Advance Researches in Civil Engineering
ISSN: 2645-7229, Vol.2, No.2, pages: 15-23

A Comparative Study on Seismic behavior of Tall Structures with Hexagrid and Diagrid Systems by using Non-linear Dynamic Analysis

Armin Mosavat [1*]

[1*] *Ph.D. Candidate, Department of Civil Engineering, Eslamshahr Branch, Islamic Azad University, Tehran ,Iran*

(armin.mosavat@iauz.ac.ir)

(Date of received: 12/02/2020, Date of accepted: 21/04/2020)

ABSTRACT

Today, tall structures are the most dominating symbol of the cities. The tall structures should be design for strength against gravity and lateral loads, stiffness, ductility and system efficiency. Ever increasing number of stories, height to depth ratio and complexity of form, need for robustness coupled to economy, awareness of limited material resources and sustainability, are all new demanding questions to be tackled with fresh approaches, novel structural systems. Modern structural system provides significant progress in establishing the necessary flexibility in design. In this study, a numerical study is conducted to estimate the seismic performance of horizontal hexagrid structural and diagrids systems. To this end, two models of twenty-story steel structures were designed. The models with horizontal hexagrid cells which transited to vertical cells using a transitional story, and a model of the diagrid system have been designed by using SAP2000 software. Also, nonlinear dynamic analyses are performed on buildings. Results indicate that roof displacement of the horizontal hexagrid structural system under nonlinear dynamic analyses is less than the diagrid structure. Also, there is no difference between the two systems for maximum drift at first floor, but increasing height, the drift values of the hexagrid structural system are less than the diagrid system. According to the results, the tall structure with a hexagrid structural system performs better than the diagrid system against earthquakes.

Keywords:

Tall Building, Nonlinear Static and Dynamic Analysis, Hexagrid System.

1. Introduction

In the early structures at the beginning of 20th century, structural members were assumed to carry primarily the gravity loads. As a general rule, when other things being equal, the taller the building, the more necessary it is to identify the proper structural system for resisting lateral loads. Tube structures represented a dramatic change in the design of steel-framed buildings to enable them remain strong enough to resist the lateral forces of wind and earthquake acting on the building, which used load bearing exterior or perimeter walls to support these forces [1]. Tall buildings emerged in the late nineteenth century in the United States of America. Tall building development involves various complex factors such as economics requirements, aesthetics, technology, functional, municipal regulations, and politics. Among these, economics has been the primary governing factor. This new building type itself would not have been possible, however, without supporting technologies. Structural systems for tall buildings have undergone dramatic changes since the demise of the conventional rigid frames as the predominated type of structural system for steel or concrete tall buildings. With the emergence of the tubular forms steel conforming to the International Style, such changes in the structural form and organization of tall buildings were necessitated by the emerging architectural trends in design in conjunction with the economic demands [2].

Enormous progress was made in the development of tall buildings after World War II, first in the U.S., followed much later by some Pacific Rim countries, parts of Europe, and the Middle East. Although technology has advanced and the architectural style of tall buildings has evolved, the architectural planning concept of vertically stacking a series of floors and achieving spatial efficiencies by increasing the net-to-gross floor area has remained almost the same. Despite architecturally ambitious thinking, as well as technical and structural advancement, the primary focus remained on economic viability and technological and constructional limitations. Beginning with the last decade of the 20th century, this has changed, however, in favor of sustainability, innovative façade treatment, free-form massing, and iconic architectural vocabulary [3].

The traditional building methods of high-rise structures are still common in southern Saudi Arabia and Yemen. For centuries, Arabs have been building towers in their cities. And houses up to 30 meters high and 8 stories are built only with masonry. But in medieval Europe, common materials for the construction of tall buildings were stone, brick, and wooden skeletons and masonry materials. The steel structure, which occurred in Chicago, has led to the present One Magnificent Mile skyscraper with bundled tube building [4]. In this multi-use building, it was possible to assemble the individual tubes in any configuration and terminated at different heights without loss of structural integrity. By carrying the idea of bundled framed tubes further, it is possible to add diagonals to them to increase the efficient height limit. In addition, it is worth noting that to behave as a bundled tube the individual tubes could be of different shapes, such as rectangular, triangular or hexagonal as is demonstrated by this building [2]. Hexagrid is composed of hexagonal grids in the outer perimeter of the building. The configuration of hexagonal grids can be either horizontal, which are called horizontal hexagrid or vertical, which are known as vertical hexagrid. This structure is inspired by natural pattern of honeycombs. Among all structural systems, the most efficient is the one with tube-type performance [5]. The aim of this study is to compare seismic performance of hexagrid structural system with diagrid systems. For this purpose, two models of twenty-story steel structures were designed. The models with horizontal hexagrid cells which transited to vertical cells using a transitional story, and a model of the diagrid system have been designed by using SAP2000 software. Also, nonlinear time history analyses are performed on models. Nonlinear response is evaluated for seven ground motion records. This ground motion scaled based on the ground motion scaling requirements of Iran's 2800 seismic provisions

2. Research Method

The three dimensional models of 20-story steel frame, equipped with horizontal hexagrid and diagrid system were designed and analyzed by using nonlinear time history analyses. Figure 1 shows the typical plan used on the models. In this figure the plan dimension is 18*18 meters. Also, Figure 2 shows elevation view of the Hexagrid and diagrid system models. The story height is 3 meters and the length of each span is 6 meters. The design earthquake load is computed based on the zone factor of 0.35g, soil II, importance factor of 1 and response reduction factor of 6. The yield strength of steel is considered as 240 MPa according to Iran's 2800 seismic provision requirements [6]. The seismic responses for maximum displacement of the roof and story drift ratios were compared for the different system types. It should be noted that the seismic analysis of the structure was carried out in accordance with the ASCE 7-16 code and the primary steel structure was designed according to the AISC 360-10 provisions with LRFD method.

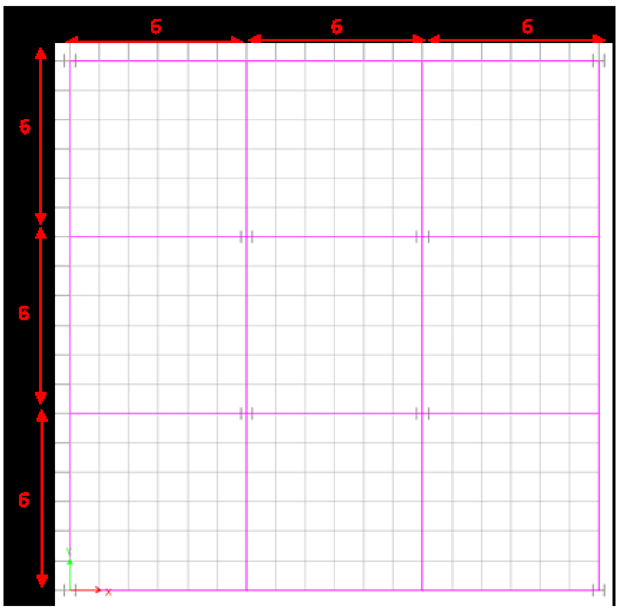
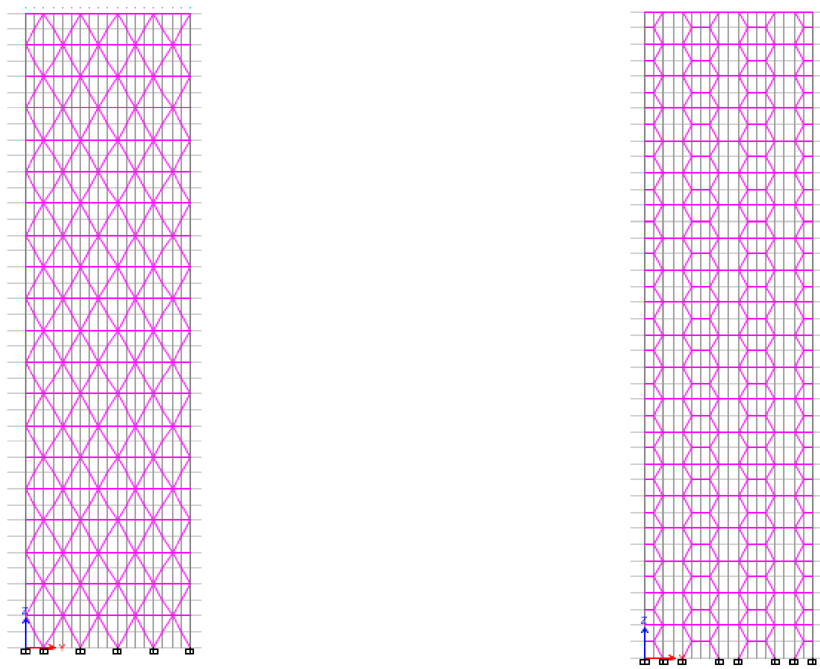


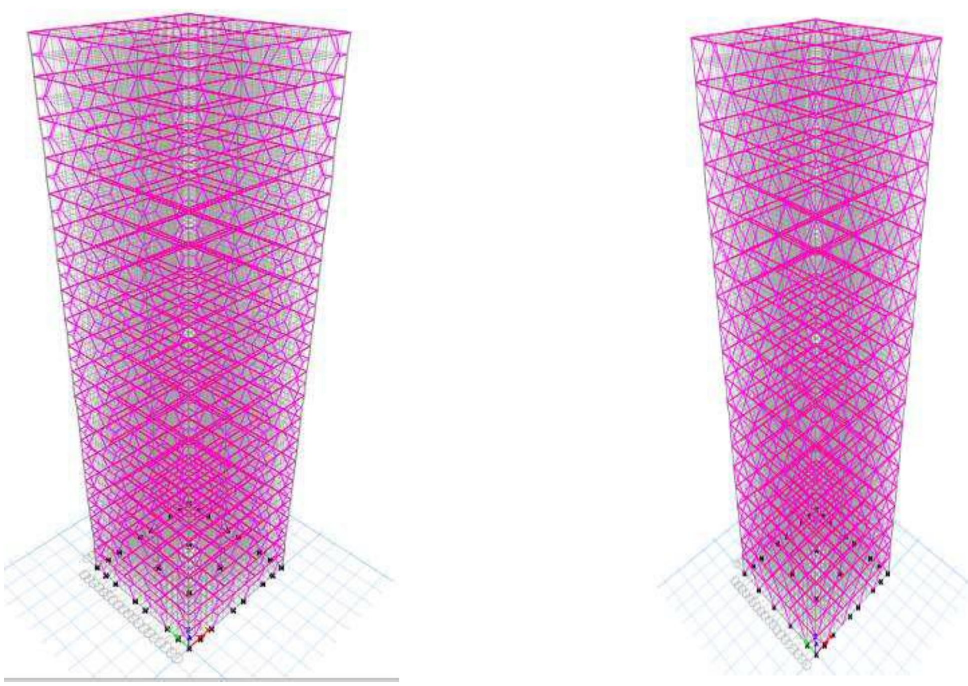
Figure 1. Typical plan used on the studied models.

Advance Researches in Civil Engineering
ISSN: 2645-7229, Vol.2, No.2, pages: 15-23



(A) (B)

Figure 2. Elevation view of the models, (A) Hexagrid system, (B) diagrid systems



(A) (B)

Figure 3. 3D view of the twenty-story structure, (A) Hexagrid system and (B) diagrid systems.

Advance Researches in Civil Engineering
ISSN: 2645-7229, Vol.2, No.2, pages: 15-23

All seven earthquake time-history records are normalized and scaled to 0.35g. All records are selected from far fault ground motion records as represented in Table 1. Also, the records are applied to the structure in three directions.

Table 1. Ground motion records used on nonlinear dynamic analysis [7].

ID No.	Earthquake	PGA
1	Chi-Chi	0.507
2	Darfield	0.632
3	Fruili	0.357
4	Iwate	0.198
5	Kobe	0.483
6	Kocaeli	0.210
7	Manjil	0.538

3. Seismic behavior Evaluation

In this section, displacement values for the top floor of structures have been evaluated by subjecting the models to the ground motion acceleration records as mentioned in Table 1. To evaluate the seismic behavior of structures, the displacement time history of top floor is computed for the seven earthquake records in both hexagrid and diagrid systems. Figures 4 to 10 compare the displacement of the structure (diagonal system and hexagonal system) for the seven earthquakes, respectively.

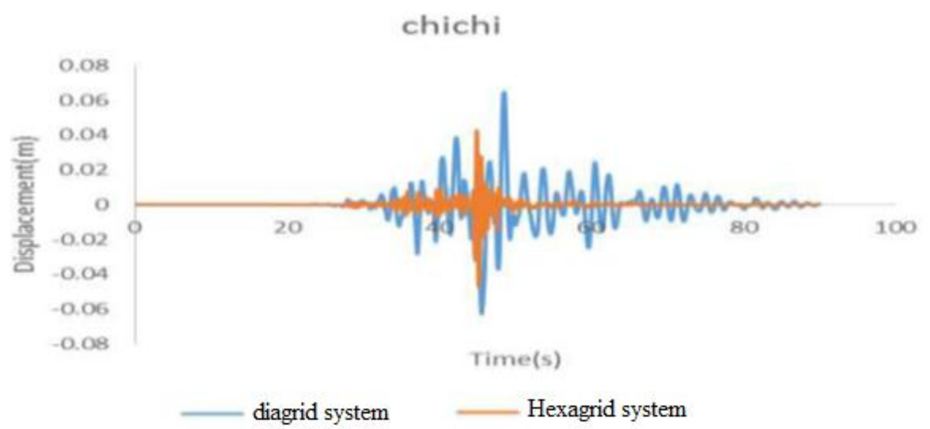


Figure 4. Comparison between computed displacement for a diagonal system (solid blue line) and hexagonal system (solid red line) for Chi-Chi earthquake.

Advance Researches in Civil Engineering
ISSN: 2645-7229, Vol.2, No.2, pages: 15-23

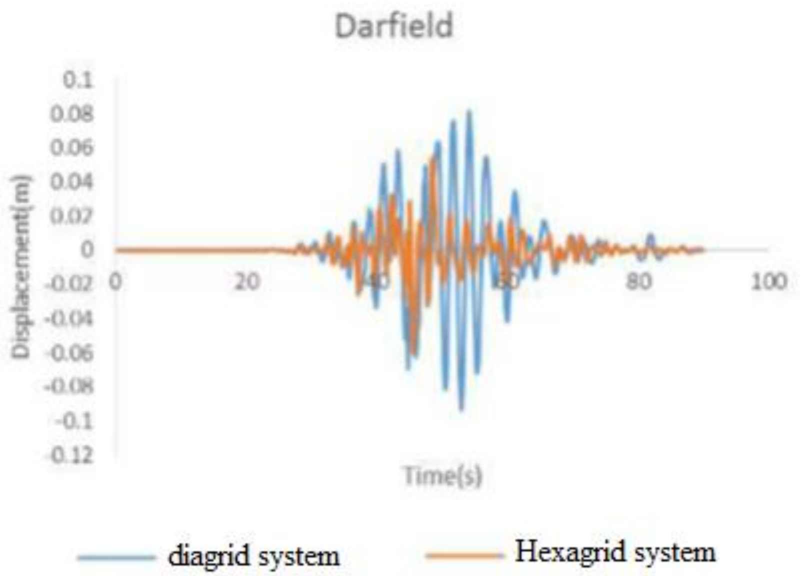


Figure 5. Comparison between computed displacement for a diagonal system (solid blue line) and hexagonal system (solid red line) for Darfield earthquake.

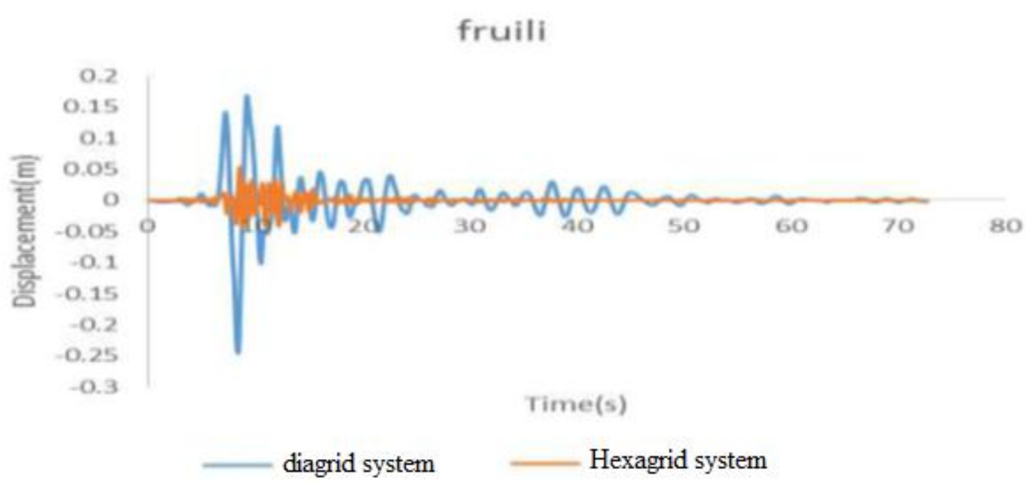


Figure 6. Comparison between computed displacement for a diagonal system (solid blue line) and hexagonal system (solid red line) for Fruili earthquake.

Advance Researches in Civil Engineering
ISSN: 2645-7229, Vol.2, No.2, pages: 15-23

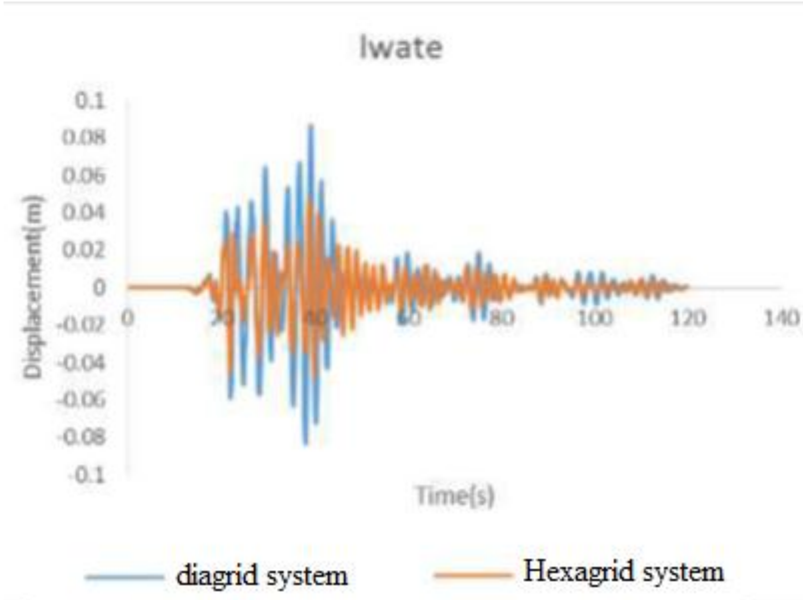


Figure 7. Comparison between computed displacement for a diagonal system (solid blue line) and hexagonal system (solid red line) for Iwate earthquake.

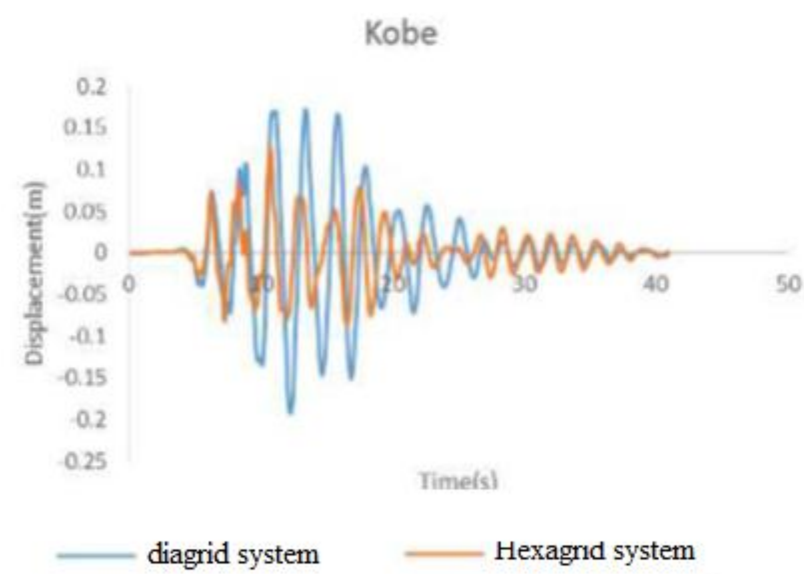


Figure 8. Comparison between computed displacement for a diagonal system (solid blue line) and hexagonal system (solid red line) for Kobe earthquake.

Advance Researches in Civil Engineering
ISSN: 2645-7229, Vol.2, No.2, pages: 15-23

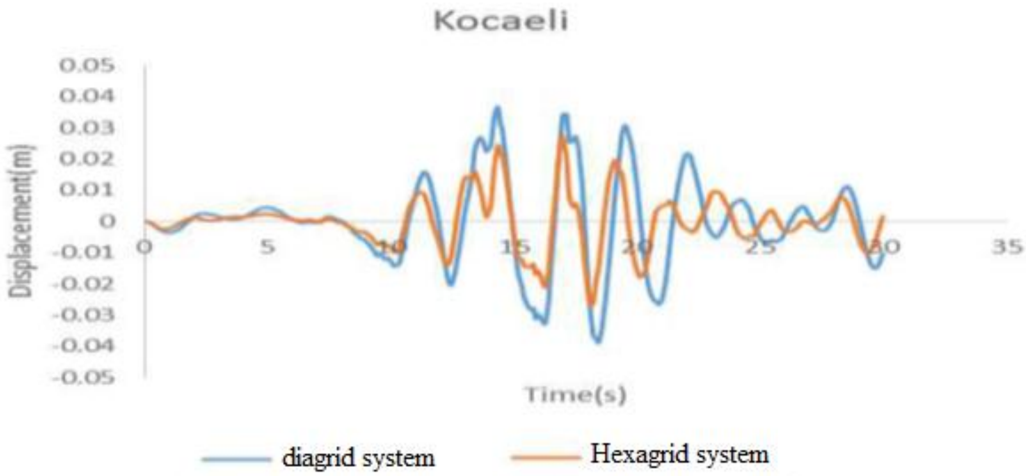


Figure 9. Comparison between computed displacement for a diagonal system (solid blue line) and hexagonal system (solid red line) for Kocaeli earthquake.

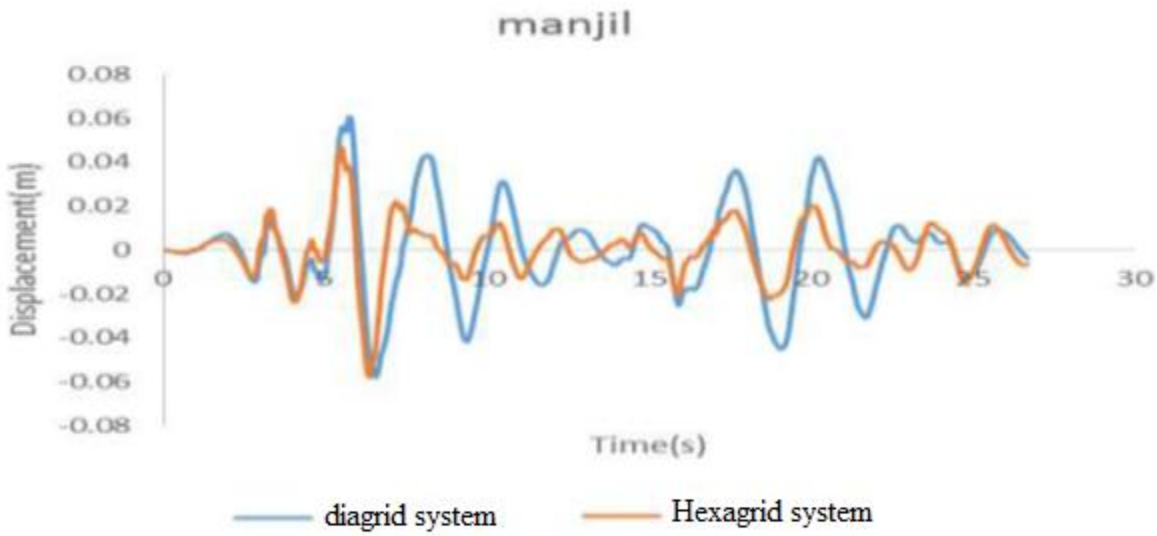


Figure 10. Comparison between computed displacement for a diagonal system (solid blue line) and hexagonal system (solid red line) for Manjil earthquake.

4. Conclusion

In this research, a numerical study is conducted to estimate the seismic performance tall structures with horizontal hexagrid and diagrids systems by using nonlinear dynamic analyses. For this purpose, two models of twenty-story structures were designed. The models with horizontal hexagrid cells which transited to vertical cells using a transitional story and a model of the diagrid system have been designed by using SAP2000 software. For nonlinear dynamic analyses seven earthquake time-history records are selected and scaled to 0.35g. The seismic responses for maximum displacement of the roof and story drift ratios were measured. Also, the results were compared for the different system types.

According to the results, the maximum displacement of the roof in the hexagrid structural system are less than the diagrid system. Also, the drift ratio of first story is so similar in both systems, but increasing the number of the stories and in the roof, the drift ratios of the hexagrid structural system are less than the diagrid system. Also, the tall structure with a hexagrid structural system has a better performance than the diagrid system against earthquakes so it can be used more for fortification.

5. References

[1]- Craighead, G., 2009, **High-rise security and fire life safety: Butterworth-Heinemann**,
[2]-Ali, M. M. and Moon, K. S., 2007, **Structural developments in tall buildings: current trends and future prospects**", Architectural Science Review, 50, 205-223.
[3]- Mir, A. M., and Al-Kodmany, K., 2012, **Tall Buildings and Urban Habitat of the 21st Century: A Global Perspective**, Buildings, 2, 384-423, doi: 10.3390/buildings2040384.
[4]- Ali, M. M., 1990, **Integration of structural form and esthetics in tall building design: the future challenge**, In L.S. Beedle & D. Rice (Eds.), Proceedings of the 4th World Congress of the Council on Tall Buildings and Urban Habitat: Tall Buildings 2000 and Beyond. Chicago, IL: Council on Tall Buildings and Urban Habitat, p. 3-12.
[5]- Mashhadiali, N., and Kheyroddin, A., 2013, **Proposing the hexagrid system as a new structural system for tall buildings**, The Structural Design of Tall and Special Buildings, 22, 1310-1329.
[6]- Standard No. 2800, 2013, **Iranian Code of Practice for Seismic Resistant Design of Buildings.**
[7]- ngawest.peer.berkley.edu