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Analysis of Steel Structure with and Without Infill

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Abstract: The present study focuses on the seismic performance evaluation of a steel structure considering two configurations: a bare frame and the same frame with infill. The analysis aims to understand the influence of bare frame & infills on the seismic behavior of steel buildings, particularly in high seismic risk areas. A G+9 storey steel framed building is modeled and analyzed using ETABS software.

The structure is located in Seismic Zone IV as per IS 1893:2016, with an importance factor of 1.5, reflecting its critical nature. The seismic analysis is carried out using the Response Spectrum Method, which effectively captures the dynamic characteristics of the structure under earthquake loading. Three models are developed: one representing the bare steel frame, and the other incorporating infills with Masonry & Glass. The primary parameters compared include base shear &storey displacement. The results indicate that the inclusion of glass infill panels alters the dynamic response of the building significantly. While the stiffness and lateral load resistance increase due to infills, the overall displacement values show noticeable variation when compared to the bare frame. This study emphasizes the importance of considering non-structural components like infills in seismic design and highlights their potential contribution to overall structural performance during earthquakes.

Keywords: Seismic Analysis, Steel Structure, Masonry infill, Glass Infill, Bare Frame, Response Spectrum Method, ETABS, Storey Displacement, Base Shear, Structural Stiffness.

I. INTRODUCTION

Earthquakes are natural disasters that instill fear due to their unpredictable and devastating nature. They arise from the release of energy within the Earth's core, leading to seismic waves that induce lateral loads on structures. Depending on factors like building design, earthquake intensity, geographical location, and more, structures may experience significant deflections or collapse during seismic events, resulting in loss of life and extensive property damage.

The rapid growth of urban areas and industries has led to the construction of High rise buildings, even in seismic zones, posing formidable challenges for engineers. High rise buildings are particularly vulnerable to seismic forces and wind-induced vibrations, which can lead to significant displacements and structural failure.

To combat these adverse effects, engineers and researchers have been developing strategies for earthquake-resistant structures. The performance of structures during earthquakes is influenced by factors such as earthquake severity and structural characteristics, including material properties, sectional properties, and overall capacity.

A. Infill

Infill in buildings refers to the non-structural walls or panels that occupy the space between the structural frameworks—typically between columns and beams. Although these elements are not intended to carry structural loads, their presence significantly influences the building's behavior under various conditions, especially during seismic or wind events. Common infill materials include brick masonry, concrete blocks, glass panels, AAC blocks, and gypsum boards. Each material contributes differently to the building's thermal performance, acoustic insulation, and structural behavior.

Masonry infill, such as brick or concrete block walls, is widely used due to its durability and thermal mass. It provides increased lateral stiffness and can reduce inter-storey drift during seismic activity. However, if not properly integrated with the structural frame, it may cause brittle failure and localized damage.

In contrast, Glass Panel Infills are favored in modern architecture for their aesthetic appeal and ability to allow natural lighting. However, they offer minimal lateral resistance and may shatter under seismic or high wind forces, posing a safety risk. Lightweight partitions like gypsum boards or AAC blocks are easier to install and handle but are less effective in resisting lateral forces. The interaction between infill panels and the structural frame is a critical aspect of building performance. While these panels can help distribute lateral loads and improve stiffness, they can also create stress concentrations that the structural frame wasn’t originally designed to handle. In seismic zones, this interaction becomes even more crucial, as infills can inadvertently alter the building's dynamic response, leading to unanticipated damage. Therefore, understanding the type, placement, and detailing of infill materials is essential in the design process to ensure both safety and efficiency. Properly detailed infill systems not only improve a building’s energy

II. LITERATURE REVIEW REVIEW

“The Performance Assessment of the Structural Bracing Model for Multi-Story Building” (2024):The study underscores the importance of retrofitting older buildings in seismically active zones like Indonesia. The application of steel bracing, especially the Inverted-V type, not only enhances structural stiffness and stability but also significantly improves seismic performance indicators such as drift control, torsional response, and lateral load resistance. This case study offers valuable insights for structural engineers and urban planners aiming to strengthen existing infrastructure against future earthquakes.

“Seismic Response Spectrum Analysis (zone v) of a G+10 steel framed structure using different grades of steel” (2024):The study confirms that Seismic Response Spectrum Analysis is a robust tool for understanding and optimizing high-rise steel structures in seismic zones. More importantly, it introduces a material-efficient, performance-driven approach through grade variation of steel, addressing both safety and cost.

By merging advanced simulation with practical engineering principles, this research bridges a critical gap in seismic design literature and offers a scalable solution for future earthquake-resilient construction.

“Analysis and Design of High-Rise Steel Building with and without Bracings: A Review” (2024):This literature review affirms that the design and implementation of bracing systems in high-rise steel buildings are central to ensuring structural integrity, safety, and cost-efficiency. While traditional systems like X and V bracing remain reliable, modern innovations such as diagrids, advanced materials, and optimization algorithms are pushing the boundaries of what's possible in structural design. As urban infrastructure continues to grow taller and more complex, the integration of smart bracing strategies will be key to achieving sustainable and resilient architectural solutions.

III. OBJECTIVES

The objective of the current research study is

1) To analyze the seismic behavior of a multi-storey steel structure under dynamic loading conditions
2) To compare the performance of different infill material specifically masonry and glass panels
3) To evaluate the structural parameters such as base shear and displacement.

IV. STRUCTURAL MODELING AND ANALYSIS

In the present study, a detailed analysis was carried out to assess the seismic performance of three 10-storey building models using ETABS software. Initially, various research journals were reviewed to finalize the study's objectives. Three structural configurations were modeled: Model 1 represented a bare frame without any infill, Model 2 included masonry infill on three sides and a glass panel on one side, while Model 3 consisted of glass panel infill on all four sides. The structural design was performed in accordance with Indian standards, considering various load combinations including dead load, live load, and earthquake loads. For seismic evaluation, both linear static and response spectrum analysis methods were employed. The analytical results for all models were carefully extracted and compared to study their behavior under lateral seismic forces. Based on the observed data, significant insights were drawn, and conclusions were made regarding the influence of different infill materials on structural performance.

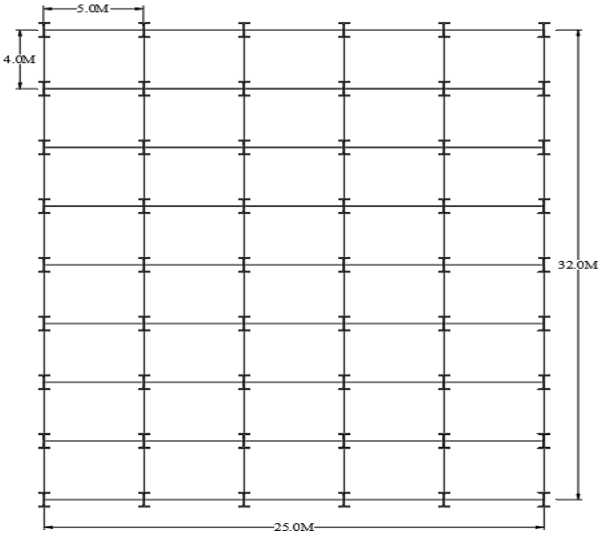

Fig.1: Plan of steel structure

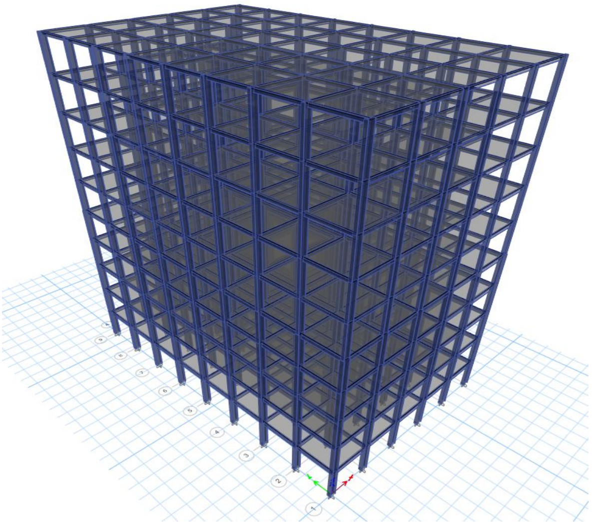

Fig.2: 3D View of Bare frame Models

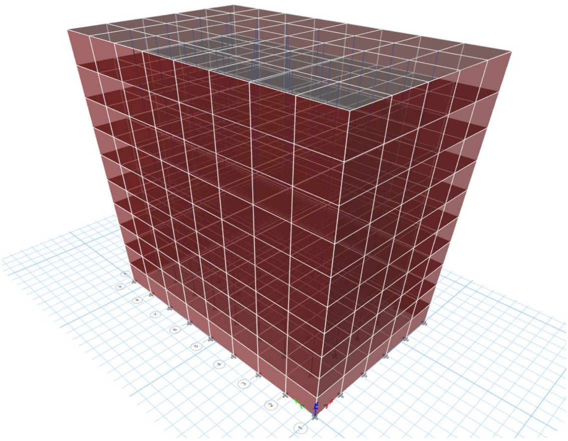

Fig.3**:** 3D View of 4 side panel frame Models

TABLE 1: MODEL PROPERTIES AND DESIGN PARAMETERS

Sl. No.	Description	Data
1.	Structure Length & Width in X and Y Direction	25m X 32m
2.	Each Bay Width	5m in X-Direction & 4m in Y-Direction
3.	Structure Height	40m (G+9)
4.	Each Floor Height	4m
5.	Column Size used	ISWB 600-2 - (1-5 Storey) ISWB 550 - (6-10 Storey)
6.	Beam Size used	ISLB 450 - (1-5 Storey) ISLB 400 - (6-10 Storey)
7.	Thickness of Roof	150mm
8.	Grade of Concrete (f_y) for Slab	M20
9.	Grade of Steel (f_y)	Fe 345
10.	Masonry wall thickness	200mm
11.	Glass Thickness	6mm

TABLE-2: MODELS CONSIDERED FOR THE ANALYSIS

Model Type	**Nomenclature**
Bare Frame Model	BFM
Three side panel & One side wall	TSP&OSW
Four side panel	FSP

V. RESULTS AND DISCUSSION

A. Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. The structure is analyzed with gravity load, static earthquake loading method and the resulting base shear is tabulated in the table below.

TABLE-3: MAX BASE SHEARS VALUES ALONG X AND Y – DIRECTION

Model Type	Max Base Shear (kN)			
	ESA		RSA	
	EQ-X	EQ-Y	RSA-X	RSA-Y
BFM	917.41	605.36	5134.11	3618.71
TSP&OSW	5268.44	5260.03	26750.29	28118.79
FSP	3622.70	4024.44	20498.29	22208.14

From Table 3 it is observed that the base shear is more for framed building with different materiel infills compared to bare framed buildings.

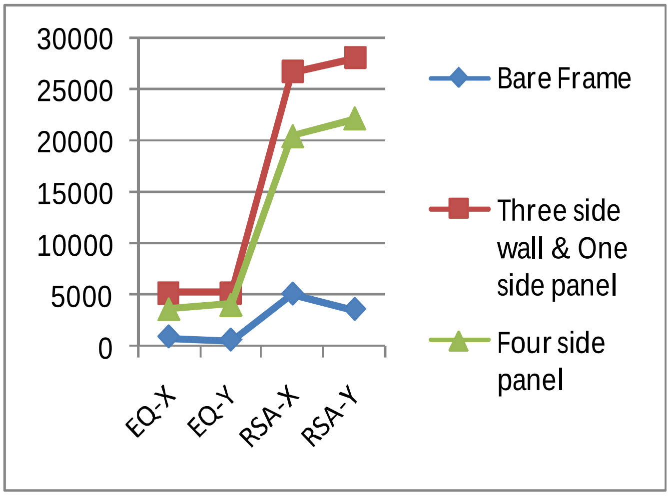

Fig.4: Comparison of Story Shear

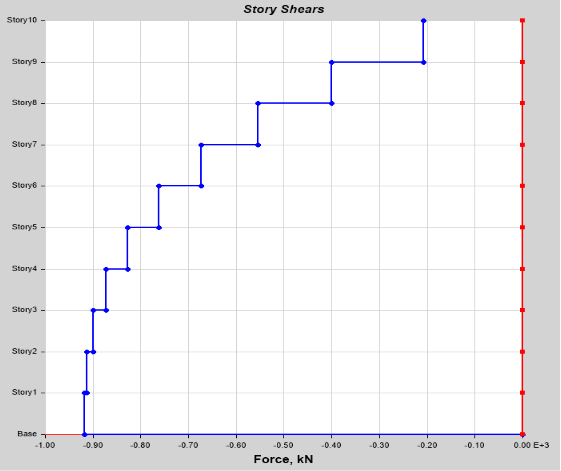

Fig.5: BFM model of Max Base Shear Value of ESA

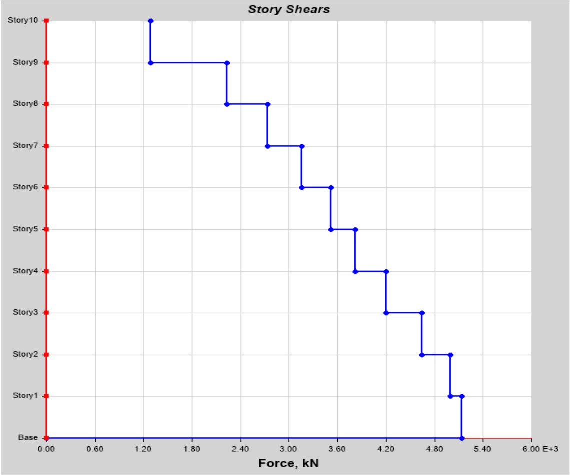

Fig.6: BFM model of Max Base Shear Value of RSA

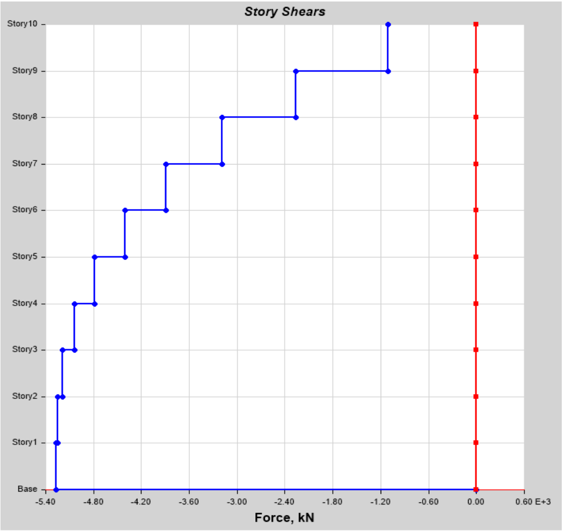

Fig.7: TSP & OSW model of Max Base Shear Value of ESA

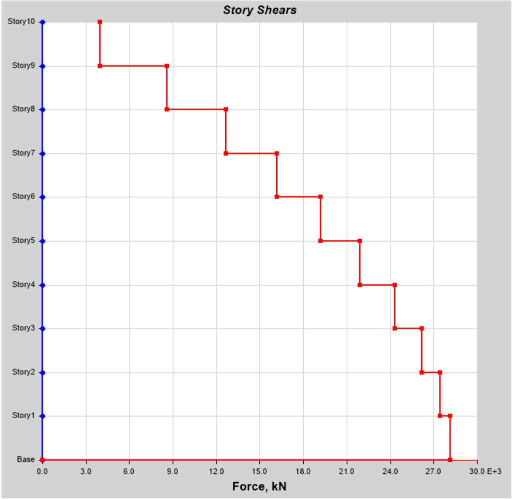

Fig.8: TSP & OSW model of Max Base Shear Value of RSA

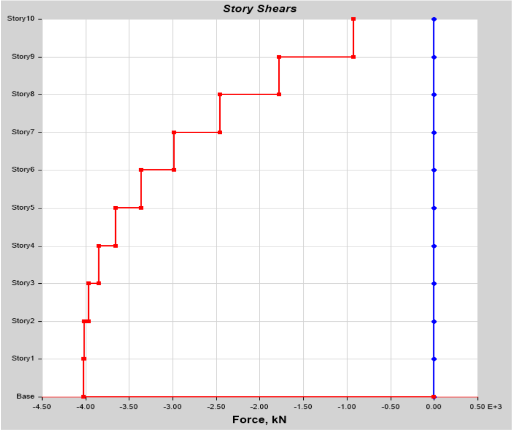

Fig.9: FSP model of Max Base Shear Value of ESA

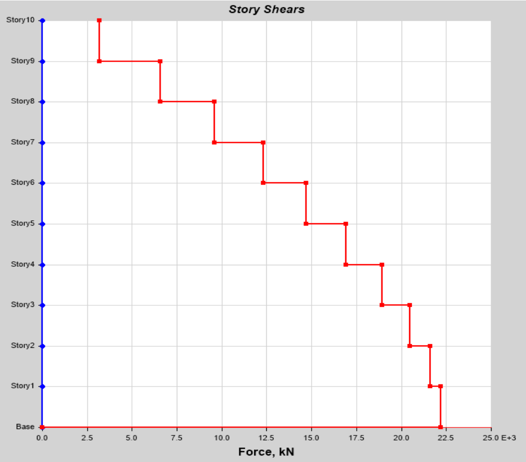

Fig.10: FSP model of Max Base Shear Value of RSA

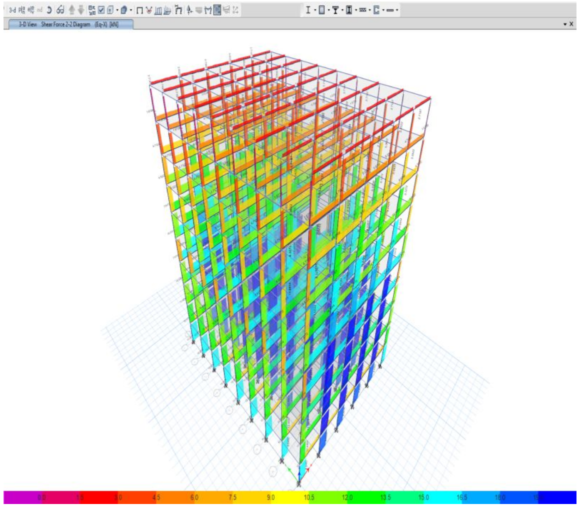

Fig.11: BFM model of Max SF Value of ESA

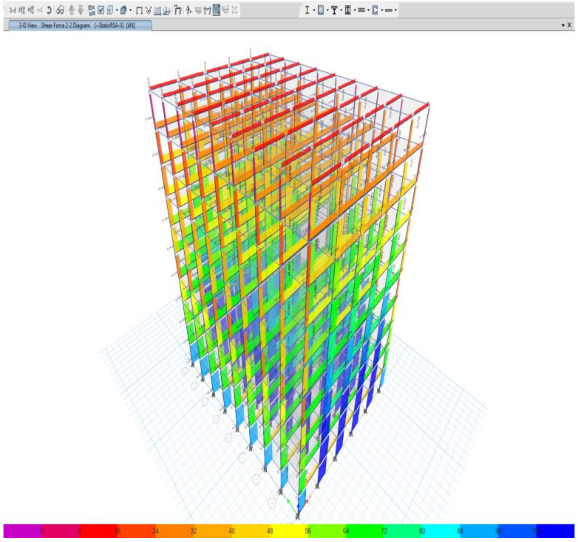

Fig.12: BFM model of Max SF Value of RSA

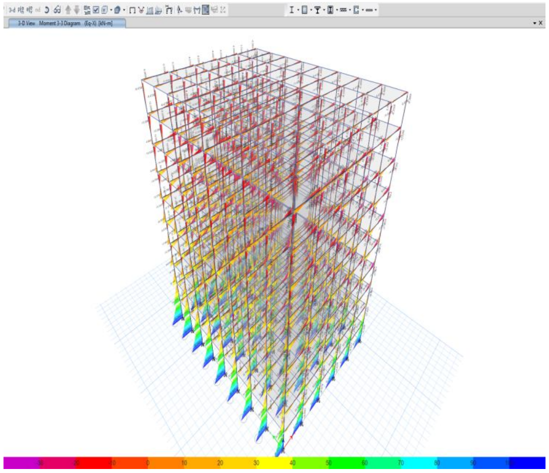

Fig.13: BFM model of Max BM Value of ESA

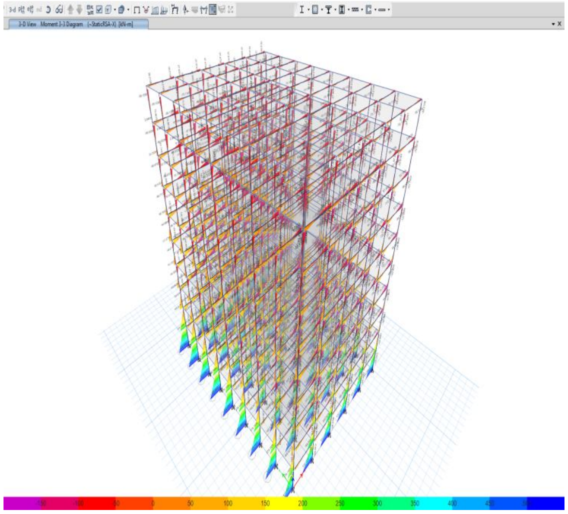

Fig.14: BFM model of Max BM Value of RSA

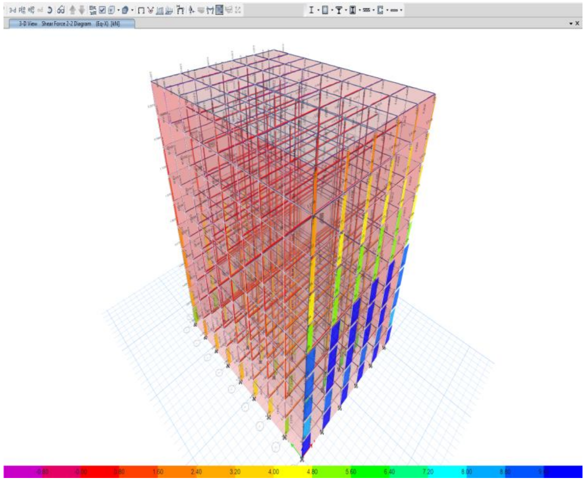

Fig.15: TSP & OSW model of Max SF Value of ESA

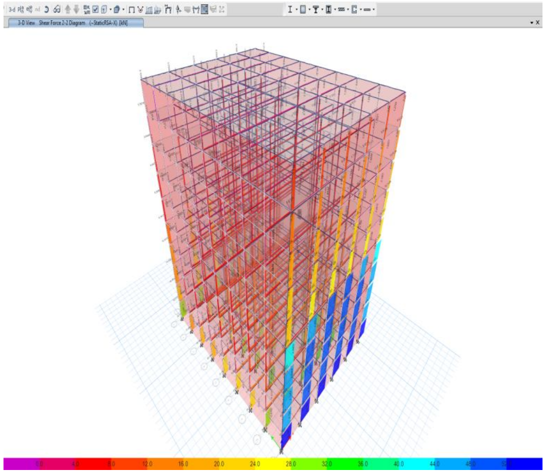

Fig.16: TSP & OSW model of Max SF Value of RSA

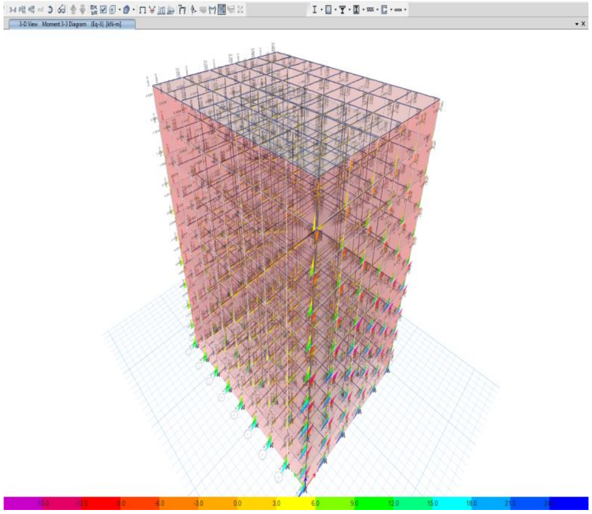

Fig.17: TSP & OSW model of Max BM Value of ESA

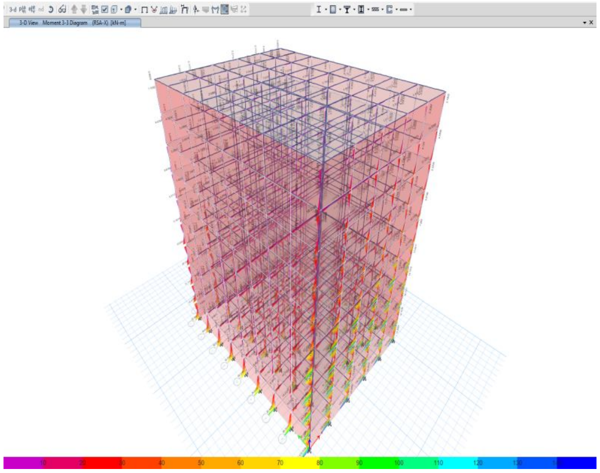

Fig.18: TSP & OSW model of Max BM Value of RSA

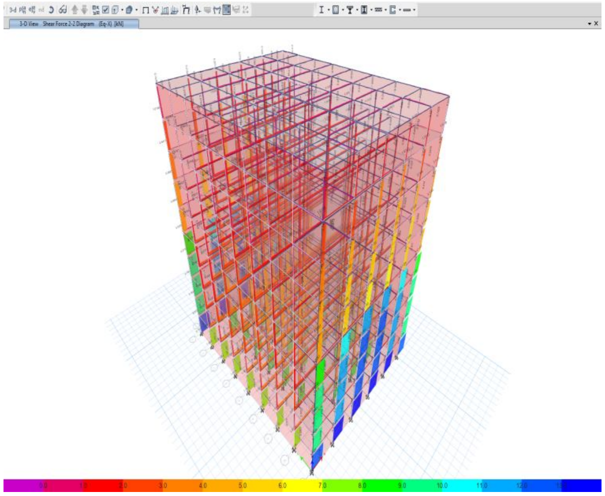

Fig.19: FSP model of Max SF Value of ESA

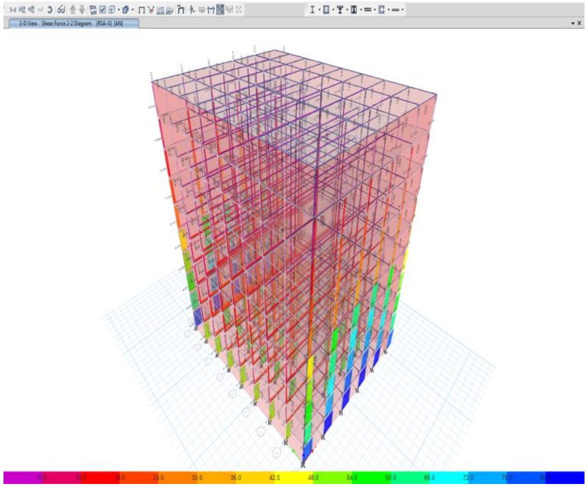

Fig.20: FSP model of Max SF Value of RSA

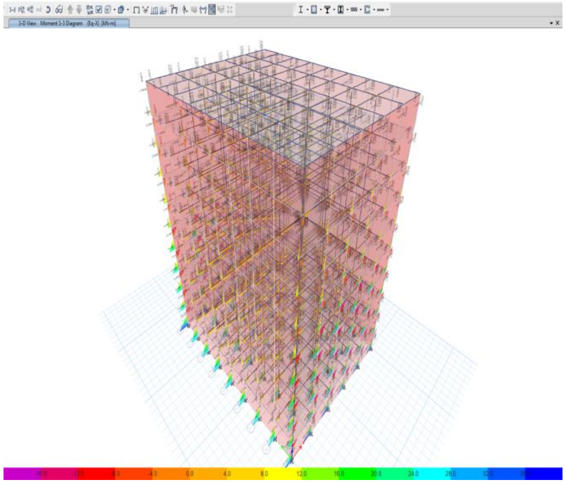

Fig.21: FSP model of Max BM
Value of ESA

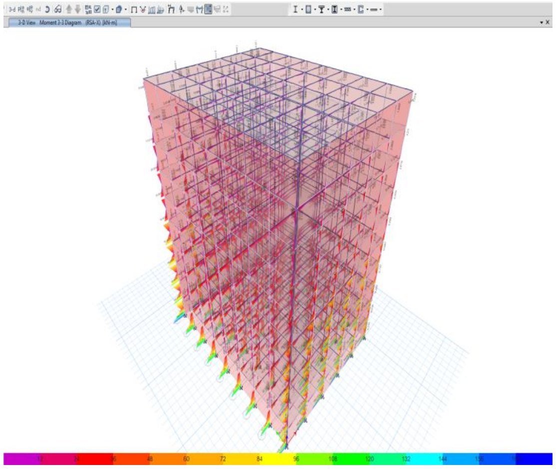

Fig.22: FSP model of Max BM
Value of RSA

B. Storey Displacement

The storey displacement is the lateral displacement of the storey with respect to the ground. The maximum storey displacement along X and Y direction obtained from the equivalent static force method and response spectrum method is shown in below table.

TABLE-4: Max Storey Displacement Values Along X And Y – Direction

Model Type	Max Storey Displacement (MM)			
	ESA		RSA	
	EQ-X	EQ-Y	RSA-X	RSA-Y
BFM	60.83	110.62	266.72	447.71
TSP&OSW	11.69	3.73	54.90	16.82
FSP	14.44	12.32	68.19	56.69

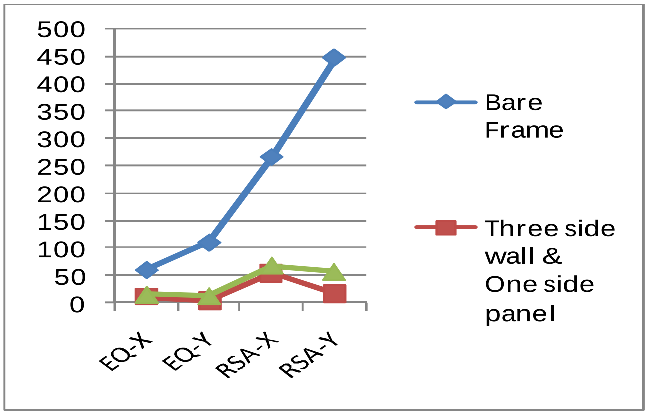

Fig.23: Comparison of Story Displacement

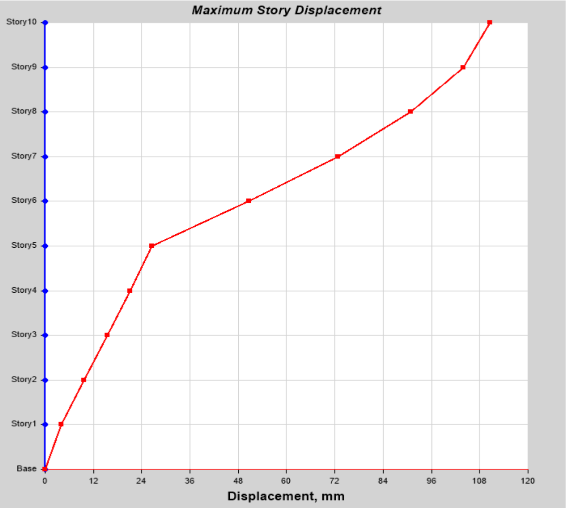

Fig.24: BFM model of Max Displacement Value of ESA

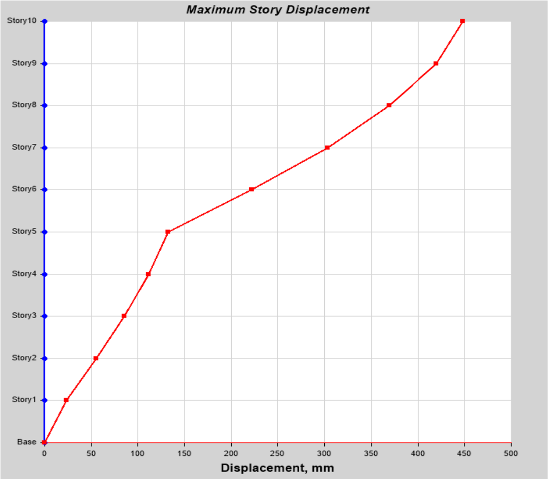

Fig.25: BFM model of Max Displacement Value of RSA

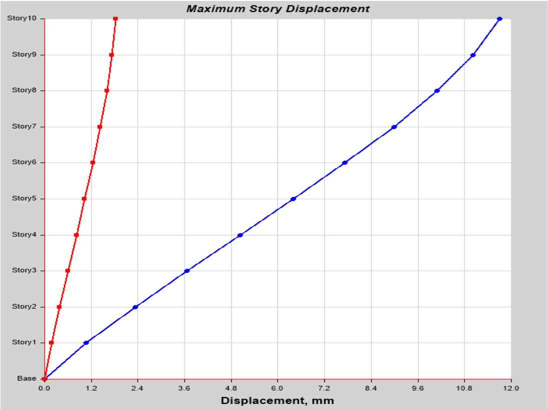

Fig.26: TSP & OSW model of Max Displacement Value of ESA

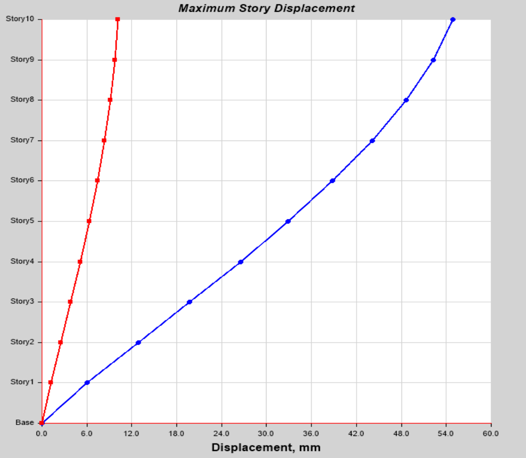

Fig.27: TSP & OSW model of Max Displacement Value of RSA

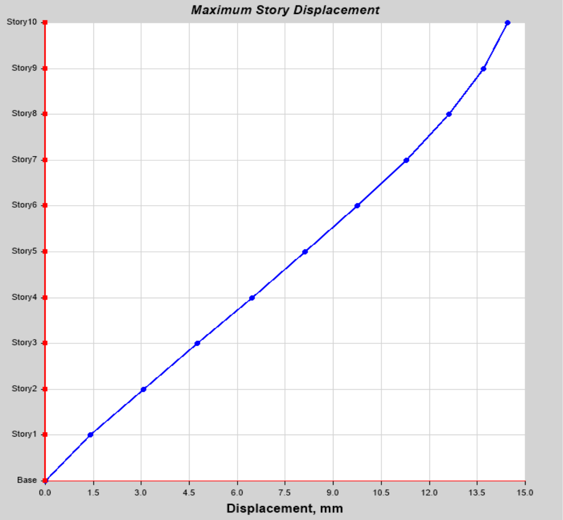

Fig.28**:** FSP model of Max Displacement Value of ESA

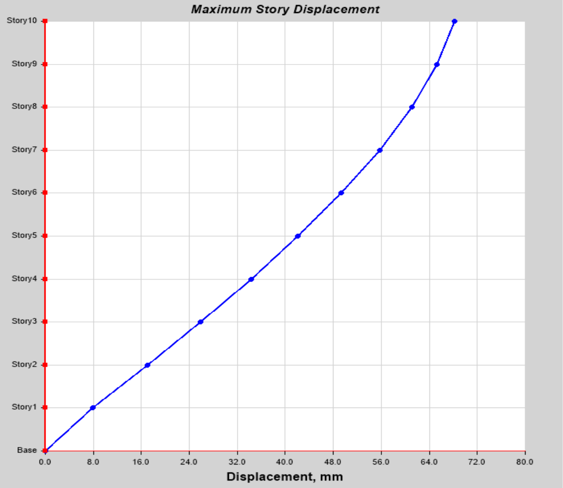

Fig.29: FSP model of Max Displacement Value of RSA

VI. CONCLUSION

The study reveals that the presence of infill walls significantly increases the storey shear capacity of the structure when compared to the bare frame model.

1) The three-side masonry wall & one-side glass panel configuration demonstrated the highest storey shear values in both EQ and RSA methods, indicating greater lateral stiffness and load resistance.
2) The four-side glass panel model also improved shear resistance over the bare frame, but performed lower than the masonry wall model due to the lower stiffness of glass infills compared to masonry.
3) RSA consistently produced higher storey shear values than EQ for all models, emphasizing its capability to capture dynamic effects more accurately.
4) Overall, masonry infill significantly enhance seismic performance, while glass infill provide moderate improvement over a bare frame. The selection of infill type should balance structural stiffness, architectural needs, and seismic safety requirements.
5) Infill significantly reduce storey displacement compared to bare frame structures, enhancing lateral stiffness.
6) Masonry infill walls provide better displacement control than glass panels due to higher rigidity and mass contribution.
7) RSA consistently produces higher displacement values than EQ, indicating its greater sensitivity to dynamic effects.
8) For earthquake-resistant design, incorporating masonry infill is more effective in controlling lateral deflections, whereas bare frames are the most flexible but most vulnerable to seismic displacements.

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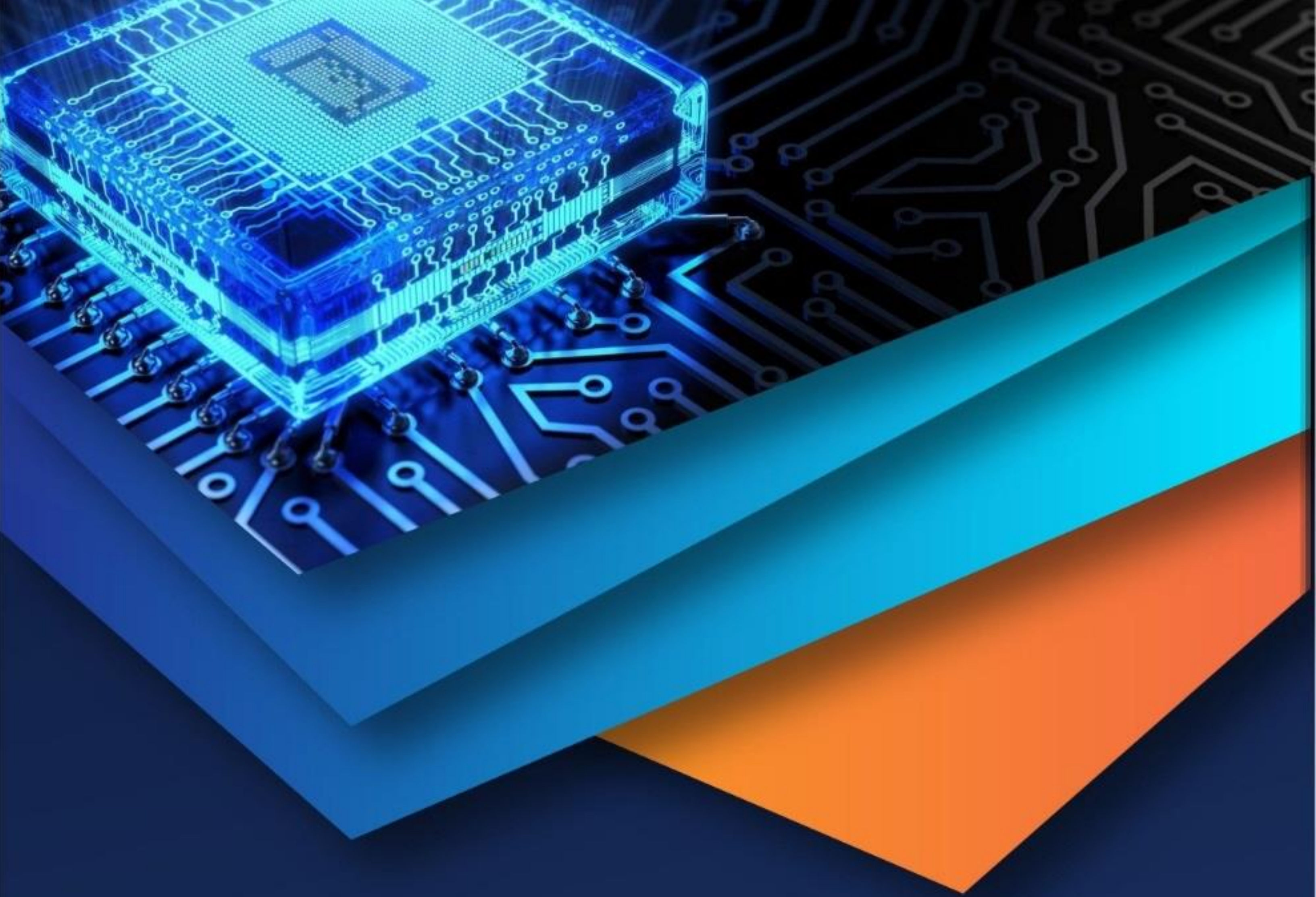

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