International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

Vol.3, Special Issue 1 Aug - 2017

Comparative Behaviour of High Rise Buildings with Diagrids and Shear Wall as Lateral Load Resisting System

Sachin Mohare [1, a], Dr. H Sharada Bai [2]

[1] Assistant Professor, Civil Engineering Department,
REVA University Bangalore, Karnataka, India.

[2] Former Professor, Faculty of Engineering-Civil,
UVCE Bangalore University, Karnataka, India.

ABSTRACT

Structural systems for tall buildings have undergone dramatic changes after observing that conventional Rigid Moment Resisting frames alone, the earlier predominant structural system for steel or concrete tall buildings was inefficient in resisting lateral loads. The intensity of the seismic and wind load increases with increase in height of the structure and demand the use of an additional Lateral Load Resisting System (LLRS) for enhancing performance. The LLRS for high rise buildings depend largely on the height of the building. Some of the LLRS that are currently used are Shear Wall (35m), Tube Structures- Frame tube (80m) and bundled tube (100m), Diagrid (100m), Super frames (160m) etc. Diagrid is a technique typically used for constructing large steel buildings by creating external triangular structures with horizontal support rings. The Diagonal members in Diagrid structural systems can carry gravity loads as well as lateral forces. In the present study, the behaviour of Diagrid structures in terms Lateral sway is compared with that of building with shear walls to evaluate the efficiency of Diagrid structures. A 45 storey steel building with a plan area of 36×36m and triangular pattern for diagonal members with a Diagrid angle of 63° is considered. The variations considered are density of Diagrid as 3, 4 and 6 and length of Shear wall, each 6m and 12m along X and Y directions at the corners of the building. Seismic analysis is carried out for seismic Zone V considering various load combination as per IS Codal provisions using SAP2000 V-15.It is found that Lateral displacements of a Diagrid structure are much less than that of shear walled structures proving its efficiency. The study also determines the optimum density of Diagrids considering the structural behaviour and practical considerations.

Keywords: Diagrid, High Rise Building, Shear Wall, Story Drift And Top Story Displacement.

1. INTRODUCTION

Structural systems for tall buildings have undergone dramatic changes after observing that conventional Rigid Moment Resisting frames alone, the earlier predominant structural system for steel or concrete tall buildings was inefficient in resisting lateral loads. The intensity of the seismic and wind load increases with increase in height of the structure and demand the use of an additional Lateral Load Resisting System (LLRS) for enhancing performance. The LLRS for high rise buildings depend largely on the height of the building.

The rapid growth of urban population and limitation of available land, the taller structures are preferable now a day. So, when the height of structure increases then the consideration of lateral load is very much important. For that the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. The lateral load resisting systems that are widely used are rigid frame, shear wall, wall frame, braced tube system, outrigger system and tubular system. Recently the Diagrid – diagonal grid structural system is widely used for tall buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. Hence the Diagrid, for structural effectiveness and aesthetics has generated renewed interest from architectural and structural designers of tall buildings.

The difference between conventional exterior-braced frame structures and current Diagrid structures is that, for Diagrid structures, almost all the conventional vertical columns are eliminated. This is possible because the diagonal members in Diagrid structural systems can carry gravity loads as well as lateral forces owing to their triangulated configuration, whereas the diagonals in conventional braced frame structures carry only lateral loads. Compared with conventional framed tubular structures without diagonals, Diagrid structures are much more effective in minimizing shear deformation because they carry shear by axial action of the diagonal members, while conventional framed tubular structures carry shear by the bending of the vertical columns. Diagrid structures do not need high shear rigidity cores because shear can be carried by the Diagrids located on the perimeter. The Diagrid system has a lot of benefits that can make it more favorable to the designer against other systems. Some of those benefits are:

- Column free exterior and interior resulting in sufficient daylight.
- Reduction in usage of steel by 20%.
- Simple and Fast construction. (Requires skilled labor)
- Aesthetically dominating and expressive.

Three non-routine structural patterns were found in nature and previous vertical buildings-triangular, hexagonal and diamond.

- Triangular pattern is widely used due to its stability and constructional economy since it can be assembled with pinned connections.
- Hexagonal pattern is the most economical pattern and can produce efficient space filling and minimum material for maximum volume (HTA 2007).
- The diamond pattern creates strength and durability. Although it is not a stable arrangement; such in a double-helix arrangement, it provides redundancy or extra strength to withstand extreme forces without collapse (Tsui 1999).

These three patterns have been found implemented in recent vertical building projects (Figure 1) - the 46 storey Hearst Headquarter (Grawe & Schmal 2006), the 26 storey Schatzalp Tower (HTA 2007), and the 41 storey St. Mary Axe building (Wells 2005).

Figure 1: Hearst Headquarter in New York (left) Schatzalp Tower in Switzerland (centre) and St. Mary Axe Tower in London (right).

2. ANALYSIS OF 45 STOREY BUILDING

2.1. details of building parameters

The aim of the present investigation is to study the behavior of High Rise Buildings using Diagrid as the Lateral Load Resisting System (LLRS). Comparative study of Diagrid structures with conventional shear walls as Lateral Load Resisting System (LLRS).

In the present study, the behaviour of Diagrid structures in terms Lateral sway is compared with that of building with shear walls to evaluate the efficiency of Diagrid structures. A 45 storey steel building with a plan area of 36×36m and triangular pattern for diagonal members with a Diagrid angle of 63^{o} is considered. The variations considered are density of Diagrid as 3, 4 and 6 and length of Shear wall, each 6m and 12m along X and Y directions at the corners of the building. Seismic analysis is carried out for seismic Zone V considering various load combination as per IS Codal provisions using SAP2000 V-15.

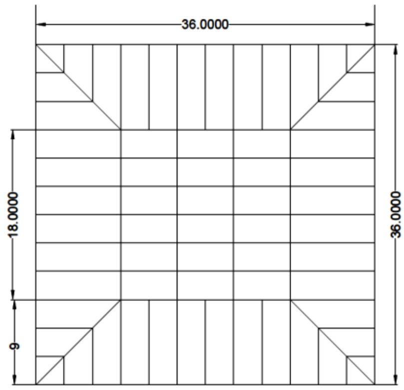


Fig -1) Plan of 45 storey Diagrid model

The cross-sections of structural members considered are as follows:

a) Slab thickness at each floor level = 0.12m
b) Cross section of Diagrid
(Tube section) = 0.6858m X 0.0658m
c) Beam Size =ISMB200@0.249kN/m2
d) Density of Concrete (γ) = 25 kN/m3
e) Density of steel =7850 kN/m3
f) RC Core wall thickness = 0.3m
g) Shear Wall length = 6m and 12m

The Dead load and Live load on the structure are 4.25kN/m2 and 3kN/m2 respectively.

The design earthquake load is computed based following factors:

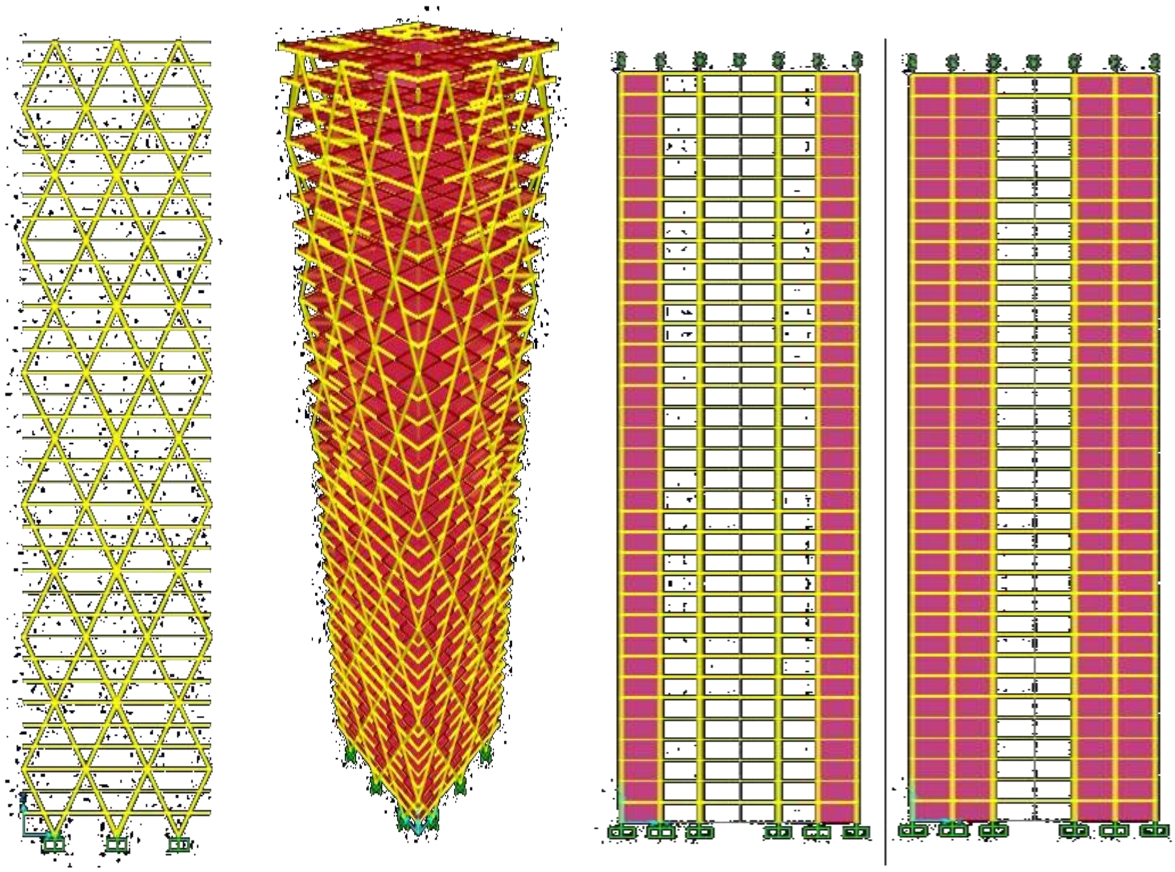
1) Type of structure considered for the analysis is a Special Moment Resisting Frame (SMRF).

2) Response reduction factor, R=5,

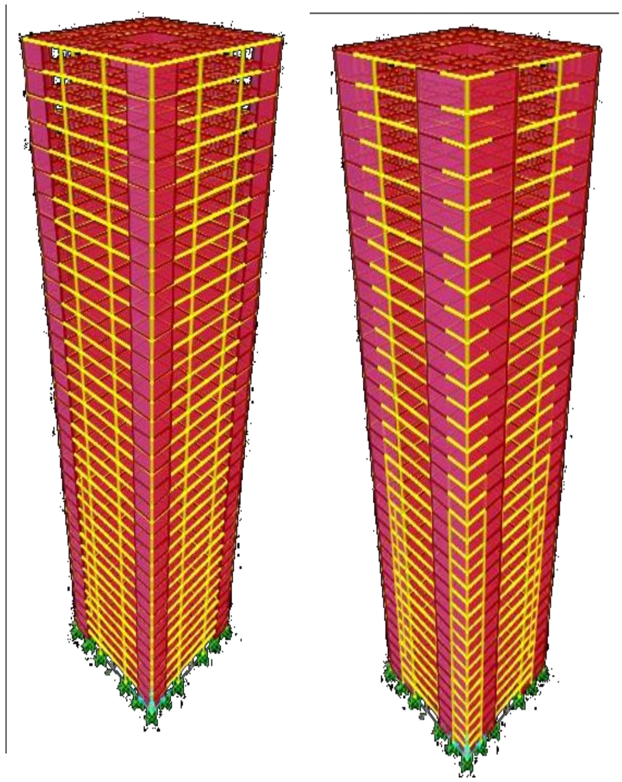
3) Structure located in zone V, it is considered that the structure is situated in type II (medium soil). 4) Importance factor of 1.5 as per IS-1893-2002.

5) The design wind load is computed based on IS-893-Part III (location Bengaluru), with a Wind speed of 33 m/s, Terrain category 2, Structure class B.

6) The analysis of the model is carried out using SAP2000 V-15.



a) b) c) d)



e) f)

Fig -1: a), c), e) Sectional elevation of Diagrid and Shear Wall (6m and 12m); b), d), f) 3D view of model

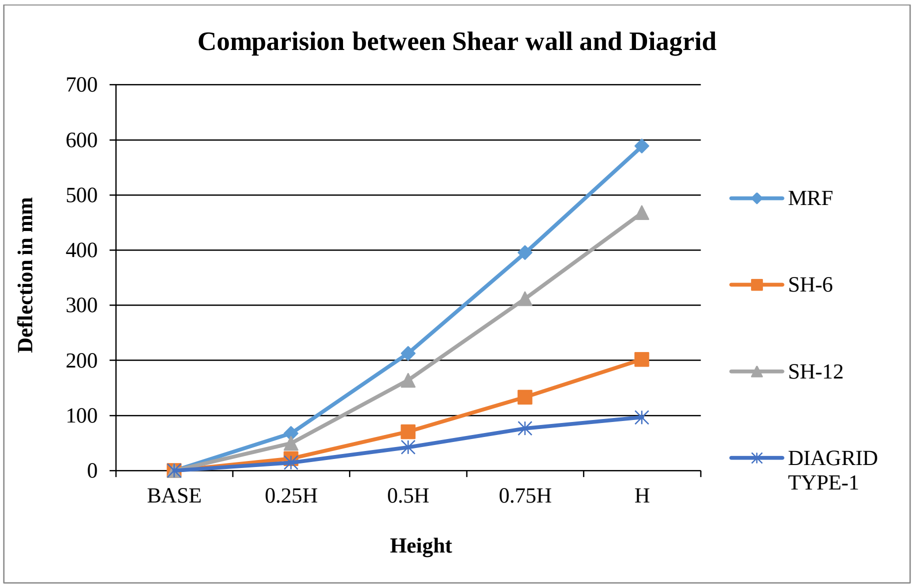
2.2. ANALYSIS OF RESULTS

The analysis results in terms of displacement, inter storey drift, storey shear are shown in table-1

Table -1: Displacement values at different levels

TYPE OF SYSTEM		BASE	0.25H	0.5H	0.75H	H
BF		0	67.7	212.9	395.5	588.9
SH-6		0	49.6	164.2	312.3	468.2
SH-12		0	21.9	70.5	133.4	201.9
DIAGRID	D4-WOC	0	14.7	42.6	76.8	96.8

Chart-1: Comparison of Lateral sway between Shear wall and Diagrid



The Lateral displacement of MRF Diagrid, shear wall of length 12m (SH-12) and shear wall of length 6m (SH-6) are presented in the table-1.

The following points can be observed:

1. Sway undergone by the Diagrid structures are considerably less than shear wall structures.
2. From the chart, it is evident that the maximum lateral sway is suffered by MRF, SH-6 and SH-12 whereas least by Diagrid.
3.

3. CONCLUSIONS

The Lateral Displacements of a Diagrid structure at different heights is less than that of conventional shear walled structures. Lateral deformations in the Diagrid structure are substantially less than that of both shear wall structures, the lateral deformation in SH-6 and SH-12 are 5.6 and 2.39 times that of Diagrid. When a Diagrid structure is compared with shear walls of different lengths provoided in similar structure, lateral sway, maximum axial force and bending moment developed in the Diagrid structure were found to be less than those of shear walled structure.

The potentials of Diagrid structure especially for High Rise structures yet to be adopted in India. The better structural behaviour exhibited by the Diagrid structures can be attributed to its triangular configuration which also exhibits aesthetic potential particularly in high rise structures producing high lateral stiffness.

REFERENCES

[1] Ali Mir M and Kyoung Sun Moon (2007) Structural Developments in Tall Buildings: Current Trends and Future Prospects Volume 50.3, pp 205-223, 13 June Architectural Science Review

[2] Ali, M.M. (2001). Art of the Skyscraper: The Genius of Fazlur Khan. New York: Rizzoli.

[3] Alexis Lee, Andrew Luong, Rory Mcgowan and Chas Pope, Chris Carroll, Xiaonian Duan, Craig Gibbons, Richard Lawson (2006), China Central Television Headquarters - Structural Design Steel Structures 6 (2006) no 387-391

[4] Charles Besjak And William Baker, (2010) Proposed methodology to determine seismic performance factors for steel Diagrid framed systems, CTBUH technical paper

[5] Eunike Kristi Julistiono (2009) The Application Of Non-Routine Structural Patterns To Optimise A Vertical Structure Journal of Architecture and Built Environment, Vol. 37 (July 2009), No. 1, 15-22.

[6] Kim J, Jun Y. and Ho Lee Y. (2010) Seismic Performance Evaluation of Diagrid System Buildings.

[7] Johan Leonard (2007) Investigation of shear lag effect in high rise buildings with Diagrid system.

[8] Kim Jong Soo1, Kim Young Sik, Lho Seung Hee (2008)Structural Schematic Design of a Tall Building in Asan using the Diagrid System CTBUH 8th World Congress 2008.

[9] Kyoung Sun Moon (2008) Sustainable Design Of Tall Building Structures And Facades.

[10] Kyoung Sun Moon (2010) Challenges, Integrated design and construction to mitigate wind-induced motions of tall buildings Opportunities and Solutions in Structural Engineering and Construction 2010.

[11] Maurizio Toreno 1; Raffaele Arpino2, Elena Mele 3; Giuseppe Brandonisio4, Antonello De Luca (2008) , An overview on Diagrid structures for tall buildings.

[12] IS: 456-2000 - Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi.

[13] IS: 1893 (Part-1) – 2002 - Code of Practice for Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings, Bureau of Indian Standards, New Delhi.

[14] IS: 875 – 1987 - Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures, Part 1: Dead Loads, Part 2: Imposed Loads, Part 5: Special Loads and Load Combinations, Bureau of Indian Standards, New Delh.