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A REVIEW ON EXPERIMENTAL INVESTIGATION OF RC FRAMED BUILDING ON SLOPING GROUND SUBJECTED TO EARTHQUAKE FORCES

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ABSTRACT – *Today's scenario of alluring building infrastructure is not limited to flat areas but also spread its legs towards the pleasant mountainous realm of India. In fact the construction activities are increasing day by day in the hilly regions because of their tempting and pleasant environment. Studies suggest that the structures built on sloping terrain are more affected by seismic activities due to their geographical formation. And due to this situation it needs to combat these lateral forces arises by seismic activities which may affect a part or whole structure. So to comprehend the situation and to find the types of problem generated and their possible solution achieved till date this review work is carried out. In this research study various papers are deliberated and compared for various seismic parameters that these researchers taken for study which will give a detailed insight about their work. This review work compares various analyses, analytical models, seismic and non-seismic constraints against varied situations and parameters to optimize the possibilities and to obtain best possible result and techniques to overcome the situation. In this study several research papers are studied and examined which lead to identify the problem statement and solution for further experimental investigation by various methods suggested by Indian standard codes.*

Keywords- Sloping terrain, multistory building, hill slope angle, seismic response, sloping ground, response spectrum, optimum case, setback case, step-back setback case.

1. INTRODUCTION

For architectural and structural engineers mesmerizing environment of hills comes not only with their natural beauty but also adds predicament in term of undulation of land, soil properties, geology and type of structure etc. As of now government also promote tourism in these types of areas which leads to development of infrastructure which includes highways, buildings landscapes etc. A very good example of this mission is development of "Char Dham Yatra Corridor" along with complete restoration and development of "Kedarnath temple", development of business convention centre in Sikkim and a lot are architectural marvels because of its altitude of formation and topography. Also according to the seismic analysis of previous times shows that these sloping areas are more affected by earthquake and falls under the category of highest seismic zone viz zone IV and zone V. This proclivity would stimulate the architectural reform in which multistoried building, complex building, irregular-configuration, parametric architecture, stiffness irregularity, vertical irregularity, and etc. comes into existence.

The major anomaly that found in the construction of building in sloping terrain is vulnerability of structure against various loading conditions along with sloping terrain and seismic activities which lead to failure whatever may be the nature i.e. fissure or collapse. So to analyze this situation various research papers are studied in which researchers have previously examined the situation along with all the constraints that might have an effect on the stability of structure. Various factors are found which influence the structure most significantly comprises of lateral loads that may be either produced by seismic activities or by wind forces. This review work compares all these possibilities which affect both workability and stability and hence laid the foundation for further problem statement and objectives of study.

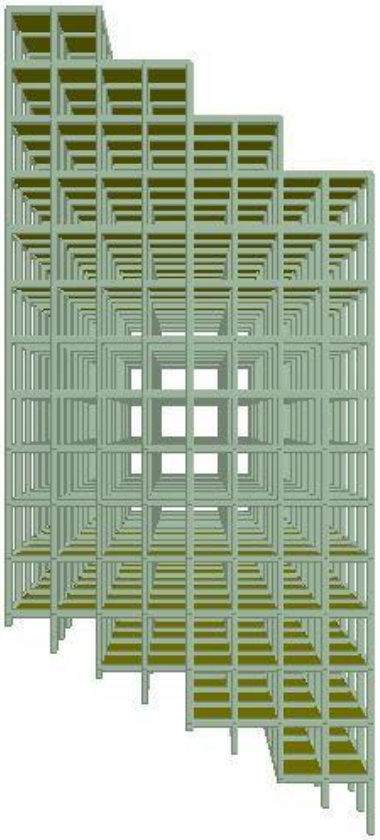

Figure 1: *15 storied inclined building having setback & step back configuration rested on 30˚ slope*

2. REVIEW OF LITERATURE

A.G.Sawant, Y.M.Ghugal, The present study shows the dynamic Response Spectrum analysis of 24 reinforced concrete building rested on sloping terrain analyzed against several seismic parameters for various configurations of buildings procurable in the hilly regions. The analysis is performed by ETabs software on seismic zone IV for various models ranging from 15.75m height to 40.25m having different configurations encompassing step back, set back and setback along with step back type. There are a total of 8 models are modeled for each type of configuration specified above and analyzed against various parameters in both lateral and longitudinal direction to cover all the aspects of study. Also along with various parameters torsional effect is also considered. Te findings of the study presents in tabular format and results are enlist are as follows. Under seismic excitation step back building shows more vulnerable behaviour out various other patterns taken for study. Torsional moment is higher in step back configuration than step back- set back configuration which proves to less perilous. Although due to symmetrical geometry of building plan along sloping line the accidental eccentricity along with torsional effect is found insignificant along X- direction. Also the reaction forces are less in setback building as compared to other configurations.

CH. Ashok, This paper presents the analytical study on building having step back type of configuration rested on hilly terrain. The study is carried out using Staad Pro software by both response Spectrum method and Seismic coefficient method of analysis to compare the results. The study is put forwarded in two phases, in the first phase height of the building is kept constant and in the second phase building width is kept staunch. Various models are configured against various seismic parameters to achieve the optimum outcome for building resting in sloping ground having a inclination of 10°, 30° and 45° respectively. Is was concluded from the study that the short column provided at the center of plan in ground floor bears higher forces in comparison to long column. The column forces in the structure were decreases with the increment in slope for fixed type and the same was increases with increment in inclination. With the increasing sloping angle in the terrain the base shear of the building for fixed height type structure was drop-off on the contrary for fixed width type structure base shear increases with increment in angle. From response spectrum analysis the peak story shear was increases with increment in angle for fixed height and the same was drop-off for fixed width type of structure with inclining slope.

Miss Pratiksha Thombre, Dr S. g. Makrande, In this paper study is conducted to examine the effects of various seismic parameters on a 5 storied RCC building with subsequent floor height of 3m. The building is modeled on plain ground and on sloping ground provided the sloping value of 0°, 10°, 20°, 30°, 40° and 50°. The building is analyzed for earthquake zone V by Staad Pro V8i software. This building is analyzed by dynamic analysis method of Response Spectrum method as per instructions given by India Standard Code IS 1893(Part 1):2002. The building is analyzed for various loading condition as per seismic code of India for both lateral and longitudinal direction. With the increase in slope displacement was found in reducing order because of the reason of column shortening. Behavior of displacement in sloping ground shows the same trend as of regular flat ground. For all the cases comprising variable sloping terrain ranges from 0˚ to 50˚ shows the decreasing trend in transposition of nodes. The displacement in building is decreases with the increment in slope because of column curtailment.

Nagarjuna and Shivakumar B. Patil, Lateral stability in a high rise multistoried building resting on sloping terrain is analyzed in the paper by researchers in the search of finding optimum results against various objectives set for this investigation. Two configurations are taken for consideration for modeling and analyzing building. For the study a G + 10 storied building is modeled which was resting on various sloping terrain ranging from 10˚ to 40˚ and compared with building model rested on flat ground. The objectives set for building are comprises of comparison among all the configured modeled taken for study, to obtain and analyze capacity curve and to analyze the effect of addition of lateral load resting member. When analyzing by both method viz response spectrum method and equivalent static method, time period and story displacement is decreased as slope of terrain increases. Base shear values have shown higher numeric value by response spectrum method over linear static method. Shear wall will reduce time period and displacement by a considerable amount for various sloping ground taken for analysis especially when it is present at center of structure. As per study building constructed on slope of 20˚ base shear is higher for all configurations.

Narayan Kalsulkar and Satish rathod, In this paper author analyses the RCC building for varying number of height instead of a constant stature. Study is carried out 6, 8 and 10 storied variable stature building resting on sloping ground for seismic zone III with varying number of bays comprises of 3X5 and 3X7 bay system. Referring the records of National Terrain data the slopes taken for study as per severity of hazards observed in sloping terrain during earthwork process are 16.32°, 21.58°, 26.56° and 31.56°. All the 48 models are analyzed against various seismic parameters as Indian Standard Code by response spectrum method of dynamic analysis by ETabs software so as to obtain the most optimize model and case set out of various configuration model

set. After analyzing various models with different combination set the conclusion drawn from the study consist of following results. Out of all the configurations taken for consideration step back frames are generating higher base shear. Time period in setback-step back type configuration register lower value as compared to step back frame. Special attention is needed while designing the short column located on the extreme left corner at the higher side of hilly terrain. It is concluded from the analysis that time period and displacement of top storey is controlled by increasing number of bays. Top storey displacement and time period was decreases with increasing slope.

Dr. R.B.Khadiranaikar and Arif Masali, In this paper the review work is carried out by the author on the effect of multistory building subjected to earthquake resting on hilly terrain. For review various research paper are studied to obtain the different outcomes and results from various authors which was concluded on basis of their research work respectively by numerous authors. Various authors conclude respective outcomes on the basic of various parameters and conditions taken for analysis when analyzed for multiple seismic zones, with varying geometry and different types of irregularities including mass, stiffness etc. For review work all the research work carried out by numerous authors compared and the results are shown in graphical and tabulated form for better indulgent and visualization of the theme. At last complete research paper summary of all papers represented in tabulated form comprising all the necessary data like type of building, input data, parameters, outcomes, remarks and references for simpler view. According to study performed by previous researchers base shear, time period and story displacement was higher in step back configuration. Experiment analysis by various studies shows that short column was poorly affected during seismic action since they entices more forces. Performance of seismic parameters is enhanced by increasing number of bays in hilly terrain.

Sujit Kumar et. Al., A five storied RCC building is framed for analyzing the behaviour of multistoried building in the hilly terrain when subjected to earthquake forces. For analysis building is modeled in Staad Pro software as per Indian Standard Code IS 1893 (Part 1):2002. The seismic zone taken for consideration is IV for which the seismic parameter "z" termed as zone factor is 0.24. Various configurations are modeled for different inclination viz. 7.5˚ and 15˚ respectively subjected to seismic forces along with the terrain situation. Various parameters are taken into consideration for comparing results some of which are horizontal reaction, axial force, bending moment etc. Various models are analyzed by linear static method of analysis as per seismic code guidelines and the results so obtained form the basis of conclusion. Following are the conclusions drawn from the investigation. As the slope of terrain increases bending moment along with critical horizontal force in footing was increased. Also vertical reaction for various slopes taken for study will remain almost same. While analyzing columns it was observed that critical bending moment was increased for building rested on sloping ground having a slope of 15˚. Axial force for various sloping ground taken shows almost same trend which implies columns required extra steel for better resistance.

Dr. S. A. Halkude et. Al., This study is carried out to analyze the seismic response of multistory building in hilly terrain against earthquake forces for variable slope and number of bays. Two basic types of building configurations are taken for study viz. step back configuration and step back and set back type configuration. Various 11 storied building is modeled and analyzed with varying configuration and geometry as per necessities. The building is analyzed for seismic zone III and the related seismic parameters are taken as per instructions given by Indian Standard IS 1893(Part 1): 2002. The various objectives set for study are effectiveness of configurations taken for analysis, determination and comparison of various building parameters including base shear, time period, storey displacement etc against several seismic parameter set for investigation. Base shear in step back type of structures was lesser when compared to other configurations. Time period along with top storey displacement was higher in step back patterns. While examining for seismic excitation performance of step back frames are more detrimental, so it not suggested in hilly terrain without any lateral load resisting support arrangement. Displacement values top stories are found higher in step back building frames in comparison to step back and set back building frames.

J. F. Rave-Arango & C.A. Blandon –Uribe, Two RCC moment frame residential buildings are selected, modeled and analyzed due to its higher flexibility in comparison to various lateral load resisting members which makes the structure effortlessly affected by asymmetrical earth pressure generated by sloping terrain. For building analysis building height is kept slightly low with a numerical value of 2.6m. Along with all the seismic parameters two basic model parameters height of the building and length of the columns are kept variable to achieve responses in terms of certain ratio proportions comprises of (Horizontal displacement / Total height) vs. (Height/Total height) and (Story drift) vs. (Height/Total height). Various models are modeled in SAP 2000 software and numerical analysis is performed to ascertain the dynamic response of response spectrum analysis. The study is conducted by Numerical Analysis model and completed by Finite Element modeling in Abacus 6.10 Software. This investigation is based on approach comprises of identifying the effect of

fluctuation in structural dynamic analysis response of a building when earth pressure is applied in sloping terrain and the second one is establishing safe and desired possibility to determine the displacement and internal forces. Movement of structure along backfill away from slope reduces deformation in building. Due to sloping terrain and reduction in deformation at lower level shear and overturning moment decreased. For alike values of base shear other seismic parameters like drift, moment and shear were larger at top of backfill to the roof.

Y. Singh et. Al., An analytical investigation and study is performed to analyze the seismic behaviour of building located on hilly terrain keeping in reference of Sikkim earthquakes occurred on September 18, 2011. Dynamic seismic response of building resting on sloping terrain is analyzed and compared with the building resting on plain or flat ground for various seismic parameters comprises of shear values in slender members, patterns obtained due to formation of plastic hinge, storey drift within the stories of building and fundamental time period of vibration. Investigation on various configurations is performed and analyzed by time history method of analysis by both linear and non linear method of dynamic analysis. A 9 storied building is modeled with two different types of configurations in which three stories are kept above road level and the remaining 6 stories are laid below ground level for seismic zone four as per Indian seismic code. For dynamic investigation relevant data for time history analysis is taken from the database of Pacific Earthquake Engineering Research Center. The results obtained from the study comprises of failure pattern of building in hilly terrain is perilous and significantly differs from building resting on flat ground. While investigating for seismic response across the slope significant torsional effects are observed. Also for configurations along the slope column height vary according to slope and causes stiffness irregularity and so the story shear generated from this condition resisted by short column.

3. CONCLUSION AND OUTLINE OF PROPOSED WORK

From the investigation it is clear that the researchers put lots of effort to comprehend the requisite construction practices, effect of seismic forces in the sloping terrain. But the analysis of several papers shows that the work is restricted to seismic analysis of multistoried building with variable slopes against multiples seismic and non seismic parameters all at a point in time. This lays the foundation of our current study which comprises of following set of objectives:

1. G+15 storied high rise building is taken for investigation lying at variable slope ranging from 10˚ to 40˚ along with flat terrain. The building possesses both step back and set back & step back type of configuration for each and every sloping model.
2. The analysis is performed for various seismic and non seismic parameters against multiple constraints to obtain and analyze the effects.
3. As a final point with the help of above results and analysis optimum case is identified and best suited solution is haul out for aforementioned problem statement.

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