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Comparative Analysis of a Conventional Structure and a Diagrid Structure Subjected to Seismic Loading

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***Abstract*: The construction of high-rise structures is rapidly increasing in all the countries. Due to unavailability of free land in urban areas, the architects and engineers have started designing cities vertically. The importance of horizontal forces is more in the process of selecting its load bearing structure as the height of a structure increases. The load-bearing structure must have sufficient strength to transfer all loads and impacts and also have appropriate rigidity, which is determined by the admissible amount of inclination at the top of the structure subjected to the lateral loading. Diagrid is a structural system in the periphery which resists the lateral forces by axial actions of diagonals provided in the exterior part instead of the conventional vertical columns. Due to the structural efficiency of diagrids, the columns can be eliminated hence providing flexibility in the design of floor plan. This paper will show the structural performance of both conventional and diagrid structure using ETABS v.15 . Various parameters like storey drift, storey displacement, storey drift and storey stiffness are obtained and compared in this study.**

***Keywords*: Diagrid structures, etabs, comparative analysis, seismic loading.**

1. Introduction

The expeditious growth of population in the urban areas and high pressure on limited space have largely influenced the development of cities. The need to preserve the agricultural and environmental areas of land and increasing cost of land have contributed to shifting towards upward residential buildings. From the structural point of view a building is considered as tall when its structural analysis and design are affected by the lateral loads particularly sway caused by such loads. Lateral loading due to wind or earthquake are governing in design of high rise buildings along with gravitational loading. With the increase in height of the building, the lateral load resisting system becomes more vital than the structural system that resists the gravitational loads. The lateral load resisting systems that are widely used are rigid frames, shear walls, wall-frames, braced tube systems, outrigger systems, diagrid systems and tubular systems. Current trends show that the diagrid structural system is becoming popular in the design of tall buildings due to its inherent structural and architectural advantages.

1) Diagrid structural system

The term "diagrid" is a combination of the words "diagonal" and "grid" and uses triangulation to achieve its structural integrity. Diagrid is a specific form of space truss. It consists of perimeter grid made up of a series of triangulated truss system. It is a structural system in which all perimeter vertical columns are eliminated and consists of only inclined columns on the façade of the building. Diagrid is formed by intersecting the diagonal and horizontal components.

A diagrid structure is designed as a vertical cantilever beam on the ground, and subdivided along the height into modules according to the pattern of the diagrid. One module is defined as a single level of diagrids that extend over many stories. The diagrid modules effectively carry all the loads i.e. lateral load as well as gravity load and distribute them in a very identical and structured pattern. For example, the structural performance of both braced tubes and diagrid structures are very similar since the systems are able to carry lateral loads very efficiently with their structural member's axial actions. The bending rigidity in braced tube structures is provided fundamentally by vertical perimeter columns, bending rigidity in diagrid structure is provided by diagonals which also provide shear rigidity because the system is not composed of columns. To be precise, the diagrid systems can be called the progressed form of braced tube structures with large-diagonal members that spread over the boundary. Also less amount of material is used for construction. Around 20% of structural steel weight is saved when compared to a conventional moment-frame structure. More space is available to make the structural deisgn flexible since the columns are majorly eliminated. There is higher stability in diagrids due to the triangulation. The integration of gravity and lateral load bearing systems certainly provides more efficiency. Therefore, the reduced weight of the superstructure can convert into a reduced load on the foundations.

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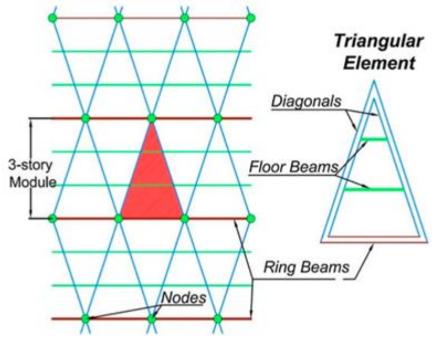

Fig. 1. Diagrid elements

2) Objective of the study

- To compare the performance of a conventional structure and a diagrid structure under seismic loading in ETABS.
- To study the behavior of the conventional and diagrid structures in terms of parameters such as storey displacement, storey drift and storey stiffness.
- To determine the most efficient structure with respect to all the parameters.

3) ETABS software

ETABS is the abbreviation of “Extended 3D Analysis of building System". It is a well-structured analysis and design program developed especially for structural systems. It is loaded with an integrated system with an ability to handle the largest and most complex building models and configurations. It is an engineering software product that caters to multi-storey building analysis and design. Interoperability with a progression of structure and documentation stages makes ETABS an organized and profitable device for plans which range from basic 2D casings to complex elevated structures. Modelling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS.

2. Design Concept

Three dimensional space frame analysis will be carried out for conventional structure and diagrid structure under seismic loading. The structures will be considered in seismic zone III. The support conditions are assumed as fixed. The end condition for diagrid is assumed as hinged. All the structural members are designed using IS 800:2007 and IS 456:2000. The main frame has the same area, number of storeys and a concrete core wall at the centre for both the structures.

Model 1: Conventional Structure (Concrete)

Model 2: Diagrid Structure (Steel)

1) Structural configuration: Diagrid specifications

- Number of storey modules in a diagrid: 3
- Total no. of diagrids: 120
- Height of diagrid: 12 m
- Centre width of diagrid: 12 m
- Angle of diagrid crossing: 63°26’
- Size of diagrid: 350mm steel tube section
- Thickness of diagrid: 20 mm

Table 1
Structural configuration

Parameter	Conventional	Diagrid
Structure type	Concrete structure	Steel structure
Plan dimensions	36*36 m	36*36 m
Number of storeys	30	30
Height of a storey	4 m	4 m
Total height of structure	120 m	120 m
Grade of concrete	Beam, column and slab: M30 Core wall: M35	Column and slab: M30 Core wall: M35
Beam dimensions	400*400 mm	ISMB 600
Column dimensions	650*650 mm	650*650 mm
Thickness of Slab	150 mm	150 mm
Thickness of Core wall		

2) Seismic specifications (AS PER IS: 1893-2002)

- Zone: III
- Zone Factor: 0.16
- Region: Chennai
- Response Reduction Factor: 5 (SMRF)
- Importance Factor: 1
- Type of Soil: II (Medium Soil)

3) Loading specifications

- Live load
- Top storey: 3.5 kN/m²
- Intermediate storey: 1.5 kN/m²
- Floor load: 1 kN/m²

3. Modelling In ETABS

A Conventional structure and a Diagrid structure were modelled using ETABS v.15. The plan, elevation and 3-D views of both the structures are given in figures below.

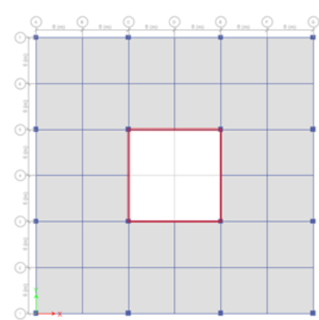

Fig. 2. Plan view of Conventional Structure

Fig. 3. Elevation view of Conventional Structure

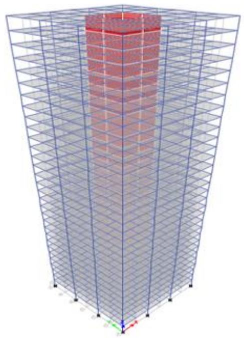

Fig. 4. 3D view of Conventional Structure

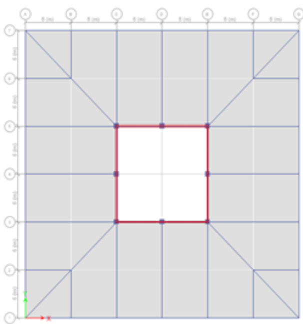

Fig. 5. Plan view of Diagrid Structure

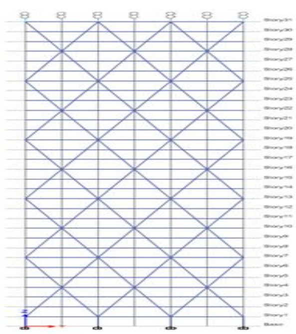

Fig. 6. Elevation view of Diagrid Structure

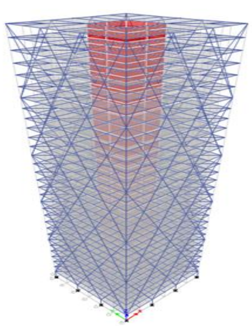

Fig. 7. 3D view of Diagrid Structure

4. Results and Discussions

Linear static analysis was carried out for the conventional structure and diagrid structure. . The parameters like storey displacement, storey drift and storey stiffness were found out for both the structures and the results of the same are represented graphically.

1) Storey displacement

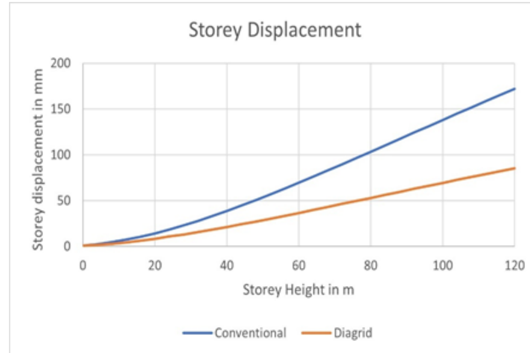

Fig. 8. Storey Displacement

It is observed that the pattern of the plot from the bottom storey to the top storey is similar for both structures but the displacement values in diagrid structure are very less compared to the conventional structure. This shows the efficiency of diagrid structures.

2) Storey drift

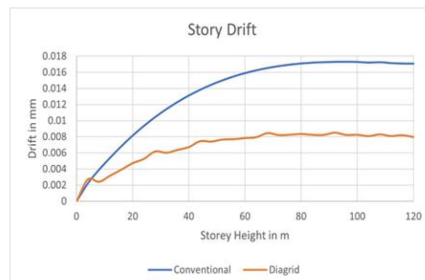

Fig. 9. Storey Drift

The Storey drift values of diagrid structure are lesser compared to the conventional structure. But the drift pattern of conventional structure is observed to be more uniform while there are some variations in case of the diagrid structure. The diagrids are 3-storey modules and it has its ends supported on a particular storey, hence the variations in the values.

3) Storey stiffness

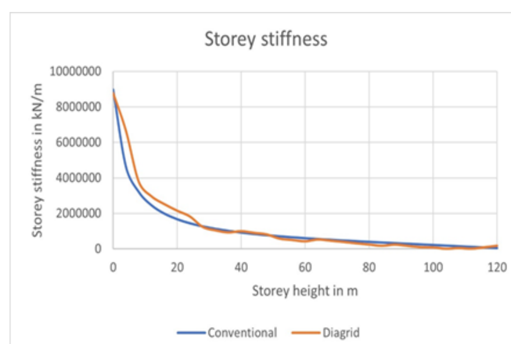

Fig. 10. Storey stiffness

It is observed that the storey stiffness values for both the structures follow similar pattern, but diagrid structure has more stiffness than conventional structure. Thus it can resist more lateral force.

5. Conclusion

Based on the comparative analysis carried out, the conclusions drawn are

1. The diagrid structure has more efficiency in terms of lateral displacement under seismic loading.
2. The diagrid structure emerged as a better solution in terms of storey drift.
3. The diagrid structure resists higher lateral forces as it has greater stiffness and can be preferred over conventional structure.
4. The diagrid structure performed so well, despite all the vertical columns being eliminated in the interior of the structure.
5. The diagrid structure is evidently more efficient than the conventional structure.

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