International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 04 | Apr 2021 www.irjet.net p-ISSN: 2395-0072

Seismic Analysis of Irregular Building on Hilly Area

Anjeet Singh Chauhan[1], Mr. Rajiv Banerjee[2]

M. Tech Scholar[1], Associate Professor[2]

Department of Civil Engineering, Integral University, Lucknow, Uttar Pradesh, India

---

Abstract- *The RC buildings construction has increased in the preferred location of north & eastern hilly areas during the last few decades due to population increase, urbanization, and tourists. The buildings located in the hilly areas are more susceptible to seismic loading as compare to the location of the flat surface building. The shape of the building on the sloping ground differs from the flat surface situated buildings. So the construction of the building on hilly areas are irregular in both vertically & horizontally, thus this type of building is susceptible to severe damage when applied the seismic condition. The column of the base storey having unequal height due to sloping ground. In this study, the behavior of G+10 storey stepback building with mass and diaphragm irregularity on the sloping ground is analyzed in seismic zone V by Response Spectrum. The analysis of the building is carried out by Etabs software as per IS 1893:2016 to compare the building based on their dynamic response and also identify the vulnerability frame in the sloping ground.*

Key word - *Seismic Analysis, Response Spectrum Method, Stepback building, Mass Irregularity, Diaphragm irregularity, Sloping Ground, Seismic Zone V,IS 1893:2016 & IS 456:2000, bare frame, CSI ETABS vi 18 software.*

1.0 Introduction

Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life against it [4]. The Himalayan range also has large mountains and many towns are spread over these mountains [8]. The multi-storeyed RC framed buildings are getting prevalent in hilly areas because of increasing the land cast in urban areas. Thus, many people are constructed on hilly slopes. Setback building frames are frequent over level grounds whereas stepback building frames are also common on sloping ground. Combinations of a stepback and setback buildings are also common on sloping ground. Buildings in hilly areas are irregular and therefore, it is subjected to severe torsion in addition to lateral forces under the action of earthquake forces. Many buildings on hill areas are supported by columns of different heights. Building loads transmitted at the foundation level to a slope create the problem of slope instability and may result in the collapse of the building. The soil profile is non-uniform on the hilly slopes and results in the total collapse of the building. Earthquake is the most disastrous due to its unpredictability and the huge power of devastation. Building structures collapse during severe earthquakes and cause direct loss of human been lives.

2.0 LITERATURE REVIEV

After surveying various research papers which has been related to irregular building in slop ground, the short explanation about its approach, methodology and conclusions has discussed.

B.G. Birajdar & S.S. Nalawade (2004) - In this paper, the seismic analysis performed on 24 RCC vertical irregularity frames with three different configurations as step back building, stepback-setback building and setback building. 3-D analysis has been carried out by using response spectrum method. The three configuration of building is compared on the basis of the performance of dynamic response results. The results show that the stepback-setback building frames were more suitable for the sloping ground.

Pradip Sarkar et.al (2010) - In this paper, it was mainly focused on the dynamic response result as fundamental time period which is unable to depict the correct value of the time period at the sloping ground that is given Empirical formula in IS: 1893-2002. The researcher is analysed the seismic load on 78 vertical irregular with 6 to 18 storey of different height of building and proposed equation for fundamental time periods is expressed as a function of the regularity index. It has been applied only for various types of stepped irregular frames.

Y. Singh & Phani Gade (2012) - An analytical study performed 3 to 10-storey RC frame building to investigate the seismic behavior of hill buildings. The buildings were analyzed for Seismic Zone IV as per Indian Code. Dynamic response of irregular buildings on sloping ground is compared with regular buildings on flat ground in terms of the fundamental period of vibration, a pattern of inter-storey drift, column shear, and plastic hinge formation pattern. The seismic behavior of two configurations of sloping ground buildings is analyzed by using linear and non-linear time history methods. The findings from the analytical study are supported by the observation of the damage in exactly a similar manner as predicted by the analytical study.

Ravikumar C M, et.al (2012) - In this paper, the seismic analysis was performed on 3 storey with vertical and diaphragm discontinuity irregularity building on sloping ground. The analysis was performed on Etabs by using different method i.e. Equivalent static method, RSA & Pushover analysis using IS1893:2002 code. The performance was studied in terms of dynamic response and compare the model to the plain ground and sloping ground. The performances of all the models on based of result except sloping ground building are lies in between life safety. This shows the buildings resting on sloping ground are more vulnerable to seismic than the rest of the models.

A.R. Vijaya Narayanan, et.al (2012) - In this paper, considered two Steep back buildings A and B (of same width along the road direction) with three storeys above and four storeys below ground level, but with different restraints at base of columns. Building A has fixed column bases, and Building B has roller column base except underneath the tallest valley-side column. This paper presents results of nonlinear analyses preformed on typical buildings on steep hill slopes with two possible types of column base connectivity to the ground. RC buildings with large plan size vulnerable to strong seismic shaking. Only small plan buildings are most suitable for construction along steep hill slopes.

Shaikh Abdul Aijaj Abdul Rahman & Girish Deshmukh (2013) - The seismic analysis performed on G+10 vertical irregular building of two frame with similar dimension but having the stiffness irregular in 2nd frame. The dynamic analysis is analysed by Etabs software as per IS: 18931-2002. The dynamic response result to compare the both frame. The frame-1 (vertically irregular) develops least storey drifts while the building with stiffness irregularity on vertically irregular building (frame-2) shows maximum storey drift on the respective storey levels.

Adrian Fredrick C. Dya & Andres Winston C. Oretaa (2015) - In this study, the seismic analysis of low-rise 5 storey irregular building analyzed by the structural software of SAP2000. The dynamic analysis is carried out by the Static pushover analysis method. Based on analysis of the modeling results for the soft story building, it can be seen that the main cause for soft-story building frames to be more susceptible to earthquakes is the localization of seismic loads.

A. S. Swathi, et.al. (2015) - The seismic performance of 5 storey buildings with open ground soft storey irregular building resting on 30 degrees sloping ground is analyzed by SAP-2000 software as per IS;1893-2002 with the help of Pushover analysis method. The performance building based on dynamic response results of open ground storey buildings is very less. The performance of building frames is improved by the addition of a shear wall.

Behzad Fatahi, et.al. (2016) - In this paper, the seismic analysis performed on a 15-storey moment-resisting structure which is stable on a 30m thick clay deposit and near 2m high shallow slope. The dynamic analysis is done by time history analysis method by using SAP2000 Software tools. Seismic slope stability analysis and as expected, the shallow slope became more susceptible to instability and large deformation issues when the building was constructed closer to the slope.

P. Manjunath et.al. (2016) - The seismic analysis performed on 10 storey vertical irregular with flat slab building on plain and various sloping ground under the seismic zone V. The seismic analysis is done by RAS method with analyzed by Etabs 2015 software and compare the dynamic response with plain and sloping ground.

Likhitharadhya Y R(2016) - In this study, the seismic analysis on G+10 storeys RC building with flat ground and the sloping ground varying from 100 to 300 have been taken for the analysis. The modeling and analysis of the RC building frame have been done by using the ETABs 2015 software tool, to study the effect of varying heights of the column in the bottom storey at different positions during the earthquake. The seismic analysis was done by the response spectrum analyses have been carried out as per IS: 1893 (part 1): 2002. The dynamic response results were obtained from the analysis of the structural frame to the comparison between flat and sloping ground building frame in the form of top storey displacement, Storey Acceleration, Base shear, and Mode period. It is observed from the dynamic response results that the short column is affected more during the earthquake.

Zaid Mohammad, et.al. (2017) - In this study, 18 models of two different configuration SB & SBSB buildings have been modeled and analyzed using Etabs software. The building is vertical irregular and varied in height and length. All the model is analyzed on 26-degree sloping ground by using Response Spectrum Method. The dynamic parameters obtained from analyses have been discussed in terms of shear forces induced in the columns at foundation level, fundamental time periods, maximum top storey displacements, storey drifts, and storey shear in buildings, and compared within the considered configurations of sloping ground buildings. SBSB buildings perform better than step-back configuration when subjected to seismic loads.

Rahul Ghosh & Rama Debbarma(2017) - In this paper, the seismic performance had been made to evaluate the setback structures resting on the plain ground as well as in the sloping ground with soft storey configuration. The analysis has been performed by three individual methods, equivalent static force method, response spectrum method, and time history method and maximum responses have been recorded for open ground storeyed setback building. To mitigate this soft storey effect and the extreme responses, three mitigation techniques have been adopted as infill wall, RCFSTC, and shear wall.

Oman Sayyed, et.al. (2017) - The seismic performance & behaviour of 8 models of G+10 regular and vertical with soft irregular building is analysed by Response spectrum analysis method with the help of Etabs 2015software.By the different seismic response to compare the regular and irregular building. The storey displacement and storey drift in case of stiffness irregular buildings is more than that of the regular building.

Ravindra Navale, et.al. (2017) - The seismic analysis of G+5 vertical irregular RC building in the 2D frame at different floor height and number of bays is analyzed by Etabs software. The seismic analysis is carried out by the response spectrum method. The dynamic response result to compare the effect of the short column at the different number of the bays.

Shaikh Abdul Aijaj Abdul Rahman & Ansari Ubaidurrahman Salik (2018) - The seismic response of G+10 storey of two frames having the same dimension with mass and the vertical irregular building has been analyzed by linear static and dynamic method with the help of Etabs software as per IS:1893-2002. The dynamic response of the structure frame-1 (vertically irregular) develops least storey drifts while the building with mass irregularity on vertically irregular building (frame-2) shows maximum storey drifts on the respective storey levels. Hence, this is the most vulnerable to damages.

Sachin Kumar gandi & Saleem Akhtar (2019) - The seismic analysis performed on 20 models of G+6 storey frame of the vertical irregular building (Step-back) with 3 different positions of the shear wall on different sloping ground. The analysis of frame building is done by using Staad-Pro software. The position of the shear wall at the periphery is the optimum position for the lateral load resistance & at the corner is the optimum position for countering axial loads.

Ruoqiang Feng, et.al. (2019) - The research presented the seismic behavior of G+4 multi-story modular box buildings using numerical simulation. Modal analysis of buildings under frequent and rare earthquakes was conducted. The analysis of the 3-model of the modular box building was done by Abaqus software. To fulfill the building model, a simplified model of a single container was established using the equivalent spring model and shear behavior of a single container was studied. In addition, the stiffness and capacity of four types of joints using in the modular box building were calculated. The results show that the multi-story modular box buildings with the current joints do not satisfy the Chinese code, and new connections are required for further application.

Kolasani Rajasekhar and Maganti Janardhana (2019) - In this paper, the seismic analysis was carried out on a 21-storeyed RC framed building resting on the sloping ground using linear static analysis and linear dynamic analysis (RSA). This paper compared the behavior of RC framed buildings resting on plain ground and resting on the sloping ground including the effect of infill wall stiffness.

G. Ajay Kumar and A. Gouthami (2019) - The seismic analysis performed on the G+10 storey regular and vertical irregular with and without a shear wall on a various sloping angle and surface ground. The modeling and the analysis of the structure have been carried out by linear static, RSA and Time history analysis with the help of SAP 2000 software and compare the result of dynamic response with and without structure at different location of the shear wall.

Apurva Arjun Gaikwad & Dr. Atul B. Pujari (2019) - The seismic analysis performed on the low rise (G+5), Mid-rise (G+10), and High rise (G+15) storey on a plain and various angle of sloping ground structures will be analyzed by Response spectrum

method and Time history methods. The seismic analysis is done on Etabs software for Storey displacement, Base shear, Storey drift, Time period, and Modal participating factors are obtained and compare at different sloping angles.

Dr. K.B. Parikh & Jayant Shaligram (2019) - The plan irregular T and L shape G+4 with and without OGS setback building column by reinforced concrete-filled steel tube columns (RCFST) resting on plain and 45-degree slope ground have been analyzed by using Time history analysis method. The performance of both models has been analyzed and compared to its results. RCFST columns provided in the open ground storey to increase the performance of the plan irregular setback building and decreased the seismic hazard.

Rayudu Jarapala & Kishore Chandra Biswal (2020) - In this paper, the seismic analysis performed on 10 models of vertical irregularity buildings & 4 to 8 number of storey buildings with Step back & Stepback-Setback buildings are presented. It is analyzed by using SAP2000 software. The dynamic responses of the buildings under three different earthquakes as low, intermediate, and high-frequency. Dynamic analysis is done by the Time history method using IS 1893-2002. The regular index is best suitable for the SB and SBSB building frames to identify the level of irregularity.

Mahdi Heshmati, et.al. (2020) - The seismic performance of 6 models of 36 storey at various angles analyzed by Pushover & time history analysis method as per IS: 1893-2002. The dynamic analysis is performed on 3D software to assess inter-story drift ratio, residual drift, energy dissipation, and hinges distribution of structures. Diagrids structures performed acceptably under MCE earthquake motions and most of the mean deformations were within the allowable range.

Shaik Akhil Ahamad & K.V. Pratap (2020) - In this study, the usage of Shear walls at different locations in G+20 multistoried residential building is analyzed for storey drift, base shear, maximum allowable displacement, and torsional irregularity. The analysis and modeling for the whole structure are done by using Etabs 2015 by the RSA method at the different seismic zone as IS 1893 (Part-1) 2016. The dynamic analysis is carried out on soft soil for an irregular structure in plan and compare the three case of shear wall with the different seismic zone. It is observed that the building with shear walls placed at four ends i.e. Case C had given better results in terms of maximum displacement, storey drift, and base shear.

3.0 Conclusion

After reviewing a lot of research papers that are based on the irregular building structure and sloping ground with various loading conditions. For further work in this direction irregular building with the various irregularity in the structure with the sloping ground would create various type of case model and using the response spectrum method & time history method to analyze to identify of Vulnerability frame.

The conclusion for the further work related to the irregular building on sloping ground are shown below:-

a) A lot of work has been seen in various research papers, but none of the papers can show the various irregularity in the building frame for the earthquake analysis.
b) For analysis, a structural tool such as Etabs 2018 could be used.
c) Various types of irregularities such as vertical, mass, and diaphragm irregularities have taken in the building with the sloping ground which is not shown by various researchers.
d) Response spectrum method and Time history analysis method could be for determining the seismic response over the structural parts.
e) The building model will be analyzed in seismic zone IV & V.
f) Determination of the dynamic response of the different building models.
g) After performing the response spectrum & time history analysis, comparing all the result parametric values and identify of Vulnerability frame.

Acknowledgement

I take the opportunity to express my hearty gratitude to Mr. Rajiv Banerjee, Associate Professor, Department of Civil Engineering, Integral University, and Lucknow (U.P.) for the valuable guidance and inspiration throughout the dissertation work. I feel thanks for his innovative ideas, which led to the successful completion of the work.

References

[1] B.G. Birajdar & S.S. Nalawade(2004), "Seismic analysis of buildings resting on sloping ground", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada, Paper No. 1472

[2] Pradip Sarkar, A. Meher Prasad & Devdas Menon (2010) "Vertical geometric irregularity in stepped building frames", Engineering Structures 32 (2010) 2175–2182, doi:10.1016/j.engstruct.2010.03.020

[3] Y. Singh & Phani Gade(2012), "Seismic Behavior of Buildings Located on Slopes -An Analytical Study and Some Observations From Sikkim Earthquake of September 18, 2011", 15th World Conference on Earthquake Engineering, LISBOA 2012

[4] Ravikumar C M, Babu Narayan K S, Sujith B V and Venkat Reddy D(2012), "Effect of Irregular Configurations on Seismic Vulnerability of RC Buildings", Architecture Research 2012, 2(3): 20-26, DOI: 10.5923/j.arch.20120203.01

[5] A.R. Vijaya Narayanan, Rupen Goswami and C.V.R. Murty (2012), "Performance of RC Buildings along Hill Slopes of Himalayas during 2011 Sikkim Earthquake", 15th World Conference on Earthquake Engineering,

[6] Shaikh Abdul Aijaj Abdul Rahman & Girish Deshmukh (2013), "Seismic Response of Vertically Irregular RC Frame with Stiffness Irregularity at Fourth Floor", International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal

[7] Adrian Fredrick C. Dya & Andres Winston C. Oretaa(2015), "Seismic vulnerability assessment of soft story irregular buildings using pushover analysis", Procedia Engineering 125(2015)925–932,doi: 10.1016/j.proeng.2015.11.103

[8] A. S. Swathi, G.V. Rama Rao & R. A. B. Depaa studies (2015), "Seismic Performance of Buildings on Sloping Grounds", International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization), ISSN(Online) : 2319 – 8753, ISSN (Print) : 2347 – 6710

[9] Behzad Fatahi, Bohan Huang, Navid Yeganeh(2016), Sergei Terzaghiand Subhadeep Banerjee(2016), "Three-Dimensional Simulation of Seismic Slope Foundation Structure Interaction for Buildings Near Shallow Slopes", International Journal of Geomechanics,© ASCE, ISSN 1532-3641, https://orcid.org/0000-0002-7920-6946

[10] P. Manjunath and Yogeendra R. Holebsgilu (2016), "Seismic Analysis of Multi Storey Building with Flat Slab Resting on Plain and Sloping Ground", Bonfring International Journal of Man Machine Interface, ISSN 2277-5064, DOI:10.9756/BIJMMI.8150

[11] Likhitharadhya Y R(2016), "Seismic Analysis of Multi-Storey Building Resting On Flat Ground and Sloping Ground", International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization), ISSN(Online): 2319-8753, ISSN (Print): 2347-6710

[12] Zaid Mohammad, Abdul Baqi & Mohammed Arif(2017), "Seismic Response of RC Framed Buildings Resting on Hill Slopes", Procedia Engineering 173 (2017) 1792–1799, doi: 10.1016/j.proeng.2016.12.221

[13] Rahul Ghosh & Rama Debbarma(2017), "Performance evaluation of setback buildings with open ground storey on plain and sloping ground under earthquake loadings and mitigation of failure", International Journal Advance Structural Engineering, DOI 10.1007/s40091-017-0151-3

[14] Oman Sayyed, Suresh Singh Kushwah & Aruna Rawat(2017), "Seismic Analysis of Vertical Irregular RC Building with Stiffness and Setback Irregularities ", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, DOI: 10.9790/1684-1401064045

[15] Ravindra Navale, Dr. Sandeep Hake & Pramod Kharmale (2017), "Analysis of Unsymmetrical Building Resting on Sloping Ground by Dividing In 2D Frame", International Research Journal of Engineering and Technology (IRJET) , e-ISSN: 2395-0056, p-ISSN: 2395-0072

[16] Shaikh Abdul Aijaj Abdul Rahman & Ansari Ubaidurrahman Salik (2018), "Seismic Response of vertical Irregular RC Frame with mass irregularity", International Journal of Recent Scientific Research, ISSN: 0976-3031, Vol. 9, Issue, 2(H), pp. 24317-24321

[17] Sachin Kumar gandi and Saleem Akhtar (2019), "Seismic Analysis of a RC building on sloping ground with shear wall at different position", AIP Conference Proceedings, https://doi.org/10.1063/1.5127154

[18] Ruoqiang Feng, Liu Shen and Qiu Yun(2019)"Seismic performance of multi-story modular box buildings", Journal of Constructional Steel Research 168 (2020) 106002, https://doi.org/10.1016/j.jcsr.2020.106002

[19] Kolasani Rajasekhar and Maganti Janardhana(2019), "Effect of Infill Wall Stiffness on Seismic Analysis of High-Rise Building Resting on Sloping Ground", Recent Advances in StructuralEngineering, https://doi.org/10.1007/978-981-13-0362-3_2

[20] G. Ajay Kumar and A. Gouthami (2019), "Seismic Analysis of RC High Raise Building with Shear Walls at Diverse Locations", International Journal of innovative Technology and Research

[21] Apurva Arjun Gaikwad and Dr. Atul B. Pujari (2019), "Seismic analysis of low rise, Mid-rise and High-Rise RCC structure on sloping Ground", International Research Journal of Engineering and Technology, e-ISSN: 2395-0056, p-ISSN: 2395-0072

[22] Dr. K.B. Parikh and Jayant Shaligram (2019), "Study on Alleviation of Seismic hazard in Irregular Building Located on Plain and Sloping Ground", American International Journal of Research in Science, Technology, Engineering & Mathematics, ISSN (Print): 2328-3491, ISSN (Online): 2328-3580, ISSN (CD-ROM): 2328-3629

[23] Rayudu Jarapala and Kishore Chandra Biswal(2020), "Dynamic behavior of vertically irregular sloping ground buildings", Asian Journal of Civil Engineering, https://doi.org/10.1007/s42107-020-00303-6

[24] Mahdi Heshmati, Alireza Khatami and Hamzeh Shakib (2020), "Seismic performance assessment of tubular diagrid structures with varying angles in tall steel buildings", Structures 25 (2020) 113–126, https://doi.org/10.1016/j.istruc.2020.02.030

[25] Shaik Akhil Ahamad & K.V. Pratap (2020), "Dynamic analysis of G+20 multi storied building by using shear walls in various locations for different seismic zones by using Etabs", Materials Today: Proceedings xxx (xxxx) xxx, https://doi.org/10.1016/j.matpr.2020.08.014

[26] Rajiv Banerjee, J.B. Srivastava(2019), "Determination of Optimum Position of Shear Wall in an Irregular Building for Zone III & IV", International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-9 Issue-1

[27] Rajiv Banerjee, J. B. Srivastava (2020), "Defining Optimum Location of Shear Wall in an Irregular Building by Considering Torsion", International Journal of Engineering and Advanced Technology, ISSN: 2249 – 8958, Volume-9 Issue-4