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COMPARE THE PERFORMANCE OF ADVANCED STRUCTURAL FORMS IN SEISMIC ZONES, AND EVALUATE THE COST AND TIME IMPLICATIONS OF IMPLEMENTING ADVANCED STRUCTURAL FORMS

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Abstract - *The construction structure resembles the skeletal framework of a human body, serving as the essential support upon which the entire building relies. Every component within construction contributes to this support, varying in their degree of importance as they uphold both themselves and adjacent elements. The present study was carried out to analyze the structural performance of the G+10 story framed structure subjected to seismic loading of Zone 3 using ETABS software. Four similar models having the Difference plan configuration is prepared. The comparison of conventional reinforced concrete structure with Mivan Technology, bracing system, Diagrid structure, steel plate shear wall system is done and the result obtained is compared in terms of the structural performance of the following parameters-maximum story displacement, story drift, story Drift and story displacement.*

Key Words: **ETABS, Storey Drift, Storey Displacement, Time and cost**

1. INTRODUCTION

Worldwide, there's a significant demand for constructing high-rise buildings due to the expanding population. Designing engineering structures to be earthquake-resistant is crucial for mitigating potential damage from future seismic events. The seismic design of structures relies on ground motion specifications derived from past earthquake data. Thus, creating earthquake-resistant designs tailored to seismic frequencies is paramount for minimizing damage. However, earthquake forces vary and are unpredictable. Hence, software tools are essential for analysing structures under various seismic forces. So the significance of effectively designing and constructing earthquake-resistant structures cannot be overstated. To address this, ETABS offers comprehensive static and dynamic analysis capabilities, accommodating a diverse array of gravity, thermal, and lateral loads.

2. OBJECTIVE

The study involves a comparison of four technologies: concrete structures, bracing systems, diagrid structures, and steel plate concrete composite shear wall structures. The primary aim is to identify suitable structural forms for effectively resisting seismic loads in high-rise buildings, as well as to compare the performance of load and drift in seismic zones and assess the cost and time implications of advanced structural forms.

3. METHODOLOGY

The objective of the study was achieved through the utilization of ETABS software for analysing story drift and displacement, while Primavera software was employed to analyse cost and time aspects.

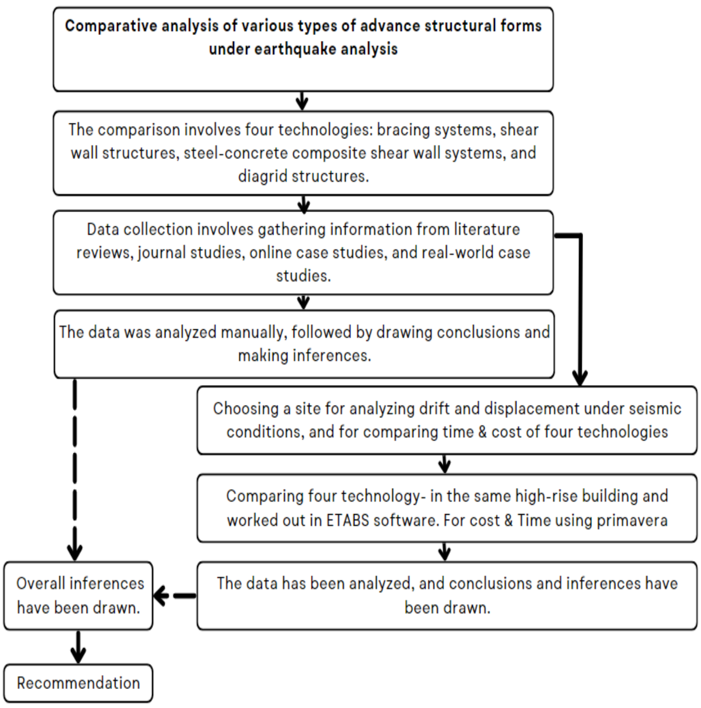

Figure 1: Methodology

4. SCOPE

Validating techniques and mediums for improved living standards aids architects and engineers in crafting building forms that are more resilient to earthquakes.

5. LIMITATION

This study exclusively compared only four technologies based on their performance in drift and displacement within seismic zones, as well as their associated time and cost factors during construction.

6. LITERATURE STUDY

6.1 LITERATURE STUDY -BRACING

The review of the journal paper involves a comparison of steel-braced and un-braced structures during the collapse, Bracing systems are highly effective in significantly reducing the deformations of structural members. Therefore, using bracing systems for seismic retrofitting can also help prevent progressive collapse **(Bikram Shah and Feng Xu, 2019).**

6.2 LITERATURE STUDY -DIAGRID

The review of the journal paper involves a comparison of DIAGRID and TUBE structures in terms of displacement, Diagonal members in Diagrid structural systems can support both gravities loads and lateral forces due to their triangulated configuration. Diagrid structures are more effective at minimizing shear deformation because they handle lateral shear through the axial action of diagonal members **(Mohsen Rostami, Fatemeh Gorji Sinaki, Abdolreza S. Moghadam, 2016).**

6.3 LITERATURE STUDY - STEEL-CONCRETE COMPOSITE SHEAR WALL

The review of the journal paper involves a comparison of braced frame structure and the SPSW system, An SPSW steel building is more effective than a braced steel building in terms of story drift and story displacement. Both SPSW steel buildings and braced steel buildings are more effective at reducing responses when they are positioned at the center rather than at the edge **(Dr. C Prabha and Mahima Mani K M,2022).**

6.4 LITERATURE STUDY – MIVAN TECHNOLOGY

The review of the journal paper involves a comparison of the seismic performance of the mivan structure and conventional structure, the displacement of a conventional structural system is 26% greater than that of a Mivan structural system. Additionally, the Mivan structural system has an average of 32% less story drift compared to a conventional structural system **(M. Walvekar and Hemant L. Sonawadekar,2017).**

7. CASE STUDY

7.1 CASE STUDY -BRACING

In 1998, a construction project was completed, incorporating an innovative integrated X-bracing system in a 10-story high-rise office building spanning an area of 20,260 square meters. The height of the building is about 40 meters. This pioneering design features a repetitive X steel bracing system on the building's exterior, with each X-bracing unit measuring about 4 meters by 8 meters, intricately connected to the edge beams. The primary function of this structural element is to enhance the building's stability, particularly during wind and seismic events such as earthquakes. By limiting lateral movement, the X-bracing system significantly reduces the risk of damage to both the structural components and the exterior cladding, ensuring the building's resilience and safety.

In terms of cost and time analysis compared to conventional structures, the cost of the X-bracing system increases by about 7% while the time required for construction increases by about 4% when compared to conventional structures.

7.2 CASE STUDY – DIAGRID

In 2024, a construction project was completed, incorporating the DIAGRID system in a 14-story high-rise office building spanning an area of 15,246 square meters. The height of the building is about 56 meters. The entire building is constructed with steel, using 316 stainless steel for the DIAGRID structure. The DIAGRID structure is connected with pin joints to the steel edge beam of the building. The base size of the DIAGRID structure is about 900 mm of steel, which gradually reduces as the height increases. At the top, the DIAGRID structure is about 250 mm thick, which effectively minimizes shear deformation by carrying lateral shear through the axial action of the diagonal members.

In terms of cost and time analysis compared to conventional structures, the cost of the DIAGRID system increases by about 42% while the time required for construction decreases by about 52% when compared to conventional structures.

7.3 CASE STUDY – STEEL-CONCRETE COMPOSITE SHEAR WALL

In 2024, a construction project was completed, incorporating the STEEL-CONCRETE COMPOSITE SHEAR WALL system in a 14-story high-rise office building spanning an area of 15,246 square meters. The height of the building is about 56 meters. The entire building is constructed with steel. The steel plate shear wall system or tube system is used with a 4mm thickness of steel plate and M20 grade of concrete. The beams are connected to the steel plate of the core, and the beam is connected to the outer edge beam and outer columns of the structure which leads to resist lateral loads (wind, seismic, impact). The building is designed to act like a hollow cylinder cantilevered perpendicular to the ground.

In terms of cost and time analysis compared to conventional structures, the cost of the STEEL-CONCRETE COMPOSITE SHEAR WALL system increases by about 37% while the time required for construction decreases by about 66% when compared to conventional structures.

7.3 CASE STUDY – MIVAN TECHNOLOGY

In 2020, a construction project was completed, incorporating Mivan technology in a 16-story high-rise residential building spanning an area of 3,227,328 square feet. The height of the building is 58 meters. The entire building is constructed with a concrete structure. The walls have a thickness of 200mm and 150mm, while the slabs have a thickness of 150mm. The shear wall structure provides more seismic resistance and durability, ensuring maximum safety during earthquakes.

In terms of cost and time analysis compared to conventional structures, the cost of MIVAN TECHNOLOGY decreases by about 20% while the time required for construction decreases by about 48% when compared to conventional structures.

8. PROJECT PROPOSAL

8.1 PROJECT PROPOSAL SITE DETAILS

The selected site for the office is a high-rise building covering approximately 950,000 square meters, with a height of 10 stories. The floor plan measures about 100 meters by 60 meters. Conventional construction methods were used. The building specifications include a story height of 4 meters, slab thickness of 200mm, wall thickness ranging from 75mm to 200mm, column dimensions of 1 meter by 1 meter, and a beam depth of approximately 800mm. The site is located in seismic zone III, with medium soil conditions.

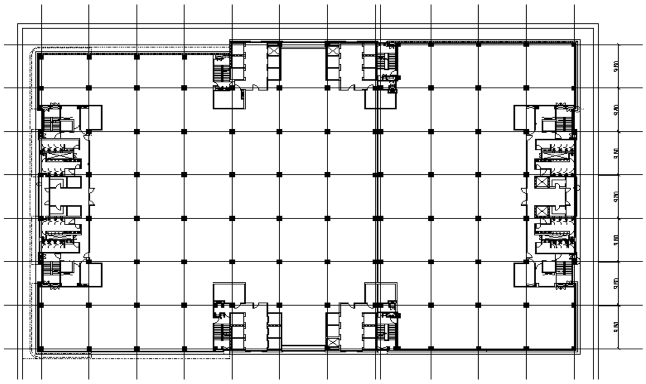

Figure 2: Existing site plan

8.2 ANALYSIS

The analysis is conducted using ETAB software to analyze the drift and displacement of buildings in various technologies. The four technologies are named as:

Model 1-Bracing system

Model 2-Diagrid system

Model 3-Steel-Concrete Composite Shear Wall System

Model 4- Mivan technology (Shear wall system)

8.2.1 Specification – Model 1

The proposed site incorporates an X-bracing system with specifications similar to conventional methods. The exterior structure utilizes steel X-bracing. The design includes a slab thickness of 200mm, wall thickness of 200mm, column dimensions of 1 meter by 1 meter, and a beam depth of approximately 800mm.

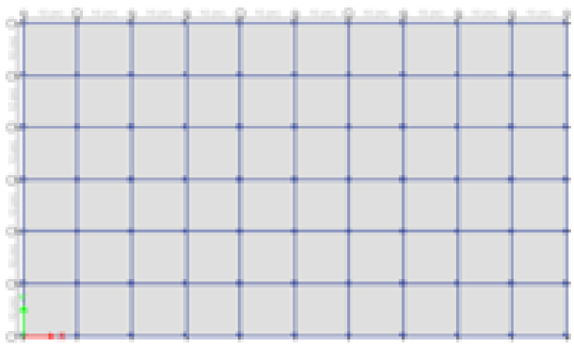

Figure 3: Model 1 - plan

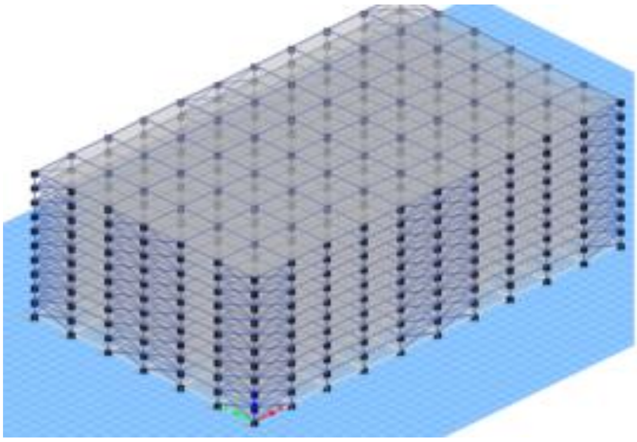

Figure 4: Model 1 - Isometric view

8.2.2 Specification – Model 2

The Diagrid system is integrated into the proposed site, with specifications including a slab thickness of 200mm, wall thicknesses of 200mm and 75mm, and a beam depth of approximately 1000mm. The entire building is constructed using a steel structure.

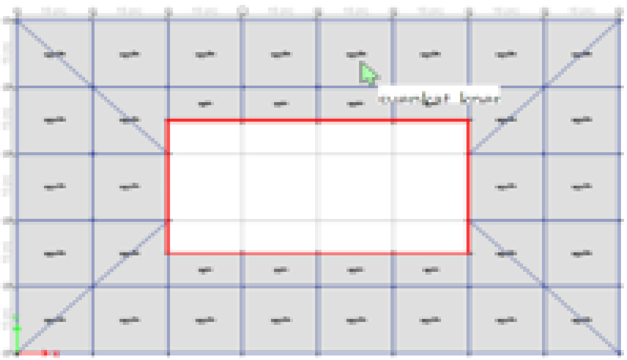

Figure 5: Model 2 – plan

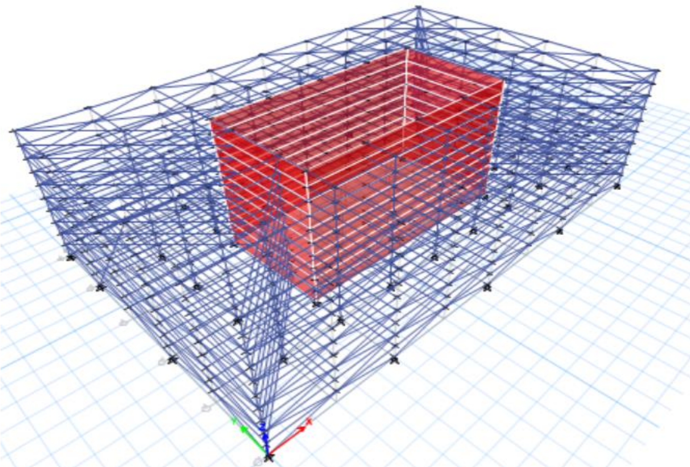

Figure 6: Model 2 - Isometric view

8.2.3 Specification – Model 3

The proposed site incorporates a steel-concrete composite shear wall system. The specifications include a slab thickness of 200mm, wall thicknesses of 200mm and 75mm, and a beam depth of approximately 1000mm.

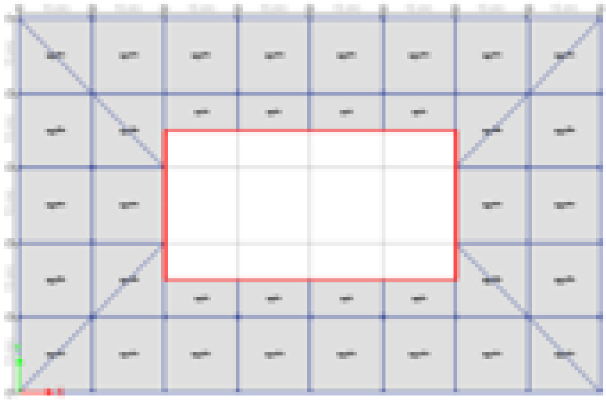

Figure 7: Model 3 – plan

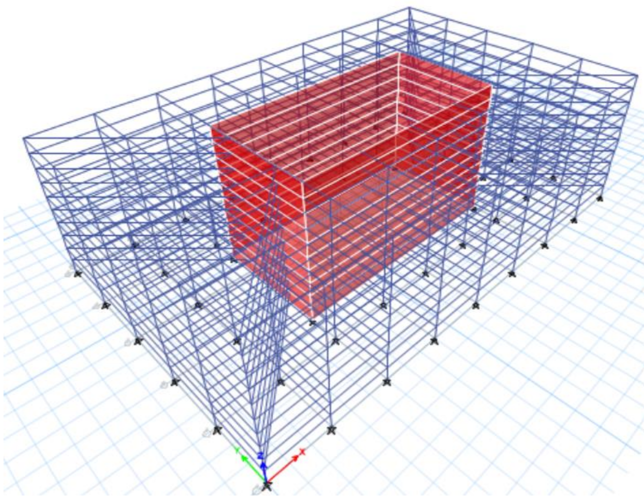

Figure 8: Model 2 - Isometric view

8.2.3 Specification – Model 3

The proposed site incorporates a steel-concrete composite shear wall system. The specifications include a slab thickness of 150mm, wall thicknesses of 200mm and 75mm, and a beam depth of approximately 1200mm.

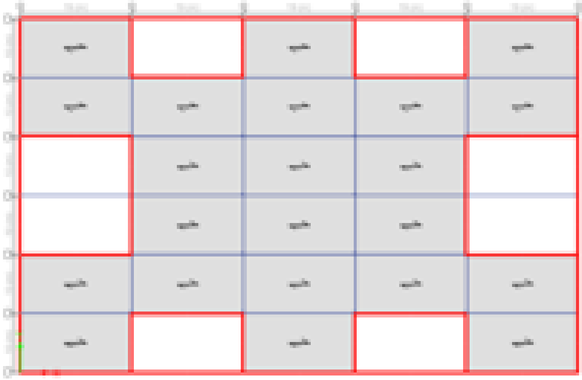

Figure 9: Model 4 - plan

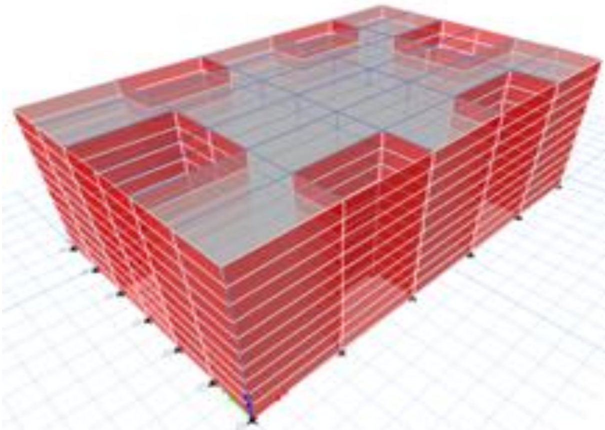

Figure 10: Model 4 - Isometric view

9. RESULT:

9.1 SEISMIC ANALYSIS RESULTS

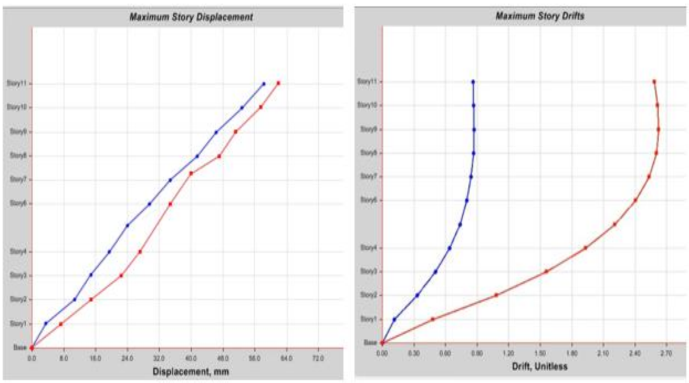

Figure 11: Model 1- Drift & Displacement

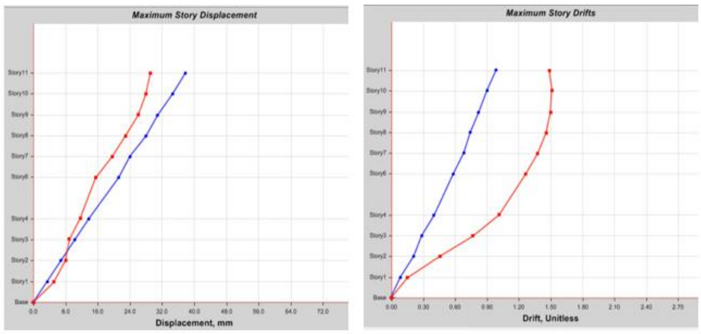

Figure 12: Model 2- Drift & Displacement

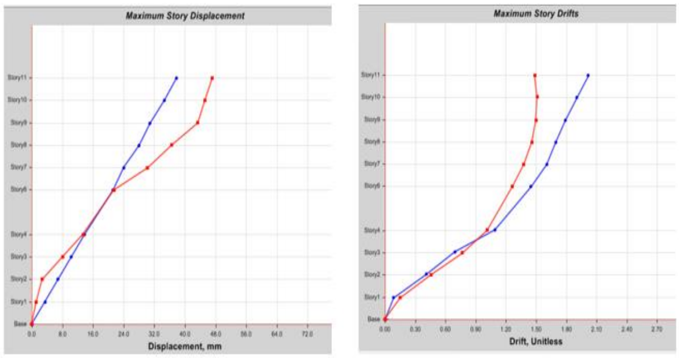

Figure 13: Model 3- Drift & Displacement

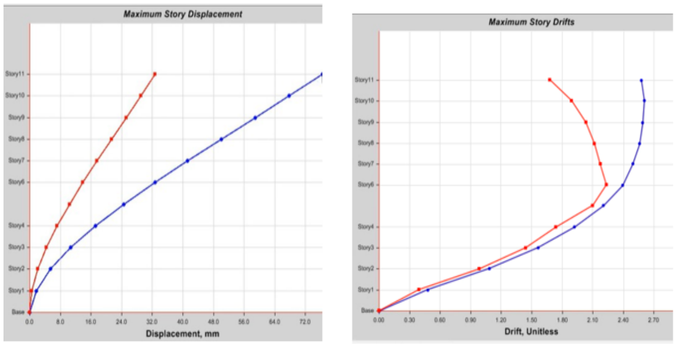

Figure 14: Model 4- Drift & Displacement

In Model 1, the seismic analysis results indicate that the maximum displacement is approximately 49.5mm in the X direction and 52.2mm in the Y direction. The maximum drift is 2.60 in the X direction and 0.88 in the Y direction.

In Model 2 , the seismic analysis results indicate that the maximum displacement is approximately 28.5mm in the X direction and 38.2mm in the Y direction. The maximum drift is 1.50 in the X direction and 0.93 in the Y direction.

In Model 3, the seismic analysis results indicate that the maximum displacement is approximately 47.0mm in the X direction and 30.1mm in the Y direction. The maximum drift is 1.50 in the X direction and 1.66 in the Y direction.

9.2 COST & TIME ANALYSIS RESULTS

In Model 1, The cost of a bracing system structure is approximately 11% higher than that of a conventional structure, and the duration is also approximately 11% longer.

In Model 2, The cost of a diagrid structure is approximately 30% higher than that of a conventional structure, while the duration is reduced by approximately 33%.

In Model 3, The cost of a Concrete-Filled Composite Plate Shear Wall System is approximately 27% higher than that of a conventional structure, while the duration is reduced by approximately 40%.

In Model 4, The Mivan technology saves approximately 13% in cost and reduces the duration by approximately 36% compared to conventional methods.

9. CONCLUSION:

The four technologies are more effective in seismic zones than conventional structures. Among them, the most effective in seismic zones is the diagrid structure, followed by the steel-concrete composite shear wall system, the bracing system, and mivan technology. In terms of time and cost efficiency compared to conventional methods, mivan technology is the most effective, followed by the bracing system, the steel-concrete composite shear wall system, and finally, the diagrid structure.

10. RECOMMENDATION:

In India, high-rise buildings, especially residential ones, are the most affected in seismic zones. These buildings are more vulnerable than mid-rise structures. Therefore, residential buildings can incorporate a combination of mivan and bracing systems for better seismic performance.

The choice of technology depends on the height of the building. For example, concrete-filled composite shear walls can be used for buildings with more than 15 floors.

If a dynamic form of the building is to be constructed, the preferred technology is the diagrid structure, as it can withstand the dynamic form of the building.

11. REFERENCE:

[1]https://www.academia.edu/76650976/Effects_of_Steel_Bracings_in_the_Progressive_Collapse_Resistance_of_Reinforced_Concrete_Building?sm=b

[2]https://www.academia.edu/43043729/Comparison_of_Braced_Steel_Building_with_Steel_Plate_Shear_Wall?sm=b