Effect of Positioning of RC Shear Walls on Seismic Performance of Building Resting on Plain and Sloping Ground

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Abstract: Buildings constructed on sloping ground are different from those in plain ground. They may be irregular and unsymmetrical in plan and elevation, and torsionally coupled. Hence, they are susceptible to damage when affected by lateral doads like earthquake ground motion and wind load. Therefore it is very important to consider lateral loads and design lateral load resistant buildings from the safety point of view. Shear wall is one of the most commonly used for lateral load resisting system like earthquake and wind load in the buildings for its better seismic performance. Shear walls are the ideal choice to resist lateral loads in high rise Concrete buildings. Hence in the present work, an number of attempt is made to study the seismic behavior of the multi-storey buildings constructed on plain and various sloping ground with and without shear walls. The behavior of the building with different configurations of shear walls such as straight, L-shape, T-shape and C-shape studied. For all shear walls configurations under considerations the length of shear wall in two directions(X &Y) in plan is kept equal. The RCC building models having (G+6) storey resting on plain and sloping ground with slope of (1V:2.33H) are considered for the analysis. The response spectrum analysis of building for Zone IV and Medium soil condition is carried out using structural engineering software Etab 2016. Finally the results for seismic behavior of buildings are compared with respect to time period, base shear, lateral displacement, and member forces. At the end of study, efficient positioning of shear walls configuration to be used is suggested.

Keywords — shear wall, seismic performance, sloping ground, response spectrum analysis, Etab.

I. INTRODUCTION

The structures are generally constructed on leveled ground however due to rapid growth of population and decrease of land construction activities have been started on sloping ground. Therefore there is popular demand for the construction of high rise buildings on hill slope in and around the cities. Construction of Buildings resting on sloping ground are different from those Construction of buildings which are resting on plain ground. The buildings which are located in hilly or sloping ground areas in earthquake prone regions are generally irregular, unsymmetrical, and torsionally coupled and hence, susceptible to damage when affected by earthquake ground motion. Such buildings have mass and stiffness varying along the vertical planes and horizontal planes, resulting the center of mass and center of rigidity do not coincide on various floors of the building, hence they demand torsional analysis, in addition to lateral forces under the action of earthquakes. These unsymmetrical buildings require great attention at the time of analysis and design. Analysis of buildings on sloping ground is somewhat different than the construction of buildings on leveled ground, since the column of buildings on sloping ground rests at different levels on the slope. The shorter column nearest to ridge attracts more forces and undergoes damage, when subjected to lateral load like earthquakes. Therefore it is mandatory to apply a system to resisting earthquake.

Now a day's many structural forms are used to resist earthquake in multistory buildings which are given below.

1. Rigid frame structure (most commonly used).
2. Shear wall-frame structure.
3. Braced frame structure.
4. Arches and cable structure.
5. Core structure.
6. Outrigger structure
7. In-filled wall-frame structure etc.

Appropriate structural forms are used as requirements. The shear wall-frame structure has been taken in interest in the presented paper. Shear walls systems are one of the most

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commonly used lateral load resisting systems in multi-storied buildings. Shear walls have very high in lateral in plane stiffness and strength, which can be used to simultaneously resist large lateral loads and support gravity loads, making them quite advantageous. The Concept of designing shear wall is to provide building structure with sufficient strength and deformation capacity to sustain the demands imposed by lateral loads with adequate margin of safety**.** Hence to upgrade the seismic performance of building shear walls play very important role. So there is important to study the shape and positioning of shear walls on seismic performance of building situated on sloping ground. In this study effort has been made to the seismic response of RC buildings with different shear walls configurations such as straight, L shape, channel shape and T shape on plain and sloping ground. The main objectives of the study are

1) To study seismic performance of building with and without shear walls resting on plain ground and sloping ground.
2) To study the potency of various shear walls configurations on seismic performance of building resting on plain and sloping ground such as straight, L shape, channel shape and T shape.
3) To suggest efficient positioning of shear walls for construction of building resting on sloping ground for its better seismic performance.
4) To study the comparison of effect of positioning of shear walls on seismic performance of building on plain ground and sloping ground.

II STRUCTURAL MODELING AND ANALYSIS

2.1 Building Description:

Models consists of (G+6) storied RCC building having six bays in each principal direction; each bay is having width of 3.5m. The models are analyzed on leveled ground as well as sloping ground (slope 1V:2.33H). The building is kept symmetrical in both principal directions in plan and the all the columns provided of square in size to avoid torsional response under pure lateral forces. While the total length of shear walls in each configuration in plan is kept same in two different directions in plan. The structure on leveled ground and sloping ground under consideration for present study is as shown in Fig. 1 (shows plan of building) and Fig. 2 (shows elevation of building on leveled and sloping ground).The detailed description of geometric properties, material properties, earthquake parameters is as shown in table1,2&3 respectively.

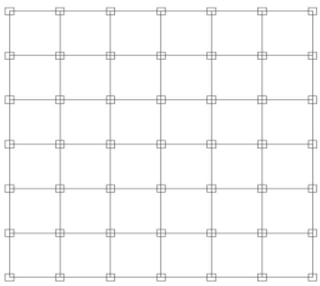

Fig. 1 Plan of building

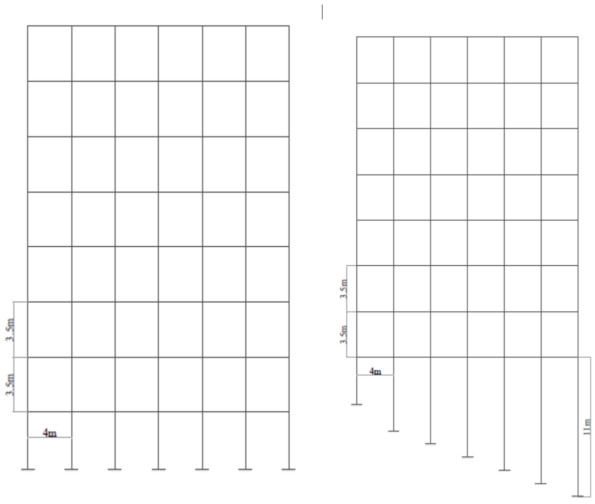

Fig. 2 Elevation of building on leveled and sloping ground.

Floor to Floor Height	3.5 m
Size of Building	24 m X 24 m
Plinth height above foundation	1.5 m
Parapet Height	1.0 m
Slab Thickness	120 mm
Wall Thickness (external)	230 mm
Wall Thickness (internal)	115 mm
Shear Wall Thickness	300 mm
Size of Beam	300 mm X 500 mm
Size of Column	500 mm X 500 mm
No of Stories	(G+6)
No of Bays in X & Y Direction	6 bays
Spacing of Bays in X & Y Direction	4 m

Table 1. Geometric Properties

Grade of Concrete	M 20
Grade of Steel	Fe 415
Density of Concrete	25 KN/m3
Density of Masonary wall	20 KN/m3
Modulus of Elasticity for Concrete	2236080 KN/m2

Table 2. Material Properties

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Seismic Zone	IV
Soil Condition	Medium
Building Frame	Special Moment Resting Frame (SMRF)
Importance Factor	1
Response Reduction factor	5

Table 3. Earthquake Parameters

2.2 Loads and Load Combinations

➢ Loads:

1. **Dead loads:** (IS 875-1987 PART-I)

Self-weight: It is calculated by the software based on section properties and material constants provided.

Super imposed dead load (floor finishes or water proofing's) all floors =1.875 kN/m^2

Wall load on periphery (external 230 mm thick) = 12 kN/m

Wall load on internal beams (internal 230 mm thick) = 6 kN/m

Parapet wall load= 4.6 kN/m

2. **Live Loads:** (IS 875-1987 PART-II)

Live load on floor = 4 kN/m^2

Live load on roof =1.5kN/m^2

➢ **Load Combinations:** (IS 875-1987 PART-II)

Following load combinations with the appropriate partial safety factor satisfying IS code provision i.e.IS 456:2000, table 18, clause 18.2.3.1 and IS 1893:2002, clauses 6.3.2.1 are shown in (table I).

2.3 Description of models:

Shear walls and its configurations play very important role to improve the seismic performance of building. So there is need to study the effect of positioning of shear wall on seismic performance of building on plain and sloping ground. Hence in this study the attempt is made to analyze the multistorey buildings on plain and sloping ground with and without shear walls. The performance of the building with various configurations of shear walls like straight, channel shape, T shape and L shape is studied with respect to the parameters such as base shear, fundamental time period, top floor displacement and member forces are compared within the considered configurations of shear walls. The three columns A, B and C as shown in Fig.3 are considered for the study of member forces.

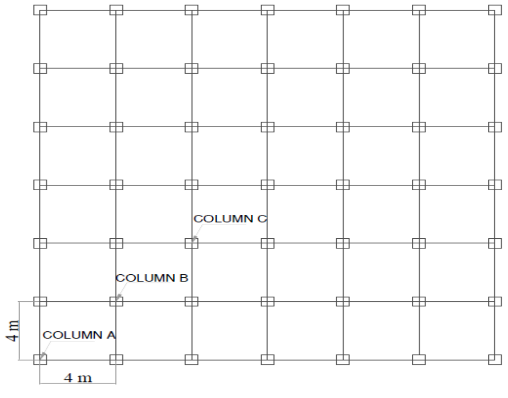


Fig. 3 Plan of building showing columns A, B and C

The models with different shear walls configurations are considered for buildings on plain and sloping ground in this study.

2.4 Modeling:

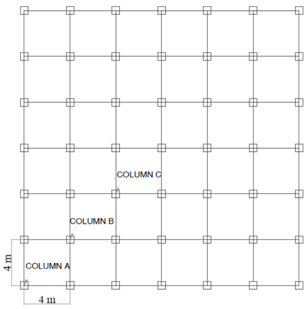
The building is modeled using finite element software ETAB 2016-V16 2.0. Beams and columns are modeled as line element with six degrees of freedom at each node. Slabs are modeled as membrane elements and diaphragm constraint is assigned. The area loads are applied on the slabs. Building modeled as a bare frame however the dead weight of wall is assigned as uniformly distributed load over beams. The shear wall is modeled by wide column analogy method and fixed supports are considered for both shear wall and columns. In wide column analogy method, each shear wall is replaced by an idealized frame structure consisting of a column and rigid beams located at floor levels. The column is placed at the centroidal axis of shear wall and assigned to have inertia and axial area of shear wall. The beams that join the column to the connecting beams are located at each floor level. In this study, the axial area and inertia values of rigid arms are assigned very large values compared to other frame elements. Total 10 numbers of models are analyzed for the study of effect of positioning of RC shear walls. The following models of building are considered on plane and sloping ground:

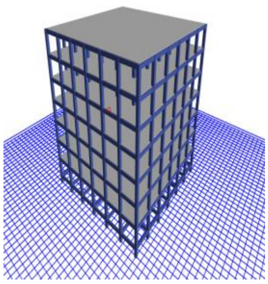
Models on plain ground

Model 1	PW-1	without shear wall	Fig. 4
Model 2	PS-2	with straight shape shear walls	Fig. 5
Model 3	PL-3	with L-shape shear walls	Fig. 6
Model 4	PT-4	with T-shape shear walls	Fig. 7
Model 5	PC-5	with channel-shape shear walls	Fig. 8

Models on sloping ground

Model 6	SW-1	without shear wall	Fig. 4
Model 7	SS-2	with straight shape shear walls	Fig. 5
Model 8	SL-3	with L-shape shear walls	Fig. 6
Model 9	ST-4	with T-shape shear walls	Fig. 7
Model 10	SC-5	with channel-shape shear walls	Fig. 8





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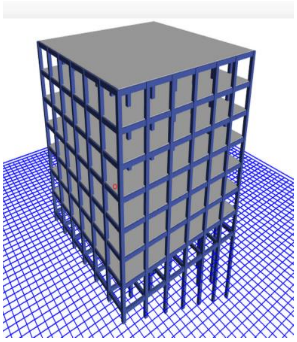


Fig. 4 Building without shear wall on plain and sloping ground

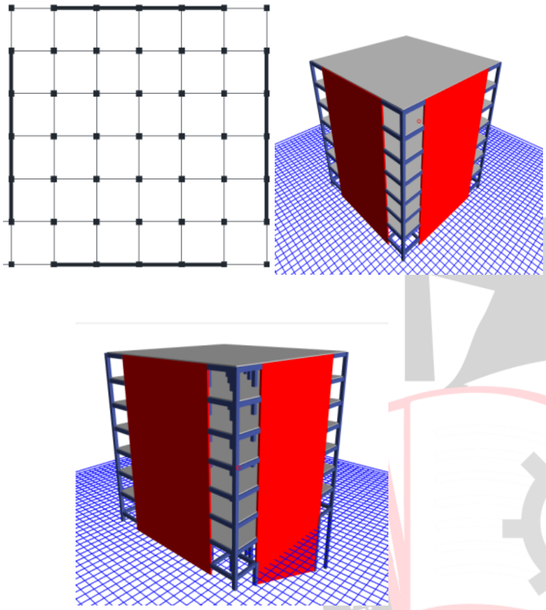


Fig. 5 Building with straight shape shear walls on plain and sloping ground

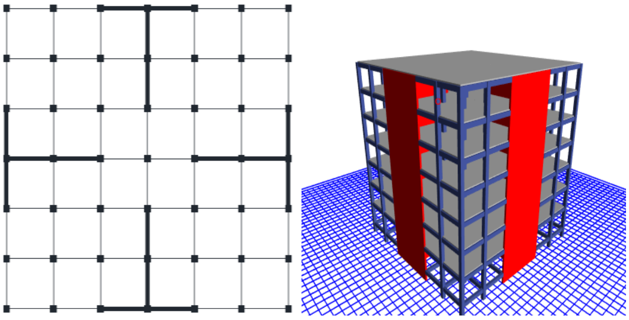
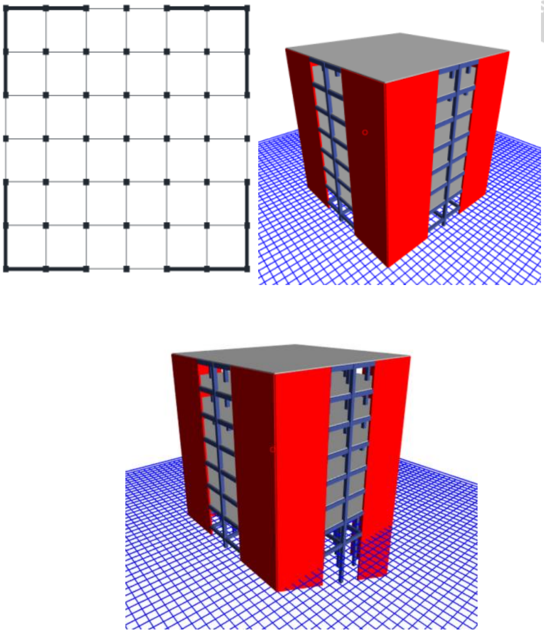


Fig. 6 Building with L-shape shear walls on plain and sloping ground



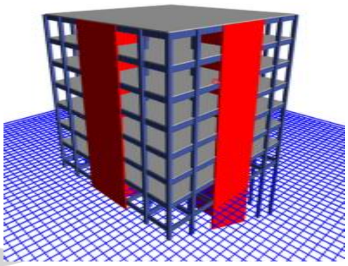


Fig. 7 Building with T-shape shear walls on plain and sloping ground

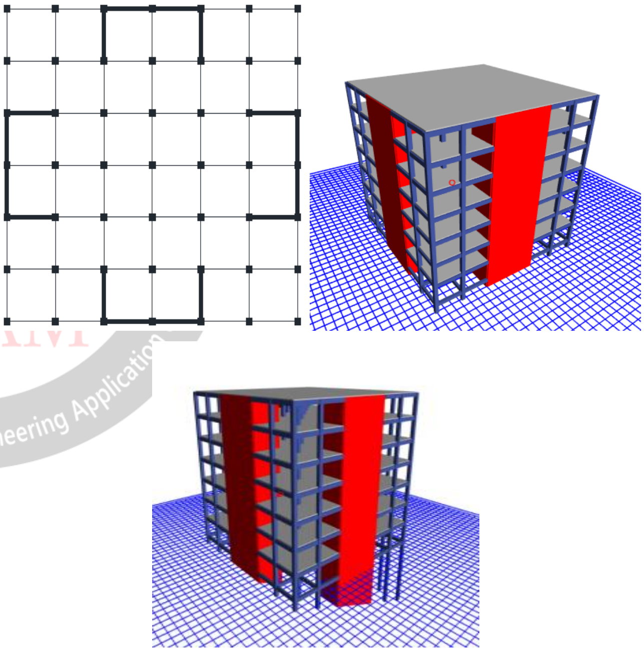


Fig. 8 Building with Channel-shape shear walls on plain and sloping ground

2.5 **Method of Analysis**:

In this present study the lateral load as equivalent static load analysis and the response spectrum analysis are carried out for the determination of seismic parameters of building. The IS 1893 (Part 1): 2002 recommends 3D modeling for dynamic analysis (Response Spectrum analyses) of irregular buildings higher than 12m in zone IV and V, and buildings those higher than 40m in height in zone II and III. 3D analysis including shear force, bending moment and torsional moment effect has been carried out by using response spectrum method for this study. Dynamic response

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of these structure, in terms of base shear, fundamental time period, roof displacement and member forces is presented, and compared within the considered configuration of shear walls as well as with considered model without shear walls on plain ground and sloping ground and at the end, potency positioning of shear walls configuration to be used is suggested. The seismic analysis of all structure is carried by Response Spectrum Method in accordance with IS: 1893 (Part 1): 2002. As per codal provisions for structure dynamic results are normalized by multiplying with a base shear ratio V_b/V_B , where V_b is the base shear evaluation based on time period given by equation from IS 1893-2002 and, V_B is the base shear from dynamic analysis , if V_b/V_B ratio is more than one. Damping considered for all modes of vibration was 5%. For calculating the seismic response of the buildings in different directions for ground motion the response spectrum analysis was conducted in longitudinal and transverse direction. The other parameters used in seismic analysis were, severe seismic zone (IV), zone factor 0.24, importance factor 1, special moment resisting frame (SMRF) for all models with a response reduction factor of 5. The default modal cases (i.e.12) in software was used and the modal responses were combined using CQC method. The response spectra for medium soil sites with 5% damping as per IS 1893 (Part1):2002 is utilized in response spectrum analysis.

III RESULTS AND DISCUSSION

The results of study are divided into two categories as follows.

1. Plain ground:

From this present study it can be observed that the incorporation of shear wall in RCC frame increases the base shear due to increase in lateral stiffness. The significant amount of reduce in time period of structure and there is considerable reduction in lateral displacement of structure also. The use of shear wall increases the base shear approximately by 40-50%. The model 3 i.e model having L-shape has minimum value of base shear among all other shear walls configurations. All the models with shear walls has approximately 65 % less time period as compared with model 1. Model 2 (Straight shape) has minimum time period. The reduction in lateral displacement is 88%, 85%, 85%,and 90% for model 2, 3, 4 and 5 as compared to model. The results gained from current study for seismic performance of building on plain ground are showed in Fig 9,10 and 11 for different models.

The comparison of member forces in three selected column shows significant reduction in shear force and bending moment in column. The axial forces parameter for all shear walls configuration does not show any significant effect. The shear force in column has reduced by 75- 85% as compared to model 1, whereas the bending moment in columns has reduced by 80%.The member forces such as axial forces, shear forces and bending moment are showed in Fig. 12, 13 and 14 respectively.

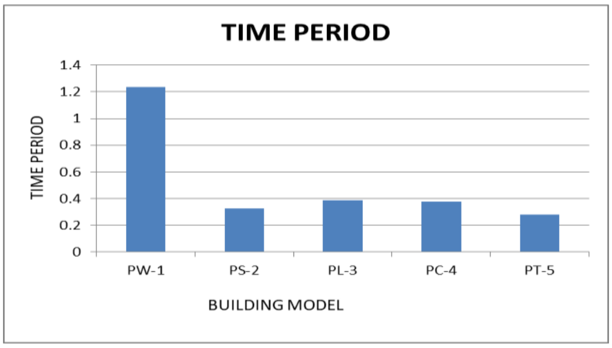

Fig. 9 Time Period for building on leveled ground

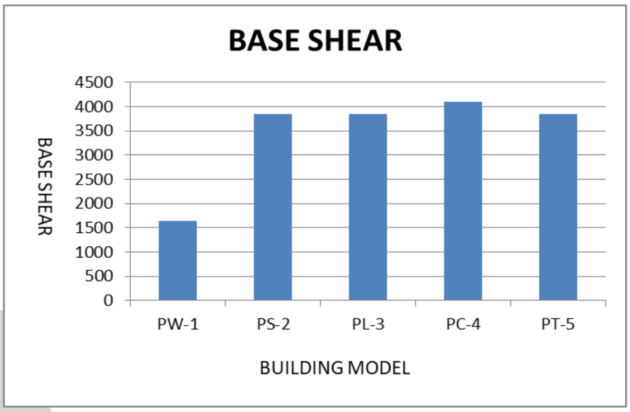

Fig.10 Base Shear for building on leveled ground

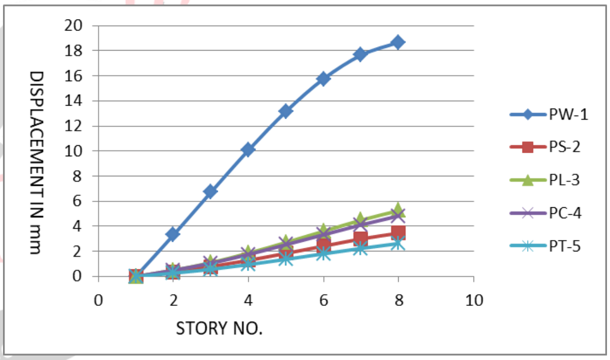

Fig.11 Lateral Displaccement for building on leveled ground

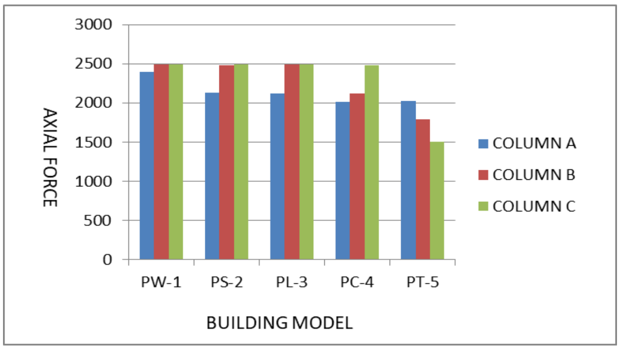

Fig.12 Axial Force in column for building on leveled ground

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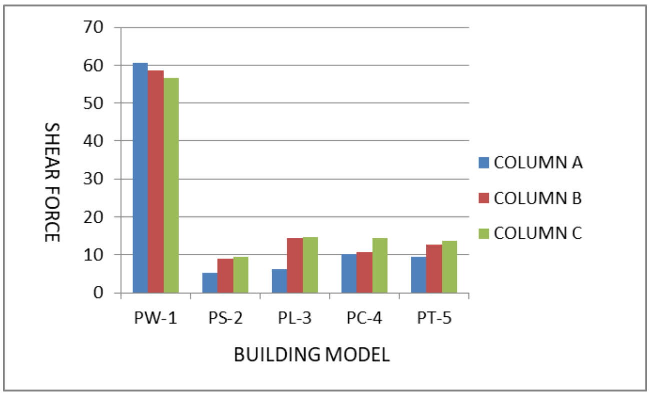

Fig.13 Shear Force in column for building on leveled ground

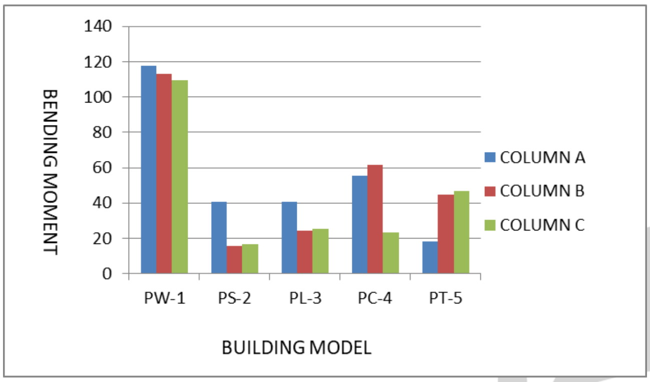

Fig.14 Bending Moment in column for building on leveled ground

2. Slopping ground:

From this study it is observed that the building on slopes are more vulnerable to seismic activity as compared to building on leveled ground of same configuration. The building on slopes shows the different behavior in two principal directions as presented in this study. The base shear of buildings on slope for different shear walls configuration is increased by approximately 50% along the both as compared to model 6. The lateral displacement observed in the direction parallel to slope is more as compared to displacement in transverse direction. Hence displacement in X-direction is only shown in fig 17. The reduction in lateral displacement is observed similar to that of models on leveled ground due to provision of shear walls in both directions. The time period of shear walled model get reduced by 50-60% as compared to model 6.The time period and lateral displacement observed is minimum for model 7 (straight shape) among all the configurations. The seismic performance of building o slope is as presented in Fig. 15, 16,17 and 18.

The shear forces and bending moments in columns also get reduced same as to model on leveled ground due to shear wall. The member forces such as axial forces, shear forces and bending moment are presented in Fig. 19,20 and 21 respectively.

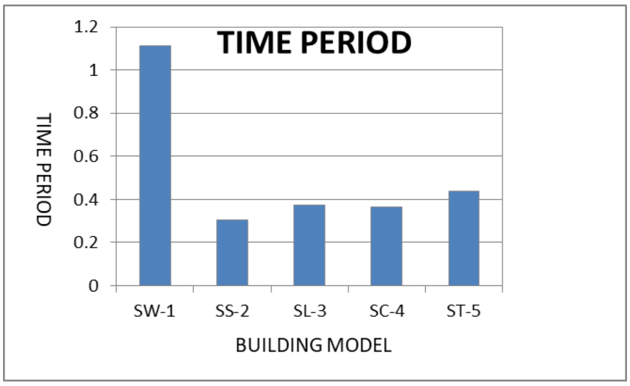

Fig. 15 Time Period for building on Sloping ground.

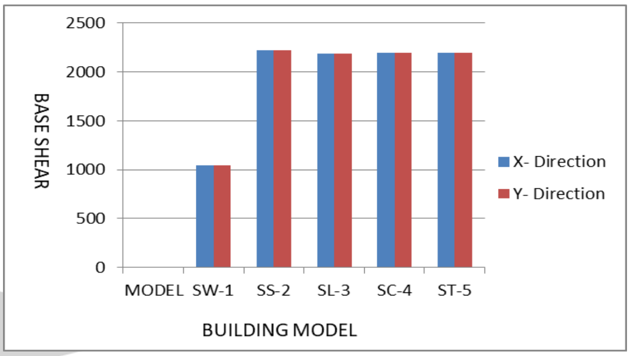

Fig. 16 Base Shear for building on Sloping ground.

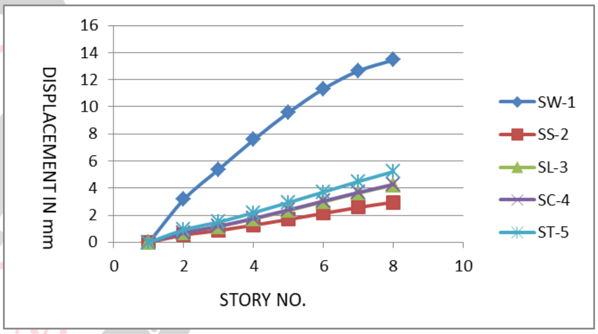

Fig. 17 Lateral Displacement in X-direction for building on Sloping ground.

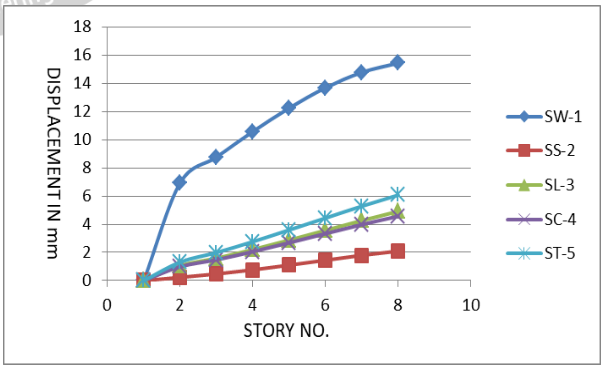

Fig. 18 Lateral Displacement in Y-direction for building on Sloping ground.

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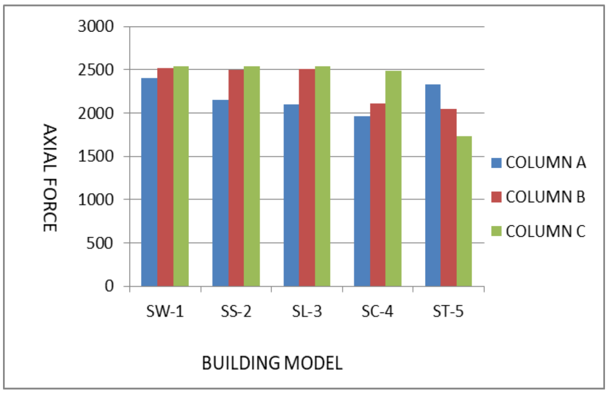

Fig. 19 Axial Force in column for building on Sloping ground.

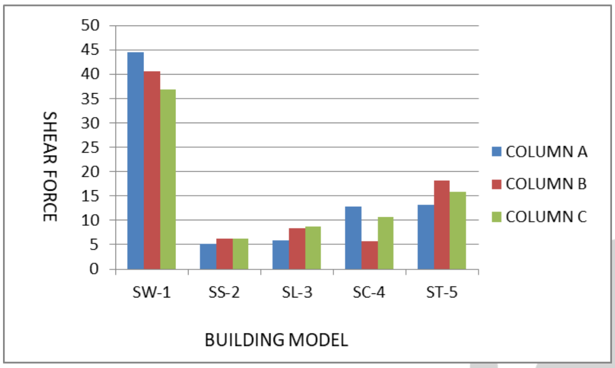

Fig. 20 Shear Force in column for building on Sloping ground.

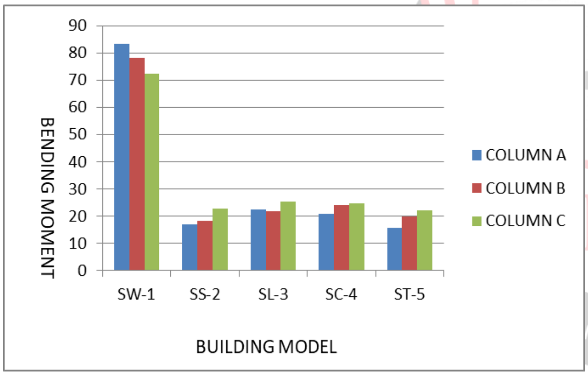

Fig. 21 Bending Moment in column for building on Sloping ground.

IV CONCLUSION

1. There is indicative improvement observed in seismic performance of building on leveled ground as well as on slopes by providing different configurations of shear wall.
2. In this project Use of T-shape shear walls gives more lateral displacement and member forces for buildings on slopes as compared to other configurations.
3. The straight shape shear walls configuration proves to be most desirable among all configurations for resisting the lateral displacement in both direction.

4. Model on plain ground is effective during seismic activity because the member forces developed in this configuration are less as compared to other configurations on sloping ground.
5. For buildings on slopes shortest column on slope side is much affected than other columns, due to higher stiffness. The base shear and displacement is more along the sloping side than in other transverse direction.
6. Model having L-shape shear wall gives more resisting to displacement and gives less base shear as compare to other.

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