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Dynamic Analysis of Unsymmetrical Buildings on Sloping Ground with Hexa Grid Structure

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Abstract: Earthquakes are very dangerous to buildings, especially ones whose structure is irregular or the buildings are constructed on slanting land. Edifice structures on sloping grounds suffer unequal distribution of stiffness and complicated load transmission, whereas irregular plans like L-shaped and T-shaped constructions are likely to be affected by torsion and consequently seismically vulnerable. The work is an investigation of the composite effect of the plan irregularity and ground slope on seismic performance considering 54 structural models created in ETABS V22, which includes Rectangular, L-shaped, and T-shaped plans on slopes between 5o and 20o. Consistent modeling was done using a six-spoke grid or the 60 degrees internal angle, and Response Spectrum Analysis according to the seismic design requirements tested such parameters as base shear, roof displacement, fundamental time period and lateral stiffness. The results indicate that the plan irregularity and slope inclination have a significant effect on the behavior of the structure- Rectangular models were found to be the best on the mild slopes, L-shape and T-shape models had higher displacements, lower stiffness, and natural periods on steep slopes. These findings strongly indicate that the consideration of geometrical and topographical factors in the design of seismic buildings is needed to improve the resistance of buildings in earthquake-prone areas.

Keywords: Tall buildings, hexagonal grid system, dynamic analysis

I. INTRODUCTION

Earthquakes are the most unpredictable and harmful nature phenomena that can result in massive life and property losses in a few seconds. The abrupt release of energy in the process of an earthquake produces ground movements which question the stability and safety of the buildings. It is a complicated process to design a building to withstand the forces and be able to comprehend the dynamics of the structure and what makes it seismic. With the increased urbanization into irregular and hilly areas of locations, the stability of buildings during seismic events has gained importance.

Several interdependent factors affect the seismic response of the building such as stiffness, lateral strength, ductility, mass distribution, and geometry in general. All these parameters lead to the effectiveness of a structure to absorb and dissipate seismic energy. Minor changes in these features can result in a major dissimilarity in the structural conduct in an earthquake. Therefore, it is essential to know how these parameters affect the overall performance of buildings to create earthquake-resistant designs.

Research and history of earthquakes have revealed that normal buildings tend to behave well under the seismic loads than irregular ones. Regular forms are uniform in geometry and have uniformly distributed mass, stiffness and strength, they are more predictable and receive less torsion or localized failure. By contrast, irregular buildings (that have L or T-shaped plans, discontinuous load paths, or weak storeys) tend to be more damaged by the distributions of stresses and more difficult vibration patterns. These anomalies result in the concentration of forces in a few areas and the risk of partial or complete collapse is eminent.

Fig .1 Building on sloping Ground

Besides the irregularities in the plan, sloping of ground also makes the seismic design more difficult. Structures erected on slopes have unequal distribution of loads and different stiffness of foundation and consequently prone to greater vulnerability in dynamic loading. The interaction of the slope inclination and plan irregularity presents engineers with some special problems since the two factors affect the torsional behavior of the building, displacement tendency, and the overall structure stability. Thus, the interaction between slope and geometry during seismic events cannot be studied comprehensively to come up with effective design strategies.

Fig .2 Building on sloping Ground

The research concentrates on the ability to assess the seismic performance of high-rise hexagrid buildings with different plan structures: Rectangular, L-shaped, and T-shaped ones based on various ground slopes 5 o to 20 o. A total of 54 models were created using ETABS V22 in order to study the effect of geometric irregularity and the slope inclination by Response Spectrum Analysis. The objective of the research is to establish the most consistent and effective structure based on base shear, roof movement, time, and lateral stiffening which will eventually render significant outputs in the safe and cost-effective construction of structures in earthquake-prone and sloping areas.

II. LITERATURE SURVEY

Many studies have focused on how high-rise buildings behave under lateral loads like wind and earthquakes to ensure stability and safety.

Rewapati (2020) highlighted that diagrid systems, made of diagonal and horizontal elements, enhance both strength and aesthetics of tall buildings. They remove the need for corner columns, improve flexibility, and perform better against wind and seismic forces, making them ideal for irregular or sloping sites.

Bhardwaj (2019) explained that hexagrid systems, developed from diagrids, provide even better stiffness, reduced deflection, and lower material use. Both diagrid and hexagrid structures are efficient, cost-effective, and offer more design freedom for modern tall buildings.

Ahammed et al. (2019) studied the seismic behavior of various building shapes like L, C, and T using ETABS. They found that C-shaped buildings had the least displacement, while T-shaped ones showed the most. Taller and irregular buildings were more vulnerable, stressing the need for advanced lateral load-resisting systems such as diagrids and hexagrids.

In this paper A comparison in the dynamic behavior of tall buildings in a diagrid and hexagrid structural system with seismic loading. The research points out the superiority of hexagrid systems in the context of lateral stiffness and energy dissipation that increase seismic resistance. The study also highlights the effectiveness of hexagrids in minimizing the displacement of buildings and the weight of the buildings. [5]

In this paper, the analytical modeling of the seismic behavior of hexa-grid structural systems is studied. The authors discovered that hexagrid structures are more efficient with earthquake loads owing to equal distribution of loads and geometry stability. They indicate that in the context of hexagrid systems, it is possible to increase the overall structural strength and ductility significantly.[6]

A study by Ahirwar, Deepak Kumar, K. Divya, and Lokesh Singh (2020) demonstrated that a rapid increase in cancer cases is possible due to socio-demographic factors (such as a greater number of children born into disadvantaged families. It proved that the development of cancer can be rapidly increased under the influence of socio-demographic factors (more children are born in disadvantaged families).[7]

This is a review paper that is concerned with outrigger and hexagrid design and analysis of high-rise buildings. It is a summary of different researchers who have found that hexagrid structures enhance load resistance on lateral direction and flexibility in the architecture. The authors conclude that such systems are very appropriate in the contemporary tall structures that are exposed to the wind and seismic forces. [8]

III. PROPOSED METHOD

The research problem addressed in the proposed methodology involves the knowledge of the behaviour of the buildings with various plan shapes that are built on sloping ground that is supported by a hexagonal grid structural system during earthquakes. The research is systematic and entails the creation of the model, analysis and comparison of results through use of ETABS software.

To start with, there are a number of structural models that are meant to reflect various building designs. The models are regular rectangular, L-shaped, and T-shaped buildings having three height variants, G+20, G+30 and G+40 storeys. These models are further placed on 5, 10, 15 and 20 degrees slope to study the effect of topography. There are 54 building models that are formed to encompass every aspect of height, shape and slope combinations.

All the structures involve hexagrid system, and these systems are hexagonal steel grids bonded with 60 degree angles. The hexagrid is more efficient in load distribution and advances the lateral rigidity of the structure. The structural material is uniform: The primary structural elements of the building are made of M40 grade concrete and Fe550 grade steel, and the grid members are made of Fe345. The frame type adopted is a Special Moment Resisting Frame (SMRF) to offer maximum ductility in seismic loads.

After the models are ready, a dynamic analysis method of Response Spectrum Analysis (RSA) which is one of the recommended seismic code is conducted. The method is used to test the reaction of the structure to the vibrations caused during the earthquake through tests of the parameters of the base shear, roof movement, time period, and lateral stiffness. These parameters are essential in the realization of the performance of a building in times of seismic activity.

To study the impact of geometric irregularity and slope slope, the analysis involves a comparison of regular and irregular models as well. To further confirm it, both Response Spectrum Analysis and Equivalent Static Analysis are applied, which also guarantees the reliability of the results and their compliance with traditional design codes.

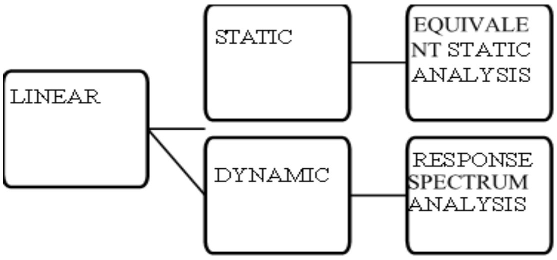
All analyses are put together and compared to determine trends and performance variations. The specific focus is put on slope angle influence on the roof displacement and base shear as well as the impact of building shape on the general stability and stiffness. Lastly, the findings are used to provide the most stable system of the hexagrid-supported buildings on sloping terrain with both safety and material efficiency.

IV. RESULTS

ETABS analysis showed that building height and plan irregularity affect the roof displacement with T shaped models indicating that the displacement may go up to 19-22% higher than the regular buildings. Moderate slopes (5^0 -15^0) increased load distributions and decreased displacements, but steep slopes (20^0) increased displacements. The base shear values were reduced by 30-55% in irregular models, which showed that there was less seismic resistance. In general, hexagrid models that were rectangular and located on mild slope had better seismic performance in terms of being more stiff and had less deformation.

Table 4.1 Details of Models

Details	Description
No of storey	G+20, G+30, G+40
Zone	V
Grade of concrete	M40
Grade of steel	Fe550
Type of frame	Special moment resistance Frame
Response Reduction Factor	5
Slab thickness	125mm
Column size	300 x 600 for G+20,450x600 for G+30,450 x 600 for G+40
Beam size	450 x 600 for G+20, 600x900 for G+30,600x900 for G+20
No of bays in X direction	8
No of bays in Y direction	6
Spacing of bays	3.5 metres
Live load	$3kN/m^2$
Floor load	$1 kN/m^2$
Wall Load	7 kN/m
Grid Member	ISA 150 x 150 x 10
Grid Angle	60^0
Grade of Grid	Fe345
Grid Shape	Hexagon



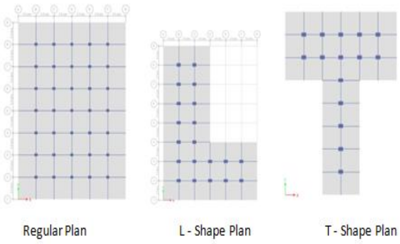


Fig. 4.1 Plan Irregularities

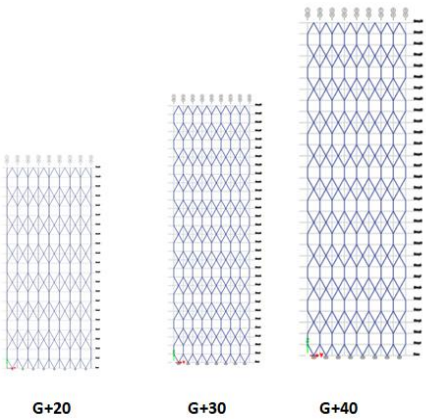


Fig.4.2 Elevation of Building on Plane Ground

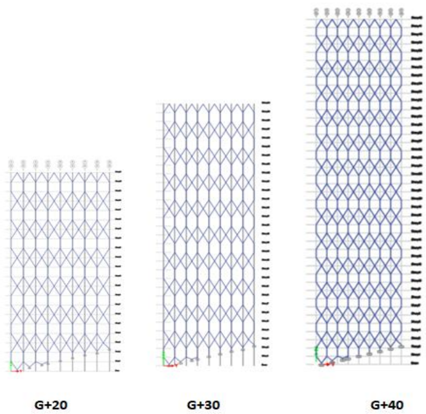


Fig.4.3 Elevation of Building On Sloping Ground

Model Geometry

The study considered 54 models where in the they were varied by plan and slope of the ground, the models considered include Rectangular, L Shape and T Shape models and the slope of the ground was varied from 5^0 to 20^0, grid was modeled as hexagon with an angle of 60^0 in ETABS V22.

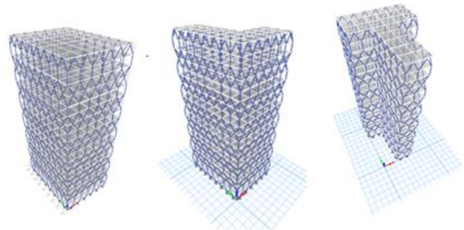


Fig.4.4 Three-Dimensional View of 20 Storey Building

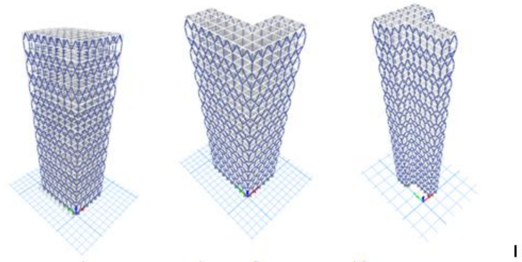


Fig.4.5 Three Dimensional View of 30 Storey Building

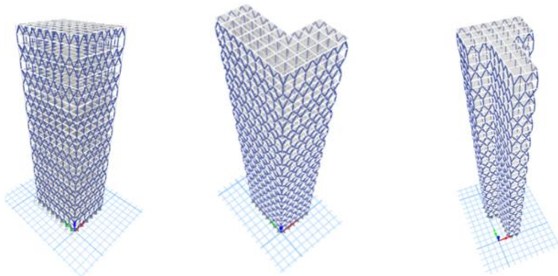


Fig4.6 Three Dimensional View of 40 Story Building

V. CONCLUSION

The analysis involved the seismic behavior of unsymmetrical high rise buildings using hexagrid systems on the sloping ground through the ETABS software. Findings indicated that shape, height, as well as slope angle of construction greatly affect the structural response. Rectangular models were the most effective models when the displacements were small and the stiffness was high and the L- and T-shaped buildings were more vulnerable. Stability was enhanced in moderate slopes (5^o -15^O) and displacement enhanced in steeper slopes (20^o). It worked well with sloping surfaces as the addition of a hexagrid system made it increase lateral resistance and minimized the displacement of the roof.

Future studies can be related to the nonlinear dynamic analysis and effects of soil-structure interaction and experimental validation. The design of the hexagrid system that facilitates safe and efficient earthquake-resistant buildings can also be enhanced by optimization of material utilization, cost-research, and incorporation of sustainable materials and AI-assisted predictive technologies.

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