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Review on Performance of Diagrid Structural System in Tall Building

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Abstract: In the most recent decades, the diagrid system has been broadly embraced for tall structure because of their structural efficiency and design possibilities. The diagrid is an exterior structural system that resist the lateral forces through the axial actions of the peripheral diagonal member. In addition, the diagrid structure reduces the number of columns, which gives increasingly rentable space in a similar plan zone as that of surrounded frame structure. In this paper, carried out a synopsis of literature linked to the diagrid structural system and diagrid structure concentrates to assess the diagrid angle for the most economic and efficient design. Therefore, the objective of this paper is to investigate the effectiveness of diagrid structure in tall building leading to lateral load and compared the results of some studies in subjected to optimum angle of diagonal members, top story displacement, time-period, story drift, story shear and steel mass usages.

Keywords: Diagrid structural system, tall building, story drift, story shear, story displacement, time period, steel weight.

Introduction

With the rapid development of tall buildings around the world in recent decades, the evolution of modern tall buildings as multi-function, multi-objective, with stylish. The layout of structural floor and the type of building is becoming increasingly complex, structural system also becoming diversified, thus raising seismic design requirements (Li, W., 2010)

Early design of tall buildings at the end of the 19th century acknowledged the efficiency the diagonal bracing components in resisting lateral forces. For initial tall buildings, most of the structural system used were steel frames with diagonal bracing of different combinations along with X, K, and eccentric (Moon, K., 2007)

With the introduction of diagrid structural system, high efficiency and architectural potential can be achieved. The incessant combination of aesthetic, aerodynamic and structural considerations has resulted in numerous studies on the structure of tall building: tilted, twisted, and free from shapes (Moon K.S., 2011).

The lateral load resistance system will turn out to be increasingly significant as the tallness of the structure compared to the resistance of gravitational load. In tall building Braced Tube System, Tubular System, Outrigger System, Wall Frame, Shear Wall and Rigid Frame are the extensively used to resistant lateral load because of its structural effectiveness and architecture potential, the remarkable geometric structure has as of late utilized the diagrid structural system for tall building (Moon K.S., 2005).

Due to its effectiveness and functionality, the diagrid structure decreased the number of structural components desired the building façade and thus reduce the impediment to the outer view. Moreover, the effectiveness of diagrid system support to eliminated edge column and indeed the inner column, accordingly permitting huge floor plan adaptability. The perimeter of diagrid system minimizes structural weight around twenty percentage when assessing conventional Moment Resistant frame structure (Leonard J., 2007).

In diagrid structure, diagonal member be able to taken both lateral loads and gravity load because of trilateral components. Because of the diagonal members taken lateral shear through axial action, the structural system is also more efficient to controlling shear deformation. For the most part, the external diagonal component can bear lateral force so that the cores of shear rigidity is no longer required. (Kim J., Jun Y. and Lee Y.H., 2010).

It has been generally known in the field of structural engineering that diagrid structural system are usually suitable for resistance to eminent lateral force. In this paper reviewed the diagrid systems of structural performance in being subjected to optimal angle, story drift, Story shear and displacement and steel weight to design most effective angle.

Optimum Angle of Diagonal Members

Kyoung Sun Moon (2008) studied the stiffness design method is functional to an established of 40,50,60,70 and 80 story diagrid structures. That diagrid structural system in every floor height is intended with diagonal constructed at various increasingly changeable angels allowing for the determination of the optimal uniform angle to each structure.

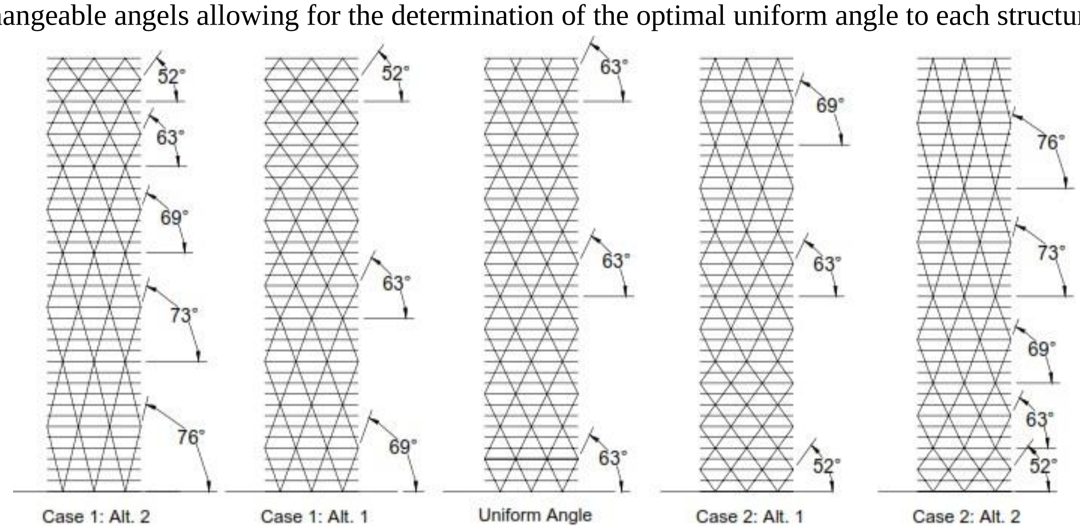


Fig. 1: Different 40 story diagrids configured (H / B = 4.3) (Kyoung Sun Moon, 2008)

Table 1: Impact of varying angles for 60-storey diagrids (Kyoung Sun Moon, 2008) description

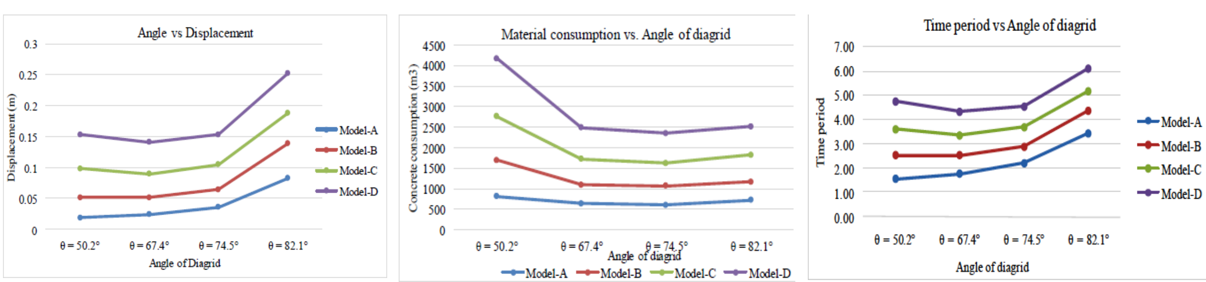
Story Module (stories)	Diagrid Angle (degrees)	Diagrid Steel Mass (Ton)	Percentage Variance
2	52	5700	50.00%
3	63	3930	3.40%
4	69	3820	Near Optimum
5	73	4200	5.30%
6	76	4960	30.50%

Table 2: 40 story diagrid design used optimum values and steel masses (Kyoung Sun Moon, 2008)

Case	Alt.	Diagrid Angle Details (degrees)	Optimum	Diagrid Steel Mass (tons)
1	2	79, 76, 73, 69, 63	0.9	1068
	1	73, 69, 63	2.7	1009
Uniform Angle		69	4.1	883
2	1	63, 69, 73	5.1	1906
	2	63, 69, 73, 76, 79	2.1	1597

In above established that the variety of the optimal angle for the tall diagrid structure from about 6 to 70 degrees, with aspect ratios ranging from around 4 to 9.

Nishith B. Panchal (2014) presented assessment investigation of the structural diagrid with a diagrid angle of 50.2 degrees, 67.4 degrees, 74.5 degrees and 82.1 degrees in regard 24 story, 36 storied, 48 storied and 60 storied. Compared to the performance analysis the use of ETABs execution is presented for story drift, diagrid angle, time period, top floor displacement and concrete consumption. They reached the resolved in the territory of 65 degrees to 75 degrees the more efficient angle of diagrid is dictated.



(a) (b) (c)

Fig. 2: (a) Angle of diagrid Vs. Displacement graph, (b) Material consumption Vs. Angle graph, (c) Time period Vs. Angle of diagrid graph (Nishith B. Panchal, 2014)

Kim and Lee (2010) studied seismic performance of 36 storied diagrid structure using nonlinear static and dynamic analysis with different brace angles. The result was comparable to those of tubular structure and a diagrid structure with a secondary bracing system. The authors observed that the shear leg effect increased as the slope of the braces increased and the lateral strength decreased. Authors concluded that diagrid structural system between 60 degrees to 70 degrees appeared to be the most effective in both gravity loads and lateral resistances.

Subsequently on above established that the optimal diagrid angle is observed from 65 degrees to 75 degrees.

Story Shear and Shear Force

Rohitkumar Singh (2014) showed the comparison review of the 5 story R.C.C structure utilizing STAAD Pro having 15 m X 15 m plan of diagrid structure and conventional structural system. Compared with the analysis of result regarding top story displacement, story drift, base axial force and shear force. Shear force of diagrid is 977 KN and maximum bending moment is 29 KN.m compared to 931 KN and 132 KN.m in consistently for the conventional system.

Harish Varsani (2015) depicted the comparative analysis of 24 stories with a plan 36m X 36m of diagrid and conventional steel frame utilizing ETABS. The examination of results for a graph story shear revealed that the diagrid structure of the story shear is tends to be higher compared to the conventional structural system due to earthquake load.

Manthan Shah (2016) demonstrated the comparison study of 4,8,12,16,20,40 and 48 storied having 18m X 18m plan of the diagrid frame and conventional frame utilizing ETABS. They have in comparison the analysis results are the two directions can be equivalent for the base shear. Due to perceived that the diagrid frame structure is more compared to conventional frame, it pulls in extra additional lateral force and base shear thus has up to 12 storied structure. By utilizing static wind load the base shear is constrained and after 12 storied, static loads will be kept up and controlling force. The base shear is therefore investigated to be similar after 12 story for the both structures.

Concluded on above reviewed that maximum base shear for a given structural height, this reduces significantly after certain height rather than conventional structural system.

Time Period

Deepika R. (2016) presented assessment study with 30-story structural system plan 30m X 30m Diagrid and structural system of Hexagrid utilizing ETABS also evaluated is a comparison of 3.268 sec of the first mode in the diagrid structure, while the structure of the hexagrid frame is 3.69 sec.

Harish Varsani (2015) determined the first time-period mode comparison result is 2.74 sec, but for a conventional structural system it is only 6.96 sec.

Manthan Shah (2016) explained the comparative end time-period result in a diagrid as a graph demonstrated that less than the conventional frame.

In respected to time period, diagrid structure is recognized best from above review than conventional building system.

Story Drift

Rohitkumar Singh (2014) studied assessment consequent of the maximum drift is 4.4 mm of diagrid frame due to load but 8.8 mm for the conventional structure system.

Harish Varsani (2015), Manthan Shah (2016) and Deepika R. (2016) verified the comparative results of diagrid showed to the graph is significantly less under the load of story drift in certainly compared to the conventional structural system.

Panchal and Patel (2014) illustrated the comprehensive design and analysis of structural system with 20 stories of diagrid and conventional frame structure. ETABS software has been used to structural modelling and analysis. The author deduced that the lateral load of the studied is counterattack by diagonal column thereat the story drift is numerous lower in the diagrid structure than the conventional structural system.

Therefore, the drift of the story is less than conventional structures acknowledged from above.

Top Story Displacement

Rohitkumar Singh (2014) showed the result of the comparison of the top floor is 18.8 mm and 34.7 mm for the structural system of diagrid and conventional in respectively.

Harish Varsani (2015) investigated in comparison with the conventional structural system; the top story displacement of lateral load is substantially lower by the diagonal column than conventional system. The maximum displacing is 172.7mm for the conventional building frame, with just 31.6mm is being observed for diagrid frame structure.

Manthan Shah (2016) carried out the evaluation result for top story displacement in type of outline likewise demonstrated that the example of the plot is similar be that as it may; for the conventional frame system the total displacement values are rather higher when designed in radical sizes of column. Therefore, this has established the effectiveness of diagrid frame system.

Raghunath Deshpande (2015) examined the correlation investigated of 60-story with 24.0 m X 24.00 m typical plan with conventional structural system and core wall of diagrid structural system utilizing ETABS. The comparative results of deflection for both systems are also observed for each story. In conventional structural system, maximum deflection is 84.90 mm whereas only 75.00 mm found diagrid structural system.

Consequently, the top story displacement mentioned above is lower compared to conventional structural system.

Steel Mass Usages

Rohitkumar Singh (2014) evaluated in conventional structural system, the result of the comparison is a steel weight at 260 KN, whereas in a diagrid structure at 170 KN the internal column of the diagrid system has found that the reinforcement area is around half-required in a conventional building.

Manthan Shah (2016) depicted the high efficiency and visual appearance of the diagrid structure is high in steel. For a 24 story structure, the weight of the conventional building frame is 100 percent higher.

Raghunath Deshpande (2015) extracted the diagrid structural result utilizes steel 11247 tons that is lower than 28 percent of conventional building which utilizations 15255 tons.

Thus, less steel consumption used in the overall diagrid structure system compared to conventional structure system.

Conclusion

A brief review of several literatures presented structural performance of diagrid structural system in tall building. From the above results, the following has been analyzed and studied and concluded:

1. The diagrid structure performs better overall assessment consideration including effectiveness, fluidity and sustainability development.
2. For the most cost-effective section, the optimal angle range of diagrid is 65 degrees to 75 degrees.
3. Compared to other conventional structures found diagrid have higher stiffness.
4. Diagrid structure have less deflection as compared to the other structure.
5. Weights of the structure gets reduced to a greater extent due to which structure has more resistance to lateral force.
6. Displacement of each story, story drift and shear are observed to be lower in diagrid structural system as compared to conventional structural system.
7. Diagrid structures added aesthetic look and gives more interior space because of fewer columns, the building façade can also be more efficiently planned.
8. Diagrid columns on the periphery resist the lateral load, while the internal columns and the peripheral diagonal columns resist the gravity load. Inner columns will therefore only be designed for vertical load.
9. In addition, as the peripheral diagonal column lever arm increases, the structural diagrid is efficiently added to the lateral load resistance.
10. The diagrid structure system makes the steel consumption more economical than other conventional structural system. Therefore, diagrid structure becomes cost-effective and environmentally friendly.

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