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Seismic Analysis of Building with Shear Wall on Sloping Ground

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Abstract: **This study investigates the seismic performance of shear wall building on sloping ground. The main objective is to understand the behaviour of the building on sloping ground for various positions of shear walls and to study the effectiveness of shear wall on sloping ground. The performance of building has been studied with the help of four mathematical models. Model one is of frame type structural system and other three models are of dual type (shear wall- frame interaction) structural system with three different positions of shear walls. Response spectrum analysis is carried out by using finite element software SAP 2000. The performance of building with respect to displacement, story drift and maximum forces in columns has been presented in this paper.**

Keywords: **Sloping ground, Shear wall, Position, Performance, Earthquake analysis, Effectiveness.**

I. INTRODUCTION

Shear walls are one of the most efficient lateral force resisting elements in multistoried buildings. Many modern construction uses shear wall as main source for lateral force resistance, and can also be used for seismic rehabilitation of existing buildings. Since plastic hinges forms in the beams and not in the wall shear wall frame interaction system is more reliable. In addition, benefit of reducing lateral sway in the building under seismic loading can be available using shear wall.

Geological features have special importance in certain area. Now days due to increasing demand of space certain building will have to be constructed without disturbing the existing geological profile. The multi-storeyed building situated on slopping ground can effectively reduce the cost of foundation. When shear walls are provided at a proper location in a building they can prove to be very efficient at the same time they can act as a partion wall. When the building is situated on a sloping ground short column effect arise in a building. The Poor behaviour of short column is due to the fact that in an earthquake a tall column and a short column of same cross section move horizontally by same amount, however a short column is stiffer as compared to the tall column and it attracts larger earthquake forces. When these columns are not properly designed for such a huge forces the building can suffer a considerable damage due to earthquake. The building on sloping ground is unsymmetrical about one of the principle axis and hence location of shear wall becomes crucial. It is important to select a position of shear wall that will offer the best resistance against the lateral forces.

II. BUILDING DISCRIPTION

Building considered for a study purpose is a G + 7 residential building situated in seismic zone IV. Structural plan of the building is shown in figure 1, and other analysis data is as shown in table.1

Table I: Analysis Data

Response reduction factor	5
Response reduction factor	1
Importance factor	Hard
Soil condition	17.5mX17.5m

Plan size	1.5m
Depth of foundation	200mm
Thickness of shear wall	120mm
Depth of slab	3.1m
Floor to floor height	500X500mm
Size of column	300X450mm
Size of beam	Fe 415
Grade of steel	M 20
Grade of concrete	3 KN/m^2
Live load	1:3 (18'26")
Slope of ground	5
Grade of steel	1
Grade of concrete	Hard
Live load	17.5mX17.5m
Slope of ground	1.5m

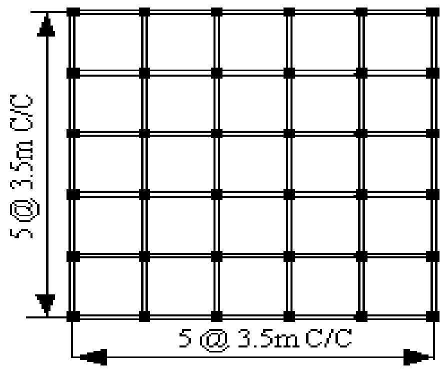


Fig. 1: Plan of building

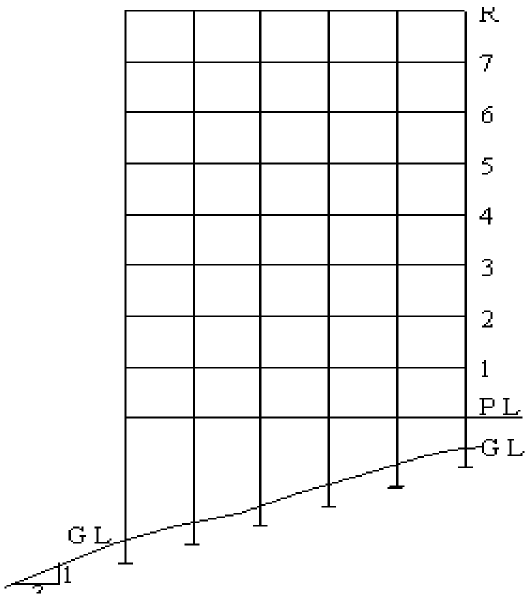


Fig. 2: Elevation of building

III. MODELLING AND ANALYSIS

Building is modelled by using finite element software SAP 2000. Beams and columns are modelled as two nodded beam element with six DOF at each node. Slab and shear wall is modelled by using shell element. Walls are modelled by equivalent strut approach. The thickness of strut is same as thickness of brick infill wall and only width of the strut is derived. Four models for the building are prepared as shown in figure 1 and 2. Model one is of frame type structural system and other three models are of shear wall frame interaction system. Total four shear walls are provided two on sloping side and other two on other side of the building. In model II all the four walls are provided towards the shorter columns of the building on corner, i.e. two on sloping side and two on other side. In model III all the four walls are provided towards the longer columns of the building. In model IV shear walls are arranged symmetrically in plan. Response spectrum analysis is carried out on the models as per IS 1893:2002 (Part I).Comparison between each of the following model is made based on analysis results and are presented in graphical format.

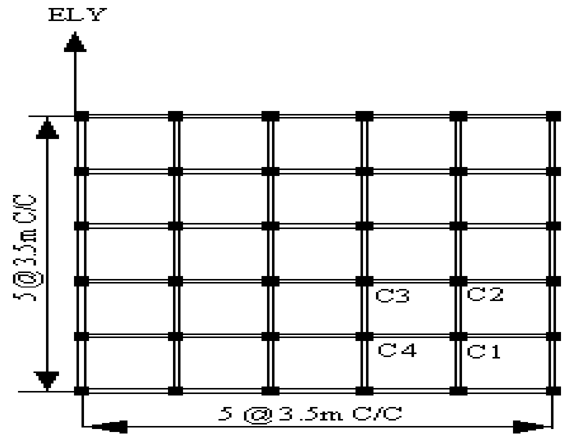


Fig. 3: Model I

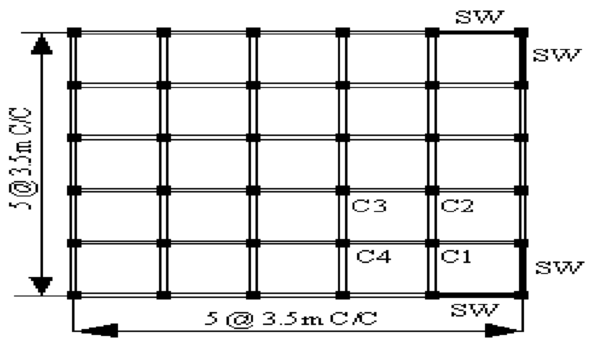


Fig. 4: Model II

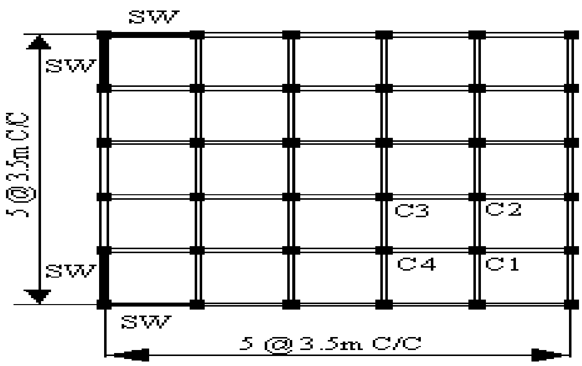


Fig. 5: Model IV

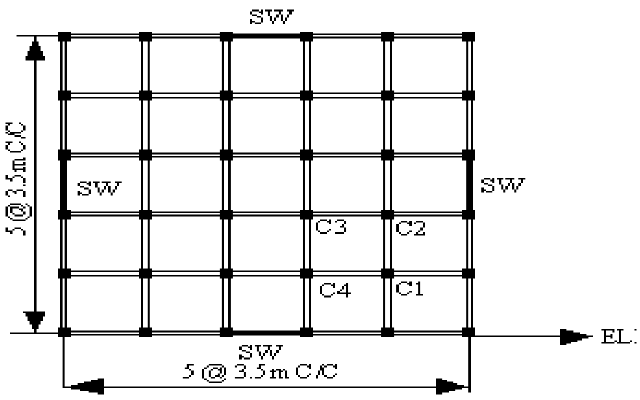
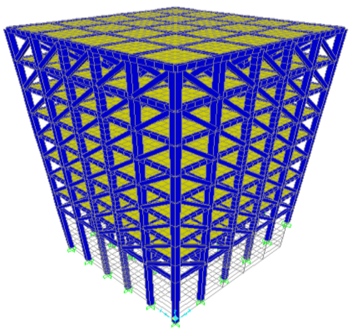


Fig. 6: Model V



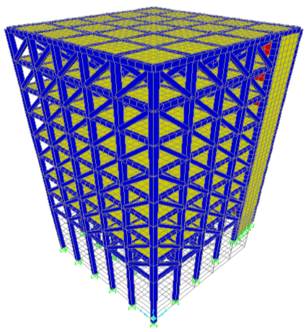
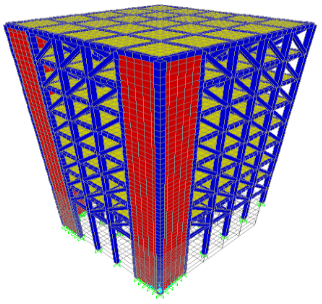


Fig. 7: Mathematical Model I **Fig. 8: Mathematical Model II**



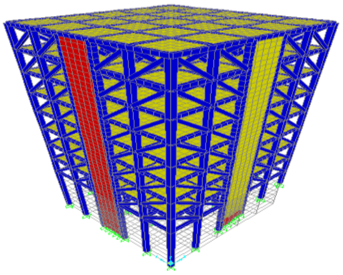


Fig. 9: Mathematical Model III **Fig. 10: Mathematical Model IV**

IV. RESULTS AND DISCUSSION

Results of response spectrum analysis as per IS 1893:2002 (Part I) on the above four models with respect to displacement, storey drift and maximum forces in columns C1, C2, C3 and C4 are shown below. Percentage reduction in bending moment, shear force and torsional forces as compared with frame type structural system is also represented.

Displacement

Displacement profile for above models along both the principle directions is shown in figure 11 and 12. In the direction of ground slope displacement is found to be minimum in model III (Shear wall provided towards long column side). The roof displacement for model III is reduced up to 43.62% as compared with model I and about 43.38% as compared with model II. In other direction where ground profile is flat Model IV gives minimum displacement. It is reduced by 33.23% as compared with model I and about 14.7% as compared with model III.

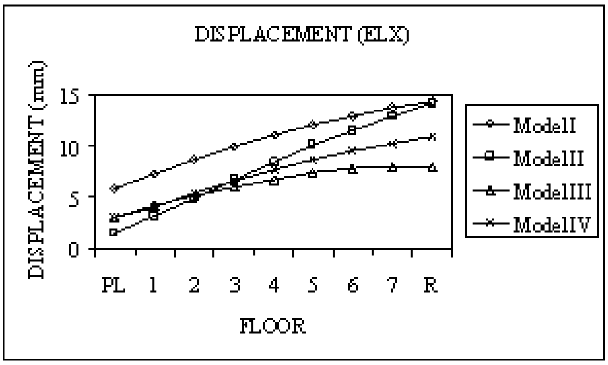


Fig. 11: Displacement along X

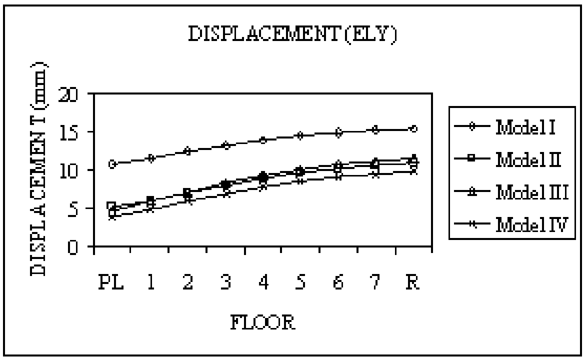


Fig. 12: Displacement along Y

Storey drift

Comparison of storey drift for above four models is as shown in figure 13 and 14. Storey drift for model III (shear wall towards long column side) is minimum along sloping side, where as on other side model I give minimum drift. Storey drift for shear wall frame interaction system is more than frame type structural system along other side of building this may be because of stiffness irregularity. On sloping side top storey drift for model III is reduced up to 94.615% as compared with model II.

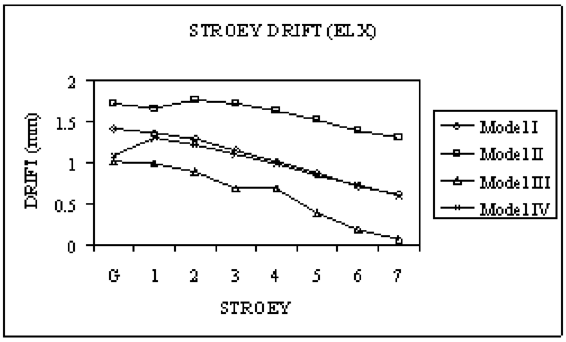


Fig. 13: Storey drift Along X

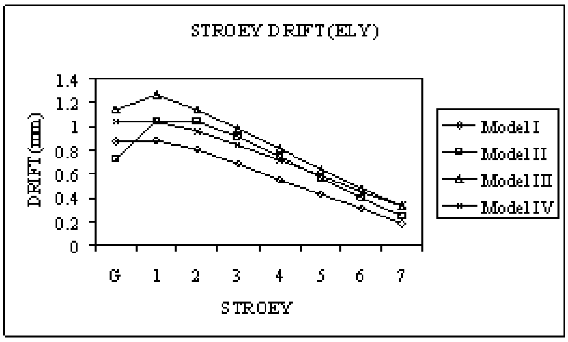


Fig. 14: Storey drift Along Y

Maximum forces

Comparisons of forces for columns are shown in figure 15 to 21 below. Percentage reduction in bending moment and shear force is represented in figure 21 to 25. Shear wall provided towards shorter column side (model II) gives minimum shear force and bending moment as compared with other two positions but torsional forces on column is found to be maximum for model II (shear wall towards shorter column). Shear force and bending moment is found to be maximum for model III (Shear walls on longer column side). Percentage reduction in shear force and bending moment for shear wall fame interaction system as compared with frame type structural system is represented in figure 22 to 25.

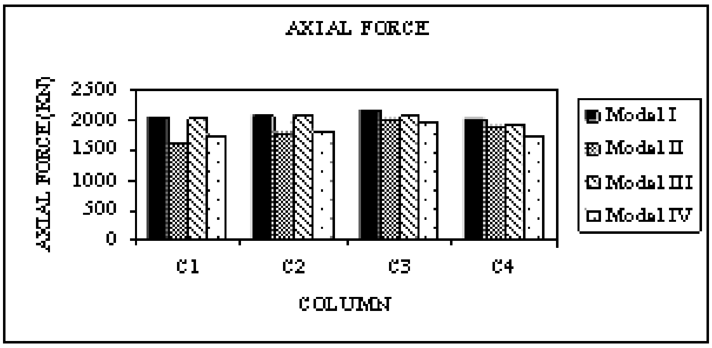


Fig. 15: Axial Force

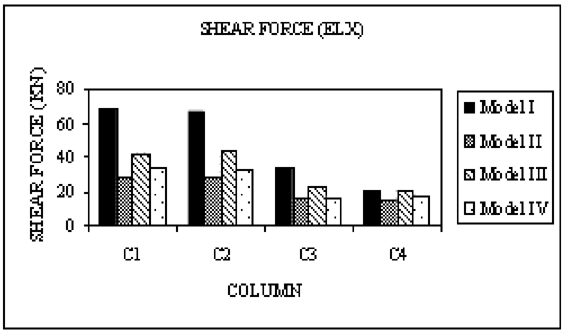


Fig. 16: Shear force along X

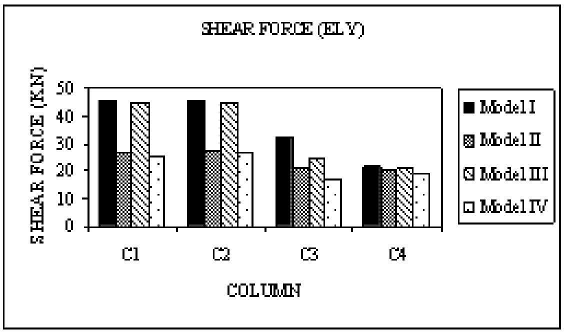


Fig. 17: Shear force along Y

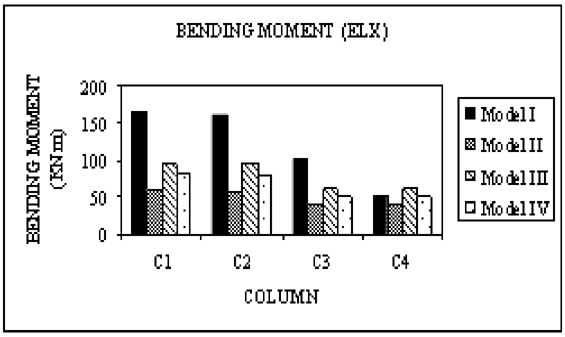


Fig. 18: Bending Moment along X

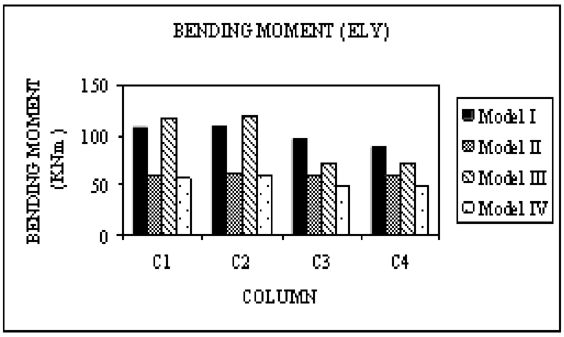


Fig. 19: Bending Moment along Y

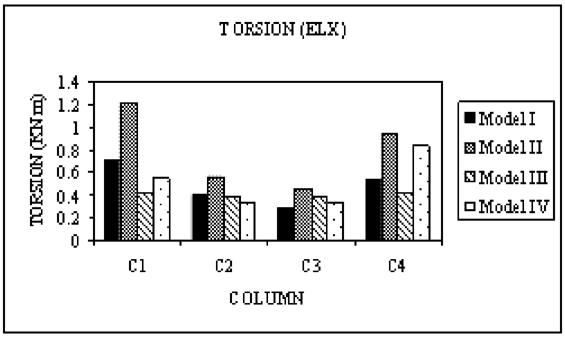


Fig. 20: Torsion along X

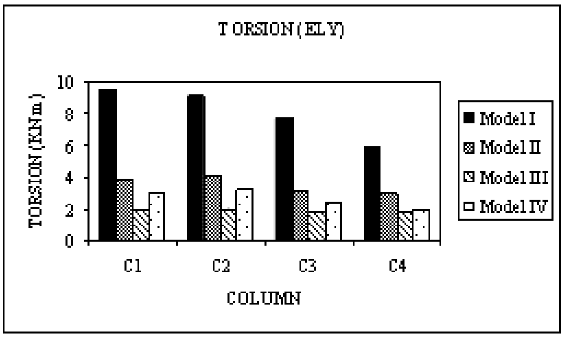


Fig. 21: Torsion along Y

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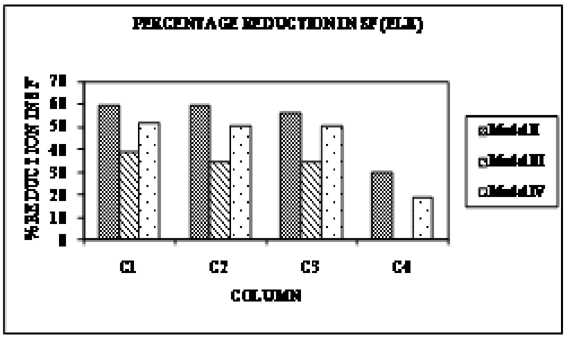

Figure 22: Percentage reduction in BM along X

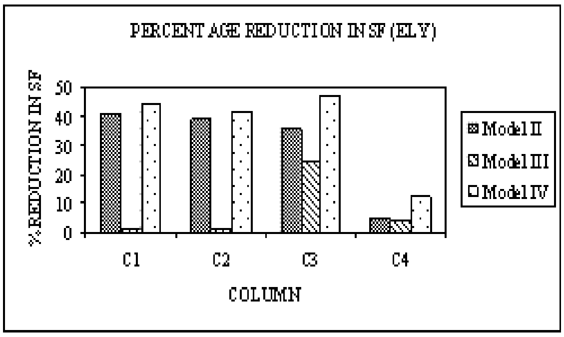

Figure 23: Percentage reduction in BM along Y

Time period and frequency of vibration

Time period and frequency of vibration for the above four models are shown in table 2 and comparison of tine period is represented in figure 26.

Table II: Time Period and Frequency of Vibration

Mode	Model I		Model II		Model III		Model IV	
	Time period (Sec)	Frequency (Cyc/ sec)	Time period (Sec)	Frequency (Cyc/ sec)	Time period (Sec)	Frequency (Cyc/ sec)	Time period (Sec)	Frequency (Cyc/ sec)
1	1.056277	0.94672	0.632194	1.5818	0.643411	1.5542	0.57603	1.736
2	0.808653	1.2366	0.492228	2.0316	0.599312	1.6686	0.55353	1.8066
3	0.61403	1.6286	0.320459	3.1205	0.387619	2.5798	0.36787	2.7183
4	0.22759	4.3939	0.185082	5.403	0.190468	5.2502	0.17667	5.66
5	0.222265	4.4991	0.164506	6.0788	0.177908	5.6209	0.17277	5.7878
6	0.158145	6.3233	0.107212	9.3273	0.11515	8.6843	0.11377	8.7895
7	0.113483	8.8119	0.104082	9.6078	0.106284	9.4087	0.10258	9.7483
8	0.103601	9.6524	0.092936	10.76	0.094139	10.623	0.09270	10.786
9	0.102919	9.7163	0.088906	11.248	0.090179	11.089	0.08943	11.182
10	0.089215	11.209	0.084335	11.858	0.08351	11.975	0.08504	11.758
11	0.08805	11.357	0.081151	12.323	0.08203	12.191	0.08016	12.474
12	0.084432	11.844	0.068498	14.599	0.073671	13.574	0.07909	12.643

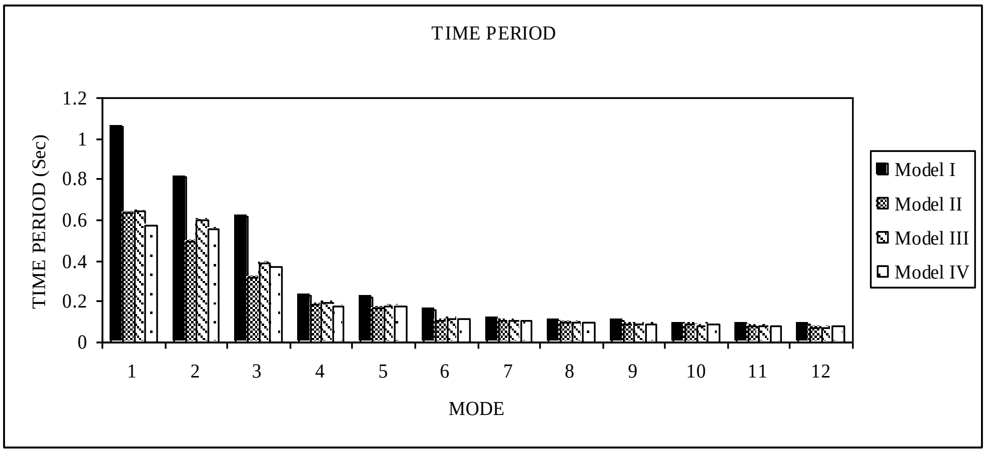

Figure 24: Time period of vibration

V. CONCLUSION

- For the buildings on the sloping ground location of shear walls are very important for resisting earthquake forces.
- Displacement and storey drift along sloping side is found to be minimum for model II where as on other side model III gives minimum displacement and drift. Good control over the displacement and storey drift can be achieved if the shear walls are located symmetrically in plan.
- Short columns are the most critical member for the building on sloping ground. To have a good control over the forces such as shear force and bending moment it is preferable to locate the shear wall towards the shorter column side.
- Bending moment and shear force along sloping side is found to be minimum for model II (shear wall towards shorter column), whereas on other side model IV (Shear wall located symmetrically in plan) gives minimum shear force and bending moment.
- There is maximum of 59.33% reduction in shear force and about 64.02% reduction in bending moment is observed for model II along sloping side as compared with frame type structural system.
- Tosional forces are minimum for model III (shear wall towards longer column) along both the principle direction. Hence torsion can be effectively reduced if shear walls are provided along longer column side.
- Twisting moment along other direction is found to be more than sloping side.
- Torsional forces are maximum for model II (shear wall towards shorter column), thus the columns which are close to shear wall carry the maximum torsional forces.
- Time period of vibration for building with shear walls located towards shorter column is found to be least than any other location.

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