Seismic analysis of tall concrete and steel diagrid structure using response spectrum and time history method in e-tabs

M Satya Sai Kiran Chowdary¹, Himath Kumar Y² and Lingeshwaran N²

¹Post Graduate Student, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, India
²Assistant Professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, India

E-mail: saikiran.mullapudi007@gmail.com, himathkumar007@gmail.com

Abstract. In the recent years due to lack of land the construction of high rise buildings widely increases and these buildings are affected by lateral loads due to wind or earthquake. To resist these horizontal loads lots of construction methods are available. Herein system peripheral columns of the building are eliminated. To resist the seismic forces we arrange the diagonal columns. In this study seismic performance of 20-story concrete and steel diagrid structures are assessed using response spectrum method. Only for concrete diagrid structure using time history method. The present work is made for studying the response and time period with acceleration of high rise building with concrete and steel diagrid structural system. To this aim response of two different diagrid structures of G+20 storey are carried out to obtain optimized position of diagrid. E-Tabs software mainly focus on seismic analysis of response spectrum and time history method. As per IS456:2000 and IS800:2007 all structural members of diagrid model are designed and IS1893:2002 and ASCE7-10 is considered for seismic analysis for concrete and steel diagrid structure. An evaluation of constraints storey shear, storey drift, storey displacement, Time period and Structural weight is done to determine the efficient and cost effective structure. The analysis of the building is carried out by using ETABS software.

Keywords. Concrete diagrid, Steel diagrid, High rise structure, Response spectrum method, Time history method, Seismic analysis, E-Tabs Software.

1. Introduction
The advancement in technology has made our life simpler and comfortable when compared to earlier times and has also led to the need for space for living for the growing population. According to the records, if we analyze our world population, it right now exceeds 7.2 billion, which mandates the need to fulfill the growing demands of the population. Due to the limited space and the need for environmental conservation, it has become important for a civil engineer to focus on stiffer, lighter and new technology methods for the construction. In this structure the vertical columns are eliminated the diagonal carries the gravity load as well as the lateral load.

K Jani P V Patel [1]. Seismic analysis of tall concrete and steel diagrid structure of G+20 storey and floor height of 3m concerning storey drift, storey stiffness, lateral displacement, overturning moment and
response spectrum graph and time history analysis. The model was analyzed then compared using E-Tabs software. The design parameters and load combination were assigned the same for both diagrid building. The paper concluded that the diagrid angle of 32.24 degree and IS1893-2002 (response spectrum) another code ASCE 7-10 (time history) for concrete diagrid structure gave optimum results for the G+20 storey building. The lateral displacement, storey drift, axial force and the shear force gradually reduced. In concrete diagrid structure wind load resistance is more when compared to steel diagrid and concrete diagrid structures has high durability compared to steel diagrid structure.

Its indicates the lateral displacement of structure decreases in concrete diagrid structure when compared to steel diagrid structure. Its causes due to lack of lateral forces acting on the steel diagrid structure.

![Displacement(Ex)](image1.png) ![Displacement(Ey)](image2.png)

**Figure 1.** Represents Concrete diagrid structure (Lateral displacement).

![Displacement(Ex)](image3.png) ![Displacement(Ey)](image4.png)

**Figure 2.** Represents Steel diagrid structure (Lateral displacement).

B D Prajapati [2]. Seismic analysis of tall concrete and steel diagrid structure using response and time history method in E-Tabs. G+20 storey of floor height 3m is designed and seismic analysis of each structure. This paper was analyzed to obtain storey drift, storey displacement, Maximum bending moment, shear force, response spectrum and time history. Where as in the case of concrete diagrid structure overturning moment was high when compared to steel diagrid structure. The steel diagrid structure model
being asymmetrical showed more deformation when compared to concrete diagrid structure. The drawback of the paper is the asymmetrical structure looks more aesthetic from outside and requires less amount of steel. Hence the asymmetrical structure must be analyzed by assigning different properties and materials referring to Indian Standard code books.

![Figure 3](image_url)

**Figure 3.** Represents the concrete diagrid structure.
2. Methodology

D R Panchal [3]. analysis and design the tall concrete and steel diagrid structure using response spectrum method. Time history method is apply used for concrete diagrid structure in E-Tabs software for wind and seismic parameters. Each concrete and steel has same dimension and the floor height is same for both the structures has 3m. IS1893:2002 for earthquake analysis to concrete and steel diagrid structures and ASCE7-10 for concrete diagrid structure using time history method. In the time history method we matching the time history data and assigning time history with target response spectrum as a load case. The zone considered for this experiment was IV and for analysis wind and seismic of modular structure, response spectrum method has followed for concrete and steel diagrid structure IS1893:2002. For concrete diagrid structure ASCE7-10 in time history method. The tabular represents the results wind and earthquake analysis. The storey displacement, storey drift in X and Y direction were calculated. Hence it was concluded that concrete diagrid structure has lesser displacement and drift compared to steel diagrid structure.

Table 1 represents that concrete diagrid structure the bending moment of Y direction is less compared to steel diagrid structure and shear is greater in steel diagrid structure related to concrete diagrid structure.

Table 1. Shows the Bending Moment and Shear force of concrete and steel diagrid.

| Forces      | Bending Moment(My) | Bending Moment(Mz) | Shear force(Fy) |
|-------------|--------------------|--------------------|-----------------|

![Figure 4. Represents the steel diagrid structure.](image)
Table 2 represents that the displacement of concrete diagrid structure has more in X direction compared to steel diagrid. Drift is lesser in both the directions of concrete diagrid compared to steel diagrid. The displacement of concrete diagrid structure has lesser in Y direction related to steel diagrid structure.

Table 2. Shows the Storey displacement and Storey drift values of concrete and steel diagrid in X and Y direction.

|          | Displacement(x) | Displacement(y) | Drift(x)  | Drift(y)  |
|----------|-----------------|-----------------|-----------|-----------|
| Concrete | 66.0472         | 0.660           | 102.2295  |           |
| Steel    | 129.2088        | 2.029           | 129.5546  |           |

Figure 5-6. The graph represents the variation of drift in X and Y direction of concrete and steel diagrid plans. When compared concrete diagrid with steel diagrid structure the storey drift is maximum to all stories in concrete diagrid except storey 20. In steel diagrid structure storey drift is maximum at storey 20 compared with concrete diagrid structure.

Figure 5. Represents the concrete diagrid of storey drift.
Figure 6. Represents the steel diagrid of storey drift.

Khushbu D. Jani [4], analyzed on G+20 buildings. The G+20 building were analyzed and design of concrete diagrid and steel diagrid structure using response spectrum method and time history method in E-Tabs software. The experiment were conducted to analyze the storey drift, storey displacement of the structure. Seismic and wind parameters were referred from Indian standard codebook. Response spectrum means the graph of response Vs its time period (frequency).

Figure 7. Response graph for concrete diagrid structure.
Before that there are three methods to combine different model cases responses into response spectrum curve. Complete quadratic combination gives the current response compared to other two methods if frequency is closely spaced. This response curve will obtained by if any structure is to be single straight line then seismic accelerate is applied on each joint of the model w.r.t of single degree of freedom of different mode cases but unique model response are obtained (i.e.) from node 1 to n. In response spectrum when time period is plotted along X-axis and acceleration has Y-axis. So, w.r.t this response curve were going to perform dynamic analysis.

Table 3 represents the sudden reaction of gravity loads, lateral loads due to wind too seismic. The concrete diagrid structure is comparison with steel diagrid structure shows more displacement when the lateral load was applied in this cases.

Table 3. Shows the data of combinations of load

| Loading(KN)          | Gravity(D.L+L.L) | EQx  | EQy  | WLx  | WLy  |
|----------------------|------------------|------|------|------|------|
| Displacement of concrete diagrid structure | 87591.6          | 35.862 | 35.862 | 37.616 | 37.616 |
| Displacement of steel diagrid structure        | 89387.3          | 245.727 | 245.727 | 313.916 | 313.916 |

Figure 9-10. Represents the time history analysis and its provides for linear or non-linear evolution of dynamic structural response. In this we have to match the time history and target response spectrum datafor both the axis. As per ASCE7-10 scaled time history has to be greater than target response
spectrum. When we scaled time history with respective target response spectrum the values of time history should be above 0.2T to 1.5T (Time period). So, here we got the fundamental time period is 1.067sec. Time period range in between 0.17 to 1.29sec.

Figure 9. Spectral matching in time domain X-axis.

Figure 10. Spectral matching in time domain Y-axis.
3. Results and Discussions

3.1. Proposed work
The structural dimension of the G+20 storey building is 25 m x 25 m and the floor height is kept as 3 m. The mass source of the building is taken as 0.25%. The ETABS is advanced software used for analyzing high rise structure. Seismic and wind analysis parameters are also examined. The angle of the both diagrid structure taken is 32.24 degree. The space between the columns is 5 m. The Zone IV region is considered for this proposed data. The load combination taken for wind and seismic parameters are referred from the IS 456:2000 and IS 1893(PART-1):2002 and ASCE7-10. Since the structure is G+20 therefore the Response Spectrum and Time history method is analyzed.

3.2. Structural data
Table 4 Shows the details of structure input data have been mentioned to analyze the concrete diagrid and steel diagrid structure.

Table 4. The dimension data of proposed work

| Storey       | G+20       | G+20       |
|--------------|------------|------------|
| Beam         | 350X600    | 350X600    |
| Column       | 550X650    | 550X650    |
| Diagonal     | 450X550    | 450X550    |
| Zone Factor  | 0.24       | 0.24       |
| Type of Soil | Medium     | Medium     |
| Wind load    | 50m/sec    | 50m/sec    |
| Live Load    | 4kN/m²     | 4KN/m²     |
| Floor Finish | 1kN/m²     | 1KN/m²     |

The damping factor is kept 5% and the importance factor is 1. Analysis results is shear, displacement, drift and base shear.

Table 5 Exhibits the response spectrum for both concrete diagrid and steel diagrid structures in X and Y direction. The concrete diagrid structure shows less displacement than the steel diagrid structure. Hence steel diagrid structures are more economical and beneficial.

Table 5. Shows the displacement of both the structures in X and Y direction w.r.t response spectrum

| Storey                  | X     | Y      |
|-------------------------|-------|--------|
| Storey 20(concrete diagrid) | 0.002 | 0.001  |
| Storey 20(steel diagrid) | 137.7 | 314.3  |

Table 6 Exhibits the wind displacement for both concrete diagrid and steel diagrid structures in X and Y direction. On the storey 20 the steel diagrid building showed higher displacement compared to 20 storey height of concrete diagrid building. The rate of displacement was more in X direction compared to the Y direction in both the diagrid structure.

Table 6. Shows the displacement of both the structures in X and Y direction w.r.t wind
Table 7 Exhibits the time history for concrete diagrid structure in X and Y direction. In storey 20 the displacement shows lesser in X direction compared to Y direction.

### Table 7: Displacement of Concrete Diagrid Structure in X and Y Direction W.r.t Time History

| Storey                    | X   | Y   |
|---------------------------|-----|-----|
| Storey 20 (concrete diagrid) | 35.63 | 2.16 |
| Storey 20 (steel diagrid)  | 313.9 | 4.37 |

Table 7. Shows the displacement of concrete diagrid structure in X and Y direction w.r.t time history.

Figure 11-12. Represents the mode shape of a concrete diagrid building at 0.566sec and steel diagrid building at 1.731sec in response spectrum method. The mode shape is the displacement of the structure at different frequencies occurring during the period of the earthquake.

Figure 11. Shows the displacement of a concrete diagrid building at 0.566sec.
Figure 12. Shows the displacement of a steel diagrid building at 1.731 sec.

Figure 13. Represents the mode shape of a concrete diagrid building at 1.067 sec in Time history method. The mode shape was taken 4 and the displacement of the structure at different frequencies occurring during the time of the earthquake. As per ASCE7-10 scaled time history has to be greater than target response spectrum. When we scaled time history with respective target response spectrum the values of time history should be above 0.2T to 1.5T (Time period).
Figure 13. Shows the displacement of concrete diagrid (Time history) at 1.067sec.

Figure 14. Represents the base reaction of both concrete and steel diagrid structure using response spectrum in both the structures. While compare concrete structure with steel structure base reaction is maximum in steel both dynamic and response analysis.

Figure 14. Represents the base reaction of both concrete and steel diagrid structure.
Figure 15. Represents the base reaction of maximum and minimum time history. So, we obtained the base shear values w.r.t static and time history analysis as per ASCE7-10. We have to scaled up time history base shear to static analysis base shear.

![Figure 15](image1)

Figure 15. Represents the base reaction of Maximum and Minimum time history.

Figure 16. Represents the base shear graph with time period and acceleration its shows the maximum 5.7 magnitude (Positive) and minimum 6.7 magnitude (negative).

![Figure 16](image2)

Figure 16. Represents the base shear graph with time period and acceleration.
4. Conclusion
The study has been successfully executed for both concrete and steel diagrid structure using response and time history method in E-Tabs software to find the flexibility of high raised structures. The structural efficiency of diagrid system also helps in avoiding interior and corner columns.

1. Fundamental time period is less in concrete diagrid compared to steel diagrid using response spectrum while using time history method as per ASCE7-10 we scaled time history w.r.t target response spectrum should be on 0.2T to 1.5T.
2. When compared to steel diagrid concrete has lesser time period.
3. The E-Tabs software is used to design and analysis the axial, shear and bending moment.

5. Acknowledgement
I would like to thank Assistant Professor Y. Himath Kumar for his guidance and support for his paper. I am sincerely thankful to my CADD class faculty Assistant Professor N. Lingeshwaran for completion of my work.

6. References
[1] Jani, K., & Patel, P. V. (2013). Analysis and design of diagrid structural system for high rise steel buildings. Procedia Engineering, 51, 92-100.
[2] Tirkey, N., & Kumar, G. R. (2020). Analysis on the diagrid structure with the conventional building frame using ETABS. Materials Today: Proceedings, 22, 514-518.
[3] Heshmati, M., Khatami, A., & Shakib, H. (2020, June). Seismic performance assessment of tubular diagrid structures with varying angles in tall steel buildings. In Structures (Vol. 25, pp. 113-126). Elsevier.
[4] Özyuygur, A. R. (2016, February). Performance-based Seismic Design of an Irregular Tall Building—A Case Study. In Structures (Vol. 5, pp. 112-122). Elsevier.
[5] Kudumula, A., Ghorpade, D. V. G., & Rao, D. H. S. (2017). Seismic Performance of RC Framed Buildings Under Linear Dynamic Analysis. International Journal of Civil Engineering and Technology, 8(1).
[6] Indian Standard. (2000). IS 456 2000: Plain and Reinforced Concrete. Code of Practice (4th revision).
[7] Standard, I. (1893). Part 1, 2002. Creteria for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi.
[8] Pawar, S. V., & Kakamare, M. S. (2017). Earthquake and wind analysis of diagrid structure. Int J Res Appl Sci Eng Technol, 5(7), 1729-1739.
[9] Moon, K. S. (2008). Practical Design Guidelines for Steel Diagrid Structures. In AEI 2008: Building Integration Solutions (pp. 1-11).
[10] Standard, I. (875). (Part 1-2), 1987. Code of practice for design loads for buildings and structures, published by Bureau of Indian standards, New Delhi.