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Comparative Analysis Between Regular and Irregular G+12 Buildings in Arunachal Pradesh

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Abstract: The way a multi-story building behaves during intense seismic activity is determined by its structural design. One of the main reasons for failure during earthquakes is recognised to be irregular configuration, either in plan or in elevation. Therefore, irregular structures are a cause for concern, particularly those found in high seismic zones. The present study addresses the seismic response of reinforced concrete structures with regular and irregular configurations. A G+12-storey building with a regular frame and an irregular frame with various irregularities is designed and they are analyzed and compared. The study's investigation of the seismic performance of Arunachal Pradesh, India, has been the main emphasis. The building is designed as per IS 456: 2000 and IS 1893(Part I): 2016. Seismic evaluation is carried out in finite element-based software ETABS. Equivalent Static Analysis and Response Spectrum Analysis are used for seismic analysis of the building where the results of Storey displacement, Storey drift, Storey stiffness, Modes, and Base shear will be compared and evaluated. Results show that the vertical geometric irregularity model is more efficient than the other models and the re-entrant corner irregularity model is the least stable.

Keywords: Irregular building, Response spectrum analysis, Storey displacement, Storey drift, Base shear.

I. INTRODUCTION

Building behaviour is influenced by its structural configuration, size, shape, and geometry. Uniform and simple designs are less damaged during earthquakes, while irregular ones are susceptible to deformations and failure. Structural safety during seismic loads is the main focus, and understanding the behaviour of structures under significant deformations is crucial for seismic loading. Serviceability and financial loss are also important considerations.

Stiffness irregularity, also known as a soft story arises due to discontinuity in mass, stiffness, or strength of a structure. Soft stories may affect a building's overall stability and seismic performance.

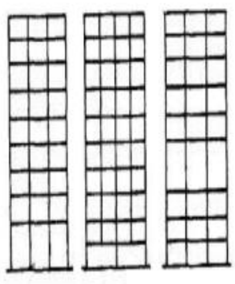

Fig. 1 Stiffness irregularity, [1]

Re-entrant corner irregularity arises when the floor plan of the building has an external corner, which is an internal corner of a concrete slab. In another manner, it describes corners where the structure extends much beyond the standard floor plan.

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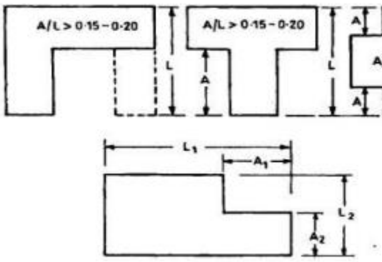

Fig. 2 Re-entrant corner irregularity, [1]

Vertical geometric irregularity arises when the horizontal dimension (such as breadth or length) of the seismic force-resisting system (SFRS) in any storey is more than 130% of that in the adjacent storey. In other words, the vertical geometric irregularity occurs when the dimensions of the seismic-force-resisting system differ dramatically from one storey to the next.

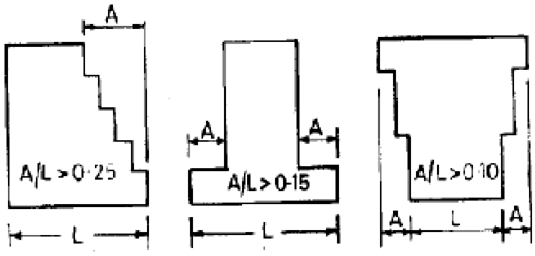

Fig. 3 Vertical geometric irregularity, [1]

METHOD OF ANALYSIS

The study investigates the structural behaviour of irregular buildings under seismic loading, recommending the use of static and dynamic analysis, with the response spectrum of dynamic analysis chosen and the equivalent static analysis using ETABS software.

Software: ETABS is a popular software application in structural engineering that aids engineers in analyzing and designing building structures, including 3D models, linear and nonlinear analysis, detailed reports, and visualizations, offering a comprehensive collection of design norms and standards.

Equivalent Static Analysis (ESA): The equivalent static lateral force method simplifies earthquake seismic impact estimation by replacing static force on structures. Engineers use this method instead of time-dependent ground movements, determining lateral seismic force based on seismic zone, building significance, soil conditions, time period, and seismic weight.

Response Spectrum Analysis (RSA): Response Spectrum Analysis (RSA) is a structural engineering method that estimates a structure's maximum seismic response to transient events like earthquakes using linear-dynamic statistical analysis. It streamlines the process by using response spectra and follows the IS 1893-2016 code, considering soil type and seismic zone factor.

II. OBJECTIVES

- Analysis of four models of G+12 Regular and Irregular buildings using ETABS.
- Examine the seismic response of the building in Arunachal Pradesh with medium soil in seismic zone V.
- Compare the seismic response of regular and irregular buildings using the Equivalent static analysis and Response spectrum analysis.
- Analysis of regular building and single irregularity buildings having stiffness irregularity, vertical geometric irregularity, and re-entrant corner irregularity.

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III. DATA COLLECTION, MODELING AND ANALYSIS

A. Location

Fig. 4 Google map area, Mirku 2 village, Pasighat, East Siang, Arunachal Pradesh – 791102

B. General Configuration

Table 1 General structural configuration for the models

Parameters	Configuration
Structural type	Multi-storey rigid Jointed RC Frame structure
Plan dimension	18 x 18 m
Floor-to-floor height	3 m
No. of storey	G+12
Slab thickness	150 mm
Grade of steel	Fe 500
Grade of concrete	M30
Column size	450 x 400 mm, 550 x 500 mm
Beam size	400 200 mm, 500 x 300 mm, 600 x 400 mm

C. Seismic Specification

Table 2 Seismic specification for the models

Parameters	Value
Zone	V
Zone factor	0.36
Response reduction factor	5
Type of soil	Medium (II)
Importance factor	1.2

D. Loading Specification

Table 3 Loading specification for the models

Loads	Value
Dead load	As per IS 875(Part I): 1987 The self-weight of the structural members used in the software is auto-calculated by the software itself based on material properties and size specified.
Live load	As per IS 875(Part II): 1987 Living room – 2 kN/m^2 Kitchen – 2 kN/m^2 Toilet/Bathroom – 2 kN/m^2 Passage – 3 kN/m^2 Floor finish load – 1 kN/m^2 Terrace load – 1.5 kN/m^2

E. Designing and Modeling of G+12 Regular and Irregular Buildings

All four buildings are reinforced concrete frame structures of G+12 storey buildings with 18 m × 18 m plan dimensions. In these structures, M30 grade of concrete is used for the beam and column and the reinforcement provided is HYSD

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500. It has a storey height of 3 m. The beam sizes used in the models are 400 x 200 mm, 500 x 300 mm, and 600 x 400 mm and the column sizes used in the models are 450 x 400 mm and 550 x 500 mm. The slab thickness is 150 mm with M30 grade of concrete.

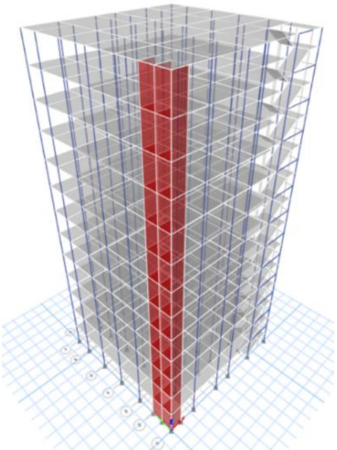
Fig. 5 Three-D view of the Model 1

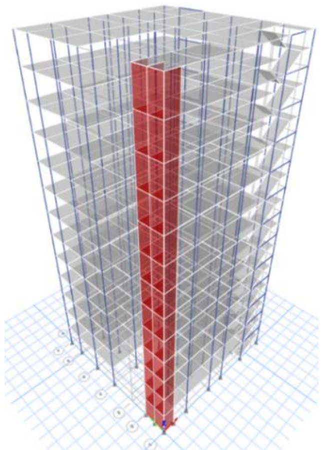
Fig. 6 Three-D view of Model 2

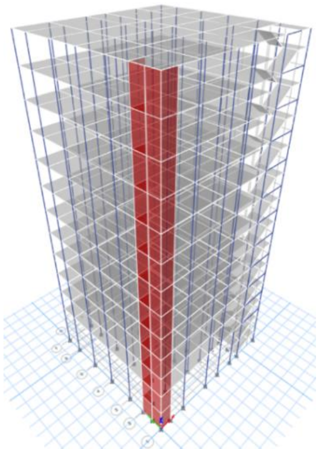
Fig. 7 Three-D view of Model 3

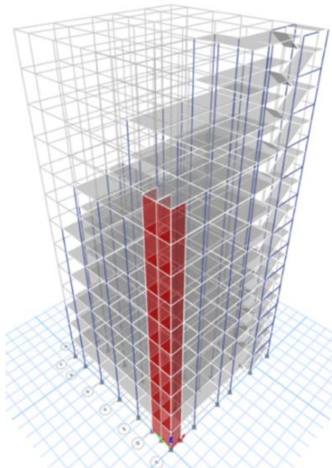
Fig. 8 Three-D view of Model 4

IV. RESULTS AND DISCUSSIONS

This includes the results and responses of various models post-analysis. The seismic response has been investigated in terms of storey displacement, drift, stiffness, modes, and base shear of the building.
Four models were analyzed: Model 1 is based on Regular building, Model 2 on Re-entrant corner irregularity, Model 3 on Stiffness irregularity, and Model 4 on Vertical geometric irregularity. For analysis Equivalent static method was adopted for static analysis and Response spectrum method was adopted for dynamic analysis, in seismic zone V, with medium soil II in Arunachal Pradesh.

A. Storey Displacement

Storey displacement is the lateral displacement of a floor or point from its original position as a result of lateral loads (such as wind or seismic forces).

Equivalent Static Analysis: The storey displacement of lateral load in Model 2 - Re-entrant corner irregularity has the highest displacement and Model 4 - Vertical geometric irregularity shows the lowest storey displacement as shown in Fig 4.1. Maximum values of storey displacement of Model 1 compared to Model 4 have a 2.85% decrease in Storey displacement. So, Model 4 shows the best result in X-direction. The storey displacement of lateral load in Model 4 – Vertical geometric irregularity has the highest displacement and Model 3 - Stiffness irregularity shows the lowest storey

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displacement as shown in Fig 4.2. Maximum values of storey displacement of Model 1 compared to Model 3 have a 0.79% decrease. So, Model 3 shows the best result in Y-direction.

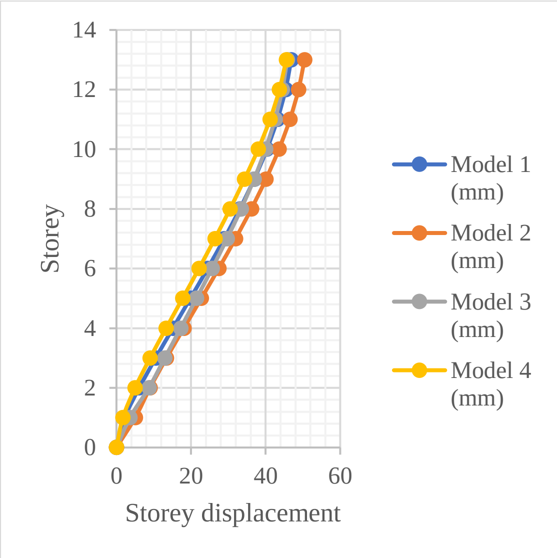

Fig. 9 Storey displacement in X-direction

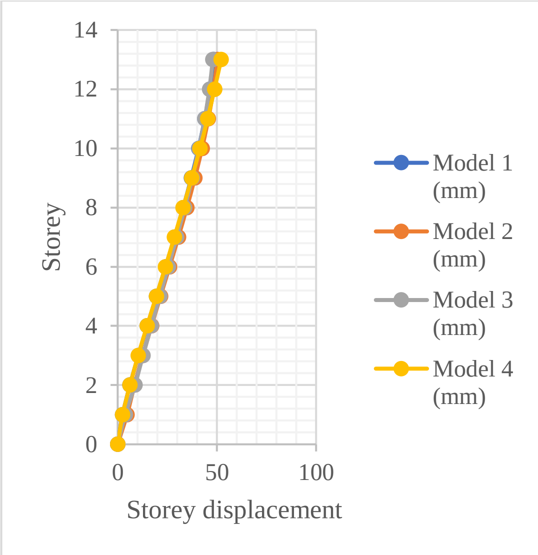

Fig. 10 Storey displacement in Y-direction

Response Spectrum Analysis: The storey displacement of lateral load in Model 2 - Re-entrant corner irregularity has the highest displacement and Model 4 - Vertical geometric irregularity shows the lowest storey displacement as shown in Fig 4.3. After observing the results of the models, the displacement value of all the models is less compared to the results for Equivalent static analysis. The maximum storey displacement of Model 1 compared to Model 4 has an 18% decrease in Storey displacement. So, Model 4 is the best compared to all other models in the X-direction. The storey displacement of lateral load in Model 4 – Vertical geometric irregularity has the highest displacement and Model 1 – Regular shows the lowest storey displacement as shown in Fig 4.4. Maximum values of storey displacement of So, Model 1 shows the best result in Y-direction.

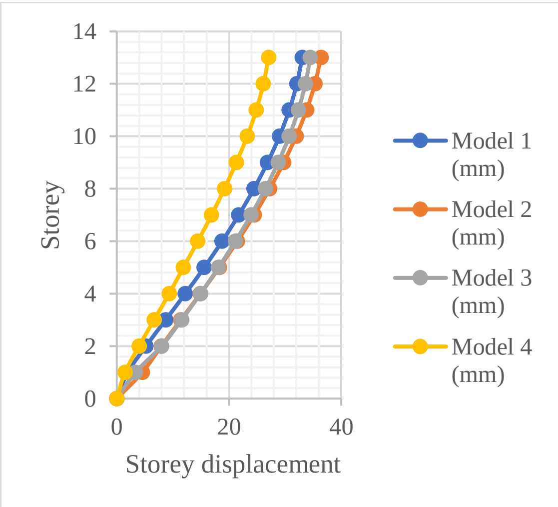

Fig. 11 Storey displacement in X-direction

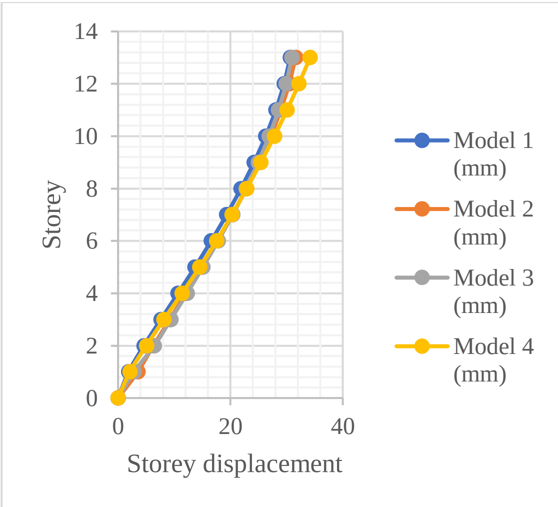

Fig. 12 Storey displacement in Y-direction

B. Storey Drift

Storey drift is closely linked to storey displacement. It represents one level's lateral displacement relative to the level immediately beneath it.

Equivalent Static Analysis: Model 3 – Stiffness irregularity and Model 2 – Re-entrant corner irregularity show a sudden extreme change in storey 1 and storey 2 due to the fewer structural members - beams and columns in the models on those

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particular storeys. Comparing the maximum values of Storey drift, Model 1 compared to Model 4 shows a 5.64% decrease in the value of Storey drift. Model 4 has the most stable storey drift among the four models in the X-direction. Model 1 has the most stable storey drift among the four models in the Y-direction.

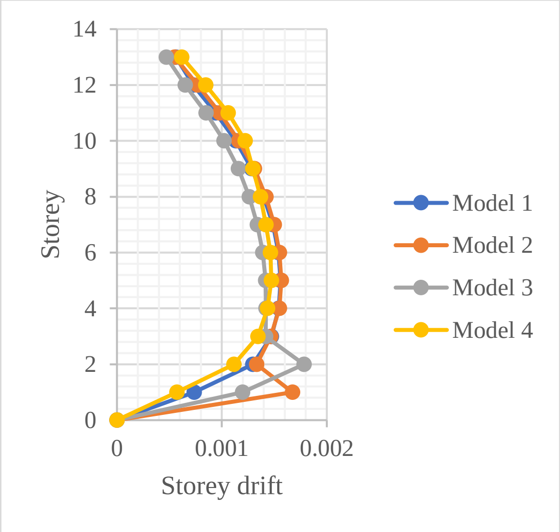

Fig. 13 Storey drift in X-direction

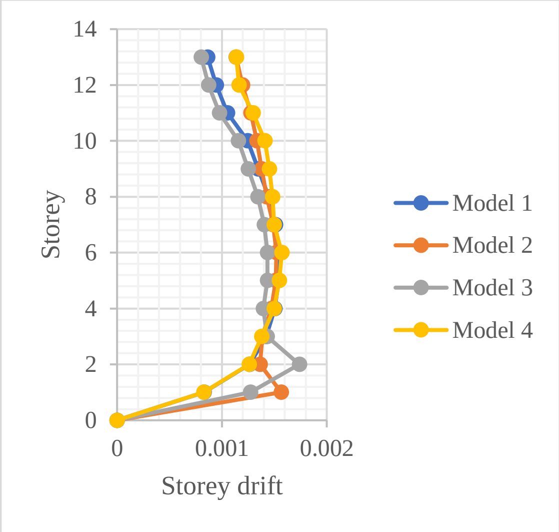

Fig. 14 Storey drift in Y-direction

Response Spectrum Analysis: Comparing the maximum values of Storey drift, Model 1 compared to Model 4 shows a 20.47% decrease in the value of Storey drift. Model 4 has the most stable storey drift among the four models in the X-direction. Model 1 has the most stable storey drift among the four models in the Y-direction.

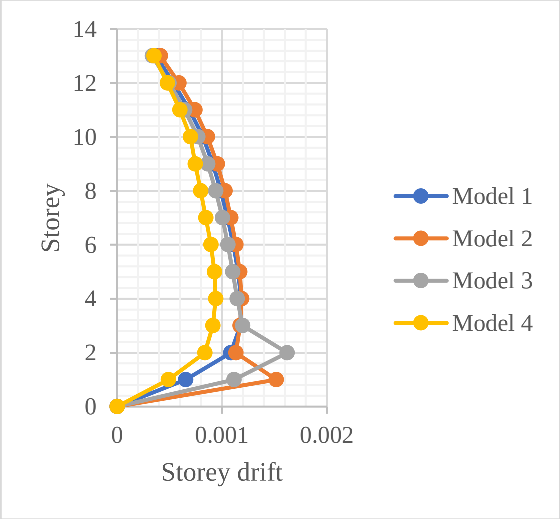

Fig. 15 Storey drift in X-direction

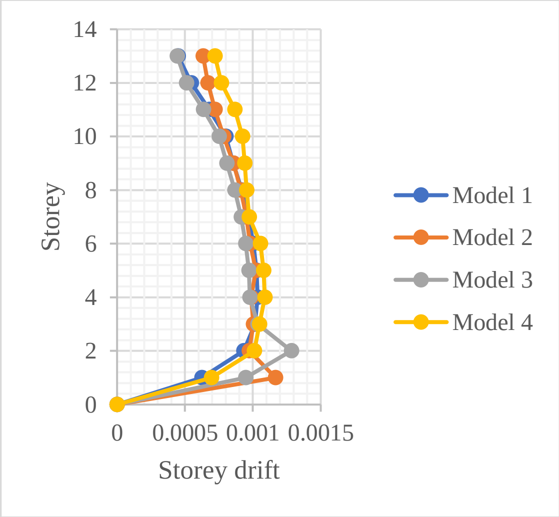

Fig. 16 Storey drift in Y-direction

C. Storey Stiffness

Storey stiffness refers to how resistant a building's lateral system is to deformation. The stiffness of a storey level is defined as its resistance to lateral movement.

Equivalent Static Analysis: Model 4 shows the highest Storey stiffness at storey 1. Model 2 shows the lowest Storey stiffness at storey 2. Comparing the maximum values of Storey stiffness, Model 1 compared to Model 4 shows a 9.25% increase in the value of Storey stiffness. So, Model 4 is the best compared to all other models in the X-direction. Model 1 is the best compared to all other models in Y-direction.

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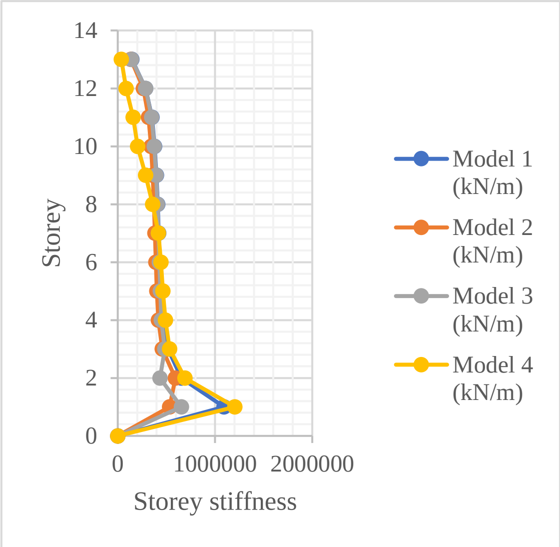

Fig. 17 Storey stiffness in X-direction

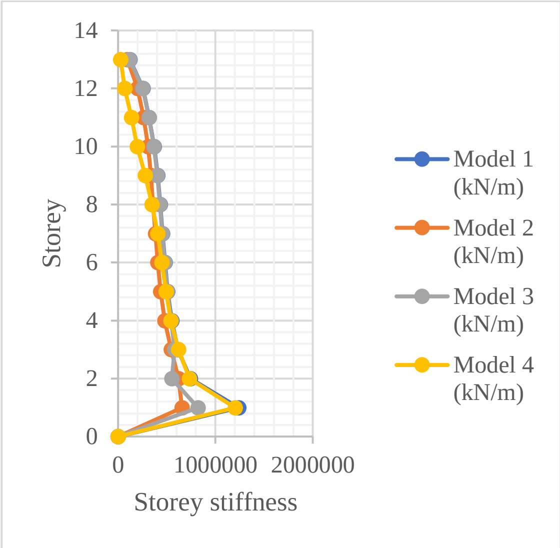

Fig. 18 Storey stiffness in Y-direction

Response Spectrum Analysis: Model 4 shows the highest Storey stiffness at storey 1. Model 3 shows the lowest Storey stiffness at storey 2. Comparing the maximum values of Storey stiffness, Model 1 compared to Model 4 shows a 15.17% increase in the value of Storey stiffness. So, Model 4 is the best compared to all other models in the X-direction. Model 1 shows the highest Storey stiffness at storey 1. Model 3 shows the lowest Storey stiffness at storey 2. Model 1 is the best compared to all other models in Y-direction.

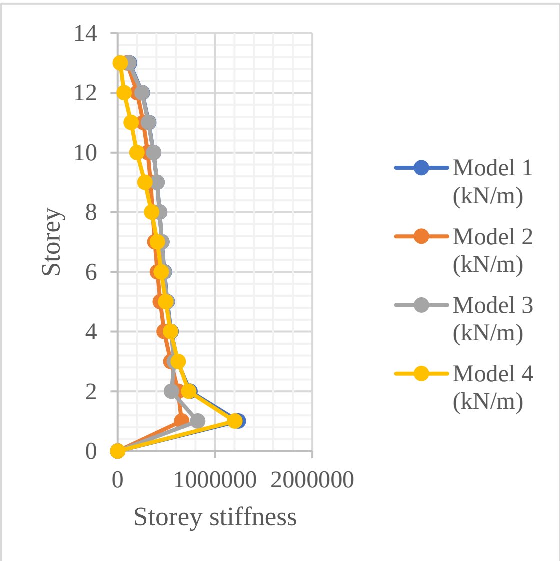

Fig. 19 Storey stiffness in X-direction

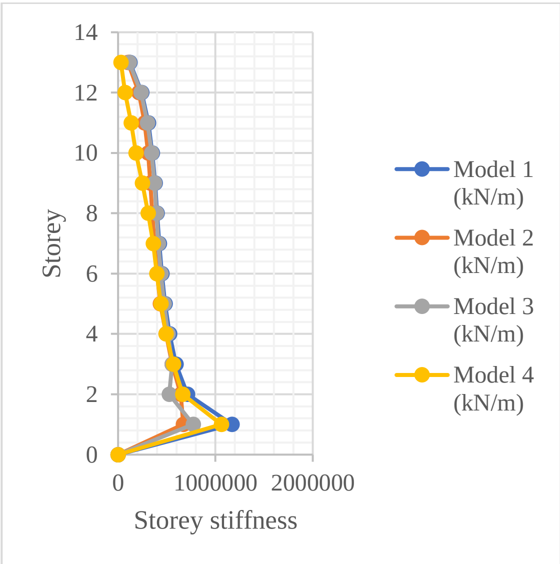

Fig. 20 Storey stiffness in Y-direction

D. Modes

Modes are the different ways a building can vibrate or oscillate during an earthquake or other dynamic the natural time period is the amount of time it takes a system to complete one full cycle of motion without being acted on by external factors.

Model 4 - Vertical geometric irregularity has the lowest time period of 1.134 sec and Model 2 - Re-entrant corner irregularity has the highest time period of 1.729 sec as shown in Fig 4.13. Comparing the maximum values of time period, Model 1 compared to Model 2 shows an 8.9% increase, and Model 1 compared to Model 4 shows a 28% decrease in the value of time period. So, Model 4 is the stiffest, and Model 2 is the least s tiff.

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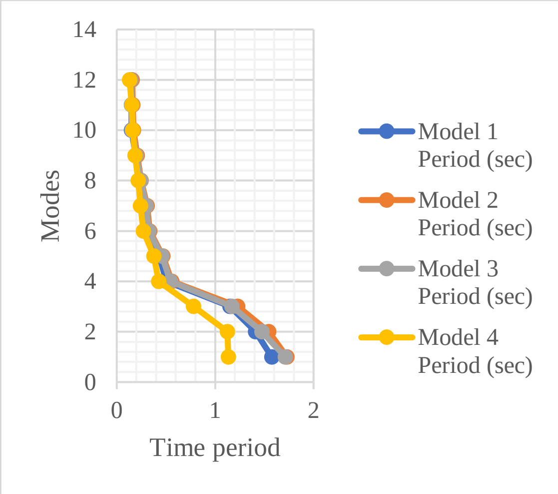

Fig. 21 Modes comparison of the models

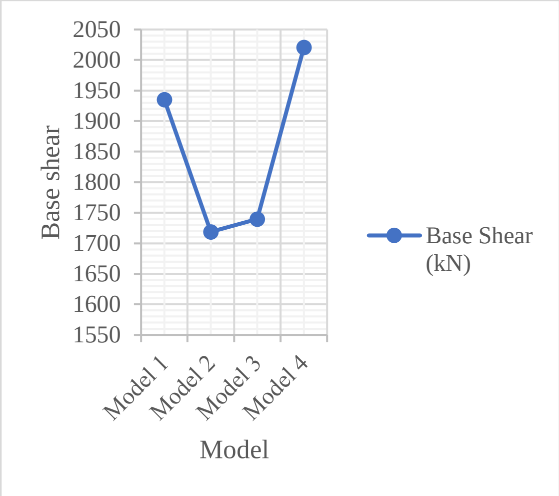

Fig. 22 Base shear comparison

E. Base Shear

Base shear is the total lateral force that an earthquake exerts on a building's base. This force is required when designing structures that can withstand seismic events effectively.

Model 4 - Vertical geometric irregularity has the highest base shear of 2020.62 kN and Model 2 - Re-entrant corner irregularity has the lowest base shear of 1718.71 kN as shown in Fig 4.14. Comparing the values of Base shear, Model 1 compared to Model 2 shows an 11.18% decrease and Model 1 compared to Model 4 shows a 4.2% increase in the value of Base shear.

V. CONCLUSIONS AND FUTURE SCOPE

CONCLUSIONS

- Storey displacement after the analysis, it is noticed that Model 4 is performing best in the X-direction and Model 3 is performing best in the Y-direction. Model 2 shows the highest displacement in both analyses.
- Storey drift after the analysis, Model 4 shows the best result in both directions. Model 3 shows the highest value for storey drift.
- Storey stiffness in Model 4 shows the best results in both the direction and the analysis. Model 2 shows the lowest stiffness compared.
- Model 4 shows the least time period and compared to Model 1 it shows a 28% decrease in time period. Model 2 shows the highest time period for the modes.
- Model 4 shows the highest base shear and compared to Model 1 it shows a 4.2% increase. Model 2 shows the lowest base shear.
- Model 4 -Vertical geometric irregularity gives the most stable result compared to any other model. Buildings with vertical geometric irregularity exhibit superior seismic performance compared to other models. This building takes maximum shear force at minimum displacement with the least storey drift and high stiffness.
- Model 2 - Re-entrant corner irregularity model is the least stable model compared to any other models. Re-entrant corner irregularity is a plan irregularity, as the plan irregularity is introduced in the model then storey displacement, storey drift and time period increase, storey stiffness and base shear decrease.
- Seismic response of vertical irregularity gives a similar or better result than regular, and plan irregularity makes the building vulnerable to risk and susceptible to seismic earthquakes.

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Overall, we may conclude that Model 4 is the most stable and efficient. Proper building design guarantees that it can survive seismic activity without being severely damaged. Overall, this study adds to our understanding of various building seismic reactions, assisting in the construction of safer and more resilient structures in earthquake-prone areas.

FUTURE SCOPE

The analysis of Regular and Irregular structures holds significant future potential and can contribute to the advancement of structural engineering and architectural design. Currently, Structural engineers need to change as architects continue to push the work with creative architectural designs. Later research may examine innovative structural designs that preserve stability and allow for irregular shapes and layouts. The behaviour of irregular buildings can be more accurately captured by utilizing advanced analysis techniques (like pushover analysis, time history analysis, or nonlinear dynamic analysis). Researchers can investigate how these methods can be applied to practical projects.

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