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Dynamic Analysis of Diagrid Structural System in High Rise RCC Buildings with Varying Geometry

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***Abstract*—Skyscraper development involves various complex factors such as economics, aesthetics look, technology, municipal regulations, and politics. Among these, economics has been the primary governing factor. For high rise building, the structural design is generally governed by its lateral stiffness. Diagrid structures carry lateral seismic loads much more efficiently by their diagonal member's axial action in comparing with conventional orthogonal structures for tall buildings such as framed tubes, A diagrid structure provides great structural efficiency without vertical columns have also opened the new aesthetic potential for tall building architecture. Diagrid has a good appearance and it is facilely apperceived. The configuration and efficiency of a diagrid system reduce the number of the structural element required on the façade of the buildings, therefore less obstruction to the outside view. The diagrid system structural efficiency also helps in avoiding interior and corner columns and therefore allowing significant flexibility with the floor plan. A diagrid structure is a type of structural system consisting of diagonal grids connected through horizontal rings which create an elegant and redundant structure that is especially efficient for high-rise buildings. In the present study a G+41 storey multistoried R.C.C building model is modelled using Etabs 2018 software. Response spectrum analysis is made by considering building situated in zone III.Building models are analyzed by Etabs 2018 software to study the effect storey shear, base shear, time period, base moments, maximum storey displacement and maximum storey drift etc**

***Keywords—* *Diagrid structures, G+41 storey, Response spectrum analysis, Etabs 2018 software*.**

I. Introduction

A diagrid structure is a type of structural system consisting of diagonal grids connected through horizontal rings which create an elegant and redundant structure that is especially efficient for high-rise buildings. A diagrid structure is different from braced frame systems since diagonals as main structural elements participate in carrying gravity load in addition to carrying lateral load due to their triangulated configuration, which eliminates the need for vertical columns. The column free structure of a diagrid system offers several advantages such as high architectural flexibility and elegance, and cyclopean day lighting due to its immensely colossal free façade surface. The lateral schemes explored different type of geometry of buildings along with different type soil and seismic zones.

A. Objectives of the Present Study

- This study is aimed to analyse and design the diagrid structures for high rise building with varying geometry,
- To study the behavior of lateral forces on high rise buildings with varying geometry.
- To apply diagrid structural systems on the structures and find out the optimum performance of this systems with suitable geometry in the respective seismic zone.
- To compare the structures based on stiffness parameters, relative displacement, ductility and resistance compared with each other
- To propose a suitable, economic and optimum position of diagrid structural system suitable according to the respective lateral load.
- To study the response of buildings in terms of storey shear, base shear, time period, base moments, maximum storey displacement and maximum storey drift etc.

B. Advantages Derived from Diagrid Structural System

Some major benefits of using Diagrids in structures are discussed below.

1) The Diagrid structures have mostly column free exterior and interior, hence free and clear, unique floor plans are Possible.
2) The Glass facades and dearth of interior columns allow generous amounts of day lighting into the structure.
3) The use of Diagrids results in roughly 1/5th reduction in steel as compared to Braced frame structures.
4) The construction techniques involved are simple, yet they need to be perfect.
5) The Diagrids makes maximum exploitation of the structural Material.
6) The diagrid Structures are aesthetically dominant and expressive.
7) Redundancy in the Diagrid design is obvious. It is this redundancy then that can transfer load from a failed portion of the structure to another. Skyscraper structural failure, as it is such an important/ prominent topic, can be minimized in a diagrid design a diagrid has better ability to redistribute load than a moment frame skyscraper. thus, creating a deserved appeal for the diagrid in today's landscape of building.

C. Disadvantages of Derived from Diagrid Structural System

1) As of yet, the diagrid construction techniques are not thoroughly explored.
2) Lack of availability of skilled workers. Construction crews have little or no experience creating a diagrid skyscraper.
3) The diagrid can dominate aesthetically, which can be an issue depending upon design intent.
4) It is hard to design windows that create a regular language from floor to floor.

II. PROBLEM STATEMENT

A. Problem Statement of Rectangular and Square geometry analysis:

1.In this project, a 41-storey structure of a diagrid structures with 3.6m floor to floor height has been analyzed by finite element method using etabs software in zone (III). the plan selected is rectangular in shape. it is not the plan of any existing or proposed building but is an architectural plan. the structure has been analysed for both static and dynamic wind and earthquake forces. diagrid column has been provided throughout height of the structure. hard soil condition has been selected for the structure.

2.In this project, a 41-storey structure of a diagrid structures with 3.6m floor to floor height has been analyzed by finite element method using etabs software in zone (III). The plan selected is square in shape. it is not the plan of any existing or proposed building but is an architectural plan. The structure has been analysed for both static and dynamic wind and earthquake forces. diagrid column has been provided throughout height of the structure. hard soil condition has been selected for the structure.

B. Model Description

1. Preliminary data required for Rectangular and Square Geometry Analysis

Rectangular and Square Geometry Analysis Model is prepared on etabs software in zone (III).

TABLE NO 1 PARAMETERS TO BE CONSIDER FOR RECTANGULAR AND SQUARE GEOMETRY ANALYSIS

Sr. No.	*Parameter*	*Values*
1.	Number of storey	G+41
2.	Floor height	3.6 m
3.	Infill wall	150 mm thick
4.	Materials	Concrete 50 and Reinforcement Fe 500
5.	Frame size	36m X45m building size (Rectangular) 36mX36m building size (Square)
6.	Grid spacing	3m grids in X-direction and 3m grids in Y-direction.
7.	Size of column	1000 mm x 1000 mm
8.	Size of beam	500mm x 600 mm
9.	Depth of slab	225 mm
10.	Plan area	$1620m^2$ $(Rectangular)$ $1296\, m2(Square)$

C. Load details

TABLE NO 2 LOAD DETAILS FOR RECTANGULAR AND SQUARE GEOMETRY ANALYSIS

a.	Dead load	In ETABS the software itself calculates the dead loads by applying a self-weight multiplier factor of one which is taken by the structure and the rest load cases are kept zero. Its defined in the load cases section.
b.	Live load on floors	4 kN/m^2 as per IS:875 (part -2)
c.	Floor finish on roof and floors	1.5 kN/m^2 as per IS:875 (part -2)
d.	Wall load on all levels	9 kN/m

D. Seismic data required for Rectangular and Square Geometry Analysis

TABLE NO 3 SEISMIC DATA REQUIRED FOR RECTANGULAR AND SQUARE GEOMETRY ANALYSIS

Sr. No.	*Parameter*	*Values as per IS 1893:2016 (Part-1)*	*Reference*
1.	Type of structure	Special RC moment resisting frame	Table 9, Clause 7.2.6
2.	Seismic zone	III	Table 3, Clause 6.4.2
3.	Zone factor (Z)	0.16	Table 2, Clause 6.4.2
4.	Type of soil	Rock or Hard Soil	Clause 6.4.2.1
5.	Damping	5 %	Clause 7.2.4
6.	Response spectra	As per IS 1893 (part 1):2016	Figure 2, Clause 6.4.6
7.	Load combinations	1) 1.5(DL + IL) 2) 1.2(DL+IL+ EL) 3) 1.5(DL + EL) 4) 0.9DL + 1.5 EL	Clause 6.3.1
8.	Response reduction factor (R)	5	Table 9, Clause 7.2.6
9.	Importance factor (I)	1.5 (Hospital, Schools Buildings)	Table 8, Clause 7.2.3

E. Wind data required for Rectangular and Square Geometry Analysis

TABLE NO 4 WIND DATA REQUIRED FOR CONSTRUCTION SEQUENCE ANALYSIS AND CONVENTIONAL LUMPED ANALYSIS

Sr. No.	*Parameter*	*Values as per IS 875-2015 (Part3)*	*Reference*
1.	Basic wind speed (V_b)	Pune=39m/sec,	Annex A
2.	Risk coefficient k_1	1	Table 1, Clause 6.3.1
3.	Terrain category	3	Table 2, Clause 6.3.2.2
3.	Topography Factor k_3	1	Table 3, Clause 6.4.2
3.	Importance Factor k_4	1	Clause 6.3.4
5.	Windward coefficient cp	0.8	Clause 7.3.3
6.	Leeward coefficient cp	0.5	Clause 7.3.3

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F. Plan of Rectangular Geometry Analysis

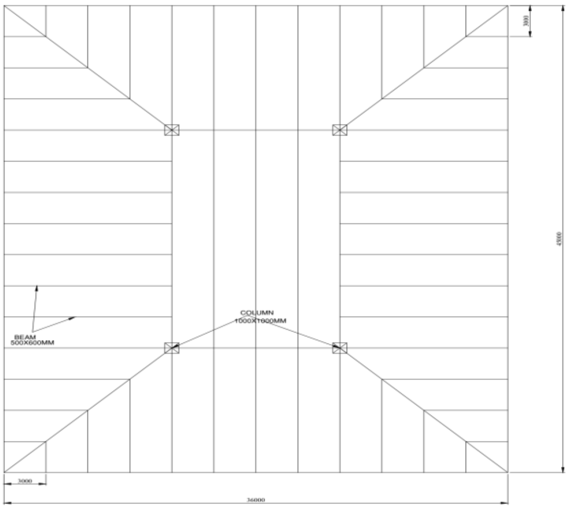

Fig. 1 Plan of Rectangular Geometry Analysis

G. Elevation of Rectangular Geometry Analysis

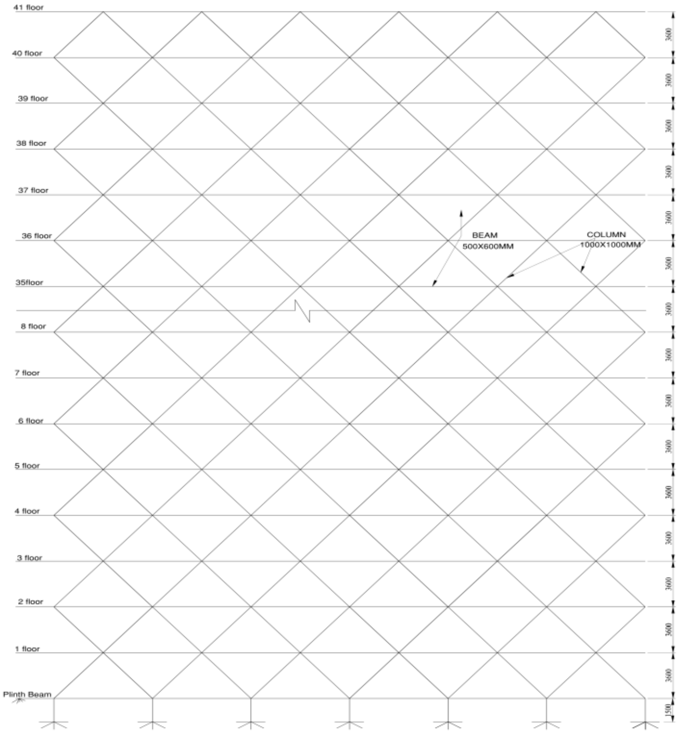

Fig. 2 Elevation of Rectangular Geometry Analysis

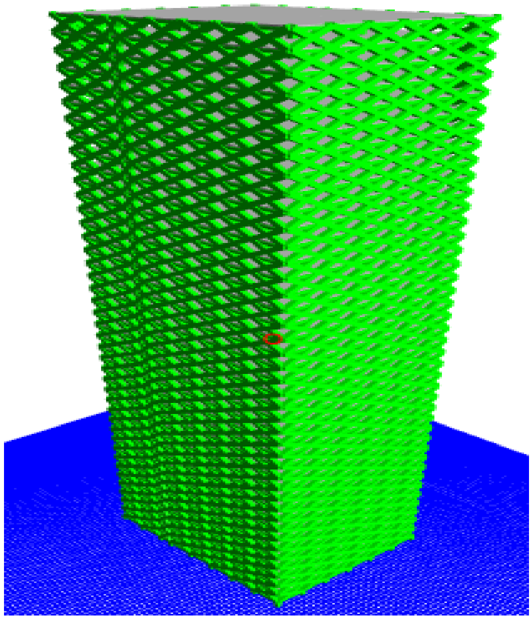

Fig. 3 3D View of Rectangular Geometry Analysis

H. Plan of Square Geometry Analysis

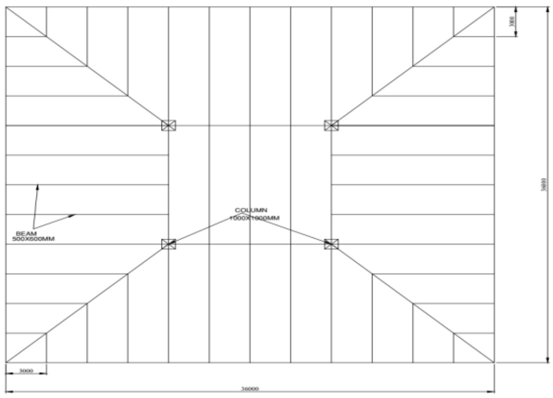

Fig. 4 Plan of Squarer Geometry Analysis

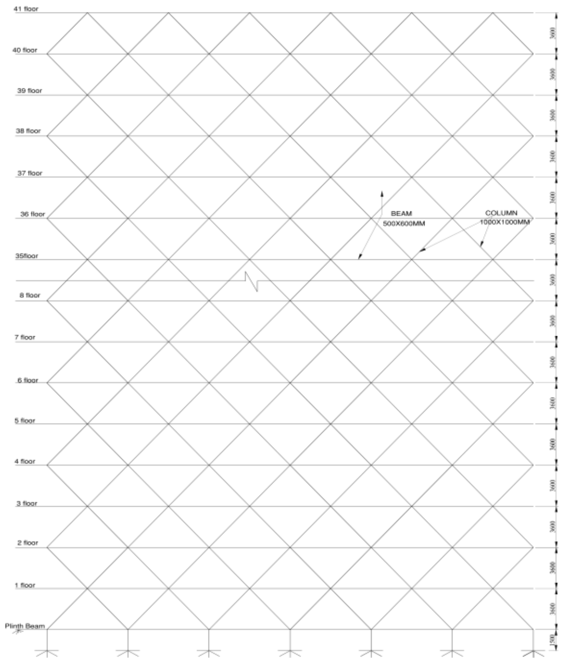

Fig. 5 Elevation of Square Geometry Analysis

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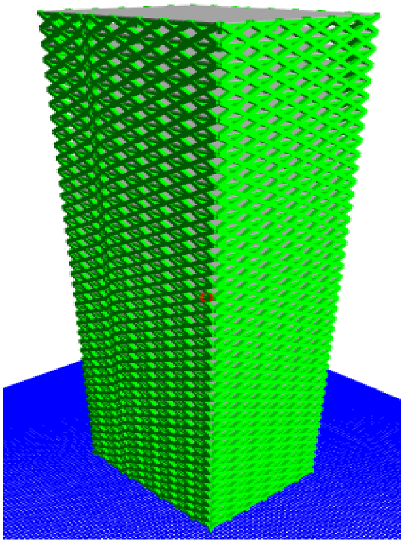

Fig. 6 3D View of Square Geometry Analysis

III. RESULTS AND DISCUSSION

A. Time Period of Building Configurations for G+41 Storey

Comparison of time period of building configurations between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building

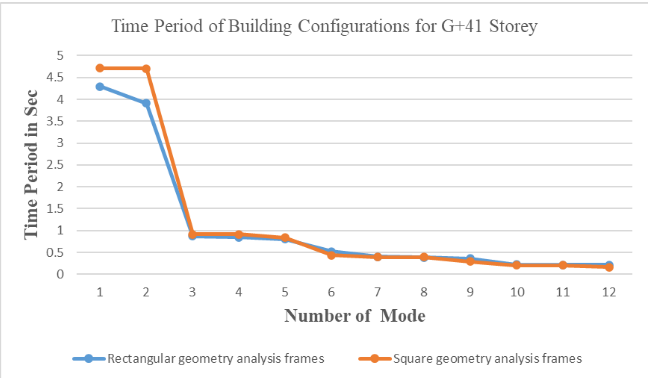

Fig.7 Time period variation with respect to G+41 Storey

B. Storey Shear in kN for Earthquake Case in X-Direction

Comparison of storey shear between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building

C. Storey Shear in kN for Earthquake Case in Y-Direction

Comparison of storey shear between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

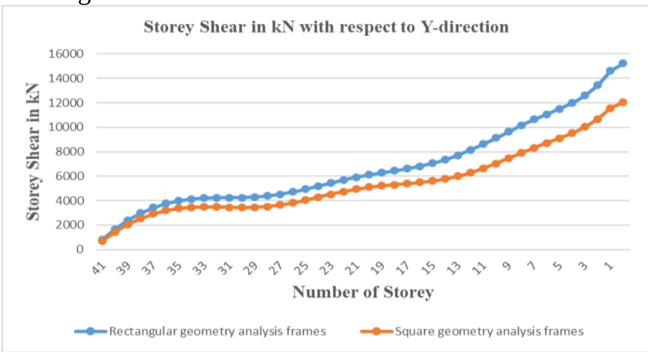

Fig.9 Storey Shear in kN for Earthquake Case in Y-Direction.

D. Base shear in kN for Earthquake Load Case in X-Direction

Comparison of Base shear for Earthquake Load Case in kN between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

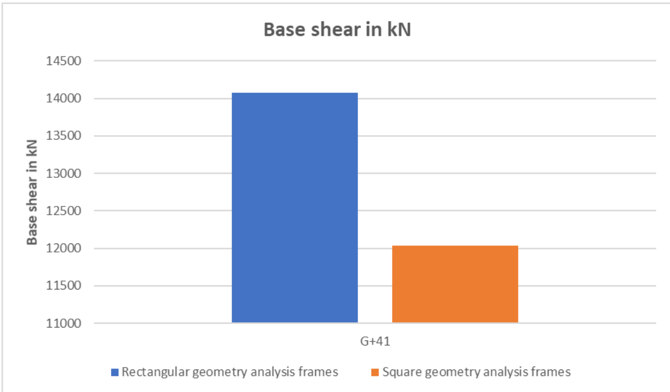

Fig.10 Base shear in kN for G+41 Storey in X-direction

E. Weight of Steel (Steel Take-Off) for tie member to column in kg

Comparison of Base shear for Earthquake Load Case in kN between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building

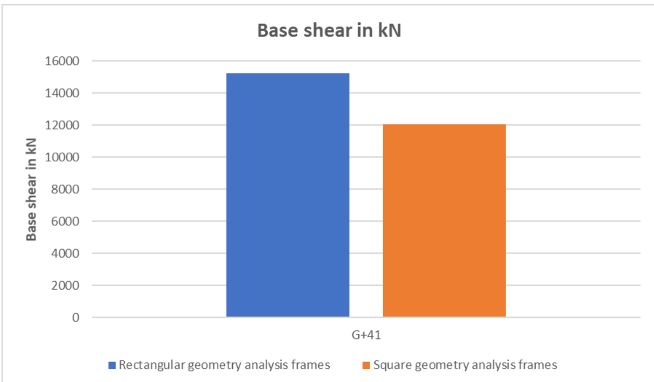

Fig.11 Base shear in kN for G+41 Storey in Y-direction

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F. Base moment in kN-m for Earthquake Case in X-Direction

Comparison of Base moment between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building

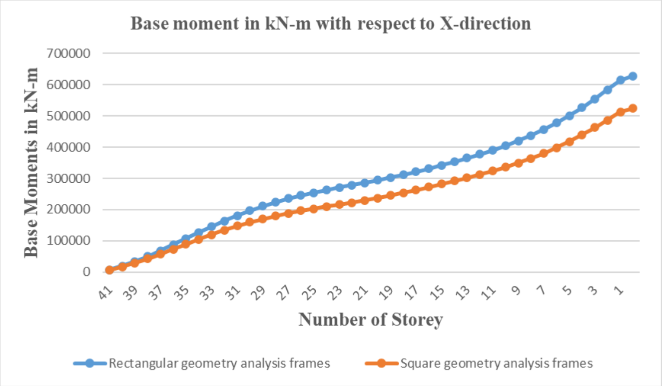

Fig.12 Base moment variation with respect X-direction for G+41 Storey

G. Base moment in kN-m for Earthquake Case in Y-Direction

Comparison of Base moment in kN-m between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

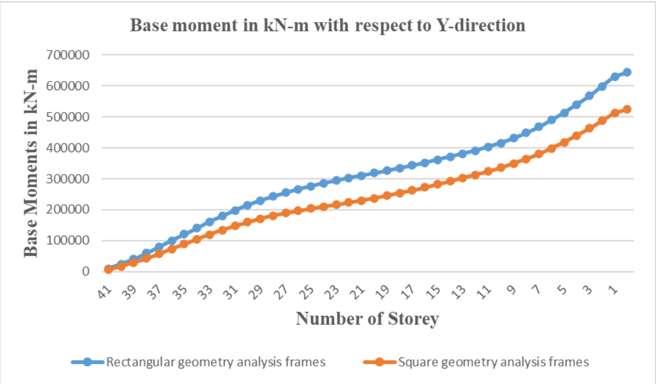

Fig.13 Base moment variation with respect Y-direction for G+41 Storey

H. Maximum storey drift in mm for Earthquake Load Case in X-Direction

Comparison of Maximum storey drift in mm for Earthquake Case in X-Direction between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

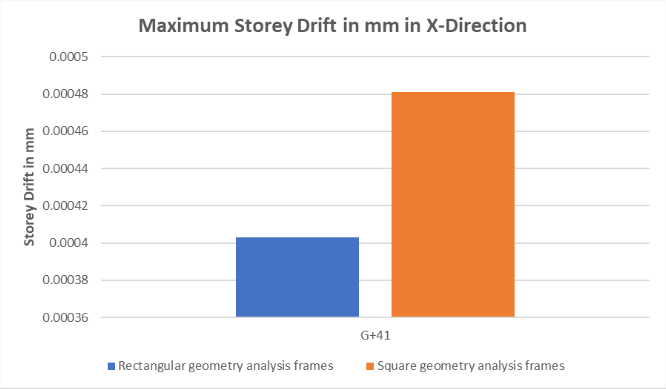

Fig.14 Maximum storey drift in mm for G+41 Storey of Earthquake Load Case in X-direction

I. Maximum storey drift in mm for Earthquake Load Case in Y-Direction

Comparison of Maximum storey drift in mm for Earthquake load Case in Y-Direction between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

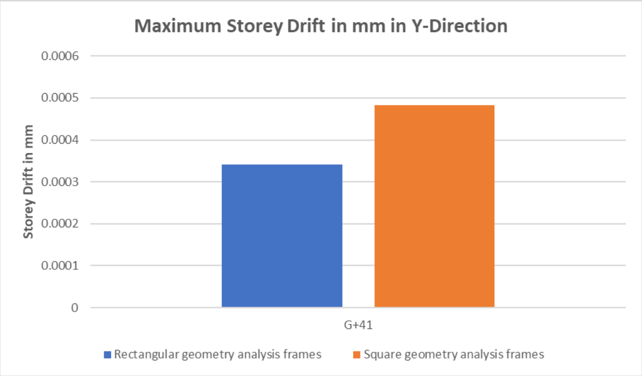

Fig.15 Maximum storey drift in mm for G+41 Storey of Earthquake Load Case in Y-direction

J. Maximum storey drift in mm for Wind Load Case in X-Direction

Comparison of Maximum storey drift in mm for Wind Load Case in X-Direction between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

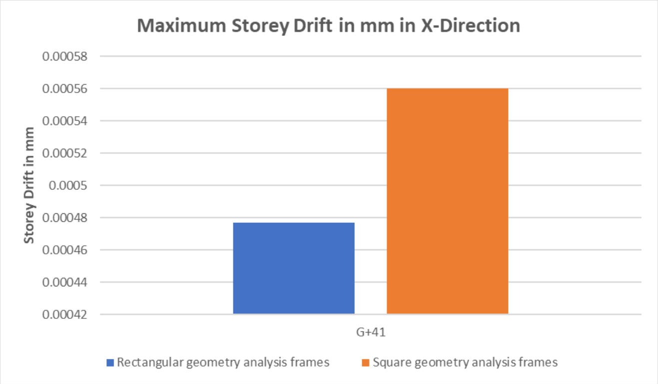

Fig.16 Maximum storey drift in mm for G+41 Storey of Wind load Case in X-direction

K. Maximum storey drift in mm for Wind Load Case in Y-Direction

Comparison of Maximum storey drift in mm for Wind load Case in Y-Direction between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

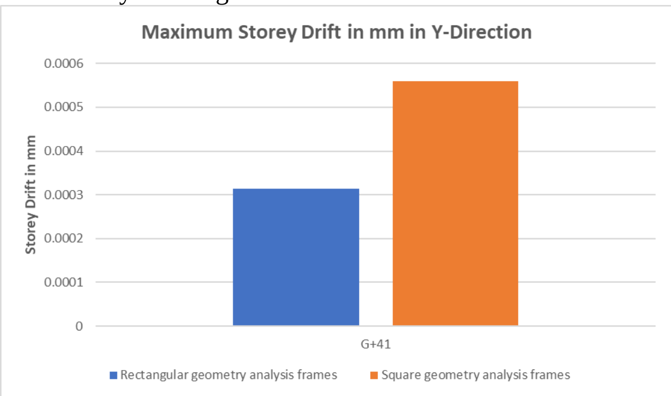

Fig.17 Maximum storey drift in mm for G+41 Storey of Wind load Case in Y-direction

L. Maximum storey displacement in mm for Earthquake Load Case in X-Direction

Comparison of Maximum displacement in mm for Earthquake Load Case in X-Direction between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

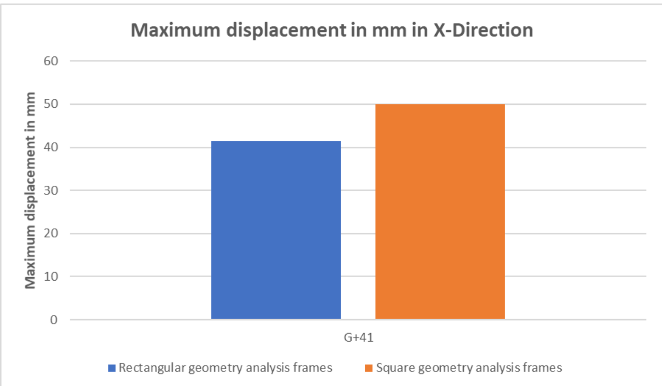

Fig.18 Maximum storey displacement in mm for G+41 Storey of Earthquake Load Case in X-direction

M. Maximum storey displacement in mm for Earthquake Load Case in Y-Direction

Comparison of Maximum displacement in mm for Earthquake Load Case in Y-Direction between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

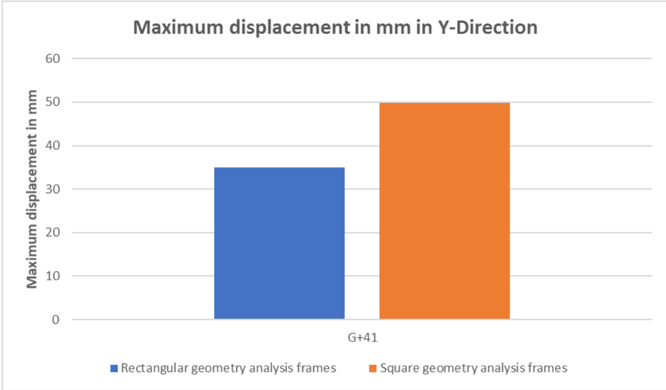

Fig.19 Maximum storey displacement in mm for G+41 Storey of Earthquake Load Case in Y-direction

N. Maximum storey displacement in mm for Wind Load Case in X-Direction

Comparison of Maximum displacement in mm for Wind Load Case in X-Direction between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

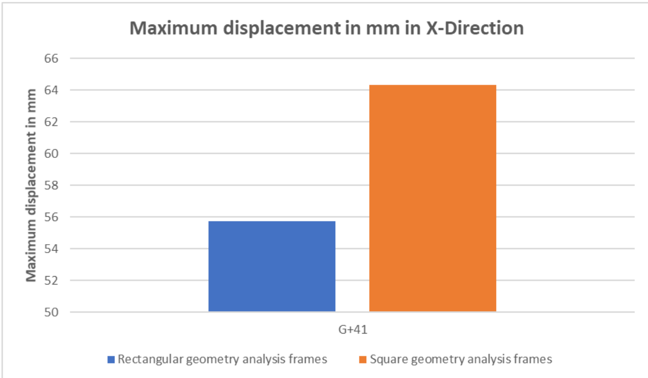

Fig.20 Maximum storey displacement in mm for G+41 Storey of Wind Load Case in X-direction

O. Maximum storey displacement in mm for Wind Load Case in Y-Direction

Comparison of Maximum displacement in mm for Wind Load Case in Y-Direction between Rectangular geometry analysis and square geometry analysis frames of G+41 storey building.

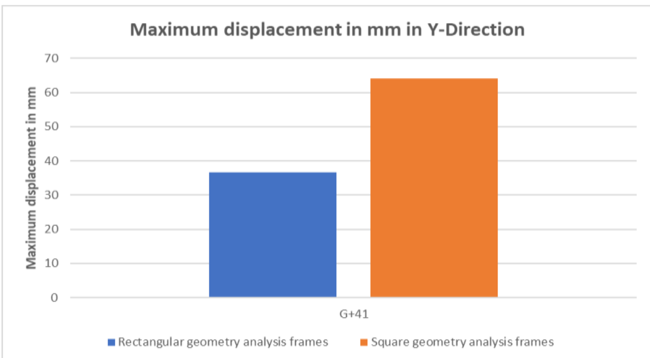

Fig.21 Maximum storey displacement in mm for G+41 Storey of Wind Load Case in Y-direction

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IV.CONCLUSIONS

The following conclusions have been drawn based on the results obtained from present study:

1) Diagrid structures can be made effective by providing additional columns near periphery of the structures.
2) From the study it is observed that most of the lateral load is resisted by diagrid columns on the periphery, while gravity load is resisted by both the internal columns and peripheral diagonal columns.
3) The dead load and beam load increases with height of structure.
4) Diagrid performs better across all the criterions of performance evaluation, such as, efficiency, expressiveness and sustainability.
5) Diagrid structure gives more aesthetic look and gives more of interior space. Due to a smaller number of columns, façade of the building can also be planned more efficiently.
6) Floor loads are more critical for tall structures but it is higher in conventional building structure than diagrid structure.
7) Buildings should be designed for loads optimized in both directions separately for deflection and stresses in buildings.
8) Time period for G+41 Storey of Rectangular geometry analysis are 8.89% less as compared to and square geometry analysis frames.
9) Earthquake load case of Storey shear of plinth level for G+41 Storey. of Rectangular geometry analysis are 20.87% less as compared to and square geometry analysis frames.
10) Earthquake load case of Base shear in kN for G+41 Storey in X-direction of Rectangular geometry analysis are 14.16% more as compared to and square geometry analysis frames.
11) Earthquake load case of Base moments of plinth level for G+41 Storey of Rectangular geometry analysis are 15%-20% more as compared to and square geometry analysis frames.
12) Earthquake and Wind load case of Maximum storey drift in mm for G+41 Storey of Rectangular geometry analysis are 10%-30% less as compared to and square geometry analysis frames.
13) Earthquake and Wind load case Maximum displacement in mm for G+41 Storey of Rectangular geometry analysis are 15%-25% less as compared to and square geometry analysis frames.

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