"STUDY AND DYNAMIC ANALYSIS OF SLOPED BUILDING"

Numesh Sahu
Department of Civil Engineering,
Kalinga University Raipur (492101), India

Swati Agrawal
Assistant Professor Department of Civil Engineering,
Kalinga University Raipur (492101), India

Akshit Lamba
Assistant Professor Department of Civil Engineering,
Kalinga University Raipur (492101), India

ABSTRACT

Buildings constructed on slopes are different from those in plains. They will be irregular and unsymmetrical in horizontal and vertical planes, and torsion ally coupled. Hence, they are susceptible to severe damage when affected by earthquake ground motion. We cannot avoid the long run earthquakes but the preparedness and safe building construction practices for earthquakes can certainly reduce the extent of injury and loss of both property and life. this is often often because of the actual fact that the columns within the bottom storey are of varied heights in such how that column in one end could also be a brief column and column in other end could also be an extended column. Dynamic characteristics of hill buildings are somewhat different from the buildings on flat ground. Torsional effect of such buildings is broken for having the difference stiffness and mass along horizontal and vertical plane during ground, motion .Short columns of RC frame buildings damage thanks to attracting more forces during earthquake. The work is concentrated to research 2-D frame of (G+8) building on plane and on sloping ground at 45degrees, 65 degrees using ETABS Software when seismic load serein corporated.

KEYWORDS: Multi-storeys building, hill slope angle, seismic response, sloping ground, response spectrum, optimum case, setback case, step-back setback case.

INTRODUCTION

Seismic history of India shows that the zones of upper seismic activity and better magnitudes are mostly presents in hilly terrains of northern and northeastern regions. Also these places are more likely attracts peoples from plains for various purposes varying from adventure, tourism, religious and also for resolving problem of habitat to decrease in habitable land within the urban areas. These all purposes may cause resolve the matter of migration of peoples from hilly regions to lack of resources, which may provide aids to comply their basic needs.

Building structures subjected to seismic forces are always more susceptible to collapse and if this phenomenon occurs on a sloping ground building structures as on hills which lies at some inclination angle to the bottom , chances of injury suddenly increase far more thanks to increase in lateral forces like seismic and wind on short column on upward hill side and on the short column side more number of plastic hinges forms. Building structures built on slopey terrain differs from those, which are on plains because sloping structures have irregularity in horizontally also as vertically. Dynamic characteristics of hill buildings are significantly different from the buildings resting on flat topography, as these are irregular and unsymmetrical.

In both horizontal and vertical directions. The irregular variation of stiffness and mass in vertical as horizontal directions, leads to centre of mass and centre of stiffness of a storey not coinciding with one another and not being on a vertical line for various floors. When subjected to lateral loads, these buildings are generally subjected to significant torsion response. Further, due to site conditions, buildings on hill slope are characterized by unequal column heights within a storey, which lands up in drastic variation in stiffness of columns of the same storey. The short, stiff columns on uphill side attract much higher lateral forces and are susceptible to damage. Three dimensional space frame analysis is 2 different configurations of buildings of (G+8) storeys resting on sloping and plane ground under the action of seismic load in ETABS software.

RELEVENCE OF WORK

Due to difference in the ground condition of building structures in plains to the sloping terrain of horizontal as well as vertical plains situations. Sloping ground building structures have more predictable to severe damage due to worse effect of earthquake ground motion. The appraoch & the accuracy of analytical results depend upon the characteristics of geometry of the structure & the loading on the structure.

The present work aims at providing an analytical approach for finding out the displacements, storey drifts, fundamental time period, base shear for a multi-storey building structures resting on a sloping ground terrain subjected to earthquake load. Response spectrum analysis (RSA) based on the IS (1893:2002) PART 1 codal provisions is to be performed on the FINITE ELEMENT model using suitable FINITE ELEMENT ANALYSIS platform. Using the displacement characteristics various structural outputs such as time period, storey drift, base shear are to be computed.

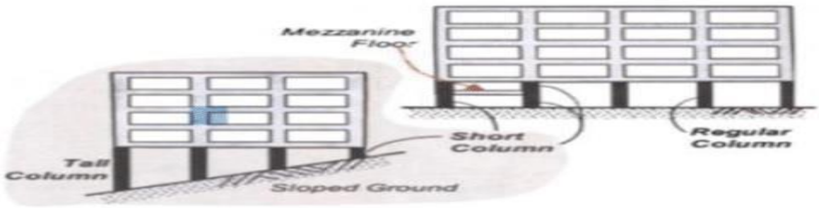
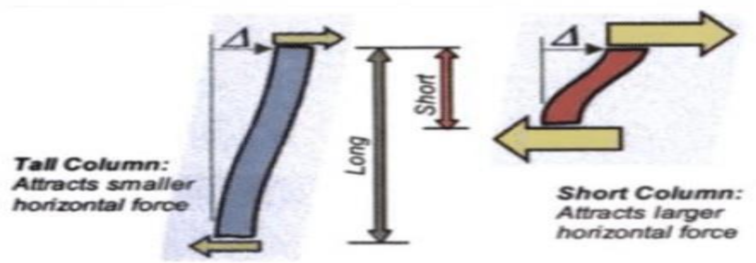


Fig.1.1 Building Frame with Short Columns



ORIGIN OF THE PROJECT

Some researchers and analyst has done few research works on the earthquake nature on the building structures on the slopes subjected to ground motion of sinusoidal behavior due to earthquake vibration. Ramanchrla and Sreerama (2013) have numerically studied the effect of earthquake vibration on different sloping angle and compare these numerical results with the same on flat ground condition. Still no work has been carried regarding the vibrative nature of the building structures on hilly ground with an experimental setup in laboratory by simulating thesame field condition. So keeping the present situation of population scenario, this project may play a vital role to solve out the space scarcity in the hilly region in north eastern region of India

RESEARCH SIGNIFICANCE

There is great amount of mountains in INDIA which consists of Himalayas region in the northen part which is formed by the collision of tectonic plates. In this particular sloping region population density were 62159 per square km as per census of 2011. Hence there is great requirement in the study of earthquake safety and designing criteria of the building structures on the sloping terrain.

The response and severity of damage depends on the frequency of the earthquake because it affects the building structure performance when it is subjected to ground motion. In this research work analytical study is done on different multy storey building of different configuration like STEP BACK, SET BACK – STEP BACK & SET BACK.

Table 1: Earthquake Classification

MAGNITUDE OF EARTHQUAKE	CLASSIFICATION OF EARTHQUAKE
Less then 3	Micro
3 to 4.9	Intermediate
5 to 5.9	Moderate
6 to 6.9	Strong
7 to 7.9	Major
Greater than 8	Sevier

OBJECTIVE AND SCOPE OF PROJECT

The purpose of this research work is to review numerically the seismic behavior of sloping groundbuilding structures subjected to earthquake vibration causing sinusoidal ground motion andseismic excitations.

The objective of this thesis is summarized as follows:

- Three dimensional (3-D) RC space frame analysis has been done on three differentconfiguration of building structures which are varying height of due to varying storey from 12.75 m to 24.25 m height (Four to Eight storey)situated on sloping and flat terrainunder the effect of earthquake loads.
- Due to seismic analysis dynamic characteristics like base shear, natural period and topstorey sway of the building structures is presented.
- Comparison of results within the considered building structure's configuration and with other configuration of the structures.
- A best suited building configuration economically also as strength point of view is usually recommended within the sloping terrain.
- By structural analysis tool STAAD PRO a linear time history analytical study is performed as per spectra of IS 1893 (PART 1) :2002 for a tough soil condition and 5% critical damping.

LITERATURE REVIEW

OVERVIEW

Dynamic analysis performed on RC space frame building structures with three different configurations like step back, step back –set back and set back buildings and analytical results are presented. Response spectrum method is used for three dimensional analyses in which torsioneffect is also considered generated from accidental eccentricity. The seismic response characteristics i.e. natural time period, top storey sway and base shear. According to building structures configuration best suitability of column on sloping ground is analyze. From analytical results it is observed that step back set back buildings are found to be more suitable on the hilly terrain.

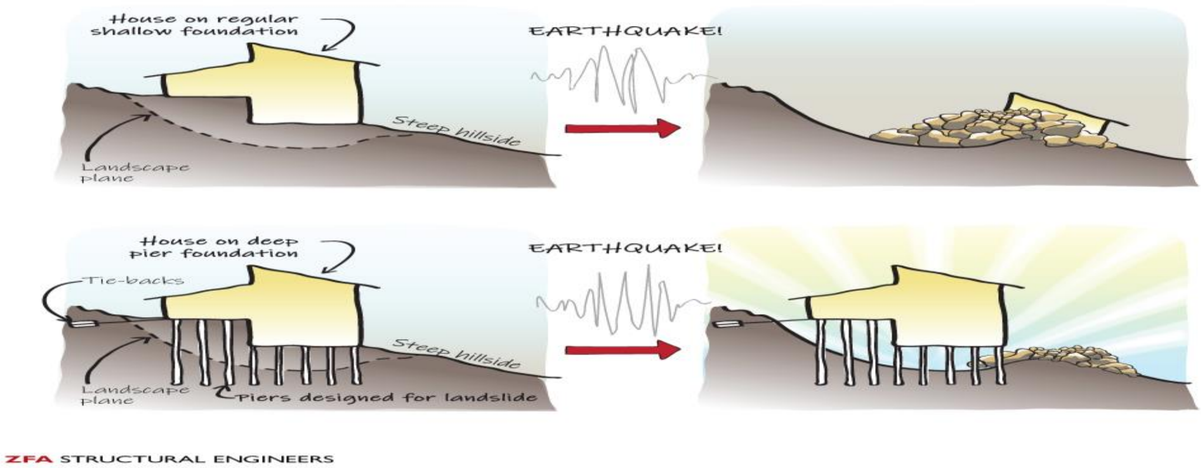
SEISMIC BEHAVIOUR OF IRREGULAR BUILDINGS ON SLOPINGGROUND IN INDIA

RAVIKUMAR AL. (2012) studied mainly two types of irregularities in building structures model 1) plan irregularity i.e. horizontal discontinuity in configuration 2) elevation irregularity with set back and sloping ground terrain. To identify the seismic behavior, push over analysis was carried out by taking different lateral load condition in all three directions respectively. All the structures considered were three storied with different plan and elevation irregularities pattern. Due to lesser amount of forces generated on plan irregular models give more deformation. The execution of all models lies in between life safety criteria and collapse prevention expect for models resting on sloping ground. Thus it can be conclude that structures resting on sloping terrain are more prone to damage rather than structures resting on flat ground even with horizontal irregularities.

RAMANCHRLA AND SREERAMA (2013) observed about recently earthquakes like BiharNepal ,Shilong plateau collision and the Kangra earthquake was cause of more than 3,75,000 people death and over 1 lac of the building structure got damaged and collapsed. Seismic features of the building structures resting on plain ground differs to buildings rested on hilly terrain sloping ground in the plan as well as elevation difference in the building configuration. Due to this irregular behavior the centroid (C.G) and the stiffness center don't match with each other corresponding torsion effect generated due to eccentricity. The mass and stiffness of the beam element differs with in the building storey causes increment in the base shear forces on column on uphill side and prone to damages. They analyze five G+3 building structure of different slope angle 00 ,150

,300 ,450 ,600 which were designed and analyzed using IS-456 and SAP-2000. They conclude that shorter column attracts more amounts of lateral forces due to increment in the stiffness. As the slope angle increases base shear on the shorter column increases and forces value decreases as the slope angle increases for the other columns.

PATEL AL. (2014) studied three dimensional model of eight stories building and analyzed by a software E-Tabs with regular and irregular configure model to study the effect of variation of height of columns due to hilly sloping ground and the effect of RCC shear wall at different position during earthquake. In the present study, as per seismic code IS-1893 PART 1 earthquake load analysis is done and proper assessment for dynamic vulnerability for building structure is performed by pushover analysis. It was seen that due to creation of plastic hinges on columns susceptibility of building structures on building structures on sloped ground increases at every base level of beam element in particular storey level at their performance point. As the irregularity increases more no. of plastic hinges forms. Building structures resting on hilly terrain gives more storey sway as compared to buildings rests on plain ground without having any shear wall. By providing the shear wall in the structures Base shear and lateral sway can be reduced.



DYANMIC BEHAVIOUR OF BUILDING STRUCTURES WITHDIFFERENT CONFIGURATION

BIRAJDAR AND NALAWADE (2004) studied 3 –dimensional three different configuration like set back, set back – step back, step back building structures of 24 RC space frame. Torsion effect due to accidental eccentricity is analyzed by response spectra. The dynamic characteristics like top storey sway, base shear and natural time period have been analyzed according to best suitability of building structures on sloping terrain. In this study three types of configuration as discussed above are used in which two of them step back and set back-step back rested onsloping ground while the third one set back is used on flat ground. This study of analysis is done on 27^o sloping angle.

Total of 24 RC buildings frames from 4 to11 stories, analytical study is done.

a) Step back building – there is linear increment in top storey sway as the number of stories increases and natural time also increase in longitudinal direction. Due to the effect of static and accidental eccentricity, torsion moments increases corresponds the value of top storey sway. Time period in lateral direction gives higher value compare to longitudinal direction. From design point of view special mention should be given to the strength, configuration and stiffness. Safety is ensure under worst load combination at short column on sloping ground in X and Z direction.

b) Step back-set back building – results obtained in the static and dynamic analysis shouldnot differ as in the case of step back building structures. The top storey sway is about 3.8 to 4 times greater in lateral direction compare to longitudinal direction's sway.

MODELLING

FRAME MODELLING IN STAAD PRO.

In this research work, three groups of building structures with different configuration are considered. Out of them step back structures and step back set back structures resting on sloping ground and set back structures rest on plain ground. The ground slope is 27 degree with horizontal, which is neither steep nor flat.

- The building structures model shown in figures having step back configuration are labeled from STEP 4 to STEP 8 for four to eleven stories.
- Step back-Set back building configuration having 4 to 8 number of stories are labeledas STEP SET 4 to STEP SET 8 as shown in figures.
- SET 4 to SET 8 are labeled for set back building structures resting on flat ground having 4 to 8 number of bays.
- All the building structures having same number of stories and same no of bays havesame floor area in all the three configuration.
- The properties of beam element of building RC frame that are considered for study are given in the table.
- The depth of footing below the ground level is taken 1.75 m where the hard rocky stratum is available.
- The height and length of the building structures in a particular frame are in multiple of blocks in plan and elevation view, the size of each block is tried to maintain at 7 m x 5 m x 3.5 min three dimensions.

MATERIAL PROPERTIES

Table 3.1: Material – Properties

PROPERPIES	
Modulus of Elasticity	25000 N/mm^2
Poissions Ratio	0.20
Density	25 kN/m^3
Thermal coefficient	1x10^{-5}
Critical Damping	.05

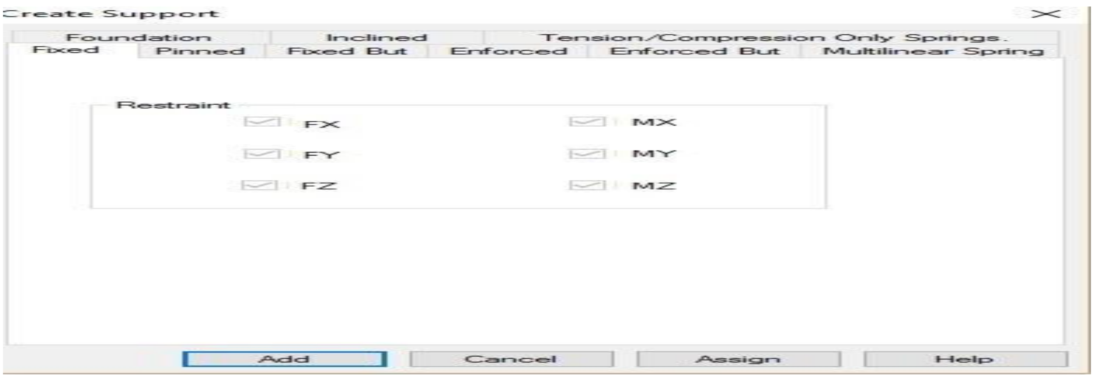
Table 3.2: Geometrical properties of members for different configuration

BUILDING CONFIGURATION	SIZE OF COLUMN (MM)		SIZE OF BEAM(MM)
Step-back Building	STEP 2 & STEP 3	600 mm x 900 mm	300 mm x450 mm
	STEP 4 & STEP 5	600 mm x 900 mm	
	STEP 6 & STEP 7	600 mm x 900 mm	
	STEP 8 &STEP 9	600 mm x 900 mm	
Step back- set back Building	STEP SET 4 toSTEP SET 8	6000 mm x 900 mm	300 mm x 450mm
Set-back Building	SET 4 to SET 8	600 mm x 900 mm	300 mm x 450 mm

In above table size of each beam element is shown.

- Size of beam kept constant 300 mm x 450 mm in each and every configuration at eachlevel.
- As storey number increases size of column also increases.
- Mostly variation of column size in step back building configuration because there issevere base shear condition in upward hill side

SUPPORT CONDITION



- Fixed support condition is used at every column base.

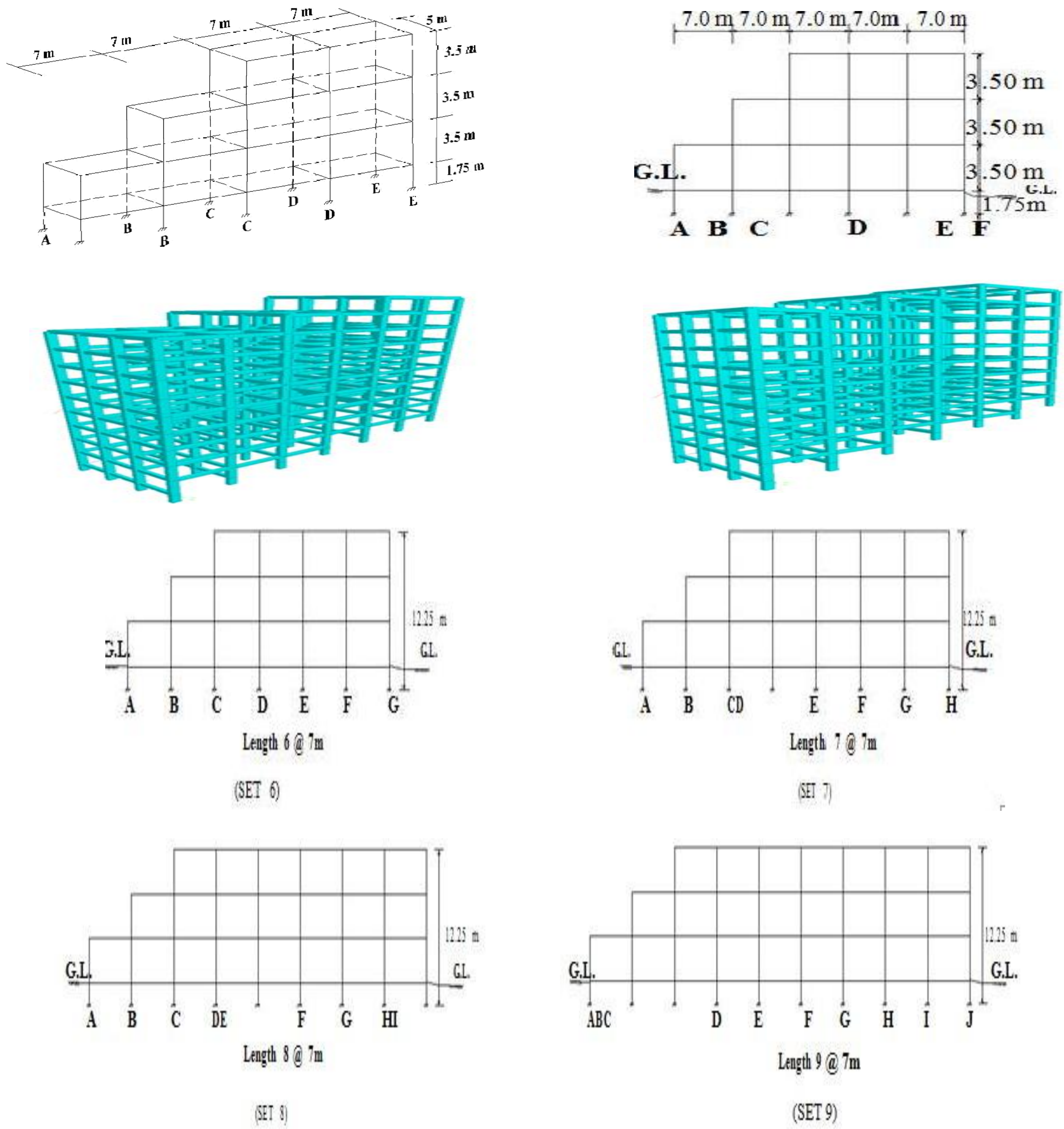


Figure 3.1: Building Model for Set Back Configuration on Plain Ground

ANALYSIS

Response Spectrum Analysis (Ras):

Response spectroscopy method is employed for dynamic analysis of all building structures configurations by using IS: 1893 (PART 1)-2002.Due to static and accidental generation of eccentricity torsion effect is additionally considered. the opposite parameters utilized in dynamic analysis are as given below–

Seismic zone – moderate (zone Ⅲ)
Zone factor - .016
Importance factor -1.0
Damping – 5%
Response reduction factor (s_a /g) – 3.0
Assumed that each one the building configuration and height of building structures is taken into account under ordinary moment resisting frame (OMRF).
For each building structure configuration, minimum six modes considered during which , the summation of modal masses of all modes was a minimum of 99 you look after the entire earthquake/ seismic mass. thanks to seismic loading, member forces were computed for every contributing mode and therefore the modal responses were combined together using CQC method.
The following design spectrum was utilized in response spectroscopic analysis (s_a/g):

$$S_a/g = \begin{cases} 1+15T & \text{when } 0.0\leq T\leq 0.10 \text{ seconds} \\ 2.50 & 0.0\leq T\leq 0.40 \text{ seconds} \\ 1/T & 0.40\leq T\leq 4.0 \text{ seconds} \end{cases}$$

First, the seismic analysis of building structure was administered without shifting the middle of mass (C.G.) from their real position. Then the results got from the appliance of torsion moment at each floor level adequate to lateral force times to the addition results of static and accidental eccentricity at that were superimposed on the results from seismic analysis.

ASSUMPTIONS USED IN ANALYSIS

The analysis is based on these following assumptions.

- Material is homogeneous, isotropic and elastic in nature.
- In this analysis, secondary effects like P-Δ effect, shrinkage and creep effects are not considered.
- The floor diaphragms are rigid by nature in their plane.
- In columns, axial deformation is considered.
- Each and every nodal point has six degree of freedom, three in translations and three in rotations.
- Induced torsion effects are considered as per IS-1893(Part 1).
- The value of modulus of elasticity and passions ratio are $2*10^5$ N/mm^2 and 0.20 respectively

ANALYSIS OF RESULTS

In all 24 building structures seismic analysis are through with earthquake loads with an impact of accidental eccentricity. The seismic load was applied in X and Z direction means along the structures and across the structures applies independently. The important got results are described within the following sections.

STEP BACK BUILDING

In this building configuration, total eight no. of structures models have been analyzed with varying height 12.75 m to 24.25 m from 4 to 8 storeys. This building rests on 27-degree angleof ground slope.

COPARATIVE STUDY OF THREE BUILDING CONFIGURATION

Step Back Building v/s Step Back Set Back Building:

- In Step Back building structure, higher base force is attracted by Frame A compare to Frame B,C and D. This uneven distribution of base shear force in the various frames suggests development of torsion moment due to static and accidental eccentricity, which has shown that profound effect in Step Back building structures.

- In Step Back Set Back building structure configuration also seen the uneven distribution of base shear force in various frames. However, this unequal distribution of base shear force is low to moderate. In this configuration also torsion moments develops under earthquake force due to accidental eccentricity but in lesser magnitude.
- The Step Back Set Back building configuration has an advantages to neutralizing the torsion moments effects.
- Step back set back building performs better than the Step back building during earthquake ground motion, provided short columns are taken special care of in design anddetailing of reinforcement.
- From observation table it is clear that Step Back building structures are subjected to higher amount of torsion moments due to irregularity compared to Step Back Set Back structures
- Step Back structures may prove more vulnerability during earthquake excitations than Step Back Set Back configuration.
- Both structures rest on sloping ground but have different seismic resisting capacity because of different configuration of the structures.

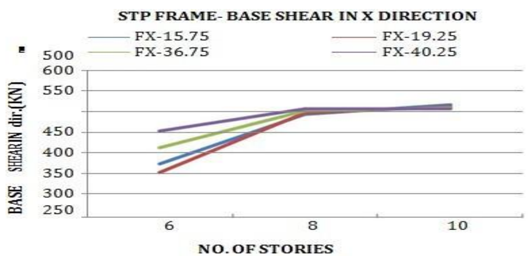
STEP BACK SET BACK BUILDING V/S SET BACK BUILDING

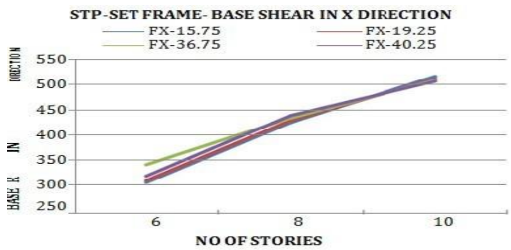
- Base shear action induced in Set Back building structures on plain ground is moderately lesser as compare to Step Back Set Back building structures configuration.
- It is to be noted that higher stiffness is required in X direction in Step Back Set Back building structures where as in Set Back building structure more stiffness is required in Z directions.
- Set back building structures on plain terrain may be more preferable than the Step Back Set Back building structures if economy of cutting the hilly sloped comes under control condition and other related issue is within acceptable limits.
- In Set Back building structures configuration stability of slopes and vulnerability during earthquake ground motion are less concerned.

GRAPHICAL REPRESENTATION OF RESULTS

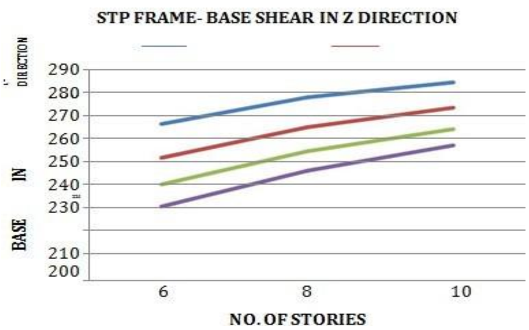
Comparison between Step frame v/s Step Back Set Back Frame with respect to base Shear and no. of stories:

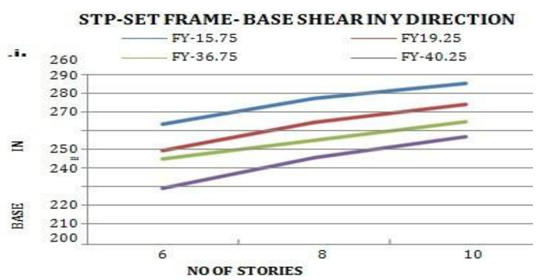
Case a- when earthquake force in X- direction





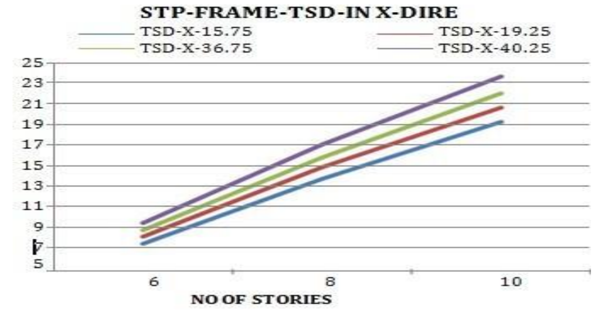
Case b- When Earthquake force in Z direction





B .Comparison between Step frame v/s Step Back Set Back Frame with respect to top Storey sway (mm) and no. of stories:

Case a- When Earthquake Force in X direction:



Case b- When Earthquake Force in Z direction

- The variation of top storey displacement is linearly varies with the height of building.
- The sway does not show much variation with the sloping angle but as the height of building varies, this variation can be seen clearly.

SUMMARY & CONCLUSIONS

SUMMARY

Due to ground motion (vibrations), earthquake is caused and because of this, structures got damage. To compensate these effects it is more important to know the characteristics of earthquake and predicts it's all possible response which occurs on the building structures. These properties which should be properly study are base shear action, maximum storey sway, velocity of nodes and acceleration etc.In this research work, analysis has been done with validation of the data on structure analysis software STAAD PRO. to know the response of the building structure under ground motion. The results of response for each configuration is carefully studied and compared.

CONCLUSIONS

1) According to results of Response Spectrum Analysis, the storey shear force was found to be maximum for the first storey and it decreased to a minimum in the top storey in all cases. It is observed that base shear decreases from lower angle to higher angle.
2) On plane ground, storey deflection is quite on sloping ground.
3) Supported on the seismic analysis of three different configurations of building structures, the subsequent conclusions are often drawn.
    a. The performance of step back building configuration during earthquake excitations could prove more vulnerable than other configuration like Step Back Set Back and Set Back building structures.
    b. In step back set back building configuration torsion moment due to accidental generates in lesser amount compare to step back building configuration. Hence Step Back Set Back building Structures are found to be less high strung than Step Back building against seismic ground motions.
    c. In step back and step back set back building structures it's observed that extreme left column at ground level which is less and shorter, worst affected so much attention is required for these columns in design and detailing.
    d. Although the Set Back configuration resting on plain ground attracts low base shear action compared

to step back set back configuration overall economic cost involved to level the inclined ground and other related issue with this is often got to study intimately.

4) Buildings resting on sloping ground have less base shear compared to buildings on Plain ground.
5) In step back and step back set back building structures, it's observed that extreme left column at ground level which is shorter, worst affected so special attention is required for these columns in design and detailing.
6) Although the Set Back configuration resting on flat ground attracts lesser base shear action compared to step back set back configuration overall economical cost involved to level the sloping ground and other related issue with this is need to study in detail.
7) As angle of ground increases top storey displacement decreases.
8) Top storey sway decreases as number of bays increases therefore it is confirmed that greater number of bays are observed to be better under seismic conditions.

FUTURE WORK

There is a great scope for future research work in this area of study. This analysis can be analyzed for different varying frequency content i.e. low frequency, intermediate frequency and high natural frequency content. In this transient linear time history analysis is performed, one can performed non linear time history analysis for the sloping frame model. Wind analysis of sloping structures can also be performed in future

REFERENCES

1) 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004, Paper No.1472.
2) Dynamic Analysis OF Sloped Building: Experimantal & Numerical Studies research paper ISSN: 2349-6002.
3) International Journal of Innovative Technologies' ISSN 2321-8665 Vol.04, issue, October-2016 on Experimental & Numerical Studies on Dynamic analysis of Sloped Buildings. Analysis & Design Software Staad pro, Bentley used.
4) R.B. Khadiranaikar, & A. Masali, "Seismic performance of buildings resting on Ground review", IOSR Journal of Mechanical & Civil Engineering, e-ISSN: ISSN: 2320-334X, Volume 11, Issue 3 Ver. III (May- Jun. 2014), PP 12-19.
5) Y Singh,. & G Phani, ., "Seismic Nature of Buildings Located on Sloping-Ground" – An Analytical Study & Some Observations From Sikkim Earthquake of September 18, 2011. 15th World Conference on Earthquake-Engineering Journal, 2012.
6) D. Prashant, K.G Jagadish., "Seismic Response of one- way slope RC-frame With soft-storey" International-Journal of Emerging Trends in Engineering &Development Issue 3, Vol.5 (Sept- 2013).
7) S. M. Nagargoje, & K. S Sable,., "Seismic Analysis of multi-storied buildingOn sloping-ground", Elixir International-Journal, December 7, 2012
8) IS 1893-2002 (Part-1), "Criteria for Earthquake-resistant design of structures, General-provisions & buildings", Bureau of Indian Standards, New Delhi 110002.
9) BirajdarBG, Nalawade SS (2004) Seismic analysis of buildings resting on sloping ground. In: 13th world conference on earthquake engineering, Vancouver, B.C., Canada, paper no. 1472.
10) Nagargoje SM, Sable KS (2012) Seismic performance of multistoreyed building on sloping ground. Elixir Int J 53: 11980–11982.