A STUDY ON BEHAVIOUR OF DIAGRID STRUCTURE USING PUSHOVER ANALYSIS

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Abstract: *The growth of population has influenced the development of cities. The costly lands, decisions to avoid urban expansion and to preserve the agricultural lands, the residential development drive upwards. As buildings height increases the lateral load resisting system of the building is important than the gravity load resisting system. The latest trend in high rise building is diagrid structures because of structural and architectural effectiveness. In the present study diagrids are provided for Circular steel Building and detailed analysis were carried out to check the behavior of circular steel building with and without diagrid. ETABS software is used for modeling, analysis and design of models. G+11 and G+23 storey buildings of circular plan of 30m diameter with storey height 4m located at zone v on a hard rock are modeled, analyzed and designed. Push over analysis is carried to obtain the base shear v/s roof displacement curves. These are Push over curves or capacity curves. Push over curves of circular steel building without diagrid and circular steel building with diagrid are compared. It is observed from the results of 4 module building that stiffness will be high which makes base-shear and overturning moment to increase and decrease in the story displacement and story drift compared with 3 and 4 module building.*

***Key words*: Diagrid, Braced tube structures, Push over analysis, Optimal grid, Neliastic deformation etc**

1. Introduction:

The Diagrids are perimeter structural configurations characterized by a narrow grid of diagonal members which are involved both in gravity and in lateral load resistance. Diagonalized applications of structural steel members for providing efficient solutions both in terms of strength and stiffness are not new, however nowadays a renewed interest in it and a widespread application of diagrid is registered with reference to large span and high rise buildings, particularly when they are characterized by complex geometries and curved shapes. The Swiss Re tower in London, Hearst tower in New York, CCTV headquarters building in Beijing, Mode Gakuen Spiral Tower in Aichi, West tower in Guangzhou, Lotte super tower in Seoul, Capital Gate in Abu Dhabi etc. are some of the popular diagrid buildings.

The diagrid systems are the evolution of braced tube structures, since the perimeter configuration still holds for preserving the maximum bending resistance and rigidity, while, with respect to the braced tube, the mega-diagonal members are diffusely spread over the façade, giving rise to closely spaced diagonal elements and allowing for the complete elimination of the conventional vertical columns. The major difference between a braced tube building and a diagrid building is that, there are no vertical columns present in the perimeter of diagrid building, whereas in braced tube building there are vertical column present in the perimeter of the building. Therefore the diagonal members in diagrid structures act both as inclined columns and as bracing elements, and carry gravity loads as well as lateral forces; due to their triangulated configuration, mainly internal axial forces arise in the members, thus minimizing shear racking effects. The term "diagrid" is a combination of the words "diagonal" and "grid" and refers to a structural system that is single-thickness in nature and gains its structural integrity through the use of triangulation. Diagrid systems can be planar, crystalline or take on multiple curvatures. They often use crystalline forms or curvature to increase their stiffness. Perimeter diagrids normally carry the lateral and gravity loads of the building and are used to support the floor edges.

2. Literature review:

Ravi Sorathiya and Pradeep Pandey [1] (*Study on Diagrid structure of multi-storey Building (IJARED-2017)*). The diagrid structures are buildings with diagonal grids in the periphery at a particular angle and in modules across the height of the building. Diagrid structures use triangulated grids which are in place of vertical columns in the periphery. Thus, systems that are more efficient in achieving stiffness against lateral loads are considered better options in designing tall buildings.

Nishith B. panchal and Vinubhai R. Patel [2] (*Diagrid structural system: strategies to reduce lateral forces on* *high-rise buildings (IJRET-2014)*). New structural concepts with newly adopted high strength materials and construction methods have been towards "stiffness" and "lightness". It is common knowledge that rather than directly standing the forces, it is better to reduce them and dissipate the magnitude of vibrations. The modelled structural system should be such that it should be effectively utilized for structural requirements. Recently diagrid structural is adopted in tall buildings due to its structural efficiency and architectural planning.

Kyoung Sun Moona [3] (*Diagrid structures for complex shaped tall buildings (ASCE-2011)*). The diagrid structures are prevalently used for today's tall building due to their structural efficiency and architectural aesthetic potentials. For each complex form category, tall buildings are designed with diagrid systems, and their structural efficiency is studied in conjunction with building forms. Here the complex shaped tall buildings such as twisted, tilted and free form towers are analysed.

Saket Yadav and Vivek Garg [4] (*Advantage of diagrid building over conventional building (ASCE-2011)*). The use of diagonal members for carrying the gravity and lateral load has increased and these members are known as 'diagrid'. In this study the structural response of conventional and diagrid building is investigated to evaluate the structural benefits of diagrid system.

Saket Yadav and Vivek Garg [5] (*An analytical study on performance of a diagrid structure using non-linear static pushover Analysis (ASCE-2011)*). In this present study the performance characteristics of diagrid structures using non-linear pushover analysis. In pushover analysis, the structure is subjected to monotonically increasing lateral loads till the target displacement is reached. In displacement control method, the displacement of the top storey of the structure is incremented step by step, such that required horizontal forces push the structure laterally

3. Objectives

1) To find the brace angle or storey module with less base shear at performance
2) To find the lateral stiffness of the circular steel building with diagrid.
3) The primary objective in designing an earthquake resistant structure is to ensure that the building has enough ductility to withstand the lateral loads.

4. Methodology

Design of Structural members:

Here, 2, 3, 4 and 6 modules of 12 and 24 storied structural models are considered for the diagrid structures are considered for the analysis. All the models consist of 12 storeys. Conventional beam-slab design is considered for the analysis. For bracings and Beams of I-section is used and the specifications are mentioned below. The plan considered is circular and it is of diameter 30m. The Storey height is 4.0m. The angle of inclination of diagrids considered are 37.94°, 49.34° and 57.32°. 10.26m spacing is maintained in diagrids along the perimeter of the building. The live load and the flooring load considered are 2.0kN/m² and 3.0kN/m² respectively. The structural models are modelled in ETABS 16.2.0 Software. The various input parameters which are considered while modeling are described in detail in the following sections.

Table 4.1 Structural elements and their materials

Structural Element	Material		
	Concrete	Rebar	Steel
Beam			Fe250
Slab	M30	HYSD500	
Diagrid			Fe250

Table 4.2 Section Properties of Structural Elements used in models

Table 4.2.1 : 12- storey building

Type of building	Structural Elements		Sectional Properties (mm)
12 Storey building	Beams	depth	550
		Bottom flange thickness	25
		Bottom flange width	225
		Top flange width	225
		Top flange thickness	25
		Web thickness	25
	Columns	depth	1000
		Bottom flange	38

		thickness	
		Bottom flange width	500
		Top flange width	500
		Top flange thickness	38
		Web thickness	38
	Slab	thickness	200

Table 4.2.2 : 24-storey building

Type of building	Structural Elements		Sectional Properties (mm)
24 Storey Building	Beams	depth	550
		Bottom flange thickness	25
		Bottom flange width	225
		Top flange width	225
		Top flange thickness	25
		Web thickness	25
	Columns	depth	1400
		Bottom flange thickness	50
		Bottom flange width	700
		Top flange width	700
		Top flange thickness	50
		Web thickness	50
	Slab	thickness	200

Table 4.3 Parameters considered for earthquake Analysis:

Parameters	Consideration
Zone factor	0.36
Response reduction factor	3
Importance factor	1
Soil type	Medium soil
Damping	5%

Table 4.4: Load combinations considered for design and analysis.

Load Combination	Load Combination Details
1	1.5(DL)
2	1.5(DL+LL)
3	1.2(DL+LL+EQX)
4	1.2(DL+LL-EQX)
5	1.2(DL+LL+EQY)
6	1.2(DL+LL-EQY)
7	1.5(DL+EQX)
8	1.5(DL-EQX)
9	1.5(DL+EQY)
10	1.5(DL-EQY)
11	0.9DL+1.5EQX
12	0.9DL-1.5RSX
13	0.9DL+1.5EQY
14	0.9DL-1.5EQY
15	1.2(DL+RSX)
16	1.2(DL+RSY)
17	1.5(DL+RSX)
18	1.5(DL+RSY)
19	0.9DL+1.5RSX

Models considered for study

Model 1**:** 12 storey Steel frame building with 2 modules

Model 2**:** 12 storey Steel frame building with 3 modules

Model 3: 12 storey Steel frame building with 4 modules

Model 4: 24 storey Steel frame building with 2 modules

Model 5: 24 storey Steel frame building with 3 modules

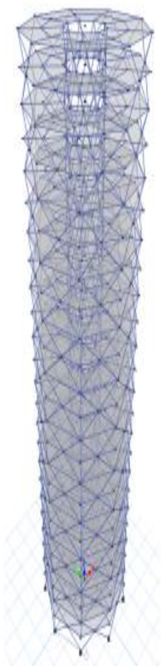
Model 6 : 24 storey Steel frame building with 4 modules

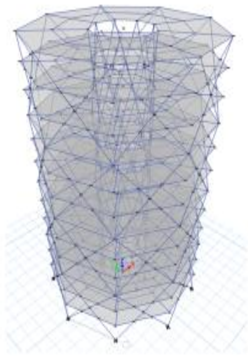
Table 4.5: Types of models considered for the study

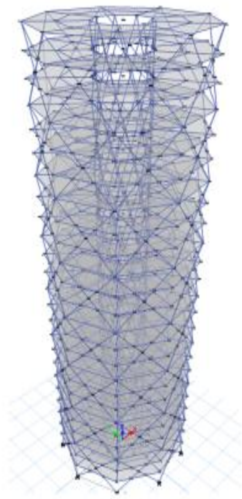
Types of structures	Diagrid angle	No. of storey	
		12 Storey (h/b=1.6) **Model Name**	**24 Storey (h/b=3.2)** **Model Name**

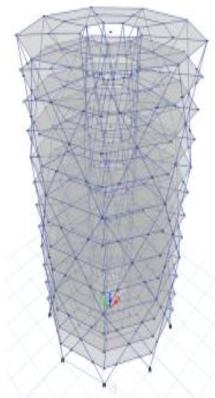
		Type 1	Type 2
Conventional frame building			
2 Storey Module	37.94°	M1	M4
3 Storey Module	49.46°	M2	M5
4 Storey Module	57.32°	M3	M6

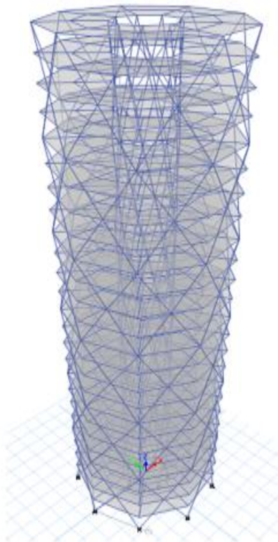

2 Modules- 12 storey


2 Modules- 24storey


3 Modules- 12 storey


3 Modules- 24storey


4 Modules- 12 storey


4 Modules- 24storey

5. RESULTS AND DISCUSSIONS

1) This study is to compare the behavior of 2, 3 and 4 modules building of conventional diagrid building to find the resistance of conventional diagrid building for lateral loads.

2) The models are designed for the gravity loads, lateral loads and the combination of loads considered.

3) Pushover analysis are carried out and the results are tabulated.

Plotting graphs of

- Storey v/s displacement
- Storey v/s drift

- Storey v/s overturning moment
- Displacement v/s base shear
- Storey v/s stiffness

Table 5.1: Comparision of maximum storey displacement of different brace angle for both 12 and 24 storied building

Building	Angle	Max story displacement-12 story (mm)	Maximum story displacement - 24 story (mm)
2-module	37.94°	28.7	86.59
3-module	49.346°	22.125	68.0035
4-module	57.32°	16.52	60.998

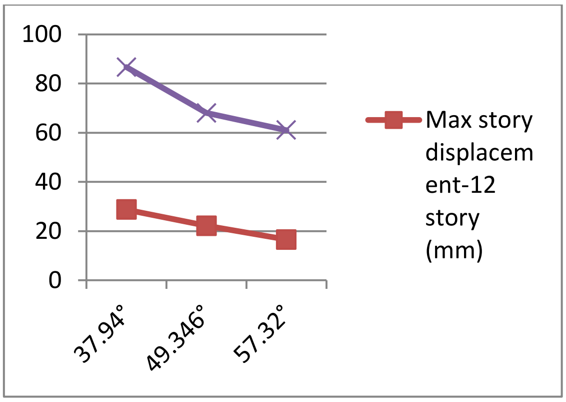


Fig 5.1: Comparision of maximum storey displacement of different brace angle for both 12 and 24 storied building

Table 5.2: comparision of Maximum Storey drifts of different brace angle of 12 and 24 story building

Building	Angle	Max story drift-12 story	Maximum story drift - 24 story
2-module	37.94°	0.000769	0.001215
3-module	49.346°	0.000565	0.000929
4-module	57.32°	0.000431	0.000819

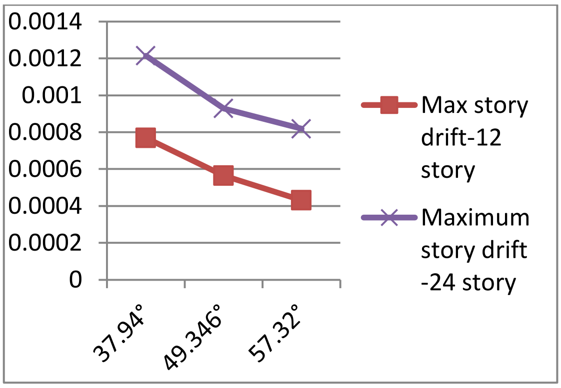


Fig 5.2: comparision of Maximum Storey drift (EQY) of different brace angle of 12 and 24 story building

Table 5.3: Comparision of Over-turning Moment different diagrid angle of 12 and 24 story building

Building	Angle	Overturning moment-12 story (KN-m)	Overturning moment -24 story (KN-m)
2-module	37.94°	331745	545481
3-module	49.346°	358255	655864
4-module	57.32°	371574	706255

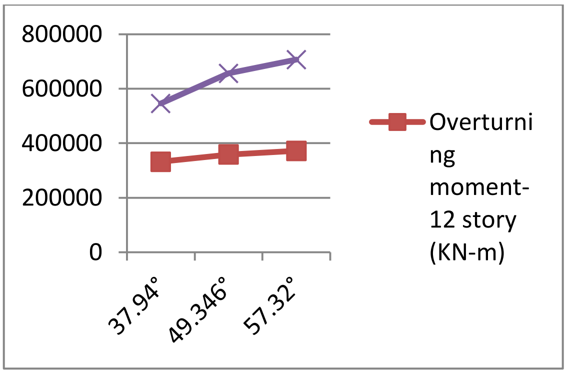


Fig 5.3: Comparision of Over-turning Moment different diagrid angle of 12 and 24 story building

Table 5.4: Comparision of Story Shear of different diagrid angles of both 12 and 24 story building

Building	Angle	Base shear-12 storey (KN)	B ase shear-24 story (KN)
2-module	37.94°	8917.31	7467.67
3-module	49.346°	9629.71	8977.64
4-module	57.32°	9990.94	9660.99

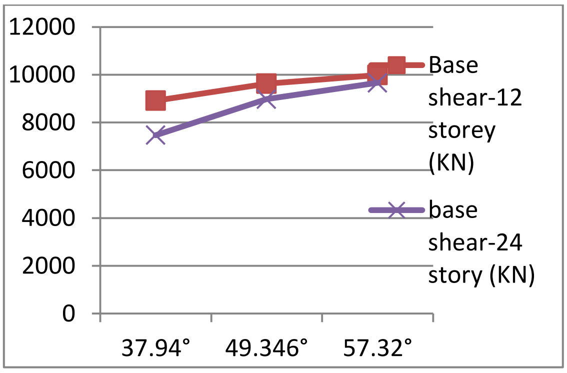


Fig 5.3: Comparision of Story Shear of different diagrid angles of both 12 and 24 story building

Table 5.4: Comparision of Story Shear of different diagrid angles of 12 and 24 storeyed building

Building	Angle	Story stiffness-12 storey(KN-m)	Story stiffness -24 story (KN-m)
2-module	37.94°	17629083	28943528
3-module	49.346°	18668177	36825374
4-module	57.32°	21206667	35126675

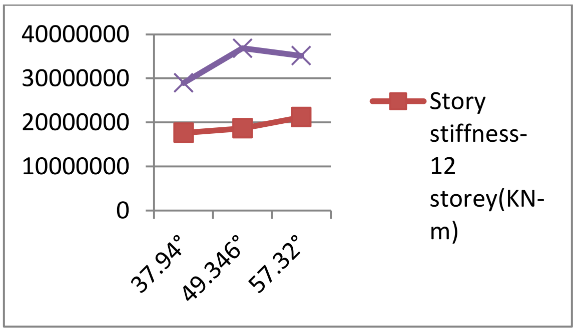


Fig 5.4 : Comparision of Story Shear of different diagrid angles of 12 and 24 storeyed building

6. CONCLUSIONS

In this study, following conclusions are drawn

1) The story displacements of 2-module is increased by 29.33% and 73.72% when compared to 3-module and 4-module respectively in 12-storied building where as 29.72% and 73.72% is increased in 3-module and 4-module respectively in 24 storied building.

2) The maximum story drift of 2-module is increased by 36.11% and 78.42% when compared to 3-module and 4-module respectively in 12-storied building where as 30.78% and 48.35% is increased in 3-module and 4-module respectively in 24 storied building.

3) The maximum over-turning moment of 4-module is increased by 12% and 3.7% when compared to 2-module and 3-module respectively in 12-storied building where as 29.47% and 7.6% is increased in 2-module and 3-module respectively in 24 storied building.

4) The maximum Base shear of 4-module is increased by 12.03% and 3.75% when compared to 2-module and 3-module respectively in 12-storied building where as 29.37% and 7.6% is increased in 2-module and 3-module respectively in 24 storied building.

5) The maximum story stiffness of 4-module is increased by 20.29% and 13.59% when compared to 2-module and 3-module respectively in 12-storied building where as 29.37% is increased in 2-module and 4.6% decreased in 3-module in 24 storied building.

It is concluded from the above that in 4 module building, Stiffness will be high which makes base-shear and overturning moment to increase and decrease in the story displacement and story drift compared with 3 and 4 module building.

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