Study on Performance of Diagrid System on High Rise Buildings with Complex Shape

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Abstract—Diagrid structures for tall buildings are very popular among engineers and architects. One of the evocative structural design solutions for sustainable tall buildings is embraced by the diagrid structural scheme. This study focuse on the concept of diagrid structural system, structural performance of a steel tall building and compare the complex shape of high rise building for diagrid system using SAP2000. The resulting diagrid structures were assessed under gravity, wind and seismic loads and various performance parameters were evaluated on the basis of the analysis results. The comparison is in terms of lateral displacement and inter storey drift.

Index Terms—Diagrids, Tall Buildings, Storey Displacement, Inter Storey Drift

1 Introduction

In the late 19th century early designs of tall buildings recognized the effectiveness of diagonal bracingmembers in resisting lateral forces. The rapid growths of urban population and consequent pressure on limited space have considerably influenced the residential development of city. The high cost of land, the desire to avoid a continuous urban sprawl, and the need to preserve important agricultural production have all contributed to drive residential buildings upward. As the height of building increase, the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. Recently, the diagrid (Diagonal Grid) structural system is widely used for tall steel buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. FazlurKhan[6] argued that the rigid frame that had dominated tall building design and construction so long was not the only system fitting for tall buildings. Feasible structural systems, according to him, are rigid frames, shear walls, interactive frame-shear wall combinations, belt trusses, and the various other tubular systems. Diagrid is a perimeter structural configuration characterized by a narrow grid of diagonal members. Since it requires less structural steel than a conventional steel frame, it provides for a more sustainable structure.

2 Methodology

1. The complex shape of high rise building for diagrid system was compared using SAP2000. The following procedure was adopted.

a) A 36 storied building was chosen for analysis using SAP2000

b) Linear static analysis is done.

c) The results were compared in terms of storey drift and displacement

2. Loading:- The live load and floor finish load on floor slab are 2kN/m² and 1kN/m² respectively. The design earthquake load is computed based on the zone factor of 0.16, medium soil, importance factor of 1 and response reduction factor of 5 as per IS: 1893-2002. The wind loading is computed based on the basic wind speed 39m/sec and terrain category III as per IS:875 (III)-1987. The steel used is of grade Fe 250. The ends of diagrids and columns are assumed as hinged.

3 Optimum angle

As the angle of the diagonals increases, the efficiency of the diagonals at carrying gravity loads increases, while the ability of the diagonals to effectively carry lateral loads decreases. Similarly, as the angle decreases, the diagonals carry lateral loads more efficiently but carry gravity loads less effectively. This dichotomy suggests the existence of an angle at which the structural capability of the member is optimized for both gravity and lateral loadings.

3.1Building Configuration

Five primary models were considered each for 3m, 6m and 12m diagrid spacing. Each building is modeled by varying number of storey per module 2,3,4,5 and 6. The building details are given in Table 1.

TABLE 1
DETAILS OF BUILDING

Sl No	Building Details	
1	Plan Area	1296m²
2	Height of Floors	3.6m
3	Total Height of Building	129.6m
4	No. of storey	36
5	Beam	ISMB550, 1SWB600
6	Column	1.5m x1.5m
7	Diagrid	450 mm pipe with 25 mm thickness
8	Slab	100 mm thick, M30 grade concrete

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3.2 Modelling

Typical plan of square building (36mX36m) is shown in Fig 1.

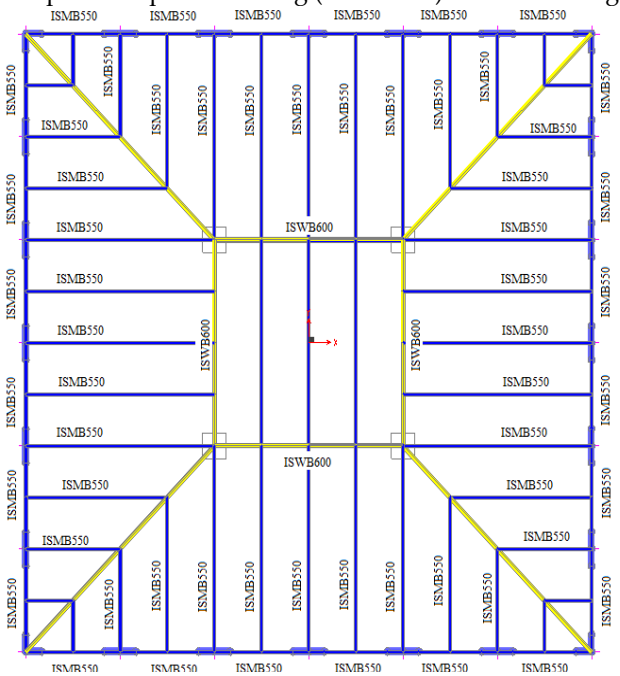

Fig. 1. Plan of Building

The diagrid angles for models are tabulated in table 2

TABLE 2
DIAGRID ANGLE FOR 5 MODELS

Model	Diagrid Module	Angle		
		3m spacing	6m spacing	9m spacing
1	2 Storey	67°	50°	39°
2	3 Storey	74°	61°	50°
3	4 Storey	78°	67°	58°
4	5 Storey	81°	72°	63°
5	6 Storey	82°	74°	67°

Fig 2 shows the elevation of the 3m, 6m and 9m spacing diagrid model.

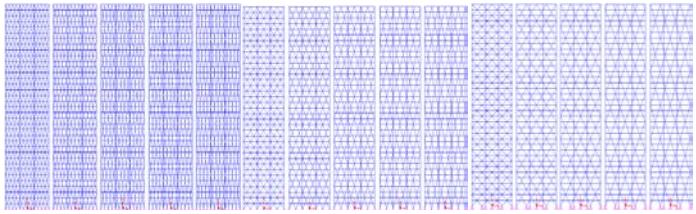

Fig. 2. 3m, 6m and 9m Diagrid Spacing

3.3 Analysis Result

Linear static analysis of the model is conducted and total weight of building for 3m, 6m and 9m spacing is presented in Fig 3. From Fig 3 it is concluded that the storey with 3m diagrid and having 2storey have the maximum weight.

The displacement of 36 storeydiagrid structures for 3m spacing, 6m spacing and 9m spacing are shown in Fig 4, Fig 5 and Fig 6. For each spacing there is 5 different models that for 2 storey, 3 storey, 4 storey, 5 storey and 6 storey. It is observed that displacement in 1.5(D.L + Seismic load in - X direction) combination is the worst load combination compared to other load combinations. After conducting static analysis 2 storey with 3m diagrid shows the minimum displacement.

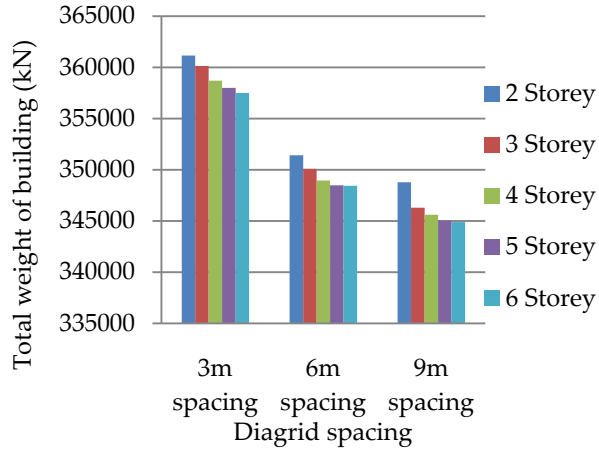

Fig. 3. Total weight of building

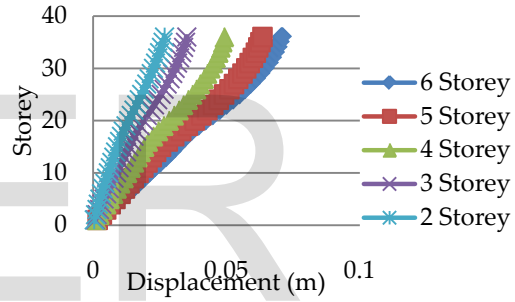

Fig. 4. Storey Displacement 3m Spacing

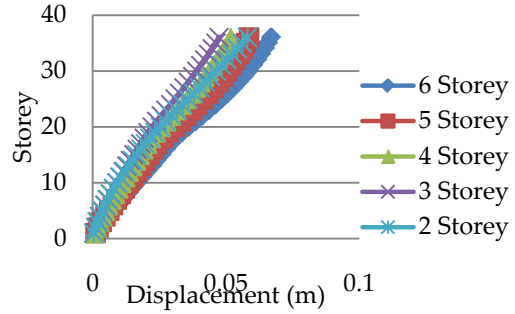

Fig. 5. Storey Displacement 6m Spacing

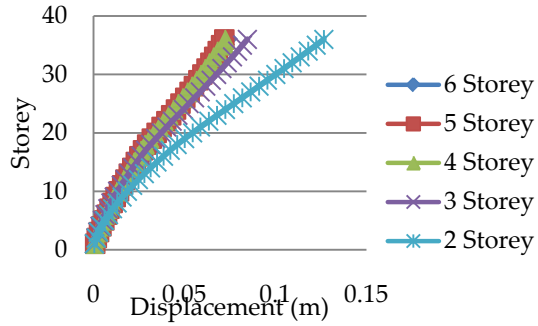

Fig. 6. Storey Displacement 9m Spacing

The inter-storey drift of 36 storeydiagrid structures for 3m, 6m and 9m spacing are shown in Fig 7, Fig 8 and Fig 9. It is observed that inter-storey drift in 1.5(D.L + Seismic load in -X direction) combination is the highest. The minimum inter-storey displacement is for 2 storey with 3m diagrid.

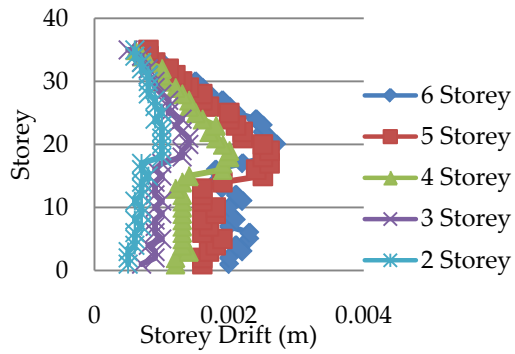

Fig. 7. Inter-Storey Drift 3m Spacing Diagrid

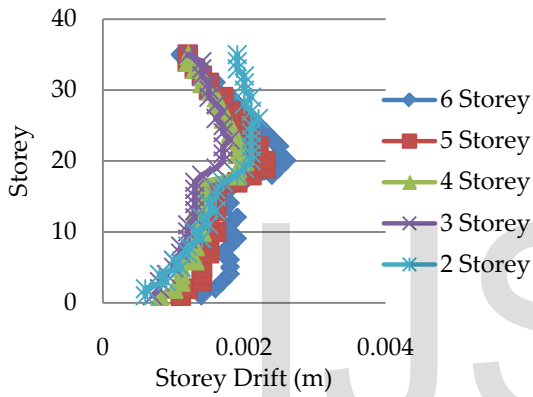

Fig. 8. Inter-Storey Drift 6m Spacing Diagrid

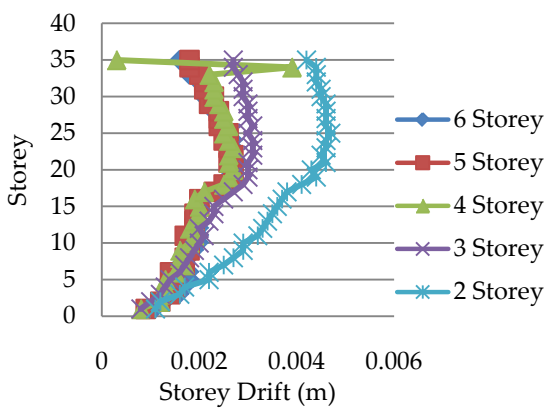

Fig. 9. Inter-Storey Drift 9m Spacing Diagrid

4 Modelling Complex Shape

4.1 Building Configuration

A 42 storey tall building is considered. The storey height is 3.6 m. The diagrids were provided at 3 m spacing along the perimeter.

4.2 Modelling

Typical plan of building is shown in Fig 10. Fig 11 and Fig 12 shows the elevation and 3D view of the model.

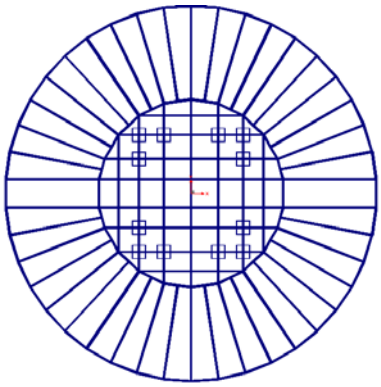

Fig. 10. Plan of Building

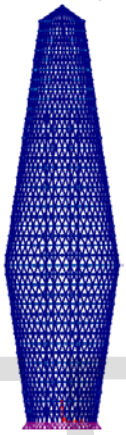

Fig. 11. Elevation

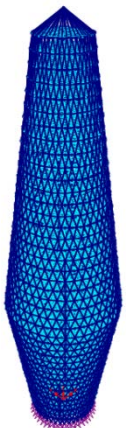

Fig. 12. 3D View

4.3 Analysis Result

Linear static analysis of the model is conducted and the results are presented in terms of storey displacement and inter storey drift. Fig 13 shows the storey displacement for building without secondary bracing and shear wall, with secondary bracing and with shear wall. After analysis it is noted that the building with shear wall gives the smalletst displacement. Fig 14 shows the inert-storey drift for building without secondary bracing and shear wall, with secondary bracing and with shear wall. After analysis it is noted that the building with shear wall gives the better result compared to the other patterns.

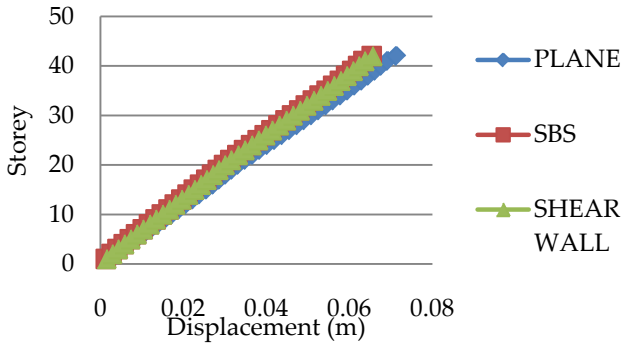

Fig. 13. Storey Displacement

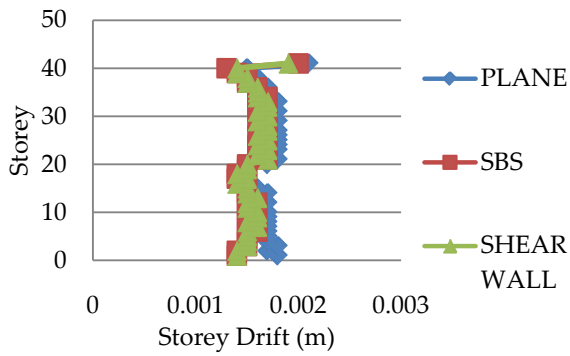

Fig. 14. Inter-Storey Drift

5 Comparision of Results

TABLE 3
DISPLACEMENT VALUES FOR SQUARE AND COMPLEX SHAPE

Building	Static analysis	
	Storey Displacement (m)	Storey Drift (m)
Square	0.0268	0.008
Complex Shape	0.0654	0.0021

6 Permissible Values

Maximum Storey Displacement is limited to H/500, Where H is the height of the building. For 36 storey building of 129.6m height,
Permissible Storey Displacement = 0.2592m
As per IS 1893 (Part 1): 2002, Clause 7.11.1, the Storey Drift in any storey shall not exceed 0.004 times the storey height (h). The storey height of the models under study is 3.6m.
Permissible Storey Drift = 0.004h = 0.0144 m

7 Conclusions

In this paper, comparative analysis of 36-storey diagrid structural system- Square and complex in plan are presented. SAP2000 software was used for modelling and analysis of structure. Analysis results like storey displacement and inter storey drift are presented here. Following are the conclusions inferred from the study:
1. For all the 18 models considered for the study the storey displacement and storey drift values are within the permissible limit for static analysis.
2. Optimum Diagrid Angle:
For Square buildings 2storey diagrid module building with diagrid angle 67°and 3m diagrid spacing has the least Maximum Storey Displacement and Storey Drift value compared to 3, 4, 5 and 6 storeydiagrid module buildings with 3m, 6m and 9m spacing.
3. Storey displacement and storey drift value is less for square building but for the complex shape the values are within permissible limit.

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