Seismic Behaviour of Buildings on Slopes

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ABSTRACT

Most of the hilly regions of India are highly seismic. A building on hill slope differs in different way from other buildings. Buildings situated in hilly areas are much more vulnerable to seismic environment. The various floors of such building steps back towards the hill slope and at the same time buildings may have setbacks also. Analysis of hill buildings is somewhat different than the buildings on leveled ground, since the column of such building rests at different levels on the slope. In present study, the analysis of G+3 building on ground slope angles 7.5^0 has been conducted. Both type of building configurations (step back and step back setback) has been considered. The seismic forces are considered as per IS: 1893:2002. The buildings are considered in seismic zone IV and damping ratio 5%. Seismic analysis has been done using Linear Static, Linear Dynamic method. 3D analytical model of buildings have been generated and analyzed using structural analysis tool "STAAD Pro v8i" to study the effect of varying height of columns in ground storey due to sloping ground. The response parameters base shear, shear in bottom storey column, time period are critically analyzed to quantify the effects of various sloping ground.

Keywords: *Behaviour of hill buildings, Earthquake loads, STAAD Pro, Seismic zone*

1. INTRODUCTION

North and northeast parts of India have large scales of hilly terrain, which are categorized under seismic zone IV and V. Due to the economic growth and rapid urbanization in hilly regions, construction of multistory reinforced concrete buildings on hill slopes has a popular and pressing demand. Buildings on hilly terrain are differ from those on plain ground i.e., they are very irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled as compared to those on plain ground which are usually regular and symmetrical and thus free from torsional moment. A scarcity of plain ground in hilly area compels the construction activity on sloping ground. Hill buildings constructed in masonry with mud mortar/cement mortar without conforming to seismic code provisions have proved unsafe and, resulted in loss of life and property when subjected to earthquake ground motions.

2. PROBLEM STSTEMENT

The present study is concerned with analyzing seismic behaviour of step back building and step back & set back building on 7.5° ground slope. In such buildings column of different heights in same storey are usually observed. In the present study two methods namely Equivalent static method and Response spectrum method are used to study the seismic response of buildings on hill slopes using STAAD Pro software.

3. METHODOLOGY

The fine detailing of the methodology and description of materials used are shown below.

3.1 LOADS

The knowledge of various types of loads and their worst combinations to which a structure may be subjected during its life span is essential for safe design of structure .Forces acting on structures are called loads. Primary loads acting on the building have been considered as dead load, Live load and earthquake load. The dead load and live load has been applied in Gravity direction and earthquake load has been applied in lateral direction.

3.1.1 DEAD LOAD

Dead loads are permanent loads and acts vertically downward. Dead loads are basically due to self weight of structure as well as due the weight of floor slab, beams, columns, walls and floor finish. Dead load of buildings can be calculated by calculating the self weight of each structural element and adding them. The formula used for calculating self weight of each structural element in KN/m is unit weight of material (KN/m^3) × depth of element × width of element.

3.1.2 LIVE LOAD

Live loads are those which may change in position and magnitude. The use of the term 'live load' has been modified to 'imposed load' to cover not only the physical contribution due to persons but also due to nature of occupancy, the furniture and other equipments which are a part of the character of the occupancy. The imposed load assumed to be produced by the intended use or occupancy of a building, including the weight of movable partitions, distributed, concentrated loads, load due to impact and vibration, and dust load but excluding wind, seismic, snow and other loads due to temperature changes, creep, shrinkage, differential settlement, etc. Imposed loads for residential buildings are taken as per IS 875 Part 2.

3.1.3 EARTHQUAKE LOAD

North and northeast parts of India have large scales of hilly terrain, which falls under seismic zone IV and V. Buildings in such regions are highly prone to earthquake. Earthquake generates due to collision of tectonic plates and hence epicenter of earthquakes is generally located at fault lines. During past earthquakes, reinforced concrete (RC) frame buildings that have columns of different heights within one storey, suffered more damage in the shorter columns as compared to long columns in the same storey and hence demands careful design of buildings on hill slopes. Indian Standard: 1893: (1962, 1966, 1970, 1975, 1984, 2002) code of practice on the "Criteria for Earthquake Resistant Design of Structures" by the Bureau of Indian Standards (BIS) provides guidelines for design of earthquake resistant structures.

3.2 LOAD COMBINATIONS

In the limit state design of reinforced concrete structures, the following load combinations shall be accounted for:

1) 1.5(Dead load + Impose load)
2) 1.2(Dead load + Imposed load ± Earthquake load)
3) 1.5(Dead load ± Earthquake load)
4) 0.9Dead load ± 1.5 Earthquake load

3.3 ANALYSIS IN STAAD PRO

The study is carried out on two types of buildings namely; Step back buildings and Step back & Set back buildings of four numbers of storeys resting on 7.5° ground slope.

The above building configurations analyzed by linear static as well as dynamic method (response spectrum method). The bay width in horizontal X-direction and horizontal Z-direction are same and equal to 4 m. The 1st, 2nd and 3rd storey are of the height 3.5 m each. As buildings are resting on sloping ground, the height of columns of ground storey is different. The column on higher side is short column while the column on lower side is long column.

MODEL DESCRIPTION

The building frames are modeled as per the parameters given in table 1. Two types of building frames are considered for analysis as given below:

Model 1: Step back building on 7.5° ground slope

Model 2: Step back & set back building on 7.5° ground slope

Model 1 and 2 are shown in figure 1 and respectively.

Table 1 Model Description

Bay width in X direction	4 m
Bay width in Z direction	4 m
Top three storey height	3.5m
Bottom storey short column height	1.5m
Bottom storey long column height	3.7 m
Size of beams	0.4 m×0.4 m
Size of columns	0.4 m×0.4 m
Slab thickness	120 mm
Exterior masonry wall thickness	200 mm
Interior masonry wall thickness	100 mm
Type of supports	Fixed
Density of brick masonry	20 kN/m^3
Live load on floor	4 kN/m^2
Live load on roof	2 kN/m^2
Seismic zone	IV
Response reduction factor	3
Importance factor	1
Damping	5%
Soil type	medium soil

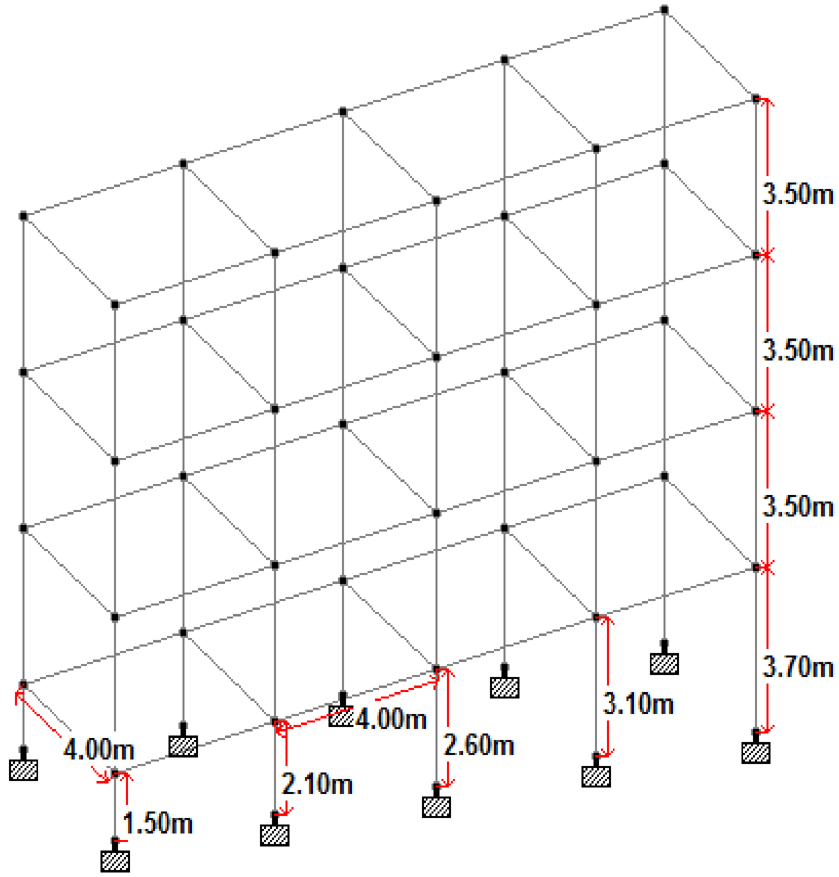

Figure 1 Building on 7.5° ground slope (G+3)

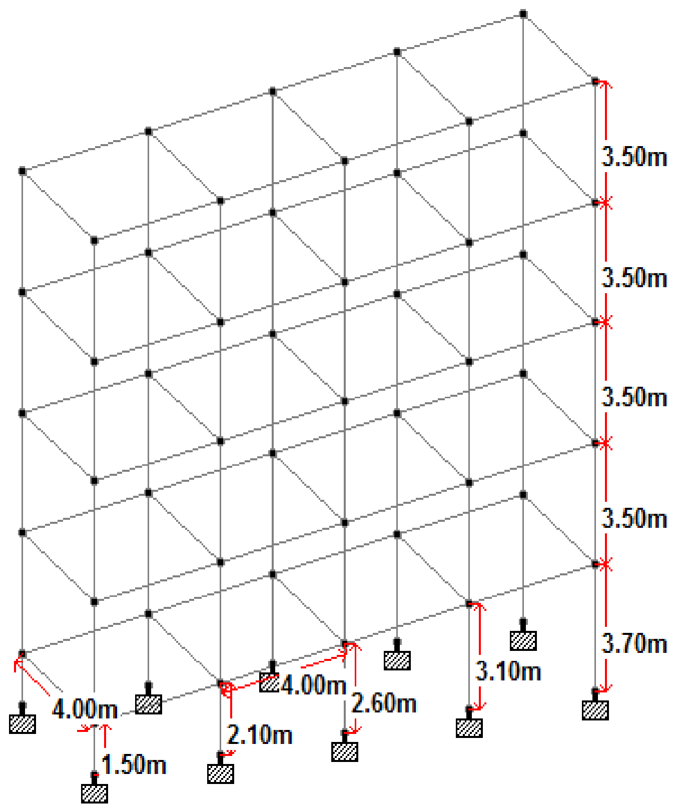

Figure 2 Building on 7.5° ground slope (G+3)

4. RESULTS AND DISCUSSION

Building configurations has been analyzed using Equivalent static method and Response spectrum method and the results are compared on the basis of time period, base shear and ground storey column shear.

Table 2 Tabulated results for analytical study

Type of building	**Step back building**	**Step back & Set back building**
Ground slope angle	7.5°	7.5°
Time period	0.50	0.40
Base shear (kN)	460.9	284.5
Short column shear (kN)	270.4	167.7
Long column shear (kN)	20.9	12.9
Top storey displacement (mm)	11.515	10

On the basis of results obtained above, graphical representation of comparison of seismic response of step back building and step back & set back building is shown below from figure 3 to figure 7.

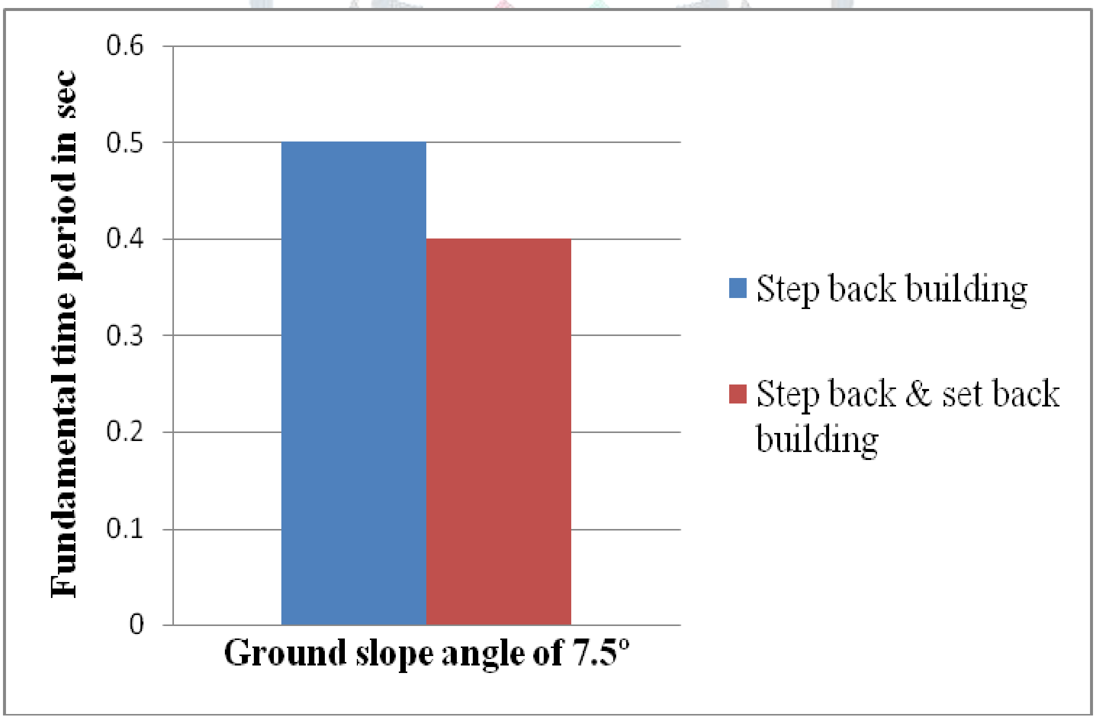

Figure 3 fundamental time period

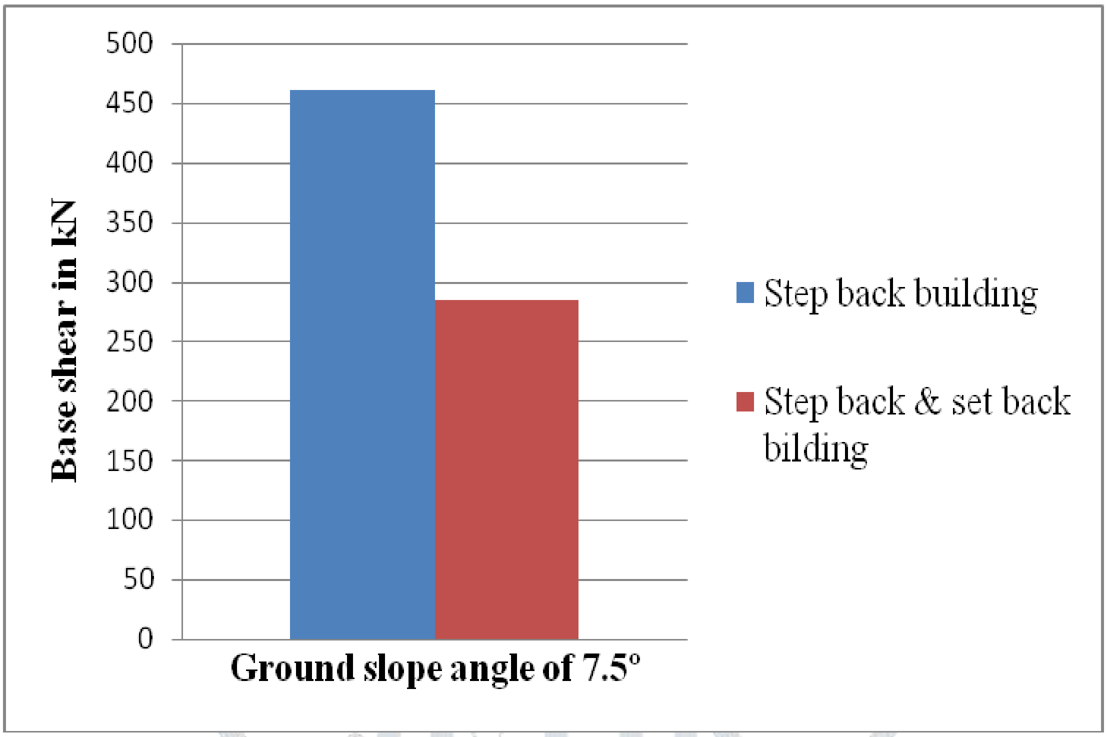

Figure 4 base shear

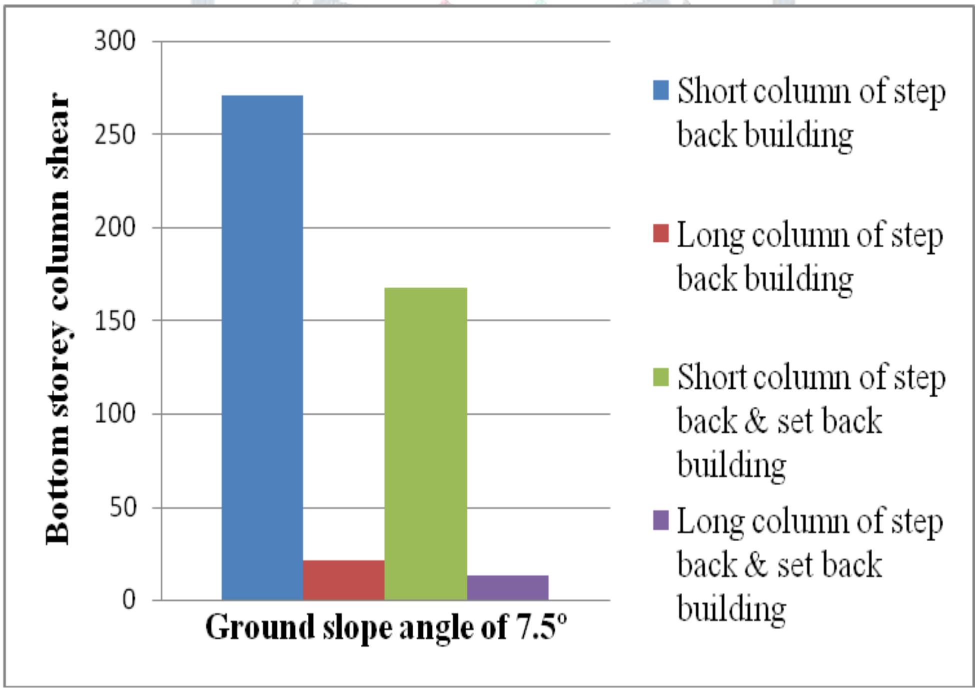

Figure 5 bottom storey column shear

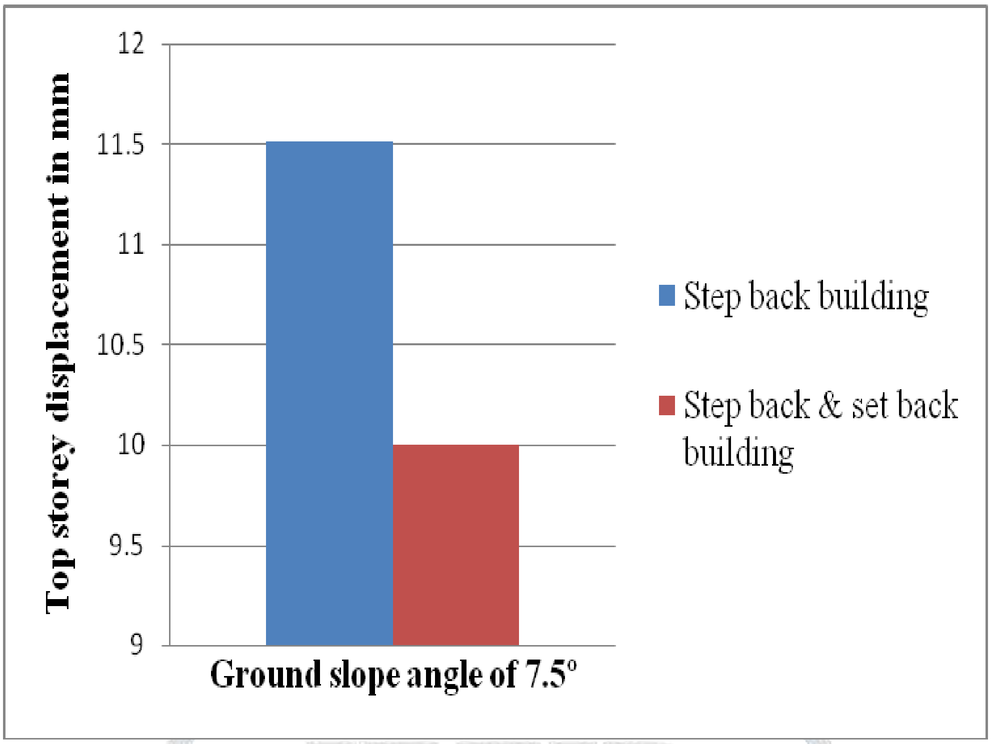

Figure 6 Top storey displacement

5. CONCLUSIONS

1. The step back building frame give higher value of time period as compared with the step back & set back building frame.
2. Step back building frame produce higher base shear as compared with step back & set back building frame.
3. In step back and step back & set back frame; it is observed from results that short columns which are on higher side of sloping ground are subjected to very high shear forces as compared to long columns and hence Special attention is required while designing these short columns.
4. The step back building frame give higher value of top storey displacement as compared with step back & set back building frame.
5. The performance of step back frame during seismic excitation could prove more detrimental than step back & set back building frame. Hence, step back building frame on sloping ground are not desirable. However, it may be adopted, provided a system to control the large displacement is adopted.

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