Analysis Of Diagrid Structure For A Building Using Different Loading

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ABSTRACT

The purpose of this study is to analyze of diagride structure with hexagonal and varied angle configurations, an optimized 45° inclined column angle Diagrid and a variable angle Diagrid to determine the resistance to seismic loads and wind loads, and to compare the structural performance of these buildings with the conventional square building This study is upon the design and analysis of G+20 structure with different Diagrid topologies, optimized inclined column angle and variable angle design in & ETABS v.18 software. It primarily focuses on the bio mimicry of the honeycomb pattern, forming the Hexagonal structural system, known as Hexagrid

1.1 INTRODUCTION

In the late 18th century a significant tall building development begun, especially in United States, and Europe continent to cope with the rapid growth of urban population and consequentreduction of the land. The first tall buildings consisted of simple structural systems based on the conventional moment resisting frame, but over time new typologies have been emerged such as diagrid systems. In this project we have studied on three symmetrical planes along with X- direction and Y-direction and analyze the each plane for the conventional R.C.C structure , conventional diagrid structure and varying angle daigrid structure for the optimum analysis of static responses and dynamic responses latral load storey overturning movement, storey displacement, storey stiffness, and stoey drift etc for G+20 storey building.

1.2 OBJECTIVE OF THE STUDY

1. To design and analyse the Diagrid structures; 45° diagonal angle Diagridstructure & varying diagonal angle Diagrid structure, along with a conventional structure model using Response Spectrum Analysis.
2. To compute the static and dynamic responses; story drift, story displacement, time period, story over-turning moment and story stiffness.
3. To compare the structural performance of the Diagrid structures with the conventional model.

1.3 SCOPE OF THE STUDY

The main scope of the project is,

1.To compare the structural efficiency of these buildings against the conventional structure.
2.To understand the sustainability and the structural reliability of using the hexagonal geometry to design the structural system of the building, and the cost-performance value of using it.
3.To utilize this structural system in tall buildings to increase structural efficiency and also influence the architecture and sustainability of the structure.

2.1 LITRATURE SURVEY

Yasaman Memarzadeh Kiani , (2021), Seismic assessment of nature-inspired Diagrid lateral load-resisting system. The study gives a general perspective of the seismic performance of Diagrid under near-field ground motions. This is achieved by modeling and understanding the modeling of two 20-storey buildings with Diagrid skeleton and bundled-tube skeleton structural system.

Sooriya P and Bushra M, (2020), Performance assessment of Diagrid structural system. The aim of the paper is to compare the various available Diagrid structural systems with different patterns and to achieve an optimized pattern that will resist lateral loads in the Diagrid structural system effectively.

Shajeea and Seethu Sunny, (2020), Seismic Performance of Soft Storey Behaviour in Irregular Steel Frames using Different Bracing Systems. This paper uses asymmetrically irregular and symmetrically irregular frames of different types; V, Octa, Hexa and Zipper frames are considered for dynamic analysis of a G+20- storey building, to understand the effect of soft storey in the steel frame.

Krishnan P A , (2019), A Study on Seismic Performance of Diagrid Structures. The study is based upon the seismic performance of the Diagrid structures, mainly considering an 18- and 24- storey structure of regular pattern Diagrid and a 36- storey structure with varying angle and varying density of the modules in ETABS software. The structural performance is evaluated with different parameters like storey displacement, storey drift, and storey shear.

Niloufar Mashhadiali and Ali Kheyroddin, (2019), Quantification of the seismic performance factors of steel Diagrid structures. The aim of this study is to assess the response modification factor, R, of Diagrid structural system under seismic loading. Set of structure models with 3-, 9-, 21 storey with varying diagonal angles of 33°, 45°, and 53° are designed with an evaluated R factor using nonlinear static and dynamic analysis under FEMA P695 methodology.

Yash Bhardwaj, (2019), Structural Behaviour of Diagrid & Diagrid Structural Systems in Multi Storey Buildings. The project focuses on the optimizing the diagonal angle and the topology of the diagonal members used in the horizontal Diagrid frame using finite element analysis. The focus also extends to compare the efficiency of the achieved Diagrid structural system with use of various parameters such as inter-storey drift, time period and displacement.

Elena Mele , (2019), Diagrid-Voronoi transition in structural patterns for tall buildings. This study is based upon the non-conventional structural patterns and systems used for the design of tall buildings. The Diagrid and Voronoi-inspired arrays. The mechanical properties of selected non- conventional structural patterns were studied and utilized with the help of Representative Volume Element (RVE) and stress-strain relationships to make them applicable effectively for tall buildings.

Vedprakash Maralapalle , (2019), Analysis & design of pile foundation for G+20 residential building, this paper is focused on the design and analysis of a G+20 building located in Mumbai andfocuses mainly on foundation design.

3.1 METHODOLOGY

The methodology for the design and analysis of the Diagrid structures and conventional structure is simplified using the ETABS v.16 software. The summary of the methodology followed is to begin with initializing the site and structure parameters. This includes site conditions, general structure parameters such as the dimensions, floor plan, storey height, grade and specifications of material

sections used, loading conditions and load case parameters. This is followed by 2- dimensional plan created using AutoCAD software, which consists of the floor plan of the structures. These structures are then modeled in the structural analysis software, ETABS v.16. The analysis is performed after considering the wind and seismic loads, as per IS 875-2015 Part – III & IS 1893: 2016 Part – I. The Response spectrum analysis is added along with it, according to IS 1893: 2016 Part – I. The analysis results are obtained in terms of various structure parameters such as story displacement, story drift, story stiffness, time period and story over-turning moment.

3.2 DIAGRID STRUCTURAL SYSTEM

Apart from the conventional building, the Diagrid buildings are designed with the variation in the inclined angle in the exterior of the structure. The Diagrid can be defined as system of hexagonal grids in a pattern on the exterior of the structure. This pattern is identical to the honeycomb structure found in beehives; they are voidof vertical columns as the inclined columns make up the structural integrity. The hexagon shape of the tightly packed honey comb cells ensures maximum utilization of area and also distribute any force acting upon it efficiently.Since the Diagrid pattern provides no vertical column, the inclined columns resistboth the gravity load and lateral load, and also provide flexibility in architectural aspects such as view, lighting and aesthetic façade.

3.3 STRUCTURE PARAMETERS

A tall building model with a square plan of 18 * 18 m, with interior columns on the corners of a 6 * 6 m square in the center of the plan is considered as the conventionalmodel. After evaluating the geometrical parameters of the reference building, two different models are created with different hexagonal topology, namely an optimized 45° inclined column angle Diagrid and a varying inclined column angleDiagrid pattern of the exterior façade. The total height of the building is 63m, making it a G + 20 story building with floor height of 3m. The 45° inclined column angle Diagrid structure

3.3.1 RF (Regular Frame) – Conventionalsquare building

This structure is a square G+20 building with the commonly used, rigid frame structural system. The rigid frame is composed of 0.45 * 0.45 m RCC columns and 0.35 * 0.3 m beams in the interior of the structure. The perimeter frame of the structure consists of a composite structural system with ISWB 500 steel columns connected with 0.35 * 0.3m RCC beams.

3.3.2 VD (Hexagonal Diagrid) – 45° diagonalangle Diagrid structure

The Diagrid structural system is utilized in the perimeter frame of this G+20 structure. Similar to the **RF** model, the interior of the structure consists of 0.45 * 0.45 m RCC columns and 0.35 * 0.3 m RCC beams as structural members along with 0.15 m thick RCC floor slabs. The exterior frame of the structural system consists of the ISWB 500 steel sections with vertical and 45° diagonal angle inclined columns, with 9 m module height hexagonal cells that make up the vertical pattern Diagrid structural system.

3.3.3 VAD (Varying angle Diagrid) – Varyingdiagonal angle Diagrid structure

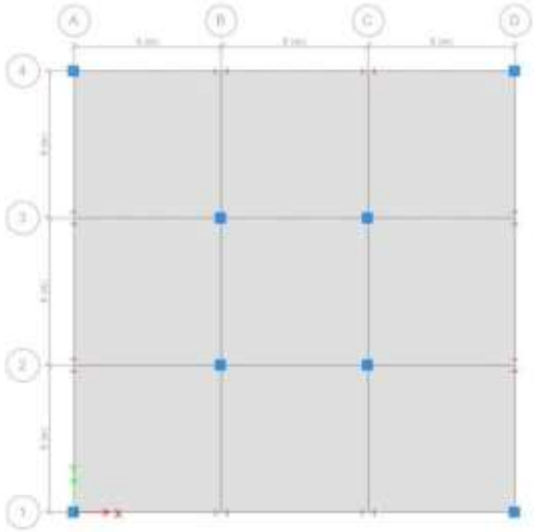
This structure is a G+20 Diagrid structure with the varying diagonal angle of the inclined columns in the exterior frame of the structural system. The interior structuralelements are identical to that of

the **RF** and **HD** models, with 0.45 * 0.45 m RCC vertical columns and 0.35 * 0.3 m RCC beams along with 0.15 m thick RCC floor slabs. The perimeter skeleton however consists of the Diagrid system with the diagonal angle having varying angles along the height of the structure. The diagonal angle starts at 40° and varies along the height of the structure with an increment of5° after each row in the Diagrid In the modeling of the two Diagrid structures, the scope of the configurations such as the module density, varying material sections, story heights are not changed and kept constant as this would influence the effectiveness of the modeling technique since the increase in the number of factors will eventually increase the complexity of the structure and its performance. Only the angle of the inclined member is considered for the modeling and it is optimized for one Diagrid model **(HD)** and varying for the second Diagrid model **(VAD).**

3.4.1 FLOOR PLAN

The square building plan of area 324m^2, the basic dimension of the three models is identical, with 18m * 18m square plan. Vertical columns are present in the corners of the perimeter and the interior 6m * 6m square. While the members of the perimeter façade vary with each model

3.4.2 Conventional R.C.C model, Hexagonal Diagrid model And Varying Angle Diagrid (RF.HD.VAD)



(Figure 3.1)

3.1 Table Data for static analysis of Conventional Diagrid and Variable angle Diagrid structural system

S.No	Particulars	Conventional system	Hexagonal system	Variable angle system
1.	Dimension of Plan	18m * 18m	18m * 18m	18m * 18m
2.	Total height of the structure	63m	63m	63m
3.	Height of each storey	3m	3m	3m
4.	Section of beams	RCC-0.35m*0.3m	RCC-0.35m*0.3m	RCC-0.35m*0.3m
5.	Section of columns	RCC-0.45m*0.45m ISWB500	RCC 0.45m*0.45m ISWB500	RCC 0.45m*0.45m ISWB500
6.	Section of inclined columns	-	ISWB500	ISWB500
7.	Angle of inclined columns	-	45° (1 Diagrid covers 3 story)	40°, 45°, 50°, 55°, 60°, 65°, 70° (1 Diagrid covers 3 story)
8.	Grade of concrete Grade of steel	M30 FE50 0	M30 FE50 0	M30 FE50 0
9.	Section of slab	RCC-150mm	RCC-150mm	RCC-150mm
10.	Dead load	3.75 kN/m^2	3.75 kN/m^2	3.75 kN/m^2
11.	Live load	4.5 kN/m^2	4.5 kN/m^2	4.5 kN/m^2
12.	Seismic load – IS CodeSeismic Zone Importance factor Zone factor Damping Ratio Response reduction factor	IS1893: 2016 (Part 1) I V 1 0.24 5% 5	IS1893-2016 (Part 1) I V 1 0.24 5% 5	IS1893-2016 (Part 1) I V 1 0.24 5% 5
13.	Wind load – IS Code Basic wind speed Terrain Category Structure Class Risk Coefficient (k1 factor)Topography (k3 factor) Windward coefficient Leeward coefficient	IS 875: 2015 (Part 3) 50 m/sec 3 B 1 1 0.8 0.5	IS 875: 2015 (Part 3) 50 m/sec 3 B 1 1 0.8 0.5	IS 875: 2015 (Part 3) 50 m/sec 3 B 1 1 0.8 0.5
14.	Soil condition	Medium soil (Type II)	Medium soil (Type II)	Medium soil (Type II)

S. No	Particulars	Conventional system - RF	Hexagonal system - VD	Variable angle system - VAD
1.	Plan dimension	18m * 18m	18m * 18m	18m * 18m
2.	Total height	63m	63m	63m
3.	Story height	3m	3m	3m
4.	Beam section	RCC; 0.35m*0.3m	RCC; 0.35m*0.3m	RCC; 0.35m*0.3m
5.	Column section	RCC; 0.45m*0.45 m Steel; ISWB500	RCC; 0.45m*0.45 m Steel; ISWB500	RCC; 0.45m*0.45 m Steel; ISWB500
6.	Inclined column section	-	Steel; ISWB500	Steel; ISWB500
7.	Angle of inclined column s	-	45°	40°, 45°, 50°, 55°, 60°, 65°, 70°
9.	Slab section	RCC; 150mm	RCC; 150mm	RCC; 150mm
10.	Grade of concrete	M30	M30	M30
11.	Grade of steel	FE500	FE500	FE500

Table.3.3 Loading and analysis parameters

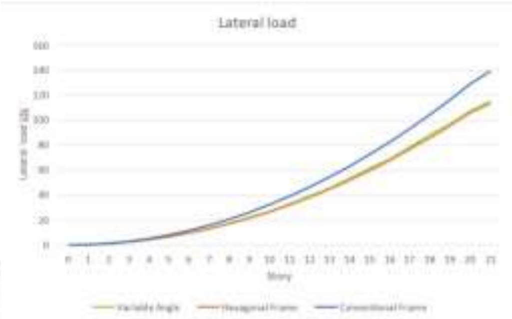
S. No	Particulars	Conventional system – RF	Hexagonal system – VD	Variable angle system – VAD
1.	Dead load	3.75 kN/m²	3.75 kN/m²	3.75 kN/m²
2.	Live load	4.5 kN/m²	4.5 kN/m²	4.5 kN/m²
3.	Seismic load – IS Code Seismic Zone Importance factor Zone factor Damping Ratio Response reduction factor	IS1893: 2002 (Part 1) IV 1 0.24 5% 5	IS1893-2002 (Part 1) IV 1 0.24 5% 5	IS1893-2002 (Part 1) IV 1 0.24 5% 5
4.	Wind load – IS Code Basic wind speed Terrain Category Structure Class Risk Coefficient (k1 factor) Topography (k3 factor) Windward coefficient Leeward coefficient	IS 875: 1987 (Part 3) 50 m/sec 3 B 1 1 0.8 0.5	IS 875: 1987 (Part 3) 50 m/sec 3 B 1 1 0.8 0.5	IS 875: 1987 (Part 3) 50 m/sec 3 B 1 1 0.8 0.5
5.	Soil condition	Medium soil (Type II)	Medium soil (Type II)	Medium soil (Type II)

4. RESULT

4.1 STATIC RESPONSES

4.1.1 LATERAL LOAD

Lateral loading is the load applied on a structure in a horizontal direction or parallel to the x-axis. Typical lateral loads would be a wind load, seismic loads or special loads such as impact loads. Lateral loads depend upon the building's terrain, structural system, height and shape



(Figure 4.1)

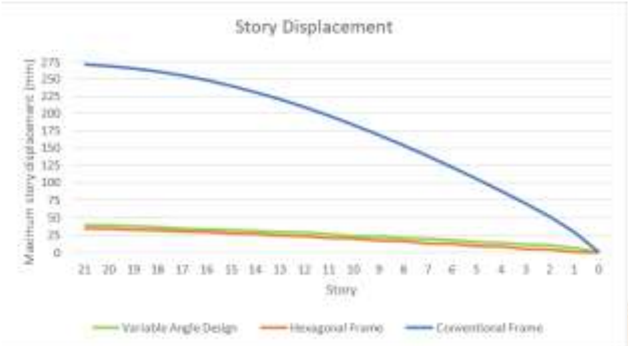
4.1.2 STORY OVERTURNING MOMENT

The overturning moment of an object is the moment that tends to make the structure overturn, topple or become unstable, when an additional lateral force acts upon it. The story overturning moment is highest for the RF structure, followed by the VD and VAD structure respectively is shown in

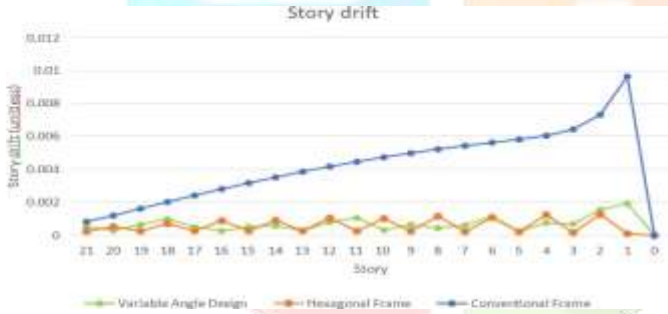
(Figure 4.2)

4.1.3 STORY DISPLACEMENT

Story displacement is the lateral displacement of the story relative to the base. The lateral force-resisting system can limit the excessive lateral displacement of the building. The acceptance lateral displacement limit for wind load case could be taken as H/500 (some may take H/400). From Figure.5.2, the displacement in the RF structure is 150% greater than that of the VD & VAD structures

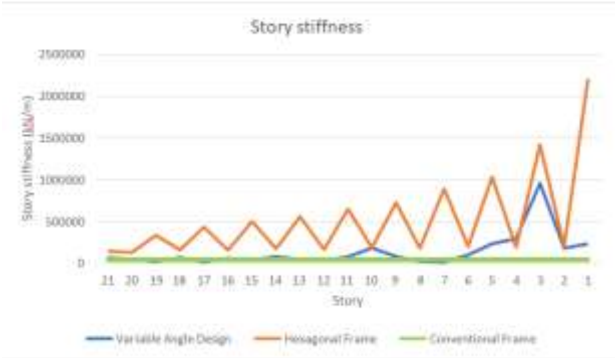


(figure 4.3)



4.1.4 STORY STIFFNESS

Story stiffness can be defined as lateral forces bystory displacement, it is basically the ability of a structure or element to resist displacement,deflection due to the applied stress. From the Figure.5.5, VD structure has a higher story stiffness than the RF & VAD structure, this may be due to the symmetrical distribution of gravity and lateral loads through the optimized and symmetrical Diagrid frame in the perimeter of the VD Structure



(figure 4.4)

4.1.5 STORY DRIFT

Story drift is the difference of displacement between the two consecutive stories divided by the height of that story. Minimum story drift is desired, in the case of the conventional frame building. From Figure.5.1 of the conventional frame model, it can be seen that there is a significant spike in the story drift for the 1st story. This is called the soft story effect, which can be identified by the comparatively high story drift. This occurs in a structure when a level of the building has lower resistance to lateral loads compared to the levels above it.

The story drift of the VD & VAD structure lies in an identical range, with the maximum story drift being 0.002.

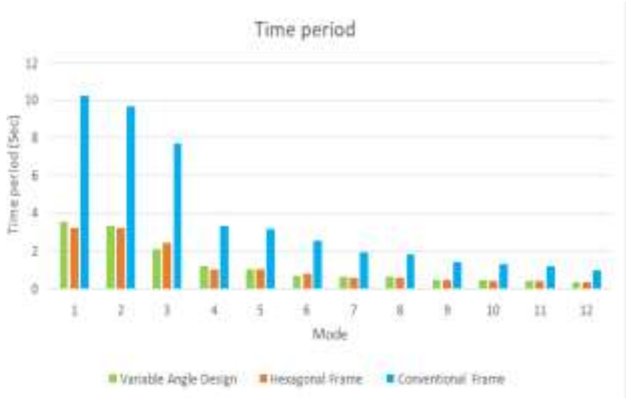
(figure 4.5)

4.2 DYNAMIC RESPONSES

4.2.1 TIME PERIOD

Simply put, the time period of a building is it's a natural period of oscillation when subjected to ground shaking in the event of an earthquake. The building is modeled to be under harmonic oscillation and the time period is calculated in a similar way as in harmonic oscillation $T = 2\pi\sqrt{(k/m)}$

where k is the total stiffness and m is the total mass

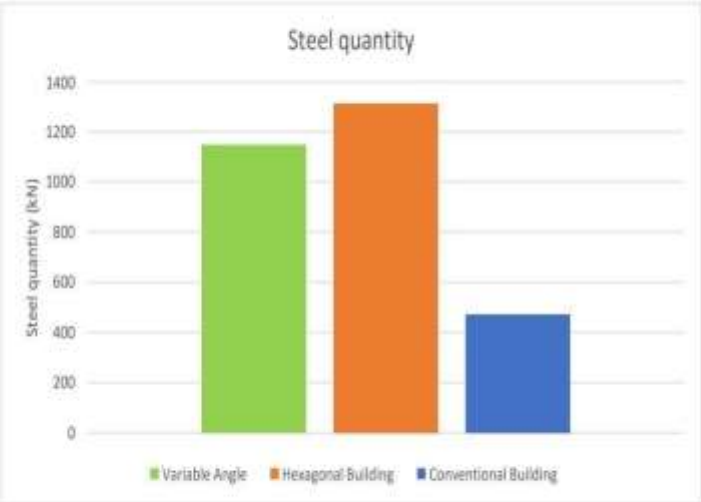


(figure 4.2.1)

4.3 QUANTITY

Quantity of material or section used presents the factor of having an economicaldesign for structures.

The ***Figure4.2.2***, the quantity of steel used in the structures are depicted.



(Figure 4.2.2)

5 CONCLUSION

The objective of the project was to design and analyses a hexagonal frame building and compare its structural performance with a conventional frame building.

1.The story drift of conventional building not only vastly exceeded the story drift of the hexagonal building but also was under the influence of the soft story effect. This can be due to the lack of lateral load resistant members in the conventional model. And about the variable angle design, there's aslight difference with the hexagonal optimal angle design.

2.In terms of the story displacement under the Response Spectrum condition, the hexagonal buildings with 45° optimal angle (VD) andvariable angle (VAD), only resulted with 12% of theconventional building,thus making it more efficientin terms of structural performance. The storydisplacement of the hexagonal two designs is approximately the same asshown in thegraph.

3.Initially, the story overturning moment is similar for the top storey of the three structures but as the storey height decreases, the overturning moment of the RF model is higher than that of the two Diagrid structures by 28.5%. This is due to lower lateral supports in the conventional frame system used in the RF structure.

4.The VD structure has a higher story stiffness than the RF & VAD structure, this may be due to the symmetrical distribution of gravity and lateral loads through the symmetrical Diagrid frame in the perimeter of the VDstructure.

5.As there are more steel sections used in the hexagonal designs, so the steel quantity is higher

than RF structure. The quantity of steel is more in the VD structure than the VAD structure because as the angle increaseswith height the story covered by the sections is also increased.

6.The time period of modes of the conventional structure is significantly higher than that of the Diagrid structures by an average of 100%. This is due to the less stiffness against the vibrations of thevarious modes

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