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STUDY ON EARTHQUAKE RESISTANT BUILDINGS ON GROUND SURFACE BY USING E-TAB

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ABSTRACT: *In many parts of India it is common practice to construct buildings on hill slopes, if there is a natural hill sloping terrain. The buildings on a sloping terrain undergo severe torsion under earthquake excitations due to considerable variation in the height of ground floor columns. Buildings constructed on hill slopes are highly unsymmetrical in nature. In the present study, three groups of building (i.e. configurations) are considered, out of which two are resting on sloping ground and third one is on plain ground. The first one is set back buildings and next two are step back and step back-set back buildings. The slope of ground is 10 degree with horizontal, which is neither too steep nor too flat. The height and length of building in a particular pattern are in multiple of blocks (in vertical and horizontal direction), the size of block is being maintained at 5m x 5 m x 4m. The depth of footing below ground level is taken as 2 m where, the hard stratum is available. Earthquake analysis has been carried out by Equivalent lateral force method (static method) or Dynamic analysis.' The static method is the simplest method with less computational effort. Dynamic analysis should be performed for regular buildings greater than 40 m in height in zones IV and V, and those greater than 90 m in height in zones II and III. For irregular buildings higher than 12 m in zones IV and V, and those greater than 40m in height in zones II and III, dynamic analysis is to be performed. In present case its height doesn't exceed 40m in any case. Using the analysis results various graphs were drawn between the Storey displacements, base shear, bending moment and torsion, being developed for the building on plane ground and sloping ground and the results were compared.*
KEYWORD: *E-TAB*

INTRODUCTION

On the earth surface, everyone is aware that many natural disasters such as earthquakes, floods, tornadoes, hurricanes, droughts, and volcanic eruptions occurs of-all natural disasters the least understood and most destructive are earthquakes. The annual losses due to earthquakes are very large in many parts of the world. They not only cause great destruction in terms of human casualties, but also have a tremendous economic impact on the affected area. Although the incidents of earthquakes of destructive intensity have been confined to a relatively few areas of the world, the catastrophic consequences of the few that have struck near centers of population have stressed on the need to provide adequate safety against this most terrible nature's quirks. India had witnessed several major disasters due to earthquakes over the past century. In fact more than 50 percent of the country is considered prone to severe earthquakes. The north - east region of the country as well as the entire Himalayan belt is susceptible to great earthquakes of magnitude more than 8.0 the main cause of earthquakes in these regions is due to the movement of the Indian plate towards the Eurasian plate at the rate of about 50 mm per year. Besides the Himalayan region and the Indo-Gangetic plains, even the peninsular India is prone to severe earthquakes as clearly .illustrated by the Koyna (1967), the Latur (1993), and the Jabalpur (1997) earthquakes, Sumatra earthquake (2004) Kashmir earthquake (2005).and Nepal earthquake (2015) The Bhuj earthquake is considered to be the largest intra-plate earthquake ever recorded. The 2001 Bhuj earthquake had great implications for earthquake hazard, not only in India, but also in other parts of the world.

REPRESENTATION OF STIFFNESS AND MASSES ABOUT A COMMON REFERENCE AXIS

In a building with rigid floor diaphragm, the following three situations may arise with respect to the centre of mass and centre of rigidity: Coincident centre of mass and centre of rigidity of each floor lie on the same vertical axis. In this case the building does not undergo torsional motion under lateral excitation and the standard stiffness approach for each storey is applicable. This is applicable to regular and symmetrical buildings. Center of mass of each floor lies on the same vertical axis, whereas the center of rigidity of each floor does not lie on the same vertical axis. In this case the stiffness of each storey is formulated about a common vertical axis.Kan and Chopra [1976, 1977, and 1981] transferred the storey stiffness from the center of rigidity to the common vertical axis passing through the center of mass of each floor. Shows that the center of mass of all the floors lies on the same vertical axis passing through the c.g. of the floors .Centre of mass of each floor does not lie on the same vertical axis and the center of stiffness of each floor also does not lie on the same vertical axis. The approach used in the first two cases cannot tackle problems. Therefore, a simplified model needs to be developed for the dynamic analysis of such irregular buildings.

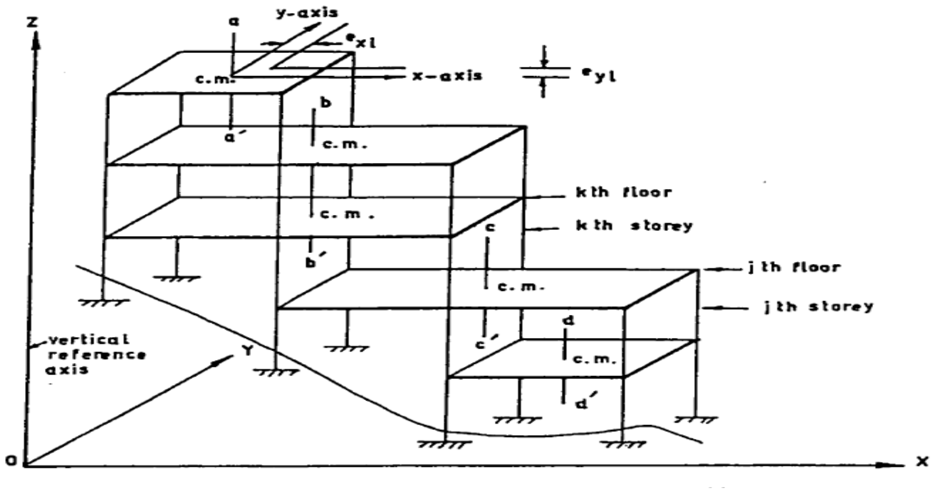


Fig.1.Idealized symmetrical set back building

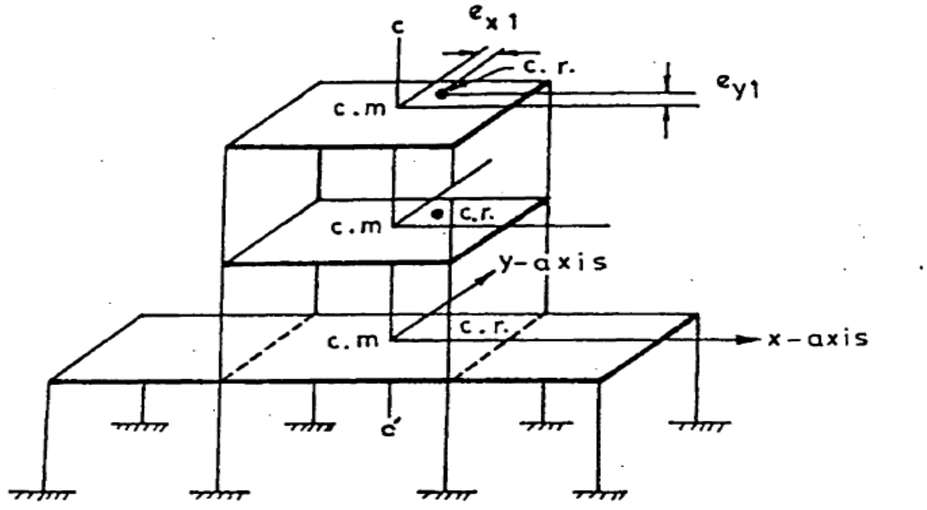


Fig.2 .Idealized multi-storey step back and setback building

- **TYPICAL DAMAGE CAUSED BY EARTHQUAKES:** The consequences of severe earthquakes arc the injury and loss of life of People, The costs of Repair of damage to structures and contents, and the costs of Disruption of Business and other activities. Almost 9,000 people were killed around the world due earthquakes during 1998, which is close to the long-term average of about 10,000 Year
- **SCOPE OF THE PROJECT**: Three dimensional space frame analysis is carried out for three different configurations of buildings ranging from 8 to 10 storey (15.75 m to 40.25 m height) resting on sloping and plain ground under the action of seismic load. Dynamic response of these buildings, in terms of base shear, fundamental time period and top floor displacement is presented, and compared within the considered configuration as well as with other configurations. At the end, a suitable configuration of building to be used in hilly area is suggested

- **BUILDING CONFIGURATION:** In the present study, three groups of building (i.e. configurations) are considered, out of which two are resting on sloping ground and third one is on plain ground. The first one is set back buildings and next two are step back and step back-set back buildings. The slope of ground is 10 degree with horizontal, which is neither too steep nor too flat. The height and length of building in a particular pattern are in multiple of blocks (in vertical and horizontal direction), the size of block is being maintained at 5m x 5 m x 4m. The depth of footing below ground level is taken as 2 m where, the hard stratum is available. The buildings of different configurations are shown in chapter-4.The building with equal number of storey's/bays have same floor area in all three configurations. The properties of frame members of buildings that are considered for analysis are given in table 4.1.The results such as Lateral loads, Base shear, Storey displacement, Storey drift and Torsion of the building are studied for buildings with different ground slopes and compared.

1. DESIGN ASPECTS

.EQUIVALENT LATERAL FORCE (SEISMIC COEFICIENT) METHOD:

This method of finding lateral forces is also known as the static method or the equivalent staticmethod or the seismic coefficient method. The static method is the simplest one and it requires less computational effort and is based on formulae given in the code of practice.In all the methods of analyzing a multi storey buildings recommended in the code, the structure is treated as discrete system having concentrated masses at floor levels which include the weight of columns and walls in any storey should be equally distributed to the floors above and below the storey. In addition, the appropriate amount of imposed load at this floor is also lumped with it. It is also assumed that the structure flexible and will deflect with respect to the position of foundation the lumped mass system reduces to the solution of a system of second order differential equations. These equations are formed by distribution, of mass and stiffness in a structure, together with its damping characteristics of the ground motion

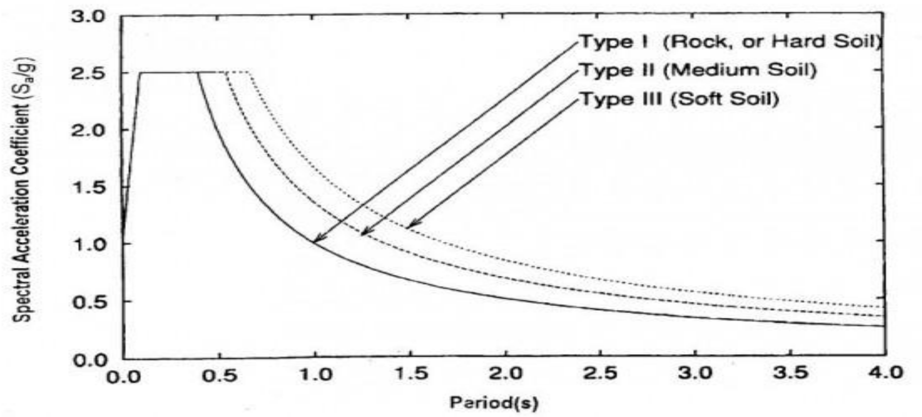


Fig:3 Design spectrums for 5 % damping as per Indian Standards

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{cases}$$

For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.55 \\ 1.36/T & 0.55 \le T \le 4.00 \end{cases}$$

For soft soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.67 \\ 1.67/T & 0.67 \le T \le 4.00 \end{cases}$$

DYNAMIC ANALYSIS: Dynamic analysis shall be performed to obtain the design seismic force, and its distribution in different levels along the height of the building, and in the various lateral loads resisting element, for the following buildings

Regular buildings: Those greater than 40m in height in zones IV and V, those greater than 90m in height in zone II and III.

Irregular buildings: All framed buildings higher than 12m in zones IV and V, and those greater than 40m in height in zones II and III.The analysis of model for dynamic analysis of buildings with unusual configuration should be such that it adequately models the types of irregularities present in the building configuration. Buildings with plan irregularities, as defined in Table 4 of IS code: 1893-2002 cannot be modeled for dynamic analysis. Dynamic analysis may be performed either by the time history method or by the response spectrum method.

3. MODELLING AND ANALYSIS

Building Configuration: In the present study, three groups of building (i.e. configurations) are considered, out of which first one is on the plain ground and the two are resting on ground of (**10^{O}**of slope)

- **Setback buildings.**
- **Step back buildings.**
- **Setback &Step back buildings.**

The slope of ground is **10** degree with horizontal, which is neither too steep or nor too flat. The height and length of building in a particular pattern are in multiple of blocks (in vertical and horizontal direction), the size of block is being maintained at 5 m x 5 m x 4 m. The depth of footing below groundlevel is taken as 2 m where, the hard stratum is available.

1. Set back buildings resting on plain ground having SET 8, SET 9 and SET 10, as shown in figure 3.1. The building with equal number of bays has same floor area in all three configurations.
2. The buildings shown in figure 3.2, having step back configuration are labeled as STEP8, STEP9 and STEP10 for 8 to 10 storey respectively.
3. Step back -Set back configuration of buildings is shown in fig3.3, are labeled as STEPSET 8, STEPSET 9 and STEPSET 10 for 8 to 10 storey.

Table 4.1: Geometrical properties of members for different configuration of building

Building Configuration	Size of Column	Size of Beam
Set Back building	300 X 600 mm	230 X 500 mm
Step Back Buildings	300 X 600 mm	230 X 500 mm
Step Back and Set Back building	300 X 600 mm	230 X 500 mm

Method of Analysis: The analysis is based on following assumptions.

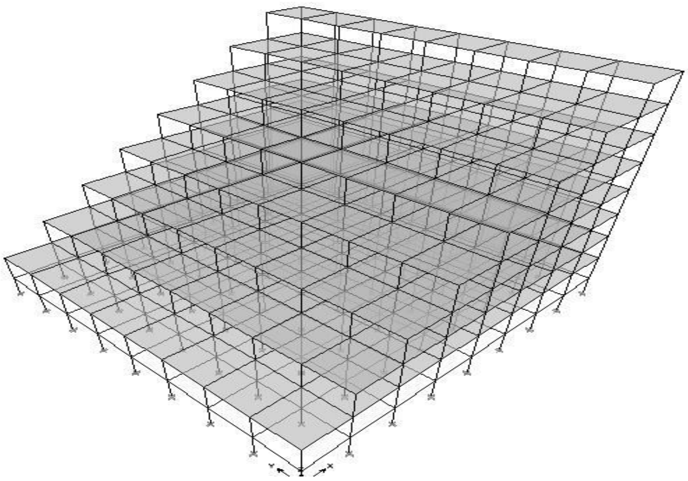
i) Material is homogenous, isotropic and elastic.
ii) The values of modulus of elasticity and Poisson's ratio are 25000 N/mm^2 and 0.20, respectively.
iii) Secondary effect P-Δ, shrinkage and creep are not considered.
iv) The floor diaphragms are rigid in their plane.
v) Axial deformation in column is considered.
vi) Each nodal point in the frame has six degrees of freedom, three translations and three rotations
vii) Torsional effect is considered as per IS: 1893 (I) –2002.

The properties of frame members of buildings that are considered for analysis are given in table 4.1.

DESCRIPTION OF BUILDING

The structure chosen for study is a Eight, Nine, and Tenth storied commercial complex building. The building is located in seismic zone II on a Rock and Hard soil site. Three dimensional mathematical models for the same are generated in ETABS software. For all structural elements, M25 grade of concrete was used. However M35 grade of concrete is used for central columns up to plinth, in ground floor and first floor. The floor diaphragms areassumed to be rigid. Seismic loads were considered acting in the horizontal direction along either of the two principal directions and not along the vertical direction, since it is not considered to be significant.

Using ETABS a Eight, Nine, Tenth storey Reinforced Concrete structure with ground slope varying from 0° and 10° is modeled, analyzed. As a building with 0° and 10° slope, the 3-D Views and elevations of a building are shown in figures3.1 below.SET BACK BUILDINGS WITH 0^0 SLOPE (STOREY'S 8, 9, 10)



Figures3.1 below.SET BACK BUILDINGS WITH 0^0 SLOPE (STOREY'S 8, 9, 10)

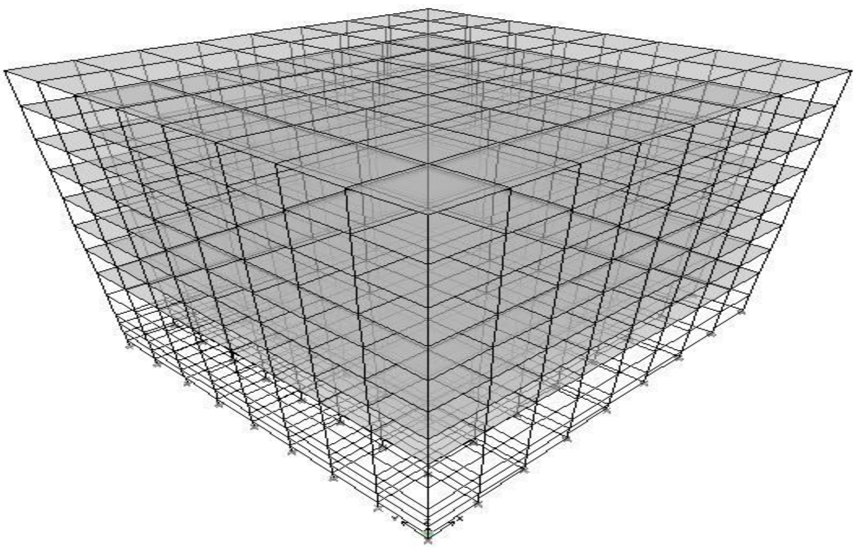


Fig 3.2STEP BACK BUILDINGS WITH 10^0 SLOPE (STOREY 8, 9, 10)

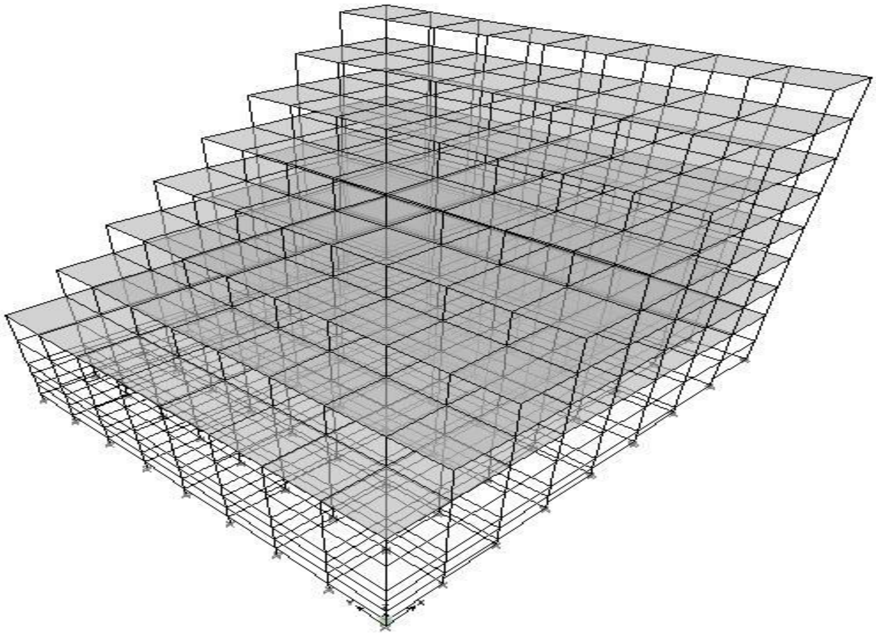


Fig3.3 SET BACK & STEP BACK BUILDING WITH 10^0SLOPE (STOREY 8, 9, 10)

LATERAL LAOD DISTRIBUTION: The lateral load distribution with storey height for different buildings of storey 8 lying on 0^0 to 10^0 ground slope using both linear static method and response spectrummethod are shown in table below.

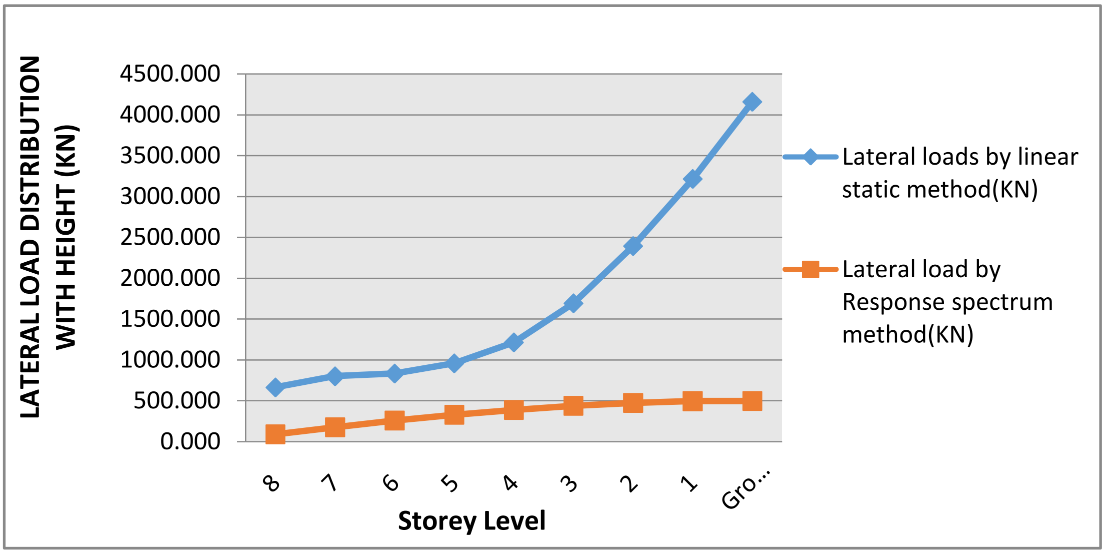


Fig3.4 Lateral load distributions for setback building of storey 8

TORSION OF THE BUILDING: The Torsion of the building with ground slope 0^0 and 10^0 at the bottom of each storey is shown in table. It is observed that the torsion of the building decreases as the storey level increases for all cases with 0^0 and 10^0 ground slope. And also it is observed that in the ground floor torsion is increased as the cases are changed. From this it is concluded that as the slope of ground increases, the torsion will affect the building

BENDING MOMENT: The variation in bending moment for the critical ground floor columns for ground slopes 0^o& 10^o are for setback, step back and set back-step back buildings are tabulated below

SHEAR FORCE: The variation in shear force for the critical ground floor columns for ground slopes 0^o& 10^o are for setback, step back and set back-step back buildings are tabulated below.

SUMMARY

The main objective of this project was to study the behavior of a eight, nine & tenth storied building with different degrees of ground slope under earthquake load. To achieve the above objectives, a detailed literature review was carried out and presented in Chapter 2 Detailed Design aspects is explained in Chapter 3 and Chapter 4 discusses in detail issues related to structural modelling. Basic modelling for the linear and nonlinear-analyses of RC framed structures is discussed in detail. Chapter 5 presents the analysis results and the discussions. Slope categories ranging from 0^O& 10^O were considered. The buildings were analysed using linear dynamic analysis (Response spectrum method) as per the IS 1893(Part-l): 2002 loading requirement and compares with the linear static analysis. For eachcase, time period, base shear, lateral load distribution, storey displacement and torsion are estimated and studied the effect of ground slopes on the different results.

COMPARISON OF THREE BUILDING CONFIGURATIONS

1 Step back building Vs. Step back Set Back Building: In Step back buildings; frame A has attracted much higher base shear force than the frames B, C, and D. This uneven distribution of shear force in the various frames suggests development of torsional moment due to static and accidental eccentricity, which has caused profound effect in Step back buildings.

.**2 Step back- set back buildings Vs. Set back buildings:**Shear action induced in Step back Set back buildings is moderately higher as compared to Set back buildings on plain ground. It is to be noted that in Step back Set back buildings, higher stiffness is required in X direction whereas, in Setback buildings more stiffness is required in Y direction. If, cost component of cutting the sloping ground and other related issues, is within the acceptable limits, set back buildings on plain ground may be preferred than the step back Set back buildings. In addition to this, issues viz. stability of slopes and vulnerability during the earthquake ground motion are less concerned in setback building

CONCLUSIONS

The Following conclusions are made from the present study

1. Since the mass is not varying with the increased ground slope, it can be concluded that the stiffness of the building is getting reduced where length of the columns is higher, relative to the other extreme end.

2. There is a considerable variation in the distribution of storey shears. The maximum variation in storey shear is about 55%. Hence it is advisable to adopt response spectrum method for building with sloping ground

3.The variation in bending moment between long column and short column is about 22%.This is due to presence of ground-slope is making one side of the building stiffer than the other side, which leads to variation in bending moment due to short column effect

4. The variation of torsion moments in Step back buildings is 2% higher compared to Step back set back buildings. Hence, Step back Set back buildings are found to be less vulnerable than Step back building against seismic ground motion.

5.. In Step back buildings and Step back-Set back buildings, it is observed that extreme left column at ground level, which are short, are the worst affected. Special attention should be given to these columns in design and detailing

SCOPE FOR FUTURE WORK

1. A high rise building of higher storeys has to be studied to check the effect of sloping ground for different seismic zones.

2. The present study is based on linear dynamic analysis using Response spectrum method. The results need to be verified with the non-linear dynamic analysis.The study can be extended to find out a method to control irregularity in such buildings by providing shear walls at appropriate locations of the building.

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