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Seismic Behavior of RC Buildings Constructed on Plain and Sloping Ground with Different Configuration of Shear Walls

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Abstract: **Buildings constructed on slopes are different from those in plains. They may be irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled. Hence, they are susceptible to severe damage when affected by earthquake ground motion. We can't avoid the future earthquakes but the preparedness and safe building construction practices for earthquakes can certainly reduces the extent of damage and loss of both property and life. Shear wall is one of the most commonly used lateral load resisting wall in buildings. Hence in the present work, an 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 and symmetrical angle shape is also studied. The RCC building models having G+8 stories is considered for analysis. The response spectrum analysis of building for Zone II and Medium soil condition is carried out using structural engineering software SAP2000. Finally the results for seismic behavior of buildings are compared with respect to time period, base shear, lateral displacement, and member forces. After studying the behavior of different shear wall configurations and positions at various sloping grounds, the efficient shape and position of shear wall is suggested for its better seismic behavior.**

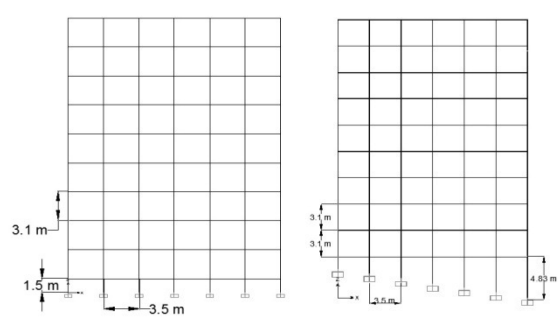
1. INTRODUCTION

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 multistory 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 multistory buildings can be improved by incorporating a shear wall. Shear wall 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 wall configurations such as straight and angular shape on plain and sloping ground. The main objectives of the study are

- To study seismic behavior of building with and without shear wall resting on plain and sloping ground.
- To study the effectiveness of different shear wall configurations on seismic performance of building resting on plain and sloping ground such as straight and angular shape.
- To suggest efficient shape of shear wall for building resting on sloping ground for its better seismic performance.

2. BUILDING DESCRIPTION

2.1 Structure and analytical model



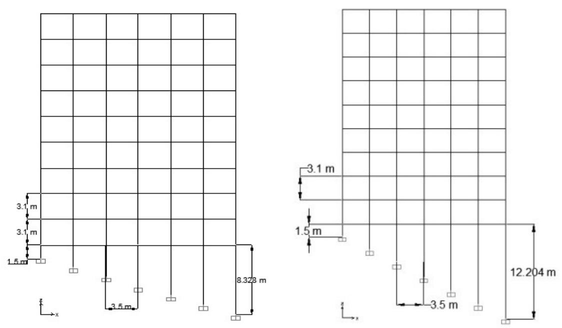


Fig.1 Elevation of building on plain and 9°, 18° and 27° sloping ground.

Model consists of G+8 storey RCC building having six bays in each direction; each bay is having width of 3.5m. The 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 also slab thickness is taken as 120mm. The models are analyzed on leveled as well as sloping ground (slope 9^0, 18^0 & 27^0 with horizontal). The frames on leveled and sloping ground under consideration for present study is as shown in Fig. 1. The concrete of grade M20 and steel of grade Fe 415 is used.

2.2 Loads

2.2.1 Dead loads:

Self-weight of building is automatically calculated by the software.
Super imposed dead load (Floor finishes or water Proofing's) all floors =1.875kN/m^2.
External wall load (230mm thick) =12 kN/m.
Internal wall load (115 mm thick) =6 kN/m.
Parapet load= 4.6 kN/m.

2.2.2 Live Loads:

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

3. MODELING

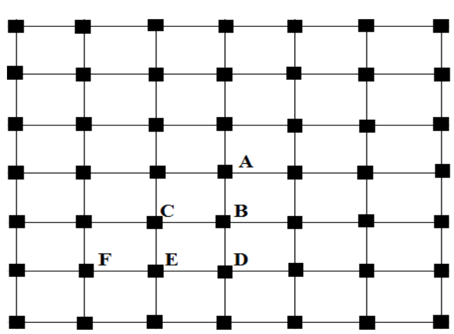


Fig. 2. Building plan without shear wall

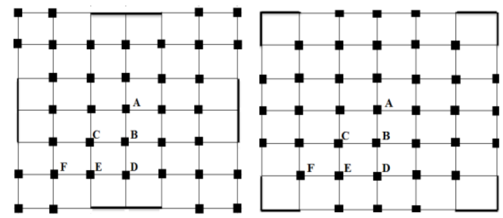


Fig. 3. Building plan with Straight and Angular shear wall

The building is modeled using finite element software SAP 2000. 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 wall is modeled by wide column analogy method and fixed supports are considered for both shear wall and columns. To improve the seismic response of building different shear wall configurations are chosen as shown in Fig 2. In every model, position of shear wall is decided to keep the building symmetrical about both the principal axes to avoid undue torsion. Length of shear wall and no of columns in both directions is kept same to keep the structure symmetrical in both principal directions in plan. Six columns A, B, C, D, E, & F as shown in Fig. 2 and 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 on plain ground

Model 2 - with straight shape shear wall on plain ground

Model 3 - with angular shape shear wall on plain ground

Model 4 - without shear wall on 9^0 sloping ground

Model 5 - with straight shape shear wall on 9^0 sloping ground

Model 6 - with angular shape shear wall on 9^0 sloping ground

Model 7 - without shear wall on 18^0 sloping ground

Model 8 - with straight shape shear wall on 18^0 sloping ground

Model 9 - with angular shape shear wall on 18^0 sloping ground

Model 10 - without shear wall on 27^0 sloping ground

Model 11 - with straight shape shear wall on 27^0 sloping ground

Model 12 - with angular shape shear wall on 27^0 sloping ground

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

3D analysis including shear force and bending moment 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, floor displacement and member forces is presented, and compared within the considered configuration of shear wall as well as with model without shear wall on plain and sloping ground and at the end, efficient positioning of shear wall configuration to be used is suggested. The seismic analysis of all building 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, seismic zone (II), zone factor 0.10, 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 SRSS method. The Response spectra for medium soil sites with 5% damping as per IS1893 (Part1):2002 is utilized in response spectrum analysis.

5. RESULTS AND DISCUSSION

5.1 Fundamental Time Period

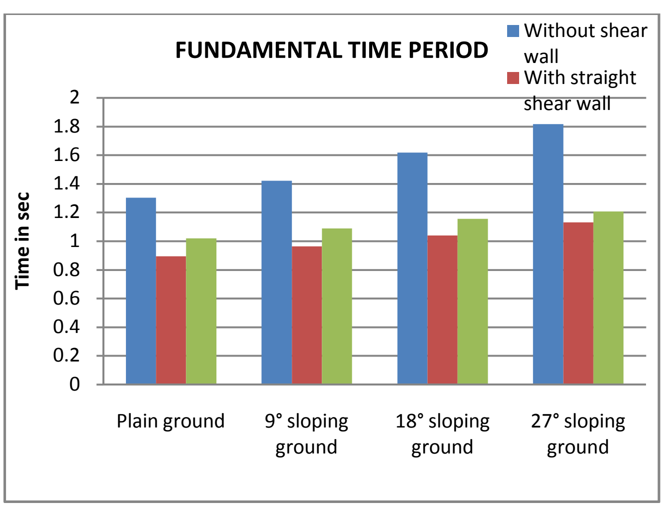


Fig. 4. Variation of Fundamental time period of building on plain and sloping ground

From Fig. 4 it is observed that the incorporation of shear wall in RCC frame decreases the fundamental time period. Time period of straight shear wall is less as compared to angular shear wall.

5.2 Base Shear

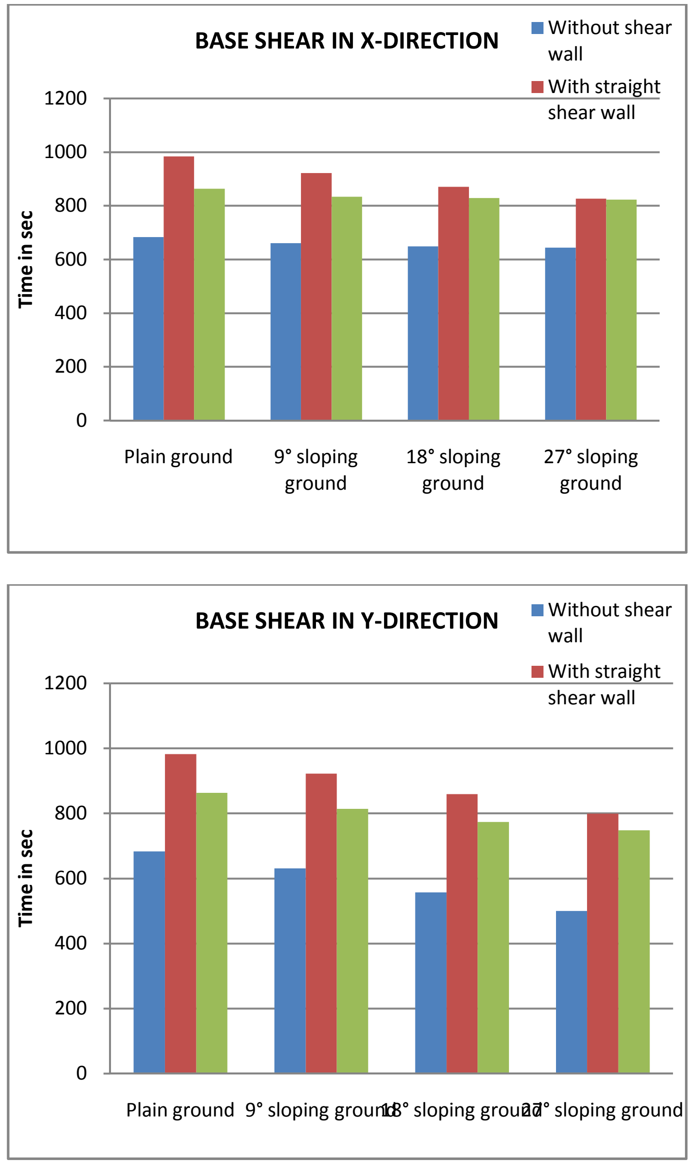
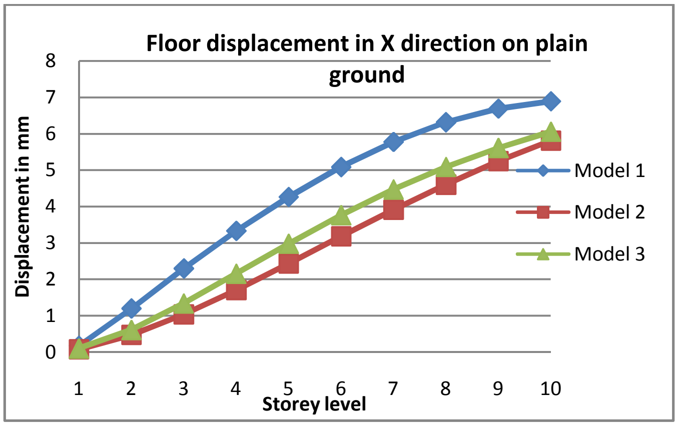
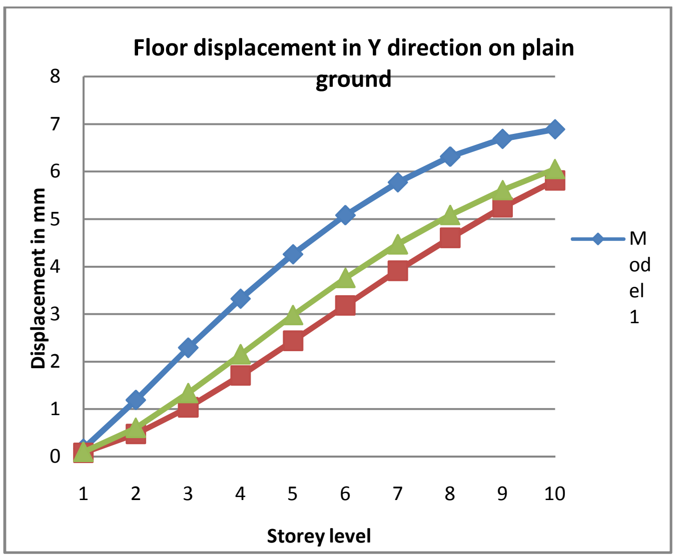


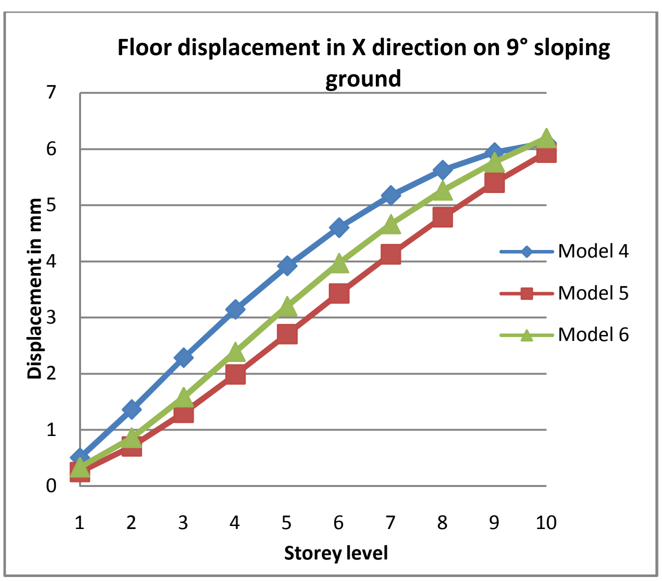
Fig. 5. Variation of base shear in X and Y direction on plain and sloping ground

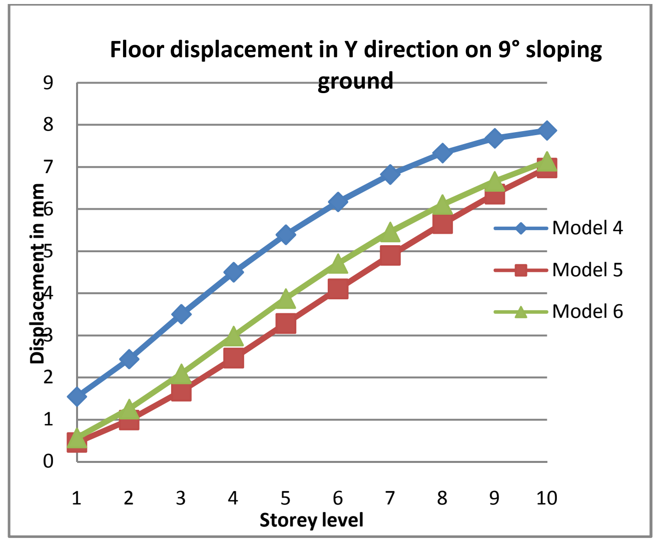
From Fig 4 it is observed that with inclusion of shear wall base shear in x and y direction increases. Increase in base shear in X and Y direction is more in straight shear wall than angular shear wall.

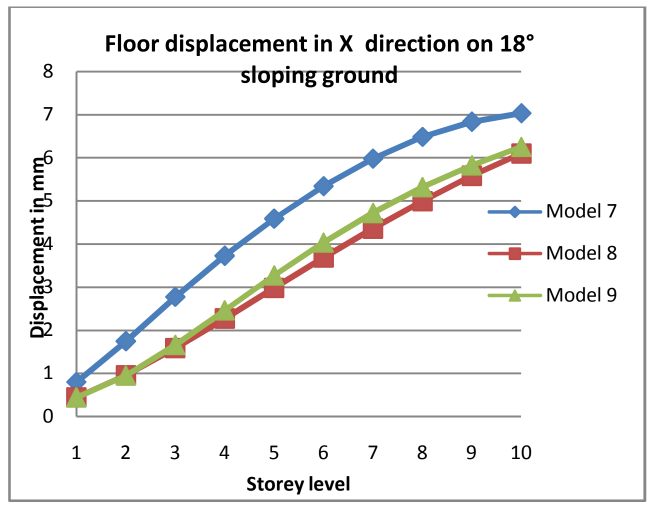
5.3 Floor Displacement

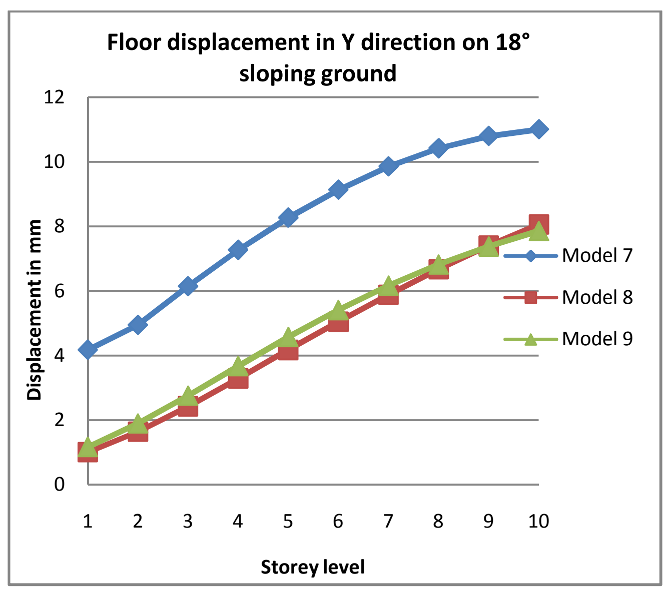












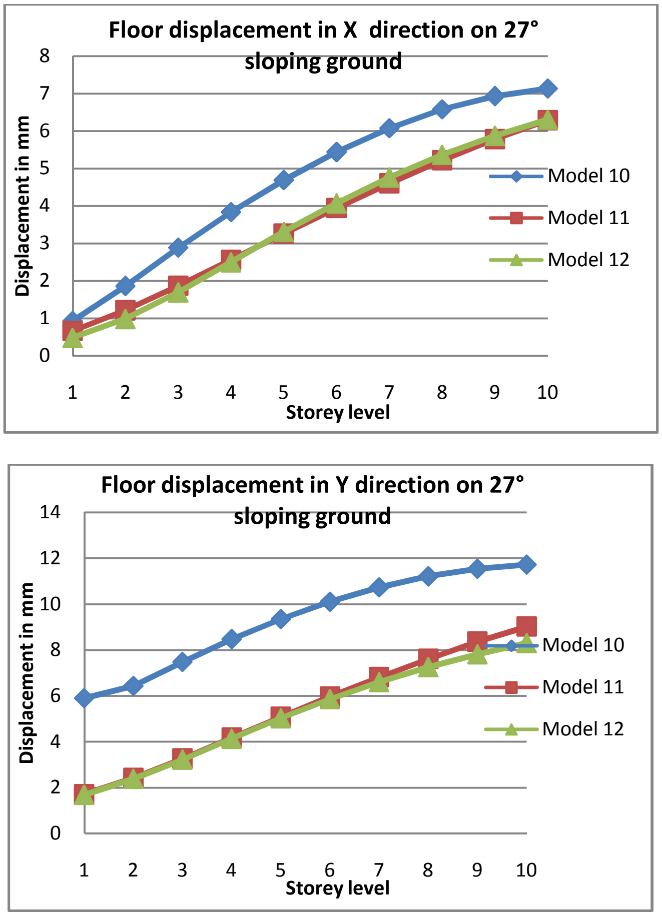
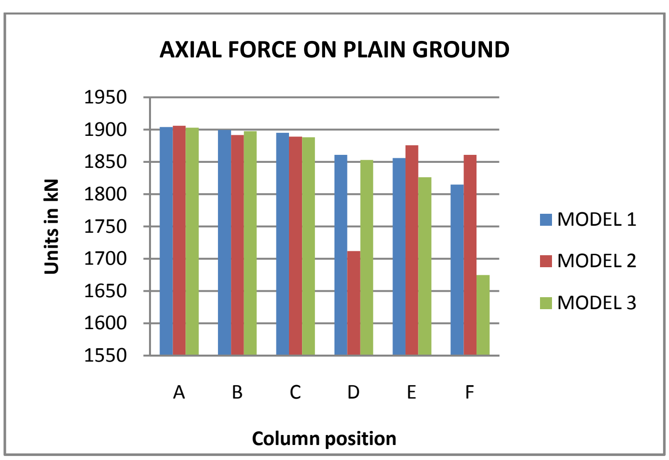


Fig. 6 Variation of floor displacement in X and Y direction on plain and sloping ground.

With incorporation of shear walls, floor displacement reduces along the height of structure on plain and sloping ground. Displacement in straight shear wall is less as compared to angular shear wall.

5.4 Axial Force



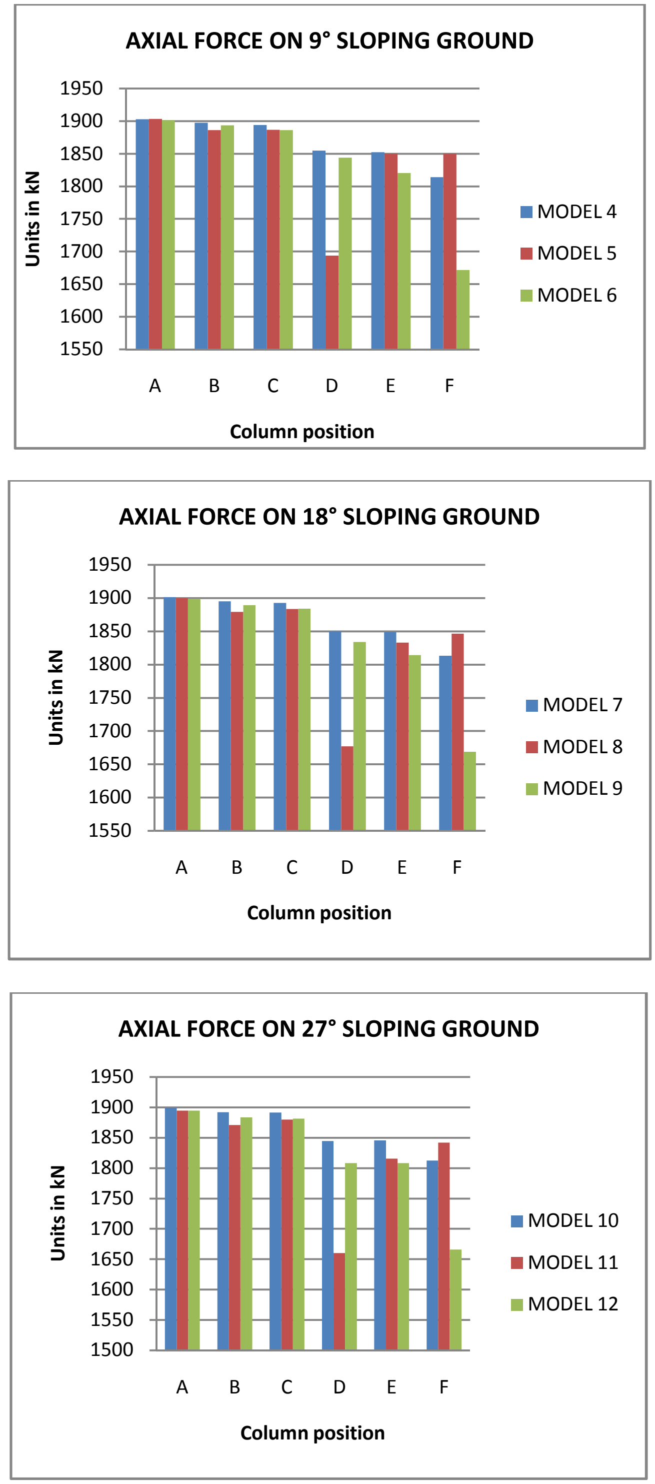
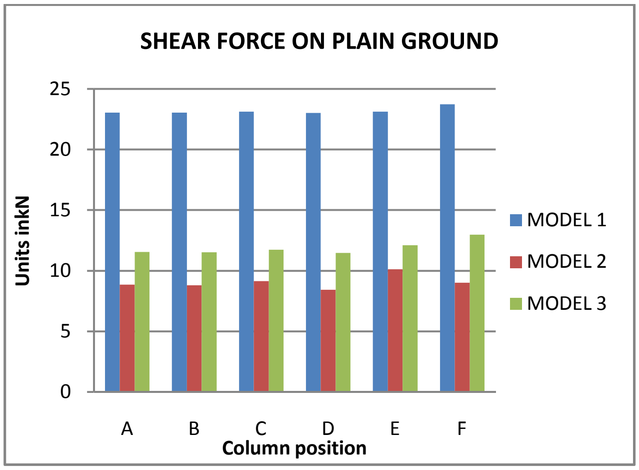
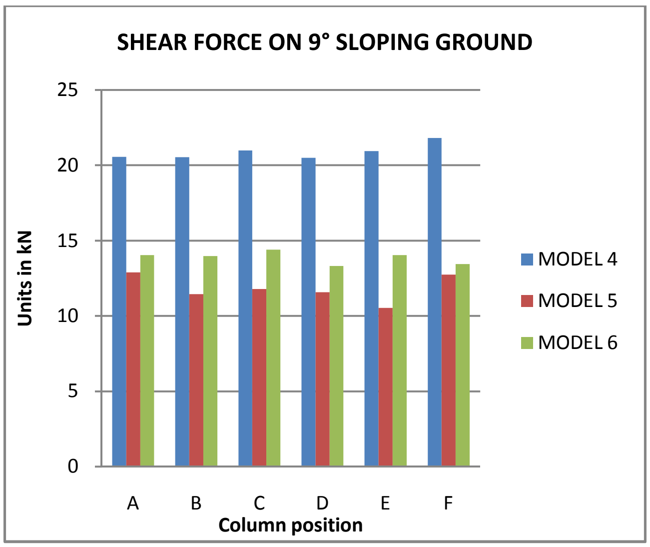


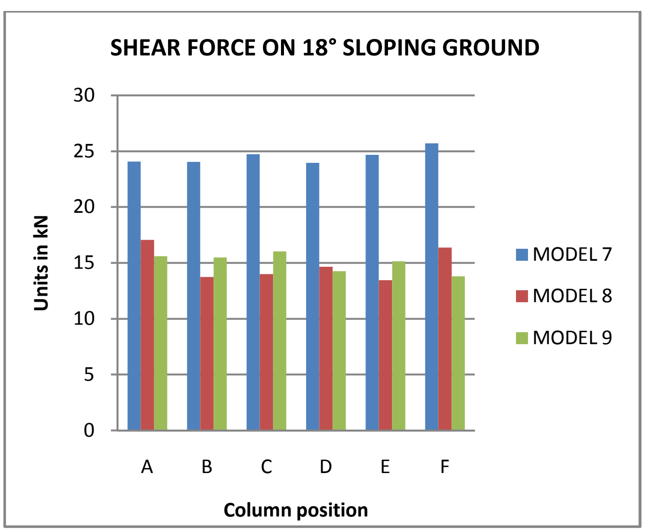
Fig. 7 Variation of Axial force on plain and sloping ground

Axial force in column A is more which is at center and in column F is less which is at longest distance from center. Axial force reduces in column D due to incorporation of straight shear wall and in column F due to incorporation of angular shear wall.

5.5 Shear Force







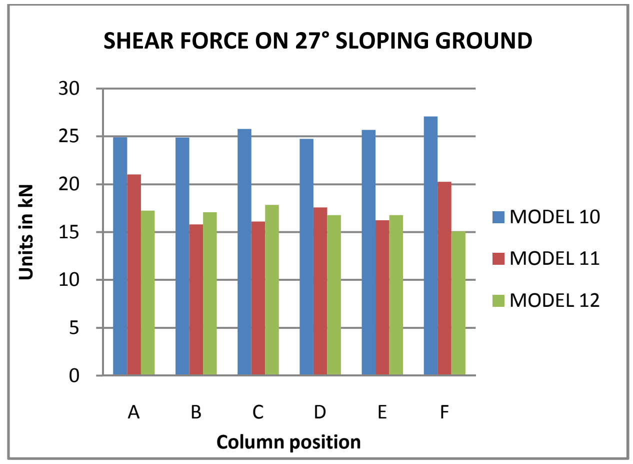
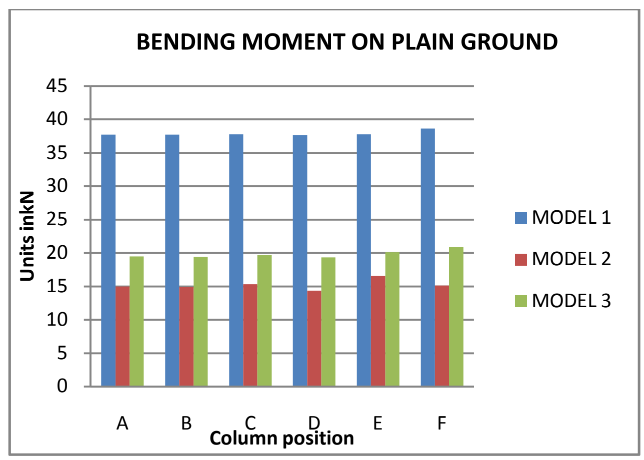
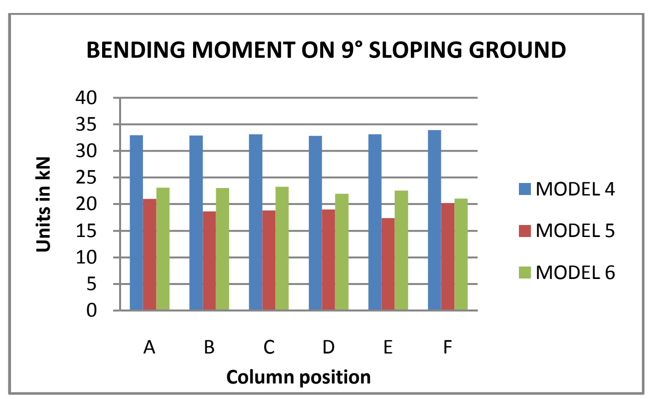


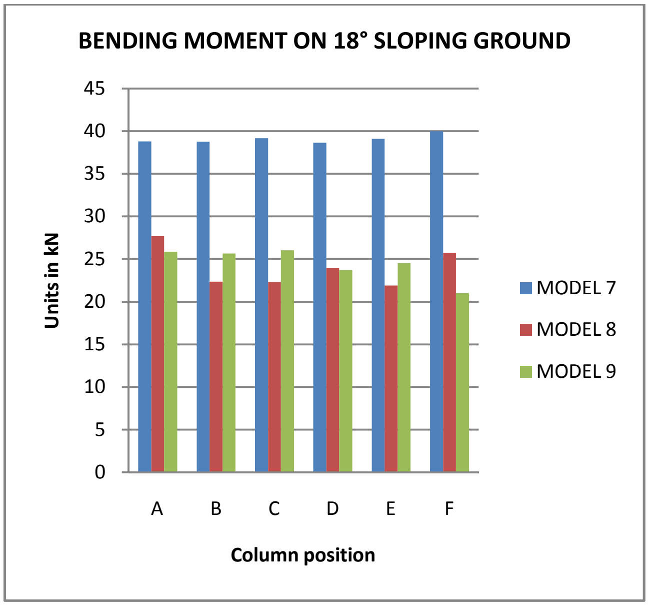
Fig. 8 Variation of shear force on plain and sloping ground

From Fig.9 it is observed that shear force in column reduces due to incorporation of shear wall. Straight shear wall is more effective in reducing shear force of column on plain and 9° sloping ground. As the slope of ground increases angular shear wall becomes more effective than straight shear wall.

5.6 Bending Moment







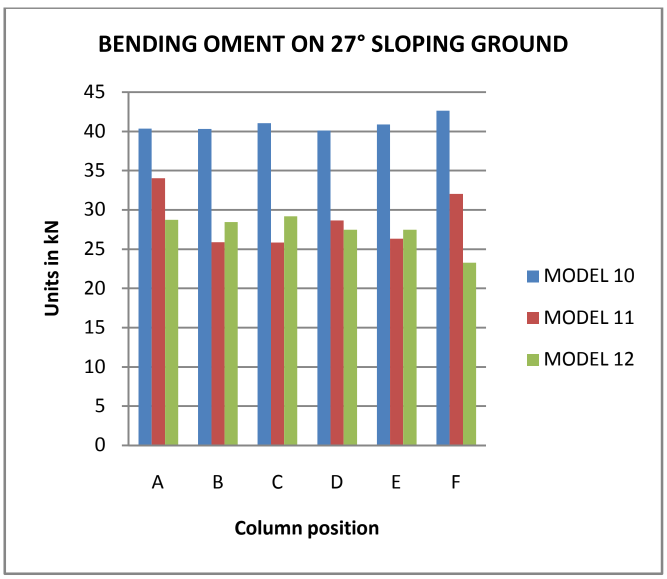


Fig. 9 Variation of bending moment on plain and sloping ground.

From Fig. 14 it is observed that incorpration of shear wall reduces bending momemt in columns. Straight shear wall is more effective in reducing bending moments of column than angular shear wall.

6. CONCLUSION

1) There is significant improvement observed in seismic behavior of building on plain as well as sloping ground by incorporation of shear wall. Since fundamental time period, floor displacement and member forces reduces considerably.

2) Base shear of building increases due to provision of shear wall in both X and Y direction on plain and sloping ground.

3) The straight shape shear wall proves to be better among both configurations for resisting lateral forces.

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