



ORIGINAL ARTICLE

Dynamic analysis of a RC building on a hilly sloping ground

Syed Muhammad Sulaiman, Zia Faruque

M.Tech Student, Department of Civil Engineering, VCTM, Aligarh, AKTU Lucknow
Assistant Professor, Department of Civil Engineering, VCTM Aligarh, AKTU Lucknow

Article Information

Received: 23 April 2021
Revised: 17 June 2021
Accepted: 22 June 2021
Available online: 25 April 2021

Keywords:

Response Spectrum;
Sloping ground;
Seismic Analysis

Abstract

Earthquake analysis of a RC building resting on sloping ground has been carried out. Three different configurations of the building were considered – reinforced concrete (RC) building without dampers, RC building with base isolation and RC building with dampers. The building models were developed using finite element based specialized software - ETABS considering different sloping ground angles and analyzed by using Response Spectrum method. The seismic parameters in terms of displacement, fundamental time period, storey drift and base shear at foundations were computed and tabulated. A comparative study was carried out and it has been found that the RC building with dampers resting on a ground slope of 27° to the horizontal was identified to be most suitable for resisting earthquakes.

©2021 ijrei.com. All rights reserved

1. Introduction

Seismology word comprises of two parts seismo and logy. Seismo means related to seismic force or vibrations caused by earthquakes and logy means study. Therefore, seismology means the study of the vibrations of earth mainly caused by earthquakes. Earthquakes are one of the most dangerous natural hazards. The main reason of its occurrence is the sudden movement of tectonic plates and releases the large amount of the energy in a few seconds. Because of its sudden and unpredictability, it affects large vicinity and that is the most harmful impact of the earthquake. It can be very dangerous as it causes large scale loss of life and property. Indian history of earthquakes shows that the zones of higher seismic activity and the higher magnitudes are mostly presents in hilly terrains of the northern and the north-eastern regions. The tendency towards the sloping terrain may raise load on these places and to make capable to bearing this load, we need to accommodate more buildings but due to the topography of the hilly terrain we could

not effortlessly use every land there. So we have to see towards the multi-storey high-rise buildings to resolve this problem. But seismic forces act more severely in the hilly regions due to the structural irregularity. Due to shortage of plain ground, the construction activity on sloping ground has become necessary, resulting in various important buildings such as the reinforced concrete framed hospitals, colleges, hotels and the offices resting on hilly slopes. The behavior of buildings during earthquake depends upon the structural stability and distribution of the mass and stiffness in both x and y planes of the buildings. In hilly region both these axes vary with the irregularity and asymmetry. The height of the columns of the structure constructed at hilly slope is different and is also asymmetric in plan and elevation. The short columns are worst effected and damaged during the earthquake. Due to the asymmetrical condition of the buildings constructed in the hilly area, behavior of the building is very much different from buildings on plain ground. And in India most of the hilly area is lying in severe earthquake zone such as zone V or IV. Therefore, the buildings constructed in hilly areas

mostly subjected to severe earthquakes. To design an earthquake resistant building resting on the sloping ground is one of the biggest challenges for a Structural engineer. In view of the importance of fact that significant population resides in hilly regions which are prone to earthquakes, investigations have been carried out previously also and for the sake of brevity and completeness, are given here [1–13].

2. Methodology

In our study, the analysis of the structure is done by the software known as E-Tabs. This ETABS software is developed by the CSI Company, which work with earthquake engineering and structural engineering. ETABS is a designing programming software that analyses and design the multi-story building. Design of steel and the concrete edges, composite bars, the composite segments, steel joists, and the concrete and stonework shear dividers is incorporated. Models might be practically rendered, and all outcomes can be indicated legitimately on the structure. Exhaustive and adjustable reports are accessible for all analysis and design yield, and schematic development drawings of confining plans, calendars, subtleties, and cross-segments might be created for concrete and steel structures. The various methods are used for this type of analysis such as static and dynamic methods. Due to the asymmetrical conditions dynamic analysis must be used for the seismic analysis of the building. These methods named are time history method and response spectrum method. In the response spectrum method, data such as the zone factor, the type of soil etc. are applied from I.S.-1893:2016. But in time history method the actual record of the accelerogram is applied on the building and the analysis of building is carried out in the software. The time history method gives more realistic result as compared to the response spectrum method because in the time history method the actual acceleration data of the earthquakes are applied and the response of building is studied. In Response Spectrum Analysis method, forms of the damping which are reasonable models for many multi-storey buildings, the response in each natural mode of the vibration can be computed independently of others, and the modal responses can be computed independently of others, and then these modal responses can be combined to determine the total response. The time history analysis (THA) technique can be considered as the most sophisticated method of dynamic analysis for buildings. In this type of method, the mathematical model of the building is subjected to the accelerations from the earthquake records that represent the expected seismic force at the base of structure. This method consists of a systematic direct integration over the time interval; and the equation of motion is solved with the displacements, the velocities, and the accelerations of the previous step serving as initial functions. In our study, Response spectrum analysis method has been used because RSA provides clear vision to how damping affects our structure. Response spectrum method is not suitable for torsional irregularity and in our model we only need responses such as displacement, stiffness and base shears etc. So, for our study

Response Spectrum Analysis approach is best suitable at this time. The IS:1893 response spectrum function is based on Figure 2 in section 6.4.5 of the IS:1893 code. The digitization of these response spectra is based on section 6.4.5. The parameters required are a seismic zone factor Z, soil type and the damping ratio of the building structure. These values can be selected from relevant sections of the IS:1893 code.

2.1 Description of model

Plan dimensions: 23.48 m x 16 m
Ground Sloping Angle: 27°
No. of stories: G + 4
Floor height: 3 m
Column Size: 450 mm x 450 mm
Beam Size: 300 mm x 450 mm
Grade of concrete used: M25
Grade of steel used: Fe415

Model 1

Simple model with 27° sloping angle with horizontal.

Model 2

Same model but with rubber isolation (base isolation) system.

Model 3

Same model but with addition of dampers on exposed surface.

3. Results and discussion

In the present study, rubber isolation base system and viscous dampers are used to reduce the effect of earthquake or we can say seismic effect of the structures which are subjected to the earthquake load. The framed structure with base isolation system and viscous damper is modeled according to the properties given in previous section above. Because of the asymmetrical model the values in both the directions are different and are stated below. The seismic behavior of the RC structure is analyzed by observing the following parameters.

- Displacement
- Story Drift
- Story Shear
- Fundamental period

3.1 Displacement

Displacement is the most important parameter as it governs the failure pattern of the structure. The values of displacements for different models used in the present study are given in Table 1. With increase in storey level, the value of displacements increases. Also, it is clear from Table 1 that Model 3 has the least displacement values.

Table1: Displacement at different story levels for different models

Story	Elevation (m)	Displacement (mm)					
		Model 1		Model 2		Model 3	
		X-dir	Y-dir	X-dir	Y-dir	X-dir	Y-dir
5	15	0.207	0.385	0.079	0.148	0.006	0.205
4	12	0.056	0.161	0.021	0.062	0.007	0.048
3	9	0.016	0.042	0.006	0.015	0.003	0.014
2	6	0.004	0.01	0.001	0.003	0.002	0.004
1	3	0.001	0.002	0.00034	0.001	0.00045	0.001
0	0	0	0	0	0	0	0

Table2: Drifts at different story levels for different models.

Story	Elevation (m)	Story Drift ($\times 10^{-1}$ mm)					
		Model 1		Model 2		Model 3	
		X-dir	Y-dir	X-dir	Y-dir	X-dir	Y-dir
5	15	68	79	26	30	2	65
4	12	15	43	6	17	2	15
3	9	5	13	2	5	1	4
2	6	1	3	0.49	1	1	1
1	3	0.29	1	0.11	0.23	0.15	0.38
0	0	0	0	0	0	0	0

Table 3: Story shear at different story levels for different models.

Story	Elevation	Story Shear (kN)					
		Model 1		Model 2		Model 3	
		X-dir	Y-dir	X-dir	Y-dir	X-dir	Y-dir
5	15	71.92	68.28	27.22	25.62	1.26	45.57
4	12	14.59	16.76	5.49	6.37	0.42	12.93
3	9	1.3	5.54	0.45	1.84	0.25	2.16
2	6	0.45	1.79	0.16	0.6	0.13	0.87
1	3	0.056	0.16	0.02	0.05	0.05	0.21
0	0	0	0	0	0	0	0

3.2 Story Drift

As the number of story increases in the structure, drift is the common factor of the structure. The displacement or variance between the lateral displacements of the two adjacent floors of the framed structure is known as story drift. Indian Code IS-1893 Part-I (2016) specifies 0.5% allowable story drift ratio for brittle partitions, 0.75% for ductile partitions and 1.0% for structural systems with partitions fully isolated from the structure motion. The values of displacements for different models used in the present study are given in Table 2. With increase in storey level, the value of displacements increases. Also, it is clear from Table 2 that Model 3 has the least displacement values.

3.3 Story Shear

The story shear is that shear value which obtained from sum of the design lateral forces at levels above the story consideration of the structure. The values of horizontal shear for different models used in the present study are given in Table 3. With increase in storey level, the value of displacements increases. Also, it is clear from Table 3 that Model 3 has the least displacement values.

3.4 Mode shapes

The fundamental frequency and the corresponding mode shape were also calculated for different models and are plotted in Figs. 1 – 3. It is clear from Figs. 1–3 that Model 2 has the least natural period whereas the largest period was observed for Model 3.

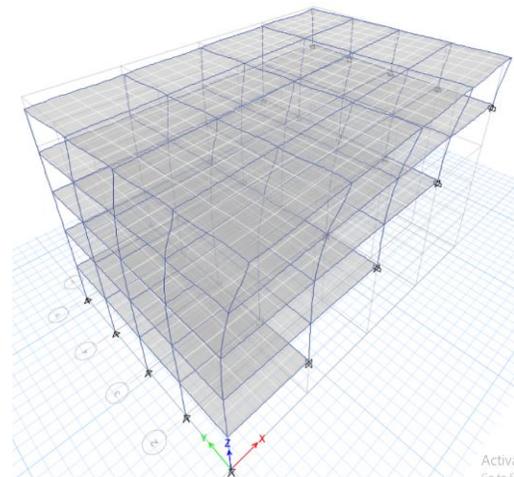


Figure 1: Mode shape 1 of Model 1 with natural period of 0.29

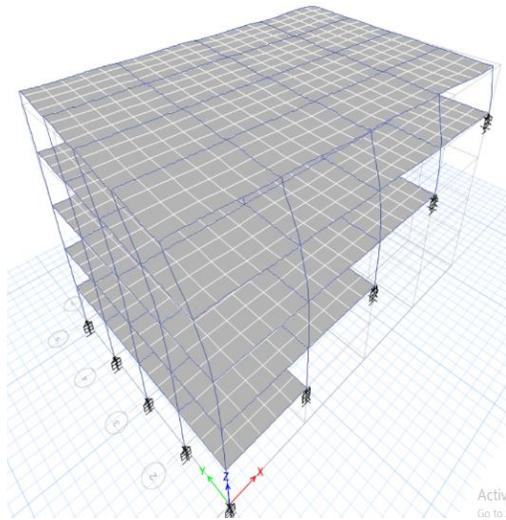


Figure 2: Mode shape 1 of Model 2 with natural period of 0.179

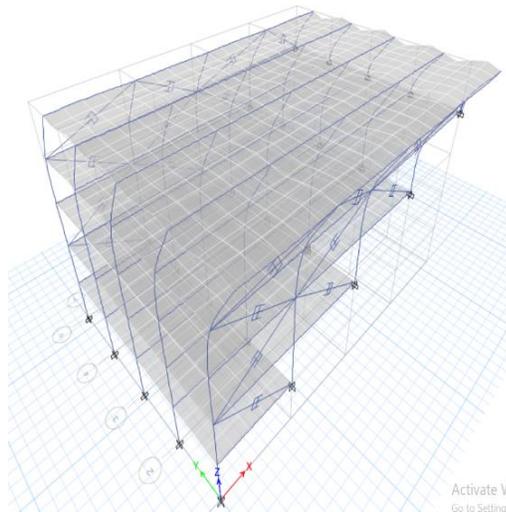


Figure 3: Mode shape 1 of Model 3 with natural period of 0.255

4. Conclusions

Response spectrum analysis has been carried out for RC buildings resting on sloping ground. A comparative study was

carried out considering different parameters like the ground slope, RC building, building with dampers and RC building with base isolation. It has been found that the RC building with dampers resting on a ground slope of 27° to the horizontal was identified to be most suitable for resisting earthquakes.

References

- [1] Vishwakarma R, Rai A. Analysis of a RCC frame Tall Structure using Staad Pro on Different Seismic Zones Considering Ground Slopes. International Research Journal of Engineering and Technology (IRJET). 2017 Mar;4(03).
- [2] Paul DK, Kumar S. Stability analysis of slope with building loads. Soil Dynamics and Earthquake Engineering. 1997 Aug 1;16(6):395-405.
- [3] Kumar S, Paul DK. A simplified method for elastic seismic analysis of hill buildings. Journal of earthquake engineering. 1998 Apr;2(02):241-66.
- [4] Birajdar BG, Nalawade SS. Seismic analysis of buildings resting on sloping ground. In 13th World conference on Earthquake engineering 2004 Aug 1 (No. 1472).
- [5] Singh Y, Gade P, Lang DH, Erduran E. Seismic behavior of buildings located on slopes—an analytical study and some observations from Sikkim earthquake of September 18, 2011. In Proceedings of the 15th World Conference on Earthquake Engineering 2012 Sep.
- [6] Sreerama AK, Ramancharla PK. Earthquake behavior of reinforced concrete framed buildings on hill slopes. In International Symposium on New Technologies for Urban Safety of Mega Cities in Asia (USMCA 2013) 2013 Oct.
- [7] Pawar SP, Pise DC, Pawar YP, Kadam SS, Mohite DD, Deshmukh CM, Shelar NK. Effect of positioning of RC shear walls of different shapes on seismic performance of building resting on sloping ground. International Journal of Civil Engineering and Technology. 2016;7(3).
- [8] Bhavikatti Q, Cholekar SB. Soil structure interaction effect for a building resting on sloping ground including infill subjected to seismic analysis. Qudisia Bhavikatti. 2017; 1:2395-0056.
- [9] Mohammad Z, Baqi A, Arif M. Seismic response of RC framed buildings resting on hill slopes. Procedia engineering. 2017 Jan 1; 173:1792-9.
- [10] Ghosh R, Debbarma R. Effect of slope angle variation on the structures resting on hilly region considering soil–structure interaction. International Journal of Advanced Structural Engineering. 2019 Mar;11(1):67-77.
- [11] Dangi SK, Akhtar S. Seismic analysis of a RC building on sloping ground with shear wall at different positions. In AIP Conference Proceedings 2019 Sep 25 (Vol. 2158, No. 1, p. 020030). AIP Publishing LLC.
- [12] Ahiwale D, Dewarde A, Narule G, Khartode R. Seismic Response Assessment of Steel Frame Step-back Building for Different Fluid Viscous Dampers. Journal of Seybold Report ISSN NO. 2020; 1533:9211.
- [13] Zaidi SA, Naqvi T, Ibrahim SM. Study on the effects of seismic soil-structure interaction of concrete buildings resting on hill slopes. Materials Today: Proceedings. 2021 Jan 1; 43:2250-4.

Cite this article as: Syed Muhammad Sulaiman, Zia Faruque, Dynamic analysis of a RC building on a hilly sloping ground, International journal of research in engineering and innovation (IJREI), vol 5, issue 5 (2021), 232-235.
<https://doi.org/10.36037/IJREI.2021.5502>