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COMPARISON OF SHEAR WALLS AND MOMENT-RESISTING FRAMES IN EARTHQUAKE RESISTING BUILDINGS' DESIGN

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The rapid growth of urban population and limited land space have greatly influenced the development of high-rise structures. Lateral loads have an important effect on the design as the building height increases. In order to resist lateral loads, safety and minimum damage should be the prime concern when designing tall buildings. To meet these requirements, the structure should have adequate lateral strength and lateral stiffness and sufficient ductility. Among the various structural systems, shear wall systems or moment resisting frame systems could be a point of choice for designers. Thus, it is important to review and observe the behavior of these systems under seismic effect. This study compared the seismic response of the above structural systems using a case study application at variable seismic zones (Zone 2B, Lebanon Zone, Zone 3, and Zone 4) and at different building stories (Eight and 12-story building). The seismic response is measured in term of time-period, maximum story displacement, maximum story drift, amount of steel and concrete needed. The outcome of this study portrayed that a shear wall system is more efficient in terms of cost and lateral load resistivity regardless of the building height and in the four seismic zones mentioned before.

Keywords: Structural system, Maximum story displacement, Maximum story drift, Bill of quantity, Columns, Beams.

1 INTRODUCTION

In order to design earthquake resisting structures, the nature of the earthquake itself and the lateral loads accompanied by it must be taken into consideration beforehand. Earthquake-resistant structures are structures designed to protect buildings from earthquakes. While no structure can be entirely immune to damage from earthquakes, the goal of earthquake-resistant construction is to erect structure that fare better during seismic activity than their conventional counterparts. According to the ACI 318-14 (2014), earthquake-resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location. This means the loss of life should be minimized by preventing collapse of the buildings for rare earthquakes while the loss of the functionality should be limited for more frequent ones.

When designing a building, structural engineers must try to create the most efficient design possible. Which is why this study including a Bill of Quantity which serves as financial insight onto which earthquake resisting system is more economical and safe.

2 PARAMETRIC STUDY

In building design, it is crucial to ensure that the structural system satisfy the strength and stiffness requirements. The response of the different structural systems is dependent on its behavior and load transfer mechanism.

This paper considers two earthquake resisting structures, shear wall and moment-resisting frame, at different building heights and seismic zones. Analysis is carried out using Etabs and SAFE to obtain the numerical data for time- period, top story displacement and maximum story drift. Analysis results for an eight-story building versus a 12-story building with two different structural systems are compared at four different seismic zones: 2B, Lebanon, 3 and 4 (ACI 318-14 2014).

The parameters for the analyzed buildings are tabulated in Table 1.

Table 1. Building parameters.

Parameter	Value			
Number of Stories	8		12	
Building Height, h (m)	25		37	
Plan Dimension (m^2)	20 x 16			
Earthquake Resisting System	Shear Wall		MRF	
Seismic Response Modification Factor, R	5.5		8.5	
Seismic Zone	2B	Lebanon	3	4
Soil Profile Type	S_c			
Importance Factor, I	1			

The 3D models of the structures representing the eight-story building and 12-story building with the two different seismic systems are shown in Figure 1.

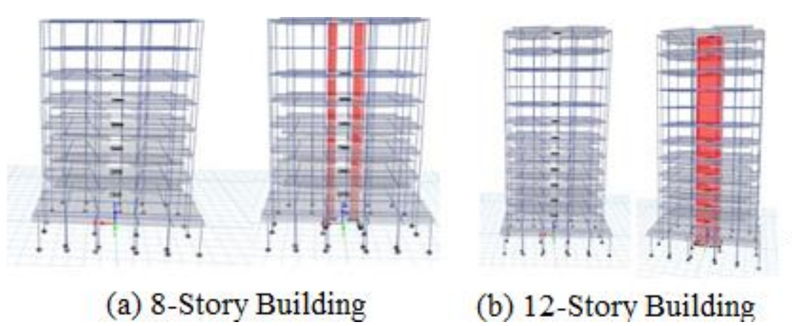
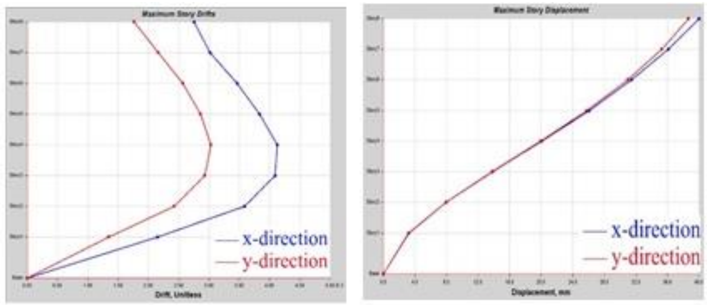


Figure 1. The 3D models of buildings with shear wall and MRF: (a) eight-Story; (b) 12-Story.

To study the serviceability of the structure with a shear wall design against the seismic impact of an earthquake, the maximum story drift and story displacement were obtained. This gives insight on whether or not the chosen structural earthquake resisting structure is sufficient to resist and withstand the effects of lateral loads while preserving its integrity. This depends on the seismic zone and building height.

After Etabs analysis the results for the eight-story building with shear wall for Lebanon zone were computed and are represented in Figure 2.



(a) Maximum Story Drift

(b) Maximum Story Displacement

Figure 2. Results for eight-story building with shear walls for Lebanon zone: (a) Max. story drift; (b) Max. story displacement.

The results for all the seismic zones for the eight-story building with shear wall and MRF are summarized in Table 2.

Table 2. Summary of data for 8-story building.

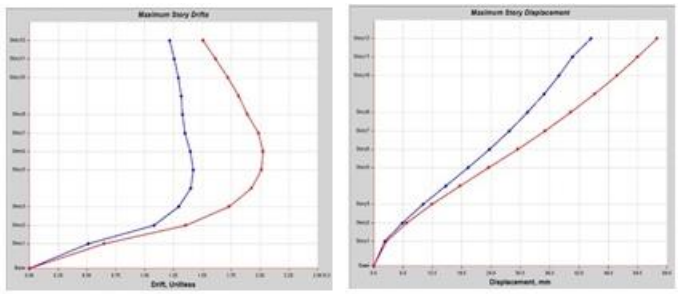
Parameters	8-Story							
	Shear Wall				MRF			
	Leb	2B	3	4	Leb	2B	3	4
Maximum Story Drifts	0.0041	0.0015	0.0019	0.0022	0.0018	0.0016	0.0021	0.0024
Maximum Story Displacement (mm)	40	31	39.8	45.7	36.9	33.9	43.9	48.6
Time Period (sec)	1.51	1.4	1.49	1.42	1.46	1.49	1.2	1.2
Max. Inelastic Story Drift (%)	1.58	0.58	0.73	0.85	1.07	0.95	1.25	1.43

This table summarizes the result of the eight-story building models. The limit for the maximum story displacement is h/500, which gives a limit of 50 mm as you can see all the values are below the limit. For T > 0.7 seconds, the limit for maximum inelastic story drift should be less than 2% which was applied in this case.

The results portray how the building height plays an immense role in earthquake resisting structures and their design. It affects the serviceability of the structure and the ability to ensure life-safety.

The results for the maximum story drift and maximum story displacement are thus computed to analyze the effect of a different building height with the same earthquake resisting structure on the building's resistance to lateral loads.

After Etabs analysis the results for the 12-story building with shear wall for Lebanon zone were computed and are represented in Figure 3.



(a) Maximum Story Drift

(b) Maximum Story Displacement

Figure 3. Results for12-story building with shear walls for Lebanon zone: (a) Max. story drift; (b) Max. story displacement.

The results for all the seismic zones for the 12-story building with shear wall and MRF are summarized in Table 3.

Table 3. Summary of data for 12-story building.

Parameters	12-Story							
	Shear Wall				MRF			
	Leb	2B	3	4	Leb	2B	3	4
Maximum Story Drifts	0.0020	0.0018	0.0022	0.0024	0.0021	0.0019	0.0023	0.0026
Maximum Story Displacement (mm)	57.9	53.4	61.8	69.5	60.8	56.4	66.3	74
Time Period (sec)	2.3	2.3	2.3	2.15	1.36	2	1.9	1.4
Max. Inelastic Story Drift (%)	0.77	0.69	0.85	0.92	1.25	1.13	1.37	1.55

This table summarizes the result of the 12 story building models. The limit for the maximum story displacement is h/500, which gives a limit of 74 mm which is apparent since all values are below the limit.

At the end of the analysis, a Bill of Quantity (BOQ) was conducted in order to provide better insight on how much such an execution would cost. The analysis was carried out in terms of amount of steel and concrete required to construct such earthquake-resisting structures.

The amount of steel was computed in tons of steel and the amount of concrete was computed in cubic meter of concrete needed for each building different zones, heights and earthquake resisting method.

The amount of material needed for each respective building in each zone are also summarized in Figure 4, Figure 5, Figure 6, and Figure 7.

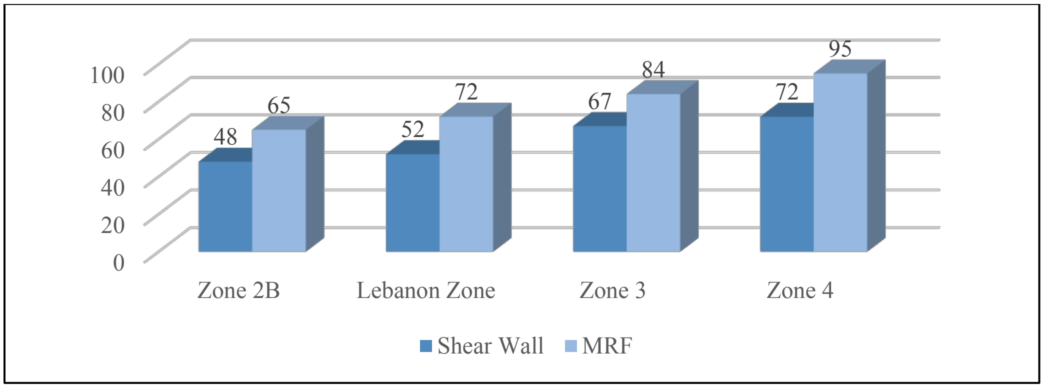


Figure 4. Amount of steel in (ton) for an eight-story building in each zone.

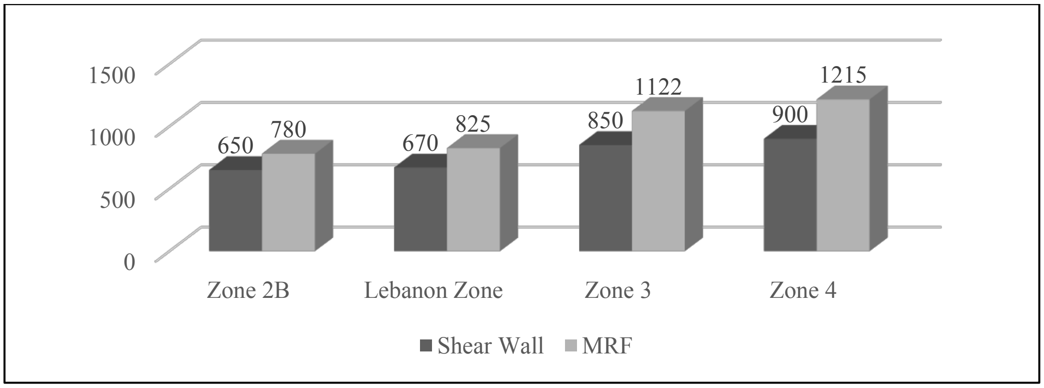


Figure 5. Amount of concrete in (m^3) for an eight-story building in each zone.

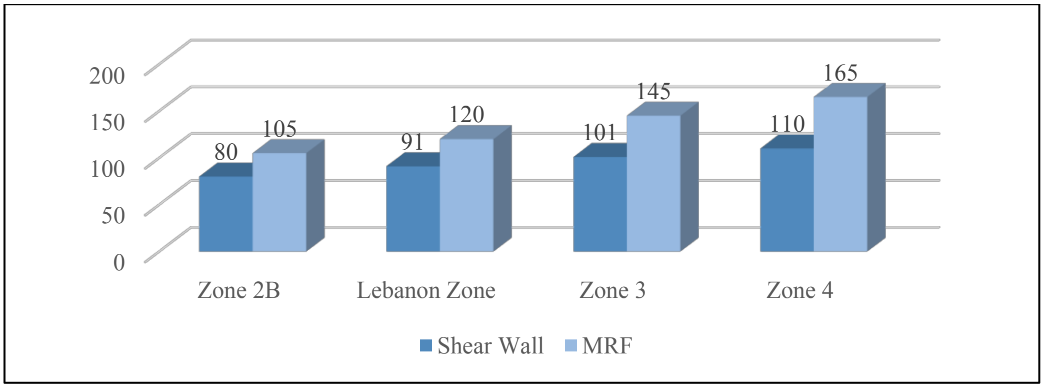


Figure 6. Amount of steel in (ton) for a 12-story building in each zone.

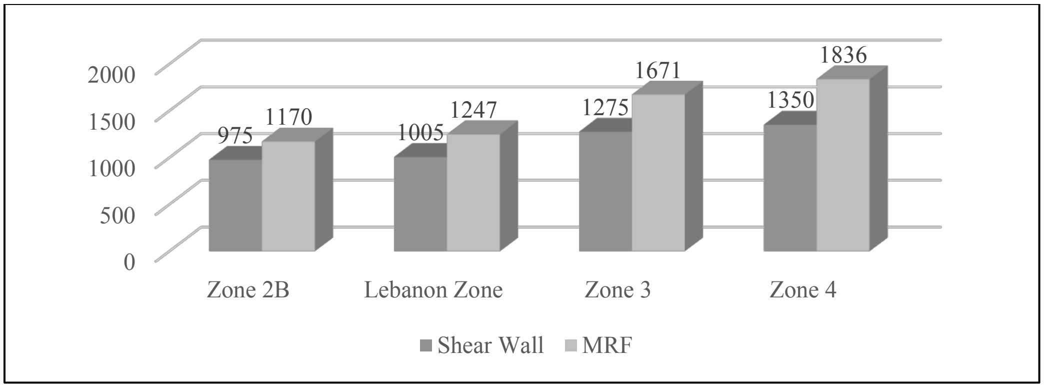


Figure 7. Amount of concrete in (m^3) for a 12-story building in each zone.

3 CONCLUSION

As apparent in the previous diagrams, the amount of steel in the moment-resisting frame system is about 25-38% more than that in the shear wall system; and the amount of concrete is about 20-35% more than that of the shear wall system for the eight-story building.

Also, the amount of steel in the moment-resisting frame system is about 31-50% more than that in the shear wall system; and the amount of concrete is about 20-36% more than that of the shear wall system for the 12-story building.

Thus, when considering an earthquake resisting system in a building in any of the above-mentioned zones at any heights it is more advisable to choose the shear wall system above any other system if cost-efficiency is required by the client in addition to optimum safety.

References

ACI 318-14, *Building Code Requirement for Structural Concrete and Commentary,* American Concrete Institute, USA, 2014.