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Effects of Sloping Ground on the Structural performance of R.C.C. Building Under Seismic loads

Er. Aditi H. Deshmukh[1] Ms. Monica S. Suryawanshi[2]

[1,2]Department of Structural Engineering, COETA Akola, S.G.B.A.U. Amravati, India

ABSTRACT

Present study summarizes the behavior of buildings on hill slopes. The analysis of G+3 buildings on varying slope angles i.e. 0^0, 7.5^0, 30^0, and 60^0 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

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

B. Objective: The objective of present study is as follows:
- To compare the effectiveness of step back frames and step back & set back frames on sloping ground.
- To study variation of base shear, time period, displacement, axial force, bending moment, shear force with respect to variation in hill slope angle and storey height for different configurations of building frames.
- To create the building resting on various slopes (0^0, 7.5^0, 30^0, 60^0).

C. Need of Study
- The study is carried out for two different configurations such as step back frame and step back & set back frame on sloping ground.
- To study on the influence of varying sloped ground on the overall behavior of structure when subjected to lateral seismic forces.
- The present work aims at proving an analytical approach for finding out the damage distribution in the structure due to earthquake loading.

II METHODOLOGY

PHASE-I
- To decide Aim, Objective, Need of work.
- To decide the flow of work i.e. Methodology.

PHASE-II
- Details study of all Structural Effects.
- Effects of Earthquake and its parameter.
- Types of Loading and Methods of Analysis.
- Soft storey Consideration.
- Fixing all general data and Case consideration of Models.

PHASE-III
- Analyzing all the selected model patterns.
- Drafting of comparative result Statements.
- Discussing all obtained Results.
- Conclusions on results obtained after analysis and Discussion.

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 figure (4.1) given

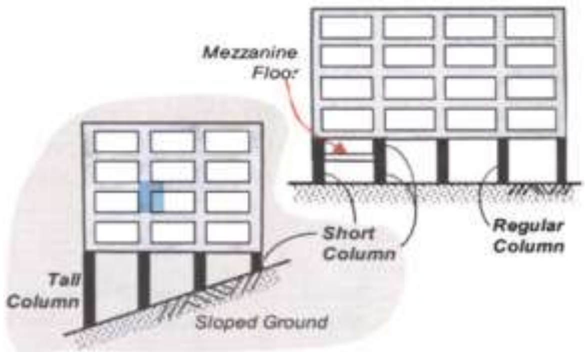

Figure 3.1 Building Frame from short column

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.

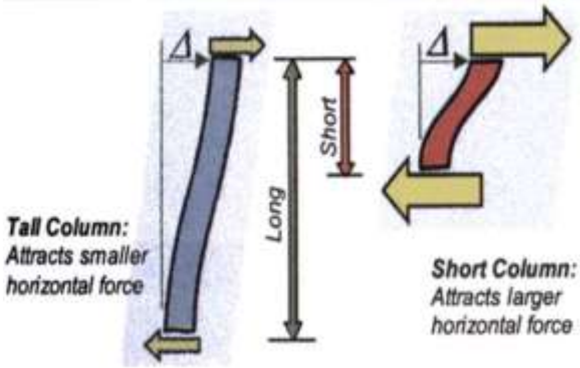

Figure 3.2 Structural behaviour of short column under lateral load

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.

i) 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.

ii) 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.

Table 3.1 Imposed floor loads for residential buildings

Residential Buildings	Uniformly Distributed Load (kN/m^2)
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

iii) 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 $\bar{V}_B$ along any principal direction is given by,

$$\bar{V}_B = A_h \times w \qquad (3.1)$$

Where,

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

Design horizontal seismic coefficient A_h is given by,

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

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.

Table 3.2 Zone factor,

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

Table 3.3 Importance factor, I

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

Table 3.4 Response reduction factor (R)

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

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

For rocky or hard soil sites,	$(\frac{Sa}{g}) = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.5; & 0.10 \le T \le 0.40 \\ 1.00/T; & 0.40 \le T \le 4.00 \end{cases}$
For medium soil sites,	$(\frac{Sa}{g}) = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.5; & 0.10 \le T \le 0.55 \\ 1.36/T; & 0.55 \le T \le 4.00 \end{cases}$
For soft soil sites,	$(\frac{Sa}{g}) = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.5; & 0.10 \le T \le 0.67 \\ 1.67/T; & 0.67 \le T \le 4.00 \end{cases}$

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. MODELING AND ANALYSIS OF STEP BACK BUILDING

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

Four story step back buildings

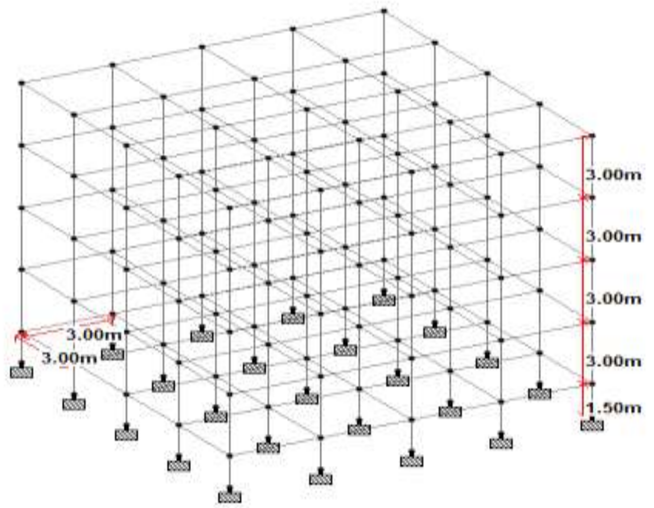

Figure 4.1 Building on flat ground (G+3)

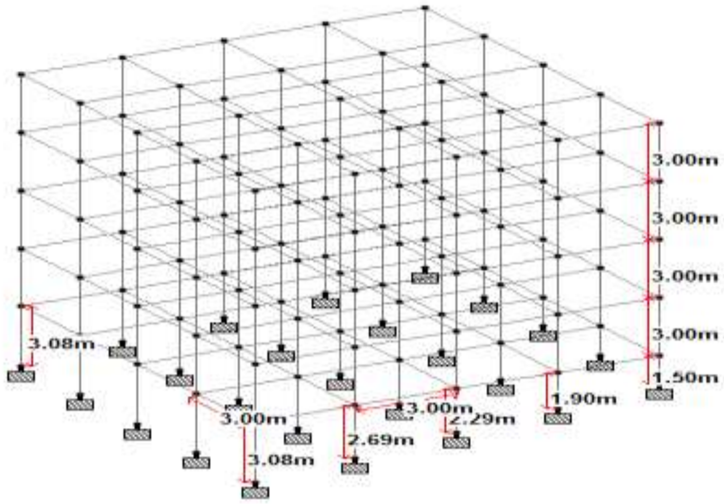

Figure 4.2 Building on 7.5° ground slope (G+3)

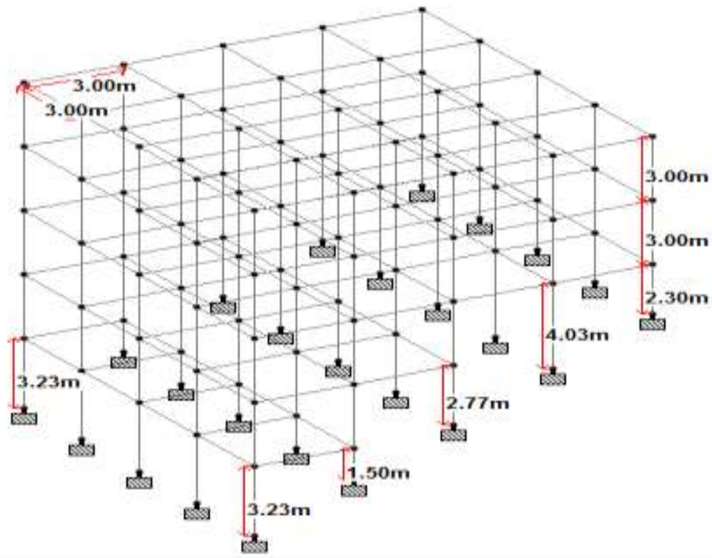

Figure 4.3 Building on 30° ground slope (G+3)

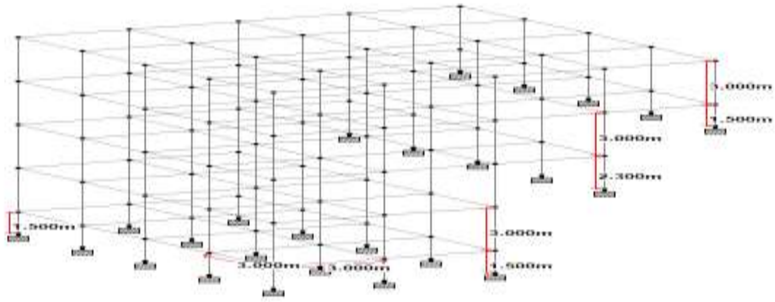

Figure 4.4 Building on 60° ground slope (G+3)

V. RESULTS

Following graphs shows the variation of fundamental time period, base shear, top storey displacement with respect to increase in angle of ground slope for step back buildings analyzed using response spectrum method and equivalent static method.

Table 5.1 Base Shear result for Step Back Building

ANGLE	BASE SHEAR (KN)	
	X-DIRECTION	Z-DIRECTION
0^0	560.02	560.00
7.5^0	657.26	657.26
30^0	575.29	575.29
60^0	607.97	607.97

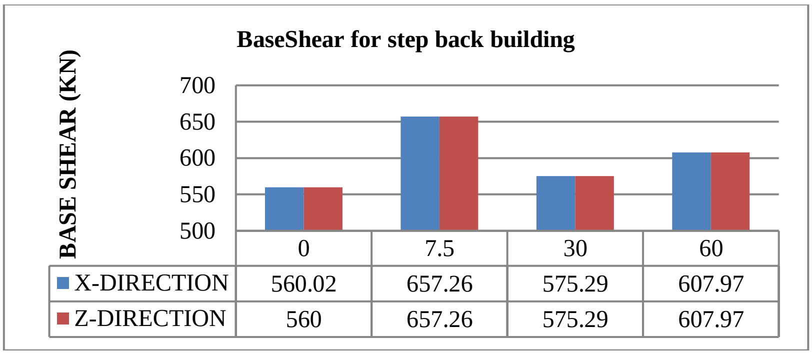

Fig. 5.1 Base Shear for step back building

Table 5.2 Displacement result for Step Back Building

ANGLE	Max. Displacement (MM)
	Step Back Building
0^0	21.09
7.5^0	32.747
30^0	24.65
60^0	22.58

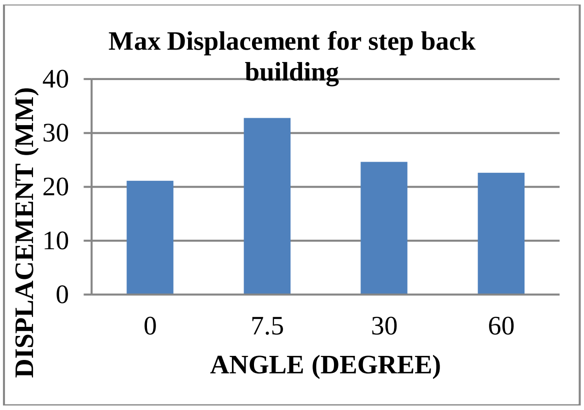

Fig. 5.2 Displacement for Step Back Building

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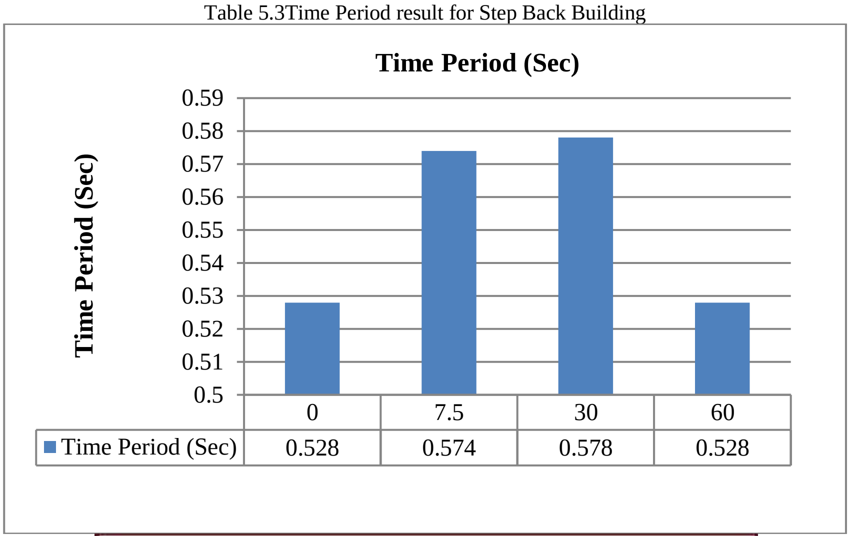
Table 5.3Time Period result for Step Back Building



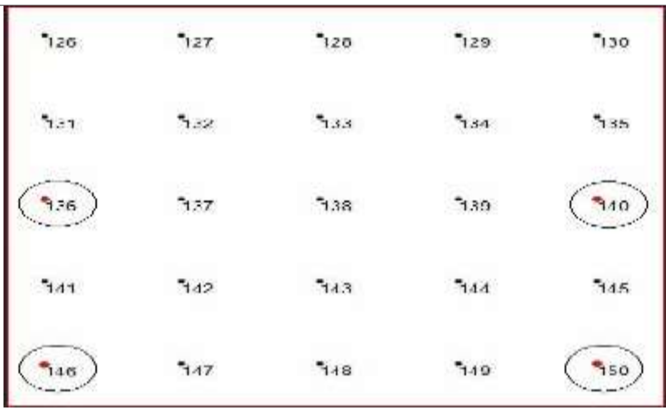


Fig 5.4 Selected column for Axial force and Bending Moment

Table 5.4 Comparison of Axial Force in columns in step back building

Comparison of maximum Axial Force in KN				
Column No.	**Slope of Ground**			
	0^0	**7.5^0**	**30^0**	**60^0**
1	109.68	119.41	119.22	110.71
2	109.68	109.90	78.64	59.80
3	168.66	184.56	128.24	170.59
4	168.66	169.28	120.25	94.10

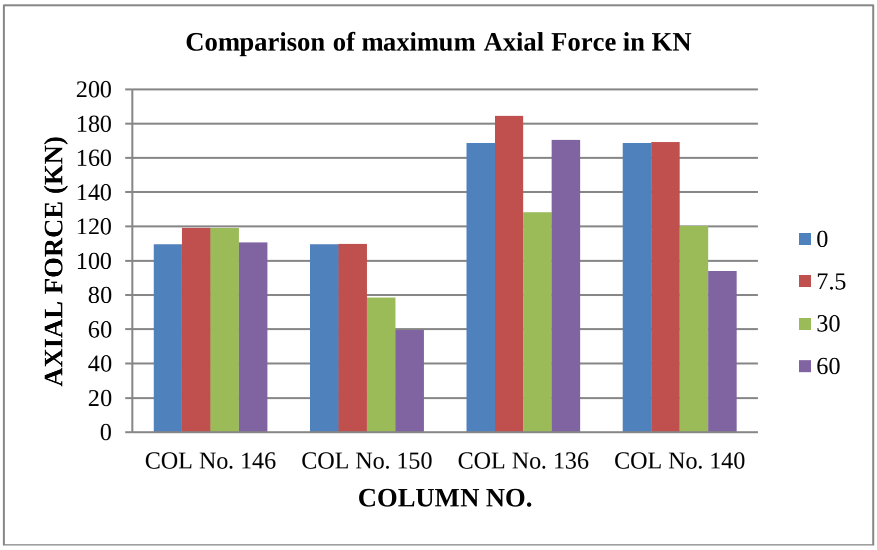


Fig. 5.5 Comparison of Axial Force in columns in step back building

Table 5.5 Comparison of Bending Moment (My) in columns in step back building

Comparison of maximum Bending Moment (My) in KN-M				
Column No.	**Slope of Ground**			
	0^0	**7.5^0**	**30^0**	**60^0**
1	14.53	12.15	7.55	8.81
2	14.53	14.03	17.22	23.79
3	15.02	12.56	7.83	9.14
4	15.02	14.49	17.9	25.24

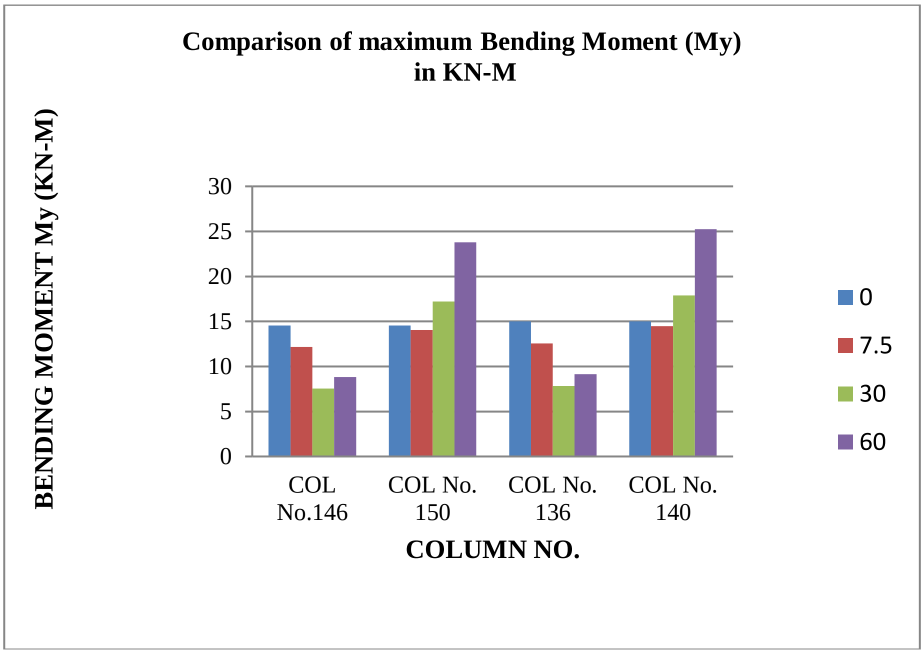


Fig. 5.6Comparison of Bending Moment (My) in columns in step back building

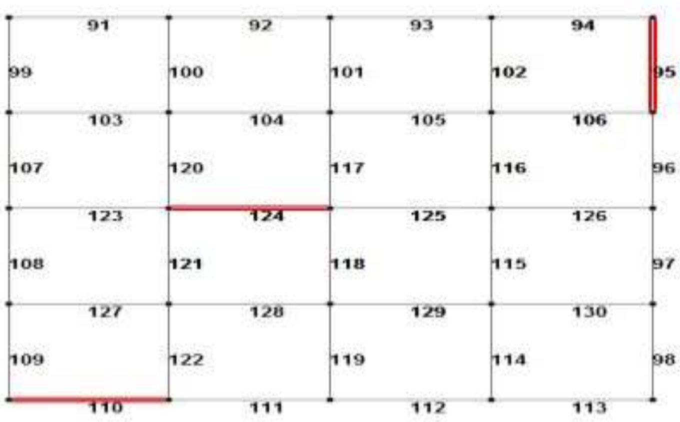


Fig 5.7 Selected Beams for Axial force and Bending Moment

Table 5.6 Comparison of Axial Force in Beam in step back building

Comparison of maximum Axial Force in KN				
Beam No.	**Slope of Ground**			
	0^0	**7.5^0**	**30^0**	**60^0**
1	2.344	1.48	1.15	2.50

2	3.44	1.61	7.19	7.11
3	2.08	3.38	10.91	17.08

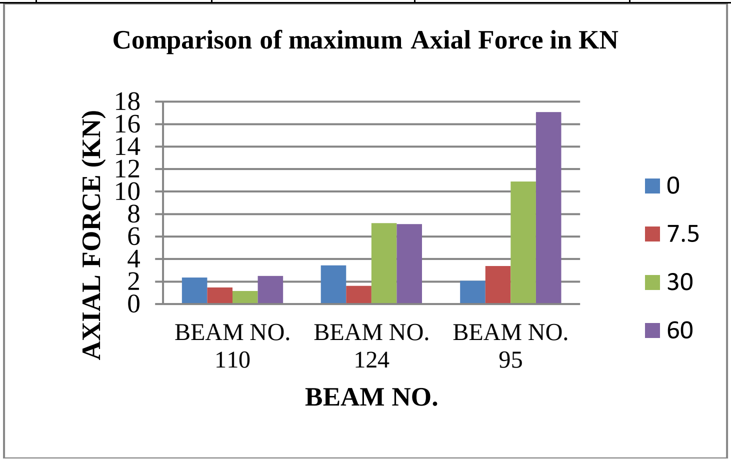


Fig. 5.8 Comparison of Axial Force in Beam in step back building

Table 5.7 Comparison of Bending Moment (Mz) in beams in step back building

Comparison of maximum Bending Moment (Mz) in KN-M				
Beam No.	**Slope of Ground**			
	0^0	**7.5^0**	**30^0**	**60^0**
1	51.33	119.62	120.52	116.71
2	64.18	59.91	35.68	43.65
3	75.23	74.65	63.03	60.63

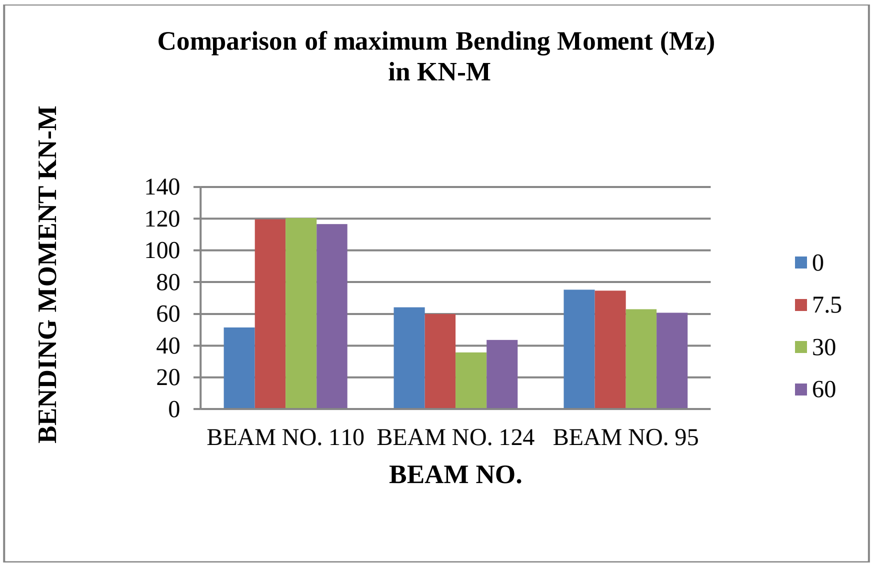


Fig 5.9 Comparison of Bending Moment (Mz) in beams in step back building

VI. CONCLUSIONS

1. Buildings resting on sloping ground have more lateral displacement compared to buildings on Plain ground.
2. The critical axial force in columns increases as slope increases.
3. Calculated time period decreases as slope of ground increases.
4. The critical bending moments is increased on 30° slope and 60^0 slope as compared to buildings on Plain ground.
5. Calculated base shear increases as slope of ground increases.

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