Comparative Study and Analysis of Conventional and Diagrid Building in Seismic Loading

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ABSTRACT
It is necessary to understand the seismic behavior of buildings of the same design under different earthquake intensities. To determine the seismic response, it is necessary to perform a seismic analysis of the structure using various methods available. The complex geometry of buildings, together with the high value of land, underlines the need to consider architectural concepts and structural concepts side by side. Lateral load resistance is more important than gravity load resistance as the building height increases. There are various lateral load resisting systems, such as moment frame systems, braced frame systems, shear wall systems, and tubular shaped advanced structural systems. Diagrid is another recent invention in this area, which is a modification of the tubular system. Diagrid is the best choice when tubular systems do not meet requirements, especially in complex geometries. In this work, diagrid and tubular structures are compared to study the structural efficiency of both types of structures. ETABS covers all aspects of the engineering design process. In the current scenario of the real estate industry, prefabricated structures are important; Generally, those that achieve the most effective results are advanced elements like beams and columns in multi-storied R.C buildings. This software is mainly used for tall buildings, structures like concrete and steel. The aim of this paper is to investigate the high-level (G+10) structure of the Earth considering seismic, dead and live loads.

Keywords: Diagrid Building, Conventional Frame Building, Time Period, ETABS Software

1. INTRODUCTION

Construction of tall buildings or taller buildings during this period; Tall buildings are preferred due to population growth, economic prosperity and scarcity of land. Height is the main purpose of this type of building, and the increasing demand of commercial and residential areas, the development of construction, high-strength structural elements, various construction materials and software such as ETABS [1].

In tall buildings, lateral load considerations become more important as the height of the building increases. There are many systems that resist lateral loads, such as steel frame systems, shear walls, reinforced pipe systems, anchorage systems, and piping systems. Currently, diagonal grid construction method is widely used in high-rise buildings due to its unique geometric configuration. This system is a combination of triangular beams that can be straight or curved and horizontal loops. The diagrid structure itself acts as columns and diagonal joints, thus carrying gravity and lateral loads. The purpose of using bent structures in high-rise buildings is, first, to increase the stability of the structure due to its triangular configuration and, second, to provide an alternative method of loading in case of structural failure [2-3].

These are the analysis and design programs that have enabled the development of high-rise buildings In the 19th century, high-rise buildings were built in the United States, but today, due to human needs, high-rise buildings are being built everywhere, leading to the sustainable development of society, “development that meets expectations. and the needs of the present generation without compromising the ability to meet the needs of future generations. According to studies and articles published in 1980, most high-rise buildings are located in America, and now the latest research shows that the number and construction process of high-rise buildings is higher in Asian countries, about 32% and 24% in North America and Europe. High rise buildings are usually constructed and used for commercial office buildings, apartments etc. [4-5].

Due to the action of lateral loads the construction of tall buildings is not as easy as simple buildings, because the lateral displacement causes bending and shear lag effects will be more resistant to lateral loads, new systems have been developed. Known for the resistance of the lateral load system, some consider the tubular system to be the most efficient in terms of weight reduction and better resistance to lateral loads. They are built with a rigid outer frame to resist lateral loads, allowing the inner frame to support only gravity loads. The distance between interior and exterior is determined by beams or trusses and is intentionally left without columns [6-7].

This increases the efficiency of the circumferential tube by transferring some of the gravity load into the structure and increases its ability to resist tipping due to lateral loads. Diagrid or Exo is a new concept for resisting lateral loads in tall buildings. These are the latest variation on the tubular chassis, where the tubes are arranged diagonally around the perimeter of the chassis. That is, the columns are placed in an inclined position to form a triangular configuration, such that all loads acting on the plan are distributed as axial forces; Instead of bending or shearing [8]. Cylindrical configurations use building plan dimensions to resist bending moments. But this potential bending capacity is not fully achieved due to the shear deformation of the structural mesh. On the other hand, diagonal grid systems, which provide shear strength and stiffness through axial movement in diagonal bars instead of momentary bending in beams and columns, allow almost complete absorption of theoretical bending forces [9].

These natural calamities have damaged and disrupted the development of natural life cycles. Since it is a global concern, a lot of analysis has to be done and results are given to prepare the framework to arrive at the right time. With the advancement of technology, people have tried to deal with these natural conditions in various ways such as developing early warning systems for disasters, taking new preventive measures and taking appropriate relief and rescue measures. However, this is not true for all natural disasters. As per IS 1893:2016 the hazard map showing the seismic zone in the seismic code is updated from time to time resulting in additional shear requirements for existing structures. Building collapses can be reduced if the following points are taken into consideration. Most building structures include structural elements such as beams, columns, foundations, shear walls, and floor slabs. Floor slabs in multi-story buildings, which normally transfer gravity loads to the building system, are required to transfer joint inertial forces to the building system.

The failure mode can be made ductile instead of brittle. If flexibility is ensured, the resulting energy dissipation will show little change.

1. Shall not fail before bending.
2. Column failure follows beam failure.
3. Joints should be stronger than knuckles
4. Perform dynamic structural analysis using the response spectrum method

2. LETERATURE REVIEW

Harish Varsani (2015) presented a comparative study of 24 stories with 36m X 36m floor plan of diagrid building system and conventional steel building system using ETABS. They compared the results of the shear floor analysis in the form of a graph, which showed that the floor shear of the diagrid structure due to earthquake loads was higher than that of the normal structure.

Manthan Shah (2016) presented a comparative study of 4, 8, 12, 16, 20, 40 and 48 stories with 18m X 18m floor plan diagrid building system and conventional building system using ETABS. They compared the results of base shear analysis, the base shear will be the same on both sides because it is known that the diagrid system is stronger than the standard frame, it attracts more lateral forces so it has base shear up to 12 buildings. After 12 stories, static wind loads take over and become the dominant force and the base shear is dominated by static wind loads. Therefore, after 12th floor, it can be seen that the shear base is same in both the systems.

Deepika R. (2016) presented a comparative study of 30 stories and 30m X 30m plan of diagrid building system and hexagrid building system using ETABS. They came up with a comparable result of first mode time of 3.268 s in digrid structure and 3.69 s in hexagrid structure. Harish Varshani (2015) presented results comparing the first mode time in diagrid structure is 2.74 s, while normal frame is 6.96 s. Manthan Shah (2016) has given the results of comparison of duration in graph form, which shows that the duration of diagrid structure is less than that of normal structure.

Rohitkumar Singh (2014) presented results comparing the top floor in diagrid construction at 18.8 mm, while conventional construction at 34.7 mm. Harish Varsani (2015) observed that diagonal columns resist the lateral loads of the structure, local displacements are less in diagrid structures compared to conventional construction. Maximum clearance for standard structure is 172.7 mm and maximum clearance for diagrid structure is 31.6 mm. **Manthan Shah (2016)** presented the results of comparing the top floor displacements in the form of a graph. They noted that the structural pattern is similar, but the overall displacement rate is much higher for conventional frames, even though they are designed for larger column sizes. Therefore, it proves the efficiency of the diagrid structure. **Raghunath Deshpande**

(2015) presented a comparative study of 60 stories with 24 m X 24 m floor plan with central wall of diagrid building system and conventional building system using ETABS. They present the results comparing each arrow in both systems. The deviation in polynomial standard system is 84.90 mm, while in diagrid system it is only 75.00 mm.

Gaurav BN et al (2021), evaluated the results of soil type I for different seismic zones of high-rise buildings from (G + 29) using ETAB software and response spectrum analysis. The response spectrum is used to compare the behavior of the model in four seismic zones (Zone II, III, IV and V), using base response, floor deflection, duration and ground stiffness as parameters. **Yashri Unclekhop etc. (2021),** studied the analysis and design of structures with rectangular and circular columns and determined all floors of the building, shear strength, average reaction, floor stiffness, floor shear, collapse moment, floor displacement, floor area. . flowing and so on. Their research shows that both analysis and design are compared with software and manual calculations as per IS 456-2000. **Nitin R. Maule and others. (2020),** their research shows that the multi-hazard approach to assess the damage risk of high-rise buildings, when a multi-story RC building is subjected to wind and earthquake hazards, the ground displacement varies from one floor to another. , i.e., storey displacement does not increase with building height compared to normal seismic excitation. Due to wind and earthquakes, the amount of landslides increases with building height but decreases significantly above the 14th floor.

W Bourouia et al (2019), their study shows that the research aims to simulate the interaction between concrete walls and soil under earthquakes. Their research objective is to investigate the influence of soil properties and soil-structure interactions on the seismic response of buildings. The results show that soil conditions have a significant effect on the seismic behavior of buildings. **Shubham Purkar (2019), studied** the analysis and design of structures (G + 6) in different seismic zones and soil types. Their research shows that Soil-I is a stiffer soil, so foundation interaction is less because the soil is stronger and stronger than Soil-II and Soil-III. The amount of floor flow increases with increasing seismic field factor. **Mandala Rohini (2019),** conducted the seismic response of a two-story residential building (G + 15) in the 3rd and 5th districts using response spectrum and ETAB chronological history methods. The results show that soil removal is higher in region V than in region III. Ground shear in the Earth is large in both the response spectrum method and the time recording method. Zone V values are higher than Zone III. **Umamaheswara Rao Tallapalem (2019),** their study shows that if an earthquake hits a multistory building in a densely populated area, it will cause significant damage. In this work, a building (G + 7) was constructed in Staad Pro and seismic analysis of the building was carried out in different seismic zones (II, II, IV and V) of India. The results show that principal shear, displacement, support interaction and metal content depend on the area, so these values are higher in area V.

Jayaprakash (2019), studied the response spectrum method for the analysis of a one-story building (G+30) with a reinforced concrete surface under seismic loads. The results show that soil displacement is higher at the top floor and it is also observed that as the height of the building increases, the side stiffness decreases and soil flow increases and decreases in the middle of the building. **Nilesh F Uke (2019),** in their study observed the effects of earthquake and wind loads on (G+11) structures. It is concluded that earthquake and wind stress in multi-storied buildings increase with increasing building height. It has been found that earthquake forces are less effective than wind forces on tall buildings because tall buildings are more flexible, but earthquake forces are more effective on short buildings. Ground displacement is important at higher levels during earthquakes, but is neglected at higher wind-driven levels. **Rajeshwari 2019),** their study reports earthquake resistance in construction through seismic investigation of building foundations using static equivalent learning method. A program of residential buildings (G+10) has been proposed for this purpose. Structural displacement increases with increasing seismic field and wind pressure. Most of the erosion occurred in the central part of the structure and increased as the seismic zone increased.

Amir Hasan (2018), studied the effect of soil conditions under closed foundations of structures (G+12) using ETAB system. The seismic performance of multi-story buildings is compared and evaluated using a systematic approach. The results show that the amount of base shear is proportional to the ductility of the soil and the stiffness of the superstructure. **Gaurav Sachdeva (2017),** studied the effect of different soils and seismic zones on different areas of the frame structure. There are three soil types: soft, medium, and hard with lengths of 15 m, 18 m, 21 m, and 24 m, respectively, and are distinguished by higher bending moments in the hard soil layer than in the soft soil layer in earthquakes. All four are read. **Mahmud Azad (2015),** their study shows the effect of building size on wind and earthquake response. In this study, three different building conditions were studied, and a comparison between the different building conditions and the lateral loads due to wind and earthquakes was presented. The investigation looked at the Bangladesh National Building Code (BNBC) 2006. The results show that building design has a significant impact on reducing building erosion.

3. METHODOLOGY

Structural response tests are planned using ETABS software which specifies all dimensional and material parameters. The history of different periods should be analyzed to find specific errors. In short description: Results are organized and compared with chronological history and some discrepancies. The folding of the structure can be reduced if the last point is considered. Most building structures include structural elements such as beams, columns, arches, shear walls and floor slabs. Floor slabs in multi-story buildings, which often transfer gravity loads to the building system, are required to transfer lateral forces to the building system.

4 DESIGNS AND ANALYSIS

4.1 Conventional Frame Building

Recent trends in high-rise commercial architecture have led to a variety of unusual configurations, innovative structural systems and efficient materials that challenge current design practices. One of the design goals of this model is to ensure that the models represent the characteristics of residential buildings Nowadays, skyscrapers vary in size, height and functionality. This is what makes each building feature different from the other. There are specific standards for each type of high-rise building such as residential, official and commercial buildings. Seismic design of modern high-rise buildings, defined as structures with running height through them, presents a series of challenges that must be addressed by considering the specific issues of scientific, engineering and modeling, analysis and an appropriate acceptance process for this unique design. Key factors for designing the model include floor orientation, grid spacing, floor length, columns and beams.

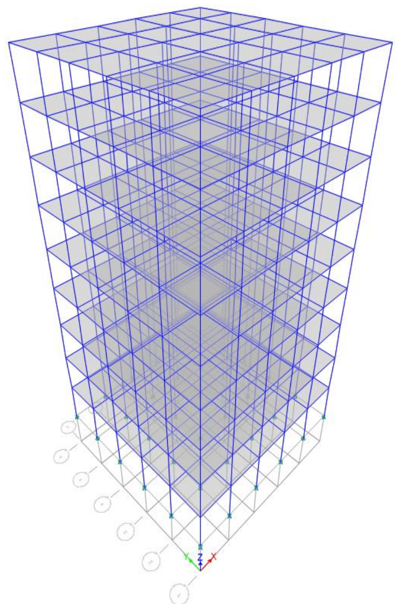

Figure 1. Geometry of conventional frame building

Seismic Load Calculation

Direction = X

Table 1: Calculated Base Shear

Direction	**Period Used (sec)**	**W (kN)**	**V_b (kN)**
X	0.598	17966.5681	1471.3083

V_b= Base shear

W=Seismic weight of the structure in 'kN'.

Applied Story Forces

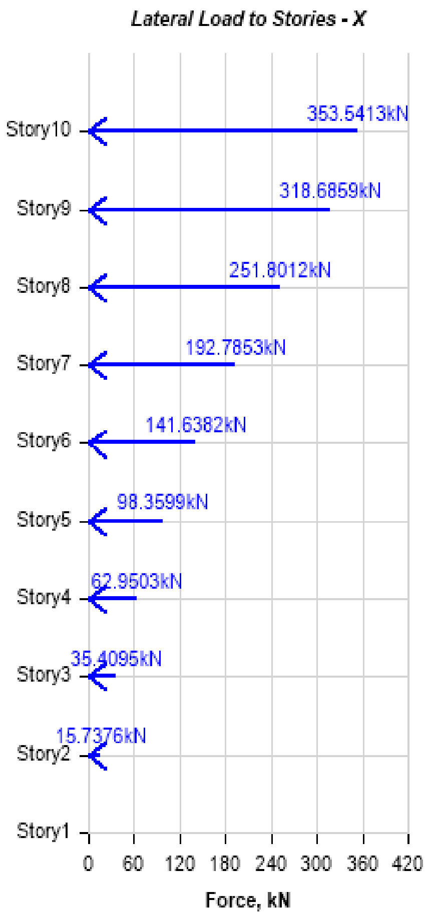

Figure 2. Applied Story Forces

Table 2: Applied Story Forces

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story10	30	353.5413	0
Story9	27	318.6859	0
Story8	24	251.8012	0
Story7	21	192.7853	0
Story6	18	141.6382	0
Story5	15	98.3599	0
Story4	12	62.9503	0
Story3	9	35.4095	0
Story2	6	15.7376	0
Story1	3	0.399	0
Base	0	0	0

Direction = Y

Table 3: Calculated Base Shear

Direction	Period Used (sec)	W (kN)	V_b (kN)
Y	0.598	17966.5681	1471.3083

Applied Story Forces

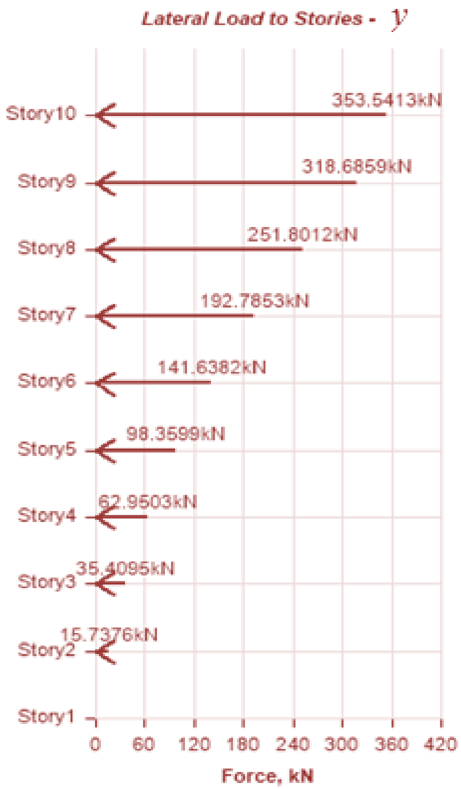

Figure 3. Applied Story Forces

Table 4: Applied Story Forces

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story10	30	0	353.5413
Story9	27	0	318.6859
Story8	24	0	251.8012
Story7	21	0	192.7853
Story6	18	0	141.6382
Story5	15	0	98.3599
Story4	12	0	62.9503
Story3	9	0	35.4095
Story2	6	0	15.7376
Story1	3	0	0.399
Base	0	0	0

Table 5: Story Stiffness

Story	Output Case	Case Type	Step Type	Shear X kN	Drift X mm	Stiff X kN/m	Shear Y kN	Drift Y mm	Stiff Y kN/m
Story10	EQX	LinStatic	Step By Step	51.554	0.918	56156.27	0	0.005	0
Story9	EQX	LinStatic	Step By Step	212.0212	1.36	155913.665	0	0.006	0
Story8	EQX	LinStatic	Step By Step	338.8101	1.803	187889.193	0	0.006	0
Story7	EQX	LinStat	Step By	435.88	2.147	203010.7	0	0.006	0

		ic	Step	28		45			
Story6	EQX	LinStatic	Step By Step	507.2016	2.385	212654.027	0	0.006	0
Story5	EQX	LinStatic	Step By Step	556.7285	2.527	220287.506	0	0.006	0
Story4	EQX	LinStatic	Step By Step	588.4257	2.592	226972.558	0	0.006	0
Story3	EQX	LinStatic	Step By Step	606.2554	2.632	230305.072	0	0.006	0
Story2	EQX	LinStatic	Step By Step	614.1797	2.914	210776.963	0	0.006	0
Story1	EQX	LinStatic	Step By Step	616.1608	4.93	124991.399	0	0.008	0
Story10	EQY	LinStatic	Step By Step	0	0.001	0	37.1656	0.772	48142.27
Story9	EQY	LinStatic	Step By Step	0	0.001	0	152.8474	1.452	105303.039
Story8	EQY	LinStatic	Step By Step	0	0.001	0	244.2503	2.057	118740.598
Story7	EQY	LinStatic	Step By Step	0	0.001	0	314.2307	2.516	124905.161
Story6	EQY	LinStatic	Step By Step	0	0.001	0	365.6448	2.84	128757.839
Story5	EQY	LinStatic	Step By Step	0	0.001	0	401.3491	3.046	131781.041
Story4	EQY	LinStatic	Step By Step	0	0.001	0	424.1998	3.151	134607.174
Story3	EQY	LinStatic	Step By Step	0	0.001	0	437.0534	3.186	137157.928
Story2	EQY	LinStatic	Step By Step	0	0.001	0	442.766	3.45	128348.095
Story1	EQY	LinStatic	Step By Step	0	0.001	0	444.1942	8.777	50609.752

Table 6: Modal Participating Mass Ratios

Case	**Mode**	**SumRX**	**SumRY**	**SumRZ**
Modal	1	0.0866	0	1.834E-06
Modal	2	0.0866	4.168E-06	0.9077
Modal	3	0.0866	0.1217	0.9077
Modal	4	0.926	0.1217	0.9077
Modal	5	0.926	0.1217	0.9761
Modal	6	0.926	0.8866	0.9761
Modal	7	0.9566	0.8866	0.9761
Modal	8	0.9566	0.8866	0.9909
Modal	9	0.9566	0.9355	0.9909
Modal	10	0.9894	0.9355	0.9909
Modal	11	0.9894	0.9355	0.9959
Modal	12	0.9927	0.9355	0.9959

Table 7: Modal Load Participation Ratios

Case	**ItemType**	**Item**	**Static %**	**Dynamic %**
Modal	Acceleration	UX	99.99	98.87
Modal	Acceleration	UY	100	99.91
Modal	Acceleration	UZ	0	0

4.2. Diagrid Building

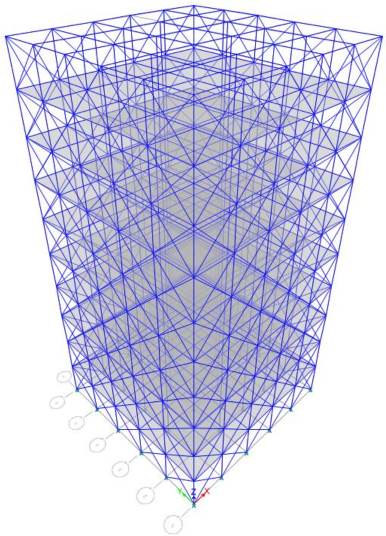

Figure 4. Geometry of Diagrid frame building

Seismic Load Calculation
Direction = X

Table 8: Calculated Base Shear

Direction	Period Used (sec)	W (kN)	V_b (kN)
X	0.291	22955.6238	2066.0061

V_b= Base shear
W=Seismic weight of the structure in 'kN'.

Applied Story Forces

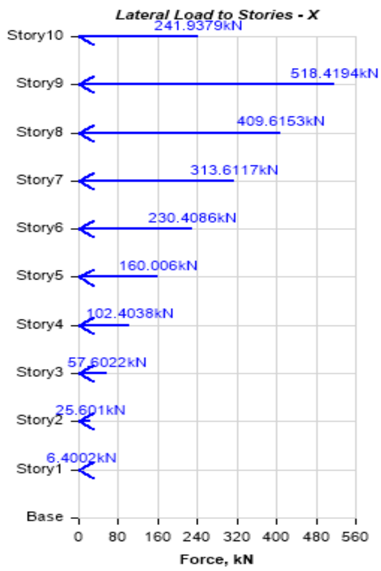

Figure 5. Applied Story Forces

Table 9. Applied Story Forces

Seismic Load Calculation

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story10	30	241.9379	0
Story9	27	518.4194	0
Story8	24	409.6153	0
Story7	21	313.6117	0
Story6	18	230.4086	0
Story5	15	160.006	0
Story4	12	102.4038	0
Story3	9	57.6022	0
Story2	6	25.601	0
Story1	3	6.4002	0
Base	0	0	0

Direction = Y

Table 10. Calculated Base Shear

Direction	Period Used (sec)	W (kN)	V_b (kN)
Y	0.294	22955.6238	2066.0061

Applied Story Forces

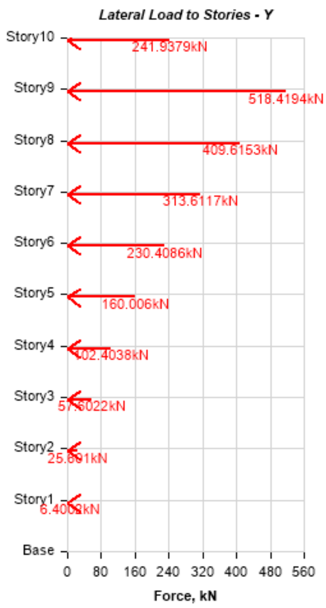

Figure 6. Applied Story Forces

Table 11. Applied Story Forces

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story10	30	0	241.9379
Story9	27	0	518.4194
Story8	24	0	409.6153
Story7	21	0	313.6117
Story6	18	0	230.4086
Story5	15	0	160.006
Story4	12	0	102.4038
Story3	9	0	57.6022
Story2	6	0	25.601

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story1	3	0	6.4002
Base	0	0	0

Table 12. Story Stiffness

Story	Output Case	Case Type	Step Type	Shear X kN	Drift X mm	Stiff X kN/m	Shear Y kN	Drift Y mm	Stiff Y kN/m
Story10	EQX	LinStatic	Step By Step	241.9379	0.318	761456.676	0	8.068E-05	0
Story9	EQX	LinStatic	Step By Step	760.3573	0.379	2007266.516	0	6.61E-05	0
Story8	EQX	LinStatic	Step By Step	1169.9726	0.428	2736599.026	0	5.898E-05	0
Story7	EQX	LinStatic	Step By Step	1483.5844	0.459	3229540.618	0	5.864E-05	0
Story6	EQX	LinStatic	Step By Step	1713.993	0.474	3616940.957	0	5.849E-05	0
Story5	EQX	LinStatic	Step By Step	1873.999	0.471	3978721.433	0	5.934E-05	0
Story4	EQX	LinStatic	Step By Step	1976.4028	0.451	4381325.256	0	5.351E-05	0
Story3	EQX	LinStatic	Step By Step	2034.0049	0.415	4906468.117	0	9.332E-05	0
Story2	EQX	LinStatic	Step By Step	2059.6059	0.36	5727241.626	0	0.0001859	0
Story1	EQX	LinStatic	Step By Step	2066.0061	0.295	6998861.978	0	0.002	0
Story10	EQY	LinStatic	Step By Step	0	3.553E-05	0	241.9379	0.32	755950.203
Story9	EQY	LinStatic	Step By Step	0	2.416E-05	0	760.3573	0.385	1973969.274
Story8	EQY	LinStatic	Step By Step	0	2.434E-05	0	1169.9726	0.436	2685259.655
Story7	EQY	LinStatic	Step By Step	0	2.223E-05	0	1483.5844	0.469	3162876.152
Story6	EQY	LinStatic	Step By Step	0	1.947E-05	0	1713.993	0.485	3537074.097
Story5	EQY	LinStatic	Step By Step	0	1.948E-05	0	1873.999	0.482	3885596.384
Story4	EQY	LinStatic	Step By Step	0	1.752E-05	0	1976.4028	0.463	4272556.421
Story3	EQY	LinStatic	Step By Step	0	1.507E-05	0	2034.0049	0.426	4777316.636
Story2	EQY	LinStatic	Step By Step	0	1.464E-05	0	2059.6059	0.371	5554348.047
Story1	EQY	LinStatic	Step By Step	0	1.472E-05	0	2066.0061	0.302	6849396.431

Table 13. Modal Participating Mass Ratios

Case	Mode	SumRX	SumRY	SumRZ
Modal	1	0.2631	0	0
Modal	2	0.2631	0.264	3.613E-06
Modal	3	0.2631	0.264	0.8504
Modal	4	0.7923	0.264	0.8504
Modal	5	0.7923	0.7925	0.8504

Modal	6	0.7923	0.7926	0.9416
Modal	7	0.8885	0.7926	0.9416
Modal	8	0.8885	0.8893	0.9417
Modal	9	0.9501	0.8893	0.9417
Modal	10	0.9501	0.9506	0.9417
Modal	11	0.9501	0.9507	0.9722
Modal	12	0.9738	0.9507	0.9722

Table 14. Modal Load Participation Ratios

Case	Item Type	Item	Static %	Dynamic %
Modal	Acceleration	UX	99.99	98.49
Modal	Acceleration	UY	100	99.27
Modal	Acceleration	UZ	0	0

5. CONCLUSIONS

ETABS covers all aspects of the engineering design process. In the current scenario of the real estate industry, prefabricated structures are important; Generally, those that achieve the most effective results are advanced elements like beams and columns in multi-storied R.C buildings. This software is mainly used for tall buildings, structures like concrete and steel. The aim of this paper is to investigate the high-level (G+10) structure of the Earth considering seismic, dead and live loads. Loading in high-rise buildings differs from low-rise buildings in several aspects, such as greater accumulation of gravity loads at the top than at lower floors, greater importance of wind loads, and greater importance of seismic effects. In the conventional building of G+10, we found static (99.99%) and dynamic (98.87%) acceleration times in the UX direction. we also found static (100%) and dynamic (99.91%) acceleration times in the UY direction. In the Diagrid building of G+10, we found static (99.99%) and dynamic (98.49%) acceleration times in the UX direction. we also found static (100%) and dynamic (99.27%) acceleration times in the UY direction.

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