comparative analysis of diagrid structures under wind loading

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Abstract - Due to the population's rapid increase and the limited amount of land available, towering skyscraper construction has developed. For tall constructions, it's important to achieve structural efficiency as well as a pleasing visual look. Therefore, Diagrid structural systems have lately been modified for use in high-rise building construction. The horizontal loads that are acting on the structure as the building's height rises determine the structure's design. For light weight tall structures and those constructed in non-seismic regions wind loads play an important role in design of the structure. In this paper 4 models of diagrid structure with angles 52º, 69º, 75º & 79º and a conventional RCC building of building plan 30m X 30m with a total height of 76.8m subjected to dynamic wind loads as per IS 875 (Part 3):2015 are modeled & analyzed using ETABS software and the comparison between these models are done to find out the optimum diagrid angle. The results are analyzed in terms of time period, storey drift and load distribution pattern due to diagrid system. From the results obtained the diagrid 69º angle shows best results compared to all other models.

Index Terms - Diagrid structures, ETABS, Dynamic wind analysis, IS 875 (Part 3), Gust factor Analysis

I. Introduction

Due to the rapid population expansion and land shortage, tall constructions are currently in trend. The trend toward embracing nature as an inspiration in contemporary architectural and engineering methods has expanded over the past several years, along with the development of taller structures and the unceasing advancements in science. Due to their high adaptability and structural resistance to lateral and gravity loading, diagrid structures have found a position in sustainable building design. Diagrid constructions with repeating triangular facade modules are under the category of developed tubular building configurations. Due to the placement of diamond nets along the height of the towers, these frame arrangements have drawn the attention of architects of tall buildings.

Without any traditional vertical columns, the diagonal elements are joined by means of horizontal ring beams. In a diagrid construction, axial diagonal tensile and compressive stresses convey horizontal loads to the foundation. The weight and structural performance of diagrid constructions are influenced by the diagonal angles with horizontal lines. Regarding this, studies on diagrid structures initially concentrated on optimizing diagonal angles in relation to the height to width ratio and type of lateral loads (wind and earthquake).

Diagrid is visually appealing and easy to identify. A diagrid system's design and effectiveness allow for less structural parts to be used on building facades, which results in less visual hindrance from the outside. The diagrid system's structural effectiveness also aids in avoiding interior and corner columns, providing a large degree of floor design freedom. When compared to a typical moment-frame structure, the perimeter diagrid system saves about 20% of the structural steel weight.

The intersection of an inclined column as a diagonal and beams as horizontal components creates a diagrid system. The building's exterior structural parts are greatly reduced by the diagrid system. Less impediment to the outside view is made possible by it. As the outside inclined column can resist the entire lateral load, there is no need to construct additional inside columns in this sort of structure. Large internal space is provided, which is crucial from an architectural standpoint.

II. METHODOLOGY

The modeling and analysis have been done using finite element software, ETABS. The dynamic wind loads are calculated as per IS 875(Part 3):2015. The diagrid columns are placed around the periphery of the building. The diagrid angle is kept constant throughout the height of the building. The behavior of the models is studied in terms of storey displacement, storey drift, time period, column forces & moments at a specified location and load distribution due to the presence of diagrid periphery.

MODEL SPECIFICATIONS

Modeling and analysis have been completed using ETABS software. Following models have been analyzed:

Model 1: Conventional building (Fig.1)

Model 2: 52º diagrid angle (Fig.2)

Model 3: 69º diagrid angle (Fig.3)

Model 4: 75º diagrid angle (Fig.4)

Model 5: 79º diagrid angle (Fig.5)

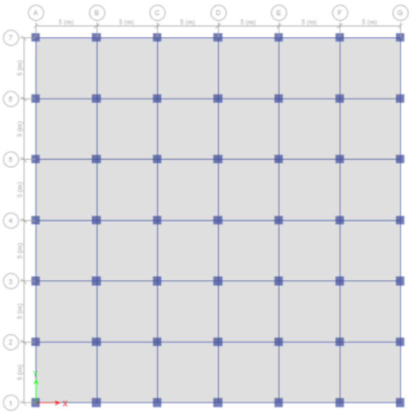

Figure 1. Plan of conventional building

Figure 2. Elevation of conventional building

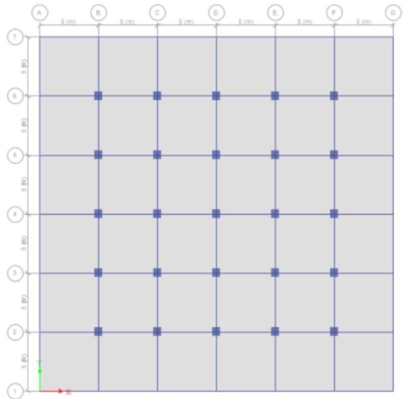

Figure 3. Plan of 52⁰ diagrid model

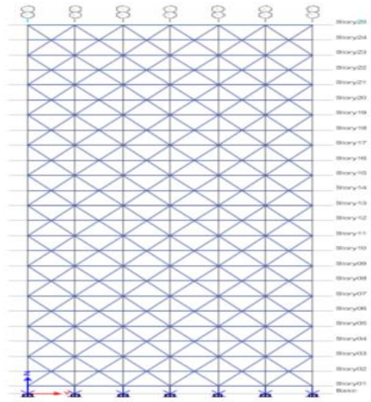

Figure 4. Elevation of 52⁰ diagrid model

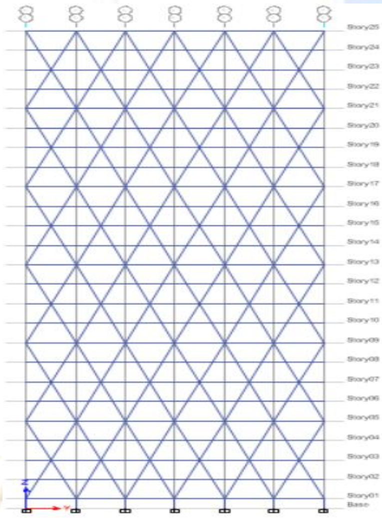

Figure 5. Elevation of 69⁰ diagrid model

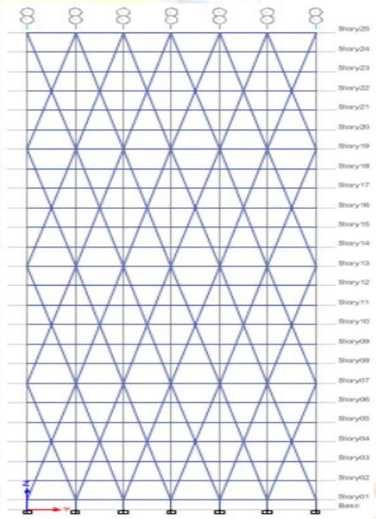

Figure 6. Elevation of 75⁰ diagrid model

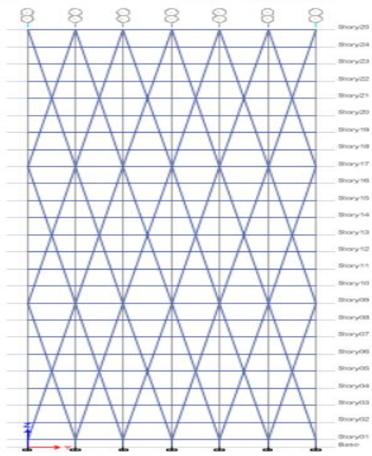

Figure 7. Elevation of 79⁰ diagrid model

DESCRIPTION OF MODEL

Table 1. Description of model

Parameter	Values
Plan dimension	30m X 30m
Total height of building	76.8 m
Storey height	3.2 m
Total number of storeys	G+23
Size of columns	700mm X 700 mm
Size of Diagrid members	700mm X 700 mm
Size of beams	300mm X 600 mm
Depth of slab	150mm
Terrain Category	Category 2
Probability factor (k_1)	1
Topography factor (k_3)	1
Importance factor (k_4)	1
Basic Wind Speed (V_b)	33 m/s (Bengaluru)
Thickness of walls	0.230 m
Live Load on slabs	3 kN/m2
Live Load on Roof slabs	1.5 kN/m2
Floor Finish Loads	1.5 kN/m2
Wall Loads on Beams	11.96 kN/m
Parapet Wall Load	5.52 kN/m
Total along wind load	2418.12 kN
Total across wind load	429.07 kN
Type of Structure	RCC

III. RESULTS AND DISCUSSION

(1) Storey Drift

The inter storey drift limit due to wind loads is H/300 (as per Cl 5.6.1 of IS 800: 2007).

$\frac{\mathbf{H}}{\mathbf{300}} = \frac{\mathbf{3.2}}{\mathbf{300}} = \mathbf{0.0167}$. All the values are in permissible limits.

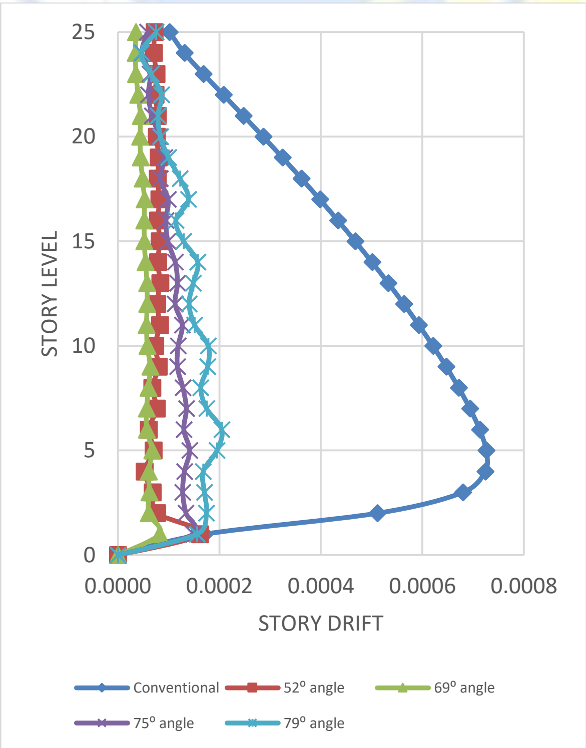

Figure 8. Storey drift in along wind direction

The highest value of storey drift obtained is for conventional RCC building of 0.0007259 and the least value obtained is for 69° diagrid model of 0.00008198.

(2)Time period

Time period or Natural period of a building is the time taken by structure to complete one cycle of oscillation.

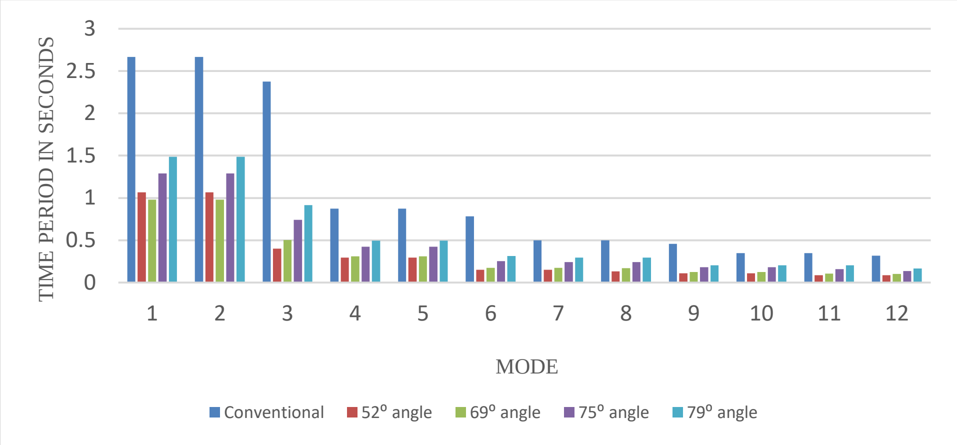

Figure 9. Time period vs. mode

From the graph above we can clearly see that 69º diagrid model has least time period of 0.98 seconds for the first mode. And the highest time period is 2.668 seconds for conventional building.

IV. CONCLUSIONS

The diagrid 69º model is optimum for the selected plan and height of building. It has least first mode time period and least storey drift value compared to all other models. Along with strength and stiffness the diagrid system can be visually appealing and provide more floor area when compared to conventional RCC building.

V. REFERENCES

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