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Comparison of Seismic Analysis of Multistorey Building Resting on Sloped Ground with Different Slope Angles and Shear Wall Using ETABS

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Abstract - *As India is the second most populous country in the world, it is increasingly becoming difficult to find areas to live as there is congestion of space in large cities. This pushes us to construct buildings on hilly regions as well, which causes certain challenges for construction. This study examines the examination of various structure for different sloping degrees like 0,10,20,30 degrees. The analysis is performed for Mysore region which falls in Seismic Zone II according to Indian Standards using Response Spectrum Method of Analysis. The shear wall being excellent lateral load resisting member, we have used the same in the study to find the behaviour of the structures. The shear wall positions play a major role in how much of lateral load is resisted. We have used RCC shear wall for the study. Then comparison is made between various parameters like Story Drift, Displacements, Shear Force for different buildings to conclude about the considered structures in ETABS through Response Spectrum Method of Analysis. We analyse and compare the structure to finalize how slope as a factor, influences the behaviour of buildings. This study helps to understand the behaviour of structures in sloped ground using shear wall.*

Key Words: conventional slab, inclination, ETABS, Response spectrum analysis, drift ratio, displacement, shear wall, seismic zone.

1. INTRODUCTION

1.1 General

Due to the lack of level ground in large cities, development on sloping soil (landslides) is becoming more and more common. Due to the challenges experienced during the implementation of projects, both for the structure and the soil, this has posed a significant issue for structural engineers with regard to the design of structures. In India, there are no guidelines or restrictions on building on sloped ground. However, landslides are a common natural hazard that pose a threat akin to an earthquake all across the planet. People may be put in danger if a massive amount of earth moves quickly and causes significant damage to buildings. Additionally, there is a need to create multi-story structures due to the rapid population expansion in various Indian cities. Additionally, building on sloping soil (landslides) is becoming increasingly common, mostly because there aren't enough level building sites available. However, a number of research in this field have been conducted recently.

1.2 Sloped Ground

Building on steeper slopes can be difficult, and this kind of construction is tightly regulated by regional authorities, who differ just as much as regional soil types do. The "cut and fill" approach or the use of stilts are the two ways to construct a home on a sloped lot. The term "cut and fill" describes the act of levelling the ground for the foundation by either removing soil, adding more soil, or doing both. To "fill" the plot and level it out, soil can be hauled in. Alternatively, it can be dug ("cut") from the slope and either trucked away or used to provide retaining walls for the house. Cutting and filling can result in building costs that are many times higher than those for a residence on a level site, depending on the gradient, the soil, and other elements.

Instead of digging into the slope, which requires lifting the house onto wooden or steel columns, employing stilts is an option. In addition to being far more affordable than cut and fill, this approach can expand the range of possible home placement options, such as constructing out over trees or water. Homes built on slopes of up to 50% are not unheard of, but the price of the intricate foundation systems needed to support them is frequently higher than the price of a home built entirely on flat ground.

Fig-1: Typical Structure on Sloped Ground

1.3 Shear Wall

Shear walls play a crucial role in huge, high-rise, or structures located in seismically active or windy regions. In most cases, concrete or masonry are used to build shear walls. Steel braced frames, which can be very successful at resolving lateral forces but may be more expensive, can also resist shear forces. Shear walls can be put in place around the outside of buildings, or they can form a shear core, which is a group of shear walls that is usually located in the middle of a building and encloses a stairway or lift shaft. Because the shear wall functions as one element, lateral pressures often cause rotating forces that produce compression forces at one corner and tension forces at the opposite. This "couple" reverses when the lateral force is applied from the opposing direction, so both sides of the shear wall must be able to handle both sorts of forces.

The shear wall's shape and plan position have a significant impact on how the structure behaves. The centre of each side of the building is the ideal location for the shear walls from a structural standpoint. But because it limits how the space may be used, this is rarely a viable arrangement, thus they are placed at the ends.

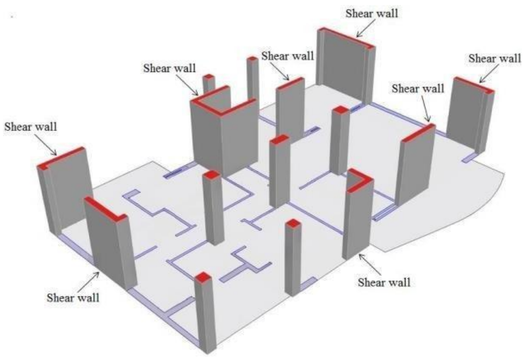

Fig -2: Typical Shear Wall

1.4 About Seismic Zones of India As Per IS Code

Based on historical earthquake activity, India is classified into 4 zones. With zone II having the lowest risk of seismic activity or earthquakes and zone V having the highest likelihood, zone factors are determined based on the zones. The design seismic forces are calculated using zone factors. The zones aid in implementing the IS code books to build the structure in the most useful and economical manner.

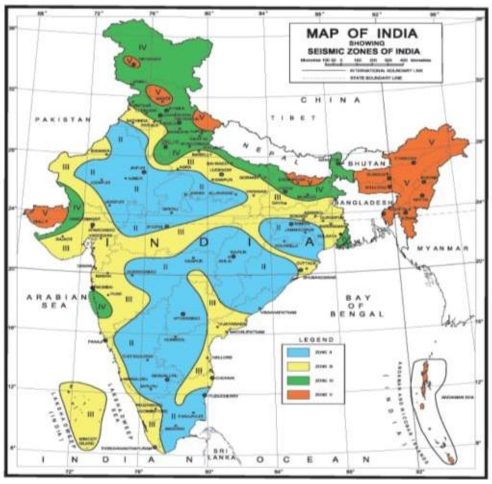

Fig -3: Seismic Zones According to IS Codes

1.5 Response Spectrum Method of Analysis

A scientific method for determining the structural reaction to dynamic vibration events is called response spectrum analysis. It is first necessary to determine the system's response spectrum in order to carry out the response spectrum analysis. For linear single degree of freedom system oscillators, the response spectrum plot shows the maximum response to the natural frequency (or natural period) applied to the specified excitation, which may be the maximum displacement, maximum velocity, maximum acceleration, or any other parameter of interest. A response spectrum is a function of frequency or period, showing the peak response of a simple harmonic oscillator that is subjected to a transient event. The response spectrum is a function of the natural frequency of the oscillator and of its damping. Thus, it is not a direct representation of the frequency content of the excitation (as in a Fourier transform), but rather of the effect that the signal has on a postulated system with a single degree of freedom (SDOF).

2. AIM OF THE STUDY

1. The study aims to find the behaviour of different structures among the considered buildings with different slopes such as 0^{o}, 10^{o}, 20^{o}, 30^{o}.
2. Loads like dead loads, live loads, wind loads, earthquake loads are applied on to the sloped structures in ETABS software tool.
3. Then various load combinations are added. A zero sloped structural frame with shear wall is modelled and then analysed, then other models with various sloped degrees are analysed and their results are compared to finally conclude the best building.

4. This involves comparison of various parameters such as Story Drift, Displacements, Story shear, etc.
5. We analyse and compare the structure to finalize how slope as a factor, influences the behaviour of buildings.

3. METHODOLOGY

1. A model with no slope is first modelled in ETABS software and checked for its behaviour using Response Spectrum Method of Analysis.
2. Loads such as dead loads, live loads, seismic loads are considered for the analysis of sloped and non-sloped RCC structure using the ETABS software.
3. Next few more RCC Structures with various sloping degrees (0^o, 10 ^{o}, 20 ^{o}, 30 ^{o}) are modelled to check their behaviour in Response Spectrum Method of Analysis.
4. Then check how the different structural systems behaves better, based on the output results from the ETABS software tool.
5. Then comparison is made between various parameters like Story Drift, Displacements, Deflections, for different buildings to finalize the better one out of all the considered structures both in ETABS through Response Spectrum Method of Analysis.
6. On the basis of obtained results, conclusion can be made about how one model with certain sloping compares with other sloped buildings.

Table -1: Project Details

Sl. No.	Particulars	Dimension/Size/ Value
1	Design Code	IS Codes
2	No. of floor/levels	G+5+Terrace
3	Site Location	Mysore
4	Seismic Zone	II
5	Type Of Building	RCC
6	Total height ofbuilding	27.473m
7	Floor to floorheight	3.2m
8	Base to groundheight	5.273m
9	Ground to 1st floorheight	3.2m
10	Plan dimensions	27.34m X 21.25m
11	Grade of concrete	M25
12	Grade of steel	Fe500
13	Size of column	300x450mm & 300x600mm
14	Shear wallthickness	225mm
15	Beam size	225x300mm & 300x600mm
16	Slab thickness	150mm
17	Concrete Density	25kN/m3
18	Solid Brick Density	20kN/m3
19	Mortar Density	20.4kN/m3
20	Earthquake Load	As per IS:1893-2016
21	Soil type	II, Medium (as per IS:1893-2016)
22	Damping ratio	5%
23	Response reductionfactor	5
24	Zone factor	0.10
25	Importance factor	1.5
26	Live load on slab	3.0 kN/m^2
27	Roof live load	2.0 kN/m^2
28	Floor finish on slab	1.5 kN/m^2

Table -2: Details Of Structural Elements

BUILDING TYPE	CONFIGURATION
RCC structure with 0 degree slope	Case-1
RCC structure with 10 degree slope	Case-2
RCC structure with 20 degree slope	Case-3
RCC structure with 30 degree slope	Case-4

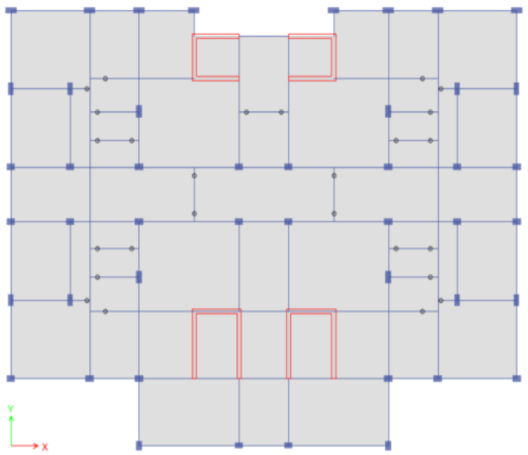

Fig -4: Architectural Plan of the Structure for all different sloped grounds

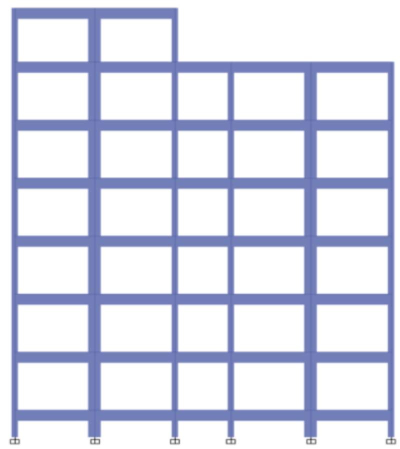

Fig -5: Structure with 0 degree slope

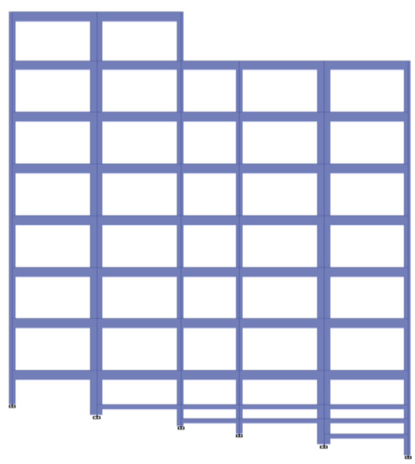

Fig -6: Structure with 10 degree slope

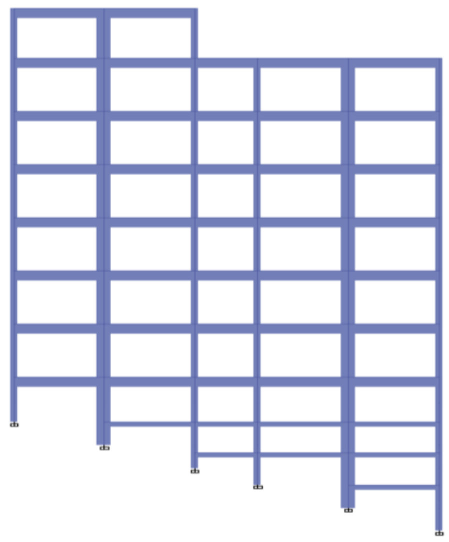

Fig -7: Structure with 20 degree slope

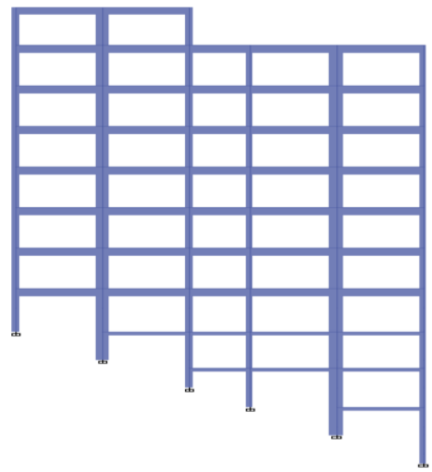

Fig -8: Structure with 30 degree slope

4. RESULTS COMPARISON OF ALL CASES

4.1 Storey Displacement

The maximum values of storey displacement in both X & Y directions for all 4 cases is shown below. Whencompared with the rest of the cases it is found that the Case- 1 has the minimum displacement values. 3.017745mm & 4.431059mm in X & Y – Directions are the values of Case-1.

4.4 DISCUSSIONS OF RESULTS

1. The maximum storey displacement in x and y direction in Case 1 is 3.017745mm and 4.431059mm respectively, whereas the minimum storey displacement in x and y direction is 0.068394mm and 0.078624mm respectively.

2. The maximum storey displacement in x and y direction in Case 2 is 3.758256mm and 4.782361mm respectively, whereas the minimum storey displacement in x and y direction is 0.459103mm and 0.324313mm respectively.

3. The maximum storey displacement in x and y direction in Case 3 is 4.123775mm and 4.964847mm respectively,

whereas the minimum storey displacement in x and y direction is 0.982931mm and 0.606763mm respectively.

4. The maximum storey displacement in x and y direction in Case 4 is 5.518464mm and 5.77299mm respectively, whereas the minimum storey displacement in x and y direction is 1.38021mm and 0.924429mm respectively.

5. The maximum storey drift in x and y direction in Case 1is 0.000106 and 0.000189 respectively, whereas the minimum storey drift in x and y direction is 4.49E-05 and 5.16E-05 respectively.

6. The maximum storey drift in x and y direction in Case 2is 0.000110 and 0.000195 respectively, whereas the minimum storey drift in x and y direction is 0.000127 and 0.000177 respectively.

7. The maximum storey drift in x and y direction in Case 3is 0.000121 and 0.000196 respectively, whereas the minimum storey drift in x and y direction is 0.000176 and 0.000298 respectively.

8. The maximum storey drift in x and y direction in Case 4is 0.000146 and 0.000204 respectively, whereas the minimum storey drift in x and y direction is 0.000376 and 0.000468 respectively.

9. The maximum storey shear in x and y direction in Case 1 is 832.3254kN and 902.3701kN in storey 1 respectively, whereas the minimum storey shear in x and y direction is 87.15073kN and 117.3832kN in storey 8 respectively.

10. The maximum storey shear in x and y direction in Case 2 is 980.5388kN and 929.8983kN in storey 1 respectively, whereas the minimum storey shear in x and y direction is 96.17316kN and 113.9995kN in storey 8 respectively.

11. The maximum storey shear in x and y direction in Case 3 is 1069.927kN and 917.5kN in storey 1 respectively, whereas the minimum storey shear in x and y direction is 103.8764kN and 107.7766kN in storey 8 respectively.

12. The maximum storey shear in x and y direction in Case 4 is 978.2714kN and 891.6722kN in storey 1 respectively, whereas the minimum storey shear in x and y direction is 99.56052kN and 101.1958kN in storey 8 respectively.

5. CONCLUSION

In the entire study we compared how the structure behaves for different sloping ground types. We had considered 0, 10, 20, 30 degree slopes and analysed the structure using ETABS software by Response Spectrum Method of Analysis for zone II. The comparisons made using the graphs and tables gave a clear insight of how those structures behave with slope and the following conclusions can be said from observation of the results obtained in the study.

1. The maximum values of Storey Displacement are found lesser in case-1 when compared with maximum values i.e., case-4.

2. The maximum values of Storey Drift are found lesser in case-1 when compared with maximum values i.e., case-4.

3. The maximum values of Storey shear are found lesser in case-1 when compared with maximum values i.e., case-4.

4. The maximum values of Storey Displacement of case-1 are found 82.89% and 34.18% lesser in X & Y- directions when compared with case-4.

5. The maximum values of Storey Drift of case-1 are found 157.53% and 129.41% lesser in X & Y- directions when compared with case-4.

6. The top most height of the structure values of Storey Drift of case-1 are found 61.32% and 24.33% lesser in X& Y- directions when compared with case-4.

7. The maximum values of Storey shear of case-1 are found 17.53% and 1.25% lesser in X & Y- directions when compared with case-4.

8. From the above compared storey displacement, drift and shears terms, we can say that case-4 has found higher values when compared with other cases i.e., 30^{o} inclined base structure.

9. The values of storey displacement, drift and shears areincreases when increased with angle of ground.

10. The values of X- directions has found higher values compared with Y- directions values.

6. FUTURE WORK CONDUCTED

Based on the work carried out in this project we had given the above conclusions. The given following are the scopes for the work ahead that can be carried out to study other characteristics related to sloped structures.

1. The structure can be studied for other seismic zones ofIndia using same or different slopes.

2. The structure on sloped ground can be studied for theeffects of wind loads.

3. The comparison of Highrise structures can be studied.

4. The study with bracings, viscous dampers, tuned massdampers can be further studied.

5. The effects of blast load on sloped structures can befurther studied for different zones.

6. The structure can compared with different Standard Codes from different countries to check the behaviour.

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