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Effect of Sloping Ground on Multistorey Building under Earthquake Response: A Review

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Abstract: ***Buildings resting on sloping ground are different from those buildings which are resting on plain ground. The buildings which are located in hilly areas in earthquake prone regions are generally irregular, unsymmetrical, and torsionally coupled and hence, susceptible to severe damage when affected by earthquake ground motion. Therefore it is very important to consider earthquake effect and design earthquake resistant buildings from the safety point of view. These buildings have a mass and stiffness that vary along vertical and horizontal planes so that the centre of gravity and the centre of gravity on different floors do not coincide. Therefore, in addition to the lateral forces under seismic action, they require a torsion analysis. The article Present the review on the study of various researches on slope determination and analysis of structure on sloping surfaces. The review concluded that it is required to analyze the behavior of slope surface such hill, sloping ground under earthquake response to meet the growing demand for commercial and residential space.***

Keywords: Sloping Ground, Irregular, Unsymmetrical, Torsionally Coupled, Hill Slopes, Earthquake Ground Motion, Mass & Stiffness.

I. INTRODUCTION

Due to a trend presented sometimes earlier in our country, generally it is said that the peoples of hilly regions are migrating from hills to adjoining city for occupation and to fulfill their need but now a days the tourism industry have seen a tremendous growth in hilly regions. The proclivity of peoples again leaned towards hilly region whether it may be towards adventure, divine approach, or for enjoyment purpose it may leads to escalate employment, sojourn people to migrate and thus ultimately promotes the construction industry to build more and more building in these areas. Also the decreasing rate of land available for human use leads to move real estate and construction business towards hilly reason where the scope of construction is high. Although the complexities are higher in terms of construction practices in hilly terrain but the scope of land and variable architecture is high. Due to devastating urbanization and economic boom in hilly region real estate and construction giants are moving towards these regions. It was seen in the past that the building on a flat ground is comparatively easier to build but in case of sloping regions the construction practices are slightly hard-hitting. As per today's architecture the irregularity in in plan as well as in vertical plane will leads to evolving complex structure. These complex structures possess various configurations like step back type, set back type and cut/steep slope type with simple and complex architectural plans. These architectural plans possess varying vertical irregularity along with mass and stiffness irregularity in different ways. Fig 1 represented the real view and impact of earthquake and vertically acting force on it. Buildings on sloping ground. Along with the issues of architectural irregularities multi-story buildings in seismic prone areas are liable to more complex structural solutions. Especially in foundations, the risk of shear failure is higher in sloping ground so the selection of type of foundation and its design is comparatively difficult. Also in the hilly region the intensity of earthquake is comparatively higher and the frequency is also higher in north-east zone that is mostly hilly region which comprises of highest no of places with different seismic zones. These places require special structural arrangements like bracings, shear wall, outrigger and especially in foundation like anchorage, base isolation, frequency pendulum, dampers, etc.

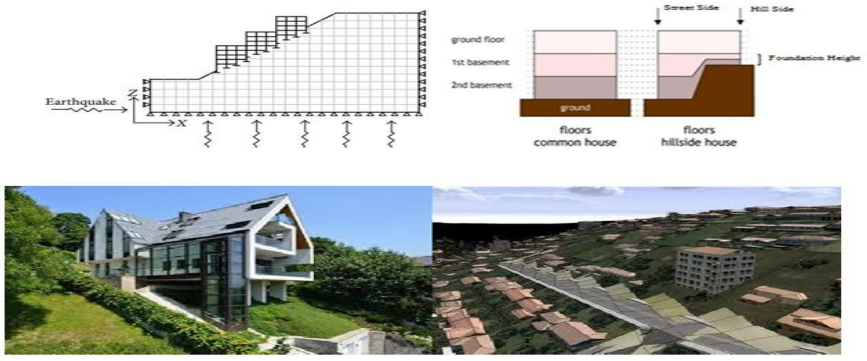

Fig. 1: Buildings on Sloping Ground

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II. REVIEW OF LITERATURE

The List out literature articles are taken for the study of building with sloping terrain. The various research on the building construction with sloping surface with different types of slopes and user requirement. The total 21 paper are consider for review and based on them the summarized reports on review on the different literatures are as follows:

A. Islam M., Pastariya S. (2020)

The article presented the comparative analysis of different configurations of G+14-story buildings with variable slopes. The model also includes the variation in plans and structural arrangements under zone III of earthquake. This comparative study are carried out for different framed reinforced concrete models and analyzes their response to dynamic loading to identify and combat the worst possible scenario. The research includes combination of 4 different slopes and different building configurations using the method of analysis of the response spectrum, and different parameters are compared with different voltages. The results from various design cases came to the conclusion that the most optimal case is the design of models 1 and 2 which is 15 storied sloping building having step back configuration rested on 10˚ slope and 15 storied sloping building having step back configuration rested on 20˚ slope respectively.

B. Mansoori S.M.H., Vyas J. N. (2020)

In manuscript worked on the behavior of G+11 stories RC building with Un-braced and Braced situation is analyzed for Response Spectrum Analysis with 0°, 10°, 20° and 30° slope angles using structural analysis tool ETABS 16. By performing Response Spectrum analysis have been carried out as per IS: 1893 (part 1): 2002. The results were obtained in the form of top storey displacement, maximum story Drift Ratio, Fundamental time period of first 12 modes and base shear It concluded that the fundamental time period of structure is decreasing due to increasing of angle of sloping. The analyzes concluded such that sloping ground for the building construction configuration of the bracing building is appropriate.

C. Sahu V., Shrivastava L. P.(2020)

The articles carried out the research on different inclined ground RCC Frames along with different cases of shear wall. The article deals to find the frames in respect to maximum displacement factor along with the quantity of materials used. It is also taken as per the retrofitting possibilities with minimum economic conditions. For these, the sloping shaped (10-D, 15-D & 20-D) addition to the different shear wall condition of multi-storey RCC frame building of equal physical properties such as built-up, beam & column size is analyzed using STAAD.Pro.V8i (Series 6) for seismic Zone –IV. The final conclusion made such that, frames have been improved by changing the ideal location of shear wall retrofitting, Seismic isolation methods and supplemental dampers or bracings are also some remedies for retrofitting

D. Dane A., Pendharkar U. (2019)

This paper has examined the effect of shear walls in multi-storey buildings built on sloping ground. Four different models have been selected for this purpose. The modal model is a classic hard-framed building and the remaining three models are still with cut walls. All conditions such as slope of soil, material, seismic zone, soil condition, etc. are identical, except for the dimensions of the shear wall. In all three cases, linear static analysis was performed to assess the table shear and the resulting reduction. The entire analysis is carried out with a software called sap: 2000. The study concludes that when the shear walls are applied towards the slope, an effective reduction of the base shear force of 65%, 71% and 80% is observed in one mode 1, the Mode 2 and 3, which indicate that model*3 has a higher sensitivity only with respect to the fundamental shear force.

E. Phatale S. S., Parekar S. R. (2019)

In this study, recessed construction with bracing systems under various its forms X, V, inverted V, diagonal, bare frame are considered. In this study, a Step back building with 8 Storey (STEPALS 8) was considered for studying the response of different types of bracings on sloping ground. The dynamic parameters obtained from analyses have been discussed in terms of base shear induced in the columns at foundation level, fundamental time periods, maximum top storey displacements and storey drifts compared within the considered configurations of hill buildings. At last, the suitability of bracing which can be effectively used in step back building on sloping ground has been suggested. These models are analyzed by response spectrum analysis using the ETABS.

The dynamic parameters obtained from the analysis were discussed in terms of fundamental time periods, maximum displacements of upper floors, floor drifts and base shear compared in the hill buildings configurations. Finally, the effective type of bracing that can be used in recessed construction on sloped ground is discovered.

F. Sawant A.G., Ghugal Y. M. (2018)

The main one focused on this research to investigate the Recoil and Recoil buildings. The results of the seismic analyzes carried out on 24 storey buildings with 3 different cases such as the recessed building, the recessed building and the recessed building are presented. 3-D analysis including the torsion effect was performed by reactive spectroscopy. The fundamental length of the time, the displacement of the upper rungs and the fundamental shear effects caused in the pillars were checked with reference to filling. sufficient of the building configuration on the sloping ground. We have found that leaning buildings are more suitable on sloping ground.

G. Irfan M. ,Patil V.B.(2018)

This paper presents case studies of the combined effects of landslides and earthquakes on sloping terrain. The case is considered after the earthquake in Sikkim on September 18, 2011. Due to a lack of flat land in hilly areas, most buildings are built on hillsides with precise structural structures based on different grades. These buildings have specific structural and construction problems. Therefore, the center of gravity and the rigid center of a degree do not coincide and do not lie on a vertical line for different degrees. When these buildings are subjected to horizontal loads, they often experience a significant Torsional response. Most results show that a building on sloping ground has greater foundation displacement and shear than a building on level ground. A shorter column pulls more force and causes damage in an earthquake. The compartment may be more sensitive to seismic stimulation.

H. Raghuvanshi D.S, Sakalle R.& et.al.(2017)

Soil with a variable angle of inclination, that is 0, 10, 15 degrees. STAAD Pro v8i software is used for modeling with 4 soil types 3 zone 3. A comparative study of the results as lateral forces, maximum BM, maximum AF, and ground direction displacement as shown is analyzed by spectral analysis. In the paper, it was found that a 15-degree tilted frame experiences the greatest shift of the story due to the low stiffness value of the short post, while a 0-degree frame experiences a minimal story. At a given load, the axial force of the columns is not significantly changed. The Torsional and bending moments in the columns are negligible, and the change is insignificant due to the introduction of the plate.

I. Ghos H.R., Debbarma R. (2017)

In the literature, the seismic properties of structures located deep on flat ground and on hillsides are evaluated with flexible stratum configurations. Analysis was performed using three individual methods, the static force equivalent method, the reaction spectrum method and the time history method, and the extreme reactions for an outdoor building. In order to minimize this soft phase effect and extreme response, three individual damping techniques were applied and the best solution out of the three is presented.

J. Shaik I., P. Rajesh (2017)

In this study, a 3D analysis model of G + 9-storey buildings is generated for the symmetrical building model, analyzed by the structural analysis tool "Staad Pro Vi8". To investigate the effect of changing the height of columns on the ground floor due to sloping floors, the layout is similar for structures on flat and sloping floors. Analytical building modeling includes all important components that influence the mass, strength, rigidity, and deformability of the structure. To study the effect of charging during an earthquake, seismic-II area analysis was performed using linear dynamics (reactive spectroscopy) and a nonlinear static process.

K. Likhitharadhya Y R, Praveen J V &et. al. (2016)

The work of the researcher takes place in the RCC building with G + 10 floors, where the slope of the floor ranging from 100 to 300 was taken into account for analysis. We made a comparison of a building resting on flat ground. Modeling and analysis of the building were performed with the ETAB 2015 structure analysis tool to examine the effect of changing the height of the lower storey pillar at different positions during the earthquake. The seismic analysis was performed by response spectrum analyzes performed in accordance with IS: 1893 (Part 1): 2002. A shorter column was found to be more affected during the earthquake.

L. Robert R.J., Ghate R.M. (2016)

Robert R.J., Ghate R.M compared the performance of a building placed on a sloping surface and on a flat surface with the same magnitude of the seismic load on both buildings. The parameters we mainly focus on are ground displacement and shear base. In this study, the ground displacement of both buildings was estimated in the + X and - X directions and in the + Z and - Z directions. Flatness under the same seismic load was also calculated and compared.

M. Kamble S.D., Dr. Bhalchandra S.A. (2016)

Investigators tried to detect the earthquake of a building that rested on a narrow floor and had no cutting wall. The seismic approach is considered to be the equivalent of temporal analysis in the SAP2000 standard design software. The mode has a 4-storey RCC building G + with four badges in X way and six badges in Y way; each bay is 3.5 m wide. The models are tested on a slippery surface (slope 200 and 300 straight). Finally, he concluded that a cutting wall at four angles is better at resisting end forces during an earthquake compared to a shear wall at two angles of a long column.

N. Kasi K.M., Kumar T.S. &et. al. (2016)

This paper deals with the comparison of G+9 residential buildings for seismic performance resting on sloping grounds without and with shear walls retrofitted when subjected on earthquake forces in zone III and in two different types of soils (soft and hard soils). The structures are analyzed by non-linear dynamic analysis using “ETABSvr13.0” for a constant sloping ground of 30° with horizontal. With this we can study the performance evaluation of building under the presence of shear wall, storey shear, displacements and storey drifts at each storey were determined and compared.

O. Daniela J., Kamasundarib S.(2014)

In this study, the seismic weight of a real building on a flat surface is similar to that of a mountain building. An exploratory study was conducted to assess the character of the building at the mountain level. The dynamic response of mountain construction is comparable to that of a permanent structure on soft ground in terms of precise earthquake time, modal shape, amount of space to take part in proportion, deformed shape and action of wool. the base is pushed into columns and the beam of this building is level. . It is observed that mountain buildings have very different characteristics than buildings on flat land.

P. Arya U., Hussain A., &et. al.(2014)

The Arya U., Hussain A. and other researcher gets results of the air velocity and design solutions for building a frame on a slippery surface were studied. Considering the different frame geometry and slope. The combination of the solid and air loads is considered. Together, sixty cases in different air zones and three different types of building frames are examined. STAAD-Pro v8i software used for objective analysis. Outcomes are grouped according to axial force, Shear strength, time, support performance, Storey-wise lift and Deposits which are analyzed in depth to measure the effects of different ground levels.

Q. G Suresh, E Arunakanthi (2014)

Dynamic analysis is performed using the recoil and recoil response spectrum method and the retraction of construction frames. The answer is powerful, i.e. significant time intervals, ground curvature and erosion, and the base of the cutting action raised in columns were investigated for buildings of different heights consecration. These results suggest that the performance of construction and retrofitting frames is more efficient than that of construction frames. But after considering the binding of built-in construction frames, better performance can be observed compared to the relaxed and rated building frames.

R. Patro S.K., Banerjee S. & et.al. (2013)

The papers deal with a dynamic approach such that recessed buildings are more vulnerable than other building configurations. The short columns left and right underground are the most damaged in earthquakes when the step back and the steps behind the Set-back buildings. Minor impacts of low soil erosion In-depth analysis of the economic value of landfills and other factors should be considered. The upper shear rose to the level of the return-restoration building and lower to the fixed house. The final rise of the upper floor is the most important step for the Step building. In a slippery slope, reconstructed construction is preferred.

S. Arjun S., Arathi S (2013)

In this study, the characteristic G + 3 cuts the frame building as well as the reverse rear axis is detected sinusoidal ground motion. The survey used different step angles, namely 16.7 °, 21.8 °, 26.57, 30.96 degree using the Staad.Pro free design test. by performing a spectrum analysis response performed in accordance with IS: 1893 (part 1): 2002.The result was obtained as a high speed zone and low shear. It is found that a short section is most affected during an earthquake. Studies have shown that when constructing a building on a sloping surface, the reinforcement of a backlash is appropriate.

T. Nagargoje S.M., Sable K.S. (2012)

The article is based on the assessment of different areas of earthquake. Buildings on steep slopes in areas prone to earthquakes are generally unusual, consistently mixed and therefore vulnerable to damage when affected by earthquake activity. Occupation and density This alternative represents a hardening in different planes and standing straight, so that the central density and complexity is added in different apartments, so they need a torsional analysis, including the powers of the latter. under the action of an earthquake. These asymmetric structures require special attention to analysis and design. Analysis of the structures are quite different from the ground level of the buildings, as the pillars of the building braking rely on different levels on the slope. The short queue attracts strong force and is damaged when earthquakes occur.

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

Researchers carried out their work in 24 RC buildings with 3 different models, with a retracted building, a retracted building and a retracted building. A 3-D analysis, including the effect of rotation, was performed using the RSM. The dynamic response by different parameters such as i.e., time period, the slope of the upper step, and the main shear motion occurring in the columns were analyzed by the adequacy of the configuration of the sloping building. We see backward buildings as more convenient on slopes.

III.CONCLUSIONS

Based on the above different research papers of the different research following conclusions are made which are as follows:

A. It is required to analyze the behavior of slope surface such hill, sloping ground etc under earthquake response. Since the level are different.
B. Seismic history of structures in hilly region shows the increasing demand but due to structure safety it needs to review the design methodology and identify the cause of collapse.
C. Generally in hilly terrain the step back type configuration was used but it was not structurally successful without any lateral load resisting system like bracings, shear wall, outrigger etc.
D. Hilly terrain buildings may possess unsymmetrical configuration and irregularity in horizontal and vertical planes and so these types of structures are torsion ally coupled
E. Most constructions adopted a setback or setback and setback configuration in hilly regions due to local topography.
F. When the models are analyzed against seismic loading the entire building configuration rested on sloping ground may suffer from Torsional effects.
G. Due to successive change in height of column leads to stiffness irregularity and almost all the story shear will have to be resisted by short columns.
H. For building constructed in sloping terrain pushover analysis suggest that more damages are found in stories situated above the road level.
I. Bending moment is reduced considerably in the models up to sloping terrain and after that it was sharply increased at the base of the structure.
J. Setback with step-back configuration is suggested to resist lateral loading generated at the time of earthquake.

IV.FUTURE SCOPE

The Following work is carried out under the future scope work which is listed below:

A. Analysis of different types of slopes for a multistorey building and compare them.
B. Comparative analysis the structure both software and manual analysis.
C. Behavior of slope with respect to soil types, nature and soil zone.

D. The comparative study of different codes on sloping surface.
E. Use of different technique to reduce to the effect of slope in the building.
F. Proposing the new theory under the behavior of slope.

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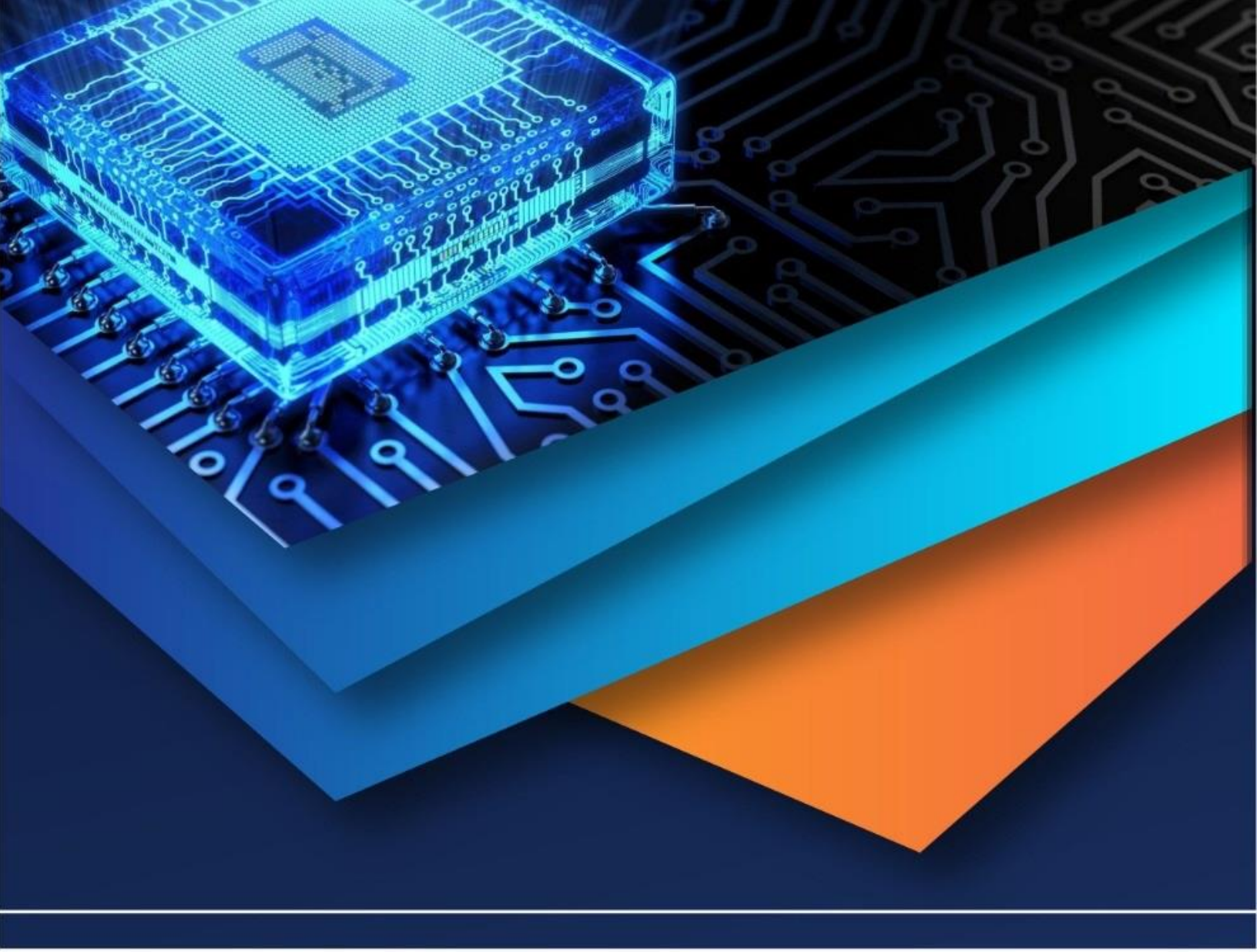

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