"Seismic Response with Retrofitting for G+9 Multistoried R.C. Structure Utilizing R.C.C Jacketing as Well as Steel Wrapping Techniques by Using ETAB"

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ABSTRACT

Seismic retrofitting greatly improves the safety and effectiveness of reinforced concrete (R.C.) buildings in earthquake-prone areas, and this study examines this phenomenon in the G+9 multiple-story concrete buildings. It examines the seismic response and the effects of two common retrofitting techniques — RCC (Reinforced Cement Concrete) Jacketing and Steel Wrapping. Using ETABS software, we carried out digital modeling and analyses, including both nonlinear static and dynamic (time history) analyses with reference to the El-Centro and Uttarkashi earthquake data. For both retrofitted and non-retrofitted scenarios, important features of the buildings, including the natural and derived (shear and axial) frequencies, lateral slip and uneven shifting (drift) of the floors and base, overall mass, and stress distribution, were assessed. The data indicated improved stiffness, overall mass, and load-carrying-ability of all retrofitted structures, and showed noticeable differences in the RCC Jacketing and Steel Wrapping techniques. For the overall retrofitting of buildings, RCC Jacketing was more effective in stiffness improvement and overall mass than Steel Wrapping. Improved strength and drift minimization were achieved, and practical applications retrofitting-system-selection of high-rise concrete structures gained based on steel wrapping development.

Keywords: Seismic Retrofitting, RCC Jacketing, Steel Wrapping, ETABS, Time-History Analysis, Inter-Storey Drift, Lateral Displacement, Base Shear, Structural Stability, Earthquake-Resistant Design.

1. INTRODUCTION

Reinforced concrete (R.C.) constructions are a major part of the built environment, particularly in the developing world, where their rapid deterioration has often been built with little consideration for seismic risk. This has made most of the existing multi-storey constructions highly susceptible to damage during earthquakes. Hence, retrofitting has become urgent in an attempt to improve multi-storey structures' seismic performance and maintain overall structural safety [1]. Of the numerous retrofitting options, RCC jacketing and steel wrapping are most popular for increasing strength, stiffness, and ductility. RCC jacketing adds concrete to the cross-section of existing structural members and steel wrapping helps with confinement and improves overall load-carrying capacity. even so, their relative performance on mid-rise buildings, esp. G+9, is still not sufficiently documented. The development of computational resources, particularly ETABS, has made it possible to quantitatively assess and contrast architectural design options of seismic retrofitting for buildings. This is the purpose of this study. The study seeks to assess and contrast the seismic performance of a G+9 R.C. building that has undergone retrofitting with RCC jacketing and steel wrapping, with emphasis on indicators such as improved displacement, drift, base shear, and overall performance of the structure [2].

1.1 Overview of the seismic vulnerability of R.C. buildings.

Reinforced concrete buildings have greatly dominated the urban civil building field owing to their great adaptability and cost-effective building solutions. and their and their cost Therefore to keep the buildings firm and intact in future contributions to Reinforced concrete buildings have greatly dominated the urban civil building field. and their and their cost and their cost-effective solutions However, these buildings show great deficiencies in sustaining earthquakes. Many of these buildings are the result of old design codes which resulted in poor flexible reinforcement detailing of concrete structures leading to poor column - strong beam syndrome, poor beam detailing, and severe and weaker flexible detailing weak ductility and folding. In addition, poor unsafe construction and poor quality materials and poor missing confinement reinforcement and lost lost functional reinforcing. The building then suffers brittle fractured building material and impacts of a segments of seismic failure. Collapse structures such as floors of ceiling void and heavy [3]. Reinforced concrete buildings have lightweight building plans and overall layout of floors. Defensive aims to improve the flexible remaining material and construction Loss of use to these buildings. to minimize their total remaining construction and improve building control to improve soft Remaining control overall Remaining and collapse[4].

1.2 Importance of retrofitting existing structures.

Concurrently, and paradoxically, many significant formal, public and private institutions globally became increasingly weak and abstractive in current reform efforts being introduced. Buffing may be the best alternative in taking protective measures to defend the weak structures from potential threats and other aggressing forces[5]. Retrofit is the process of incrementally adding in new functionalities to a legacy system and accompanying model extensions. Buffing protects the existing structures from sustaining further damage and potential collapse in the event of an earthquake. It is a modification of the existing design to be more resilient to more extreme events including earthquakes, other extreme weather events and conditions to include high winds and hail, in addition to soil liquefaction [6].

1.3 Common retrofitting techniques

Retrofitting is the process of upgrading or improving an existing building or structure to enhance its performance or extend its lifespan. It can involve a range of modifications, from structural improvements to energy efficiency upgrades. As explained by Melbourne VIC, retrofitting can address issues such as outdated systems, structural weaknesses, and compliance with modern standards [7].

1.4 Importance of Retrofitting

Retrofitting is essential for several reasons:

- **Compliance with Modern Codes:** Updating buildings to meet current building codes and regulations.
- **Enhanced Safety:** Improving structural integrity and safety features.
- **Energy Efficiency:** Reducing energy consumption and operating costs through modern technologies.

Figure.1 Retrofitting

Structural Retrofitting

Structural retrofitting focuses on strengthening the building's structural components to handle increased loads or seismic activity. Techniques include adding new support elements, reinforcing existing structures, and using advanced materials like carbon fibre [8].

Energy Efficiency Upgrades

Energy retrofitting aims to reduce energy consumption and improve the environmental performance of buildings. This can involve installing new insulation, upgrading windows and doors, and implementing advanced HVAC systems. Elmhurst Energy provides detailed insights into various energy efficiency upgrades [9].

Seismic Retrofitting

Seismic retrofitting involves enhancing a building's ability to withstand earthquakes. Techniques include strengthening foundations, adding shock absorbers, and reinforcing walls. This type of retrofitting is particularly important in earthquake-prone regions.

Water Management Improvements

This technique addresses issues related to water ingress and drainage. It includes upgrading waterproofing systems, improving drainage systems, and installing new water management solutions to prevent water damage and improve the building's longevity.

Benefits of Retrofitting

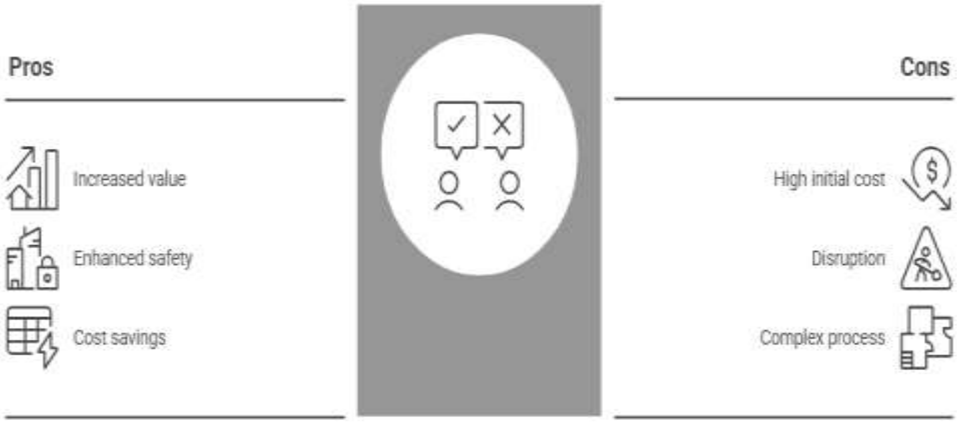

Figure 2. Benefits of Retrofitting

Increased Property Value

Retrofitting can significantly increase the value of a property by modernizing its features and improving its performance. Updated buildings often attract higher rental yields and resale values.

Enhanced Safety and Comfort

Improved structural integrity and modern amenities enhance the safety and comfort of occupants. Energy-efficient upgrades also contribute to a more comfortable living or working environment by maintaining stable indoor temperatures.

Cost Savings

Energy efficiency retrofitting can lead to substantial cost savings on utility bills. Additionally, addressing maintenance issues through retrofitting can prevent costly repairs in the future [10].

2. RELATED WORK

The reviewed studies highlight the need for a comparative seismic assessment of different retrofitting techniques, forming the basis for the present research.

Mr. Harshal Katolkar et.al (2024) In this investigation. A seismic design is based on the combination of strength and ductility. With frequent seismic shocks, the structure is predicted to stay elastic. More changes to design techniques are required that take into account the real dynamic character of environmental disturbances. In addition, several advanced procedures are employed to enhance existing buildings, such as various retrofitting approaches. All of these strategies have their own benefits. The primary goal of this research is to investigate the behaviour of retrofitted buildings, namely the use of steel jacketing to improve building performance. The current research seeks to examine the suitability of multi-storey frame buildings employing retrofitting techniques for seismic excitations [11].

Akshay V. Sawdekar et.al (2022) The report provides a short literature assessment of several retrofitting strategies, including relevant methodology and distinction based on uses and constraints. According to the findings, retrofitting jacketing is the most effective strategy for enhancing member strength. However, before performing any seismic retrofit strategy on a damaged or insufficient building, a complete and accurate assessment of the structure's seismic performance and present condition is essential. The retrofitting of structural elements is dependent on the evaluation methodologies that provide the condition index to determine the appropriate approach for retrofitting. This paper also includes a comparison of numerous retrofitting strategies depending on their efficacy[9].

Mr. Harshal Shankar rao Khode et.al (2019) Investigate the research on the selection of materials and processes to be employed, which is influenced by several factors that may be regarded from various perspectives. Financial resources are required and available, as are the applicability and appropriateness of materials for repairing damaged buildings. The use of conventional and creative repair materials, suitable technology, craftsmanship, and quality control throughout implementation are critical components in the effective repair, strengthening, and restoration of damaged buildings. The refit process encompasses a wide range of treatments, including preservation, rehabilitation, restoration, and rebuilding. Selecting the suitable treatment technique is a significant difficulty in the retrofit process, and it must be addressed uniquely for each project. Depending on the project goals, building preservation and rehabilitation may require an array of various technical issues, such as fire life safety, geotechnical dangers and remedies, weathering and water penetration, structural performance under earthquake and wind loads[12].

Karan Singh et.al (2019) In this investigation. Many current reinforced concrete buildings in the globe are unsuitable for earthquakes. Recent earthquakes that happened over the previous decade have shown that substantial damage was caused by poor structural performance during the earthquake rather than earthquakes themselves. The present building structure, which was designed and built according to early codal standards, does not meet the criteria of the current seismic code and design methods. Seismic retrofitting is widely recognised as the most effective means of lowering the danger of structural damage. Retrofitting procedures have improved significantly in recent years. This research focusses on the fundamentals of analysing and retrofitting structures against seismic disasters. A three-dimensional R.C. frame constructed utilising linear elastic dynamic analysis and the response spectrum approach[10].

Trupti K. Talwekar et.al (2018) performed a study of A seismic design is based on the combination of strength and ductility. With frequent seismic shocks, the structure is predicted to stay elastic. More changes to design techniques are required that take into account the real dynamic character of environmental disturbances. In addition, several advanced procedures are employed to enhance existing buildings, such as various retrofitting approaches. All of these strategies have their own benefits. The primary goal of this research is to investigate the behaviour of retrofitted buildings, namely the use of steel jacketing to improve building performance. The current research intends to assess the seismic soundness of multi-story frame buildings using retrofitting approaches. The retrofitted building, which includes steel jacketing, is analysed and compared to a bare frame structure utilising time history and the pushover analysis approach. Commercial software SAP2000 v16 is utilised for the study. The structure's reactions are compared using various factors such as displacement, base shear, plastic hinges, and the time period of mode shapes from FEMA-356. The results demonstrate that plastic hinge creation during earthquake at beam-column junction may enhance performance with the application of retrofitting approach, such as steel jacketing [13].

3. RESEARCH METHODOLOGY

The research methodology outlines the systematic approach adopted to analyze and compare the seismic performance of a G+9 reinforced concrete structure before and after retrofitting using RCC jacketing and steel wrapping techniques. The methodology integrates analytical modelling, simulation-based analysis, and comparative evaluation to ensure an accurate and reliable assessment of structural behavior under seismic forces.

3.1 Research Approach

This study follows an **analytical and simulation-based approach**, where the structural models are developed and analyzed using ETABS software. The process includes developing baseline and retrofitted models, applying seismic loads, performing dynamic analyses, and evaluating performance parameters. The study is quantitative in nature because it uses numerical outputs such as displacement, drift, stresses, and base shear.

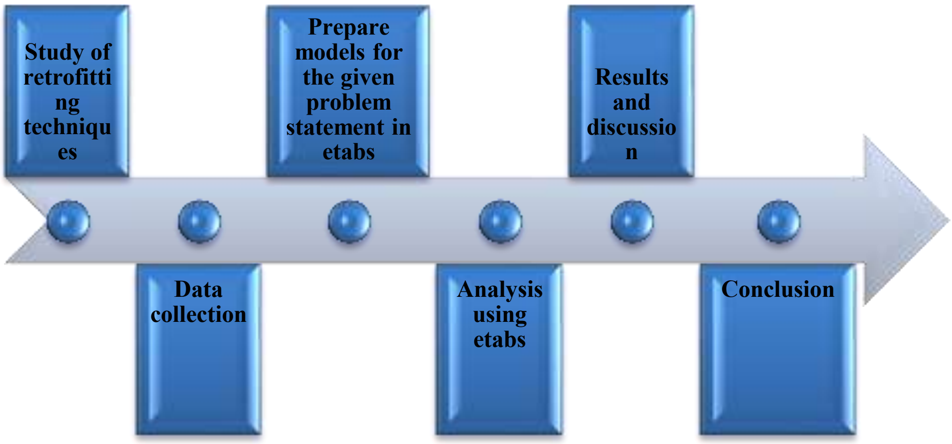

Figure 3.1 Research Plan

3.2 Data Sources

Primary Data (Simulation Outputs)

Data generated through ETABS software:

- Natural frequencies and mode shapes
- Time-history response
- Displacement, drift, velocity, and acceleration
- Axial forces, stresses, and support reactions

Secondary Data

- IS Codes: IS 1893:2016, IS 875, IS 456:2000
- Research papers, journals, and technical standards
- Earthquake ground motion records (El Centro 1940 & Uttarkashi)

3.3 Model Development in ETABS

Two structural conditions were modeled:

3.3.1 Existing (Retrofitted) Model

A G+9 reinforced concrete building was modeled based on:

- Building geometry
- Material properties (M25 concrete, Fe500 steel)
- Dead load, live load, wind load, and earthquake load
- Seismic parameters: Zone III, medium soil (Pune region)

3.3.2 Retrofitted Models

Two retrofitting techniques were modeled:

a) RCC Jacketing Model

- Columns were enlarged by adding concrete with extra reinforcement.
- Proper shear connectors and bonding interfaces were considered.
- Member stiffness and strength were modified accordingly.

b) Steel Wrapping Model

- Steel plates were wrapped around columns.
- Anchored using bolts/adhesives and filled with grout.
- Confinement effects and increased load-carrying capacity were modeled.

3.4 Application of Loads

The following loads were applied as per IS codes:

- **Dead Load (DL)**
- **Live Load (LL)**
- **Wind Load (WL)**
- **Earthquake Load (EL)** using:
  - El Centro time history data
  - Uttarkashi earthquake time history

Load combinations were generated automatically as per IS 1893:2016.

3.5 Types of Analysis

Several analyses were performed to assess seismic performance:

3.5.1 Modal Analysis

- To determine natural frequencies and mode shapes.
- Helps understand dynamic characteristics of the structure.

3.5.2 Nonlinear Time History Analysis

Using ground motion data to evaluate:

- Displacement
- Drift
- Velocity
- Acceleration
- Structural response under real earthquake conditions.

3.5.3 Static Analysis

Conducted for:

- Gravity load effects
- Stresses and support reactions
- Wind load response

3.5.4 Comparative Analysis

Results from unretrofitted, RCC-jacketed, and steel-wrapped models were compared using:

- Lateral displacement
- Inter-storey drift
- Base shear
- Axial forces
- Stress distribution
- Dynamic response parameters

3.6 Validation of Analytical Results

To ensure the reliability of results:

- Manual calculations of axial forces were performed and compared.
- STAAD-Pro results were used as cross-validation.
- Findings were matched with trends reported in existing literature.

3.7 Summary

The adopted methodology ensures a comprehensive evaluation of seismic performance in both unretrofitted and retrofitted conditions. By integrating advanced modeling in ETABS with real earthquake data and comparative assessment, the study effectively identifies the most suitable retrofitting technique for improving the structural stability of G+9 RC buildings in seismic-prone regions.

4. RESULTS AND DISCUSSION

The results clearly demonstrate the improvements achieved through retrofitting and offer valuable insights into the relative effectiveness of RCC jacketing and steel wrapping

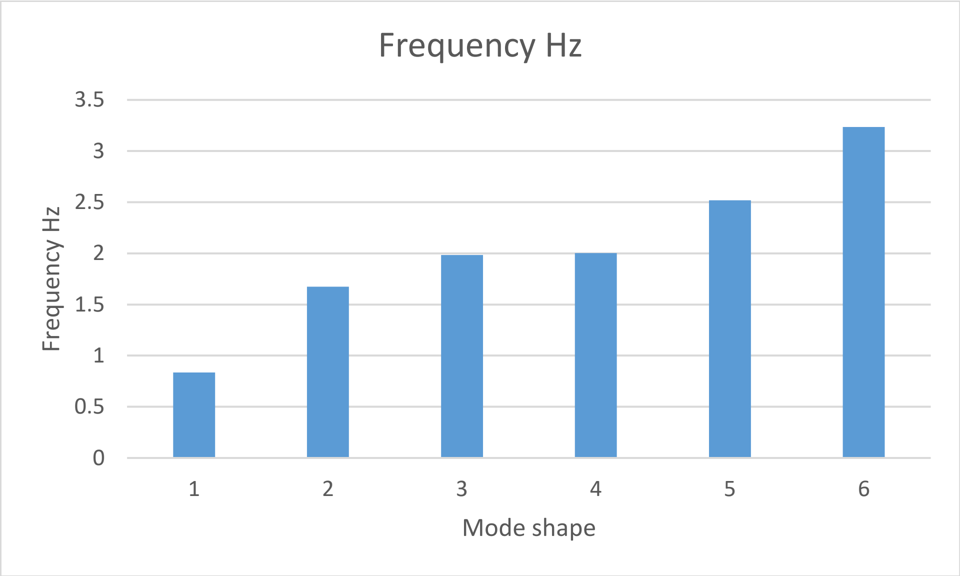

Figure 4. 1 Frequency due to EL-Centro for flat roof

Above graph shows frequency due to EL-Centro for flat roof. In which, x-axis shows the mode shape and y-axis shows the frequency Hz. Mode shape 6 has the highest frequency of 3.234 and mode shape 1 has the lowest freqency of 8.835.

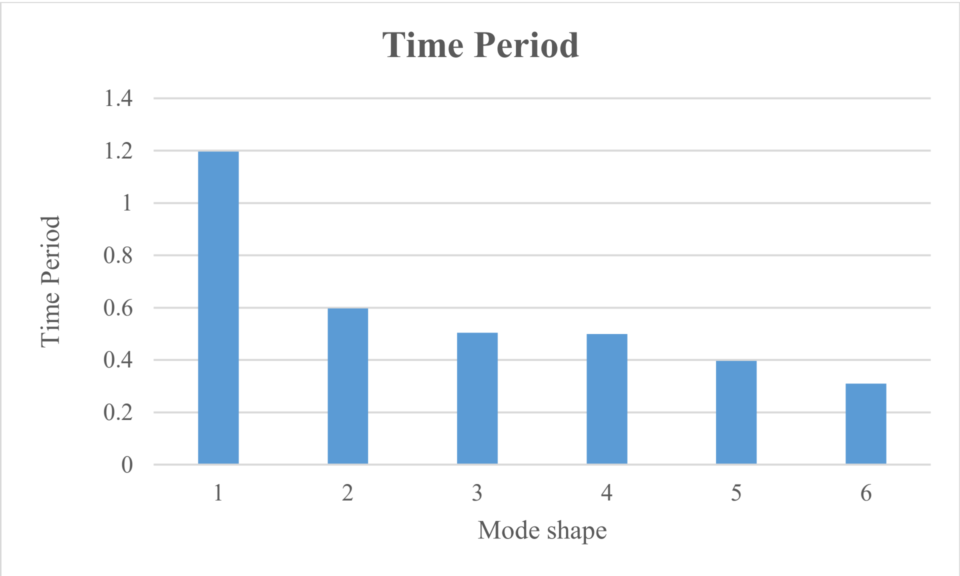

Figure 4. 2 Time period

Above graph shows the time period for flat roof. In which, x-axis shows the mode shape and y-axis shows the time period. Mode shape 1 has the highest time period of 1.197 and mode shape 6 has the lowest freqency of 0.309.

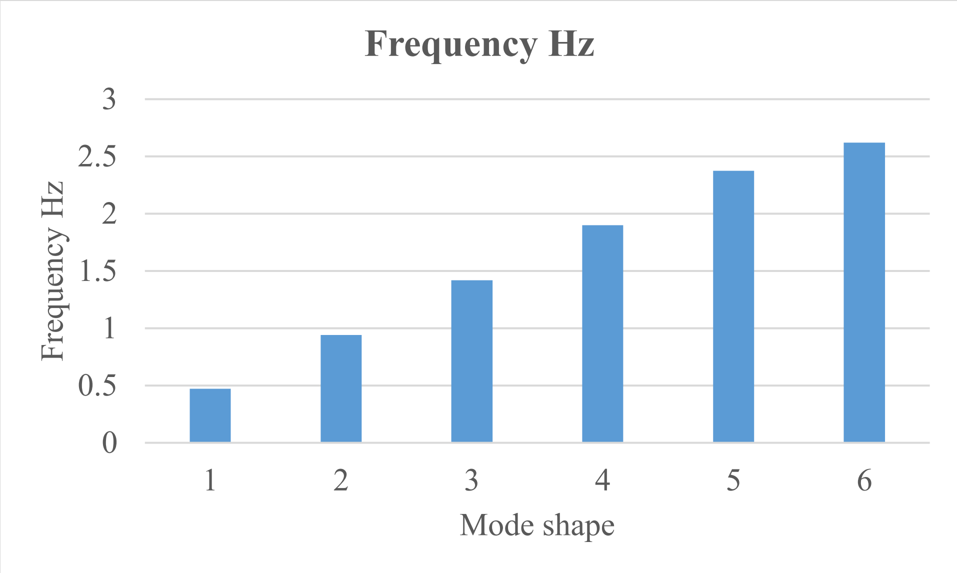

Figure 4. 3 Frequency Due To El-Centro Curved Roof

Above graph shows frequency due to EL-Centro for curved roof. In which, x-axis shows the mode shape and y-axis shows the frequency Hz. Mode shape 6 has the highest frequency of 2.622 and mode shape 1 has the lowest freqency of 0.473.

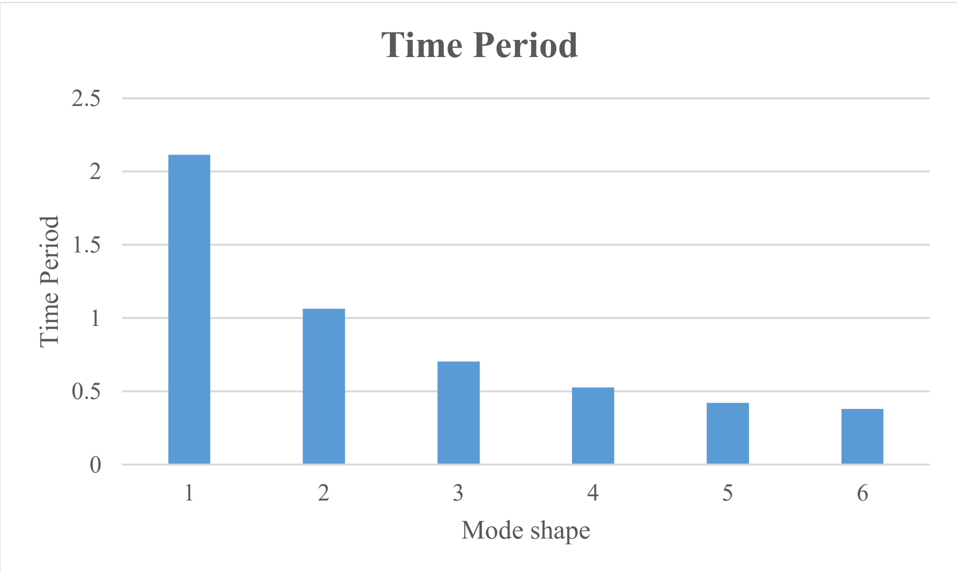

Figure 4. 4 Time period

Above graph shows the time period for curved roof. In which, x-axis shows the mode shape and y-axis shows the time period. Mode shape 1 has the highest time period of 2.115 and mode shape 6 has the lowest freqency of 0.381.

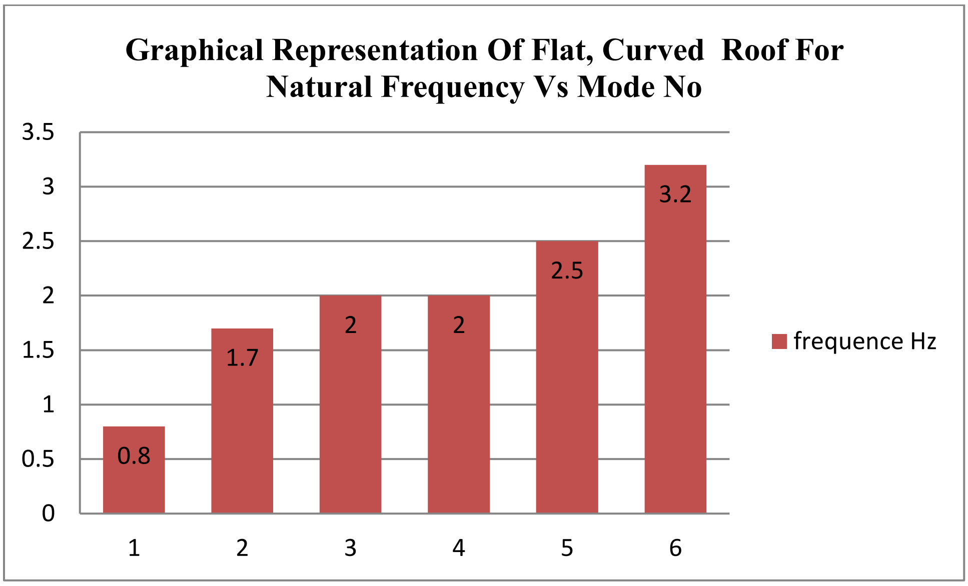

Figure 4. 5 Graphical Representation Of Flat, Curved Roof For Natural Frequency Vs Mode No

Above graph shows frequency comparison between flat and curved roof. Frequencies for the flat roof range from 0.8 Hz (Mode 1) to 3.2 Hz (Mode 6), while the curved roof shows higher frequencies, from 1.7 Hz (Mode 2) to 3.2 Hz (Mode 6). This indicates that the curved roof structure generally exhibits greater natural stiffness and potential resilience against dynamic forces like wind or seismic activity compared to the flat roof. Engineers can use this information to optimize roof designs for enhanced structural stability and reduced vulnerability to oscillations induced by external loads.

Flat Roof

Time-Displacement for Flat Roof

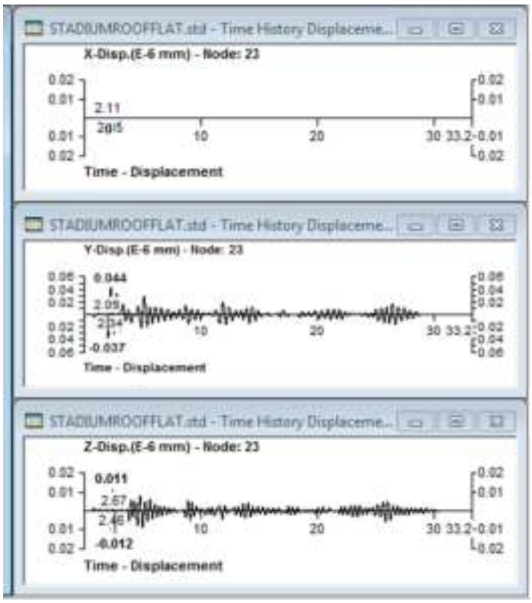

Figure 4. 6 Time-Displacement for Flat Roof

Above figure shows time displacement for flat roof. As we can see in the X-direction it shows high displacement of 2.11 and low displacement of 2.05, in Y-direction it shows high displacement of 2.34 and low displacement of 2.09 and in the Z-direction it shows high displacement of 2.67 and low displacement of 2.46.

Time Velocity for Flat Roof

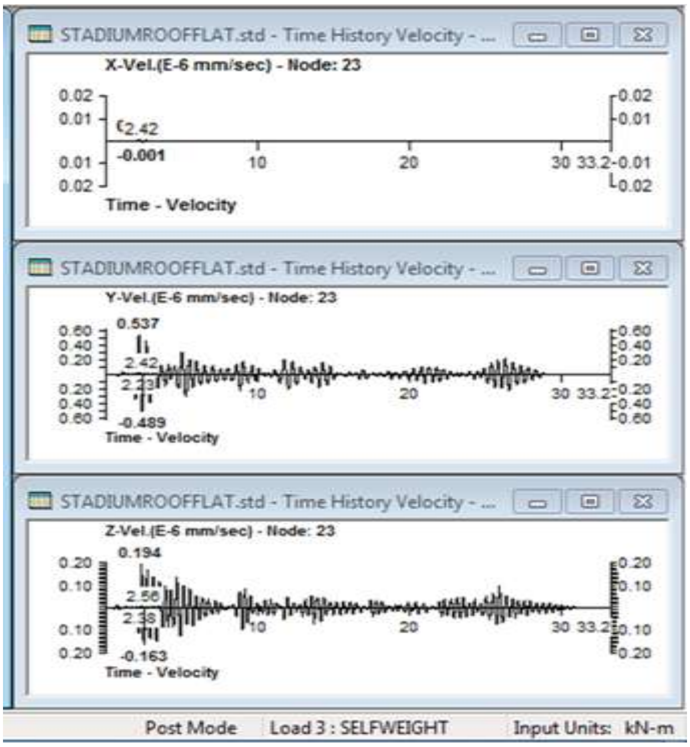

Figure 4. 7 Time Velocity for Flat Roof

Above figure shows time velocity for flat roof. As we can see in the X-direction it shows high velocity of 2.42 and low velocity of -0.001, in Y-direction it shows high velocity of 2.42 and low velocity of 2.23 and in the Z-direction it shows high velocity of 2.56 and low velocity of 2.38.

Time Acceleration for Flat Roof

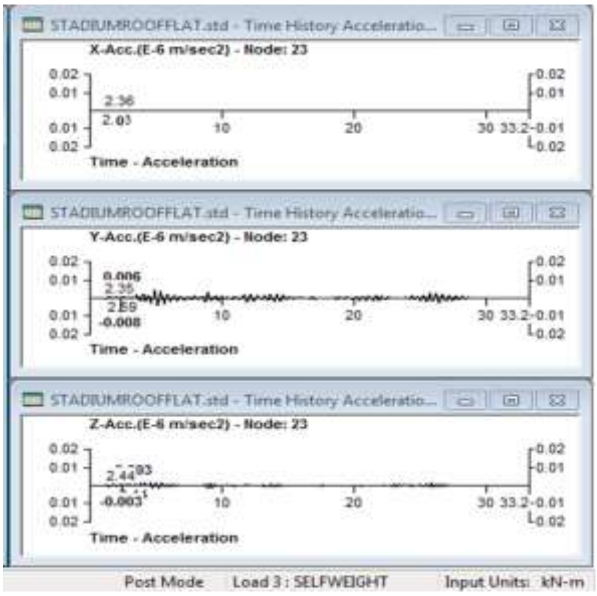

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Figure 4. 8 Time Acceleration for Flat Roof

Above figure shows time acceleration for flat roof. As we can see in the X-direction it shows high acceleration of 2.36 and low acceleration of 2.03, in Y-direction it shows high acceleration of 2.69 and low acceleration of 2.35 and in the Z-direction it shows high acceleration of 2.44 and low acceleration of -0.003.

Curved Roof

Time Displacement for Curved Roof

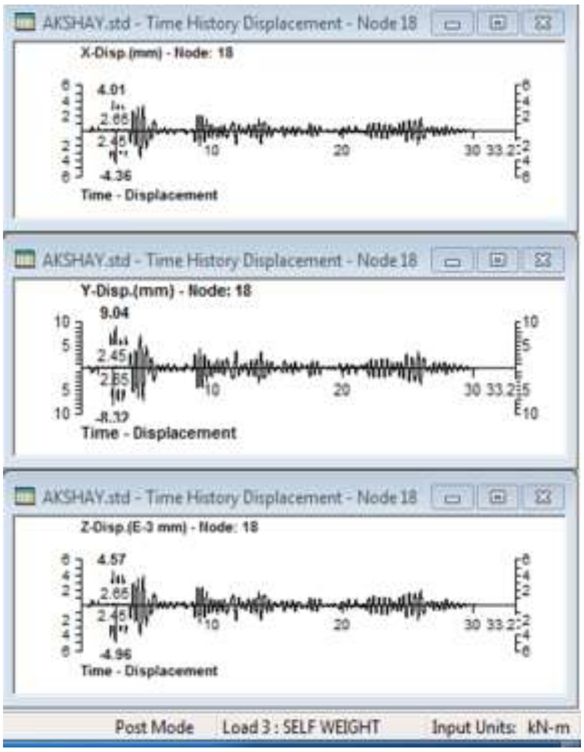

Figure 4. 9 Time-Displacement for Curved Roof

Above figure shows time displacement for curved roof. As we can see in the X-direction it shows high displacement of 2.65 and low displacement of 2.45, in Y-direction it shows high displacement of 2.65 and low displacement of 2.45 and in the Z-direction it shows high displacement of 2.65 and low displacement of 2.45.

Time Velocity for Curved Roof

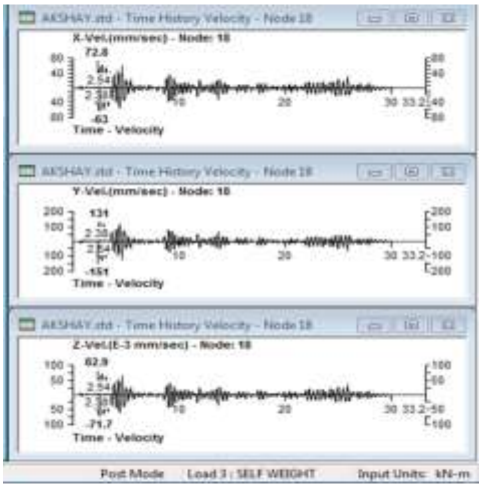

Figure 4. 10 Time-Velocity for Curved Roof

Above figure shows time velocity for curved roof. As we can see in the X-direction it shows high velocity of 2.54 and low velocity of 2.38, in Y-direction it shows high velocity of 2.54 and low velocity of 2.38 and in the Z-direction it shows high velocity of 2.54 and low velocity of 2.38.

Time Acceleration for Curved Roof

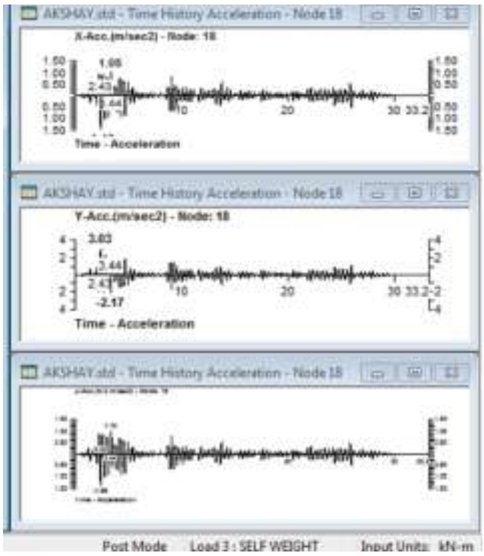

Figure 4. 11 Time-Acceleration for Curved Roof

Above figure shows time acceleration for curved roof. As we can see in the X-direction it shows high acceleration of 3.44 and low acceleration of 2.43, in Y-direction it shows high acceleration of 3.44 and low acceleration of 2.43 and in the Z-direction it shows high acceleration of 3.44 and low acceleration of 2.43.

Results of Time History Analysis For Flat Curved And Inclined Roof By Uttarakashi Data

Time Displacement For Flat Roof

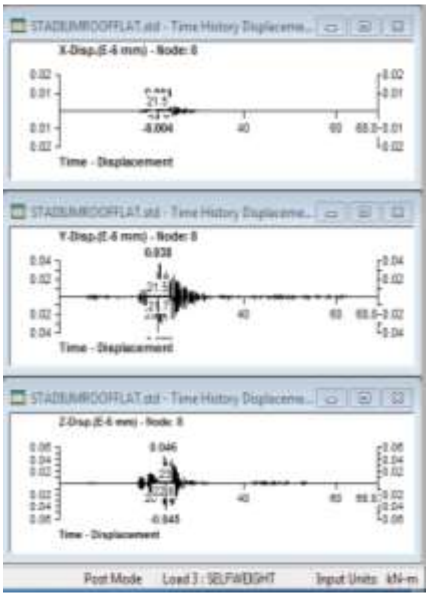

Figure 4. 12 Time-Displacement for Flat Roof

Above figure shows time displacement for flat roof. As we can see in the X-direction it shows high displacement of 21.5 and low displacement of -0.004, in Y-direction it shows high displacement of 21.7 and low displacement of 21.5 and in the Z-direction it shows high displacement of 23 and low displacement of 22.8.

Time Velocity for Flat Roof

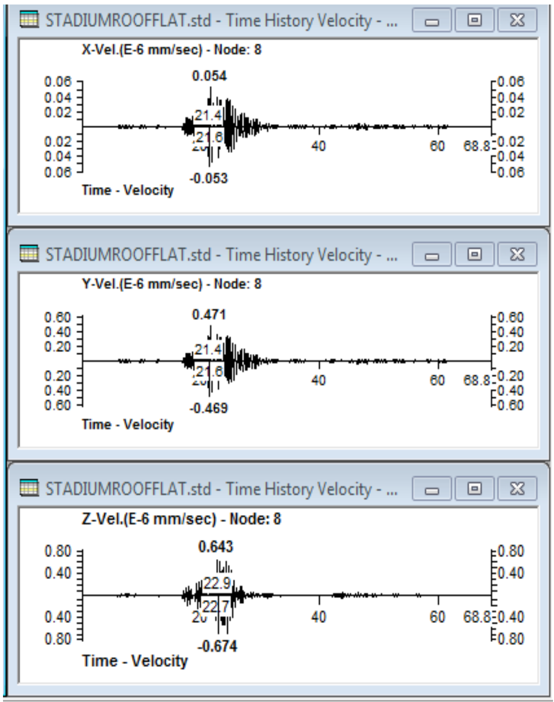

Figure 4. 13 Time-Velocity for Flat Roof

Above figure shows time velocity for flat roof. As we can see in the X-direction it shows high velocity of 21.6 and low velocity of 21.4, in Y-direction it shows high velocity of 21.6 and low velocity of 21.4 and in the Z-direction it shows high velocity of 22.9 and low velocity of 22.7.

Time Acceleration for Flat Roof

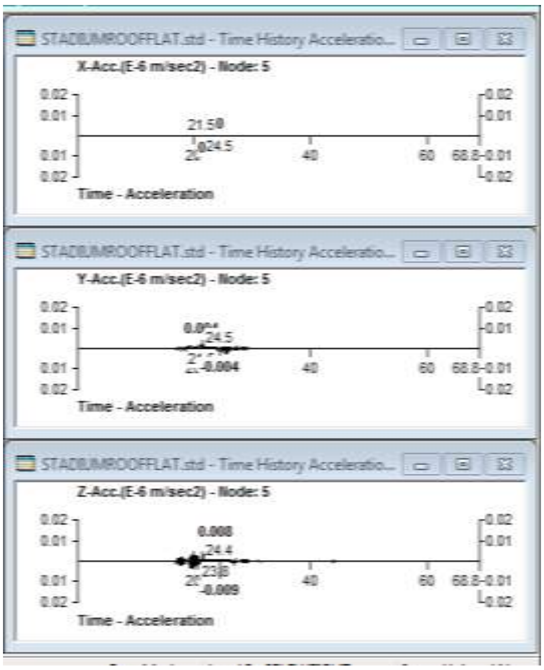

Figure 4. 14 Time-Acceleration for Flat Roof

Above figure shows time acceleration for flat roof. As we can see in the X-direction it shows high acceleration of 24.5 and low acceleration of 21.5, in Y-direction it shows high acceleration of 24.5 and low acceleration of -0.004 and in the Z-direction it shows high acceleration of 24.4 and low acceleration of 23.8.

Curved Roof

Time Displacement for Curved Roof

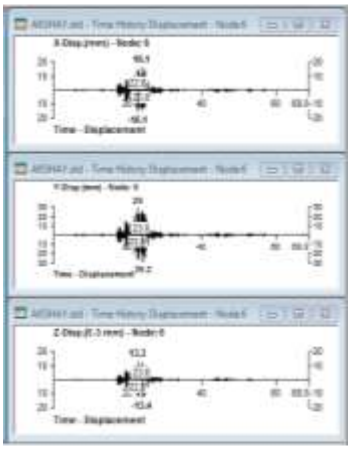

Figure 4. 15 Time-Displacement for Curved Roof

Above figure shows time displacement for curved roof. As we can see in the X-direction it shows high displacement of 23.8 and low displacement of 22.8, in Y-direction it shows high displacement of 23.8 and low displacement of 22.8 and in the Z-direction it shows high displacement of 23.8 and low displacement of 22.8.

Time Velocity for Curved Roof

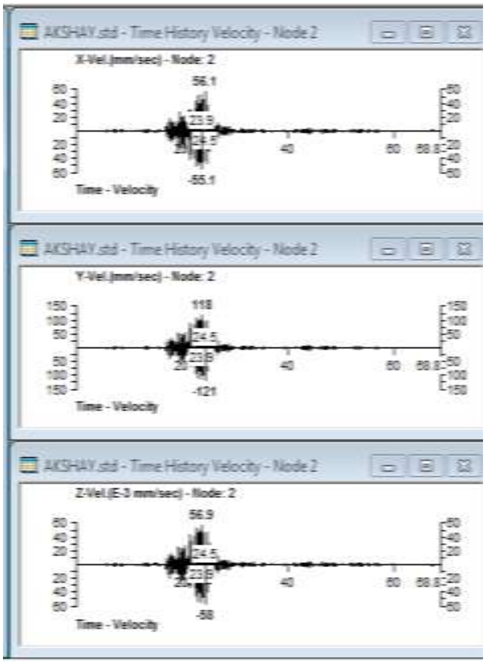

Figure 4. 16 Time-Velocity for Curved Roof

Above figure shows time velocity for flat roof. As we can see in the X-direction it shows high velocity of 24.5 and low velocity of 23.9, in Y-direction it shows high velocity of 24.5 and low velocity of 23.9 and in the Z-direction it shows high velocity of 24.5 and low velocity of 23.9.

Time Accelaration For Curved Roof

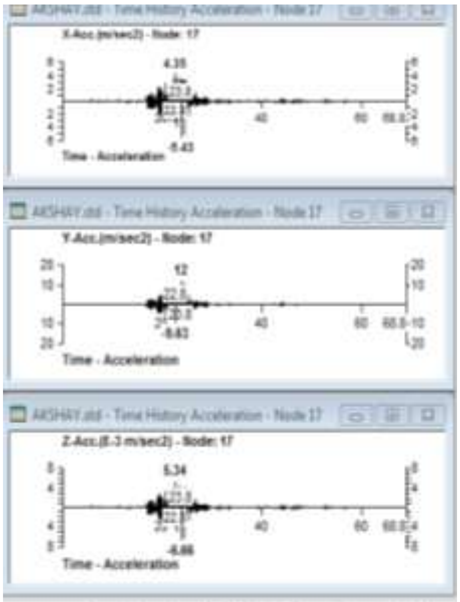

Figure 4. 17 Time-Acceleration for Curved Roof

Above figure shows time acceleration for curved roof. As we can see in the X-direction it shows high acceleration of 23.8 and low acceleration of 22.8, in Y-direction it shows high acceleration of 23.8 and low acceleration of 22.8 and in the Z-direction it shows high acceleration of 23.8 and low acceleration of 22.8.

Results of Maximum Displacement and Normal Stresses for Roof Live Load

Finite Element Analysis of Flat Roof for Roof Live Load

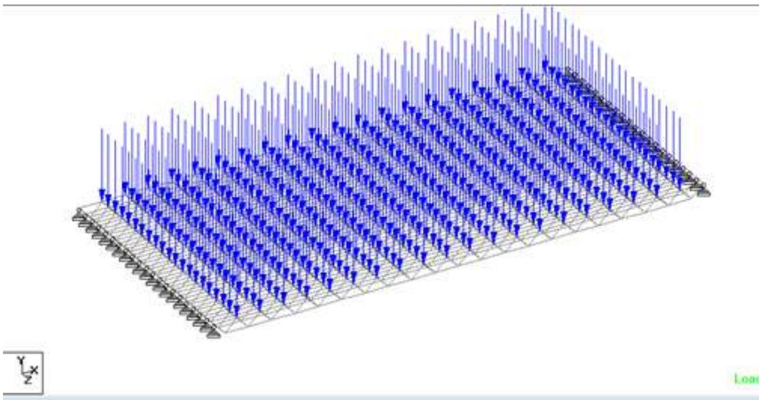

Figure 4. 18 Displacement for Flat Roof

Finite Element Analysis of Flat Roof for Roof Live Load

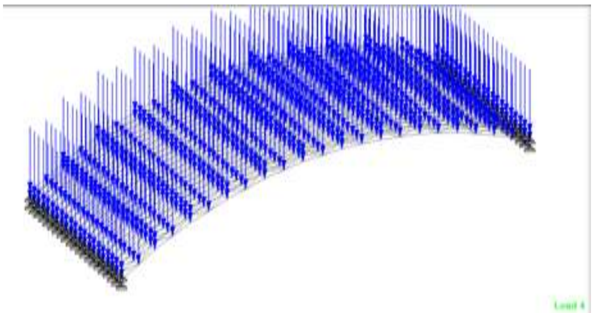

Figure 4. 19 Displacement for Curved Roof

Max. Displacement in X-Direction

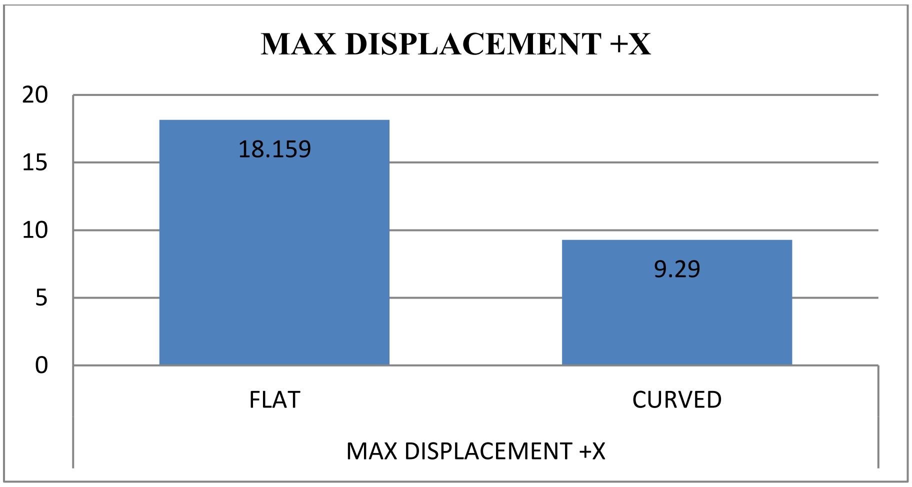

Figure 4. 20 Max. Displacement in X-Direction

The above graph shows that in the +X direction, the flat configuration exhibits a maximum displacement of 18.159 units, whereas the curved configuration shows a significantly lower displacement of 9.29 units. This substantial difference underscores the influence of configuration on structural response to applied forces.

Max. Displacement in Y-Direction

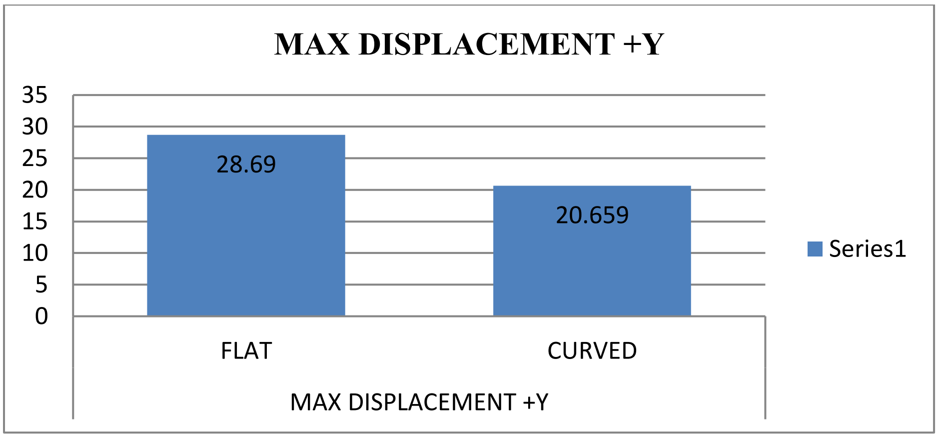

Figure 4. 21 Max. Displacement In Y-Direction

The graph shows that for the +X direction, the maximum displacement is 18.159 units for the flat configuration and 9.29 units for the curved configuration. This suggests that the flat configuration experiences significantly higher displacement compared to the curved configuration under the applied conditions.

Normal Stresses for Flat, Curved and Inclined Roof

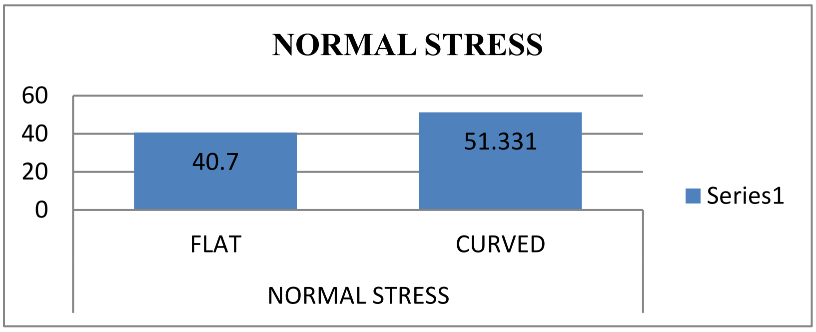

Figure 4. 22 Normal Stresses for Flat, Curved roof

The above graph shows the normal stress values for both flat and curved configurations. The flat configuration exhibits a normal stress of 40.7 units, whereas the curved configuration shows a higher normal stress of 51.331 units. This indicates that the curved configuration experiences greater stress distribution across its surface compared to the flat configuration.

5.4 Results of Wind Load for Longitudinal Direction

Wind Load For Longitudinal Direction For Flat Roof

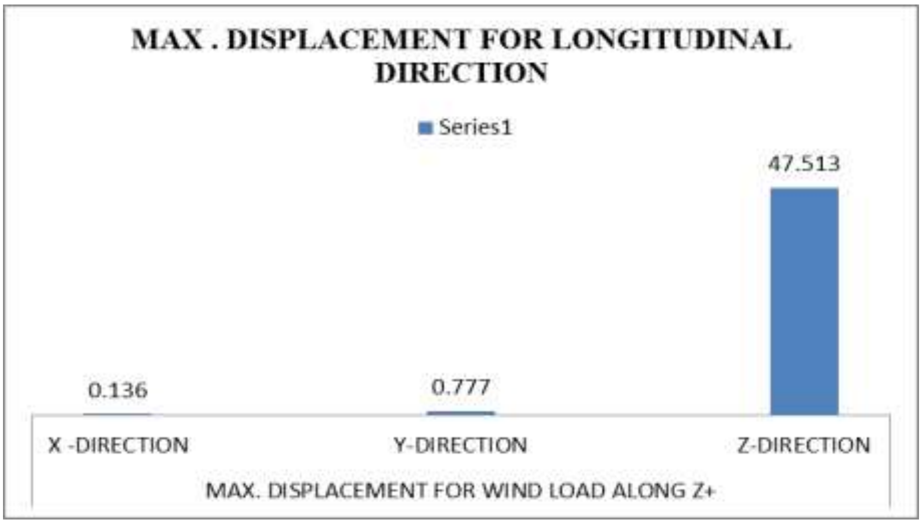

Figure 4. 23 Wind Load For Longitudinal Direction For Flat Roof

The chart illustrates the maximum displacements of the structure in the longitudinal direction under wind load applied along the positive Z-axis. The results show that displacement in the Z-direction is significantly higher, reaching 47.513 mm, indicating that the primary effect of the wind load is along this axis. In contrast, the displacements in the X-direction (0.136 mm) and Y-direction (0.777 mm) are very small, suggesting minimal lateral or vertical deformation relative to the main direction of loading. This pattern confirms that the structure responds predominantly in the direction of the applied wind force and that its stiffness in the transverse and vertical directions is adequate. Overall, the results highlight the need to consider Z-direction deformation as the governing factor in serviceability checks for this loading condition.

Wind Load For Longitudinal Direction For Curved Roof

Figure 4. 24 Wind Load For Longitudinal Direction For Curved Roof

Validation of Flat Roof

The flat roof model is analysed for purline load and axial forces are calculated by joint method. The axial forces of all members are compared with stadd pro results whichis mentioned in table no.

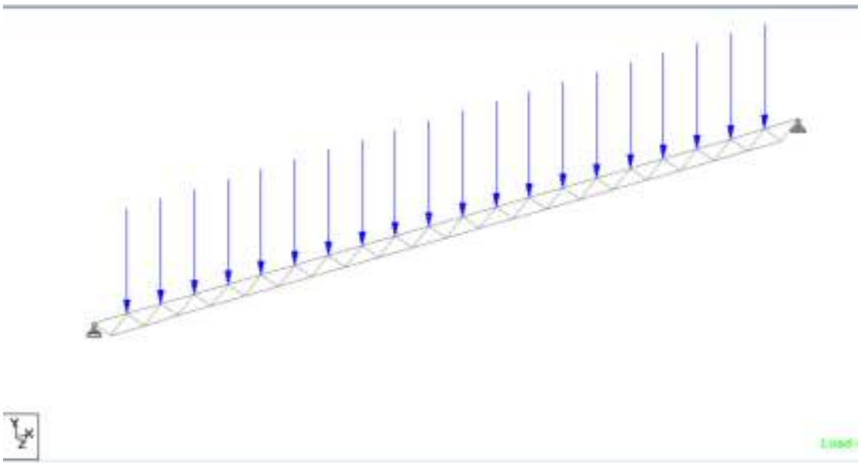

Figure 4. 25 Validation of Flat Roof

Results for Axial Forces from Stadd-Pro and By Joint Method

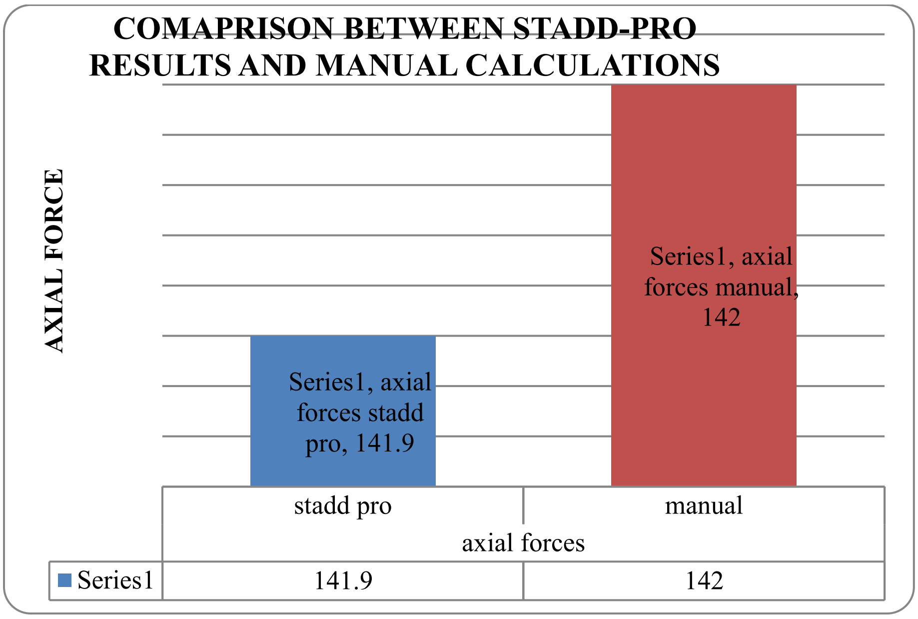

Figure 4. 26 Comparison of Stadd Pro Result And Manual Calculation For Truss No.

The graphic compares axial force values acquired via STAAD-Pro analysis to those produced by hand calculations. The STAAD-Pro results reveal an axial force of 141.9 kN, whereas the manual approach yields a slightly higher figure of 142 kN. This very little difference—only 0.1 kN—shows a high link between the two techniques. It shows that the modelling assumptions, structural behaviour, and calculation methodologies employed in both systems are consistent and dependable. The tight agreement reinforces the quality of the software model and demonstrates that the manual analysis was properly executed, boosting trust in the structural evaluation.

Validation Of Curved Roof

The stadium roof model is analysed for purline load and axial forces are calculated by joint method The axial forces of all members are compared with stadd pro results which is mentioned in table no.

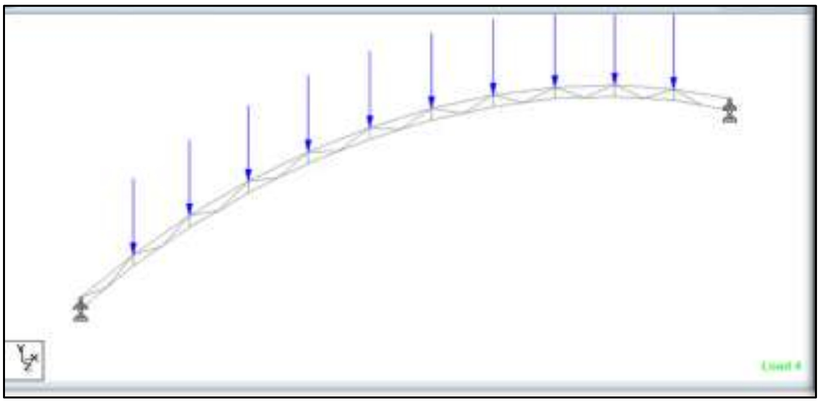

Figure 4. 27 Validation of Curved Roof

Results From Stadd-Pro And By Joint Method

The graphic depicts the validity of a curving roof structure subjected to dispersed loads. The figure depicts a succession of vertical loads applied along the curved profile, which reflect the roof's loading conditions. The structural model has supports on both ends, representing a common arch-shaped or curved beam structure. The load distribution and deformation pattern demonstrate that the structural model reacts as predicted under applied loads, indicating that the analytical or software-based representation properly represents the actual structural response. This validation process is required to check that the curved roof geometry, boundary conditions, and loading assumptions are accurately applied before continuing with further analysis or design.

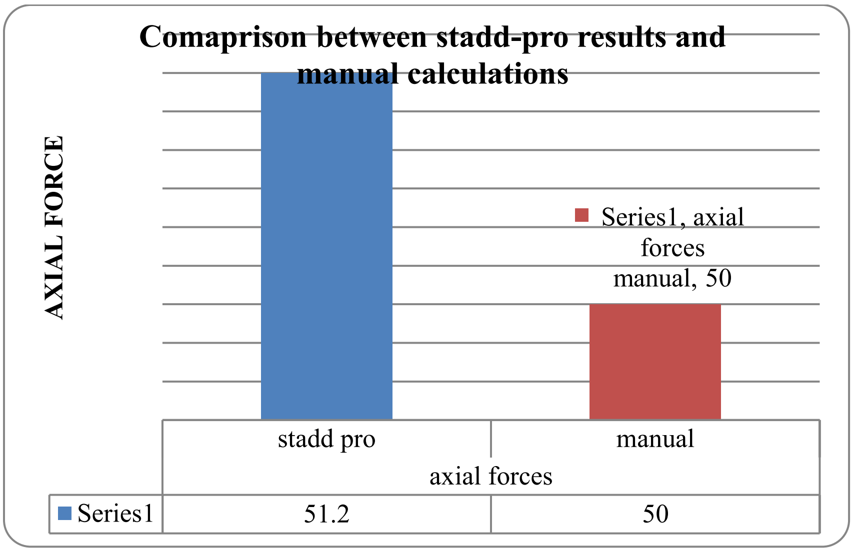

Figure 4. 28 Comaprison between stadd-pro results and manual calculations

The graphic compares axial force levels acquired from STAAD-Pro analysis to those estimated manually. The STAAD-Pro results reveal an axial force of about 51.2 kN, but the manual calculation yields a little lower value of 50 kN. This little discrepancy implies that the human technique roughly approximates the software result, indicating strong agreement between analytical and computational methods. The comparison indicates that the structural assumptions and calculation processes utilised manually are compatible with those used by STAAD-Pro, and the little discrepancy may be ascribed to rounding, modelling accuracy, or software-based numerical refinement.

Figure 4. 29 Comparison of Stadd Pro Result And Manual Calculation For Truss No. 1

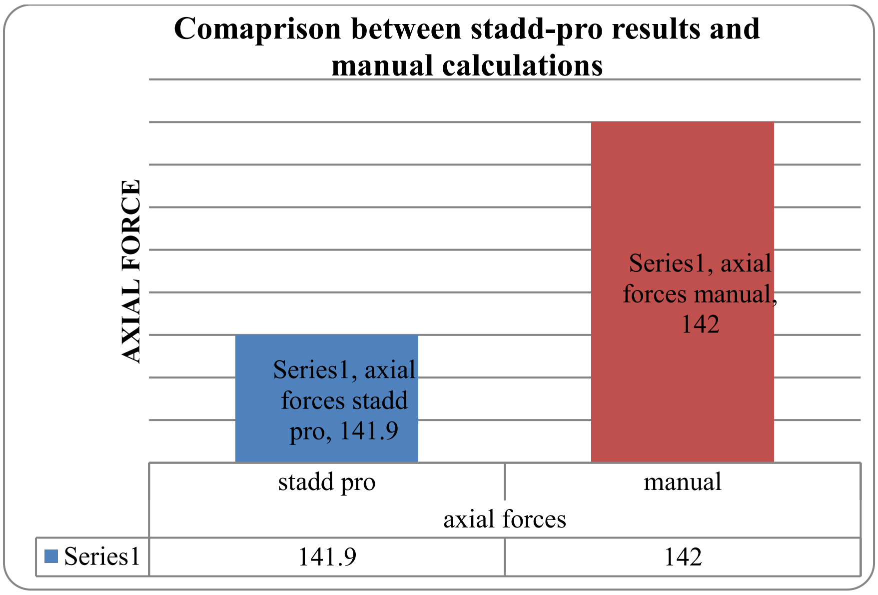

Figure 4. 30 Comparison Of Stadd Pro Result And Manual Calculation For Truss No. 16

A comparison of the axial force produced from STAAD-Pro analysis to the manually computed axial force for Truss No. 16. The STAAD-Pro result indicates an axial force of 141.9 kN, but the manual calculation yields 142 kN. The discrepancy between the two values is negligible (0.1 kN), showing very good agreement. This tiny deviation proves the accuracy of STAAD-Pro's analytical model and validates the human computations. Overall, the comparison shows that the structural analysis done using STAAD-Pro is reliable and compatible with theoretical design techniques.

6. CONCLUSION

The study of flat, sloped, and inclined roofs under varied loads provides important insights into their structural performance. Time-velocity and time-acceleration measurements for each roof type show significant differences. Velocities and accelerations on flat rooftops are essentially homogeneous in all directions. Curved roofs have somewhat lower displacement but higher normal stresses, suggesting greater stability under load but higher material stress. Inclined roofs behave differently than flat roofs, with displacement values that are quite similar, but with larger acceleration peaks, particularly under dynamic loading circumstances. Finite Element Analysis indicates that flat and inclined roofs have identical maximum displacements, however curved roofs have lower displacement, indicating their potential for increased stiffness. However, standard stress analysis reveals that curved roofs experience greater strains, which may demand stronger materials or extra support systems. Wind load study for longitudinal direction shows that curved roofs are more vulnerable to wind forces, particularly in the Z-direction, than flat and inclined roofs. The validation of axial forces using manual calculations and STAAD-Pro findings demonstrates a significant connection, confirming the robustness of the computational models utilized. To summaries, although flat and inclined roofs function effectively under varied loads, curved roofs provide increased stiffness but need careful consideration of stress distribution and wind load effects. These insights are critical for developing roof structures that balance displacement, load, and wind resistance properly.

REFERENCES

[1] M. N. Meena, S. K. Patil, and M. Hinal, "' RETROFITTING OF EXISTING STRUCTURE ,'" vol. 10, no. 4, 2023.

[2] Retrofit Strategy in Existing Building for Implementing Energy Conservation Building Code in India

[3] . A. Pringopoulos, A. K. Thomoglou, J. G. Fantidis, A. A. Thysiadou, and Z. S. Metaxa, "Advanced Lime Mortars for Historical Architectural Structures †," *Engineering Proceedings*, vol. 70, no. 1, 2024.

[4] K. Bedi and G. Nagpur, "Study on Methods and Techniques of Retrofitting," *International Journal of Engineering Research & Technology*, vol. 2, no. 9, pp. 621–627, 2013.

[5] Ezenwobodo and S. Samuel, "International Journal of Research Publication and Reviews," *International Journal of Research Publication and Reviews*, vol. 04, no. 01, pp. 1806–1812, 2022.

[6] A. Sawdekar, P. S. Pajgade, and M. A. Banarase, "Retrofitting techniques for reinforced concrete structural members using different materials - A review," *Journal of Emerging Technologies and Innovative Research*, vol. 9, no. 2, pp. 413–423, 2022.

[7] K. Singh and A. Uniyal, "Analysis of Seismic Retrofitting on RC Building," *International Journal of Engineering Research & Technology*, vol. 7, no. 12, pp. 1–6, 2019.

[8] H. Katolkar and P. G. Sawai, "Seismic Response Of Retrofitting R . C . Structure Using Steel Wrapping Method," vol. 10, no. 5, 2024.

[9] A. Sawdekar, P. S. Pajgade, and M. A. Banarase, "Retrofitting techniques for reinforced concrete structural members using different materials - A review," *Journal of Emerging Technologies and Innovative Research*, vol. 9, no. 2, pp. 413–423, 2022.

[10] Mohd Irfan, p. Scholar, d. A. Sharma, and d. V. Garg, "strengthening demand of columns in a rcc structure due to construction of an additional storey," *international journal of engineering research*, vol. 3, no. 8, 2014.

[11] Praveen Anand and a. K. Sinha, "effect of reinforced concrete jacketing on axial load capacity of reinforced concrete column," *civ eng j*, vol. 6, no. 7, pp. 1266–1272, jul. 2020, doi: 10.28991/cej-2020-03091546.

[12] Praveen Kumar Nigam and s. Akhtar, "retrofitting practices in various categories of rcc structures – a comprehensive review," *materials today: proceedings*, vol. 45, pp. 7123–7131, 2021, doi: 10.1016/j.matpr.2021.01.953.

[13] Prem Pal Bansal, m. Kumar, and m. A. Dar, "retrofitting of exterior rc beam-column joints using ferrocement jackets," *earthquakes and structures*, vol. 10, no. 2, pp. 313–328, feb. 2016, doi: 10.12989/eas.2016.10.2.313.

[14] S.Saha and showmen, "behaviour of reinforced concrete beam strengthened in shear with geosynthetic," *advances in structural engineering*, vol. 23, no. 9, pp. 1851–1864, jul. 2019, doi: 10.1177/1369433220901820.

[15] Sachin Motghare, s. Gaikwad, and a. Khedikar, """seismic behavior of retrofitting for r.c. structure using r.c.c jacketing and steel jacketing," vol. 8, no. 7, 2021.

[16] Sanjay Kumar Tiwari *et al.*, "seismic microzonation of indian cities and strategy for safer design of structures," in *social and economic impact of earth sciences*, v. K. Gahalaut and m. Rajeevan, eds., singapore: springer nature singapore, 2023, pp. 393–419. Doi: 10.1007/978-981-19-6929-4_20.