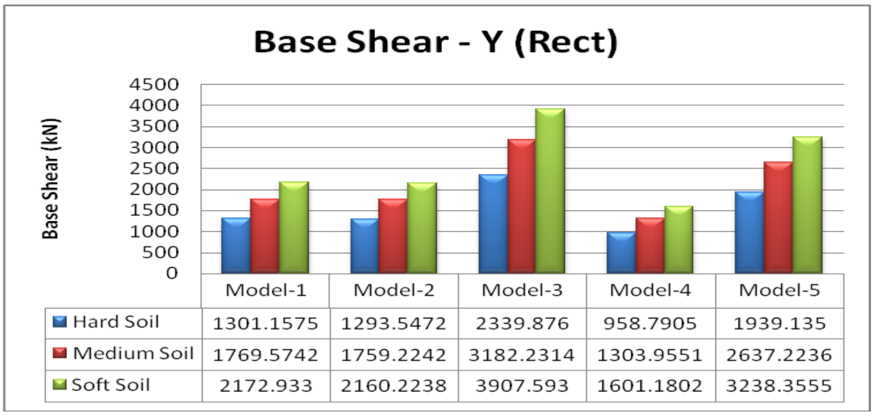


Figure 15. Base Shear in Y-Direction

3.4. Torsional Moment

Maximum torsional moment occurs at bottom storey. So here data collected are from Storey-1 for Response Spectrum case.

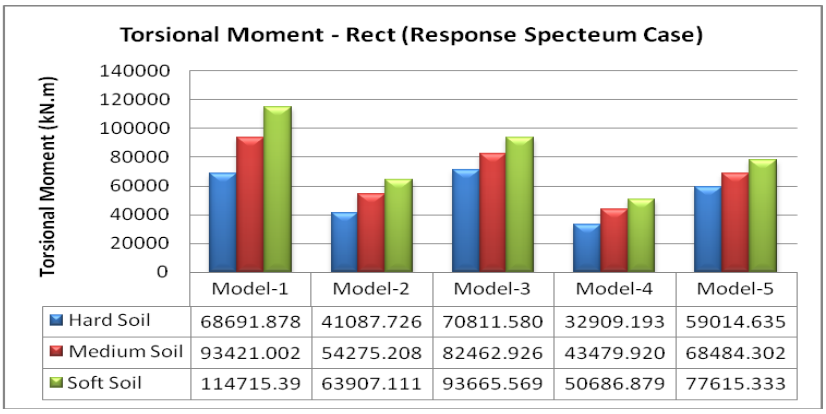


Figure 16. Torsional Moment

3.5. Time Period

Fundamental natural period is first longest modal time period of vibration. The results of natural time period for various LLRS are presented in charts for all types of soils.

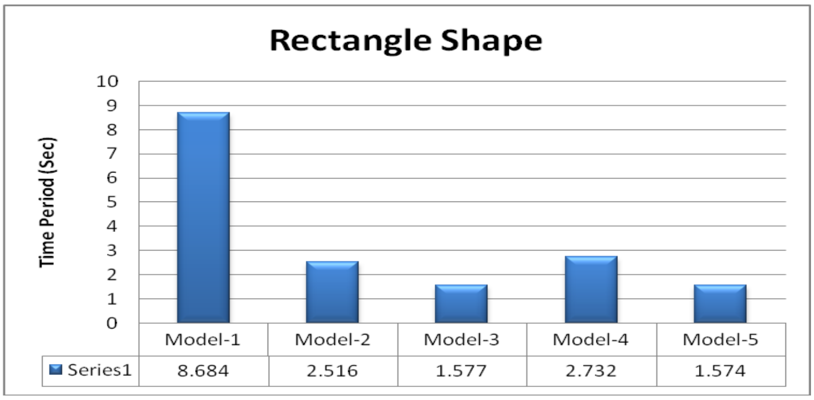


Figure 17. Time Period

3.6. Storey Acceleration

Maximum storey acceleration occurs at top storey for Response Spectrum case. So here data collected are for top storey.

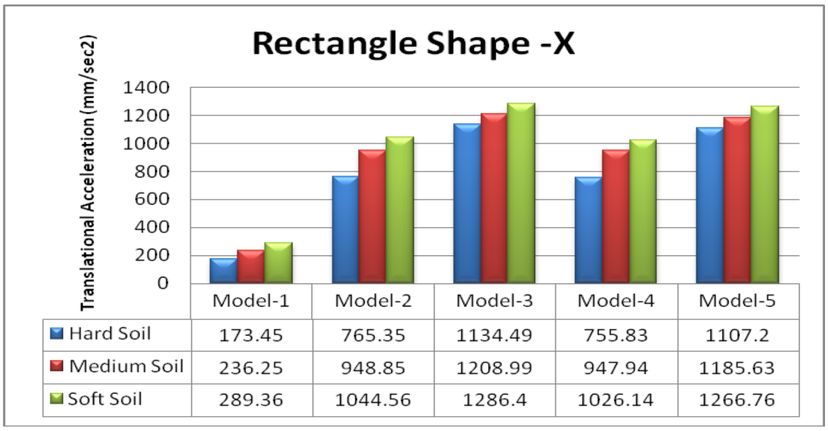
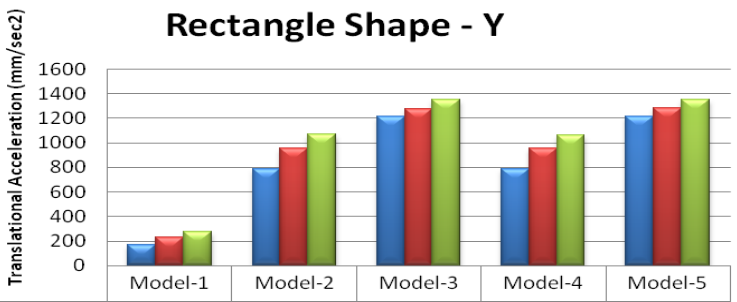


Figure 18. Storey Acceleration in X-Direction



	Model-1	Model-2	Model-3	Model-4	Model-5
Hard Soil	166.51	786.52	1211.82	785.56	1214.44
Medium Soil	226.53	954.36	1279.73	956.36	1282.49
Soft Soil	278	1068.4	1350.9	1066.26	1353.81

Figure 19. Storey Acceleration in Y-Direction

IV. CONCLUSION

● As per IS 1893 (Part 1) (2002) in clause 7.11.1 Page.27, permissible deflection should not exceed 0.004 times the total height of the building. So in present study for Model-1 (Bare frame), this limit exceeds for all types of soils. But after providing Lateral load resisting systems to the frame it is within the permissible deflection.

● There are decrements in top storey displacements for Model-2, Model-3, Model-4 and Model-5. But Model-3 (MRSW) is showing least top storey displacements and these decrements are 86.50%, 86.48% and 86.49% in Y-direction for Hard soil, Medium soil and Soft soil respectively.

● Storey Drifts are greater in Model-1 (Bare Frame) compare to all other four models for all types of soils (Hard soil, Medium soil and Soft soil).

● After providing Lateral Load Resisting Systems to the frame there is massive decrement in storey drifts. But Model-3 (MRSW) and Model-5 (FSSW) are showing least and almost same storey drifts.

● The average increase in Base Shear in X-direction is about 82% and 58% for Model-3 (MRSW) and Model-5 (FSSW) respectively as compared to bare frame. This is due to the increase mass of the structure the base shear also increases.

● Similarly the increase in Base Shear in Y-direction is about 79% and 49% for Model-3 (MRSW) and Model-5 (FSSW) respectively as compared to bare frame. This is due to the increase mass of the structure the base shear also increases.

● Base Shear is greater in X-direction compare to Y-direction is due to shape of building (Rectangle Shape) and also due to position of Shear walls. Longer side of building is in X-direction, that's why mass of structure is greater in X-direction compare to Y-direction.

● Torsional Moment is maximum for Model-1 (Bare Frame) in Medium Soil and Soft Soil but in Hard soil Model-3 (MRSW) is showing high Torsional Moment compare to Bare Frame. After providing lateral load resisting systems to the frame, Torsional moment reduces for Medium soil and Soft soil.

● Time Period for Bare frame building is too high when compared to building with lateral load resisting system. It indicates that the Time Period for Model-3 (MRSW) and Model-5 (FSSW) has less and almost same Time Period when compared to all other models. Since the mass and stiffness of the building increases, it is effective in resisting the lateral forces which helps in reducing the time period.

● As the Time Period is reduces for Model-5 (FSSW) and Model-3 (MRSW), Storey acceleration becomes higher in both the direction for Model-5 (FSSW) and Model-3 (MRSW) for all types of soils.

● So overall, Model-3 (MRSW) is most convenient Lateral Load Resisting System for rectangle Shape buildings to reduce Top Storey Displacements, Storey Drifts, Time Period etc.

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