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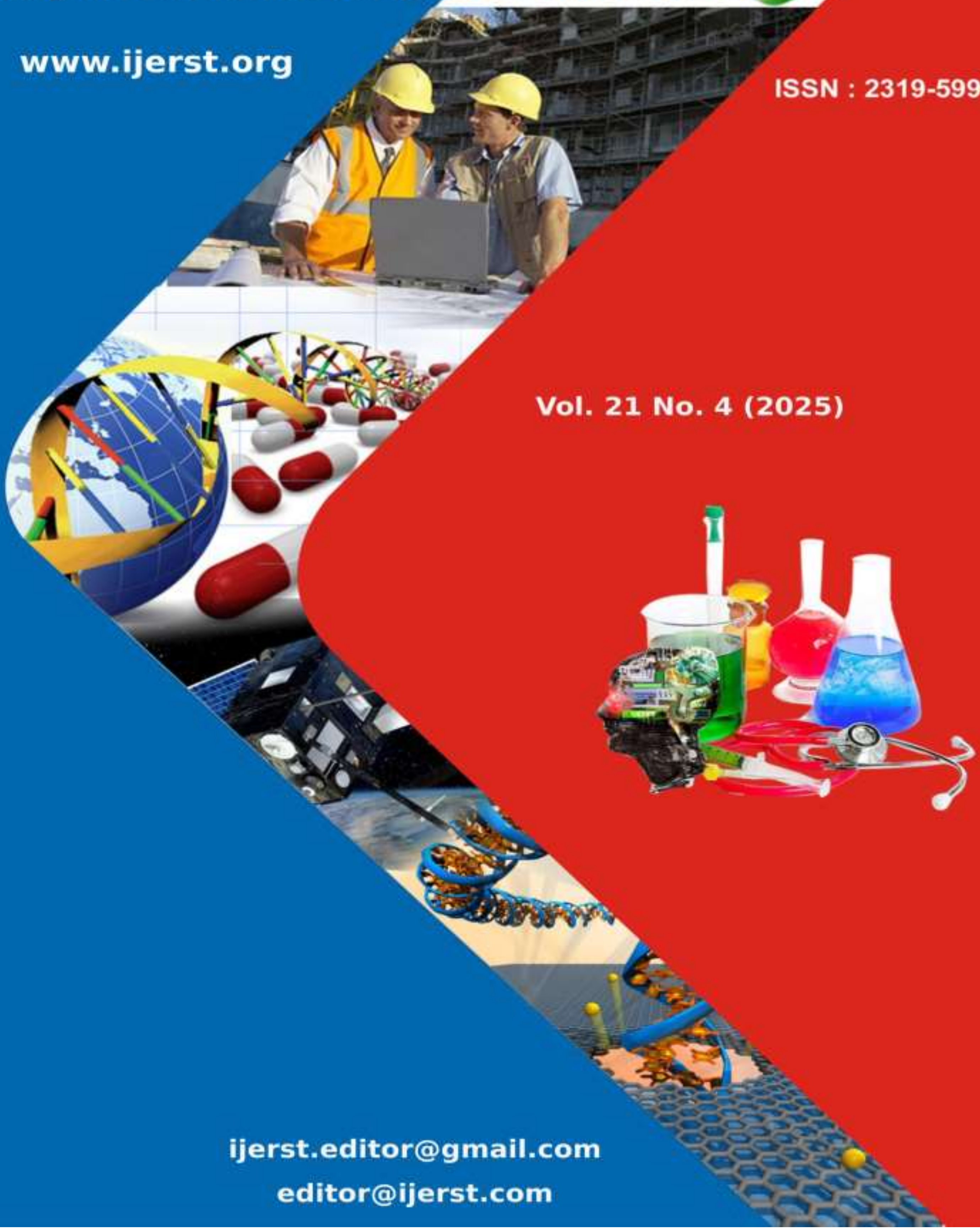

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Research Paper

INFLUENCE OF GROUND SLOPE ON THE SEISMIC RESPONSE OF REGULAR AND IRREGULAR BUILDINGS

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ABSTRACT

In a growing nation such as India, land scarcity resulting from urbanisation and industrialisation has facilitated the development of high-rise multi-storey structures in hilly areas. Structures erected on inclines vary from those built on level terrain due to their uneven and asymmetrical configurations in both vertical and horizontal planes. Furthermore, structures situated on elevated terrain are far more susceptible to seismic shocks. The primary aim of this research is to examine the performance of structures on inclined and level terrain. Structures situated on elevated terrain must be designed differently from those on level land. Hill structures vary from those on plains; they exhibit significant irregularity and asymmetry in both horizontal and vertical planes, and are torsionally linked, rendering them vulnerable to severe damage during seismic events.

This research examines the behaviour of regular and irregular multi-story buildings with two distinct slope angles, comparing them to level ground conditions. by examining seismic zone V. A comparison is conducted between flat ground construction and sloping ground construction. The models are developed via ETABS structural analysis software. The analysis is conducted with response spectrum analysis. The analytical findings, including displacement, moments, storey shear, and storey drifts, are tallied and examined.

KEY WORDS: irregularity, sloping ground, sloping angles, ETABS software, Response spectrum analysis.

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I. INTRODUCTION

The seismic history of India indicates that areas of elevated seismic activity and magnitudes mostly occur in the steep terrains of the northern and northeastern regions. Moreover, these locations are more likely to draw individuals from the plains for many objectives, including adventure, tourism, religious activities, and addressing habitat issues resulting from the decline of usable land in metropolitan centres. All these objectives may contribute to addressing the issue of migration from mountainous areas owing to insufficient resources that may support their fundamental requirements.

The inclination of the terrain may increase the burden on these areas, necessitating the construction of more structures. However, the geography of hilly landscapes restricts our ability to use space uniformly. We must transition to multistoried high-rise buildings to address this issue. The structural stability of the edifice will be the subsequent challenge in addressing numerous limits, whether arising from specific topographical characteristics or the seismic vicinity of the region, which will vary from location to location.

These issues may be resolved by implementing appropriate architectural configurations tailored to requirements, while considering the project's economic constraints and construction procedures, which will ultimately determine the stability and closeness of the structure.

Figure 1: Buildings on sloping ground

1.2 IRREGLAR BUILDINGS

In order to design a structure to resist wind and earthquake loads, the forces on the structure must be specified. The exact forces that will occur during the life of the structure cannot be anticipated. Most National Building Codes identify some factors according to the boundary conditions of each building considered in the analysis to provide for life safety. A realistic estimate for these factors is important; however the cost of construction and therefore the economic viability of the project are essential. Owing to lack of earthquake and wind forecasting centers the Egyptian Codes 1993 and 2003 give more concentration on calculating these lateral loads and the corresponding additional stresses to be taken into account in the design of the structures.

During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. For example structures with soft storey were the most notable structures which collapsed. So, the effect of vertically irregularities in the seismic performance of structures becomes really important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the "regular' building. IS 1893 definition of Vertically Irregular structures:

The irregularity in the building structures may be due to irregular distributions in their mass, strength and stiffness along the height of building. When such buildings are constructed in high seismic zones, the analysis and design becomes more complicated.

Figure 2: Irregularity in Building

Objectives of the study

The following are the main objectives of the project

1. To study the seismic behavior of multi story regular and irregular buildings by using IS 1893:2002
2. To compare the multi story slope buildings with flat ground.
3. To study the seismic behavior of multi story buildings in Zone V as per IS 1893:2002.
4. To compare the results of Story Drift, Shear force, Bending moment, Building torsion of regular and irregular buildings with 5 degree and 10 degree slope ground structures with flat ground models.
5. To study the buildings in ETABS Software

II LITERATURE REVIEWS

Ravikumar et al. (2012) Researchers examined two categories of irregularities in a building model: plan irregularity, characterised by geometric and diaphragm discontinuities, and vertical irregularity, defined by setbacks and sloping terrain. A pushover analysis was conducted to ascertain the seismic demands under several lateral load scenarios in all three axes. All constructions under examination are three-story edifices exhibiting various plan and elevation irregularities.

Sreerama and Ramancharla (2013) Recent earthquakes, such as the Bihar-Nepal earthquake (1980), the Shillong Plateau tremor, and the Kangra earthquake, resulted in the deaths of over 375,000 individuals and the destruction of more than 100,000 residences, according to the research. Structures on flat floors possess distinct dynamic characteristics compared to those on sloping floors, owing to their differing horizontal and vertical geometrical shapes. The centre of mass and the centre of rigidity no longer coincide owing to this irregularity, resulting in a torsional response.

Patel et al. (2014) The influence of alternates in the upper column due to sloping topography and the effect of concrete shear walls at specific spots during an earthquake was examined using the analysis tool ETabs with both symmetric and asymmetric models. This study conducted lateral load assessment in accordance with seismic codes to analyse the effects of seismic loads and evaluate seismic vulnerability using pushover analysis. The use of flexible hinges on columns at each base level and on beams at every floor level has been shown to enhance the vulnerability of structures on inclined terrain.

III METHODOLOGY

Response Spectrum Method

Response spectrum analysis is sometimes referred to as the linear dynamic statistical analysis approach. This study is often conducted using the IS code for seismic evaluation. The standard used for this investigation is IS 1893:2002 (Part 1). The seismic zone factor and soil type values are derived from the tables in IS 1893:2002 (Part 1) code. The damping ratio is often assumed to be 5% for this study. The response spectrum graph for medium soil conditions is shown in the graph below. The graph illustrates the relationship between the time period and the spectral acceleration coefficient (Sa/g).

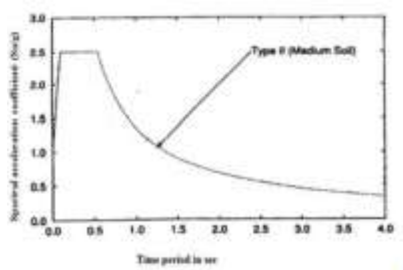


Figure 3: Response spectrum for medium soil type for 5% damping

We must ascertain the magnitude of powers completed for X, Y, and Z, and thereafter evaluate the implications for the structure. Mixed approaches include the following elements:

1. Absolute - peak valuations are included
2. Square basis of the sum of squares (SRSS)
3. Complete Quadratic Blend (CQC) - a methodology that modifies the Square Root of the Sum of the Squares (SRSS) for distinctly separated modes.

The results from the response spectrum analysis differ significantly from those obtained through linear dynamic analysis when applied to irregular or high-rise structures. In such cases, the response analysis is not accurate compared to other methods, necessitating the use of nonlinear static or dynamic analysis. This research examined a medium-rise building with a regular construction under seismic loading conditions for response analysis.

IV STRUCTURE MODELING

The following are the basic data considered for analysis

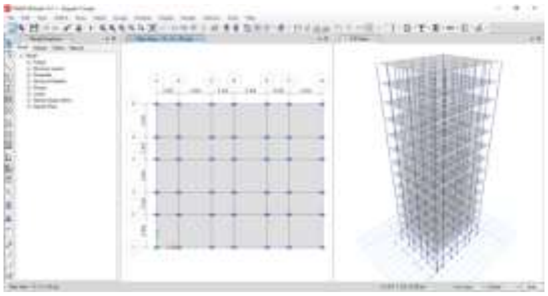
1. Height of typical Storey = 3 m
2. Height of ground Storey = 3 m
3. Length of the building = 15 m
4. Width of the building = 13 m
5. Height of the building = 39 m
6. Number of stores = 13 (G+12)
7. Wall thickness = 230 mm
8. Slab Thickness = 150 mm
9. Grade of concrete = M30
10. Grade of the steel = Fe500
11. Support = Fixed
12. Column size = 460mmX230mm
13. Beam size = 350mmX230mm
14. Location of Building = India
15. Live load = 3 KN/m^2
16. Dead load = 2 KN/m^2
17. Density of concrete = 25 KN/m^3
18. Seismic Zones = Zone 5
19. Site type = II
20. Importance factor = 1.5
21. Response reduction factor = 5
22. Damping Ratio = 5%
23. Structure class = C
24. Basic wind speed = 44m/s
25. Risk coefficient (K1) = 1.08
26. Terrain size coefficient (K2) =1.14
27. Topography factor (K3) = 1.36
28. Wind design code = IS 875: 2015 (Part 3)

International Journal of Engineering Research and Science & Technology

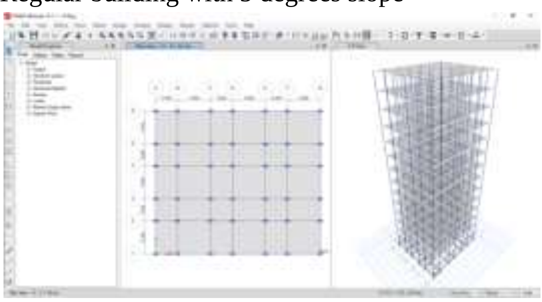
29. RCC design code = IS 456:2000
30. Steel design code = IS 800: 2007
31. Earth quake design code
    = IS 1893: 2016 (Part 1).

Models in ETABS Software

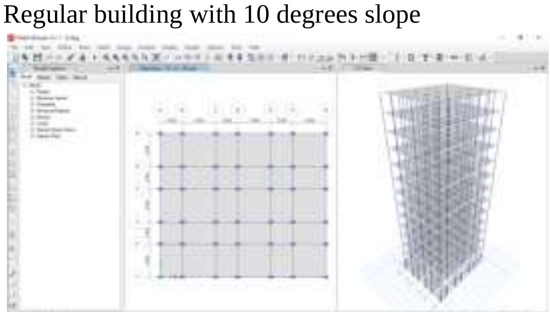
Regular building with 0 degrees slope



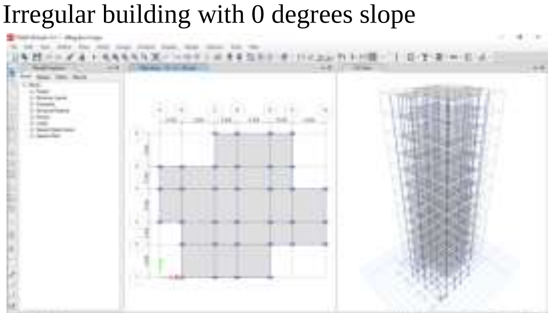
Regular building with 5 degrees slope



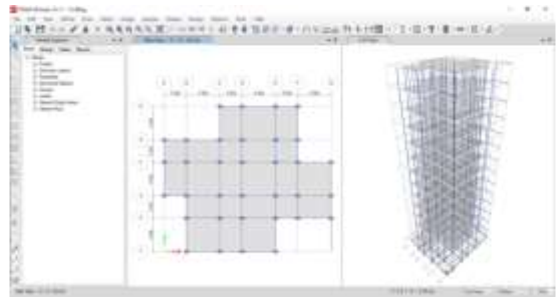
Regular building with 10 degrees slope



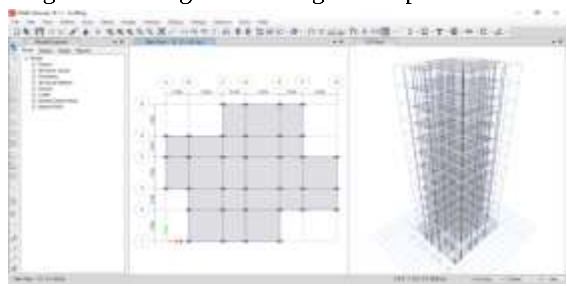
Irregular building with 0 degrees slope



Irregular building with 5 degrees slope



Irregular building with 10 degrees slope

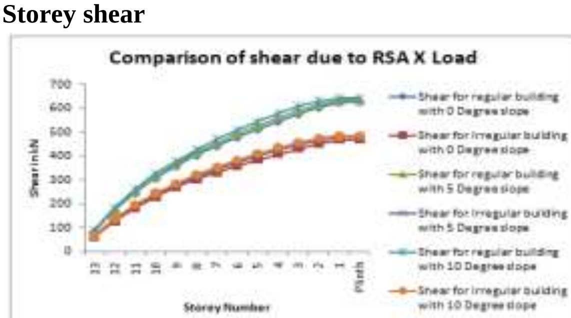


V RESULTS AND ANALYSIS

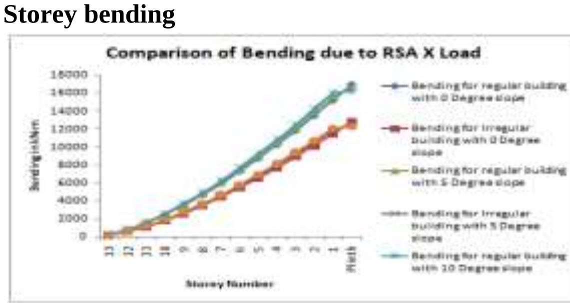
RSA X Results

Storey drift

Storey shear



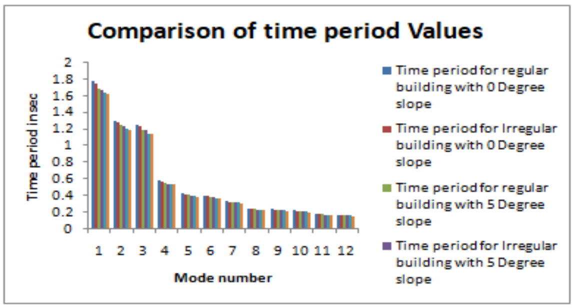
Storey bending



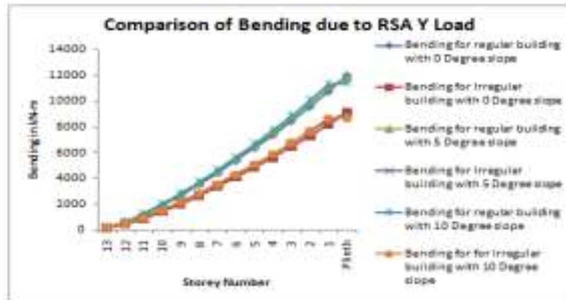
Storey torsion

Storey shear

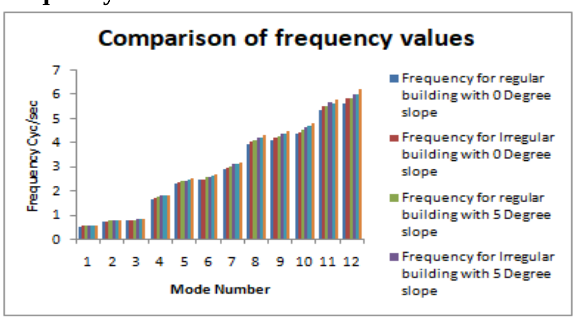
Time period



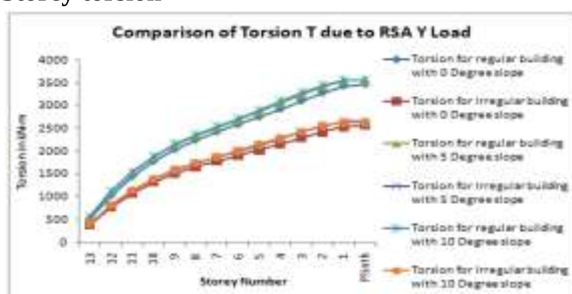
Storey bending



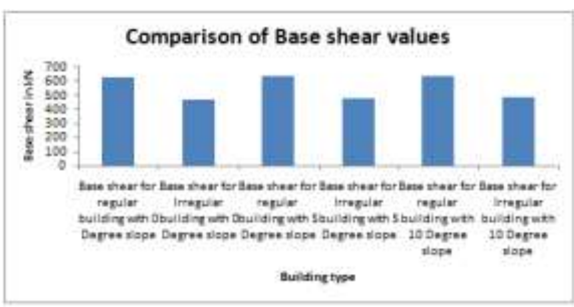
Frequency



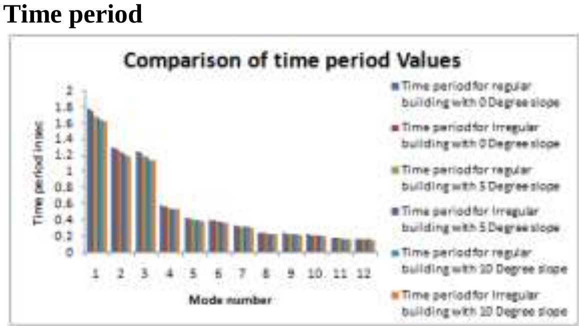
Storey torsion



Base shear

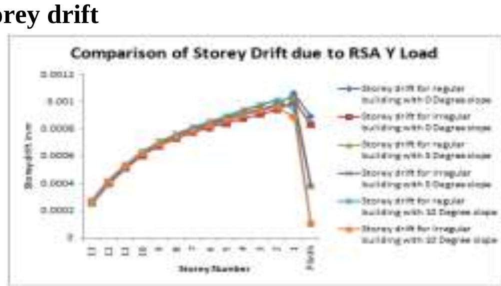


Time period

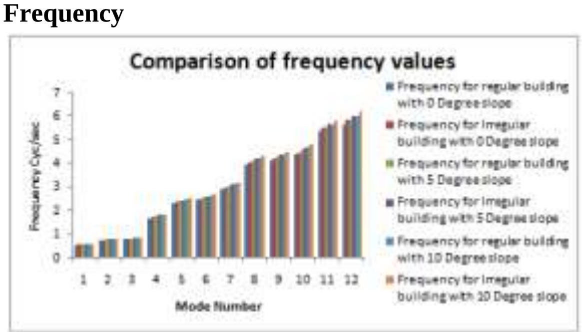


RSA Y Results

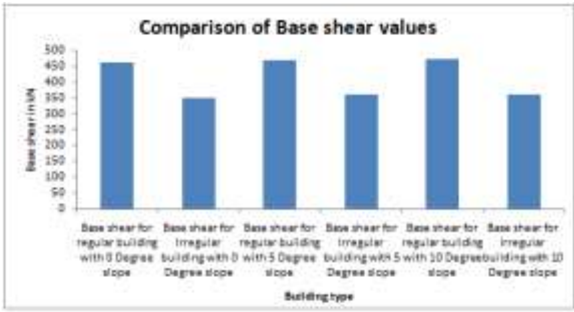
Storey drift



Frequency



Base shear



VI CONCLUSIONS

The following findings were drawn from the aforementioned research.

1. The deflection values are notably elevated for a 10-degree slope in the irregular structure, whereas the storey drift values for the other five models exhibit almost uniform intensities in the RSA X load situation. However, for the irregular building models, the drift value is lower for all models according to the criteria for the RSA Y load situation.
2. The shear, bending, and torsion values are lower for irregular structures compared to conventional building models in zone V.
3. The intensities are escalating as the slope increases from 0 degrees to 10 degrees. Lower values are recorded at a 0-degree slope, whereas higher values are seen at a 10-degree slope.
4. The duration is reduced by adjusting the ground slope and by addressing building imperfections. The duration is extended due to the ground slope and the presence of construction flaws.
5. The irregularities in the building structure result in a reduction in base shear values due to the reduced intensity of lateral loads in irregular models. Providing a slope to the ground has little impact on the structure.
6. On level terrain, a setback building experiences less lateral stresses compared to alternative structures on sloped land, resulting in greater stability and decreased susceptibility to damage from lateral loads.
7. On sloped terrain, step-back buildings have reduced action pressures compared to traditional buildings; yet, if the costs associated with grading the slope are within acceptable bounds, a step-back design may be favoured.
8. Observing the graphs, we can deduce that the seismic impact on buildings situated on inclined terrain is less pronounced than that on structures located on level ground.

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