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Dynamic Analysis Of Diagrid System 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 focus 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 comparisons are in terms of lateral displacement, base shear and inter storey drift.

Keywords: **Diagrids, Tall Buildings, Storey Displacement, Inter Storey Drift, Base shear**.

1. Introduction

In the late 19th century early designs of tall buildings recognized the effectiveness of diagonal bracing members 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. Fazlur Khan[14] 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) Non-linear time history analysis is done.

2) The results were compared in terms of storey drift, base shear and displacement

3) Loading:- The live load and floor finish load on floor slab are 2kN/m^2 and 1kN/m^2 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.

4) Nonlinear dynamic analysis (time history)

Nonlinear Dynamic analysis can be done by direct integration of the equations of motion by step by step procedures. A time dependent forcing function (earthquake accelerogram) is applied and the corresponding response–history of the structure during the earthquake is computed. That is the moment and force diagrams at each of a series of prescribed intervals throughout the applied motion can be found. Computer programs have been written for both linear elastic and non-linear inelastic material behaviour using step-by-step integration procedures. Fig 1 shows the Acceleration time history of El Centro Imperial valley 1940 Ground motion records.

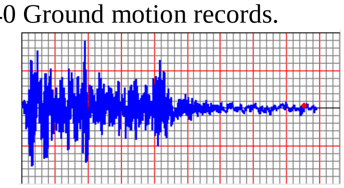

Fig. 1 Acceleration time history of El Centro Imperial valley 1940 Ground motion records.

3. Determination of Optimum Angle

3.1 Building 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	1296m^2
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

3.2 Modelling

Typical plan of square building (36mX36m) is shown in Fig 2.

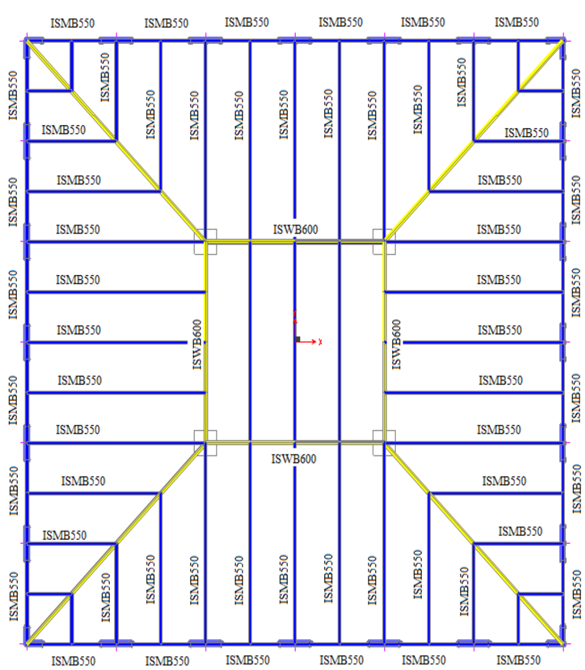

Fig. 2 Plan of Building

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

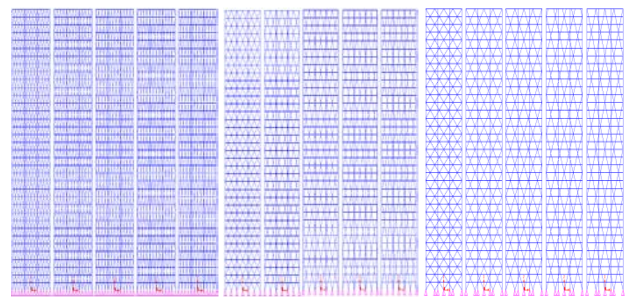

Fig. 3 3m, 6m and 9m Diagrid Spacing

3.3 Static 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 4. From Fig 4 it is concluded that the storey with 3m diagrid and having 2storey have the maximum weight.

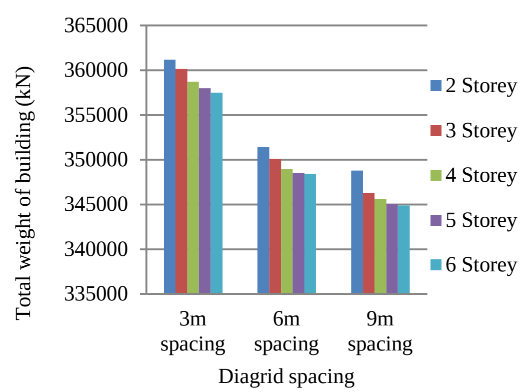

Fig. 4 Total weight of building

The displacement of 36 storey diagrid structures for 3m spacing, 6m spacing and 9m spacing are shown in Fig 5, Fig 6 and Fig 7. 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.

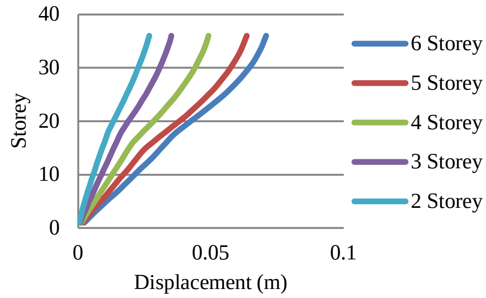

Fig. 5 Storey Displacement 3m Spacing

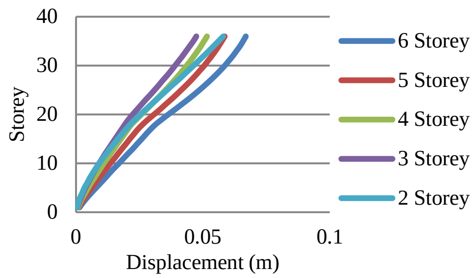

Fig. 6 Storey Displacement 6m Spacing

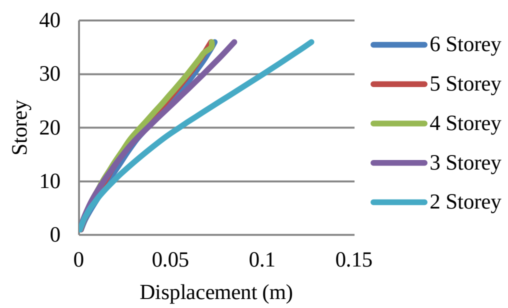

Fig. 7 Storey Displacement 9m Spacing

The inter-storey drift of 36 storey diagrid structures for 3m, 6m and 9m spacing are shown in Fig 8, Fig 9 and Fig 10. 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.

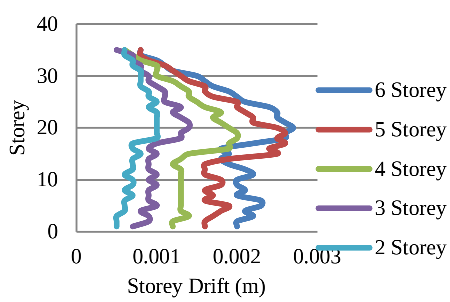

Fig. 8 Inter-Storey Drift 3m Spacing Diagrid

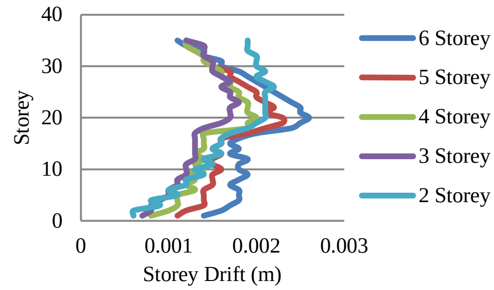

Fig. 9 Inter-Storey Drift 6m Spacing Diagrid

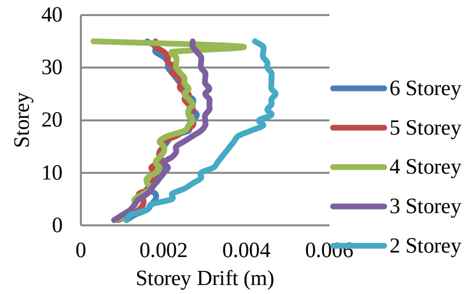

Fig. 10 Inter-Storey Drift 9m Spacing Diagrid

3.4 Dynamic analysis result

Dynamic analysis is done for 3m diagrid spacing with 2 storey. The displacement versus time plot is shown in Fig 11. The maximum displacement is 0.3126m at 10.19sec.

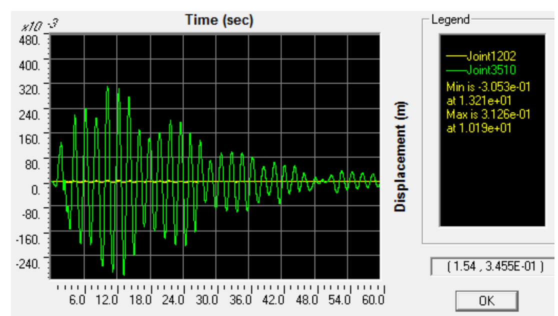

Fig. 11 Displacement Vs Time Graph

4. Modelling of Complex Shape

4.1 Building configuration

A 36 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 12, Fig 13 and Fig 14 shows the elevation and 3D view of the model.

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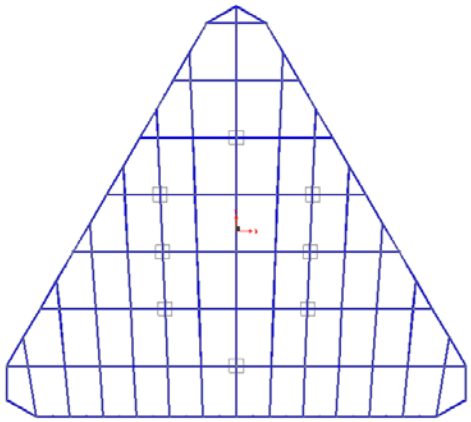

Fig. 12 Plan of Building

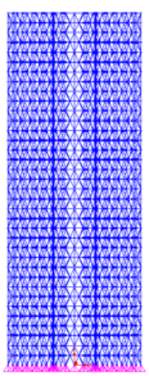

Fig. 13 Elevation

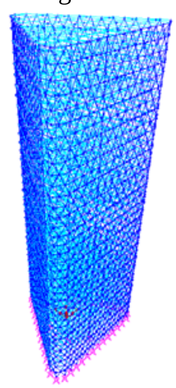

Fig. 14 3D View

4.3 Static 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 15 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 16 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 17 shows the base shear for building.

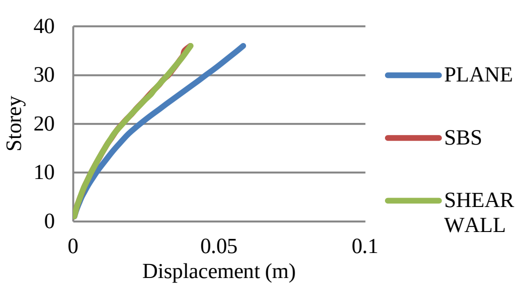

Fig. 15 Storey Displacement

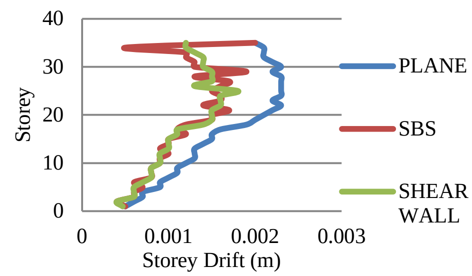

Fig. 16 Inter-Storey Drift

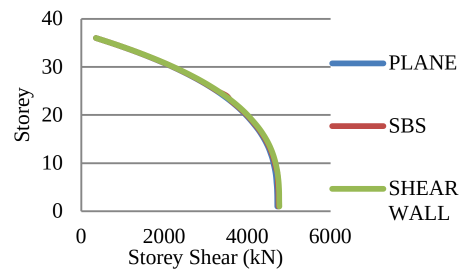

Fig. 17 Base shear

4.4 Dynamic Analysis Result

The displacement vs time for secondary bracing is shown in Fig 18. The maximum displacement is 0.2774m at 8.92sec.

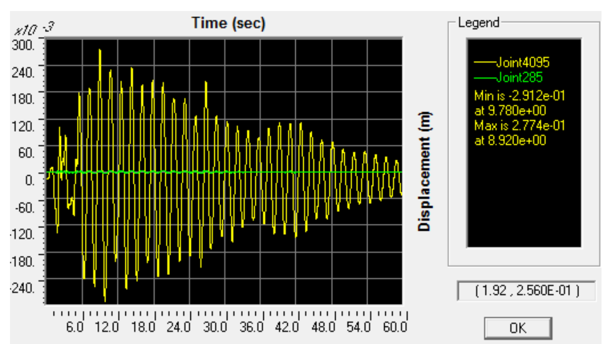

Fig. 18 Displacement Vs Time Graph

5. Comparison of Result

Table 3 Maximum Storey Displacement Values for Square and Complex Shape Building

Building	Static analysis		Dynamic analysis
	Storey Disp. (m)	Storey Drift (m)	Storey Disp. (m)
Square	0.0268	0.008	0.3126
Complex Shape	0.0654	0.0021	0.2774

6. 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, 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. 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. Optimum diagrid angle for square building is 67^0, 2storey diagrid module building with 3m diagrid spacing.
3. In terms of economy most suitable diagrid storey is 6m diagrid spacing with 4 storey diagrid with diagrid angle of 67^0.
4. Storey displacement and storey drift value is less for square building but for the other building the values are within permissible limit in static analysis.
5. In complex shape analysis building without shear wall and secondary bracing has the largest storey displacement and storey drift compared with other two systems. The building with shear wall and secondary bracing will not has much effect in seismic resistant. But it provides more stability compared with plane building.
6. By doing static and dynamic analysis it may be concluded that the complex shape building acts similarly during static and dynamic analysis.

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