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ANALYZING THE HIGH RISE STRUCTURE WITH LATERAL LOADS

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ABSTRACT

Multi-storey building requirements are increasing day by day. There are various different new technologies which are developed regarding construction technique, material, type of system and analysis and design. Recently, the diagrid structural system has been widely used for tall buildings due to structural efficiency and aesthetic potential provided by triangulation of the system. Diagrid structures for tall buildings are very popular among engineers and architects. It is one of the evocative structural design solutions for sustainable tall buildings which are embraced by the diagrid structural scheme.

In this paper, a thirty five storey residential diagrid structure with plan size 22.5 m × 21.65 m located in seismic zone III is considered for analysis. ETABS software is used for modelling and the analysis of seismic performance of typical diagrid structures was investigated. All structural members are designed as per IS 456: 2000 and load combinations of seismic forces are considered as per IS 1893 (Part I) 2016. Diagrid structures with various slopes of external braces were designed and their seismic performances were evaluated using dynamic linear method that is response spectrum method. A normal R.C.C frame residential structure is designed with the same designed loads and their seismic performance were evaluated.

The comparison done on various parameters like base shear, story shear, top story displacement, time period and storey drift are plotted graphically to study the pattern of variation in diagrid structures with various slopes of external braces and normal frame structure. In diagrid structure, the major portion of lateral load is taken by external diagonal members who in turn release the lateral load in inner columns. It also concludes optimum diagrid angle for economical design and aspect ratio for the use of diagrid in case of residential buildings.

Keywords: Diagrid Structure, External Braces Slope, Response Spectrum Method, Base Shear, Story Shear, Top Story Displacement, Time Period, Storey Drift, Aspect Ratio

1. INTRODUCTION

The growing use of high strength materials and advanced construction techniques, in combination with urbanization needs, has led a significant increase in the number and variety of high rise structures, causing these super tall buildings with mega frame systems. The diagrid structural system has been widely used for tall buildings due to structural efficiency and aesthetic potential provided by triangulation of the system. Diagrid is composed of triangulated braces and horizontal rings that together make up an efficient structural system for a skyscraper. It is a particular form of space truss mixed with tubular system and the perimeter diagonal grids make the structure stable even without any vertical columns in the perimeter of the building.

Diagrid structures of the steel members are efficient in providing solution both in term of strength and stiffness. The bracing angle is important in resisting lateral as well as gravity load. Diagrid can save from 20% to 30% the amount of structural steel in high rise buildings. Diagrid structures carry lateral loads much more efficiently due to their diagonal member's axial action compared to the conventional orthogonal structures for tall buildings such as framed tubes.

In this paper, the seismic performance of diagrid structural systems with various slopes of braces was investigated using linear dynamic analysis i.e. Response Spectrum Analysis. The seismic performance of tubular structure with the same was also evaluated for comparison.

2. RESPONSE SPECTRUM ANALYSIS

Response-spectrum analysis (RSA) is a linear-dynamic statistical analysis method which measures the contribution from each natural mode of vibration to indicate the likely maximum seismic response of an essentially elastic structure. Response-spectrum analysis provides insight into dynamic behaviour by measuring pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a given time history and level of damping. It is practical to envelope response spectra such that a smooth curve represents the peak response for each realization of structural period.

Response-spectrum analysis is useful for design decision-making because it relates structural type-selection to dynamic performance. Structures of shorter period experience greater acceleration, whereas those of longer period experience greater displacement. Structural performance objectives should be taken into account during preliminary design and response-spectrum analysis.

2.1. MODEL DESCRIPTION AND ANALYSIS

The objective of this study is to determine the seismic performance of various lateral systems. The computational model was prepared and analysed using the ETABs. Linear Dynamic Analysis i.e. Response Spectrum Analysis was carried out in-order to evaluate their seismic performance in terms of Time period, Base Shear, Top Storey Displacement, Drift, and Optimum Angle.

For analysis a 36 storey residential building was considered on which Response Spectrum Analysis is directed. For this, along with residential building i.e. normal frame building, three more different models such as diagrid at 5 floors, diagrid at 3 floors, and variation in diagrid intensities were created and analysed according to IS: 1893 (Part-I) 2016. The typical floor plan of the building considered for the analysis is as shown in figure 1.

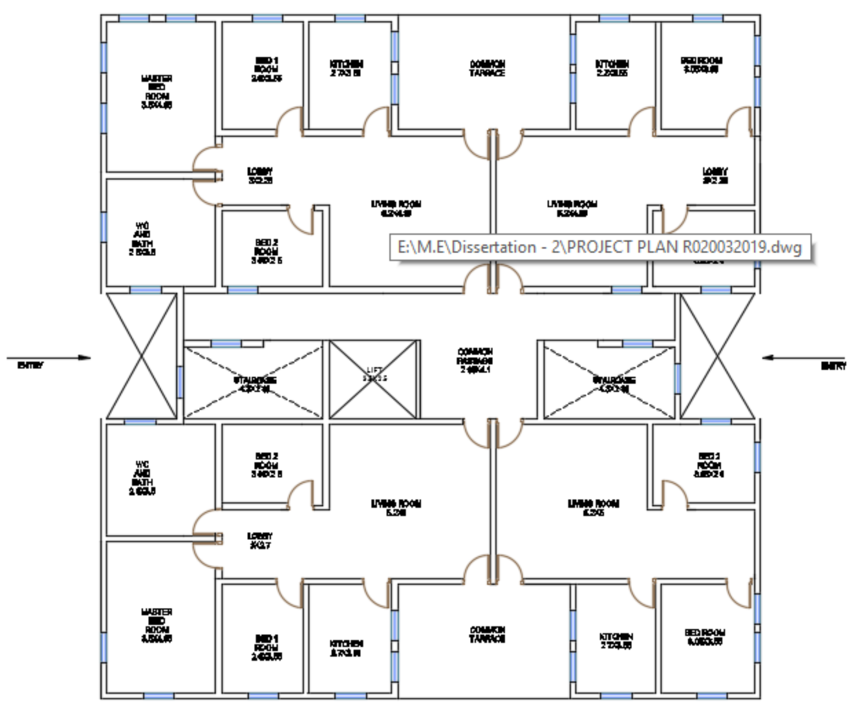

Figure 1 Typical floor plan of the building considered

1) Building Configuration:

Architectural details –

- Area covering : 22.5 m 21.65 m
- Total Height of the building : 101.50 m
- Floor to Floor Height : 2.9 m
- Number of Storey : 35

2) Earthquake parameters considered –

- Zone : III
- Soil type : Hard soil
- Importance factor : 1.2
- Time period : IS 1893 (Part I) 2016

3) Wind parameters considered –

- Wind Speed : 44 Km/hr
- Terrain Category : IV
- Building Class : C
- Values of k1, k2 and k3 : 1

3. LOADINGS CONSIDERED FOR MODELS

Various Dead loads are calculated based on the dimensions and material properties of structure. However, self-weight of the beams and columns are taken into consideration by ETABS software itself. Live load and Wind load are calculated as per code of provisions.

Table 1 Thickness and various loading parameters

Sr. No.	Parameters	Values
1.	Slab Depth	125 mm thick (Assumed)
2.	Wall Thickness	230 mm thick (Assumed)
3.	Live load in floor area	2 KN/m2 (As per IS 875 Part II)
4.	Live load in balcony	2 KN/m2 (As per IS 875 Part II)
5.	Live load in passage area	2 KN/m2 (As per IS 875 Part II)
6.	Live load in Urinals	2 KN/m2 (As per IS 875 Part II)
7.	Floor finish load	1.5 KN/m2 (As per IS 875 Part I)
8.	Stair case loading	3 KN/m2 (As per IS 875 Part II)

RESULT AND DECISIONS

The analysis results in terms of Time period, Base Shear, Top Storey Displacement, Drift and Optimum angle are discussed in this section. Figure 2 show the time period along the height of 35 storey structure. It is observed that the time period for diagrid structure is quite less as compared to normal frame and diagrid at 3 floors has 28 % of difference in time period with respect to normal frame.

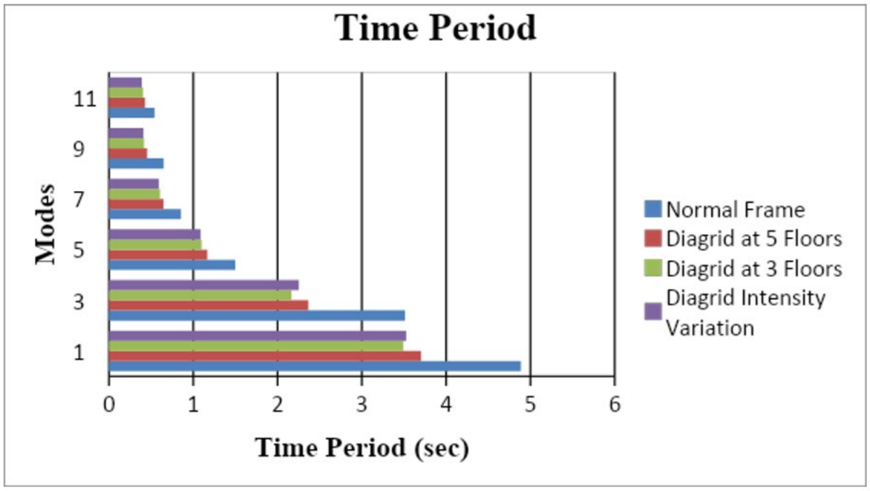

Figure 2 Time Period of various lateral structural systems

Figure 3 show the base shear graph along the height of 35 storey structure. It is observed that the base shear values in X – direction and Y – direction due to dynamic loading for diagrid structures is higher compared to normal frame. Table 2 shows the summary of lateral loads for normal and diagrid structure.

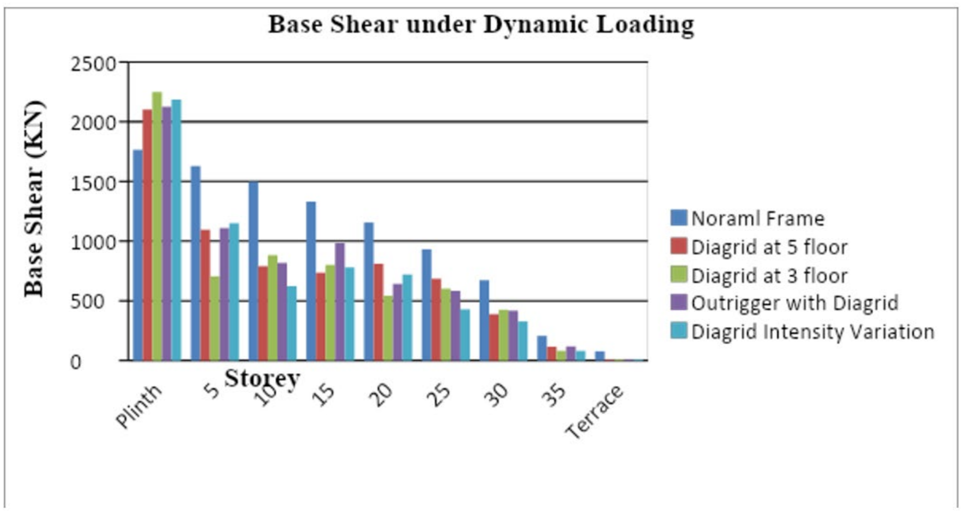

Figure 3 Base Shear of structures under Dynamic Loading

Table 2 Lateral load due to earthquake on 35 storey normal and diagrid structure

Loading	Structure	Total load (KN)
Load in X – direction	Normal Frame	1764.26
Load in Y – direction		1764.26
Load in X – direction	Diagrid at 3 Floor	2247.33
Load in Y – direction		2247.33

As the structures are nearly same in plan along both the span, the values of base shear in both dimensions are same. We found that the base shear values are increasing with the increase in the mass and as the mass and stiffness increases the values for the base shear also increases because it depends on the load which is acting against the earthquake.

Figure 4 and figure 5 shows the maximum displacement and inter story drift details of a 35 storey normal and diagrid structures. It can be observed that the maximum story displacement of framed structure is higher as compare to the other diagrid structure. And hence diagrid structures show better results for earthquake loading. It can also be seen that Diagrid at 3 Floors model shows the minimum top story displacement in dynamic analysis of the model.

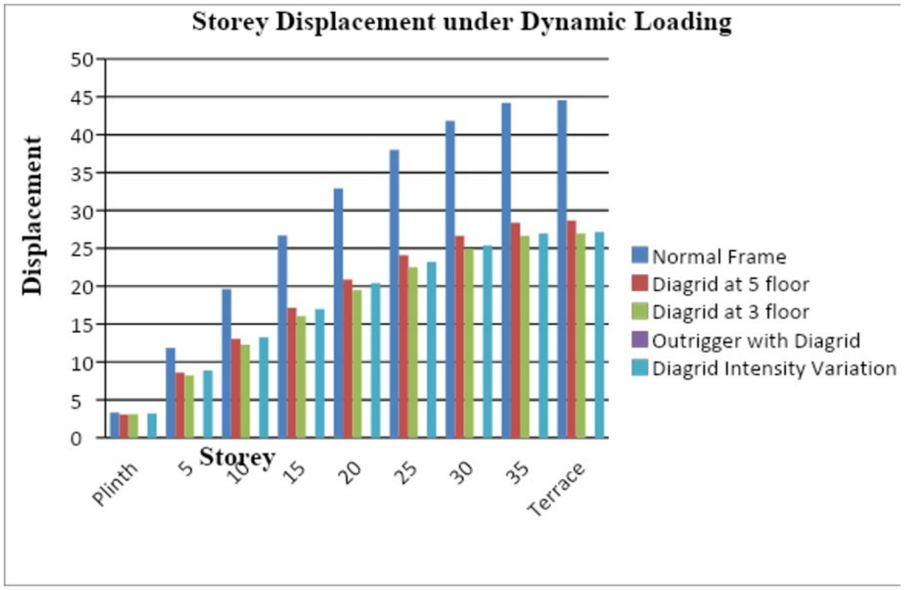

Figure 4 Storey Drift of structures under Dynamic Loading

Table 3 Storey displacement and drift due to earthquake on 35 storey normal and diagrid structure

Case	Loading	Structure	Total displacement and drift (m)
Storey Displacement	Load in X – direction	Normal Frame	0.044
	Load in Y – direction		0.044
	Load in X – direction	Diagrid at 3 Floor	0.026
	Load in Y – direction		0.027
Storey Drift	Load in X – direction	Normal Frame	0.0005
	Load in Y – direction		0.00057
	Load in X – direction	Diagrid at 3 Floor	0.00044
	Load in Y – direction		0.00044

Drift nothing is nothing but the individual floor displacement. And if we check the value for the drift for normal and braced frame, we are in safer side in the case of drift values. And table shows the drift for both normal and braced frame for the respective earthquake directions.

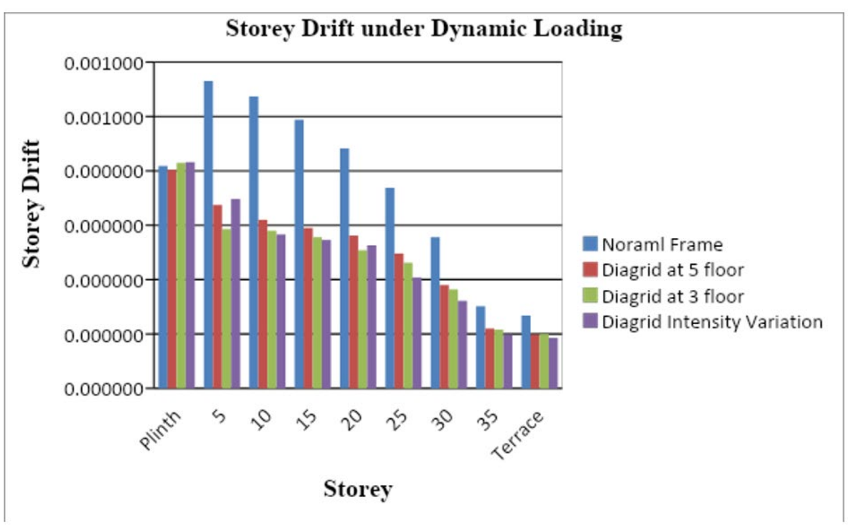

Figure 5 Storey Drift of structures under Dynamic Loading

Optimum Angle:

The angle of inclination is varying in these structural model based on the geometry of the plan and position of columns as it is due to the difference in bay distance at same floor. Therefor by considering the geometry we have found some inclination angle on analysis based on which we can conclude the following results:

- **Angle inclination for Diagrid at 5 floor level:**
  1) While considering the diagrid at 5 floor level for elevation in X – direction, the angle varies for same floor as – 71.99°, 63.51°, 63.23°
  2) While considering the diagrid at 5 floor level for elevation in Y – direction, the angle varies for same floor as – 66.0°, 69.66°, 71.60°
- **Angle inclination for Diagrid at 3 floor level:**
  1) While considering the diagrid at 3 floor level for elevation in X – direction, the angle varies for same floor as – 55.14°, 55.42°, 65.82°
  2) While considering the diagrid at 3 floor level for elevation in Y – direction, the angle varies for same floor as – 58.40°, 65.37°, 62.89°
  3) From above obtained result, we can conclude that the optimum angle of inclination of diagonal diagrid varies between 60° to 75°. This optimum angle results in control of lateral resistivity of tall building by easily allowing the flow of lateral load through the exterior diagonal columns and gravity load is only taken by the interior columns.

4. CONCLUSION

In present work, Normal frame structure and diagrid structures have been used to understand their seismic performances. From dimensions of elevation of the building, the optimum angles ranging from to 60° to 75° were chosen for analysis. Models for different combinations were modeled in ETABs using linear approach. The models are analysed using Response Spectrum Analysis Method. The analysis gave results based on parameters such as Time period, Base Shear, Top Storey Displacement, Drift, Stiffness and Optimum Angle. From above we can conclude that, the Diagrid at 3 floors model is having better seismic performances than any the other models. These models has excelled in terms of all parameters considered for analysis and came out as the effective result for lateral resistivity. It is also observed that most of the lateral load is resisted by diagrid columns on the periphery, while gravity load is resisted by both the internal columns and peripheral diagonal columns. So, internal columns need to be designed for vertical load only.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

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