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Impact Of Plan Irregularities On Performance Of Building Subjected To Seismic Load.

Afiya tamkeen[1], Dr. Gajendra[2]

[1]PG Student, Department of Structural Engineering, Sharnbasva University, Kalaburagi, India.
[2]Asst Prof, Department of Civil Engineering, Sharnbasva University, Kalaburagi, India.

ABSTRACT

The present study, investigates the impact of different types of plan irregularities on the building subjected to seismic force. The L, H, T, U Shaped plan irregular building are moderate in ETABS software, then seismic load along with gravity load is assigned as per IS codes. The equivalent static method is used for analysis. The study confirms that plan irregularities play a critical role in determining seismic performance, and among the studied configurations, the T-shaped structure shows the most suitable for resisting earthquake-induced forces. These results provide valuable insights for engineers and designers in optimizing irregular building layouts for both functionality and resilience.

Keywords: Plan irregularities, seismic performance, storey drift, storey displacement, base shear, storey shear, lateral load.

1. INTRODUCTION

Earthquakes are one of the worst natural disasters, resulting in significant damage to buildings and infrastructure due to the sudden release of seismic energy. The way a building reacts during an earthquake largely depends on its structural configuration, geometry, and load-resisting system. One of the critical factors influencing seismic behavior is the plan irregularity of a structure. Modern architectural and functional requirements often lead to irregular building shapes such as L, T, U, or H configurations, which deviate from conventional rectangular forms. These irregularities tend to create non-uniform distribution of mass, stiffness, and strength, resulting in torsional effects, concentration of stresses, and uneven displacement demands during seismic events. Consequently, irregular buildings are generally amore prone compared to regular ones when subjected to seismic loading. Studying the impact of plan irregularities is therefore essential for ensuring safety, improving structural performance, and guiding engineers and architects in earthquake-resistant design.

Irregularities in the plan configuration of buildings have a significant influence on their seismic behaviour and overall structural performance. With the growing demands of modern architecture, structures are often designed with irregular shapes such as T-shape, H-shape, L-shape, and U-shape configurations. While these forms may enhance aesthetics and functional utility, they also introduce complexities in structural response under earthquake loading. This study addresses the research problem of evaluating how plan irregularities affect seismic performance and identifying which configuration provides improved resistance against seismic forces. The research methodology involved modelling and analyzing different structural configurations using ETABS software. Both regular and irregular plan buildings were designed in accordance with IS 1893:2016 seismic provisions. The equivalent static analysis method was adopted to simulate earthquake effects on the structures. From the simulations, seismic response parameters such as storey displacement, storey drift, storey shear, and base shear were extracted and compared across the different building geometries. The findings revealed that the T-shaped building performed most effectively in controlling storey displacement and drift, attributed to its higher stiffness, uniform mass distribution, and efficient load transfer mechanism. In contrast, L-shaped buildings exhibited lower base shear due to their relatively smaller mass but showed higher stress concentrations at re-entrant corners.

Irregularities are introduced in real structures for both aesthetic and utility. The magnitude of variation in response depends on the type, degree, and location of irregularities present. There are two main types of irregularities in building.

- Plan irregularities.
- Vertical irregularities.

Definition of plan irregularities: It refers to an uneven shapes and layouts in the floor plan that can cause parts of the structure to respond differently to forces, like during an earthquake. These irregularities can lead to uneven distribution of mass, stiffness, or strength, increasing the likelihood of disproportionate damage to certain parts of the structure.

Plan irregularities are categorized into different types, including.

- Torsional irregularities:
  - When the center of mass does not align with its center of rigidity, leading to torsional (twisting) motion when lateral forces like earthquake occur.

- Buildings with significant torsional irregularities experience excessive stress in some areas, increasing the risk of damage.

- Re – entrant corners irregularities:
  - Arises when a building has large concave corners, such as L-, U-, T-, or H- shaped plans. These re-entrant corners cause stress concentration during lateral loading, as parts of the building try to move in different directions.
  - Re-entrant corners are more susceptible to damage during earthquakes.
- Diaphragm discontinuity:
  - happens when there is are significant changes or openings in the floor slabs (diaphragms) of a building, leading to uneven distribution of lateral forces.
  - Examples include large openings for staircases, elevators, or atriums, weakening the diaphragms, ability to distribute forces evenly.
- Out – of – plan offsets:
  - Refers to discontinuities or misalignment in the vertical load – resisting elements of a building (such as walls or frames) across different floors. For example, a wall on one floor that does not line up with the wall on the floor below.
  - This misalignment results in a non – uniform transfer of forces, making parts of the structure more vulnerable to damage.
- Non parallel lateral – force – resisting systems: -
  - Occurs when the structural elements designed to resist lateral forces (such as shear walls or braced frames) are not aligned or symmetric.
  - Nonparallel systems lead to uneven force distribution during lateral loading, increasing the risk of damage in different parts of the building.
- Mass irregularities:
  - Occurs when there is a large variation in mass (weight) between adjacent floors, such as in buildings with very heavy equipment on one floor.
  - This leads to uneven force distribution, increasing the seismic demand on certain parts of the structure.
- Vertical geometric irregularities:
  - Although primarily a vertical irregularity, it can affect plan irregularities when there is a drastic change in building dimensions at different floor levels, causing stress concentrations in the structure.
- Stiffness irregularities (soft story):
  - Happens when one or more floors have significantly less stiffness than the floors above or below them. Although considered a vertical irregularity, this condition can impact the lateral load distribution within the building plan.
- Setback irregularities:
  - These occur when there is a sudden change in the building's footprint at a certain level, such as a building that narrows at higher floors.
  - Setbacks create areas of stress concentration and complicate the distribution of forces through the structure.

Methods of analysis:

- **Linear Static Analysis:** It is also known as equivalent static method, is the simplest form of seismic analysis in ETABS. It assumes linear elastic behavior of the structure and applies lateral forces based on building weight, height, and seismic zone factors. This method is suitable for low-rise, regular buildings where dynamic effects are not significant. It provides a quick estimate of base shear, storey shear, and overall structural response but does not capture higher mode effects.
- **Nonlinear Static Analysis :** It commonly known as pushover analysis, is used to study the inelastic performance of structures under increasing lateral loads. In ETABS, this method applies incremental lateral forces until the structure reaches failure, showing the sequence of plastic hinge formation and overall capacity curve. It helps in understanding the ductility, energy dissipation, and performance level of buildings during strong earthquakes.
- **Nonlinear Dynamic Analysis (Time History Analysis):** Time history analysis is the most advanced and detailed method in ETABS for seismic evaluation. It involves applying actual or synthetic earthquake ground motion records to the structure and analyzing its response over time. This method captures both nonlinear material behavior and dynamic effects, making it highly accurate for irregular or critical structures. However, it is computationally intensive and requires reliable ground motion data.
- **Linear Dynamic Analysis (Response Spectrum Method):** It is one of the most widely adopted seismic analysis methods used in ETABS for evaluating the dynamic response of buildings. Unlike static methods, it takes into account the dynamic characteristics of the structure such as natural frequencies,

mode shapes, and modal participation factors. The method is based on the principle of representing the maximum response of a structure to earthquake ground motion using a response spectrum curve, which is typically provided by seismic design codes. This spectrum shows the peak structural responses (acceleration, velocity, or displacement) of a single-degree-of-freedom system for different natural periods when subjected to a particular ground motion.

- In ETABS, the structural model is divided into multiple vibration modes, and the dynamic response is calculated separately for each mode using the response spectrum. Since real buildings vibrate in multiple modes simultaneously, the modal responses are then combined using mathematical techniques such as **Square Root of Sum of Squares (SRSS)** or **Complete Quadratic Combination (CQC)**. This ensures that the influence of higher modes, which can significantly affect tall or irregular buildings, is properly considered. As a result, response spectrum analysis provides more accurate estimates of seismic demands like base shear, storey shear, displacements, and drifts compared to equivalent static methods.
- The main advantage of response spectrum analysis is its balance between accuracy and computational efficiency. While it does not require actual earthquake ground motion records like time history analysis, it still accounts for the dynamic properties of the structure and the frequency content of seismic loading. Hence, it is widely recommended in building codes for medium to high-rise structures, and for irregular buildings where static methods may underestimate seismic effects. By using response spectrum analysis in ETABS, engineers can ensure more reliable earthquake-resistant designs, evaluate torsional effects, and enhance the safety and stability of structures under seismic loading.

2.LITERATURE REVIEW: -

G.C. Jawalkar et.al. [2020][1] They examine numerically on "Comparitive analysis of plan irregularities for RCC structure In High Seismic Zone." This study focuses on the response spectrum analysis of RCC buildings with different plan configurations, particularly H-shaped and L-shaped structures, located in seismic zone IV, which is categorized as a high seismic risk zone. The analysis and design were performed using ETABS software based on the finite element method to evaluate key seismic parameters such as base shear, storey drift, storey shear, and storey displacement. The results indicate that buildings with severe plan irregularities experience greater deformation compared to those with more regular configurations, especially under high seismic loading. Among the studied shapes, the storey drift was found to be maximum in rectangular plan buildings and minimum in H-shaped buildings, highlighting the influence of geometry on seismic response. Overall, it is concluded that re-entrant corners in irregular structures significantly increase vulnerability, making such configurations less safe against seismic forces. **Mirza Aamir Baig et.al. [2021][2] They studied on "Comparison of analysis and design of regular and irregular configuration of multistorey buildings in seismic zones."** This study aims to calculate and compare the design lateral forces on regular and irregular RCC buildings using response spectrum analysis, focusing on three types of irregularities: mass, stiffness, and vertical geometry. The selected structures were modeled and analyzed dynamically in ETABS, with storey shear forces calculated and compared through plotted graphs. The results revealed that mass irregular buildings experience higher base shear compared to regular frames, while stiffness and vertical geometry irregularities also significantly affect the seismic performance, emphasizing the greater vulnerability of irregular structures under seismic loading. **Aysha S [2021][3] They defines a "Seismic analysis on a plan irregular multistorey commercial building using ETABS."** This study involves modelling and analysing a G+4 storey RCC building in seismic zone III using ETABS as per IS 1893. Time history and pushover analyses were performed to evaluate the building's dynamic and seismic response. The analysis considered self-weight of structural members and load combinations as per the code, with results presented through response curves. It was concluded that properly designed sections and reinforcement details enhance seismic performance, while hinges formed at lower floors indicate the need for stronger reinforcement in lower columns compared to upper floors. **M.T. Raagavi et.al. [2021][4] They investigated on "A Study on seismic performance of various irregular structures."** This study examines the effect of floor plan on the seismic behaviour of structures by analyzing H-shaped and L-shaped G+14 storey buildings in seismic zone IV using ETABS. Dynamic analysis through equivalent static and response spectrum methods showed that plan irregular buildings experience higher storey displacement and drift compared to regular ones, with re-entrant corners performing worst during earthquakes. It was concluded that increasing structural ductility and designing as per seismic considerations are essential to improve earthquake resistance and minimize damage in irregular structures. **Bhaskar et.al. [2024[5]] The study investigates on "A Comprehensive study on the impact of configurationally irregularities."** This study analyzes a G+15 residential framed building in seismic zone V using ETABS under different soil conditions. Results show that increased setbacks raise shear forces, while irregular frames have lower shear and bending moments compared to regular ones. Overall, regular frames perform better and show more stable seismic behaviour than irregular frames. **Isha Pachkawade et.al. [2020][6]**

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The study gives the "effect of irregular configuration on seismic performance of buildings." This study analyses multistorey RCC framed buildings of different plan shapes (+, C, L, and Square) using time history analysis in ETABS for seismic zone V. Models of G+11 and G+14 storeys were compared, showing that irregular buildings have higher natural periods and storey overturning moments than regular square buildings. It was concluded that IS 1893:2002 does not fully account for irregularities, while time history analysis provides more accurate results than the equivalent static method.

3.OBJECTIVES

1) To study the seismic performance of buildings such as story drift ratios, storey displacement, base shear, storey shear and lateral load to storey.
2) To investigate the variation of degrees of plan irregularities affect the buildings seismic performance.

4. METHODOLOGY

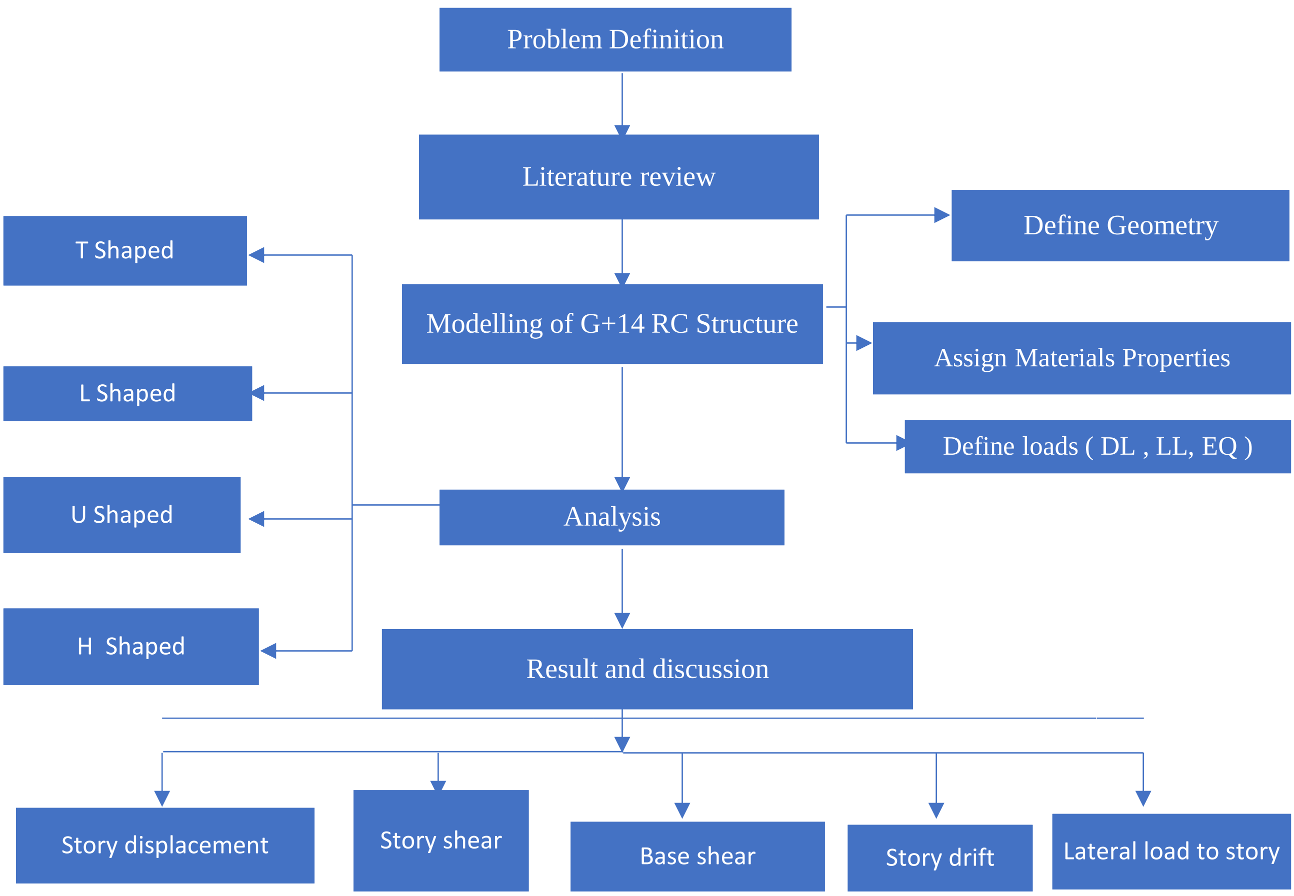


Fig 1: Flow Chart of Research Work

Model the Building Geometry
The H, L, T, U Shape RCC Buildings were modelled in ETABS Software and then analysis under response spectrum.

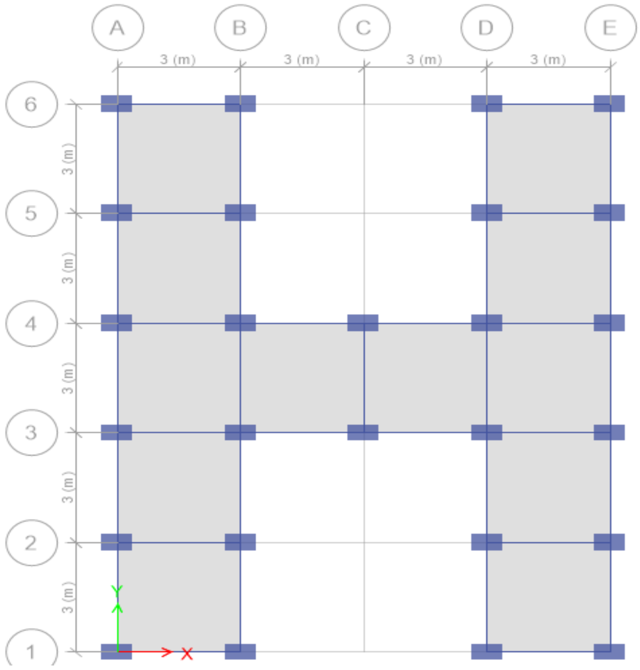


Fig 2: Plan of H-Shaped RCC Building

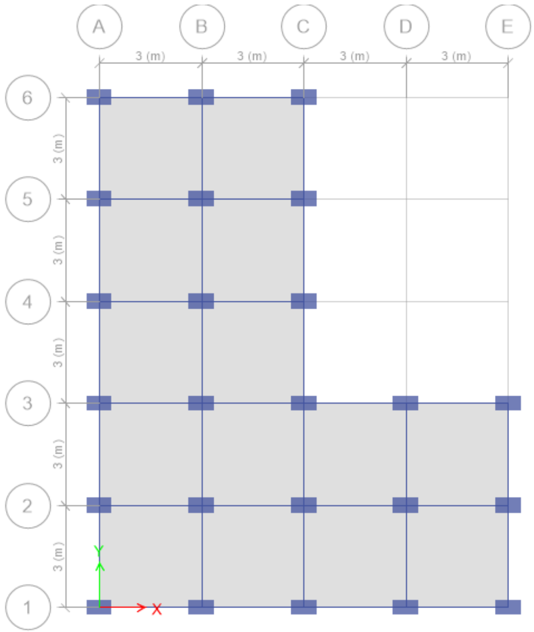
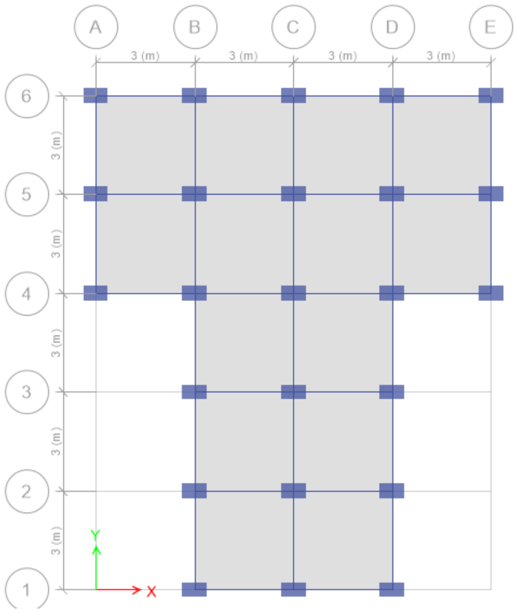


Fig 3: Plan of L-Shaped RCC Building



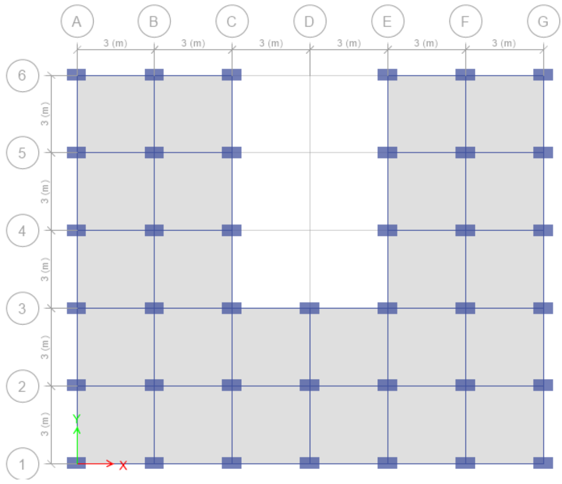


Fig 4: Plan of T-Shaped RCC Fig 5:
Plan of U-Shaped RCC Building

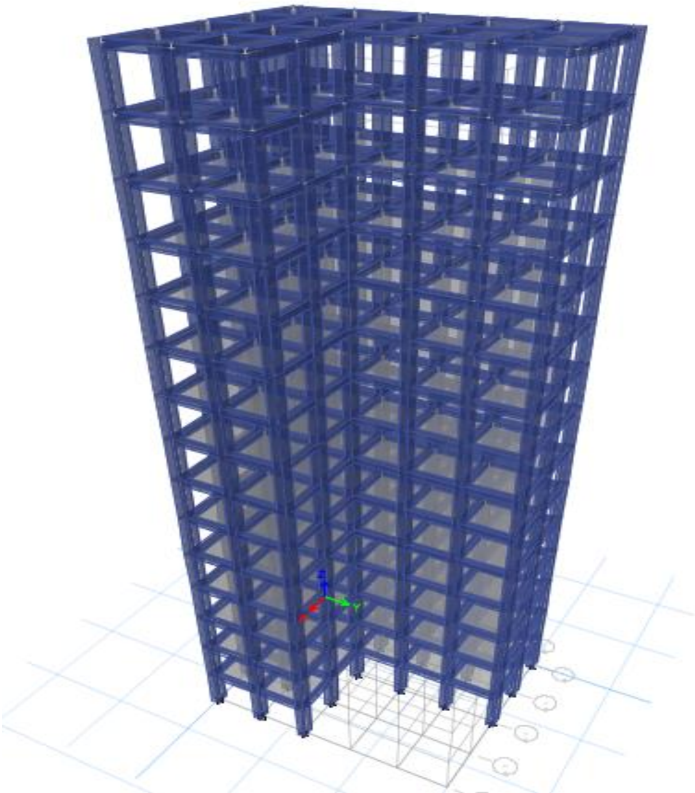


Fig 6: 3D View of T- Shaped RCC building

5. RESULTS AND DISCUSSIONS

STOREY DISPLACEMENTS

Storey displacement is the lateral movement of a floor level of a building when subjected to earthquake or wind forces. It shows how far a storey move away from its initial spot due to applied lateral loads. Excessive displacement can cause damage to structural and non-structural components. Unit: millimetres (mm) or metres (m).

Fig 7 shows the displacement v/s storey level graph. This graph shows that the variation of displacement is similar for all different irregular shape of structures. the H Shape building shows the maximum displacement compare to other shape building. The H Shape building exceeds the permissible displacement limit of 75mm. Hence the H Shape building is not suitable for this combination.

Further T shape structure is showing minimum displacement compare to other structures. From the graph it is clearly observed that the T Shape structure is suitable for this combination. Because its gives higher stiffness more uniform load distribution compare to other irregular shapes.

From the graph it is clearly observed that T Shape irregular structure is suitable compare to all other irregular shape of buildings.

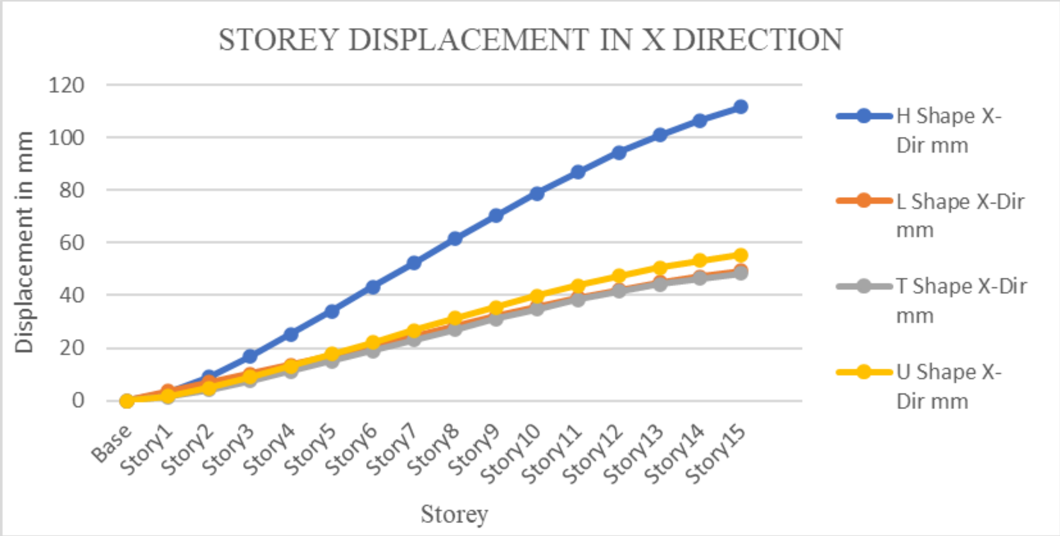


Fig 7 Storey displacement in X direction

STOREY DRIFT

Difference in lateral displacement between two consecutive stories it shows how much each story moves relative to the one below it. High drift can cause structural damage or collapse, especially in earthquakes

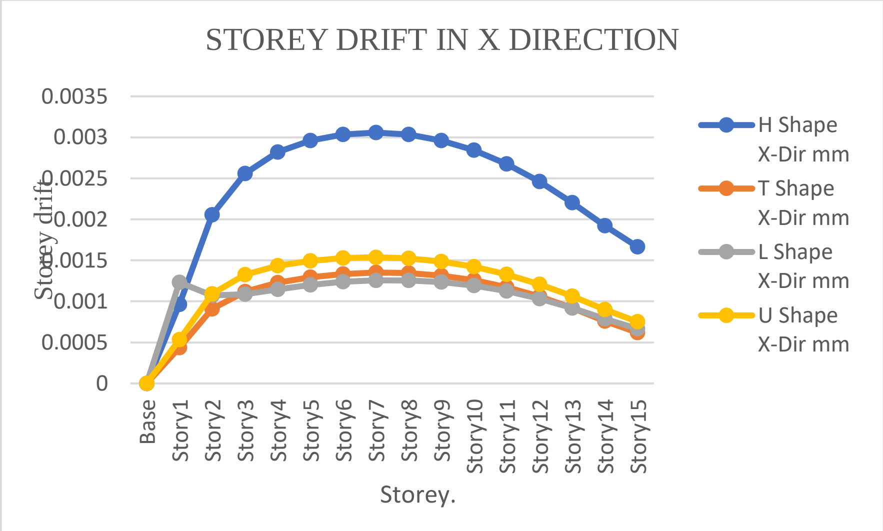


Fig 8: Storey drift in X direction

Fig 8 shows the storey drift v/s storey level graph. This graph shows that the variation of storey drift in H, T, U Shape is similar except L Shape. The H Shape building shows the maximum storey drift compare to all other irregular shapes of building structures. The H Shape has large re-entrant corners and discontinuities in stiffness along the plan, creating weak zones that undergo more deformation during seismic zones. As per the code book which is given above all curves on the plot peak is below 0.012. Hence the H shape structure is suitable for the combination.

Further T Shape structure is showing minimum storey drift compare to other structures. From the graph it is clearly observed that the T shape structure is suitable for this combination, because of its efficient load transfer, and higher stiffness which is end up with one of the lowest storey drift compare to other irregular shapes of structure. From the graph it is clearly observed that T shape irregular structure is most suitable compare to all other irregular shapes of buildings.

STOREY SHEAR

Storey shear is the overall sideways force (in KN) acting at the bottom of each storey due to lateral loads like earthquake forces (seismic) and wind loads.

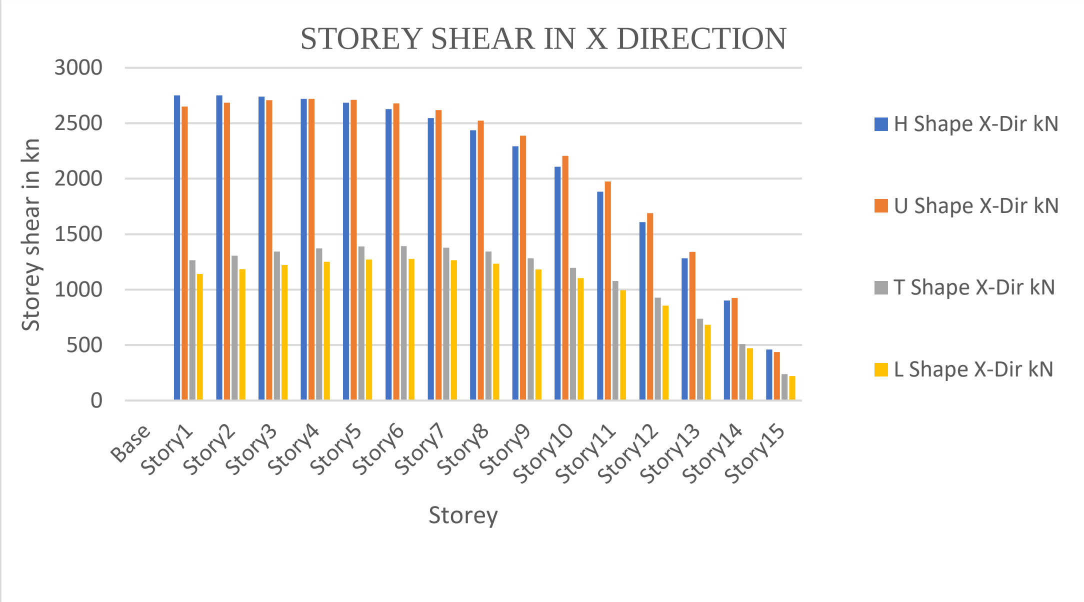


Fig 9 Storey shear in X Direction

Fig 9 shows the storey shear v/s storey level graph. This graph suggest that the variation of storey shear is similar for all the different types of irregular structures. the H Shape building has the maximum storey shear compare to other shapes of buildings. The H shape tends to have more floor area and mass, leading to higher base shear under seismic loading. The H Shape has the higher shear, strong seismic force demand, but high risk of member overloading. Hence, the H Shape building is suitable for this combination.

Further, L shape structure is showing minimum storey shear compare to other structures. From the graph it is clearly observed that the L shape structure is suitable for this combination, L shape has less floor area and projecting mass in this direction, so the seismic force generated is lower, compare to other irregular shapes of structure.

From the graph it is clearly observed that L shape irregular building structure is suitable compare to all other irregular shapes of buildings.

LATERAL LOAD TO STOREY

Lateral load to storey is the horizontal force acting on each floor (storey) of a building. The forces are usually caused by wind pressure and earthquake loads.

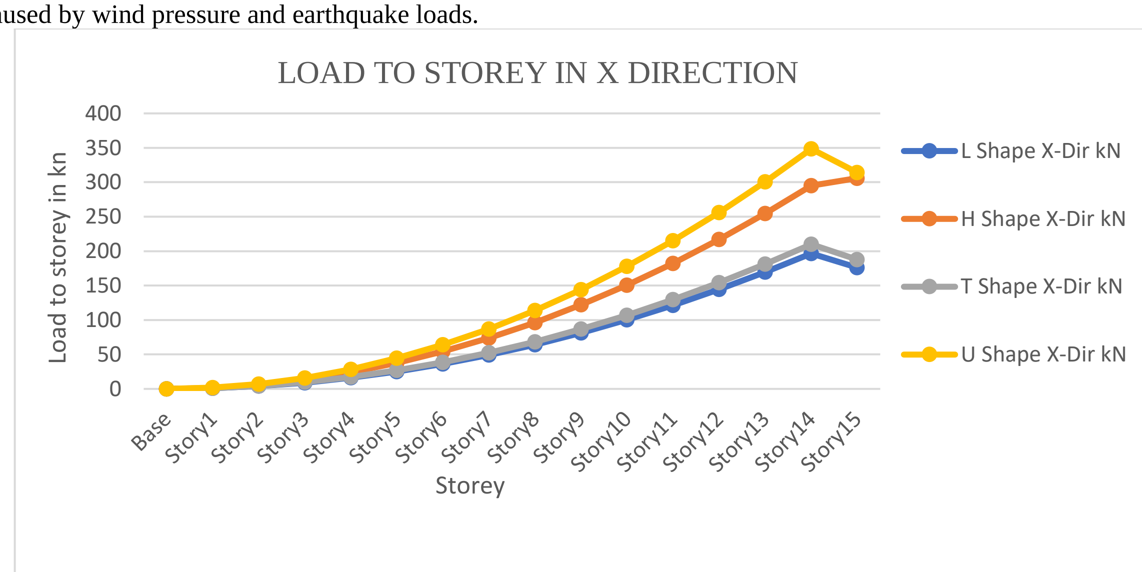


Fig 10 Load to storey in X direction

Fig 10 shows the lateral load to storey v/s storey level graph. This graph shows that the variation of lateral load to storey is similar for all different irregular shapes of structures. it is shows that the U Shape structure has the maximum lateral load compare to other shapes of buildings. Since the U shape building has higher base shear,

storey loads distributed from it are larger. The U shape has higher seismic demand and members need to be designed for greater forces. Hence the U shape building is suitable for this combination.
Further L shape structure is showing minimum lateral load compare to other structures. From the graph it is clearly observed that the L shape structure is suitable for this combination because L shape produces smaller base shear, lowering storey loads and L Shape may have local stress concentration at re-entrant corner and less overall stiffness compare to other irregular shapes.
From the graph it is clearly observed that L shape irregular structure is suitable compare to all other irregular shapes of buildings.

BASE SHEAR

Base shear is the total horizontal force at the base of a structure due to lateral loads like wind and earthquakes. It represents the overall lateral force demand transferred to the foundation during an earthquakes.
We can see that the T shape building shows the maximum base shear compare to other shape of buildings. The T shape likely exhibits the highest base shear due to its potentially larger mass and stiffness distribution, which would attract greater seismic forces during an earthquake.
Further L shape has the minimum base shear compare to other structures. From the table it is clearly observed that the L shape is suitable for this combination, because its geometry inherently offers less resistance or smaller effective mass and stiffness compared to the other irregular shapes. L shape stiffness and distribution of mass are essential in how a structure responds to lateral forces and how much shear force is transferred to its base during an earthquake.
It is clearly observed that L shape irregular structure is suitable compare to all other irregular shapes of buildings.

6. CONCLUSION

According to the results and discussion, the investigation conforms that irregular building plays critical role in enhancing the structural performance of this buildings subjected to seismic load.

- The story displacement analysis shows that the T Shape buildings effectively reduces the lateral moment, improving the overall stability. This is attributed to its higher stiffness and more uniform load distribution. T shape structure is found to be more suitable for controlling story displacement compared to other irregular buildings shapes.
- The story drift analysis shows that the T Shape structure effectively reduces the lateral moment, improving the overall stability. This is due to its efficient load transfer mechanism and higher stiffness which enhance stability and reduce lateral deformations under seismic loading.
- The story shear analysis shows that the L Shape structure effectively reduces the lateral moment, improving the overall stability. The L Shape building exhibits the minimum storey shear compare to other shapes of buildings, this can be explained by its less floor area and structure mass, which result in lesser base shear demands during seismic events.
- The lateral load analysis shows that the L Shape structure effectively reduces the lateral moment, improving the overall stability. The L Shape building experienced smaller base shear, lowering storey load distribution, due to its geometry and load distribution. The L shape have local stress concentration at re-entrant corner and less overall stiffness.
- The base shear analysis shows that the L Shape structure effectively reduces the lateral moment, improving the overall stability. The L Shape structure provides less resistance or smaller effective mass and stiffness compared to others. Its stiffness and distribution pf mass plays a critical role in how a structure response to lateral forces and how much shear force is transferred to its base during an earthquake.

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