Story drift Analysis of Diagrid structural system with varying Angle for High rise buildings as per Indian Standards

[1]Ashwin G. Hansora and [2]Kushal S. Patel
[1]Assistant professor, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad, Gujarat, India
[2]P.G. Student, Applied Mechanics Department, L.D. College of Engineering, Ahmedabad, Gujarat, India.

Abstract : Enhancements in structural systems, development innovation, materials and systematic strategies for analysis and design streamlined the development of tall structures. Governing factor in structural design of high rise buildings are lateral load due to wind and earthquake. Lateral load resistance is given by inward structural systems or outer structural systems. Lately diagrid structural system is introduced in high rise structures because of its basic capability and adaptability in building arranging. When compared with firmly distributed vertical columns in framed tube, diagrid structure contains inclined columns on the outer surface of structure. Because of inclined sections lateral loads are opposed by axial action of the diagonal column. The present investigation is focused to figure the story drift and displacement of diagrid structure under gravity and lateral loading. This analysis is expecting to decide optimal/variable angle of inclination for minimum story drift.

Keywords: Diagrid structural system, Varying angle, Story Drift

I. INTRODUCTION

The development of tall structures is contributed by the advancement of effective structural system, enhancements in development innovation, deficiency of urban land and imaginative computational practices. Elevated structures are developing in real urban communities of world since a decade ago. Lateral loading because of wind or earthquake are driving load in elevated structures alongside gravitational loading. For tall structures, inside structural systems and outside structural systems are giving to counterattack the lateral loads. The broadly developed interior lateral load opposing systems are: rigid frame, braced frame, shear wall structural and outrigger structure. The outer systems are: tubular structure and diagrid structure. As of late, the diagrid structural system has been practical to a few tall steel structures due to its supporting skill. Diagrid is specific type of space truss, which does not have any vertical column on the outer fringe of the structure. Diagrid is planned by interconnecting the diagonal columns and horizontal beams and is comprised of the arrangement of triangulated support system. Diagrid structural system gives greater adaptability in arranging inner space and exterior of the structure.

Various examples of diagrid structure all around the world are the Swiss Re in London, Hearst Tower in New York, Central china television in China and Capital Gate Tower in Abu Dhabi as shown in Figure 1 (Leonard 2007).

(a) (b) (c) (d)

Figure 1. Diagrid buildings (a) Swiss Re (b) Hearst Tower (c) Central china television (d) Capital Gate Tower

The diagrid structural system can convey gravity load just as lateral load because of their triangulated course of action. Diagrid structures are extra workable in lessening shear distortion since they convey horizontal shear by axial action of diagonal members. Generally, diagrid structural system does not require any inside center to counterattack the horizontal load since sidelong burden is opposed by the peripheral inclining member (Kim et al, 2010). In diagrid structures, diagonals transfer both story shear and moment. In this manner, the optimal angle of diagonals is incredibly dependent upon the structure height. (Moon, 2008).

In this paper analysis of 60 story diagrid steel building is presented. Lateral forces because of wind and earthquake are estimated according to Indian Standards for structure. Every basic member is designed according to IS 800:2007 considering all load combinations. So as to get optimum story drift and displacement, variable diagrid angle for G+60 story building is considered. Stiffness based method is applied to find optimum angle for diagonal column on periphery.

II. Analytical study of 60 story Diagrid system

Building Configuration: The 60 story tall building is having 36 m × 36 m plan dimension. The story height is 3.5 m. The representative plan and elevation are shown in Figure 2. In diagrid structural system, pair of braces is situated on the periphery of the building. The angle of inclination is variable during the course of the height. The inclined columns are provided at six-meter spacing along the boundary. The inner frame of the diagrid structure is designed only for gravity load. The design dead load and live loads on floor slab are 3.75 kN/m² and 2.5 kN/m² separately. The wind loading is calculated based on the basic wind speed of 30 m/sec and terrain category III as per IS:875 (III)-1987 (Gust factor method). Transversely wind load is calculated as discussed by Gu and Quan (Gu and Quan, 2004). Total height of building is 210m.
Interior columns of size 1500×1500 mm are provided. Steel section of ISWB 550 is provided as beam B1 and B3. For beam B2 ISWB600 with top and bottom cover plate of 220×50 is provided.

Model 1 with 69.62° diagonal angle with Horizontal
Model 2 with each 4 modules of 68°, 71° and 73.47° diagonal angle with Horizontal
Model 3 with each 4 modules of 69°, 71° and 72.85° diagonal angle with Horizontal
Model 4 with each 4 modules of 70° ,71° and 72.11° diagonal angle with Horizontal

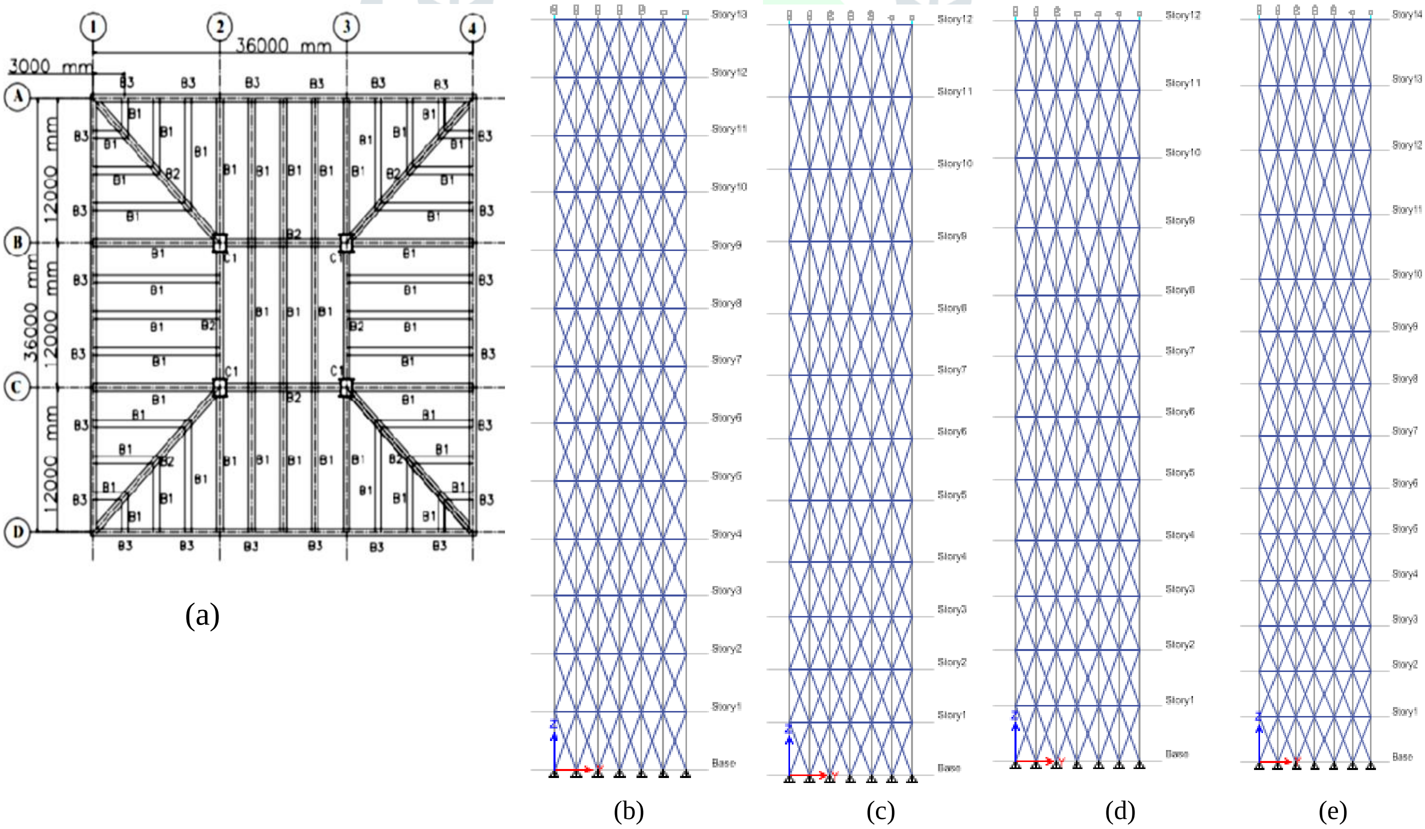


Figure 2. Typical (a) Floor Plan (b) model 1 (c) model 2 (d) model 3 (e) model 4

The stiffness based method is applied for approximate analysis of 60 story diagrid structures. The top story permissible displacement is H/500. The essential lateral stiffness is allocated to the perimeter diagrids. Shear forces and bending moments at several modules are determined in view of lateral loadings. Member sizes for each module are calculated using equations (1) and (2), which are derived using stiffness based, approach (Moon 2007).

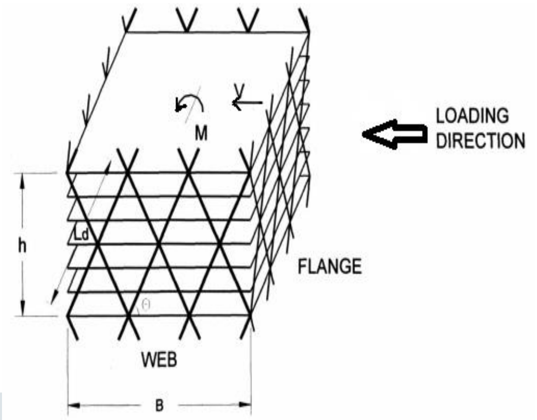


Figure 3. Typical six story module of diagrid structure

$$\mathrm{Ad,w} = \frac{V\mathrm{Ld}}{2\mathrm{NwEdh}\,\gamma\cos^2\theta} \quad (1)$$

$$\mathrm{Ad;f} = \frac{2M\mathrm{Ld}}{(\mathrm{Nf}+\delta)\mathrm{B}^2\mathrm{Edh}\chi\sin^2\theta} \quad (2)$$

$A_{d,w}$: Area of Each Diagonal on the Web
$A_{d,f}$: Area of Each Diagonal on the Flange
V: Shear Force
M: Moment
L_d: Length of Diagonal
E_d: Modulus of Elasticity of Steel
θ: Angle of Diagonal Member
γ: Transverse Shear Strain
χ: Curvature
$N_{d,w}$: Number of Diagonals on Each Web Plane
$N_{d,f}$: Number of Diagonals on Each Flange Plane
δ: Contribution of Web Diagonals for Bending Rigidity
B: Building Width in the Direction of Applied Force

Determination of a value for δ is an engineering decision. Typical values for δ are in the neighborhood of 500 (Moon 2005).

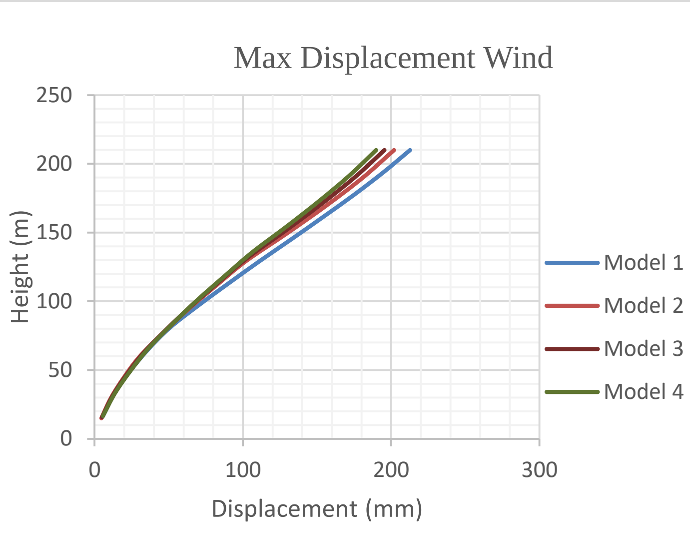
Table 1. Preliminary Member Sizing and Diagonal Steel Area for the 60-story Diagrid Structure of Module 2

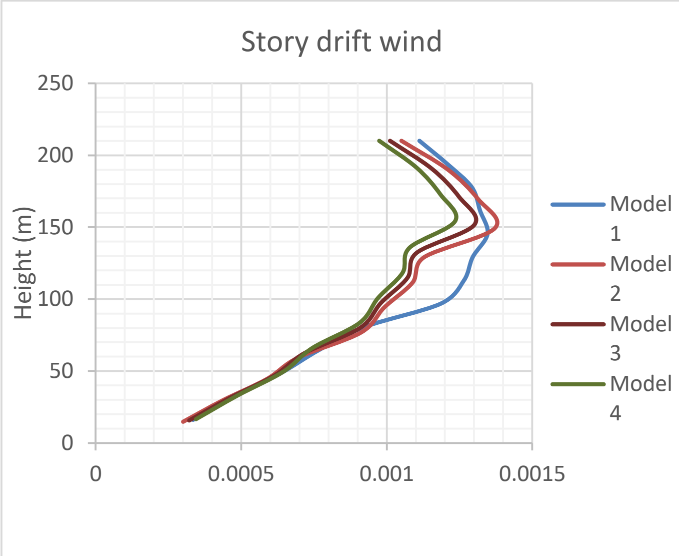
Module	Story Shear (kN)	Overturning Moment (kNm)	Shear Area (m^2)	Overturning Area (m^2)
12	388.4074	7852.4318	0.001244426	0.00038003
11	1155.081	31204.7037	0.003700786	0.00151019
10	1906.2724	69743.8138	0.006107542	0.00337533
9	2639.0815	123098	0.008455403	0.00595746
8	3303.9926	180703	0.013800588	0.00824541
7	3900.7043	248712	0.016293018	0.01134863
6	4470.4501	326654	0.018672814	0.01490509
5	5012.4666	414047	0.020936786	0.0188928
4	5483.8668	495482	0.029384521	0.0217081
3	5877.2698	582760	0.031492515	0.02553194
2	6206.4877	674926	0.033256583	0.02956992
1	6352.4921	769260	0.034038927	0.03370289

III. Analysis result

The diagonal members are designed according to equation (1) and (2). The story drift and displacement are compared for all 4 models.

SUMMARY AND CONCLUSIONS





IV. CONCLUSION

Based on study carried out in this paper following conclusions are derived for diagrid structural system:

- Maximum displacement and story drift is more in wind as compared to earthquake loading.
- In variable angle analysis if we go with higher angle than the optimal angle for uniform angle model, displacement at top of building and story drift at each module is reduced.
- It is also 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 peripherals diagonal columns.

V. REFERENCES

[1] Gu M.and Quan Y. (2004), "Across-Wind Loads of typical Tall Buildings", Journal of Wind engineering and Industrial Aerodynamics, pp.1147-1165.
[2] Kim J., Jun Y. and Lee Y.H. (2010), "Seismic Performance Evaluation of Diagrid System Buildings", 2nd Specialty Conference on Disaster Mitigation, Manitoba.
[3] Leonard J. (2007), "Investigation of Shear Lag Effect in High-Rise Buildings with Diagrid System", M.S. thesis, Massachusetts Institute of Technology.
[4] Moon K.S. (2005), "Dynamic Interrelationship between Technology and Architecture in Tall Buildings", Ph.D. dissertation, Department of Architecture, Massachusetts Institute of Technology.
[5] Moon K.S. (2008), "Material-Saving Design Strategies for Tall Building Structures", CTBUH 8th World Congress, Dubai.
[6] Moon K.S. (2008), "Optimal Grid Geometry of Diagrid Structures for Tall Buildings", Architectural Science Review.
[7] Khushbu D. Jani and Paresh V. Patel, "Design of Diagrid Structural System for High Rise Steel Buildings as per Indian Standards" Structures Congress 2013 ASCE 2013