"Analysis of Seismic Behavior of RCC Building Frame on Sloping Ground with Different Types of Bracing in Soft Soil Condition of Seismic Zone-V"

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Abstract

The buildings situated on hill slopes in earthquake prone areas are generally irregular, torsional coupled and hence, susceptible to serve damage when affected by earthquake ground motion. Such buildings have mass and stiffness varying along the vertical and horizontal planes, result the center of mass and center of rigidity do not coincide on various floors. The dynamic analysis is carried out using response spectrum method. The dynamic response that's fundamental time period, storey displacement and base shear action induced in columns has been studied for buildings of various combinations. From some past results show that the performance of step back-set back building frames are more suitable as compared with step back building frames. But after considering bracings to the step back building frames, a far better performance is observed in comparison with step back, and step back-set back building frames. Three dimensional space frame analysis is carried out for five different configurations of eight storey building with different types of bracing system resting on sloping ground. Building models are analyzed by Staad.pro V8i software to study the effect on time period, storey displacement and base shear by various positions of bracing system.

Keywords: Earthquake, Sloping Ground, Response spectrum method, step back frames, step back with bracings, XBS,VBS,DBS,KBS, Staad.pro V8i software.

1. INTRODUCTION

General

The analysis of earthquakes and the structure of the earth, by both naturally and artificially generated seismic waves. From the seismic history of our country, it's observed that majority of the devastating earthquakes are occurred in northern and north-eastern states of India.

In the past decade, all these regions have gone under quick changes due to economic development. Being the Border States rapid urbanization is going on these boundary of country, states with growing real estate development. Due to this, population density in

hill region has increased enormously and every one sorts of construction practices are followed.

All in need of building materials that's adobe, burnt bricks, stone masonry, dressed stone, bamboo, timber and reinforcement concrete etc. are used dependent upon the locally available material.

The adobe burnt brick, stone masonry and dressed stone masonry buildings are generally remodeled level ground in hilly regions. Since plain ground in hilly region is extremely limited, therefore there's a pressing demand to construct buildings on hill slope.

Hence construction of multistory R.C. frames buildings on hilly slope is that the only feasible option to accommodate rising demand for residential and commercial activities.

Three major earthquakes of magnitude greater than 8, Kangra (1905) have occurred during this hilly track within the last century. The hilly seismic region of our country ranges from Jammu Kashmir, Himachal Pradesh, North Uttar Pradesh, North Bihar, Sikkim, North Bengal, Assam, Meghalaya, Nagaland, Arunachal Pradesh, Manipur, and Tripura and Mizoram.

it's observed from the past earthquakes, buildings in hilly regions have experienced high degree of injury leading of collapsed though they need been designed for safety of the occupants against natural hazards. Hence while adopting tradition of multi-storey buildings in these hilly and seismically active areas, utmost care should be taken making these buildings earthquake resistant

1.2 Seismic Behavior of Buildings on Slopes in India

North and northeastern parts of India have large scales of hilly region, which are considered under seismic zone IV and V. through this region the construction of multistory RC framed buildings on hill slopes features a popular and pressing demand, because of its economic development and rapid urbanization. This development in construction activity is increasing population density.

While construction, it must be noted that hill buildings are different from those in plains that's they're very irregular and unsymmetrical in horizontal and vertical planes, and torsional coupled. Since there is lack of plain ground in hilly areas, it necessitates the construction of buildings on slopes.

During past earthquakes reinforcement concrete frame buildings that have columns of different heights within one storey, experienced more damage in shorter columns as compared to taller columns within the same storey.

1.3 Hill Building

The buildings situated on hill slopes are generally irregular, torsional coupled hence vulnerable to severe damage during the earthquake such buildings have mass and stiffness varying along the horizontal and vertical plane. The Centre of mass and center of rigidity don't coincide on various floors. The peak and gradient of hill slopes depend on strength and deformation chart of soil rock mass.

As per design point of view various problems attributed building on sloping ground.

1.3.1 Torsional Coupling

1.3.2 Slope Stability

1.3.3 Variation in Column Stiffness

1.4 Step Back Building

In step back multistoried building configuration top at same level but base unequal of all bays. The floors of such buildings step back towards the hill slope. Center of mass of all floors does not lie on one vertical axis.

Bracing system

In step back multistoried building configuration top at same level but base unequal of all bays. The floors of such buildings step back towards the hill slope. Center of mass of all floors does not lie on one vertical axis. Bracings hold the structure stable by transferring the loads sideways (not gravity, but wind or earthquake loads) down to the ground and are used to resist lateral loads, thereby preventing sway of the structure.

Structural Configurations of the Tall Building

1. Bare frame (Step back building)
2. X-braced system (XBS)
3. Diagonal bracing system (DBS)
4. K bracing system (KBS)
5. V bracing system (VBS)

The objectives of this work are as follows:

1. The seismic analysis of RCC frames structure on sloping ground.
2. Effect of bracings on RCC frame structure on sloping ground.
3. Studies of effect of different Types of bracing.

2. LITERATURE REVIEW

2.2.1Chauhan Anjeet Singh1 Banerjee Rajiv2 [May-2021]

The structure irregularities are considered as one of the main fundamentals of its failure. Structural frames having a combination of different irregularities as vertical, mass, stiffness, diaphragm, strength, torsional irregularity, etc. Also, for the analysis of this type of structure, it is necessary to carry out dynamic analysis to determine the maximum dynamic response of the building. Since it would be difficult to get the time history record for all the places, it is feasible to go with Response Spectrum Analysis. In this paper, a G+10 RCC Step back building having each storey of height 3.6m with a horizontal angle of inclination 20°, 30°, 40º, and 45° on the sloping ground is analyzed in seismic zone V by Response Spectrum method for the purpose of commercial of people

during a disaster with two of the top storey to be used for setup of machinery equipment which induces as Mass irregularity and ground to top of the storey at the edge of the planned building used as an opening for the purpose of natural lighting and stair which induces as Diaphragm irregularity. The analysis and modeling of the Step back building are carried out by Etabs software as per IS 1893:2016 to compare the building based on their dynamic response properties like mode Period, Base Shear, Story deflection, Story drift, and story shear and also find out the frame vulnerability in irregularities of structure on the sloping ground.

2.2.2 1Mr. Wahane Anurag, 2Mr. Sahu Vedprakash [2020]

In this study, the three different sloping ground frame building i.e. 12 degree slope , 23 Degree slope & 40 Degree slope frames of G+9 storey is been analyzed by using structural software which is STAAD.Pro.V8i (Series 6) for seismic Zone –IV, Raipur, Chhattisgarh or we can say that Seismic Analysis on different sloping frames on vertical irregularity buildings. The objective of this study is too carried out equivalent static analysis (ESA) for three different sloping RCC frame building by considering equal physical properties such as built-up area, beam size, column size, load calculations, seismic parameters & material specifications etc. Here, the comparison between displacement and quantity of material parameters will give us the best efficient building on the existing conditions but the building which least efficient is also been revised or re-design by adopting retrofitting method. The research study is all about the solving the problem of maximum displaced building by applying retrofitting method. More specifically, objectives of this project are:

 To compare the seismic parameters such as story displacement, quantity of material of all frames and,

 To achieve best responsive slope building along with cost efficient i.e. providing it with retrofitting's in ideal location.

2.2.3 Cutinha Laril Lawline 1, Karanth Pradeep 2[2018]

Building under seismic effect and the effect of lateral loads on a structure, it is necessary to evaluate the time period of a structure. It is necessary to determine the significance of the time period before evaluating the time period of a structure. Time period plays an important role in estimating the lateral loads and hence contributes to the seismic assessment of a structure. Time period depends on mass and stiffness. Based on the time period which is purely dependent on stiffness and mass, the behavior of building under lateral loads can be evaluated. It is difficult to determine the exact time period. For the design of earthquake resistant structures which seem to be safe and economical, the determination of time period is necessary. In this paper an attempt is done to understand the various parameters which affect the time period of a building. Hence a parametric study is done on time period of a structure as per the codal provisions. IS code (IS 1893(part I):2016) is referred for the parametric study. The model is prepared and analyzed using ETABS software considering various parameters in the model. The value obtained for time period as per the code and as per the software is compared. The variation in time period from model to model by varying the parameters is studied.

2.2.4 Nagarjuna, Patil Shivakumar B. [Jul 2015]

The structures are generally constructed on level ground; however, due to scarcity of level grounds the construction activities have been started on sloping grounds. There are two types of configuration of building on sloping ground, the one is step back and the other is step back setback. In this study, G+ 10 Storeys R.C.C building and the ground slope varying from 10o to 40o have been considered for the analysis. A comparison has been made with the building resting on level ground (setback). The modeling and analysis of the building has been done by using structure analysis tool ETABS, to study the effect of varying height of the column in bottom storey and the effect of shear wall at different position during the earthquake. The results have been compared with the results of the building with and without shear wall. The seismic analysis was done by linear static analysis and the response spectrum analyses have been carried out as per IS: 1893 (Part 1): 2002. The results were obtained in the form of top storey displacement, drift, base shear and time period. It is observed that short column is affected more during the earthquake. The analyses showed that for construction of the building on sloping ground the step back setback building configuration is suitable, along with shear wall placed at the corner of the building.

2.2.5 Kalsulkar Narayan, Rathod Satish [Jun. 2015]

Generally, building frames are analyzed for gravity loads in vertical direction and lateral loads like earthquake load and wind load in lateral direction. The analysis of structure depends on idealization of geometry of structure and idealization of load system on the structure. The behavior of buildings during earthquake depends upon the distribution of mass and stiffness in both horizontal and vertical planes of the buildings. General behavior is shattered when the structure has irregularities. These kinds of irregularities are especially seen in hilly regions, where the structure rests on the sloping ground. In the present study, the response spectrum method is carried out on the type of structure that rests on the sloping ground. Building frames which occurs in hilly regions are narrowed down to two basic formats such as step back frames and step back-set back frames and dynamic responses have been studied for various building configuration.

3. METHODOLOGY

Introduction

The economic development and rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density within the hilly region has increased enormously. Therefore; there is popular and pressing demand for the development of multi-storey buildings on hill slope in and round the cities. It is observed from the past earthquakes, buildings in hilly regions have experienced high degree of demand resulting in collapse though they have been designed for safety of the occupants against natural hazards. Hence, while adopting practice of multi-storey buildings in these hilly and seismically active areas, utmost care should be taken, making these buildings earthquake resistant.

Most of the constructions in hilly regions are constrained by local topography which ends up within the adoption of either a step back or step back and set back configuration.

Because of this the structure is irregular by virtue of varying column heights resulting in torsion and increased shear during seismic ground motion. The dynamic analysis is performed using response spectrum method to the bare frame and various bracing system.

The dynamic response that's fundamental time period, storey displacement and drift, and base shear action induced in columns are studied for buildings with different bracing systems

Model Description

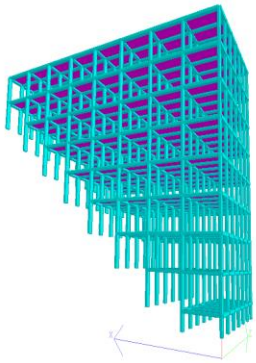
• The height and length of building during a particular pattern are in multiple of blocks (in vertical and horizontal direction), the dimensions of block is being maintained at 5 m x 3 m x 3.5 m.
• The height of all floors is 3.5m
• The depth of footing below ground level is taken as 1.8 m.
• The slope of ground is 37 degree with horizontal, which is neither too steep or nor too flat.
• Basically model consists of six bays with five groups of building configurations.
• The dynamic analysis is performed using response spectrum method to the step back without bracing and step back with different bracing system.
• Three dimensional space frame analysis is performed for two different arrangements of G+7 building of different Bracing systems resting on sloping ground under the action of seismic load by using Staad.pro V8i software.

3.3.1 Geometrical Properties of Members

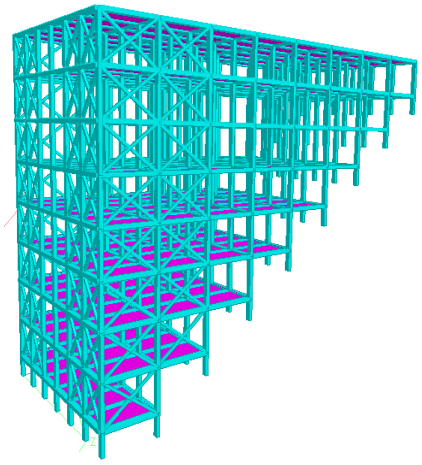
For analysis of seismic performance of multistoried building on sloping ground considered following geometrical properties of members.

Table 3.1 Geometrical properties of members for different configurations of Building.

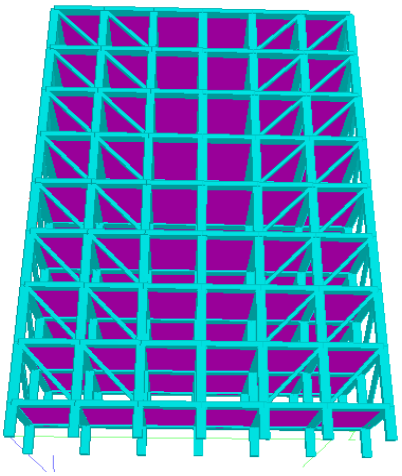
S.no.	**Configurations**	**Size of Column in mm**	**Size of Beam in mm**
1	STEP-8	300X500	300X600
2	BARCING	ISMB250	



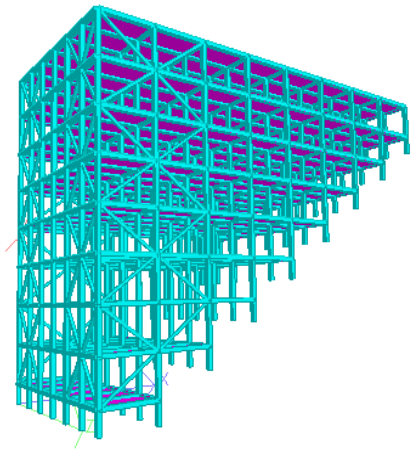
Bare frame



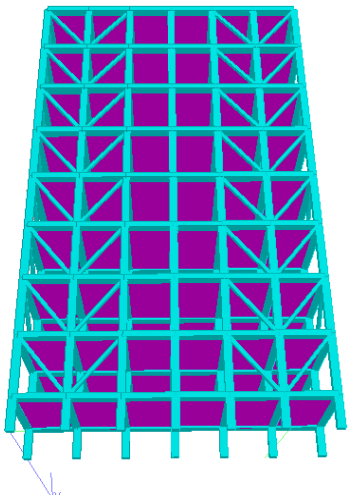
Cross or X-Bracing

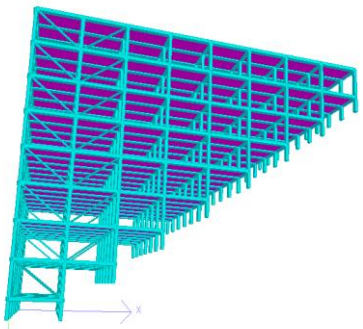


Diagonal bracing



K-bracing





V-bracing

4. RESULTS AND DISCUSSIONS

In all, five buildings are analyzed for seismic load. The seismic force was applied in X direction and Z direction independently. Important results are presented in terms of base shear, time period and top storey displacement.

Lateral Displacement

Ranking	Configuration system	Lateral Displacement (mm)		Change in maximum displacement	
		UX	UZ	X-direction	Z-direction
1	XBS	39.77	87.73	27.53%	44.53%
2	KBS	41.54	89.283	24.23%	44.39%
3	DBS	42.58	89.3	22.41%	44.38%
4	VBS	43.79	96.71	20.20%	39.75%
5	BARE FRAME	54.88	160.316		

Comments- From the above table the maximum reduction in lateral displacement is seen in XBS system

Base Shear

Ranking	Configuration system	Base Shear in kN	Change in Base shear
1	XBS	2423.653	0.94%
2	KBS	2412.349	0.44%
3	DBS	2412.349	0.44%
4	VBS	2411.769	0.43%
5	BARE FRAME	2401.02	

Comments- From the above table the base shear increases in XBS are more than other Bracing systems.

Maximum bending moment

Ranking	Configuration system	Bending moment in kN-m	Change in B.M.
1	XBS	694.76	24.37%
2	KBS	722.15	21.39%
3	DBS	752.12	18.12%
4	VBS	787.45	14.2%
5	BARE FRAME	918.53	

Comments- From the above table the maximum bending moment decreases in XBS are more than other Bracing systems.

From above analysis it is found that overall performance of XBS is better than other configurations.
But as number of members in XBS is double as compare to other models the economical design would be for K-bracing system in step back building on sloping ground.

5. CONCLUSIONS AND RECOMMENDATIONS

The buildings situated on hill slopes in earthquake prone areas are generally irregular, torsional coupled and hence, susceptible to serve damage when affected by earthquake ground motion. Such buildings have mass and stiffness varying along the vertical and horizontal planes, result the center of mass and center of rigidity do not coincide on various floors. The present investigation was conducted on the effect of structural configuration on seismic behavior on G+7 RC framed structures resting on sloping ground by analyzing and evaluating different types of bracing systems to assess the Changes in lateral displacement, bending moment and base shear compare to bare frame structure. Based on the results obtained the following conclusion are drawn.
The structural configurations investigated are found to be effective in reducing the BM in columns. For instance, the highest BM in column is 918.53kN-m was obtained in the Bare Frame as seen from table.
For the bracing configuration system, the XBS reduced the BM in the column about 25% compared with Bare Frame system. The KBS reduced the bending moments in column about 22%, while DBS and VBS reduced the bending moment in column around 19% & 15% respectively.
it can be see that the bare frame undergoes a maximum storey displacement of 54.88mm & 160.31mm along X and Z- direction at the top story level which are well within the permissible range of story displacement i.e. 0.0015 h to 0.003h in X- direction but not in Z-direction. According to IS-1893 the permissible limit of displacement is 89.4mm.
All the bracing systems analyzed in this study are effective in reducing displacement in Z-direction by 39-46% in compare of bare frame, however in X-direction were found well effective in the reducing the displacement by about 21-28% in compare of the bare frame.
Among the all bracing system minimum displacement in X-direction is shows 39.77mm in XBS and in Z-direction is 87.23mm in XBS.
For bracing configuration systems, the XBS, KBS systems are found to be most effective configurations and resulting in substantial reduction of lateral displacement (43-45%) & column bending moments (22-25%) in compare to bare frame system.

6. REFERENCES

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