Effects of Sloping Ground on Step-Back Configurations of R.C.C. Building under Seismic loads

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Abstract— Present study summarizes the behavior of buildings on hill slopes. The analysis of G+3 buildings on varying slope angles i.e. 00, 7.50, 300, and 600 has been conducted. Step back building configurations 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%. 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, top storey displacement, shear in bottom storey column, time period are critically analyzed to quantify the effects of various sloping ground. It is found that column on the higher side of slope i.e. short columns are subjected to large shear force than longer columns on lower side.

Keywords: Step Back, Seismic Force, Irregular, Stability

I. INTRODUCTION

Earthquake is the most disastrous due to its unpredictability and huge power of devastation. Earthquakes themselves do not kill people, rather the colossal loss of human lives and properties occur due to the destruction of structures. Building structures collapse during severe earthquakes, and cause direct loss of human lives. Numerous research works have been directed worldwide in last few decades to investigate the cause of failure of different types of buildings under severe seismic excitations. Massive destruction of high-rise as well as low rise buildings in recent devastating earthquake proves that in developing counties like India, such investigation is the need of the hour. Slope structures are not the same as those in fields; they are exceptionally sporadic and unsymmetrical in level and vertical planes, and torsionally coupled. Consequently, they are defenseless to extreme harm at the point when influenced by earthquake ground movement. Seismic powers acts more separate in sloping areas because of the auxiliary anomaly. Likewise it has been contemplated that the earthquake activities are inclined in sloping ranges.

The economic growth and rapid urbanization in hilly terrain, 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. 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.

II. CONFIGURATION OF BUILDINGS ON HILL SLOPES

A. *Configuration of Hill Buildings*

Buildings on hill slopes may have following types of configurations:

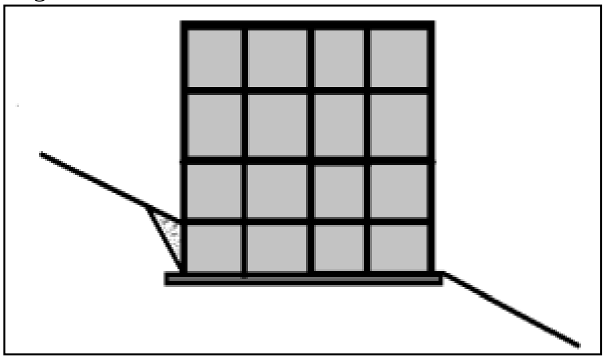

Fig. 2.1: Foundation of the entire building on the same level

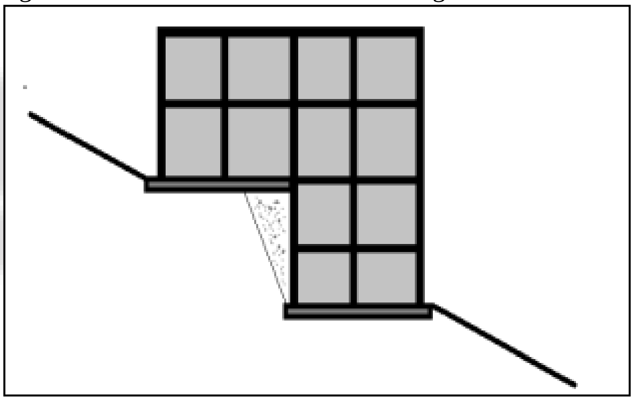

Fig. 2.2: Building founded on two different levels

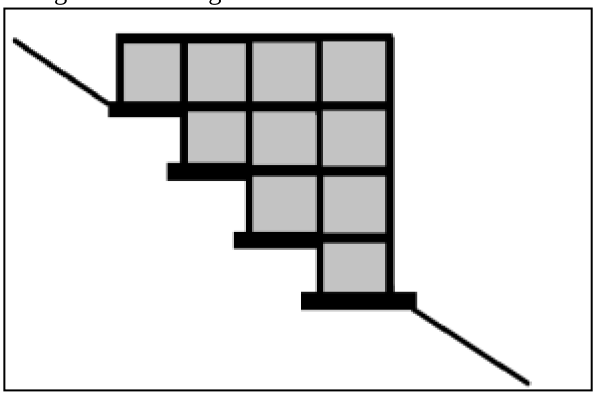

Fig. 2.3: Step-back configuration

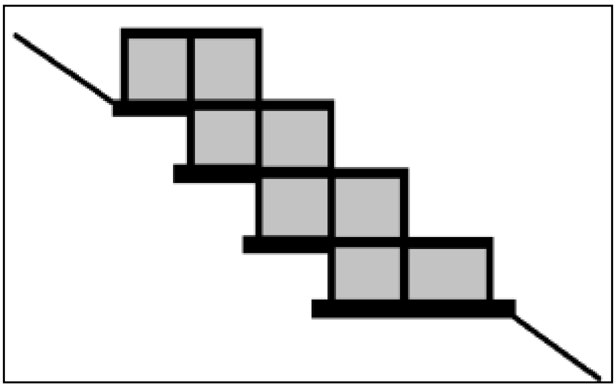

Fig. 2.4: Step-back & set-back configuration

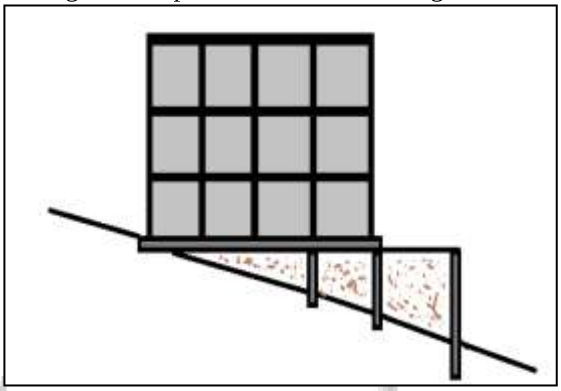

Fig. 2.5: Building partly founded on an artificially created platform supported by a retaining wall on the downhill side

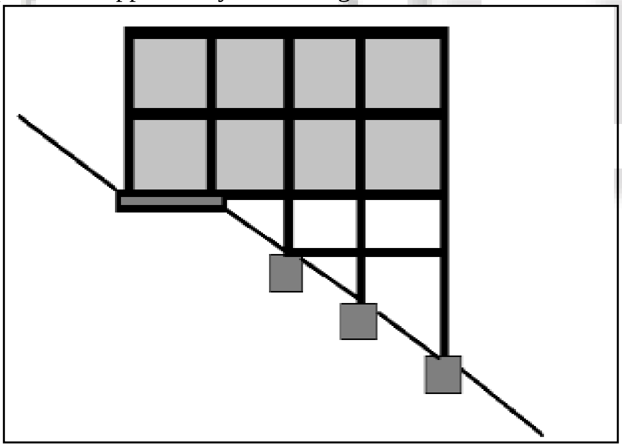

Fig. 2.6: Parts of the building supported by stilts on the downhill side

Out of several such configurations, step back configuration are commonly observed in hill regions. A step back configuration may be defined as a configuration whose foundation structure more or less follows the natural shape of the slope and at the same time there is sudden change in plan dimension or stiffness along the height of the building.

III. Detailed Studies

A. *Seismic Behavior of Buildings on Slopes in India*

North and northeastern parts of India have large scales of hilly region, which are categorized under seismic zone IV and V. In this region the construction of multistory RC framed buildings on hill slopes has a popular and pressing demand, due to its economic growth and rapid urbanization. This growth in construction activity is adding increase in population density. While construction, it must be noted that Hill buildings are different from those in plains i.e., they are very irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled.

Since there is scarcity of plain ground in hilly areas, it obligates the construction of buildings on slopes. 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 taller columns in the same storey. One example of buildings with short columns in buildings on a sloping ground can be seen in the Fig.(4.1) given

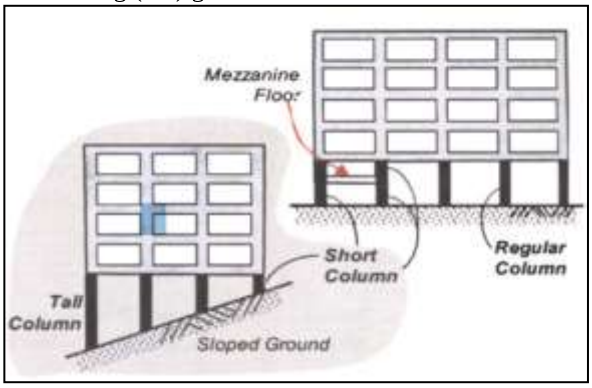

Fig. 3.1: Building Frame from short column

poor behavior of short columns is due to the fact that in an earthquake, a tall column and a short column of same cross section move horizontally by same amount which can be seen from the given figure(4.2)below.

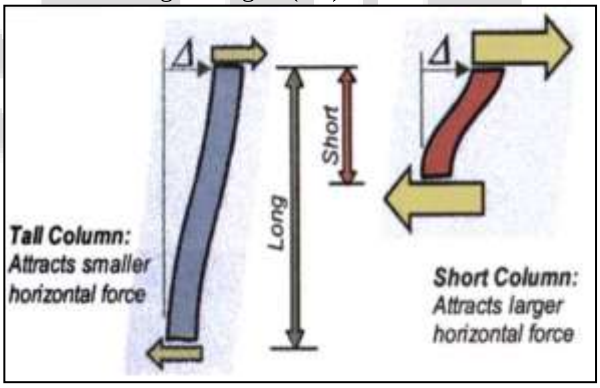

Fig. 3.2: Structural behavior of short column under lateral load

However, the short column is stiffer as compared to the tall column, and it attracts larger earthquake force. Stiffness of a column means resistance to deformation the larger is the stiffness, larger is the force required to deform it.

Therefore a short column should be design very carefully for large horizontal forces otherwise it can suffer significant damage during an earthquake. This behavior is called Short Column Effect.

A building resting on sloping ground when acted upon by an earthquake, all columns of bottom storey moves by same amount along with the floor slab (this is called rigid floor diaphragm action). Since in bottom storey of buildings resting on sloping ground there exist both short and long columns and hence shorter columns attract several times larger earthquake force and suffer more damage as compared to longer ones due to short column effect.

B. Methods and Materials

The present study is concerned with analyzing seismic behavior of step back buildings on different hill slopes. 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 V8i software.

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.

a) 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. The formula used for calculating self weight of each structural element in KN/m is unit weight of material (KN/m3) × depth of element × width of element.

b) 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 imposed load 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 as described below.

Residential Buildings	Uniformly Distributed Load (kN/$\mathbf{m2}$)
All rooms and kitchens	2
Toilet and bath rooms	2
Corridors, passages, staircases and store rooms	3
Balconies	3
Dining rooms, cafeterias and restaurants	4

Table 3.1: Imposed floor loads for residential buildings

c) 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. Determination of design lateral force is an important aspect of seismic analysis.

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)

3) Equivalent static method

For simple regular structures, analysis by equivalent linear static method is often sufficient. Equivalent static analysis can therefore work well for low to medium-rise buildings without significant coupled lateral-torsional modes.

In Equivalent static method of seismic analysis, the Base Shear $\bar{\mathbf{V}}_B$ along any principal direction is given by,

$$\bar{\mathbf{V}}_B = A_h \times w \tag{3.1}$$

Where,

A_h=Design horizontal seismic coefficient
w=Seismic weight of building

Design horizontal seismic coefficient A_h is given by,

$$A_h = \left(\frac{Z}{2}\right)\left(\frac{I}{R}\right)\left(\frac{Sa}{g}\right) \tag{3.2}$$

Where,

Z = Zone Factor
I = Importance Factor
R = Response Reduction Factor
$\frac{Sa}{g}$ = Response Acceleration coefficient

Is code 1893 (part 1):2002 recommends the following values of zone factor, importance factor, response reduction factor and response acceleration coefficient.

Seismic zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very severe
Zone factor	0.10	0.16	0.24	0.36

Table 3.2: Zone factor,

Structure	Importance factor
Important service and community buildings, such as hospitals, fire station buildings.	1.5
All other buildings	1

Table 3.3: Importance factor, I

Ordinary RC moment-resisting frame (OMRF)	3
Special RC moment-resisting frame (SMRF)	5

Table 3.4: Response reduction factor (R)

For rocky or hard soil sites,	$\left(\frac{Sa}{g}\right) = \begin{cases} \mathbf{1+15T}; & \mathbf{0.00 \le T \le 0.10} \\ \mathbf{2.5}; & \mathbf{0.10 \le T \le 0.40} \\ \mathbf{1.00/T}; & \mathbf{0.40 \le T \le 4.00} \end{cases}$
For medium soil sites,	$\left(\frac{Sa}{g}\right) = \begin{cases} \mathbf{1+15T}; & \mathbf{0.00 \le T \le 0.10} \\ \mathbf{2.5}; & \mathbf{0.10 \le T \le 0.55} \\ \mathbf{1.36/T}; & \mathbf{0.55 \le T \le 4.00} \end{cases}$

For soft soil sites,	$\left(\frac{Sa}{g}\right) = \begin{cases} 1+15T; & 0.00 \leq T \leq 0.10 \\ 2.5; & 0.10 \leq T \leq 0.67 \\ 1.67/T; & 0.67 \leq T \leq 4.00 \end{cases}$

Table 3.5: Response acceleration coefficient (**sa**/**g**)

4) Response Spectrum method

According to the IS 1893 (part I) : 2012, High rise and irregular building must be analyzed by response spectrum method using spectra shown.

The purpose of dynamic analysis is to obtain the design seismic forces, with its distribution to different levels along the height of the building and to the various lateral load resisting elements similar to equivalent lateral force method. The procedure of dynamic analysis of irregular type of buildings should be based on 3D modeling of building that will adequately represent its stiffness and mass distribution along the height of the building so that its response to earthquake could be predicted with sufficient accuracy.

IV. BUILDING DESCRIPTION

To Analyze and Design multi-storey building in with step back buildings on different hill slopes.

A. Design Data:

Type of Building: RCC Frame Structure
Number of storey: 4 storey
Plan Size: 12 m X 12 m
Floor to Floor height: 3.0 m
Bottom storey short column height: 1.5 m
Bottom storey long column height: 3.0 m
External walls: 230 mm thick
Internal walls: 230 mm thick
Height of parapet: 1.2 m
Material: Reinforced Concrete for the Columns and Beams
Slab Thickness: 130 mm
Size of Beam: 230 mm X 380 mm
Size of Column: 230 mm X 450 mm
Grade of concrete: M25
Grade of Steel Reinforcement: Fe 500
Type of supports: Fixed
Type of Frame: OMRF
Live load on Floor: 3 KN/m2
Live load on Roof: 1.5 KN/m2
Seismic Zone: IV
Response reduction Factor: 5
Important Factor: 1
Damping: 5%
Soil type: Medium Soil
Poisson ratio for concrete: 0.17
Elasticity of Concrete: 2.5×10^4 N/mm^2
Density of Concrete: 25 KN/m^3
Density of Brick masonary: 20 KN/m^3

B. Model Details

1) Four storey step back buildings

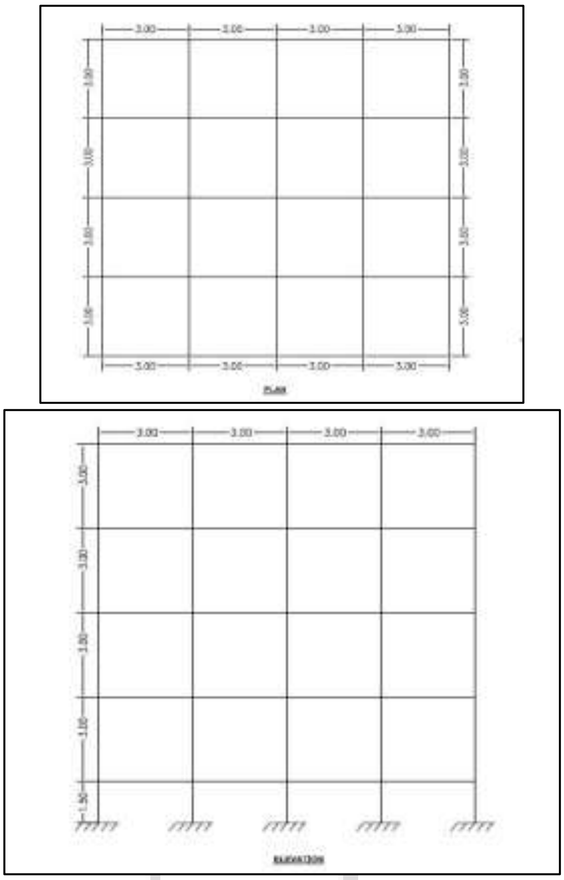

Fig. 4.1: Building on flat ground (G+3)

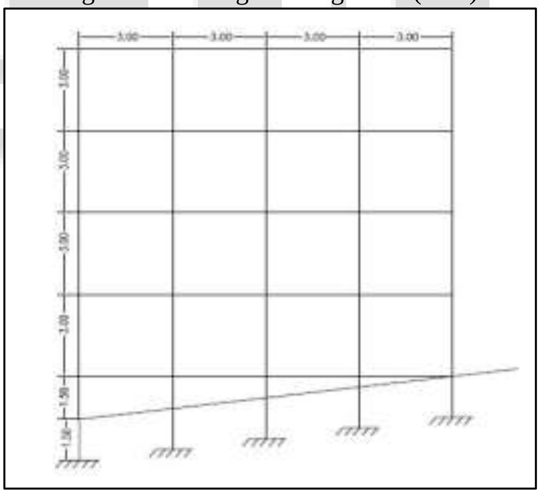

Fig. 4.2: Building on 7.5° ground slope (G+3)

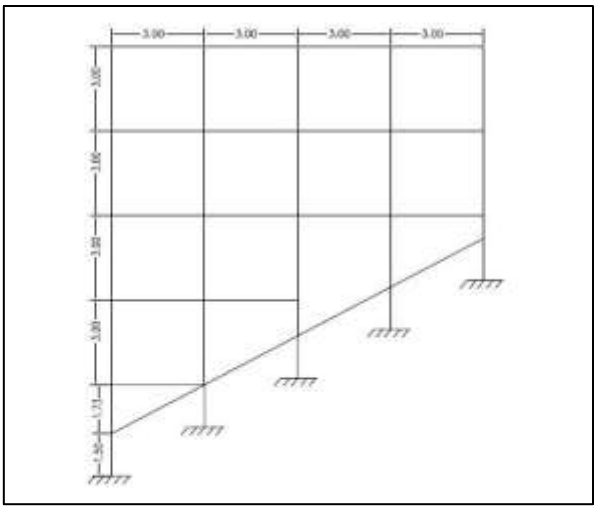

Fig. 4.3: Building on 30° ground slope (G+3)

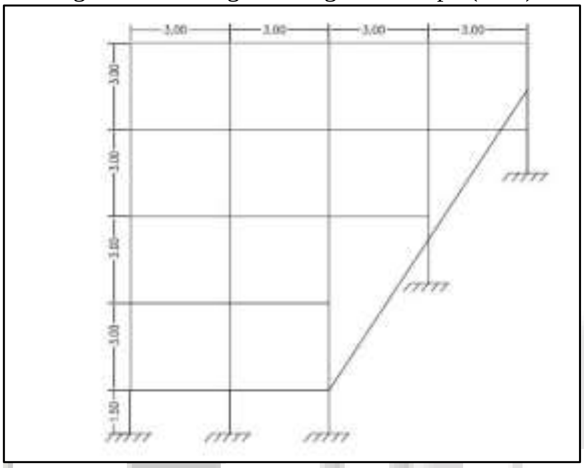

Fig. 4.4: Building on 60° ground slope (G+3)

V. CONCLUSION

- Buildings resting on sloping ground have more lateral displacement compared to buildings on Plain ground.
- The critical axial force in columns increases as slope increases.
- Calculated time period decreases as slope of ground increases.
- high quality of construction to be provided conforming to related IS codes such as IS 1893 , IS 13920 to ensure good performance during future earthquakes.
- To implement the design of building elements and joints between them in accordance with analysis.
- After designing, it is concluded that steel quantity on sloping ground is more than on plain ground for same cross section of column and beam.
- Thus cross section required more steel on sloping ground to make earthquake resistant structures.

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