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Research Article

Study of Comparison of different Lateral Force Resisting Systems (LFRS) at various Building Heights

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Abstract **–** This research thoroughly analyses how different lateral force resistance systems work in 20, 40, and 60-story buildings. Diagrids, outriggers, shear walls, and moment resisting frames are some of the designs that have been studied. The main goal is to test and compare how these systems work and how well they can handle earthquakes at different building heights. Building models are designed and studied under different earthquake condition using ETABS. The success of the systems at different heights is found by looking at structural factors like storey drift, storey displacement and base shear. The results of this study give us important information about how to choose the best horizontal force resistance systems based on the height of the building. The comparison study can help engineers and designers pick the best method for a project by giving them more information. This study aims to learn more about how tall buildings behave to lateral forces and to encourage the creation of stronger and more efficient building designs in areas prone to earthquakes.

Keywords – LRFS, Seismic Analysis, Bracing, Diagrid, Outriggers.

I. INTRODUCTION

Lateral Force Resisting Systems (LFRS) are significant in structure engineering because they protect against the effects of lateral loads like earthquakes and winds. These systems keep buildings stable and whole, lowering the chances that they will be damaged or fall in harsh circumstances. LFRS protects people and property in areas prone to shocks and high winds. The development of LFRS shows a path from past practices, where early civilizations built simple versions of these systems into their buildings, to complex engineering solutions used today. This growth was marked by important turning points, such as the scientific discovery of LFRS after earthquakes like the 1906 San Francisco earthquake, which caused people to rethink how buildings are designed and built. As technology and materials have improved, more complicated and efficient LFRS have been made, such as flex walls, braced frames, and diagrid systems that meet the needs of modern high-rise design. However, it takes work to make LFRS work well for buildings of different heights. Because earthquake and wind forces are constantly changing, new ways of building must be found to ensure structures are strong. Engineers have to figure out these complicated problems while considering how buildings behave differently when they are under horizontal stress to come up with safe and cost-effective solutions. This study is important because it fills in a significant gap in the research by comparing different LFRS across a range of building heights. This study aims to help us better understand how structures respond to side loads by looking at the performance and efficiency of different systems in middle to very tall buildings. This comparison is essential for fostering innovation in the field, which will create better and more durable buildings. The study's results will help architects and builders make better designs to withstand natural disasters as environmental problems and city populations grow.

II. RESEARCH GAP

The current study on Lateral Force Resisting Systems (LFRS) has laid a solid basis by explaining how they are designed and implemented and how well they work in buildings hit by lateral forces like winds and earthquakes. Researchers have looked at many types of LFRS in different building situations, including flex walls, braced frames, and diagrid systems. However, there is a clear need for more studies that compare these methods across a wide range of building heights. This lack of comparison research means that we need to know which LFRS works best for different building scales and shapes, especially when there are different weather conditions and earthquake zones. To move the field of structural engineering forward, these gaps must be filled. This is especially important as cities grow and buildings get bigger and more complicated. The study aims to fill these gaps by carefully looking at various LFRS in buildings of different heights. This study will make a big difference in the field by giving us new information about choosing and improving LFRS. This will help make cities safer and more adaptable. The study's purpose is to help architects and engineers make better choices by analyzing and comparing things in great detail. This will help ensure that buildings are nice to look at, safe, and long-lasting.

III. AIMS AND OBJECTIVES

The aim of this study is to critically compare the efficacy of different Lateral Force Resisting Systems (LFRS) across a variety of building heights, thereby enhancing structural safety and efficiency. The objectives are;

- To evaluate the performance of various LFRS involving an in-depth examination of how shear walls, braced frames, and diagrid systems, among others, fare in buildings of different heights, assessing their ability to withstand lateral forces.
- To analyze structural responses under Lateral Loads to understand how different LFRS respond to wind and seismic loads.
- To identify the Most Effective LFRS for Various Building Heights focusing on 20, 40, and 60 storeys as benchmarks for comparison.

IV. MATERIALS AND METHOD

Building Details

The Floor Plan of the Building belongs to the Commercial Plaza, Cavalry Ground Commercial Area, Lahore, Pakistan. The Grid of the building is un-symmetrical. The grid layout of the building is shown in fig.4.1.

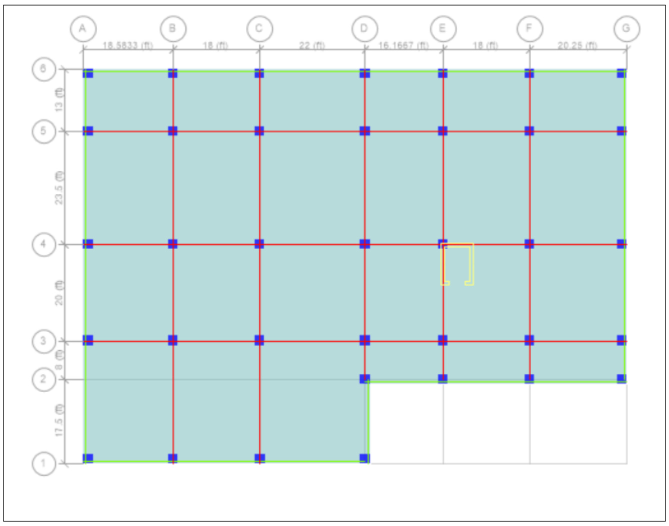


Figure 4.1. Grid layout of Building

Floor to Floor Height is 12’-0” each floor.
Seismic Force is applied in X direction of the building
Building Types: Simple Moment Resisting Frame(SMRF), SMRF with Shear Wall, Diagrid Structure, Outrigger Structure.
Three Building Heights are used: G+19, G+39, G+59

Table 1. Cross sectional sizes and material properties

Cross Sectional Sizes	
Column Sizes	C1=24”x24”
Beam Sizes	B1=12”x21”,B2= 18”x21”
Shear Wall	SW= 12” thick
Outrigger Beam	OB=12”x21”
Diagrid Coloumn	DC=12”x12”
Materials	
compressive strength of concrete, f’c	4 t
Elastic modulus of concrete , E	3600 Ksi
Poison ratio of concrete	0.2
Yield stress of steel	60 Ksi
elastic modulus of steel	29000 Ksi
poison ratio of steel	0.3

Methodology

1. Following is the step by step procedure to execute our research:
2. Aquisition of floor plan of Mall in Lahore.
3. Model the Building in Etabs (Define Materias, Cross sections, Load Patterns)
4. Apply Static Loading using IBC-2019
5. Apply Earthquack Load using Equivalent Lateral Force (ELF) method.
6. Analyse the Ordinary Moment Resisting Frame for 20, 40 and 60 storey building.
7. Analyse the Ordinary Moment Resisting Frame with Shear Wall for 20, 40 and 60 storey building.
8. Analyse the Building with Diagrid structure for 20, 40 and 60 storey building.
9. Analyse the Building with Outrigger structure for 20, 40 and 60 storey building.
10. Parameters of consideration: Storey Displacement, Storey Drift, Base Shear.

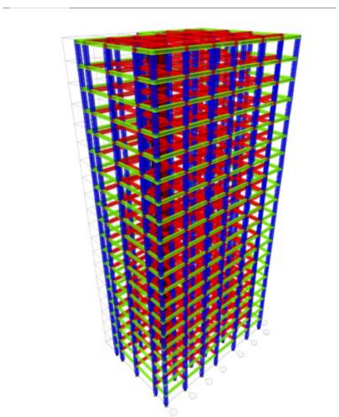


Figure 4.2. 20 Storey Moment Resisting Frame

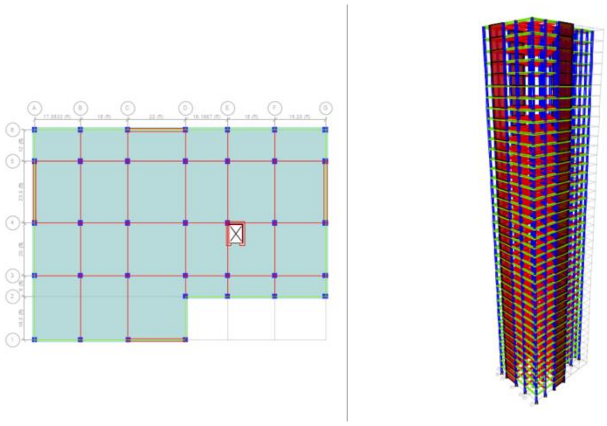


Figure 4.3. 40 Storey Building with Shear Wall

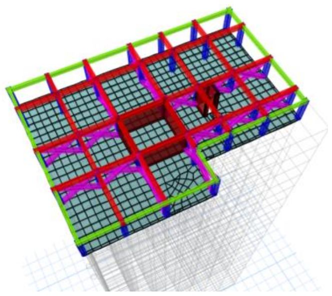


Figure 4.4. 40 Storey Building with Outrigger

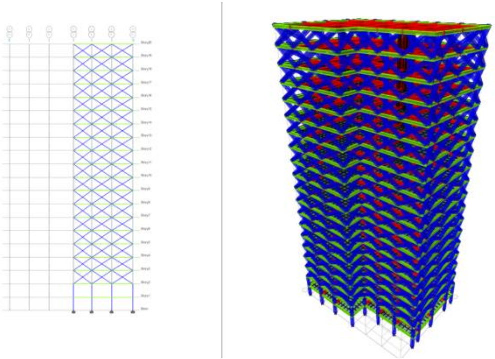


Figure 4.5. 20 Storey Diagrid Structure

V. RESULTS

The model analysis is done by using various parameters and with some relationship by comparing with the pattern of identical parameters

The parameters for this analysis are- □

- Storey Displacement □
- Base Shear
- Storey Drift

Storey Displacement

From this study, we saw that the displacements of three different models. Displacement of Building with Outrigger is minimum in all storey heights.

Table 2. Storey Displacement of 20 Storeys

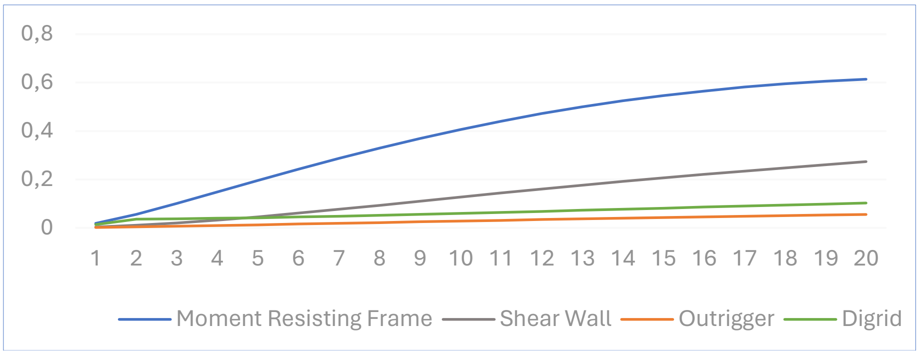


Table 3. Storey Displacement of 60 Storeys

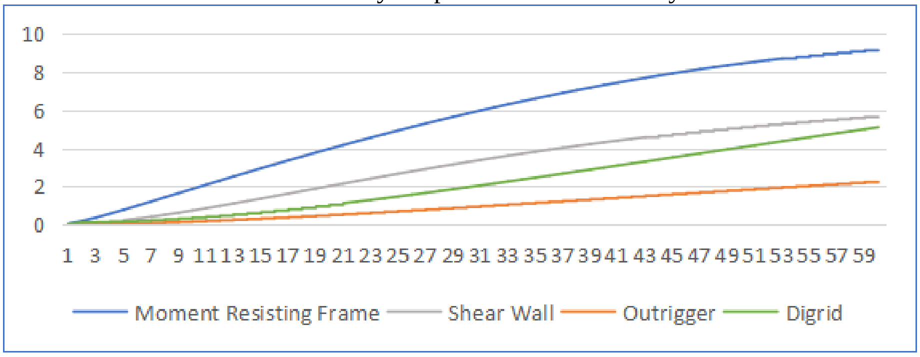
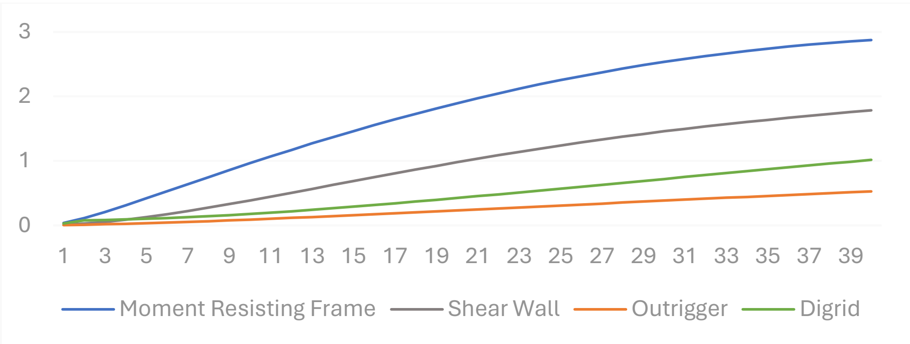


Table 4. Storey Displacement of 40 Storeys



Base Shear

The base shear is the total amount of force at the base that's trying to make the building tip over. Base shear appears to be maximum in case of Diagrid structures.

Table 5. Base Shear of 20 storey building

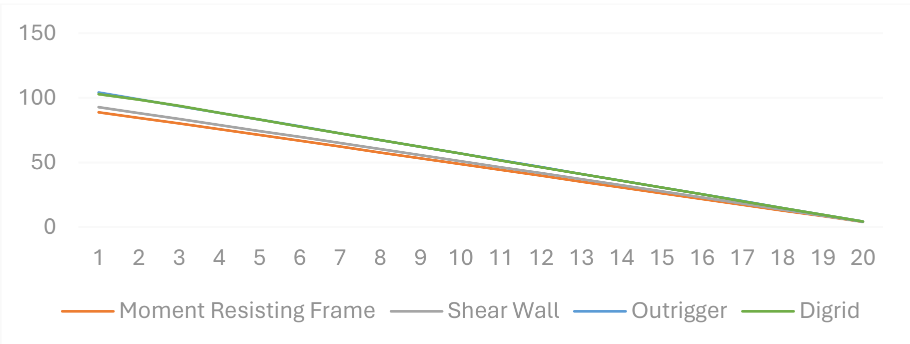


Table 6. Base Shear of 40 storey building

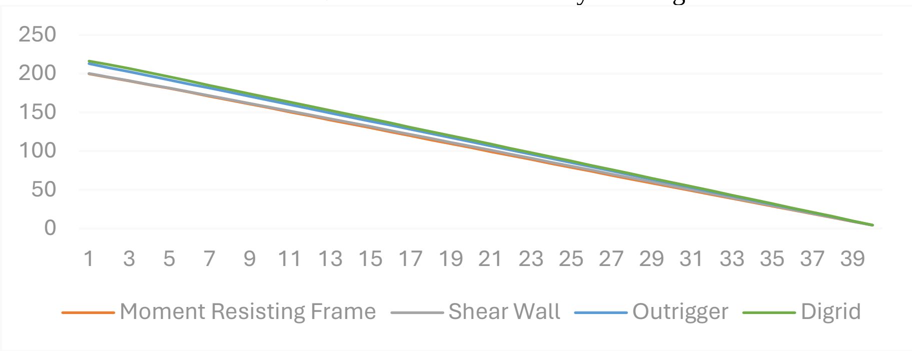
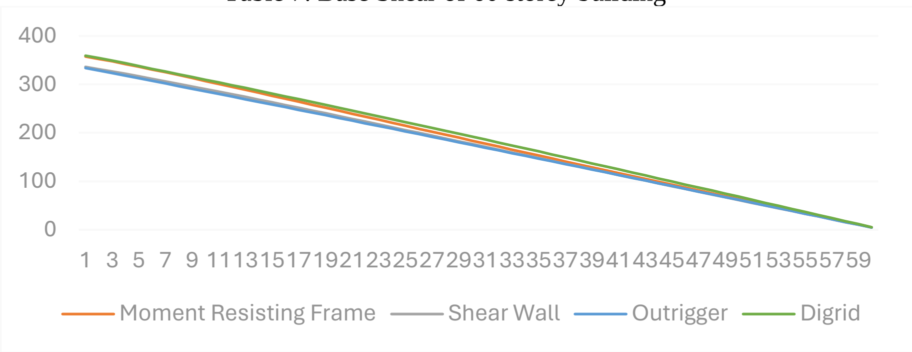


Table 7. Base Shear of 60 storey building



Storey Drift

Storey Drift defines how much a single floor moves horizontally compared to the floor beneath it. Storey drift is least in case of outriggers and maximum in moment resisting frames.

Table 8. Storey Drift of 20 storey building

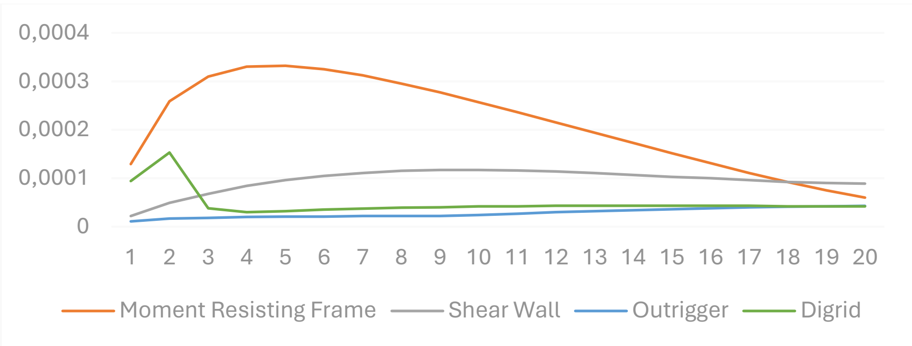


Table 9. Storey Drift of 40 storey building

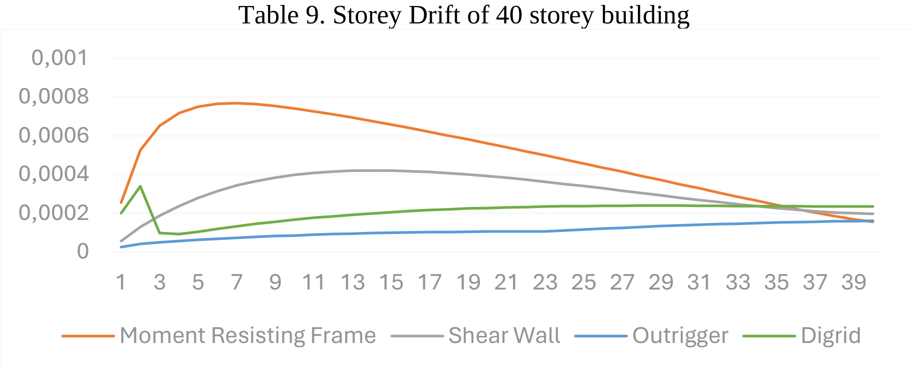
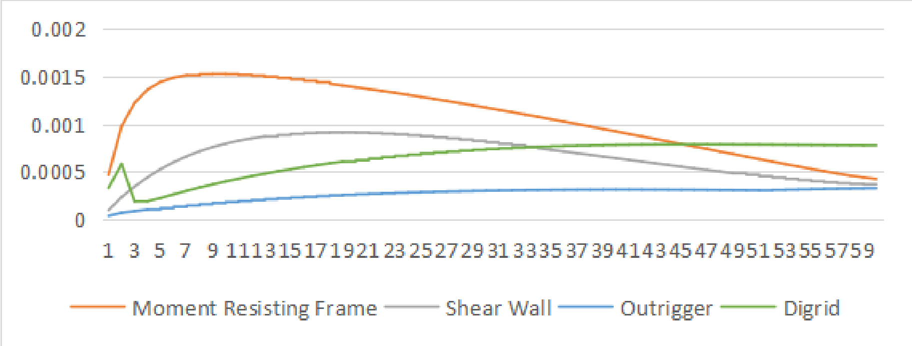


Table 10. Storey Drift of 40 storey building



VI. CONCLUSION

A comparative analysis using ETABS software investigated the seismic performance of various lateral resisting systems (shear walls, diagrids, moment resisting frames, and outriggers) in 20, 40, and 60-story buildings subjected to X-directional seismic loads. The results revealed that outrigger systems exhibited the most efficient performance across all building heights, suggesting their superior ability to manage lateral displacements and seismic energy under earthquake forces. These findings can inform the selection of appropriate LFRS for high-rise buildings in seismic zones, with further research recommended to explore cost-effectiveness and multi-directional seismic behavior.

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