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A Comparison of Geometric Shapes of Seismic and Wind Load Resistance In G+49 Building Designs

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ABSTRACT

As the world progresses towards modernization, the increasing population has led to one of the most pressing challenges—limited land availability. To address this issue, the conventional approach of horizontal building designs must be reconsidered, and the focus should shift towards high-rise buildings. This study explores the design of a 50-story high-rise building using different geometric shapes, specifically rectangular, square, triangular, circular, and elliptical. The design is based on maintaining constant parameters, including floor area, column size, beam size, and slab thickness across all shapes.Following the design process, various loads—seismic, wind, live, and dead loads—are applied to the structure to simulate real-world conditions. The primary objective of this work is to evaluate and determine the most stable and feasible building shape for high-rise structures in the most critical seismic (Zone V) and wind (Zone V) zones. The Shear Force (Fy) on the beam of different shapes of building is maximum for the Triangular shape building.i.e.25.058 kN, and minimum for the elliptical shape building. i.e.4.838kN. The Shear Force (Fy) on the Column of different shapes of building is minimum for the elliptical shape of building.i.e.25.498kN.The Bending Moment (kNm) on the beam of different shapes of building is maximum for the Triangular shape building.i.e.116.840kNm, and minimum for the elliptical shape building. i.e.13.939kNm.The Bending Moment (kNm) on the Column of different shapes of building is minimum for the elliptical shape building. i.e.37.083 kNm. The Displacement (mm) on the Beam of different shapes of building is maximum for the Triangular shape building.i.e.711.662 mm, and minimum for the elliptical shape building. i.e. 231.377 mm. The Displacement (mm) on the Column of different shapes of building is maximum for the Triangular shape building.i.e.705.039 mm, and minimum for the elliptical shape building. i.e. 226.707 mm. The Stress (N/mm) on different shapes of building is maximum for the Triangular shape building.i.e.39.5231N/ mm^2, and minimum for the elliptical shape building. i.e. 0.0034N/mm^2.The most safe shape of 50 storey high rise building in seismic zone v and in wind zone v is Elliptical shape. The most unstable shape of 50 storey high rise building in seismic zone v and in wind zone v is Triangular Shape. The study shows the most safe shape of 50 storey high rise building in seismic zone v and in wind zone v is Elliptical shape. The most unstable shape of 50 storey high rise building in seismic zone v and in wind zone v is Triangular Shape. Additionally, the study focuses on assessing the stress distribution and structural performance of each shape under these extreme loading conditions. The results aim to provide valuable insights into the optimal high-rise building design for seismic and wind resistance, contributing to safer and more efficient urban development.

Keywords: -High rise building, Seismic load, Wind load, ZoneV, critical, shapes.

1. Introduction

They are primarily a reaction to the rapid growth of the urban population and the demand by business activities to be as close to each other as possible. Architects reinterpretations of the building type, the high cost of land in urban areas, the desire to prevent the disorganized expansion, the need to preserve agricultural production, the concept of skyscraper, influence of cultural significance and prestige, have all contributed to force buildings upward. Today, it is virtually impossible to imagine a major city without tall buildings. The importance of tall buildings in the contemporary urban development is without doubt ever increasing despite their several undeniable negative effects on the quality of urban life. Many researches and studies have been done in order to mitigate excitations and improve the performance of tall buildings against wind loads & earthquake loads. An extremely important and effective design approach among these methods is aerodynamic modifications, including, modifications of building's corner geometry and its cross-sectional shape. Tall buildings are gigantic projects demanding incredible logistics and management, and require enormous financial investment. A careful coordination of the structural elements and the shape of a building which minimize the lateral displacement, may offer considerable savings. Nowadays, the challenge of designing an efficient tall building has considerably changed. The conventional approach to tall building design in the past was to limit the forms of the buildings to a rectangular shape mostly, but today, much more complicated building geometries could be utilized.

1.1 OBJECTIVE OF THE PRESENT STUDY

- To contribute to the development of design guidelines for high-rise buildings, focusing on the impact of different building shapes in controlling wind and earthquake loads, providing a reference for architects, engineers, developers, and students.
- To design and analyze a 50-story high-rise building in accordance with the relevant Indian Standards (IS codes) for structural integrity and safety.
- To analyze the building's earthquake resistance as per IS 1893-2016 (Part I) criteria for earthquake-resistant structures
- To assess the building's wind load resistance following the guidelines set in IS 875 (Part 3)-1987 for wind-resistant structures.
- To provide comparative data on the performance of different building shapes, aiding in the selection of the most suitable shape for high-rise construction.
- To identify the most and least desirable building shapes based on structural stability, feasibility, and compliance with design codes.

2. LITERATURE SURVEY

These buildings may have better architectural appeal but require sophisticated computational analysis for load distribution, as they often lead to vortex shedding and unbalanced wind forces (Rathore et al., 2017). The geometric shape of a building plays a major role in determining its response to dynamic forces such as wind and seismic activities. Research has explored how different shapes influence factors like load distribution, torsional behavior, and overall stability.

Rectangular and Square Shapes: While these shapes are popular due to their simplicity and efficiency, they are often subject to lateral twisting under wind and seismic forces. Recent studies have focused on optimizing the core and shear wall placement to resist these torsional effects (Kim et al., 2023). New materials like carbon fiber reinforced polymer (CFRP) are also being considered for retrofitting and improving lateral stability.

Circular and Cylindrical Shapes: Circular buildings are gaining attention due to their superior aerodynamic properties, reducing wind-induced vibrations and torsion. Recent studies show that cylindrical shapes can effectively minimize vortex shedding effects (Li et al., 2024). The application of advanced Computational Fluid Dynamics (CFD) models has improved wind load predictions and the overall design of these buildings.Irregular and Non-Symmetrical Shapes: Buildings with irregular geometries, such as triangular, star-shaped, or twisting forms, are increasingly popular in modern architecture. However, they pose challenges in terms of torsion and load distribution. Recent research (Gupta et al., 2024) suggests using dynamic response analysis and tuning of damping systems to mitigate the adverse effects of irregular shapes under seismic and wind loads. Integrated design approaches combining both architectural and structural requirements are being developed to optimize these shapes without compromising structural integrity.

Recent studies show that the geometric shape of a building significantly influences its response to dynamic loads, including wind and seismic forces. The latest research has focused on how different shapes affect the structural stability, load distribution, and torsional behavior of 50-storey high-rise buildings.

Rectangular and Square Shapes: These shapes, though conventional, present significant challenges due to wind-induced torsion and differential displacement. Research from 2024 (Sharma et al., 2024) highlights new optimization techniques in the design of shear walls and core structures to combat torsion. Advanced techniques, such as performance-based design and AI-assisted load distribution, are now increasingly applied to minimize torsional effects.

Irregular Shapes (Twisting, Elliptical, and Asymmetrical Designs): Recent developments in computational methods are making it easier to design and analyze high-risebuildings with irregular geometries. Irregular shapes, while offering architectural appeal, can lead to unpredictable seismic and wind responses. A 2024 study by Kumar et al. focuses on reducing vortex shedding effects in such buildings using advanced CFD simulations and hybrid damping techniques.

Loading Conditions in High-Rise BuildingsHigh-rise buildings are subjected to several loading conditions, with wind and seismic forces being the most critical for tall structures.Wind Loads: Wind load analysis is especially crucial for buildings over 30 storeys high. According to the International Building Code (IBC), the wind load must be

calculated considering the wind velocity, exposure, and the height of the building (Sinha et al., 2014). The building shape influences the wind pressure distributionacross the facade. Buildings with more irregular shapes can experience higher vortex shedding and wind-induced vibrations.

Seismic Loads: High-rise buildings, particularly in seismic zones, are susceptible to lateral forces induced by earthquakes. Shape has a significant influence on the distribution of these forces. For example, buildings with a more compact shape tend to experience less torsion compared to elongated shapes (Basu & Ray, 2018). In the case of irregular shapes, seismic analysis can be more complex due to unpredictable modes of vibration and torsional resonance.

Dead and Live Loads: These loads typically don’t pose as much of a challenge as wind or seismic loads. However, they need to be considered in the overall design. Buildings with irregular shapes may have additional challenges in terms of efficient structural layout to accommodate these loads.High-rise buildings are subjected to a variety of loading conditions, the most significant of which include wind loads, seismic loads, and dead/live loads. Recent research has focused on how different shapes affect the response to these loads.

Wind Loads: As building heights increase, wind load analysis becomes increasingly critical. Recent studies (Xu et al., 2024) have highlighted the importance of using turbulence models in wind load analysis for buildings taller than 30 storeys. New findings suggest that buildings with aerodynamic shapes, such as tapered or twist-shaped designs, significantly reduce wind pressure and minimize vortex-induced oscillations, improving structural safety.

Seismic Loads: Seismic forces are a primary concern in earthquake-prone regions. Modern research emphasizes the importance of dynamic analysis in high-rise buildings. The shape of the building influences the torsional modes of vibration, which can lead to differential displacements and non-uniform structural behavior. Advances in hybrid structural systems, such as a combination of damping devices and tuned mass dampers (TMD), have been shown to mitigate the seismic response in buildings with complex shapes (Nakamura et al., 2023).

Dead and Live Loads: Although dead and live loads are less critical than lateral forces, they still require detailed analysis, especially in irregularly shaped buildings where load distribution can be uneven. Recent studies (Patel et al., 2024) have proposed advanced load distribution models that incorporate shape and material behavior, ensuring efficient structural design.

A major focus of research in 2024-2025 is on how various shapes of high-rise buildings respond to dynamic and static loads. The latest studies have refined methodologies for analyzing wind and seismic forces.

Wind Loads: Wind-induced forces are a primary concern for tall buildings. The latest research (Xu et al., 2025) uses advanced turbulence models to better predict wind pressures, particularly on buildings taller than 40 storeys. Optimized aerodynamic shapes (e.g., tapered or twisting forms) have been shown to significantly reduce wind load effects and vortex-induced oscillations, enhancing the building's overall stability.

3. METHODOLOGY

1.2 STAAD Pro V8i

STAAD Pro V8i is a structural analysis and design software initially developed by research engineers in Yorba Linda, California, in 1997. In late 2005, Bentley Systems acquired Research Engineers International. STAAD Pro is now one of the most widely used programs for structural analysis and design, supporting various design codes for steel, concrete, and timber. STAAD Pro V8i is a comprehensive, integrated finite element analysis and design program capable of analyzing any structure subjected to static loads, dynamic responses, wind, earthquake, and moving loads. As a leading tool in the field, STAAD Pro is commonly used for structural design tasks. The process of using STAAD Pro to achieve a design goal typically involves four main steps:

1. Prepare the input file: In this stage, the structure is described by specifying the geometry, materials, cross-sections, and support conditions.

2. Analyze the input file: It is crucial to use the correct STAAD Pro syntax to avoid errors. The structure must be stable based on the input data, otherwise, the program will flag an error. The output data must be carefully verified to ensure the accuracy of the input.

3. Watch the results and verify them: In POST-PROCESSING mode, the results are reviewed. The output file corresponding to various loads or load combinations is chosen to analyze the results.

4. Send the analysis results to the design engines: Once the analysis is complete, STAAD Pro can be instructed to transfer the results to the steel or concrete design engines for further design. Important data, such as Fy (yield strength) and Fc (concrete strength), is assigned, and the design process for beams and columns is performed. Running the analysis will present the full designed structure.

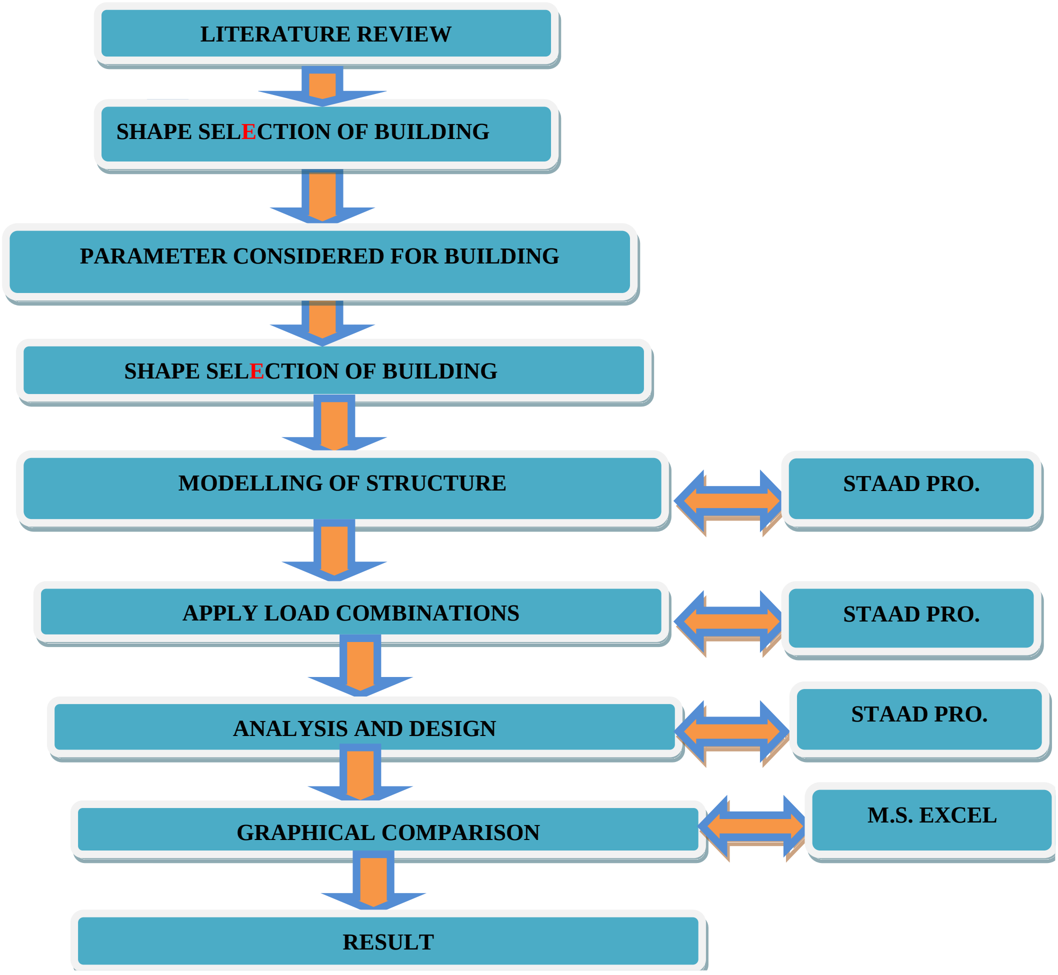
The current study focuses on the analysis and design of a high-rise building using STAAD Pro, a popular software in structural engineering. We selected STAAD Pro due to its advantages, including:

- User-friendly interface
- Conformance with Indian Standard Codes
- Versatility in solving various types of structural problems
- High accuracy of results

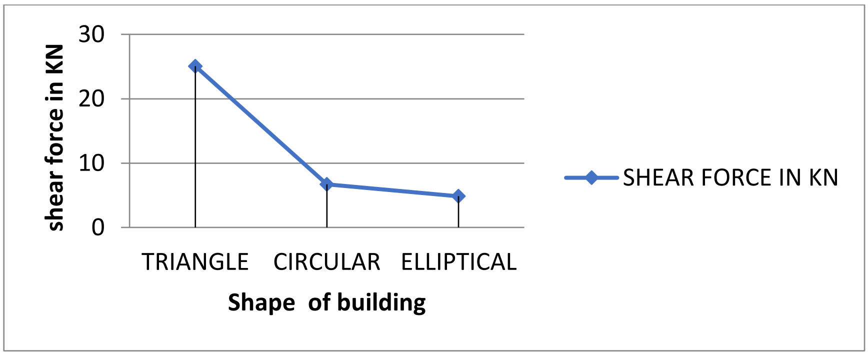
4. Flow Chart

defining the geometry of a structure, assigning material properties, specifying supports and loads, selecting the appropriate analysis method (like linear static, dynamic, or buckling), performing the analysis, and then interpreting the results to design structural elements like beams and columns, all within the software's interface.

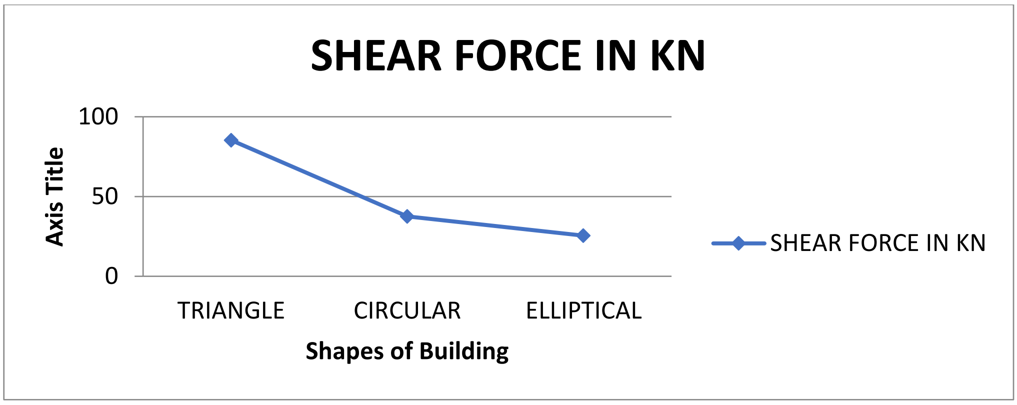
FLOW CHART OF THE PRESENT STUDY



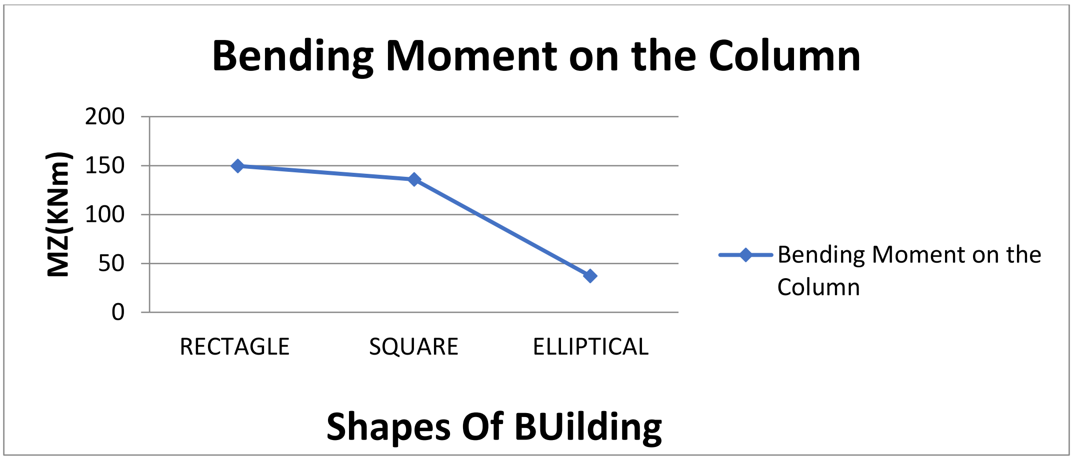
5. RESULTS&DISCUSSIONS



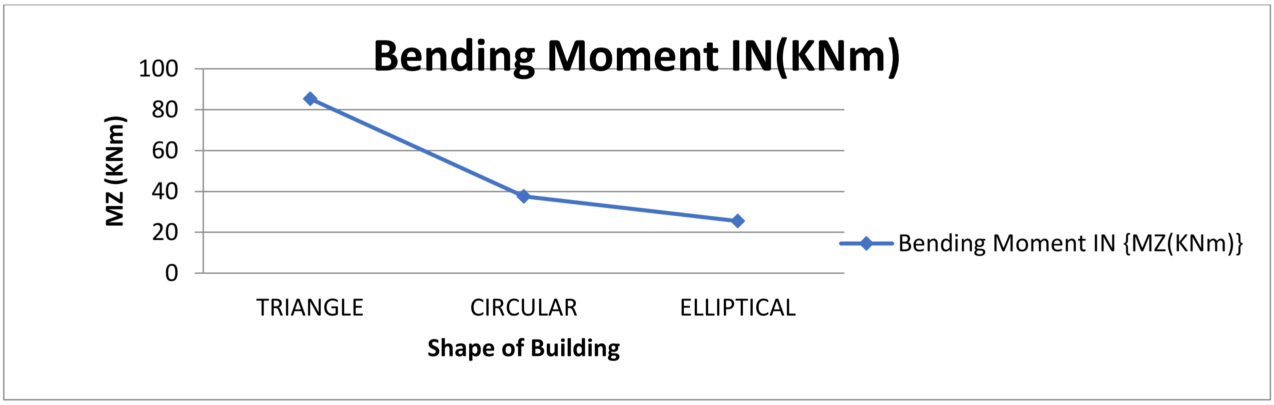
GRAPH 1 SHAPE OF BUILDING V/S SHEAR FORCE IN BEAM



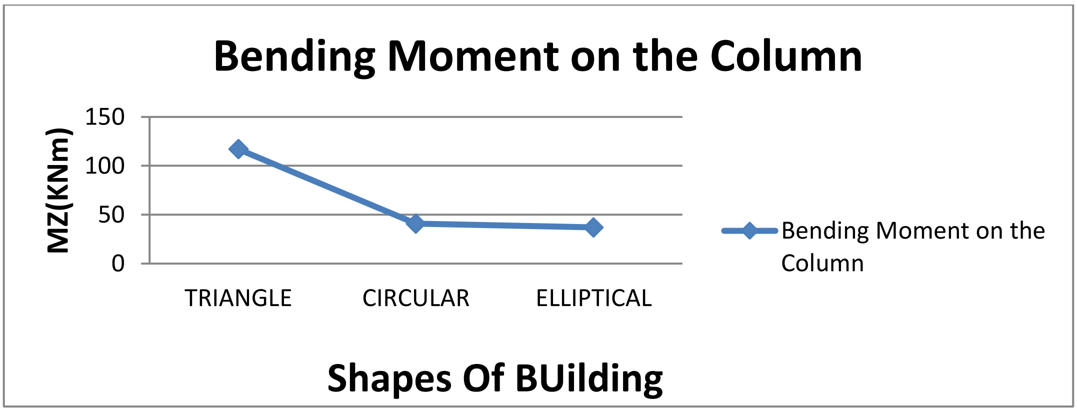
Graph 2 SHAPE OF BUILDING V/S SHEAR FORCE IN COLUMN



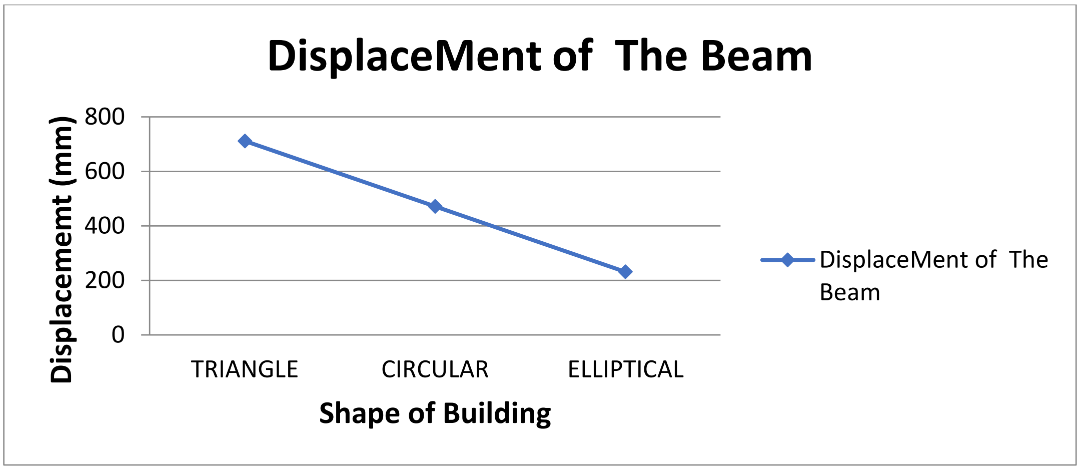
Graph 3 SHAPE OF BUILDING V/S BENDING MOMENT IN COLUMN



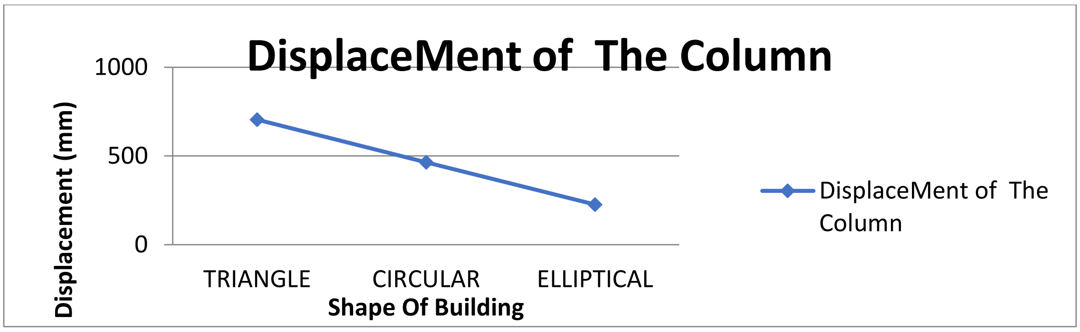
Graph 4 SHAPE OF BUILDING V/S BENDING MOMENT IN BEAM



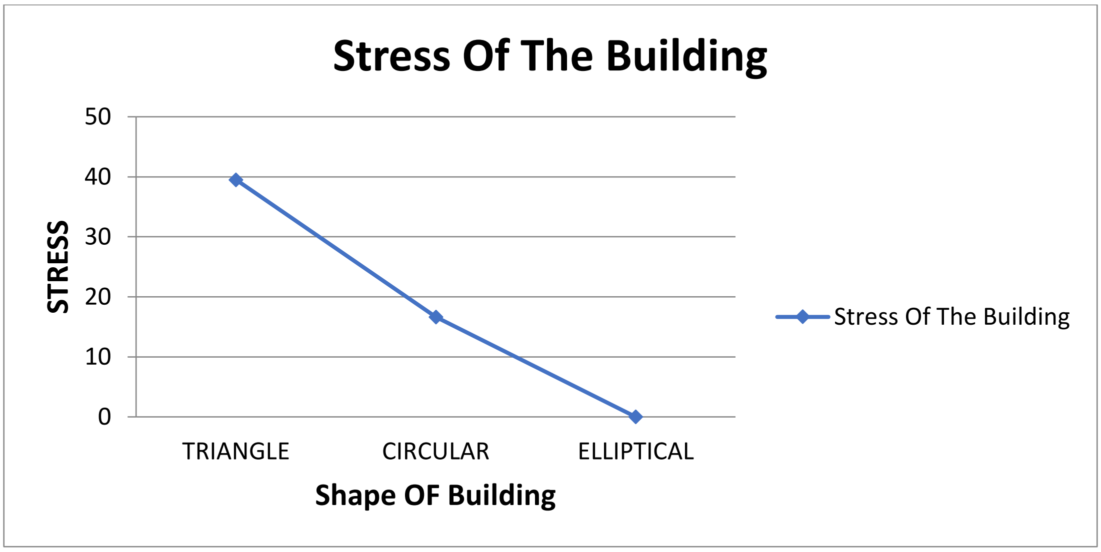
Graph 5 SHAPE OF BUILDING V/S BENDING MOMENT IN COLUMN



Graph 6 SHAPE OF BUILDING V/S DISPLACEMENT IN BEAM



Graph 6 SHAPE OF BUILDING V/S DISPLACEMENT IN COLUMN



Graph 8 SHAPE OF BUILDING V/S STRESS IN BUILDING

6. CONCLUSIONS

- The Shear Force (Fy) on the beam of different shapes of building is maximum for the Triangular shape building.i.e.25.0 kN, and minimum for the elliptical shape building. i.e.4.84kN.
- The Bending Moment (kNm) on the beam of different shapes of building is maximum for the Triangular shape building.i.e.116.85kNm, and minimum for the elliptical shape building. i.e.13.94kNm.
- The Displacement (mm) on the Beam of different shapes of building is maximum for the Triangular shape building.i.e.711.67 mm, and minimum for the elliptical shape building. i.e. 231.38 mm.

- . The Stress (N/mm) on different shapes of building is maximum for the Triangular shape building.i.e.39.52N/ mm, and minimum for the elliptical shape building. i.e. 0.0034N/mm.
- The most unstable shape of 50 storey high rise building in seismic zone v and in wind zone v is Triangular Shape.

Overall conclusion:

These results indicate the relative performance of different building shapes under seismic and wind load conditions, with the Elliptical shape being the most stable .

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