iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: III Month of publication: March 2026

DOI: https://doi.org/10.22214/ijraset.2026.77982

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

Seismic Analysis and Performance Assessment of Earthquake-Resistant Buildings

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Abstract: The seismic analysis and performance assessment of earthquake-resistant buildings, aiming to provide a comprehensive understanding of how structures behave under seismic forces and how their safety and resilience can be enhanced. The study involves detailed architectural planning, accurate structural modelling, precise load assignment, and seismic enhancement techniques, all implemented using advanced software tools such as AutoCAD for drafting, ETABS for analysis and Microsoft Excel was used for data tabulation and graph preparation. Various earthquake-resistant strategies, including shear walls and bracing are applied and their effects on structural performance are thoroughly evaluated. Key response parameters such as base shear, story displacement, story drift are measured, and comparative analysis is performed to assess the effectiveness of different mitigation approaches. The project provides a systematic, practical, and professional framework for designing, analysing, and assessing buildings to ensure safety, structural integrity, and optimal performance under seismic conditions.

Keywords: Seismic analysis, Earthquake-resistant buildings, Structural performance assessment, ETABS, AutoCAD, Base shear, Storey displacement, Story drift, Shear walls, Bracing systems, Seismic mitigation techniques, Earthquake, Structural modeling, Performance-based design

I. INTRODUCTION

Earthquakes are one of the most dangerous natural hazards affecting buildings and infrastructure. During an earthquake, ground motion generates lateral forces in structures, which cause displacement, storey drift, shear forces, and bending moments in structural members. If a building is not properly designed to resist these forces, it may experience severe damage or collapse. Therefore,
seismic analysis plays a vital role in ensuring the safety and stability of multi-storey buildings. Seismic design of buildings in India is governed by the provisions of IS 1893 (Part 1): 2016 issued by the Bureau of Indian Standards. These guidelines help engineers evaluate the structural response of buildings under earthquake loading and ensure that the structure performs within acceptable safety limits. In this project, an 8-storey reinforced residential building is modeled using AutoCAD and analyzed using ETABS software and data tabulation and graph preparation using Microsoft Excel. The structure is subjected to seismic loading, and its performance is evaluated based on important parameters such as base shear, storey displacement, storey drift, time period, and member forces. To assess earthquake resistance, different structural systems are considered, including normal RC frame, shear wall system, braced frame system, and base isolation system. A comparative study is carried out to understand how each system influences the seismic performance of the building and to identify the most effective and practical earthquake-resistant technique. suitable structural system based on performance assessment.
This study aims to provide a clear understanding of the behavior of multi-storey buildings under seismic forces and to recommenda In this project, materials like RCC and structural steel are used because of their strength and durability in resisting seismic forces. Software such as AutoCAD, ETABS, and Microsoft Excel are used for drawing preparation, structural analysis, and plot graphs.

II. SCOPE

1) Higher storey buildings can be analyzed for seismic performance
2) Nonlinear dynamic analysis can be performed for accurate results
3) Soil-structure interaction effects can be considered
4) Cost optimization of earthquake-resistant design can be explored
5) Real-time structural health monitoring can be implemented
6) Sustainability aspects of earthquake-resistant structures can be investigated

III. OBJECTIVES

The main objectives of this project are:

1) To reduce lateral displacement and story drift
2) To study building behavior under seismic loads
3) To perform seismic analysis of an 8-storey RCC building using ETABS
4) To conduct response spectrum analysis as per IS 1893 Part 1
5) To compare different seismic enhancement techniques such as shear wall and bracing
6) To assess storey drift, displacement, base shear and time period for performance evaluation
7) To identify the most effective earthquake-resistant technique for the selected site
8) To improve structural safety and seismic performance of the building

IV. METHODOLOGY

A. Site Selection

The site selection process was completed after analyzing the location, soil condition, and seismic characteristics of the area. The selected site is located at Nallepilly, Chittur, Palakkad, Kerala, with a total land area of 20 cents and a square-shaped plot, which was suitable for uniform planning and structural stability. The soil was identified as hard soil with well-graded gravel, classified as Type I soil, providing good bearing capacity for construction. The region falls under Seismic Zone III, indicating moderate seismic risk. Historical records showed that an earthquake had occurred in the area several years ago, and studies suggest that this region has comparatively higher seismic vulnerability within Kerala. Based on these factors, the site was finalized for carrying out seismic analysis and performance assessment of an earthquake-resistant building.

B. Architectural Planning

The architectural planning was completed using AutoCAD software by considering the site conditions and project objectives. The building layout was designed efficiently within the square plot to ensure proper space utilization and structural symmetry, reducing possible torsional effects during seismic loading. The floor plan included proper room arrangement, circulation spaces, and aligned beam-column grids to ensure structural stability and ease of modeling in ETABS. All architectural dimensions and structural element positions were finalized before proceeding to structural modeling and seismic analysis.

C. Structural Modeling

The structural modeling of the building was completed using ETABS software based on the finalized architectural drawings. The beam, column, slab, and structural grid details prepared in AutoCAD were accurately transferred into ETABS to develop a three-dimensional analytical model. Material properties such as grade of concrete and steel were defined, and appropriate section properties were assigned to all structural elements. The model was developed considering proper connectivity between beams and columns to ensure realistic structural behavior. Storey heights, supports, and boundary conditions were defined according to design requirements.

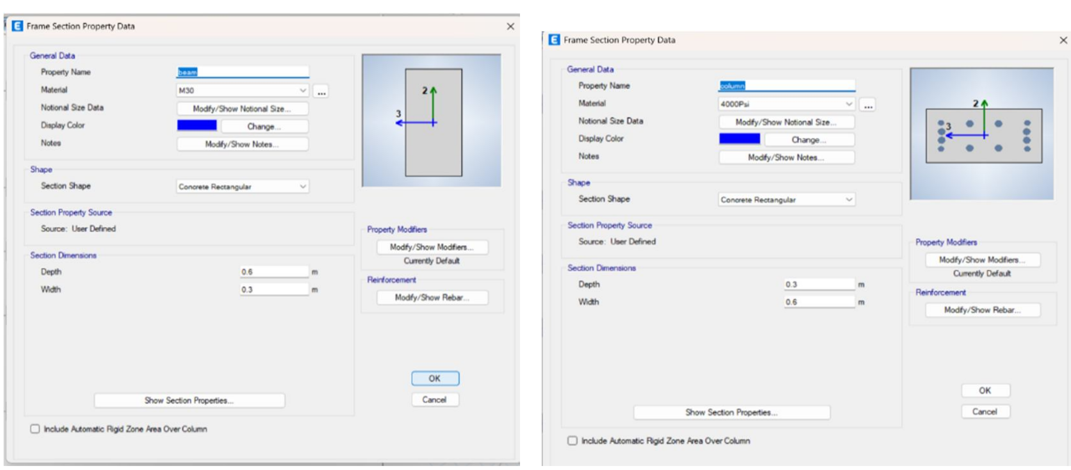

Fig 1 Beams and Columns

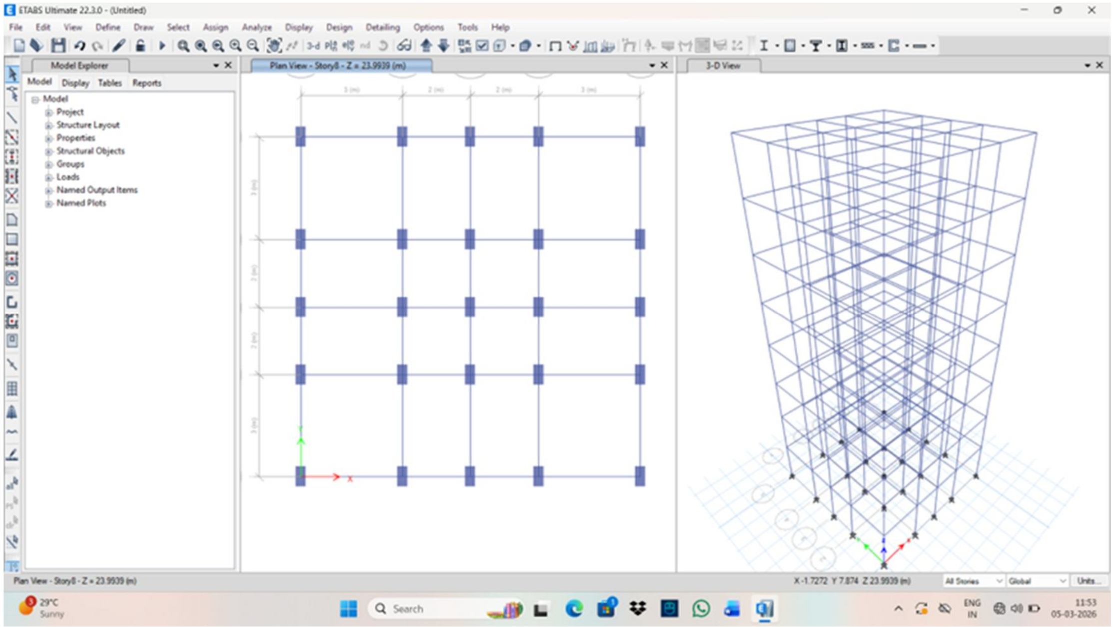

Fig 2 Structural Model

D. Load Assignment

After completing the structural modelling in ETABS, the required loads were defined and assigned to the structural elements. The dead load was automatically calculated by the software based on the self-weight of beams, columns, slabs and other structural components. Additional dead loads such as floor finish and wall load were also considered.

The live load was assigned according to the provisions of IS 875 Part 2. For seismic analysis, earthquake loads were defined using response spectrum analysis based on IS 1893 Part 1. All necessary loads were assigned to simulate the actual behavior of the building under gravity and seismic forces.

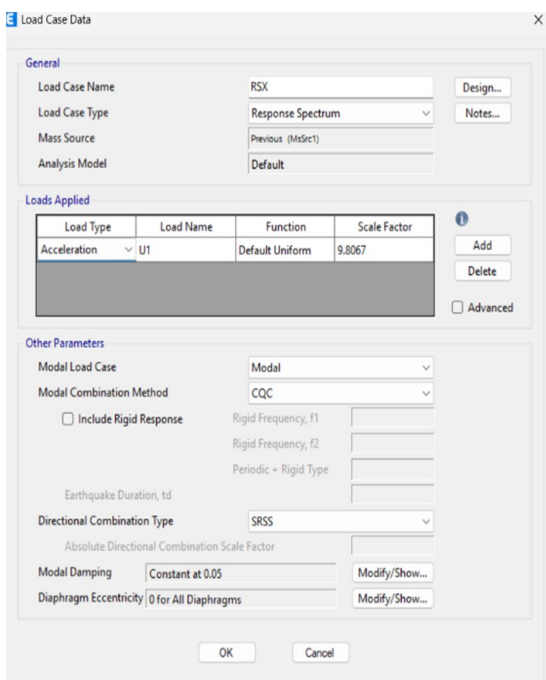

Fig 3 Load Case Data

V. SEISMIC ENHANCEMENT

Seismic enhancement techniques were successfully incorporated into the structural model to improve the earthquake resistance of the building. The enhancement methods such as shear wall, bracing system and base isolation were introduced and modeled using ETABS. These techniques were applied to the building model to study their influence on structural stability and seismic performance. The models with different enhancement systems were prepared for further seismic analysis and performance comparison.

A. *Bracing System*

Bracing system was provided in the building frame to improve the lateral stability of the structure during seismic loading. The bracing members help in transferring the earthquake forces effectively to the ground and reduce structural deformation. The bracing system was modeled and analyzed using ETABS.

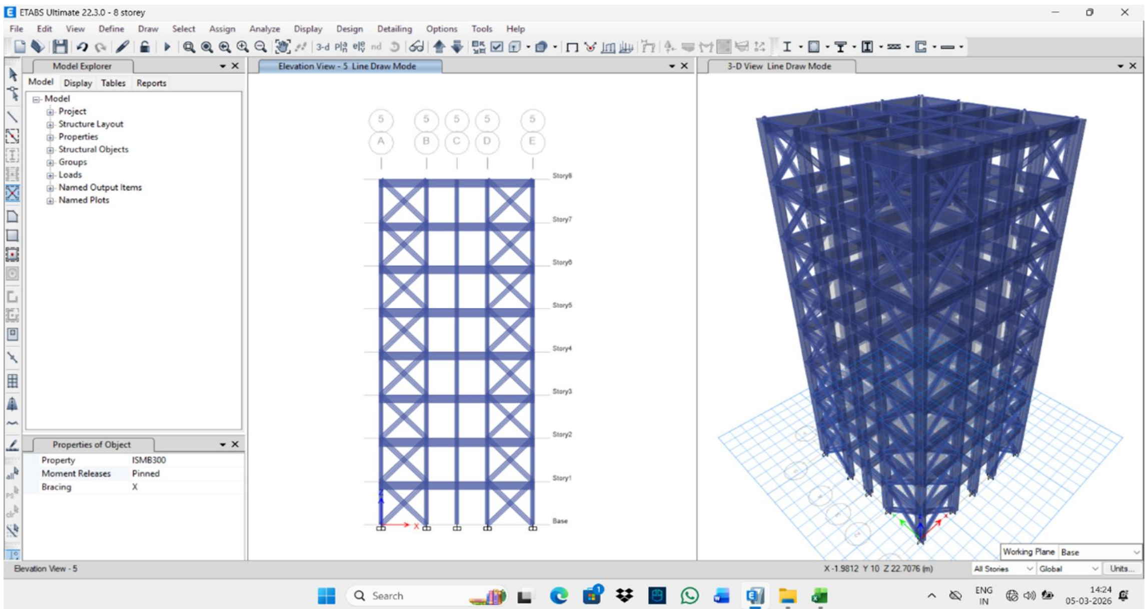

Fig 4 Structural model with Bracing System

B. *Shear Wall System*

Shear wall was introduced in the structural model to increase the lateral stiffness and strength of the building. The shear walls help the structure resist earthquake forces by transferring lateral loads safely to the foundation. The shear wall system was modeled using ETABS and incorporated into the building model for seismic performance analysis.

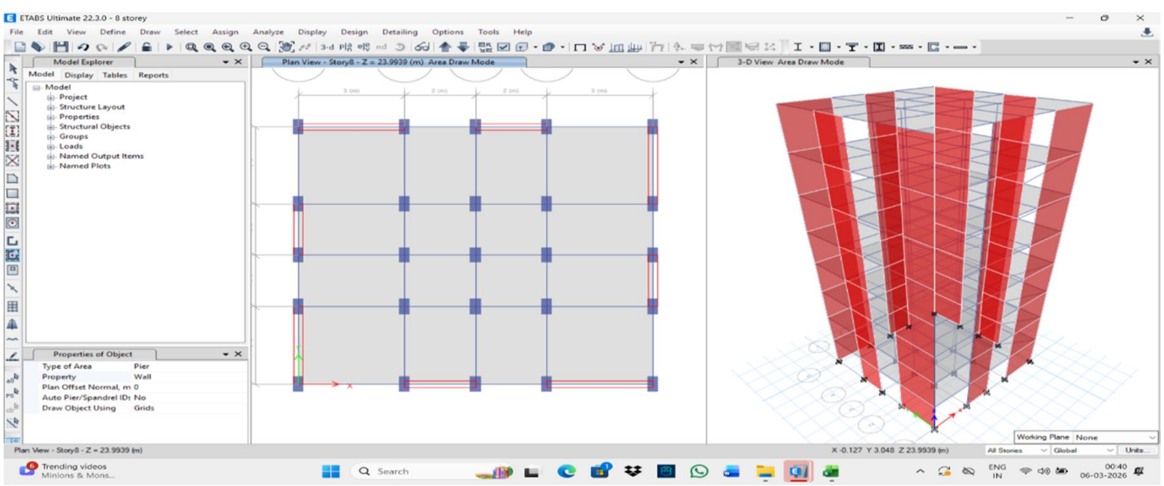

Fig 5 Structural model with Shear Wall

VI. STRUCTURAL ANALYSIS

Structural analysis of the building was carried out using ETABS. The structural model was analyzed by considering dead load, live load and seismic load. Response spectrum analysis was performed according to IS 1893 Part 1.

Analysis was carried out for different structural configurations such as normal frame, shear wall, bracing system and base isolation to study the seismic behavior of the structure. Deformation and displacement behavior of each model were evaluated for performance assessment and comparison.

A. Normal Structure

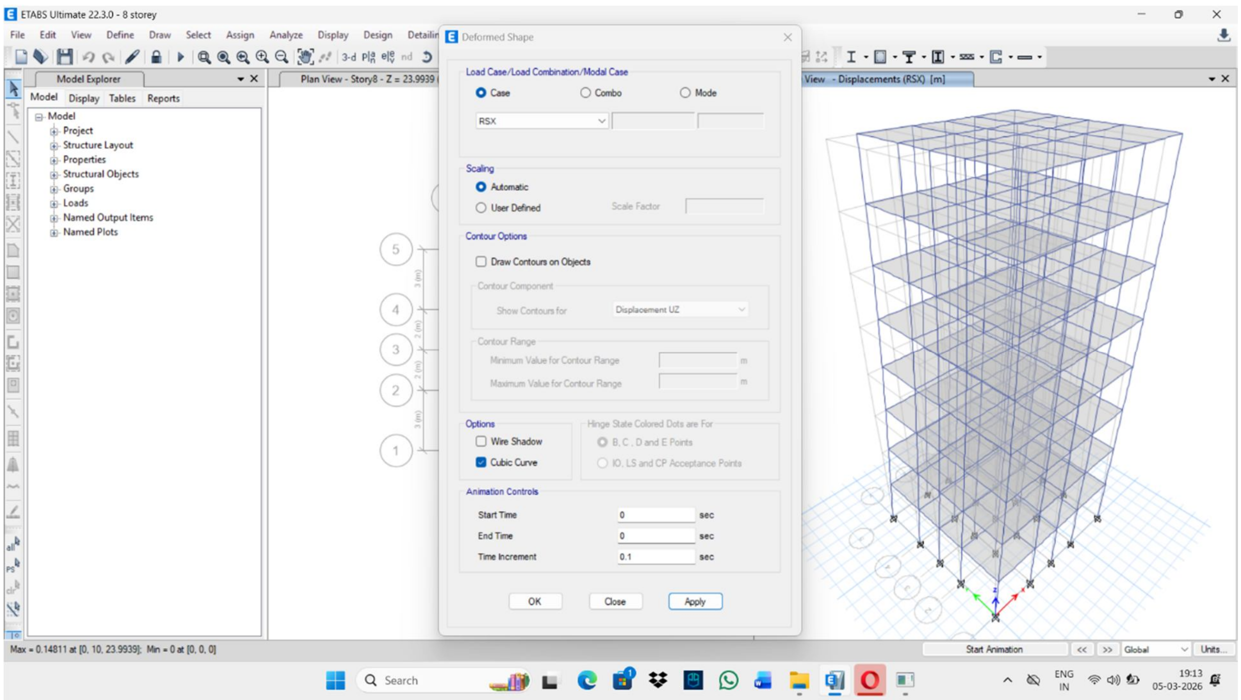

Fig 6 Deformed shape of Normal structure in X direction (RSX)

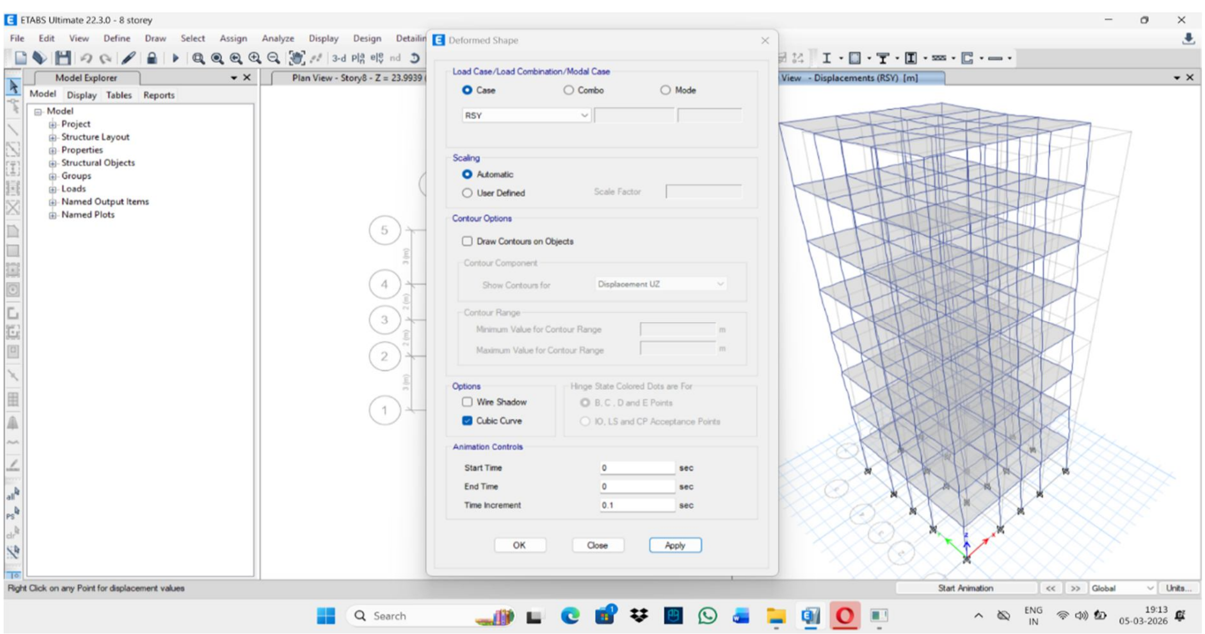

Fig 7 Deformed shape of Normal structure in Y direction (RSY)

B. *Bracing System Model*

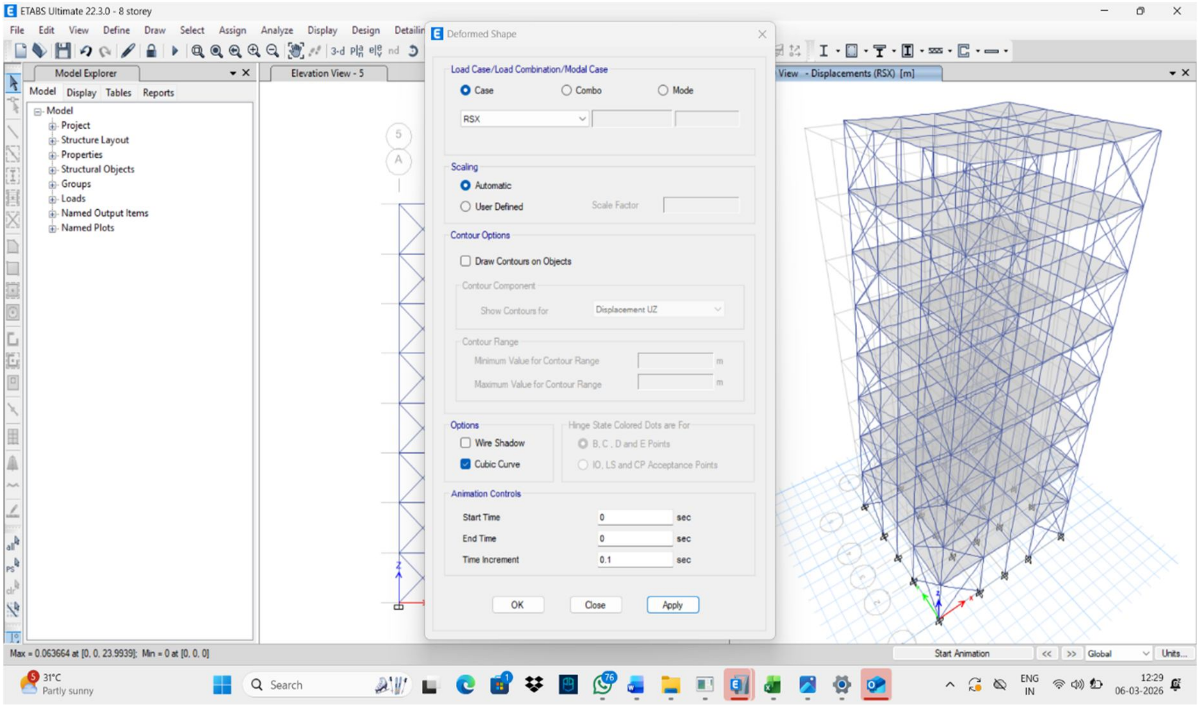

Fig 8 Deformed shape with Bracing System in X direction (RSX)

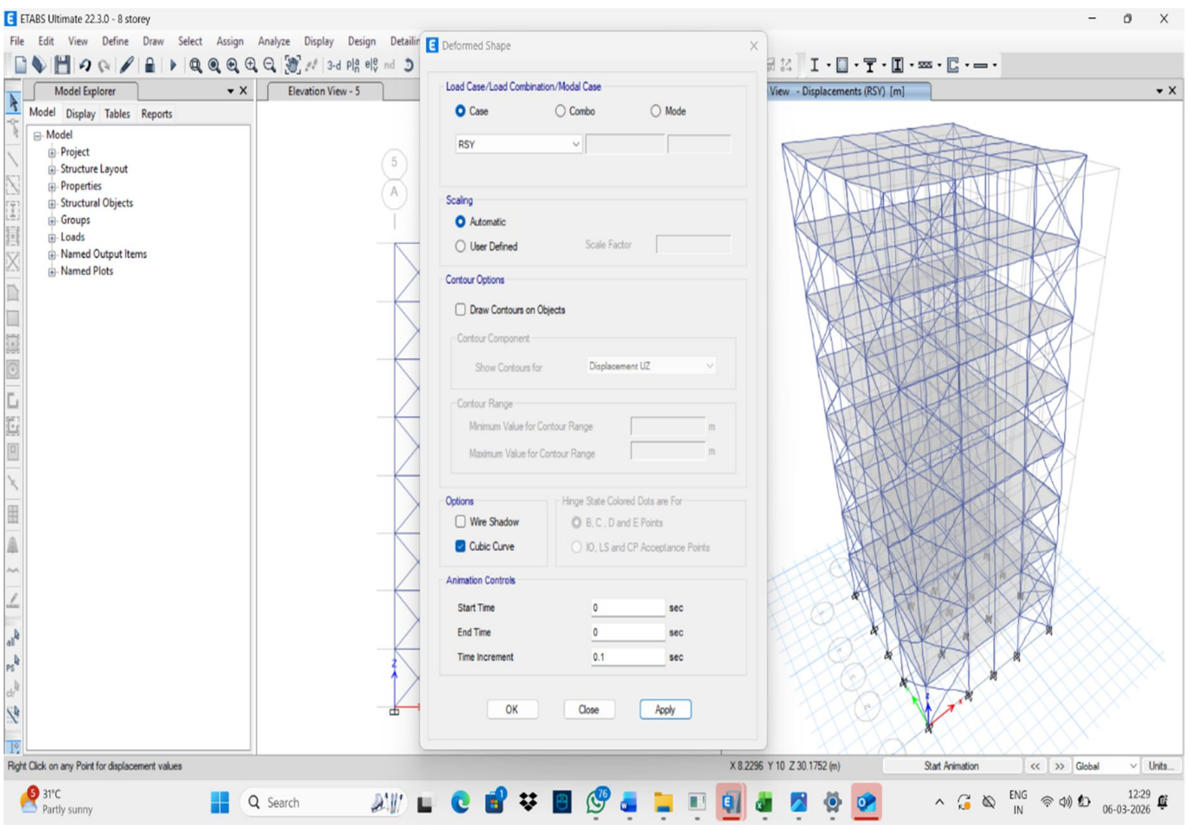

Fig 9 Deformed shape with Bracing System in Y direction (RSY)

C. Shear Wall System Model

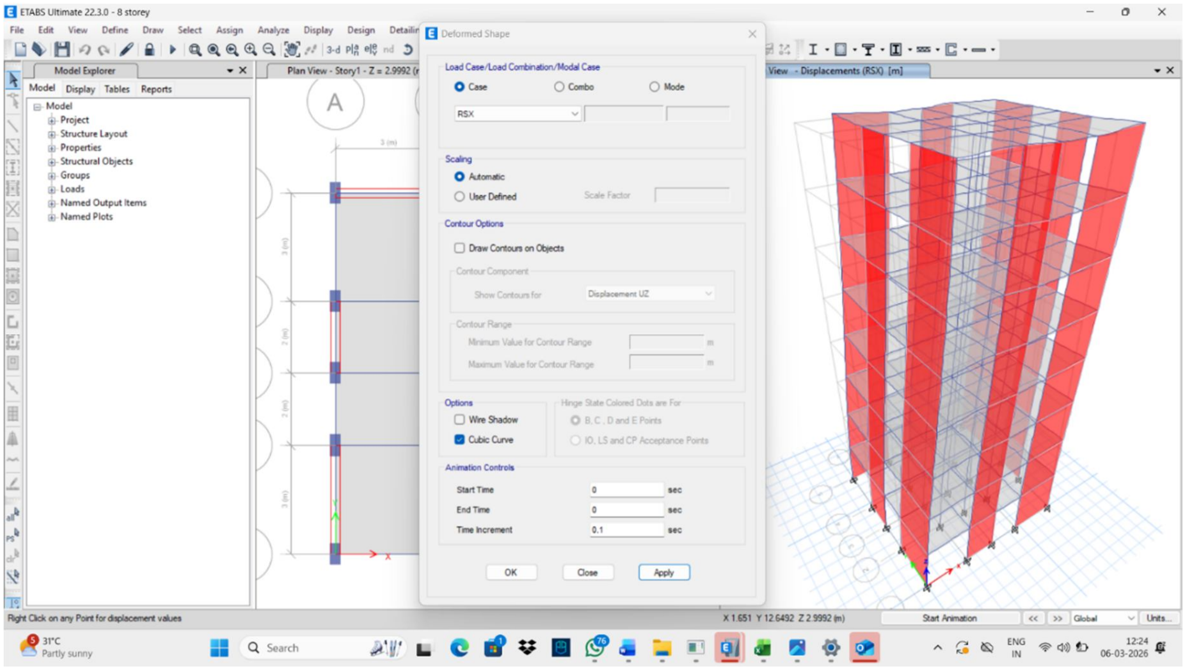

Fig 10 Deformed shape with Shear wall system in X direction (RSX)

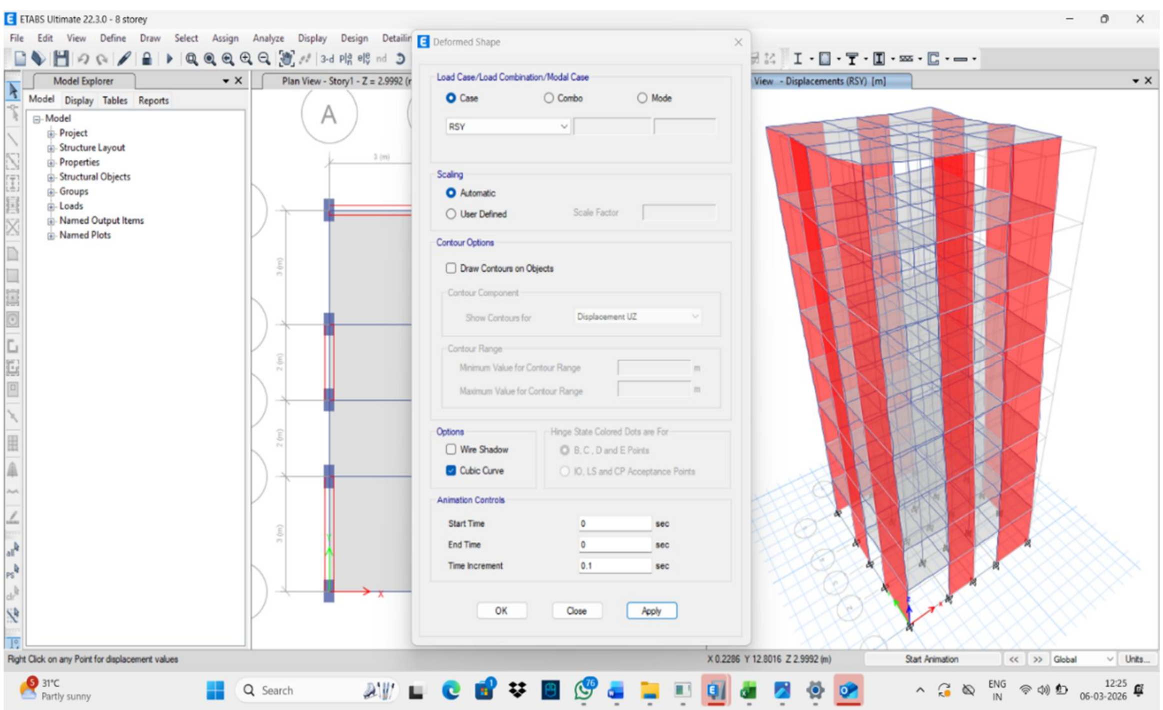

Fig 11 Deformed shape with Shear wall system in Y direction (RSY)

Structural analysis is completed and the results were used for performance evaluation and comparison of different seismic enhancement techniques.

VII. RESULT AND COMPARISON

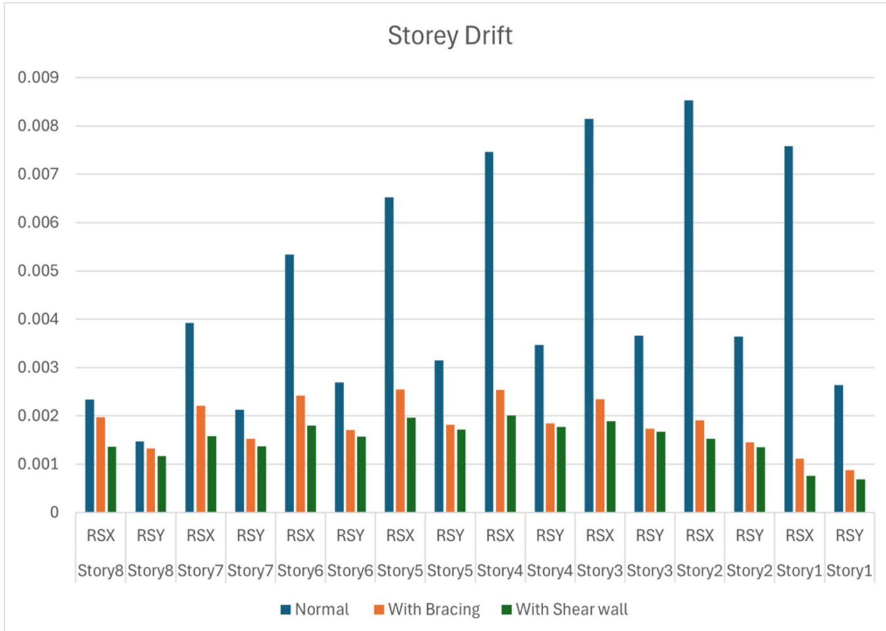

Fig 12 Comparison of Storey drift for Different structural systems

Storey drift is the relative horizontal displacement between two consecutive floors during seismic action.
The analysis shows that the normal building experiences the highest storey drift, especially in the upper storeys. When bracing is provided, the storey drift decreases because the bracing system helps resist lateral loads. The shear wall system shows the minimum storey drift among the three models. This indicates that shear walls effectively control lateral movement and improve the seismic performance of the structure.
This clearly shows that shear walls improve the lateral stability of the building.

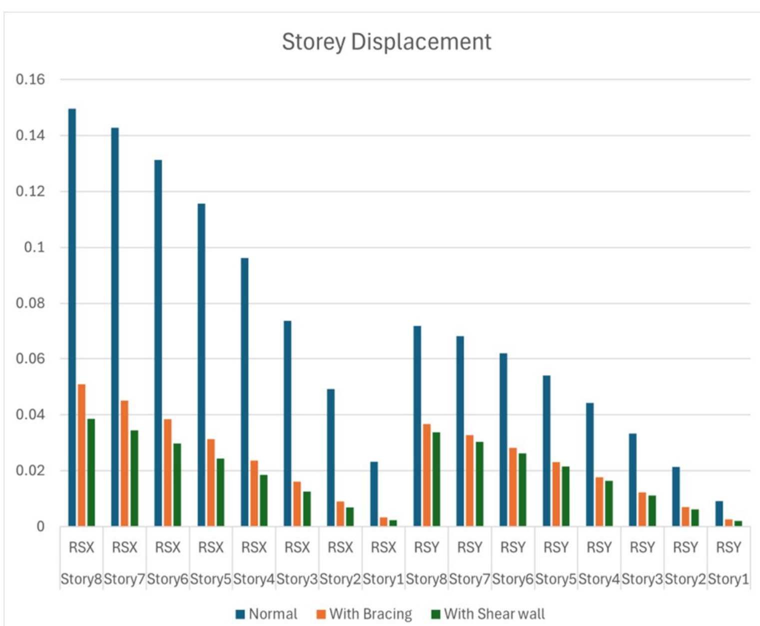

Fig 13 Comparison of Storey Displacement for Different structural systems

Storey displacement represents the total lateral movement of each floor due to earthquake forces.
The results indicate that the normal building shows the maximum displacement, especially at the top storey. The displacement gradually decreases when bracing is introduced. The shear wall system produces the least storey displacement, which means the building experiences less lateral movement during seismic activity.
This clearly shows that shear walls improve the lateral stability of the building.

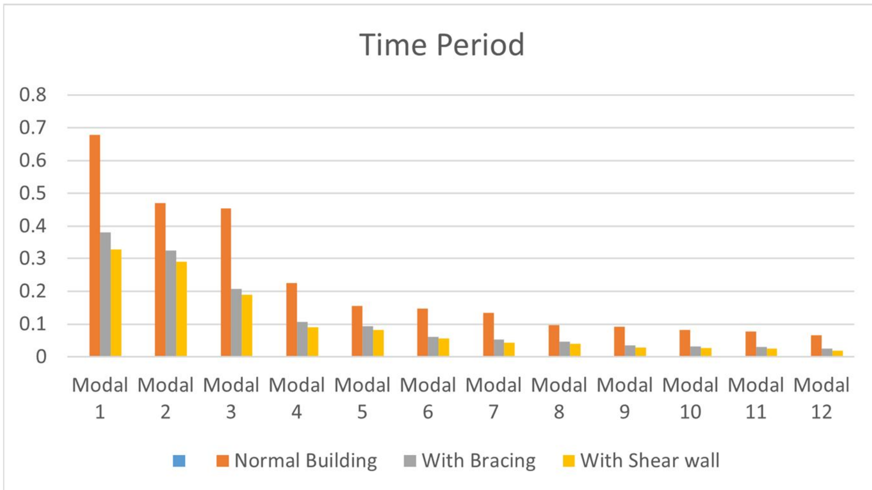

Fig 14 Comparison of Time Period for Different structural systems

The time period represents the time taken by the structure to complete one cycle of vibration during seismic motion.
From the analysis results, the normal building shows the highest time period in all vibration modes, indicating that the structure is more flexible. The building with bracing shows a reduced time period, which means the stiffness of the structure increases when bracing is provided. The building with shear wall has the lowest time period, showing that it is the stiffest structure among the three models.
Therefore, the shear walls significantly improves the stiffness of the building, making it more stable under earthquake loading.

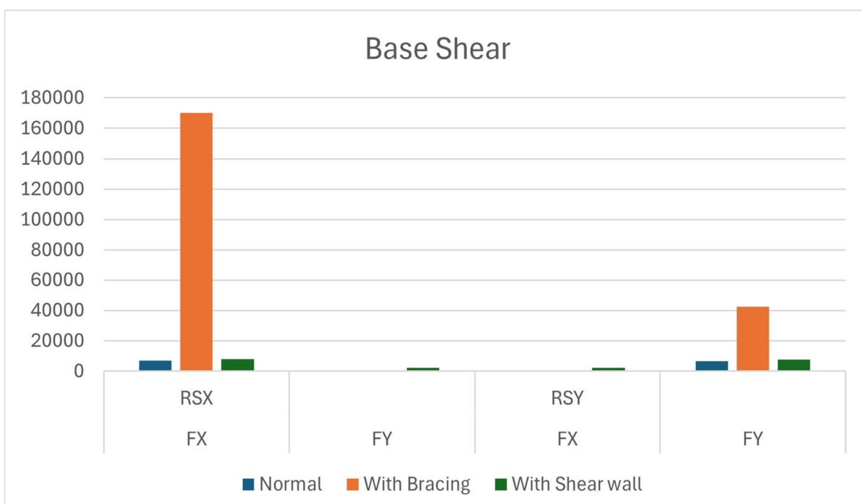

Fig 15 Comparison of Base shear for Different structural systems

Base shear is the total horizontal force acting at the base of the structure during an earthquake.
The analysis results show that the braced structure experiences higher base shear compared to the normal building, which indicates that the structure can resist higher seismic forces. The shear wall structure also shows improved resistance to seismic forces.

This means that both bracing and shear walls enhance the seismic load carrying capacity of the structure.

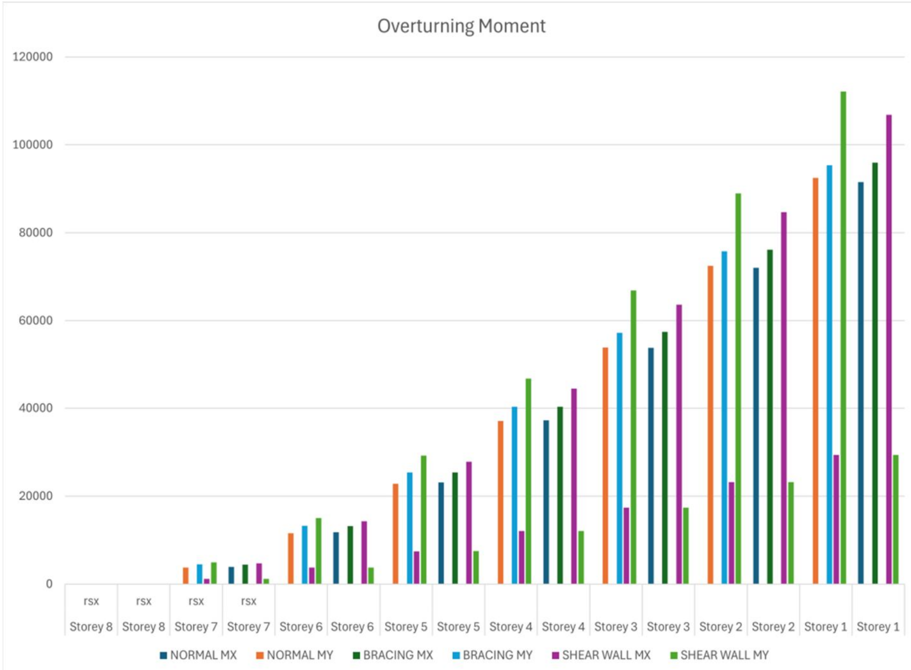

Fig 16 Comparison of Overturning Moments for Different structural systems

Overturning moment is the moment produced at the base of the structure due to lateral seismic forces.

From the analysis results, normal buildings show lower resistance to overturning forces, while buildings with bracing and shear walls show better resistance.

Among the three models, the shear wall system provides the highest resistance to overturning moments, due to its high stiffness and strength.

VIII. FINAL RESULT

From the comparison of time period, storey drift, storey displacement, base shear, and overturning moment from the graph,

The normal building shows the highest time period, storey drift, and storey displacement, indicating lower stiffness and poor seismic resistance. The building with bracing shows improved performance compared to the normal building by reducing drift and displacement. The building with shear wall provides the best seismic performance, showing the minimum storey drift and displacement and greater structural stiffness. Based on the analysis results, the shear wall system is the most effective technique for earthquake-resistant buildings, followed by the bracing system, while the normal building shows the least resistance to seismic forces

IX. CONCLUSION

The project was carried out starting from architectural planning using AUTOCAD and structural modeling of an 8-storey reinforced concrete building. The structural model was developed based on the architectural plan and analyzed using ETABS.

The study was conducted for the site located at Palakkad, Chittur – Nallepilly, which falls under seismic zone III. Structural analysis was performed by considering dead load, live load, and seismic load to evaluate the structural behavior under different loading conditions. Response spectrum analysis was carried out as per the provisions of IS 1893 Part 1 for seismic evaluation.

Different structural configurations such as normal frame, bracing system and shear wall system were modeled and analyzed for performance comparison. Results of the analysis showed that the normal frame structure exhibited higher storey drift and displacement, indicating lower seismic resistance. The bracing system improved lateral stability by reducing displacement, while the shear wall system provided superior seismic performance by significantly controlling drift and enhancing structural stiffness.

Based on the comparative analysis, it is concluded that the shear wall system is the most effective seismic enhancement technique for the selected site and building configuration. The implementation of earthquake-resistant design techniques improves structural safety and reduces the risk of seismic damage, ensuring better performance under earthquake loading conditions.

Thus, the project successfully achieved its objectives of seismic performance evaluation and comparison of different structural systems. The study highlights the importance of earthquake-resistant structural design and demonstrates the effectiveness of seismic enhancement techniques in improving the safety and stability of buildings in seismic regions.

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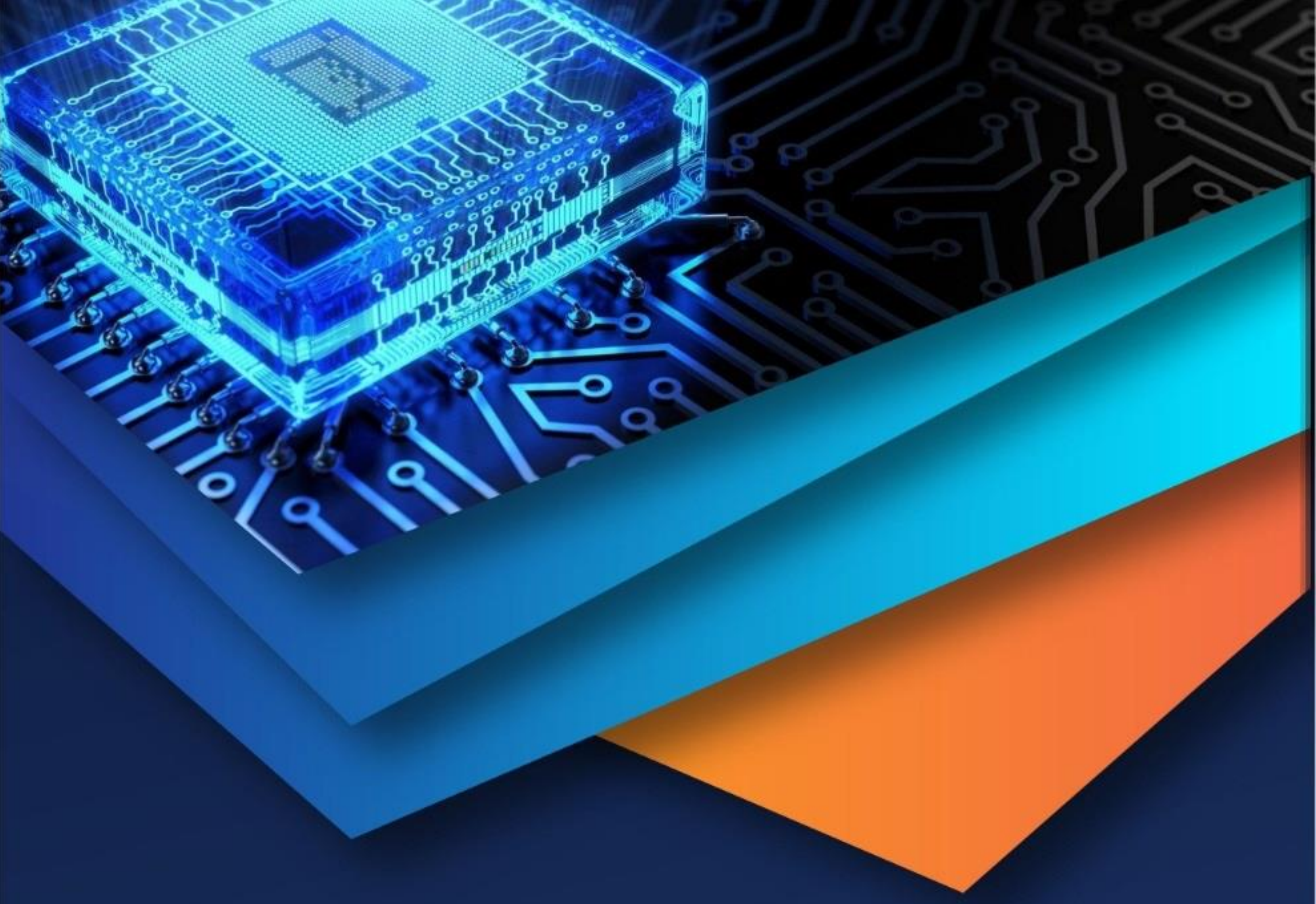

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