# Comparative Analysis Of Steel Diagrid Building and conventional Building - A REVIEW

**Kumar Saurabh**
**M.Tech Scholar**
**Department of Civil Engineering**
**IES Institue of Technology and Management**
**Bhopal, MP**

**Vikesh Kumar Mewada**
**Assistant Professor**
**Department of Civil Engineering**
**IES Institute of Technology and Management**
**Bhopal, M.P**

***Abstract- Throughout the world the multi-storey building construction has been increasing day by day. The development of highly advanced structural system which has the quality of aesthetic expression, structural efficiency and most importantly geometric versatility requires the design and construction of artificial infrastructure on the lines of bio-mimicking principles. Recently, the use of diagonal members for carrying the gravity and lateral load has increased and these members are known as 'diagrid'. The unique geometrical configuration of the diagrid structural system has led them to be used for tall buildings providing structural efficiency and aesthetic potential.***

***In this study, the structural response of conventional and diagrid building is investigated to evaluate the structural benefits of diagrid system. A regular G+15 storey steel building with a plan size of 18 m x 18 m, located in a seismic zone V is analysed and designed by STAAD Pro. Software. All structural members are designed as per Indian standard for general construction in steel (IS 800:2007) and the seismic forces are considered as per Indian codal provision for earthquake resistant design of structure (IS 1893 (Part 1): 2002). In diagrid structure, the major portion of lateral load is taken by the external diagonal members, which in turn releases the forces in other members of the structure.***

***The use of diagrids significantly decreases the maximum shear force and bending moment in internal and perimeter beams. The diagrid configuration also provides a reduction in the span of perimeter beams at alternate floors, hence reducing the beam forces at alternate floors. The bending moment in internal column also decreases in diagrid building. This reduces the sectional requirement of beams and columns in diagrid building. An overall economy of nearly 12% is achieved in diagrid building compared to conventional building.***

***The lateral displacement and storey displacement has been reduced significantly in the diagrid building compared to the conventional building. The maximum lateral displacement in diagrid building reduces by nearly 15% compared to conventional building.***

***Keywords— Diagrid Structure, Graphic User Interface,Codal Provisions,Lateral Displacement,Aesthetic Potential,Concentric Brace Frame, Finite Element Method, Eccentric Braced Frames***

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## INTRODUCTION

Diagrids are perimeter structural designs with a small grid of diagonal members that are used for both gravity and lateral load resistance. Although diagonalized applications of structural steel members for providing efficient solutions in terms of strength and stiffness are not new, there is a renewed interest in it and a widespread application of diagrid in large span and high rise buildings, especially when they are characterised by complex geometries and curved shapes, sometimes completely free forms.

Some examples of large-span buildings include the Seattle Library, London City Hall, and others. The Swiss Re skyscraper in London, the Hearst tower in New York, the CCTV headquarters building in Beijing, the Mode Gakuen Spiral Tower in Aichi, the West tower in Guangzhou, the Lotte super tower in Seoul, and the Capital Gate in Abu Dhabi are just a few examples of towering buildings.

**Fig – 1**: Swiss re Tower (London) & Hearst Tower (New York)

The diagrid systems are the evolution of braced tube structures, because the perimeter configuration still holds for maximum bending resistance and rigidity, while the mega-diagonal members are diffusely spread across the façade, giving rise to closely spaced diagonal elements and allowing the complete elimination of conventional vertical columns. The main difference between a braced tube building and a diagrid building is that the diagrid building has no vertical columns around the perimeter, whereas the braced tube building has vertical columns around the perimeter. As a result, the diagonal components of diagrid structures serve as both inclined columns and bracing elements, carrying both gravity and lateral forcesBecause of their triangulated structure, the members experience mostly internal axial forces, reducing shear racking effects. The term "diagrid" is a combination of the words "diagonal" and "grid," and it refers to a single-thickness structural system that achieves structural integrity by triangulation. Diagrid systems can be planar, crystalline, or have numerous curvatures; crystalline forms or curvature are frequently used to increase stiffness. Perimeter diagrids are used to support the floor edges and carry the building's lateral and gravity loads.

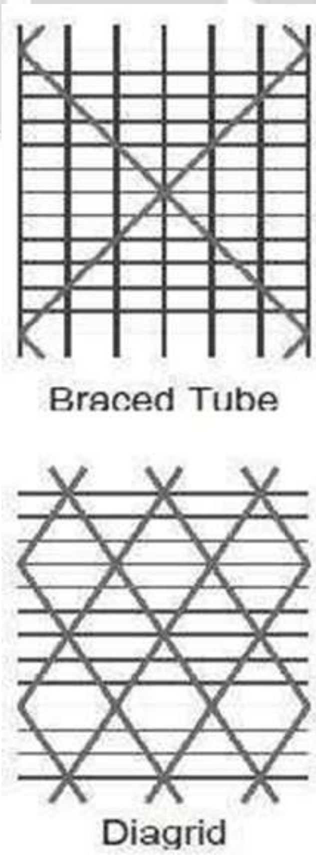


**Fig – 2**: Braced Tube v/s Diagrid

Diagonalized grid structures, sometimes known as "diagrids," have emerged as one of the most inventive and versatile construction systems of this era. The diagrid system has grown to the point that it is no longer restricted to tall buildings. Diagrid construction can also be found in a number of cutting-edge mid-rise steel structures.
The creation of highly advanced structural systems with aesthetic expression, structural efficiency, and, most importantly, geometric versatility is required for the design and construction of artificial infrastructure based on biomimetic principles. Diagrids, the most recent tubular structural mutation, exhibit the best mix of the above features.
Thus, the diagrid, with its ideal combination of artistic expression, structural efficiency, and geometric diversity, is the modern builder's language.
There are a number of engineering reasons why a diagrid should be used. Diagrids can handle a wide range of non-rectilinear geometric shapes, such as irregular curves and angles. This task cannot be accomplished by any other sort of framed building.

## I. OVERVIEW OF WORK

. The modelling, analysis and design of a G+15 storey conventional and diagrid building is done with the help of STADD Pro. software. The geometric parameters of conventional and diagrid both the building are shown in below

1 Number of Storey G+15
2 Plan Size 18m x 18m
3 Storey Height 3.0m
4 Number of Bays along X and Z direction 3
5 Length of each bay 6m
6 Dead Load:
  a) Floor load 3 kN/m2
  b) Wall
  (i) Parapet wall 2.6 kN/m
  (ii) Other wall 8.5 kN/m

7 Live Load:
  a) At roof 2 kN/m2
  b) Other floors 4 kN/m2
8 Seismic Zone as per IS 1893(Part 1): V
9 Response Reduction Factor 5
10 Importance Factor 1.5
11 Soil Type Hard
12 Structure Type Steel frame
13 Diagrid Angle 63.43 o
14 Diagrid Module 4

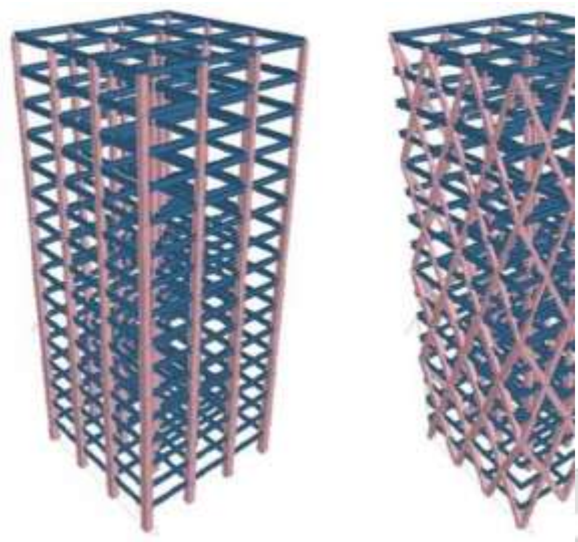

**Fig- 3** : Isometric view of Conventional building and Diagrid building

## II. LITERATURE REVIEW

A large number of papers has been published in the field of diagrids. Following are the few notable outcomes of the related literature:

- The most efficient rehabilitation technique for a low-rise building to reduce drift is column strengthening.
- The X bracing and single bracing systems are the most effective for inelastic behaviour and characterising the hysteric response owing to cyclic stress.
- For a 60-story skyscraper, the most ideal diagrid angle is between
- 53 and 76, with 63 as a viable option.
- A cost-effective material-saving design for systems having diagonals, such as braced systems.
- In resisting lateral and gravitational loads, braced tube and diagrid structures were discovered at an angle of 40 to 50 for braced tube and 60 to 70 for diagrid.
- In terms of shear lag ratio and lateral displacement, diagrid buildings outperform framed tube buildings by three times.
- Utilizing the performance-based method to design a building is preferable to using the traditional method.
- Self-centering energy dissipating frames with advanced bracing systems show a reduction in residual building deformation.
- When compared to tubular structures, the diagrid construction has more strength and ductility.
- Complex-shaped tall buildings, such as twisted, tilted, and so on, can be erected thanks to diagrids structural efficiency and architectural aesthetic potential.
- Over the recent decade, countries such as China, Dubai, Qatar, and England have developed more interested in diagrid constructions.
- When compared to traditional buildings, the RCC diagrid construction has a steel reinforcement benefit of 33%.

It is observed that analysis and design of diagrid structure is carried for high rise steel building only.

**Moon (2008)** investigated a stiffness-based design process, focusing on systems with diagonals such braced tubes and diagrid structures. A material-saving, cost-effective design was created, along with recommendations for optimal geometry. The usefulness of diagrid on tall structures was studied, and it was shown that the best angle for braced tube was 40 to 50 degrees, whereas the optimum angle for diagrid was 60 to 70 degrees.

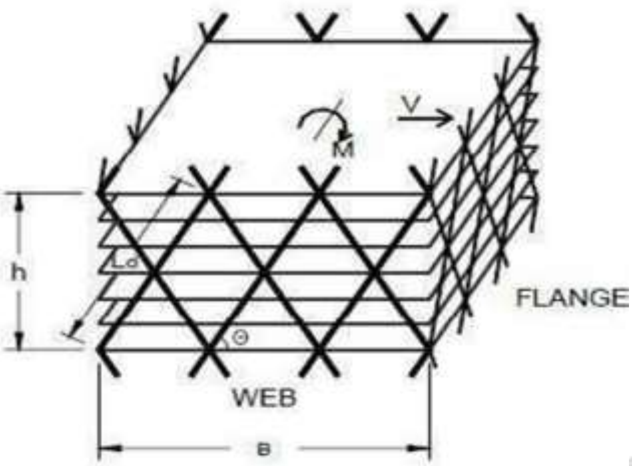


**Fig – 4** Typical diagrid module

**Vishwanath (2010)** examined a four-story building in seismic zone 4. The building's performance is measured in terms of storey drift. The study is then expanded to eight and twelve stories. The most efficient type of steel bracing has been discovered to be X.

**Kim et.al (2010)** studied the seismic performance of diagrid building. Design and Analysis of the building was carried at different angle. The analysis model structure was a 36-storey diagrid structure with various slopes (50.2o, 61.0o, 67.4o, 71.6o, 74.5o and 79.5o) of external braces having a 36m X 36m plan. The diagrid structure showed higher over strength with smaller ductility compared with the tubular structure. An increase was seen in both the strength and ductility. The diagrid with braced angle between 60o and 70o proved to be most efficient in resisting the lateral
and gravity load both.

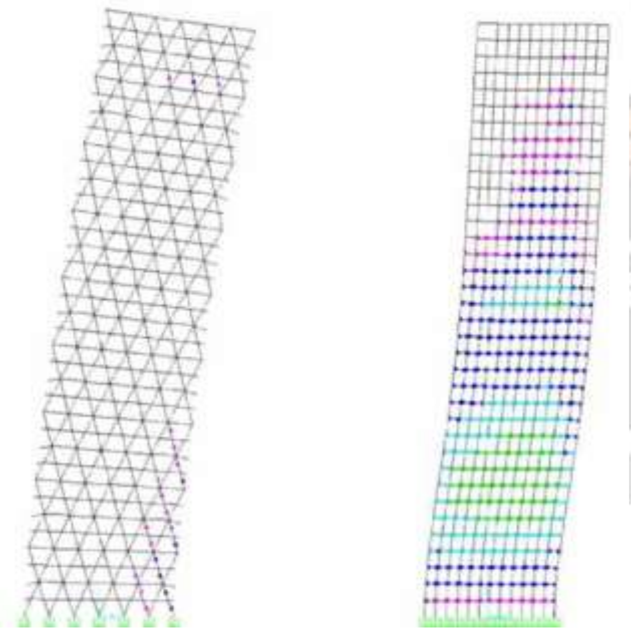

**Fig – 5** : Plastic hinge formation in the model structures obtained by nonlinear static analyses. (Diagrid structure (67.4°) & Tubular structure )

**Jani and Patel (2013)** looked at the study and design of a 36-story steel diagrid building with a plan dimension of 36m X 36m and a floor height of 3.6m. The diagrid angle was maintained throughout the height, and the inclined columns were spaced at 6m intervals around the perimeter. The load distribution in diagrid systems, as well as the analysis and design of 50, 60, 70, and 80-story diagrids, were investigated.
structure. Top storey displacement, time period and inner storey drift was also compared.

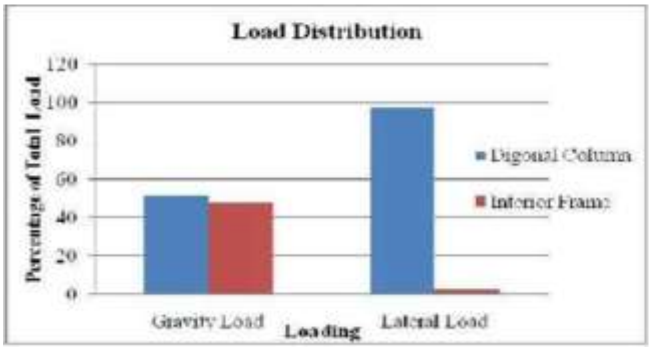


**Fig – 6**: Load distribution in exterior and interior frame

From the above study, it is clear that lateral study is resisted by outer periphery columns and internal column is designed only for vertical loads only.

**Panchal and Patel (2014)** studied the usage of diagrid structural solutions in high-rise structures to reduce lateral forces. For top storey displacement, storey drift, and material consumption, ETABS 9.7.4 software was used to compare a 20-story basic frame building to a diagrid building with a plan dimension of 18m x 18m. They came up with a difference of 57.9% in terms of steel use**.**

**Korsavi and Maqhareh (2014)**, the evolutionary process of diagrid structures and their developments leads to significant breakthroughs in architectural, structural, and sustainability principles. The constructions met the bulk of the design requirements, according to the findings. According to the data, countries like China, Dubai, Qatar, and England have been increasingly popular in diagrid structures during the last decade.

## IV. NEED FOR THE PROPOSED WORK

There are a number of engineering reasons why a diagrid should be used. Diagrids can handle a wide range of non-rectilinear geometric shapes, such as irregular curves and angles. This task cannot be accomplished by any other sort of framed building.

There are several functional and economic advantages that underlie the use of this system:

- Increased the stability due to triangulation
- Combination of the gravity and lateral load-bearing systems, potentially providing more efficiency.
- Provision of alternate load paths (redundancy) in the event of a structural failure (which lacks in case of conventional framed building).
- Reduced weight of the superstructure can translate into a reduced load on the foundations.
- Reduced use of structural materials translating into environmental savings.
- It has ability to reduce dependency on the core for achieving lateral stability.

The first diagrid- supported office building “IBM Building” now known as United Steelworkers Building was completed in 1963 in Pittsburgh, designed by Curtis and Davis and engineered by the firm of Leslie E. Robertson.

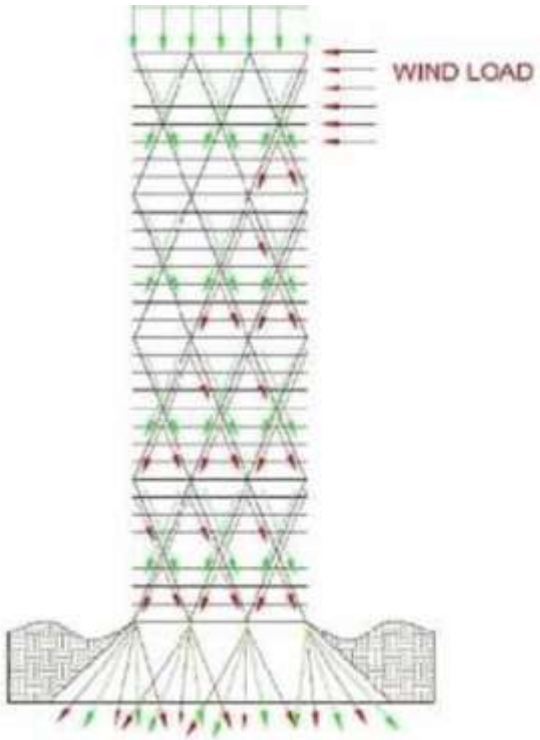


**Fig - 7**: Distribution of loads in diagrid structure

V. OBJECTIVE OF THE WORK

The following points fulfils objectives of research:

- Comparison of Column Force between conventional and diagrid building.
- Comparison of Beam Forces between conventional and diagrid building.
- Comparison of Lateral Displacement between conventional and diagrid building.
- Comparison of Weight of Building between conventional and diagrid building.

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