Structural Vulnerability Analysis of R.C.C. Hill Side Building on Sloping Ground with Building on Plains under Seismic Conditions

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Abstract: -*In recent years, it has become need in growing cities located in mountainous regions to undertake the construction of buildings of considerable height and large base area on slopes. These buildings are irregular and unsymmetrical in both horizontal and vertical plane such buildings create special structural and constructional problems.This paper presents the structural performance of step back R.C.C building located on sloping ground with a building located on plain ground under seismic conditions, using Response spectrum analysis method on E-TAB 2017 software. Both buildings are compared on the basis of seismic parameter viz time period, base shear, storey displacement storey drift, storey stiffness, torsion and shear force as per IS 1893-2016:part-I guideline and it is found that step back RCC building is subjected to higher lateral force and shows significance torsion and irregularities in stiffness and more vulnerable to failures under seismic forces.*

Keywords: -*Hill slope, Irregular building, Response spectrum, E-TABS 2017, IS 1893-2016*

1. INTRODUCTION

The buildings in hilly areas have to be configured differently because of these areas are more prone to landslides and unstable steep slopes. A scarcity of plain ground in hilly area compels the construction activity on sloping ground. The behavior of buildings during earthquake depends upon the distribution of mass and stiffness in both plane of building. In hilly region both these properties vary and termed as irregularity and asymmetry. Such types of structures are subjected to greater shear and torsion. If these structures are constructed without confirming to seismic code provisions, results in loss of property and life when subjected to seismic ground motion. The economic growth and rapid urbanization in hilly region have accelerated the real estate development. Due to this population density in hilly region hasincreased enormously. Therefore, there is popular and pressing demand for constructionof multistory building on hill slopes in and around cities near foot hills or on hills

1.1 SIGNIFICANCE OF STUDY

Dynamic characteristic of hill buildings are significantly different from the building resting on plain ground, as they are irregular and unsymmetrical in both horizontal and vertical directions. The irregular variation of stiffness and mass in vertical as well as horizontal planes,results in centre of mass and centre of stiffness of a storey do not coincide with each other. When subjected to lateral loads these buildings are generally subjected to significant torsional moment and short stiff column on uphill side attract much higher lateral forces and are prone to heavy damage.

Less research work has been carried out about the performance of building on sloping ground. The aim of present paper is to figure out the seismic response of building located on hilly slope and to compare it with regular building resting on flat ground.

2. OBJECTIVES OF RESEARCH

1. To analyse the structural performance of multi-storey Step back RCC building located on hilly slopes under gravity and seismic loads and compare it with RCC building located on flat ground.
2. To determine and study the effects of various seismic parameters i.e. time period, base shear, storey displacement, storey drift, storey stiffness,torsion and shear force on the behavior of building.

3. DESCRIPTION OF BUILDING

1. Building type- Residential building
2. Plan area-20mx20m
3. Total number of storey-10
4. Height of building-30m
5. No. of bays in X direction @ 4m each -5 No.
6. No. of bays in Y direction @ 4m each -5 No.
7. Depth of slab-150mm
8. Size of beam-300mmx450mm
9. Size Periphery column-500mmx650mm
10. Size Centre column-500mmx500mm
11. Height of each storey-3m
12. Dead load- Self weight of building
13. Live load-3 kN/m^2 (IS 875 part 2)
14. Angle of slope-16^0 with horizontal
15. Grade of Concrete-M25 and M30
16. Steel Grade-Fe-500

4. METHOD OF ANALYSIS AND STRUCTURE MODELLING

The seismic analysis of building has been carried out by Response spectrum method using E-TABS 2017 software and IS 1893-2016 Part-I guidelines. The other parameters used in analysis are following.

Seismic zone-III

Zone factor(Z)=0.16(clause 6.4.2)

Importance factor(I)=1.2(clause 7.2.3)

Response reduction factor(R)=5(SMRF) (clause 7.2.6)

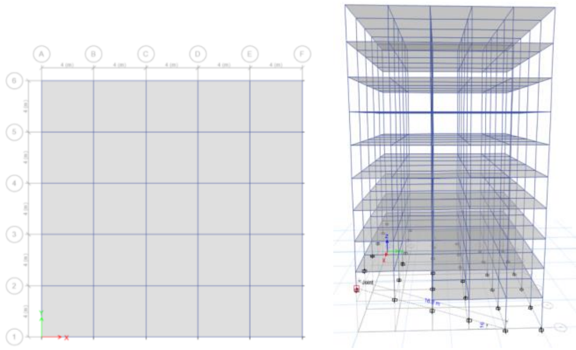
Damping=5%

Soil type=II(medium soil)

Model 1- Step back RCC building located on slope angle 16^0 with horizontal

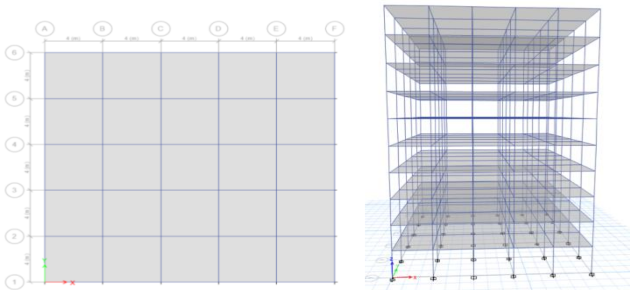
Model 2- RCC building located on plain ground having same dimensions as in model 1

The plan and elevations view of model 1 and model 2 buildings are given in **fig. 4.1** and **fig. 4.2.**



(a) Plan view (b)Elevationview

Fig. 4.1Model 1- Step back RCC building located on slope angle 16^0 with horizontal



(a) Plan view (b) Elevation view

Fig. 4.2Model 2-RCC building located on plain ground

5.ANALYSIS AND RESULT

5.1 Natural Time Period:- Variation of time period is shown in **Table 5.1** and **fig. 5.1**

Table 5.1 Variation in natural time period

Mode	**Model 1(sec)**	**Model 2(sec)**
Mode 1	0.985	1.007
Mode 2	0.969	0.977
Mode 3	0.889	0.877
Mode 4	0.319	0.326
Mode 5	0.311	0.313
Mode 6	0.286	0.282
Mode 7	0.183	0.185
Mode 8	0.175	0.174
Mode 9	0.171	0.159
Mode 10	0.133	0.124
Mode 11	0.128	0.115
Mode 12	0.117	0.105

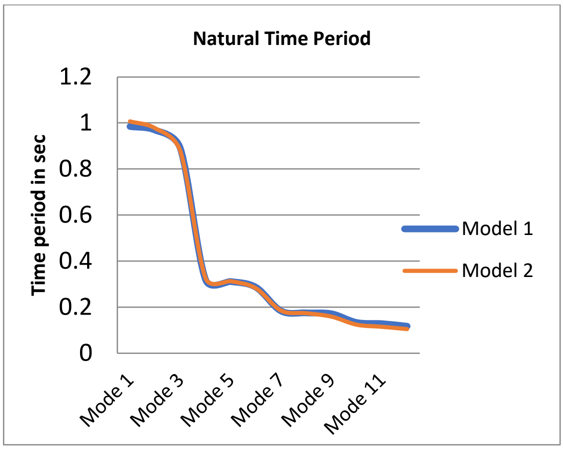


Fig. 5.1 Natural Time period variation

The building having heavy mass and smaller stiffness have larger natural period than light and stiff buildings. In above **fig. 5.1,** the value of maximum time period were observed in model 2 i.e. **1.007sec** and minimum value observed in model 2 i.e. **0.985 sec**as mass of model 1 is 32141.152 kN and mass of model 2 is 32515.4068 kN.

5.2Base Shear Distribution:-Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of structure.As per **IS-1893:2016 clause 7.6.1** the design base shear is given as

$$V_B = A_h W \qquad \ldots(i)$$

where,

A_h is design horizontal acceleration coefficient

W is the seismic weight of building

As per **IS-1893:2016 clause 7.6.3**the design base shear is distributed as,

$$Q_i = \left(\frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}\right) V_B \qquad \ldots(ii)$$

where,

Q_i is the design lateral force at floor i

W_i is seismic weight of floor i

h_i is the height of floor I measured from base

n is the number of storeys in building

Base shear of model 1 and model 2 is shown in **table 5.2** and **fig. 5.2.**

Table 5.2 Base shear distribution

Storey	Model 1(kN)	Model 2(kN)
Storey10	200.4781	197.7746
Storey 9	190.28	182.25
Storey 8	150.62	144.2644
Storey 7	115.59	110.7138

Storey 6	85.19	81.5967
Storey 5	59.42	56.9137
Storey 4	38.28	36.6648
Storey 3	21.76	20.85
Storey 2	9.69	9.4692
Storey 1	1.55	2.5426

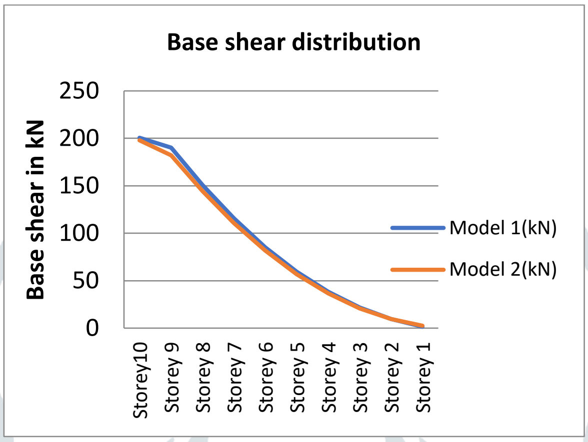


Fig.5.2 Base shear distribution

From the above figure it is observed that building on sloping ground (model 1) attract more shear force than regular building resting on flat topography(model 2).

5.3 Storey Displacement:-Storey displacement may be defined as the lateral displacement of any particular storey from its mean position with respect to the base of the structure. Storey displacement of both models are compared as per Eurocode 8 and tabulated below in **table 5.3** and **fig. 5.3.**

Table 5.3 Storey displacement variation

Storey	Model 1 (mm)	Model 2 (mm)	Eurocode8 Limitation (H/250)
Storey 10	21.983	18.016	120
Storey 9	21.32	17.282	108
Storey 8	20.237	16.12	96
Storey 7	18.757	14.569	84
Storey 6	16.958	12.706	72
Storey 5	14.91	10.614	60
Storey 4	12.671	8.366	48
Storey 3	9.902	6.027	36

Storey 2	6.623	3.671	24
Storey 1	2.711	1.461	12

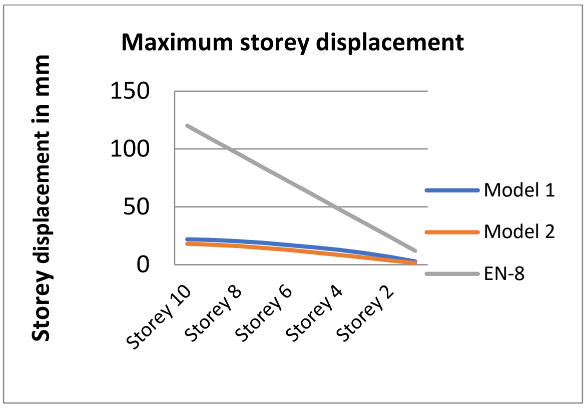


Fig. 5.3 Variation in storey displacement

Maximum storey displacement is observed in model 1 i.e. **21.914mm** at 10th storey and both model`s displacement limits are within the permissible limit of **Eurocode 8.**Hence, both are safe in displacement.

5.4 Storey drift:-Storey drift is the relative displacement between floors above or below the storey considered and it should not exceed 0.004 times of height of building as per **IS 1893:2016 part-I**(clause 7.11.1). storey drift for model 1 and model 2 is given in **table 5.4** and **fig. 5.4.**

Table 5.4 Variation in storey drift

Storey	**Model 1 (mm)**	**Model 2 (mm)**	**IS1893:2016 (part-I) (mm)**
Storey 10	0.673	0.747	12
Storey 9	1.087	1.162	12
Storey 8	1.482	1.553	12
Storey 7	1.8	1.863	12
Storey 6	2.053	2.093	12
Storey 5	2.302	2.248	12
Storey 4	2.941	2.339	12
Storey 3	3.388	2.356	12
Storey 2	3.914	2.223	12
Storey 1	2.711	1.461	12

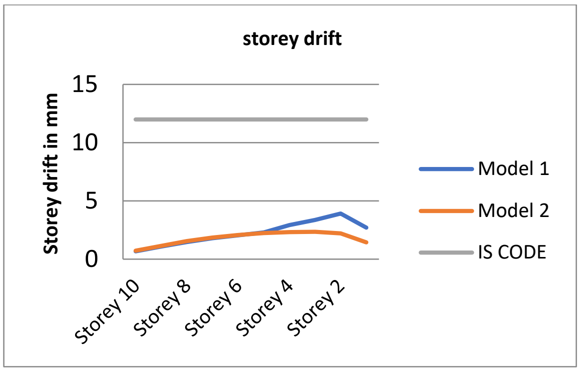


Fig.5.4 Storey drift variation

From the above **fig. 5.4** it is observed that both models are safe in storey drift.

5.5 Storey Stiffness:-Storey stiffness for both models is given below in **table 5.5** and **fig. 5.5**

Table 5.5 Variation of storey stiffness

Storey	Model 1 (kN/m)	Model 2 (kN/m)
Storey 10	420323.5	409772.7
Storey 9	501618.4	493471.6
Storey 8	512502.8	506538.6
Storey 7	516282.5	511569.8
Storey 6	518167.3	514741.3
Storey 5	519905.9	518189.2
Storey 4	503122.8	523380.4
Storey 3	**314550.9**	534643.6
Storey 2	**149414.4**	577038.2
Storey 1	**248870.2**	880820.6

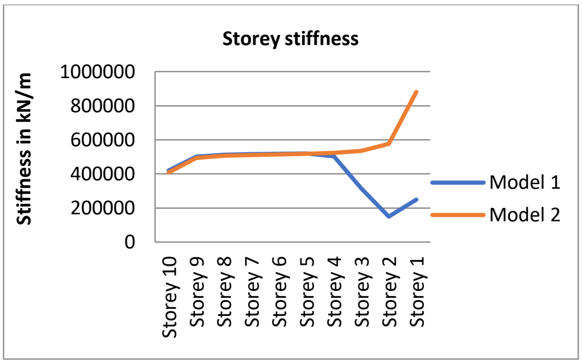


Fig.5.5 Variation in Storey stiffness

From the above **fig. 5.5** it is noticed that for step back building there is variation of stiffness along the storey height, Storey 1, storey 2 and storey 3 shows less stiffness in model 1 so this exhibits soft storey effect which need to be eliminated to prevent soft storey failure.

5.6 Torsional irregularity: -The torsion irregularity will occur when max storey drift/avg. storey drift is more than **1.5**. Max/Avg drift ratio(Torsional irregularity) for model 1 and model 2 is shown in **table 5.6** and **fig 5.6**

Table 5.6 Variation in Torsional irregularity

Storey	Model 1	Model 2
Storey 10	1.67	1.003
Storey 9	1.667	1.001
Storey 8	1.667	1
Storey 7	1.667	1
Storey 6	1.667	1
Storey 5	1.67	1
Storey 4	1.681	1
Storey 3	1.673	1
Storey 2	1.67	1.002
Storey 1	1.666	1.004

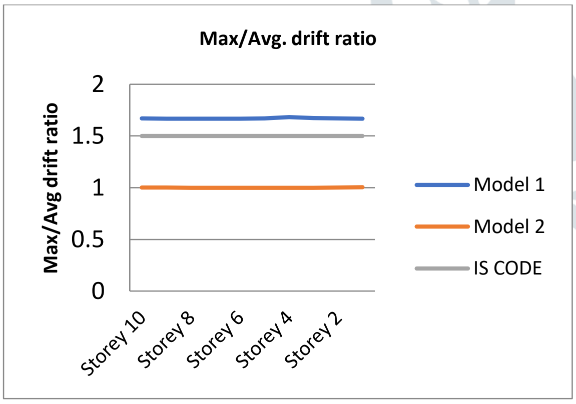
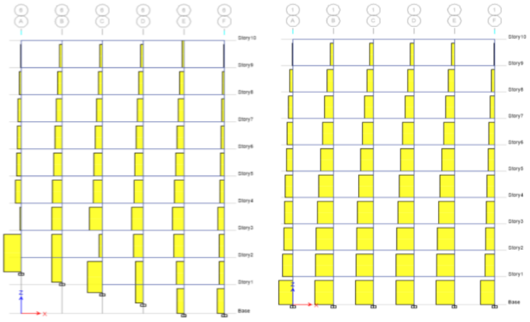


Fig.5.6 Torsional irregularity storey wise variation

As the angle of building increases building goes under significance torsion due to unequal variation of center of mass and center of stiffness. Under the earthquake force along X direction model 1 shows significant torsional irregularity as its max/avg drift ratio**1.67**which indicates the structure will undergo significant moment of torsion during earthquake.

5.7 Shear force: -Variation of shear force along the height of building for both models are shown in **fig. 5.7.**



Model 1 **Model 2**

Fig 5.7 shear force variation along the height of building

From the above **fig. 5.7** it is concluded that when subjected to earthquake forces shorter column on uphill side attract higher shear force than the long column within same storey.

6. CONCLUSIONS

- As the angle of building increases time period of building decreases.
- Step back building attract more lateral shear force that's why base shear in model 1 is more than model 2
- It is noticed that for step back building there is variation of stiffness along the storey height, storey 1 storey 2 and storey 3 shows less stiffness in model 1, so this exhibits soft storey effect.
- When subjected to earthquake forces shorter column on uphill side attract higher shear force than the long column within same storey.
- Under the earthquake force along X direction building undergoes significant torsion.

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