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Literature Review on Seismic Analysis of Building Resting on Sloping Ground

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ABSTRACT

Over the past 20 years,1.35 million people have been killed by natural hazards, more than half died in earthquakes and the remaining due to weather and climate-related hazards. The poorest nations paid the highest price in terms of the numbers killed per disaster and per 1,300,000 populations. So new advance, ideal and economical techniques should be used for designing and constructing the structures. The study helps us to understand the significant difference between seismic behaviors of building on slopes and building on flat surface. In summary, the natural period of building depends on the distribution of mass and stiffness along the building. As the slope angle increases, it was observed that the short column resists almost all the storey shear since other columns are flexible and tend to oscillate. It had been observed that the footing columns of shorter height attract more forces.

Keywords : RC building, seismic forces, sloping ground, STAAD-PRO

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INTRODUCTION

This study will provide a detailed review of literature related to seismic evaluation in its entirety, would be immense to address in this project. However, there are many good references that can be used as a starting point for research. This literature view and introduction will focus on recent contributions related to seismic evaluation and past efforts most closely related to the needs of the present work.

REVIEW OF LITERATURE

B.G. Birajdar, S.S. Nalawade. (2004 August)

3D analysis including torsional effect had been carried out by using response spectrum method. The dynamic response properties, i.e., the important time period, top storey displacement and, the base shear action tempted in columns had been considered with locus to the correctness of a building conformation on sloping ground. It was detected that "Stepback Setback" buildings were found to be more suitable on sloping ground.

The development of torsional moments in stepback buildings was higher than that in the stepback setback buildings. Hence, stepback setback buildings was found to be less vulnerable than stepback building in contradiction of seismic ground motion.

Y. Singh and Phani Gade, D.H. Lang and E. Erduran (2011)

An analytical study was also performed to investigate the peculiar seismic behavior of hill buildings. Dynamic response of hill buildings was compared with that of regular buildings on flat ground in terms fundamental period of vibration, pattern of inter-storey drift, column shear, and plastic hinge formation pattern. The seismic behavior of two typical configurations of hill buildings was investigated using linear and non-linear time history analysis. It was

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observed that hill buildings have significantly different dynamic characteristics than buildings on flat ground. The storey's immediately above the road level, in case of down-hill buildings, were particularly vulnerable to earthquake action. The analytical findings were corroborated by the damage pattern observed during Sikkim earthquake.

The behavior of hill buildings differed significantly from the regular buildings on flat ground. The hill buildings were subjected to significant torsional effects under cross-slope excitation. Below along-slope excitation, the fluctuating heights of columns cause toughness irregularity, and the short columns resist almost the entire storey shear. The linear and non-linear dynamic analysis shown that the storey at road level, in case of downhill buildings, was most susceptible to damage.

Ajay Kumar Sreerama, Pradeep Kumar Ramancharla (2013 October)
Recent earthquakes, 18 Sep 2011, Sikkim earthquake, M6.9 and 1 May 2013 Doda earthquake, M5.8 formed two major effects, namely on buildings and on hill slopes. The extreme concentration of ground trembling well-informed during these earthquakes was only about VI or less on the Medvedev–Sponheuer–Karnik (MSK) scale. Considering the low intensity of ground shaking in the affected areas, the damage attributed was disproportionately higher. It is mainly due to high amplification in local site areas. In this regard, a research was carried out to understand the performance of buildings on hill slopes. In this paper, the study of the behavior of a G+3 building on varying slope angles, i.e., 15°, 30°, 45° and 60° is studied and compared with the same on the flat ground. Building was designed as per IS 456 and later subjected to earthquake loads. It was observed that as the slope angle is increasing, building is becoming stiffer. Two types of analyses were conducted viz., lateral load analysis and incremental dynamic analysis. It was observed from the initial results that the columns on the higher side of the slope, i.e., short columns were subjected to more shear force then longer columns on the lower side. Finite element method was used to study the static behavior where as Applied Element Method (AEM) was used to perform incremental dynamic analysis.

The study clearly helps us to understand the significant difference between the seismic behaviors of building on slopes to building on flat surface. In summary, the natural period of building depends on the distribution of mass and stiffness along the building. As the slope angle increases, it was observed that the short column resist almost all the storey shear since other columns are flexible and tend to oscillate. A hinge mechanism was formed near the shorter column zone and was damaged earlier as the slope angle increases. From the fragility curve we can easily observe the damage of the structure was more, when it is on steep angle. Major challenge which has to be focused further is considering together plan irregularity (i.e. Torsional effect) and vertical irregularity. It would be desirable to study more cases before reaching some definite conclusions about the behavior of reinforced concrete framed buildings on slopes.

A.E. Hassaballa, M.A. Ismaeil, A.N. Alzead, Fathelrahman M. Adam (2014)
A four-story housing existing armored concrete building in the city of Khartoum-Sudan, exposed to seismic hazard, was examined. Plastic hinge was used to represent the failure mode in the beams and columns when the member yields. The pushover study was made on the building using SAP2000 software (Ver.14) and equivalent static method according to UBC 97. The principles of performance based seismic engineering were used to govern the analysis, where inelastic structural analysis is combined with the seismic hazard to calculate expected seismic

performance of a structure. Base shear versus tip displacement curve of the structure, called pushover curve, was a vital results of pushover analysis. The pushover analysis was carried out in both positive and negative x and y directions. Defaulting pivot properties, existing in some plans based on the FEMA -356 and Applied Technology Council (ATC-40) guidelines were cast-off for each member. One case study had been chosen for this purpose. The evaluation had proved that the four-story residential building was not seismically safe.

The main output of a pushover analysis was in terms of response demand versus capacity. If the demand curve interconnects the capacity envelope near the elastic range, then the structure had a good resistance. If the demand curve interconnects the capacity curve with little standby of strong point and distortion capacity, then it could be decided that the structure will behave unwell during the imposed seismic excitation and need to be retrofitted to avoid future major damage or collapse.

Sujit Kumar, Vivek Garg, Abhay Sharma (2014 August)

The seismic analysis of a G+4 storey RCC building on adjustable slope angles, i.e., 7.50 and 150 was studied and equated with the same on the flat ground. The seismic forces were considered as per IS: 1893-2002. STAAD-Pro was used to check the effect of sloping ground on building performance during earthquake. Seismic analysis had been done using linear static method. The analysis was carried out to evaluate the effect of sloping ground on structural forces.

The horizontal reaction, bending moment in footings and axial force, bending moment in columns are judgmentally investigated to quantify the effects of numerous sloping ground. It had been observed that the footing columns of shorter height attract more forces, because of a considerable increase in their stiffness, which in turn increases the horizontal force (i.e. shear) and bending moment significantly. Thus, the section of these columns should be designed for modified forces due to the effect of sloping ground.

Authors concluded that the critical bending moment in column increases significantly for sloping ground (15 degree) compared to flat ground. Critical value of axial force in column remains almost same for different ground slopes to provide greater resistance more steel was required.

Salman I. Khan and Ashok R. Mundhada (2015 February)

This paper presented a review of the earlier work done on the seismic performance of tall buildings with different reinforced concrete slab systems. It focused on flat slab and grid slab system. These two systems include the most striking and frequently used floor systems, especially in high rise construction. The flat slab building in which slab was directly supported by columns, had been adopted in many buildings constructed recently, due to the benefit of reduced floor to floor height. Grid slab system consists of thin beams spaced at regular intervals in perpendicular directions, monolithic with slab. The seismic performance of buildings having grid slab and flat slab was comparable but the differences exist. Tall buildings with flat slab system were feebler in shear whereas those with grid/conventional floor system were strong but taller and functionally less friendly.

This paper presented review of the seismic performance of multi-storied buildings for different floor heights and having unlike floor systems like Flat slabs, Grid slabs and conventional solid slab-beam systems. It seems that the seismic performance of

buildings having grid slab and flat slab was comparable but the differences exist, e.g. the base shear of a multi-storey assembly with flat slab was a smaller amount as equated to Grid slab, however the axial force in the intermediate columns are more in case of flat slabs than grid slabs. Buildings having the flat slab system were feebler in shear as related to those with straight or even grid slab systems. The storey drift in building with flat slab construction was significantly more as compared to conventional RCC building. As a result, additional moments were developed.

Therefore, the columns of such buildings should be designed by considering additional moments caused by the drift. Base shear of flat slab building would be less than the base shear in grid slab building. To draw definite conclusions, more and more research is required.

Manish D. Meshram, Ashok R. Mundhada (2015 December)

Buildings on the hilly slopes were always irregular and unsymmetrical in both horizontal and vertical directions and had foundation at different levels. All this means center of mass and center of rigidity do not coincide with each other, which required considering torsional effect during analysis. Short columns affect more damage in earthquake. Such buildings pose special structural and constructional problems. Shear wall may also be used if required.

The buildings which were resting on sloping ground were subjected to short column effect, attract more base shear and forces and were worst affected during seismic excitation. Shear Wall and bracing also more suitable to reduce base shear, lateral displacement and story drift as per different configurations and sloping conditions.

Manjunath C.S., Siddu Karthik C.S. (2016 February)

Author would have been compared various types of eccentric steel bracings for 12 storey RC frame building resisting on sloping ground. For this 5 types of bracing systems like X-Bracing, Diagonal bracing, K- bracing, V-bracing and inverted V bracing was well-thought-out on the outer periphery of the buildings with stepback and setback stepback type configurations were modeled and analyzed. The models were equated for different characteristics within the structure, such as the maximum storey displacement, base shear, storey drift and storey shear, the structure is investigated for seismic zone V and medium soil condition as per IS 1893:2002 using E-TABS software. Outcomes determined that on sloping ground due to anomaly on ground surface, the structures were more susceptible to earthquakes. Hence use of eccentric steel bracing was an actual and cost-effective way to counterattack earthquake forces, inverted V type bracing performs well equated to other bracing types. By using inverted V type bracing in step back buildings types maximum storey displacement of 70% and storey drift of 66% are obtained. Equally for setback stepback configuration maximum storey displacement of 74% and storey drift of 70% were found respectively.

With the provision of different types of bracings, the storey drift and storey displacement got reduced. Models with inverted V bracings in longitudinal and transverse direction were found to be efficient against lateral seismic loading as they shown better performance in terms of strength and stiffness.

Anghan Jaimis, Mitan Kathrotiya, Neel Vagadia, Sandip Mulani (2016 March)

Research on the design of structure had started not only India but in other developed countries also. The building still damages due to some or other reasons due

to earthquake. In over-all normal frame construction utilize column, slab and beam. Though it may be possible undertake construction without providing beams, in such a case the frame system would comprise a slab and column without beam. In our learning it had been strategic to investigates a building having flat slab and conventional slab under the consequence of various loading conditions. The focus of those project was compared the behavior of building having flat slab and having conventional slab using software aid.

In comparison of the conventional RC building to flat slab building, the time period was more for conventional building than flat slab building because of monolithic construction. The time period will be maximum at mode 1, 2 and 3. After mode 3, time period will reduce drastically. The natural time period was increasing as the numbers of floors increases. Base shear of conventional RC framed building was more than the flat slab building. Base shear in flat slab was increasing constantly up to 3 floors and then it increases very slowly. And in conventional RC framed it increases up to 6 floors and then it decreases slowly. Story drift (Sway) in buildings with flat slab structure was knowingly more as related to conventional RCC building. As an outcome of this, supplementary moments are developed. Therefore, the columns of such buildings should be designed by considering additional moment caused by the drift. Sway at terrace level was maximum for both types of building. Sway increases as the numbers of floors increases. Axial force on column due to all load combination was approximately same in both building but shear force and bending moment is comparatively more in conventional slab building. The column behavior changes as height of the building increases. The columns have been designed for the combination of dead load and earthquake load for all cases and the load combination 1.5[DL±EX] is the most critical. The column moments were more in conventional RC building compared to flat slab building. As increasing earthquake zone, all forces acting on both structures were increases constantly. Building in soft soil was more critical than building situated in medium and hard soil.

Likhith aradhya Y.R., Praveen J.V., Sanjith J., Ranjith A. (2016 June)
In this study, authors had been considered G+10 storeys RCC building and the ground slope varying from 10^0 to 30^0 for the analysis. An assessment was made with the building resting on level ground. The modeling and analysis of the building had been done by using structure analysis tool ETAB 2015, to study the effect of varying height of the column in bottom storey at different position during the earthquake. The seismic analysis done by the response spectrum analyses had been carried out as per IS:1893 (part 1): 2002. The outcomes that were found in the form of top storey displacement, storey acceleration, base shear and mode period. It was observed that short column is affected more during the earthquake. The sloping ground buildings hold comparatively more maximum movement and shear forces which may give to serious conditions than that of the flat ground. Base shear was maximum at 20^0 slope compared to other models. Displacement was maximum at the top story when compared with bottom storey's in all other models along x and y direction.

Likhith Aradhya Y.R., Praveen J.V., Sanjith J., Ranjith A. (2016 June)
The buildings were usually constructed on equal ground; however, due to deficiency of equal grounds the construction activities had been ongoing on sloping grounds. There were two types of configuration of building on sloping ground, the one was stepback and the other was stepback

setback. In the study, G+ 10 story's RCC building and the ground slope fluctuating from 100 to 300 had been measured for the analysis. A comparison had been made with the building resting on level ground. The modelling and analysis of the building had been done by using structure analysis tool ETAB 2015, to study the effect of varying height of the column in bottom storey at different position during the earthquake. The seismic analysis was done by the response spectrum analyses had been carried out as per IS:1893 (part 1): 2002. The results were obtained in the form of top storey displacement, storey acceleration, base shear and mode period. It was observed that short column is affected more during the earthquake.

The slanted ground buildings own relatively more maximum shift and shear forces which may give to serious circumstances than the flat ground. Base shear was maximum at 20^0 slope compared to other models. Base shear was maximum in X direction compared to Y direction for sloping ground building. From the analysis, mode period was decreasing with increase in slope angle. Mode period was directly proportion to the mass of the structure, the mass of the structure increases, the mode period also increases. From the analysis, storey displacement was decreasing with increase in slope angle. Displacement was maximum at the top story when compared with bottom storeys in all other models along x and y direction. From the analysis, Storey Acceleration was decreasing with increase in slope angle. Acceleration was maximum in storey-11 when compared to storey-1 in all other models along x and y direction.

Sripriya Arjun, Arathi S. (2016 July)

Buildings on slopes varied from other structures since they were asymmetrical both vertically and horizontally hence torsional coupled and was liable to severe harm when exposed to seismic action. The columns of ground storey had varying height of columns due to sloping ground. In the study, performance of G+3 storied sloped frame building having stepback setback conformation was examined for sinusoidal ground motion with dissimilar slope positions, i.e., 16.7°, 21.8°, 26.57° and 30.96° using structural analysis tool STAAD Pro. by performing Response Spectrum analysis had been carried out as per IS:1893 (part 1): 2002. The results were obtained in the form of top storey displacement and base shear. It was observed that short column was affected more during the earthquake. The analysis shown that for construction of the building on slopping ground the step back setback building configuration was suitable. It was found that the 16.7^0 (degree) sloped frame experiences maximum storey displacement due to low value of stiffness of column. It could be seen that the top storey displacement decreases with the increase in slope angles.

B. Arif Basha, A.B.S. Dada Peer (2016 December)

The dynamic analysis was carried out using response spectrum method to the stepback and stepback and setback building frames. The dynamic response, i.e., fundamental time period, storey displacement and drift, and base shear action induced in columns had been studied for buildings of different heights. These results revealed that the performance of stepback and setback building frames was more appropriate in contrast with step back building frames. However, after considering bracings to the stepback building frames, a better performance could be detected when related with stepback and setback building frames.

Stepback and setback frames produced less torsion effects as compared to stepback frames. In case stepback building frames were proposed, then stepback frame should be designed for higher moments

induced in columns due to earthquake. As number of storey's increases time period and top storey displacement also increased. Stepback frames with bracings gave less displacement compared with stepback frames without bracings and step and setback frames.

K.S.L. Nikhila, B. Pandurangarao

Irregularities in dimensions affect the distribution of stiffness, and in turn affect capacity, while mass irregularities tend to influence the imposed demand. Elevation irregularities had been observed to cause story failures due to non-uniform distribution of demand-to-supply ratios along the height. The Plan irregularities, that cause non-linear demand-to-capacity in the ratios between the columns. In this paper the building chosen for study is a 4, 5 storied commercial complex building. The building was located in seismic zone IV on a rock soil site. Three dimensional mathematical models for the same were generated in ETABS software. The structural elements, M40 grade of concrete, floor diaphragms were assumed to be rigid. Seismic loads were measured acting in the horizontal direction along either of the two principal directions and the ground slope chosen in between 0° and 25° and building that which produce less torsion effect for setback stepback with irregular configuration in horizontal and vertical direction was modeled and analyzed.

Observations were as the angle of slope increases base shear increases and displacement decreased. The base shear acts more in longitudinal direction than in transverse direction. It is detected that left columns, which were on the higher side of the sloping ground and were short, were most affected. Special consideration was required while designing short columns. As the slope increases no of hinges will decreases. From this we observed that for 15, 16, 32 degrees were safe up to 5 bay. But as the bay increased more no of hinges were to be formed and subjected to collapse region. In static linear analysis we observed that as the angle of slope increased storey shear decreased and base shear decreased.

D.J. Misal, M.A. Bagade

The dynamic analysis was carried out using response spectrum method to the stepback and stepback and setback building frames. The dynamic response that was fundamental time period, storey displacement and base shear action induced in columns had been studied for buildings of different heights. These results shown that the performance of stepback and setback building frames were more suitable in comparison with stepback building frames. But after considering bracings to the stepback building frames, a better performance could be observed when compared with step back and set back building frames. Three-dimensional space frame analysis is carried out for four different conformations such as stepback buildings without bracings, stepback buildings with bracings, stepback and setback building without bracings and regular building on plain ground of buildings ranging from eight, ten and twelve storey resting on sloping ground. Building models were analyzed by E-tabs software to study the effect of time

CONCLUSION

This article discusses briefly the previous work done on the area of seismic behavior of RC buildings, there failures and types of analysis. Several studies, experiments, and research works have been carried out since a long time all over the globe to understand and to evaluate the effect of seismic forces on buildings. From these published work it can be concluded that forces, deflection and stresses in the members increased due to seismic forces. A lot of literature is available on the earthquake resistant structures and their

failures due to seismic forces, but there is still need of research on the Mf. Mf to increase the design forces of the columns and beams of RC buildings wouldn't gave in any literature.

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