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Research Article

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

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Abstract

Shear wall has high in plane stiffness and strength which can be used to simultaneously resist large horizontal loads and support gravity loads. For the buildings on sloping ground, the height of columns below plinth level is not same which affects the performance of building during earthquake. Thus to improve the seismic performance of building on sloping ground the shear walls play very important role. Hence in this study the attempt is made to analyse the multi-storey buildings on plain and sloping ground with and without shear walls. The performance of the building with various configurations of shear walls such as straight, L shape, T shape and channel shape is studied. For all shear walls configurations under considerations the length of shear wall in two principal directions in plan is kept equal. The RCC building models having G+6 storeys with shear walls and without shear walls resting on plain and sloping ground (slope 1V:2.33H) are considered for the study. The response spectrum analysis of building is carried out using structural engineering software SAP 2000 V 15.2.2 and the seismic performance of building with various shear walls configurations is compared with respect to parameters like base shear, lateral displacement, time period and member forces.

Keywords: *Buildings on slopes, buildings on plain ground, shear wall system, seismic performance, response spectrum analysis.*

1. Introduction

The economic growth and rapid urbanization in hilly region has accelerated the real estate development and resulted in increase in population density in the hilly region enormously. Therefore, there is popular and pressing demand for the construction of multistorey buildings in that region. A scarcity of plain ground in hilly area compels the construction activity on sloping ground. Hill buildings behave different from those in plains when subjected to lateral loads due to earthquake. Such buildings have mass and stiffness varying along the vertical and horizontal planes, resulting the center of mass and center of rigidity do not coincide on various floors. Also due to hilly slope these buildings step back towards the hill slope and at the same time they may have setback also, having unequal heights at the same floor level the column of hill building rests at different levels on the slope. The seismic response of multistorey buildings can be improved by incorporating a shear wall. Shear walls systems are one of the most commonly used lateral load resisting systems in high-rise buildings. Shear walls have very high in plane stiffness and strength, which can be used to simultaneously resist large horizontal loads and support gravity loads, making them quite advantageous. In this paper 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 and sloping ground.
2) To study the effectiveness 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 building resting on sloping ground for its better seismic performance.

2. Building description

2.1 Structure and analytical model

Model consists of G+6 storey RCC building having six bays in each direction with width of bay as 3.5m. The

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story height for each floor and plinth height is kept as 3.1m and 1.5m respectively. The RCC frame consists of beam and column of sizes 0.3m x 0.5m and 0.45m x 0.45m respectively. Slab thickness is taken as 120mm. The models are analyzed on leveled as well as sloping ground (slope 1V:2.33H). The frames on leveled and sloping ground under consideration for present study is as shown in Fig. 1 and Fig. 2. The concrete of grade M20 and steel of grade Fe 415 are used.

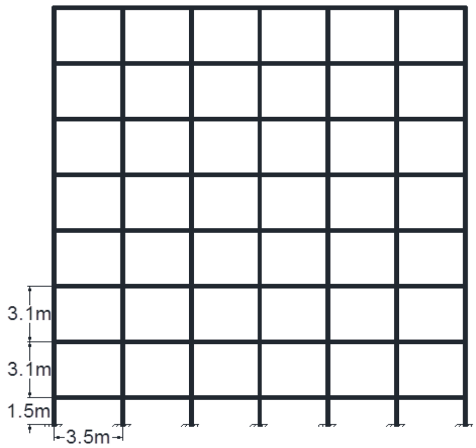

Fig. 1 Building frame on leveled ground

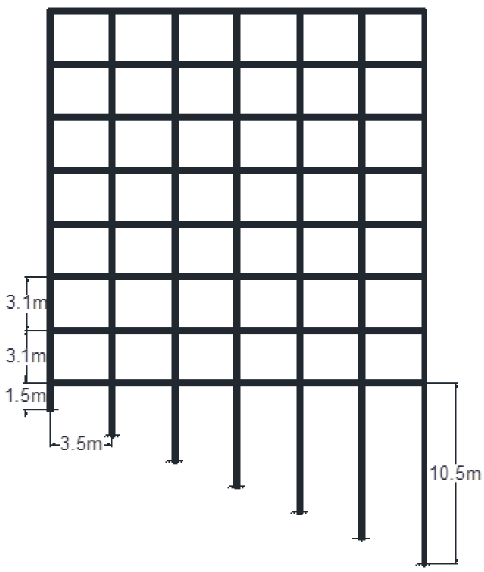

Fig. 2 Building frame on sloping ground

2.2 Loads

1) Dead loads
Self-weight is calculated by the software based on section properties and material constants provided. In addition to this super imposed dead load due to floor finishes or water proofing's applied on all floors and also the load of wall is superimposed on beams.

2) Live Loads
Live load on floor = 4 kN/m^2
Live load on roof = 1.5 kN/m^2.

3. Modeling and analysis

The building is modeled using finite element software SAP 2000 V 15.2.2. Beams and columns are modeled as two node beam element with six degrees of freedom at each node. Slabs are modeled as rigid 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 infill is assigned as uniformly distributed load over beams. The shear walls are modeled by wide column analogy method and fixed supports are considered for both shear walls and columns. To improve the seismic response of building different shear walls configurations are chosen as shown in fig 4 to Fig 7. In every model, position of shear walls is decided to keep the building symmetrical about both the principal axes to avoid undue torsion. Length of shear walls and no of columns in both directions is kept same to keep the structure symmetrical in both principal directions in plan.

3.1 Load Combinations:

The following load combination has been used for the calculating the member forces and for comparing its results as per IS 1893 (Part 1): 2002.

- 1.5 (DL + IL)
- 1.2 (DL + IL ± EL)
- 1.5 (DL ± EL)
- 0.9 DL ± 1.5 EL

4. Method of analysis

The IS 1893 (Part 1): 2002 recommends 3D modeling for dynamic analysis (Response Spectrum analyses and Time History analyses) of irregular buildings higher than 12m in zone IV and V, and those greater than 40m in height in zone II and III. 3D analysis including torsional effect has been carried out by using response spectrum method for this study. Dynamic response of these buildings, 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 model without shear walls on plain and sloping ground and at the end, efficient positioning of shear walls configuration to be used is suggested. Three columns A, B and C as shown in Fig. 3 are considered for comparison of member forces in the present study. The following models of building are considered on plain and sloping ground.

Model 1	without shear wall	Fig. 3
Model 2	with straight shape shear walls	Fig. 4
Model 3	with L-shape shear walls	Fig. 5
Model 4	with T-shape shear walls	Fig. 6
Model 5	with Channel-shape shear walls	Fig. 7

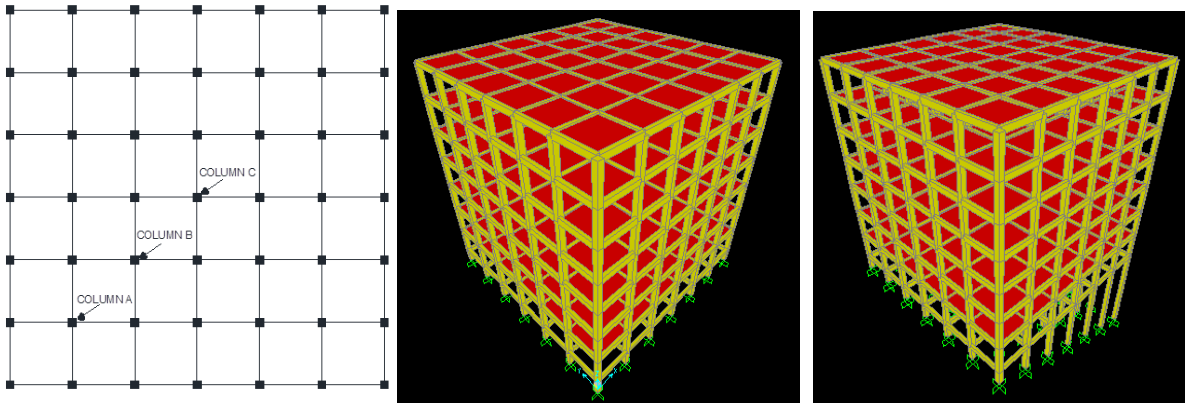

Fig. 3 Building without shear wall on plain and sloping ground

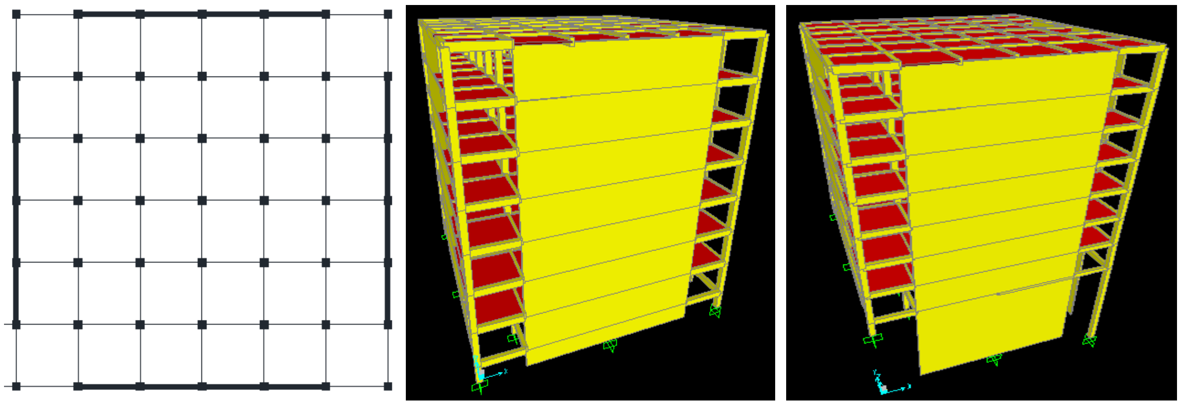

Fig. 4 Building with straight shape shear walls on plain and sloping ground

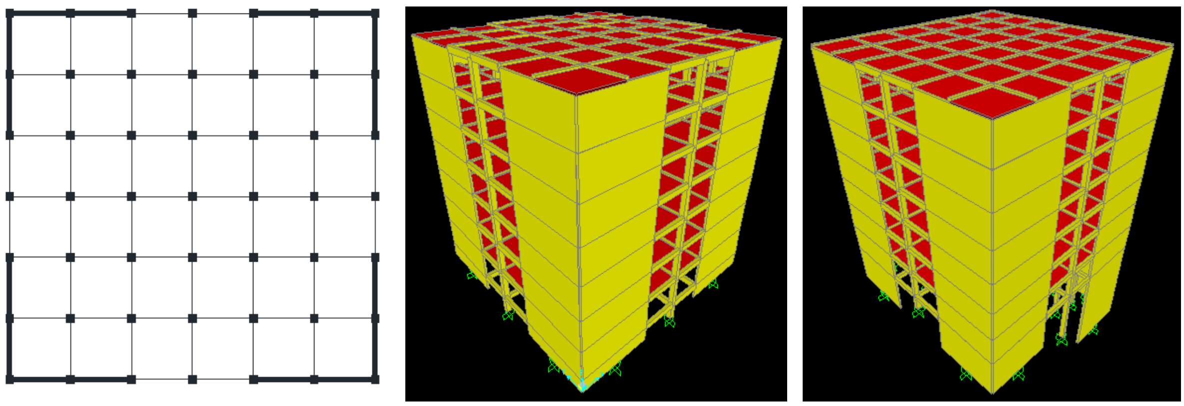

Fig. 5 Building with L-shape shear walls on plain and sloping ground

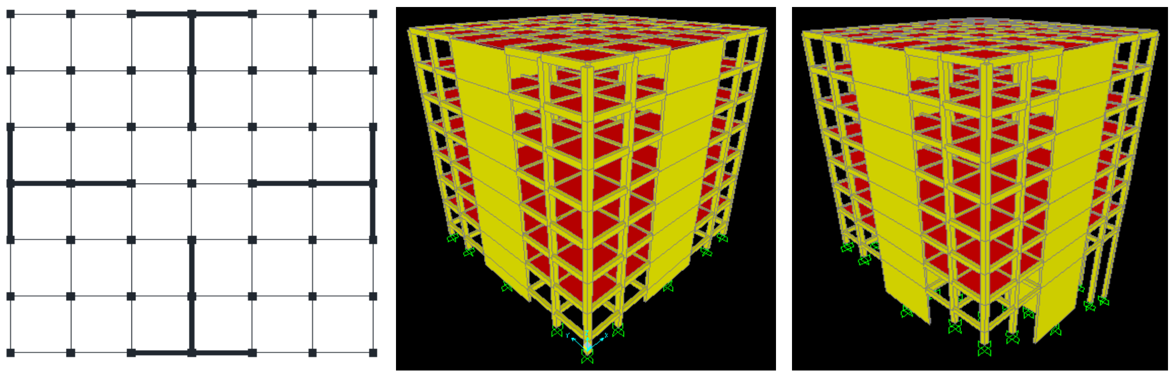

Fig. 6 Building with T-shape shear walls on plain and sloping ground

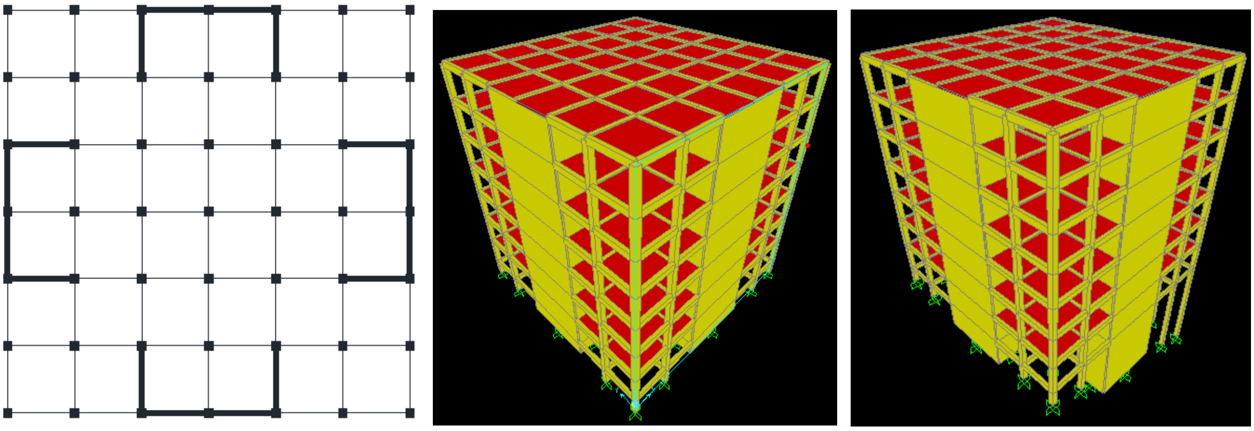

Fig. 7 Building with Channel-shape shear walls on plain and sloping ground

The seismic analysis of all buildings is carried by Response Spectrum Method in accordance with IS: 1893 (Part 1): 2002. As per codal provisions 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 empirical equation 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 five percent. For determining the seismic response of the buildings in different directions for ground motion the response spectrum analysis was conducted in longitudinal and transverse direction (X and Y). 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 number of modes (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.

5. Results and Discussion

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

5.1 Plain Ground

From the results obtained from this 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 time period of structure reduces and there is considerable reduction in lateral displacement of structure also. The incorporation of shear wall increases the base shear approximately by 10-17%. The model 3 (L-shape) has minimum value of base shear among all other shear walls configurations. All the models with shear walls has approximately 60% less time period as compared with model 1. Model 2 (Straight shape) has minimum time period. The reduction in lateral displacement is 85%, 78%, 76%, and 78% for model 2, 3, 4 and 5 as compared to model 1. The results obtained from present study for seismic performance of building on plain ground are presented in Fig 8, 9 and 10 for different models.

1) Base shear

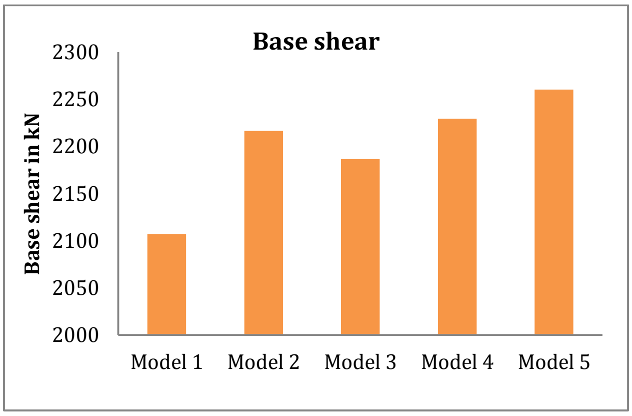

Fig. 8 Variation of base shear for building on leveled ground

2) Fundamental time period

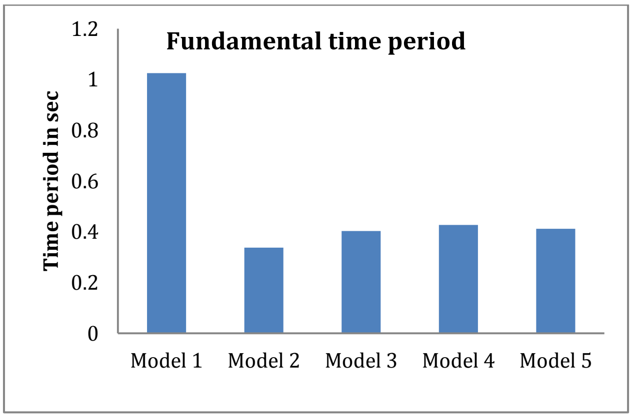

Fig. 9 Variation of time period for building on leveled ground

3) Floor displacement

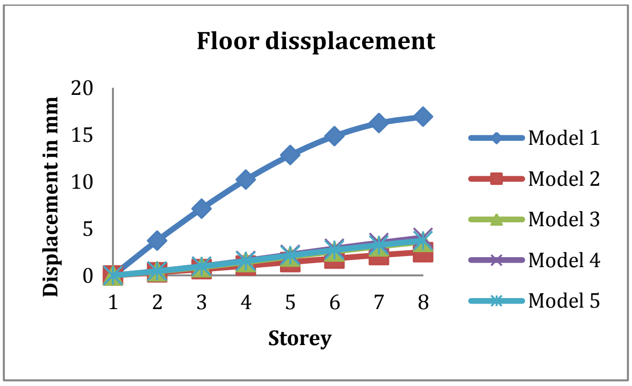

Fig. 10 Lateral displacement of building on leveled ground

4) Member forces

The comparison of member forces in three selected column shows considerable reduction in shear force and bending moment in column. The axial forces for all shear walls configuration does not show any significant effect. The shear force in column has reduced by 70-80% 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 presented in Fig. 11, 12 and 13 respectively.

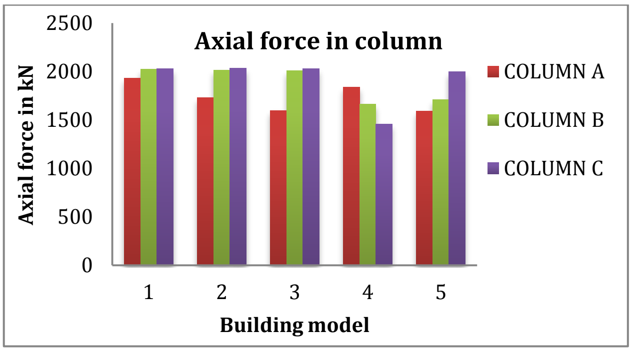

Fig. 11 Axial forces in column for building on leveled ground

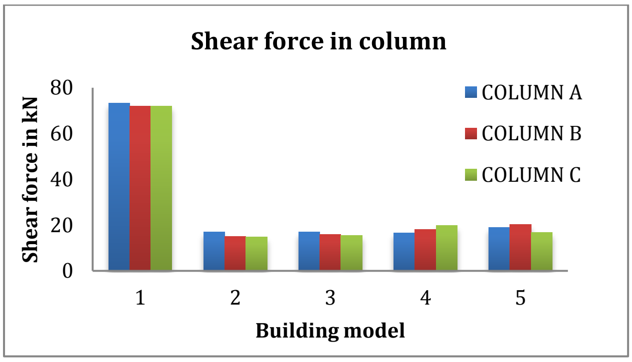

Fig. 12 Shear forces in column for building on leveled ground

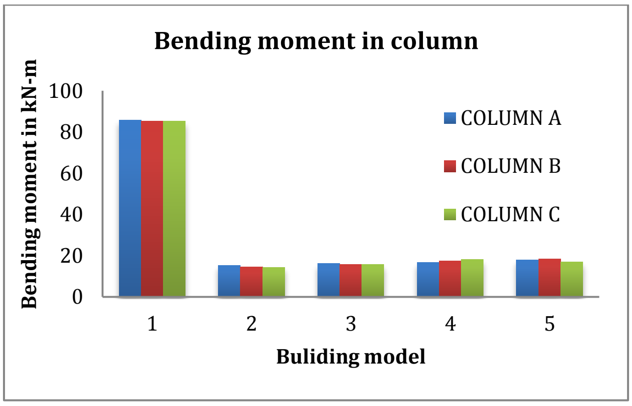

Fig. 13 Bending moment in column for building on leveled ground

5.2 Sloping ground

From the results obtained in present 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 direction parallel to slope whereas it is increased by 30-45% in other transverse direction as compared to model 1. 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 16. 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 1.The time period and lateral displacement observed is minimum for model 2 (straight shape) among all the configurations. The seismic performance of building o slope is as presented in Fig. 14, 15 and 16.

1) Base shear

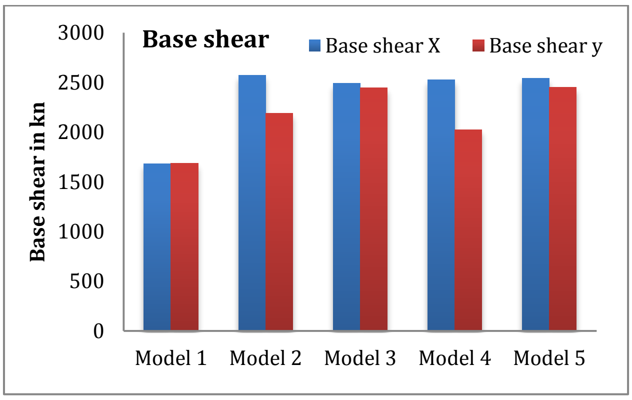

Fig. 14 Variation of base shear for building on sloping ground

2) Fundamental time period

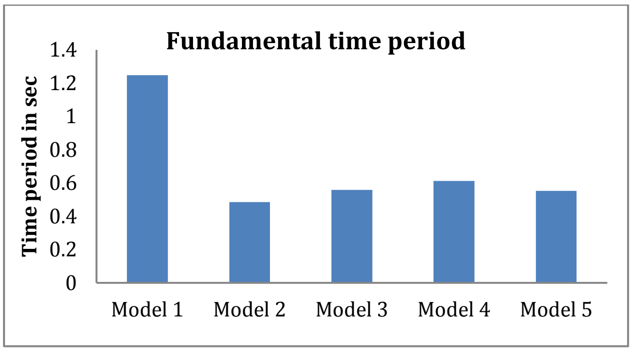

Fig. 15 Variation of time period for building on sloping ground

3) Floor displacement

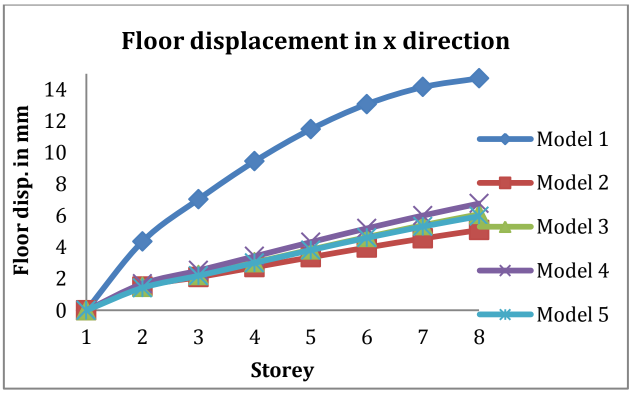

Fig. 16 Lateral displacement of building on sloping ground

4) Member forces

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. 17, 18 and 19 respectively. The buildings on slope are subjected to torsion when subjected to lateral load. Hence the torsional moments are also compared. These torsional moments get reduced by 75-90% as shown in fig 20.

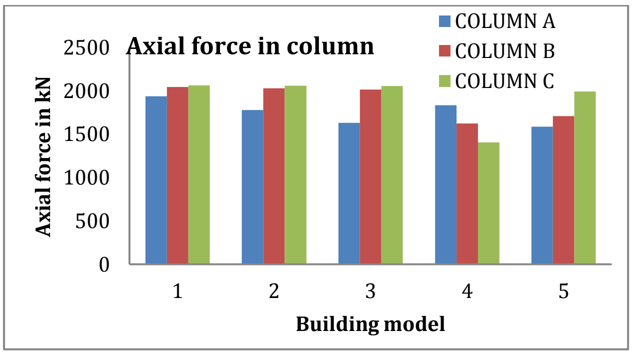

Fig. 17 Axial forces in column for building on sloping ground

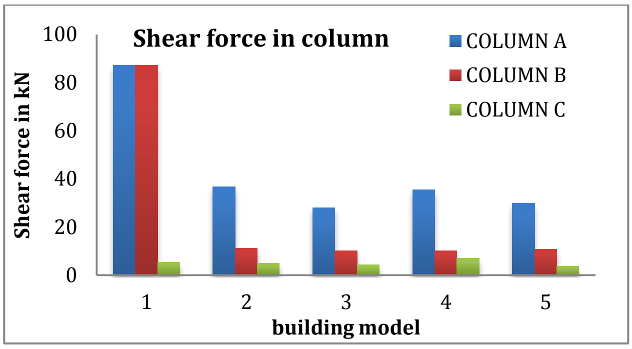

Fig. 18 Shear forces in column for building on sloping ground

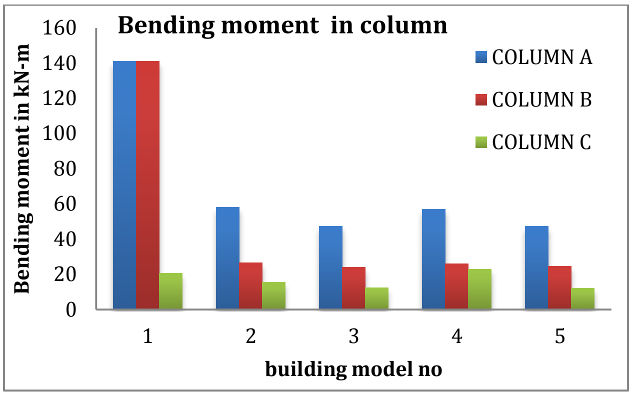

Fig. 19 Bending moment in column for building on sloping ground

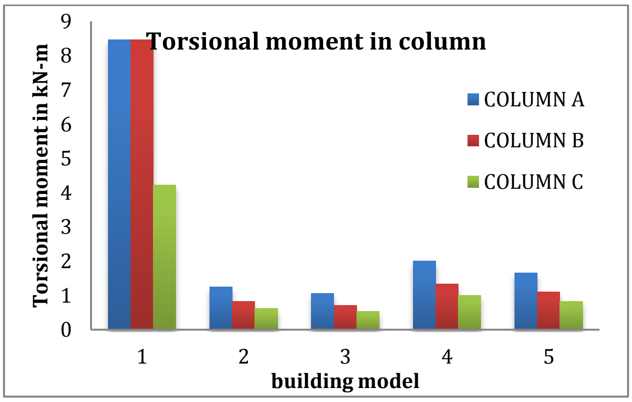

Fig. 20 Torsional moment in column for building on sloping ground

Conclusions

From the present study the following conclusions are drawn

1) There is significant improvement observed in seismic performance of building on leveled ground as well as on slopes by providing shear walls with different configurations since lateral displacement and member forces reduces considerably in building due to provision of shear walls.
2) 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 slope than in other transverse direction.

3) The straight shape (or rectangular) shear walls configuration proves to be better among all configurations for resisting the lateral displacement.
4) The L-shape shear walls configuration is effective during seismic activity because the member forces developed in this configuration are less as compared to other configurations on sloping ground whereas on plane ground this configuration has approximately same member forces for all configurations. Also for this configuration base shear is minimum among all configurations on leveled ground.
5) Use of T-shape shear walls gives more lateral displacement and member forces for buildings on slopes as compared to other configurations.

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