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OPTIMAL GRID GEOMETRY OF A DIAGRID STRUCTURE

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Abstract -*Introduction and advancement of new technologies, materials, structural systems have led to the speedy boom of high rise buildings. The adaptability in architectural design and efficiency of the structure has made a diagrid structural system a go to structural system for tall building. Structural design of the diagrid structure is designed with respect to lateral loads like wind and earthquake. Closely spaced vertical column are existing in the framed tube structures whereas, in diagrid structural system the columns are inclined columns on the exterior surface of the building. The wind and earthquake loads are resisted by the action of axial action of the diagonal columns in contrast the framed tube structure where the wind and earthquake loads are resisted by the action of bending of vertical columns. The core in a diagrid structural system can be eliminated in most of the cases because the lateral shear can be carried by the peripheral diagonals of the building. The modeling and evaluation of structure is executed in ETABS. In this studies, diagrid structures are analyzed and compared to find the optimum angle for various height of the structure and to study the effect of varied angle and shape of the structures. The Models are designed as per Indian standard code IS800:2007 considering all the load combinations.*

***Key Words*: Lateral load resisting system, diagrid structural system, Displacement, Time period**

1.INTRODUCTION

The population is increasing at a high rate; the limited space has considerably influenced the development of residential area. The high cost of land, the desire to avoid a continuous urban rush has resulted in the drive of residential buildings upward. As the number of storey in a building increases, the lateral load resisting system turns into greater necessary than the structural system that can resist gravitational loads. Lately, the diagrid structural system is used for tall steel structures due to its aesthetic potential structural effectivity and furnished through the special geometric configuration of the system.

Aesthetic nature of the diagrid structure makes it to stand out from other buildings. The configuration and efficiency of a diagrid system decreases the quantity of structural component required on the façade of the buildings, consequently reduces the obstruction of the outside view. The structural efficiency of diagrid system additionally helps in avoiding interior and corner columns, therefore permitting considerable flexibility with the floor plan.

1.1 METHODOLOGY

Step 1: Studying various thesis on diagrid structure.
Step 2: Generating the parametric model
Step 3: Applying the load on the structure
Step 4: Analyzing the structure
Step 5: Comparing the models for obtaining the optimum model

Table 1 Specification of the Model

Dimension of the building	36*36 m
Area	1296 m^2
Area of the core	324 m^2
Live load	4 KN/m^2
Dead load	2KN/m^2
Bay length	9 m
Height of each floor	4 m
Deck slab thickness	90mm
Grade of concrete	M30
Grade of steel	Fe345
Damping ratio	5%
Type of building	Important
Importance factor	1
Type of soil	medium
Seismic zone	Zone III

2. BUILDING PARAMETER

The Models have 36 m × 36 m plan dimension. The storey height is 4 m. In diagrid structures, pair of braces is positioned at the periphery of the building. The spacing between the inclined columns are provided at 9m along the perimeter. Only gravity load is considered for the design of interior frame of the diagrid structure. The design dead load is taken as 4 kN/m^2 and live loads as 2 kN/m^2. The design earthquake load is computed based on the zone factor of 0.16. The importance factor of 1 and response reduction factor of 5 is considered. Modelling and analysis of diagrid structure are carried out using ETABS software. All structural members are designed using IS 800:2007. Secondary effect like temperature variation is not considered.

3. OPTIMUM ANGLE

The diagonal member of the diagrid carries both shear and moment. the geometry of the single module plays an important function in the internal axial force distribution, as well as in conferring global shear and bending rigidity to the structure. The optimal angle of the columns for maximum bending rigidity and shear rigidity in the normal building is 90 degrees and 35 degrees respectively. It is persumed that the optimal angle of the diagrid falls in between the above two values

Analysis is performed on 12 storey(A), 24 storey(B), 36 storey(C),48 storey(D), 60 storey(E), 72 storey(F) with the provision of different angles 41038'(2-module), 60035'(4 module), 69029'(6 module), 74017'(8 module), 79022'(12 module).

3.1 Top Storey Displacement

As per Indian standard code IS: 456-2000, the maximum top storey displacement should not be more H/500, where H is total height of the building. The displacement results for all the models are within the permissible limit

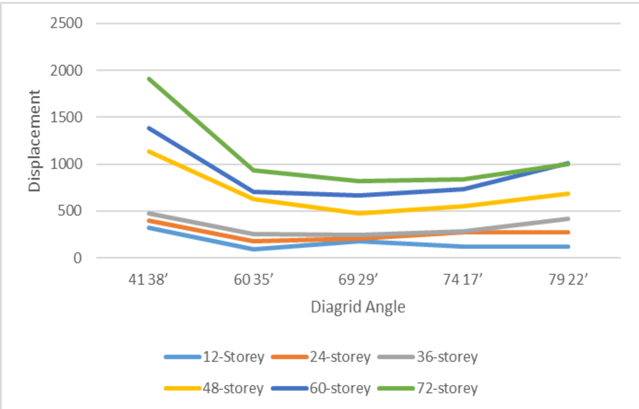

Fig 1: Top storey displacement

In case of 12-storey model and 24-storey model, the optimum angle is found to be 60 degrees. The maximum displacement in both the model appears in 41 degrees and is almost 3 times more than the optimum angle.

In case of 36-storey model, the displacement is least in 60 degrees and 69 degrees. The maximum displacement appears in 41 degrees is almost 2times more than the optimum value

From the above graph considering the top storey displacement, the angle of diagrid is optimum in the region of angle 60° to 70

3.2 Time Period

The time period is inversely proportional to the stiffness of the structure. Time period depends upon the mass and stiffness of the structure. If the time period is less, the modal mass is less but the stiffness of the building is more vice-versa.

In case of 12-storey and 24-storey model, the time period is least in 60 degrees which suggests that the stiffness of the model is at maximum when the diagrid is inclined at the angle 60degrees

In case of 36-storey, 48-storey, 60-storey and 72-storey the stiffness is maximum when the diagonal is inclined at an angle 69degrees because the time period is maximum at 69 degrees

Considering the first time period the optimum angle can be seen between 60 -70 degrees

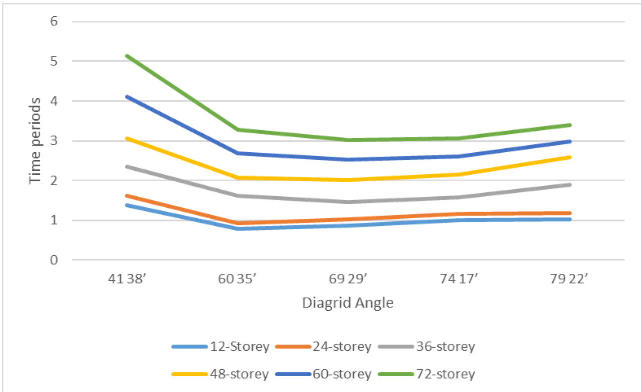

Fig 2: First mode Time period

4. SHAPE OF THE STRUCTURE

Shape of the model plays an important role in designing of the structure. In this project 3 different shapes of square, rectangle and circle. The structure are modelled for same area of 1296 m2. Dimension of Rectangle is 54*24m. Dimension of Square is 36*36 m and circle model has a diameter of 42.6m.

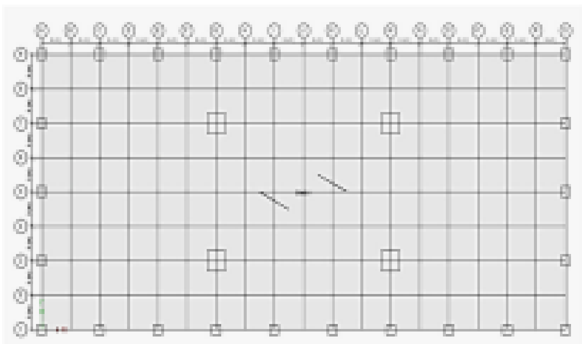

Fig 3 Rectangle model

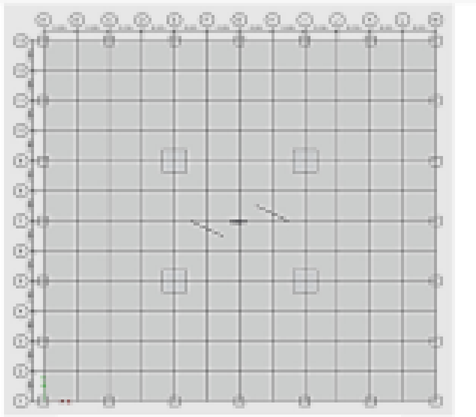

Fig 4 Square model

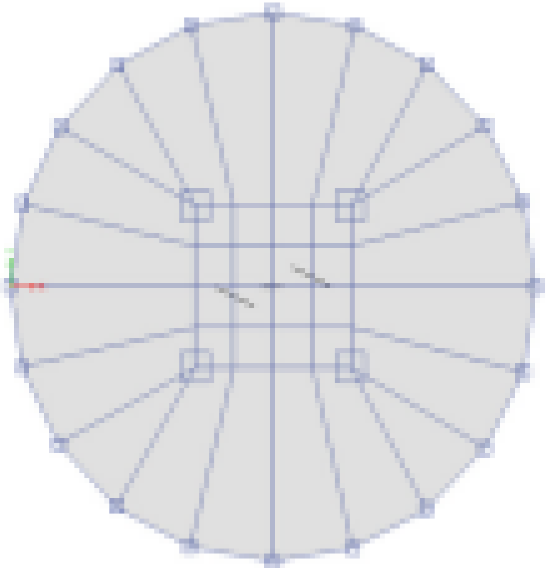

Fig 5 Circle model

4.1 Top Storey Displacement

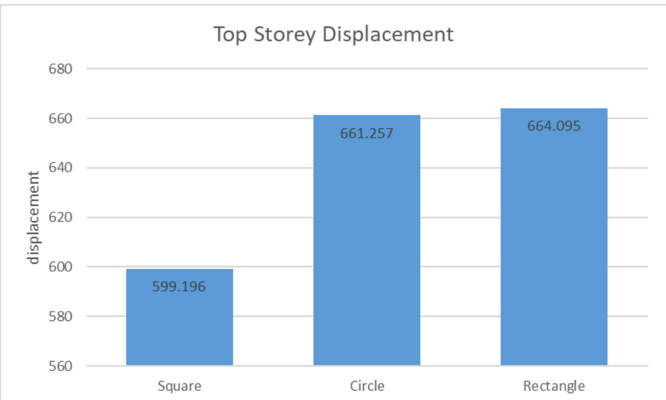

Fig 6 Top Storey displacement of different shape

Square model performed better compared to rectangle and circle structure. Top storey displacement of Rectangle structure is 11% more compared to the square model and almost same compared circle structures. Top storey displacement of Circle structure is 10% more compared to square structure.

4.2 Time period

Square model performed better compared to rectangle and circle structure. Top storey displacement of Rectangle structure is 11% more compared to the square model and almost same compared circle structures. Top storey displacement of Circle structure is 10% more compared to square structure

Time period is more in rectangle structure by 0.032 compared to square structure and by 0.02 compared to circle. Time period of Circle structure is 0.012 more than the time period of square structure. Time period of a structure is indirectly proportional to the stiffness of the structure. Therefore, we can conclude that the square structure has maximum stiffness and rectangle has the least stiffness.

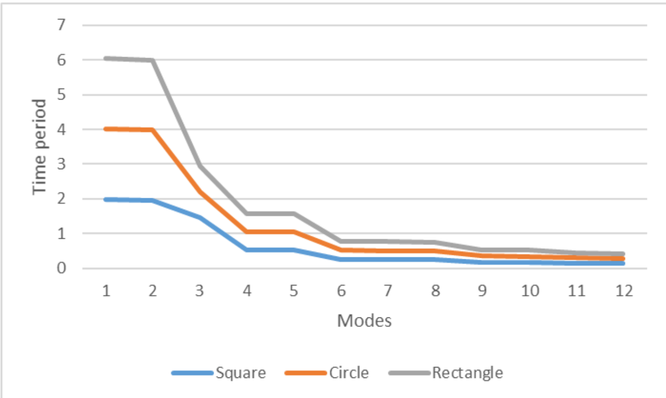

Fig 7 Time period for different shape

5. VARIED ANGLES

Analysis is carried out on 3 models with angle varying along the width of the structure and 3 models with angle along the height of the structure

VVA1(42, 74 and 79 degrees), VVA2(42, 69 and 79 degrees) and VVA3(61, 69 and 79 degrees) has angles varying along the height and HVA1(61 and 69 degrees), HVA2(69 and 74 degrees), HVA3(69 and 79 degrees) has angles varying along the width.

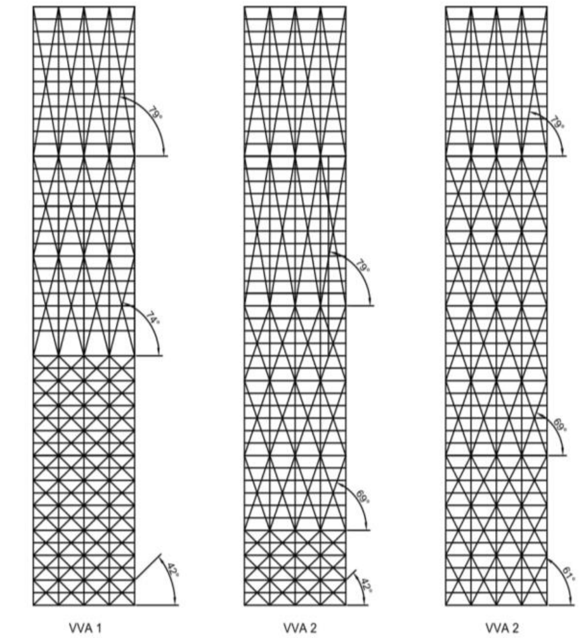

Fig 8 VVA1(42, 74 and 79 degrees), VVA2(42, 69 and 79 degrees) and VVA3(61, 69 and 79 degrees)

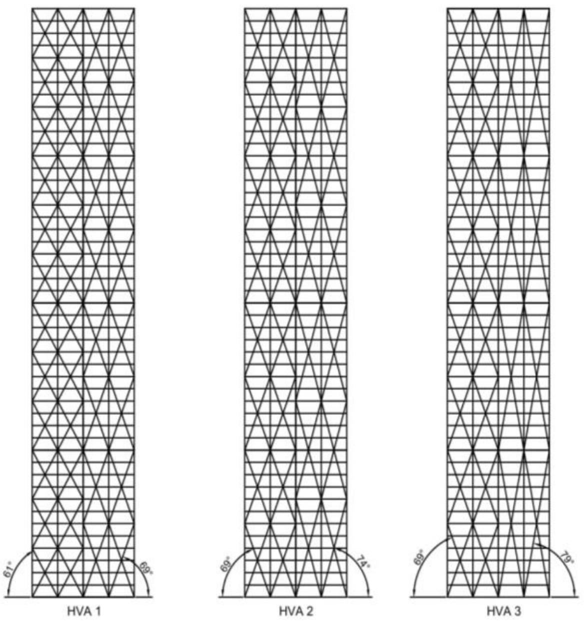

Fig 9 HVA1(61 and 69 degrees), HVA2(69 and 74 degrees), HVA3(69 and 79 degrees)

5.1 Top Storey Displacement of Varied Angle

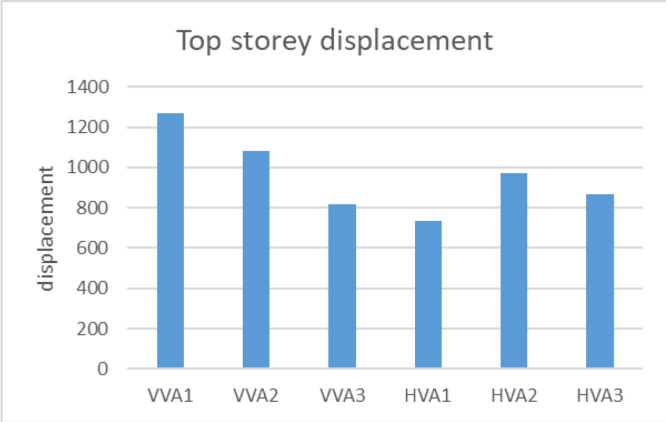

Fig 10 Top storey displacement of Varied angle

In case of the varied angles along the height, VVA3 performed better compared to other structure. The top storey displacement of VVA2 is 33% more compared to that of VVA3 and The top storey displacement of VVA1 is 55% more compared to that of VVA3Time period is least in the model VVA3 hence the stiffness is more in that structure. From above the data we can conclude that the model with more optimum angles perform better.

In case of varied angles along the width, HVA1 was performed better than the other two structure because both the angles are in the optimum range. Top storey displacement of HVA2 is 33% more than the top storey displacement of HVA1 and 13% more than the top storey displacement. HVA3 performed better than HVA2. This is due to the fact that HVA3 model had more common joints compared to HVA2

5.2 Time Period of Varied Angle

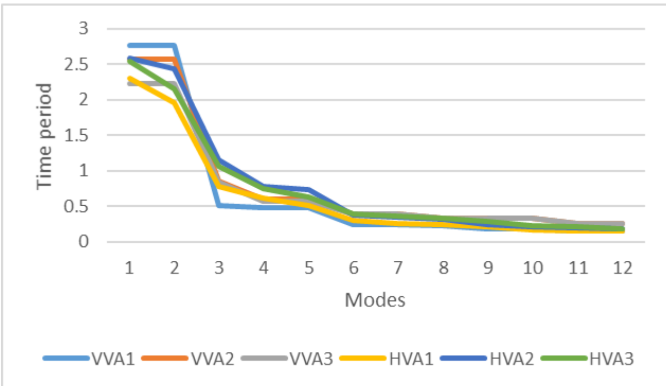

Fig 11 Time period of Varied angle

In case of the varied angles along the height, Time period is maximum in VVA1 and least in VVA3. Therefore, we can say that stiffness is maximum in VVA3 followed by VVA2 and least in VVA1.

In case of varied angles along the width, Time period is maximum in HVA1 and least in VVA3. Therefore, we can say that stiffness is maximum in HVA3 followed by HVA2 and least in HVA1.

CONCLUSIONS

From the above analysis we can confirm that

- It was found that 60 degrees is near optimal angle for 12 and 24-storey diagrid structures, and 69 degrees for the 48,60 and 72- storey diagrid structures. In case of 36-storey diagrid structure the angle 60 and 69 degrees gave almost similar values
- These results agree with the assumption that the optimal angle becomes steeper as the height of the structure becomes taller.
- Lower angle of 41 degrees were more prone to damage compared to other angles followed by 79 degrees
- Square model performed better compared to circle and rectangle
- Circle showed minimum displacement and maximum stiffness compared to the rectangle
- In case of the varied angles along the height, stiffness is maximum in VVA3 followed by VVA2 and least in VVA1.
- In case of varied angles along the width, stiffness is maximum in HVA3 followed by HVA2 and least in HVA1.
- The model with more optimum angles perform better to other structure

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