PARAMETRIC STUDY OF TALL STRUCTURES WITH DIAGRID

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Abstract : In the present study parametric study of tall structures with diagrid structural system is carried out. Diagrid is an exterior structural system which resists the lateral forces by axial actions of diagonals provided in periphery. The main objective was to determine the optimum module size of diagrid. In this study five steel buildings having typical plan area and loadings were considered. of 12, 24, 36, 48 and 60 storeys were analyzed for the 4, 6 and 8 storey diagrid module size. The analysis was carried out in ETABS 2017 software. Parameters like fundamental time period, maximum storey displacement, maximum storey drift, maximum base shear were considered for the present study.

***Keywords* - Diagrid structure, Tall Buildings, Lateral Load Resisting System, ETABS 2017**

I. INTRODUCTION

Early tall building systems started with steel/iron frame structure which minimized the dimensions of the structural members at building perimeters. In this system, large openings were filled with transparent glasses and steel/iron members were clad with solid materials. Later on, new cladding concept of curtain walls was developed with the emergence of new structural systems. Most of tall buildings employed steel rigid frame with wind bracings as a structural system, and were quite over-designed as the advanced structural analysis techniques and computer software were not available at that time. Innovative structural systems like composite structures, mega-frames, tubes, core-and-outrigger structures and artificially damped structures are some of the new developments since the 1960s. The diagrid system, however used at few places in past but utilized for buildings with unique shapes and form, developed in the beginning of twenty-first century; so diagrid can be considered as one of the latest structural systems for tall buildings. Diagrid structures are emerging as a new aesthetic trend for tall buildings in the modern age of architecture as a most versatile structural system and it is a special form of the space truss. Diagrid system gives unique façade and it can be identified at a first glance. Diagrid structural system differs from conventional braced systems in a way that, almost all the vertical columns are eliminated. Gravity load is shared approximately 50-50% in interior frame and peripheral diagrid and about 98% of lateral loads are taken by the peripheral diagrid system .

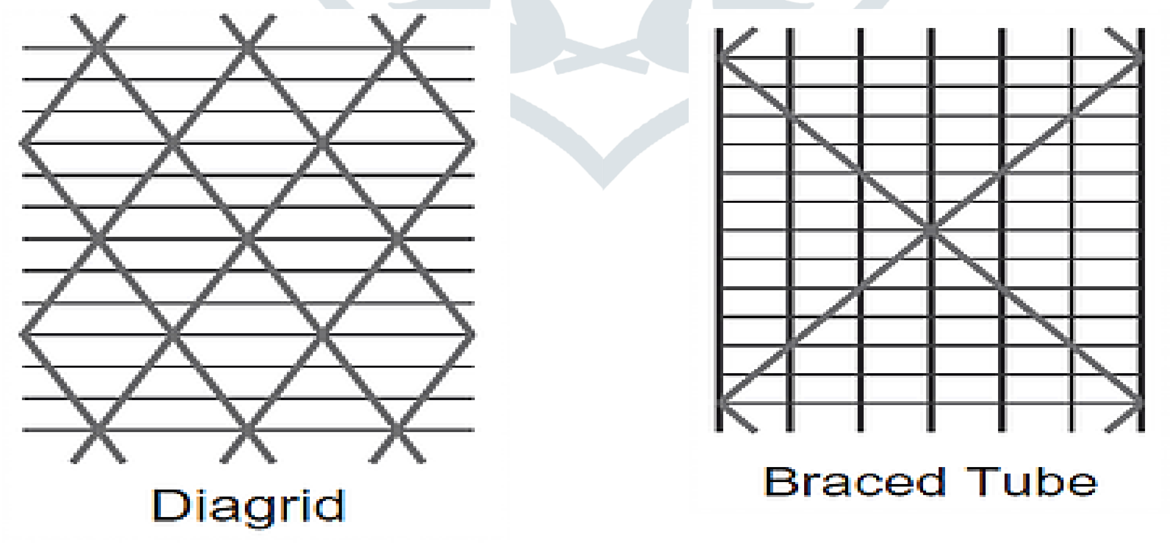

Fig. 1. Comparison between Braced Tube Structure and Diagrid Structure

Diagrid is an advancement of the Braced Tube system for lateral load resisting. In diagrid structures the columns in the periphery of the building are eliminated while in the braced tube structure the peripheral columns are closely spaced and the bracing is connected between columns.

II. PARAMETRIC STUDY OF DIAGRID STRUCTURES

For the parametric comparison, a rectangular building is selected. Five steel buildings for different heights are modeled, analyzed and designed in ETABS for diagrid structural systems. Analysis and design are carried out for dead load, live load, lateral earthquake load and lateral wind load. For earthquake loads, both static and response spectrum analysis are done. To consider extreme conditions of lateral loads, the buildings are considered to be located in Zone V. The parameters selected for the comparison are fundamental time period, maximum base shear, maximum storey displacement and maximum storey drift. Further, governing lateral force is also determined.

2.1 Building Configuration

Five buildings are designed with different number of storeys such as 12, 24, 36, 48 and 60 for diagrid structural systems. The physical properties and data of the building considered for the present study is as follows:

Plan Area	24 m X 36 m
Location	Bhuj
Typical Storey Height	3 m
Steel Sections	Fe 250
Concrete (Slabs)	M 25
Dead Load	3 kN/m2
Live Load	2.5 kN/m2
Wall/Cladding Load	4 kN/m
Slab Thickness	120 mm
Earthquake Load	IS 1893 (Part 1) : 2016
Importance Factor	1.2
Response Reduction Factor	5
Modal Damping	2 %
Wind Load	IS 875 (Part 3) - 2015
Basic Wind Speed	50 m/s
Steel Design Code	IS 800 : 2007
Limiting Top Storey Displacements	H/500
Limiting Inter Storey Drifts	0.004h
Beam Sections	ISMB sections with cover plates
Column Sections	Square Box Sections
Diagrid Sections	Square Box Sections

Table 1. Preliminary Building Data

2.2 Diagrid Building

The structural elements like columns, beams and diagrids are assigned structural steel properties while the slabs are considered of RCC. All sections in buildings are optimized for design sections. For that, all buildings are divided into three parts along the height of the buildings. For the design of diagrids and columns, built-up box sections are used and for the design of beams, Indian Standard I-Sections are used. The typical plan, 3D views of a 24 storey diagrid building with 4, 6 and 8 storey module are shown in figure.

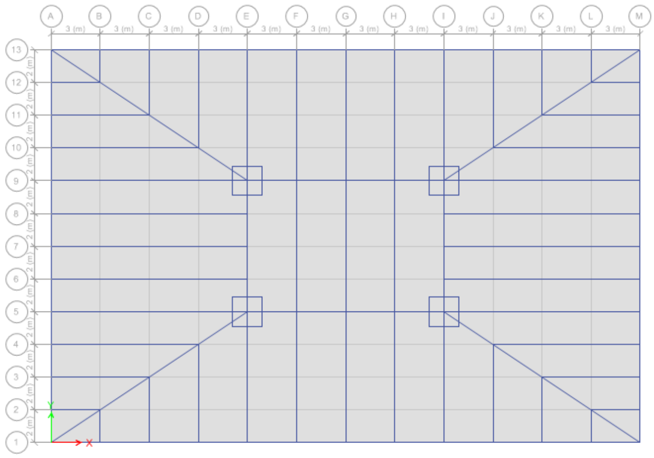

Fig. 2 Typical Floor Plan

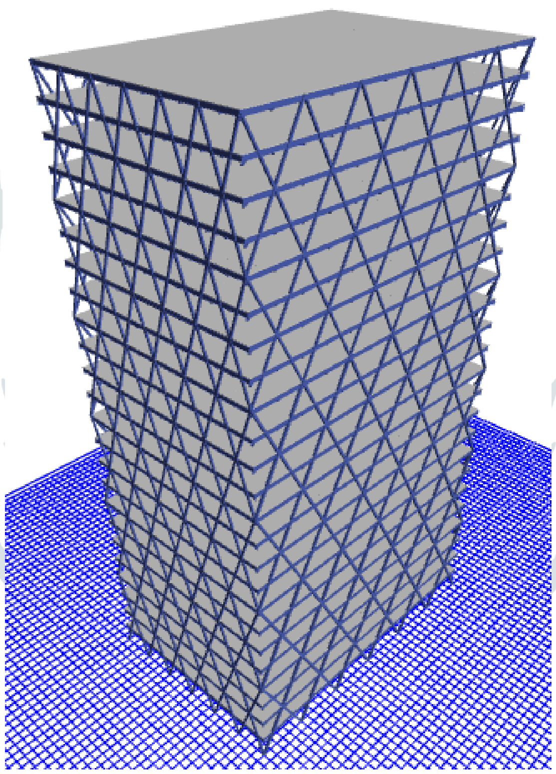

Fig. 3. 3D View of 24 Storey Building - 4 Storey Module

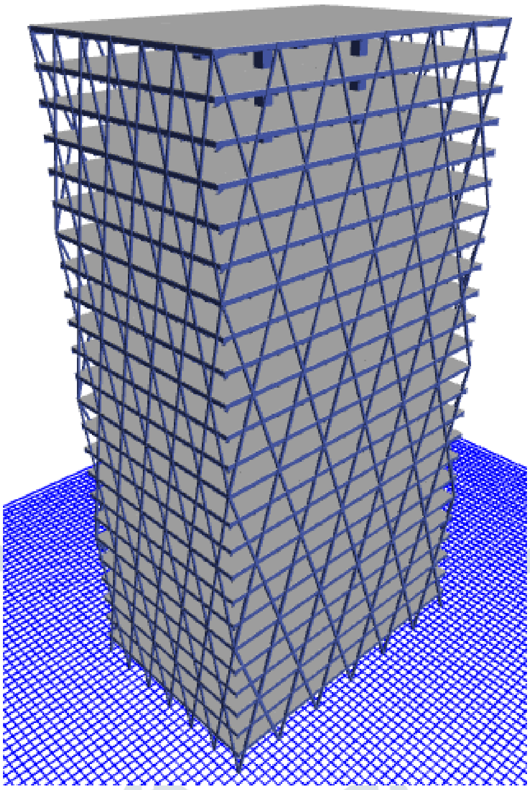

Fig. 4. 3D View of 24 Storey Building - 6 Storey Module

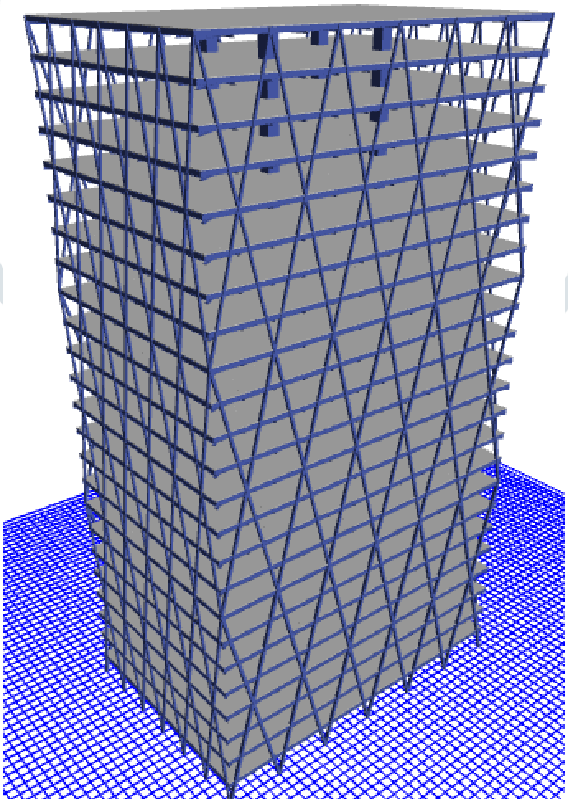

Fig. 5. 3D View of 24 Storey Building - 8 Storey Module

III. RESULTS AND DISCUSSION

After analyzing and designing all the structures, the governing loads for each building are tabulated in the Table 2. It is observed that in diagrid system earthquake forces are predominant up to 24 storeys . This means wind forces are predominant after 24 storeys in diagrid system.

	No. of Storey	12	24	36	48	60
Module	M – 4	EQ	EQ	WL	WL	WL
	M – 6	EQ	EQ	WL	WL	WL
	M – 8	EQ	EQ	WL	WL	WL

Table 2. Governing Loads

3.1 Time Period Comparison

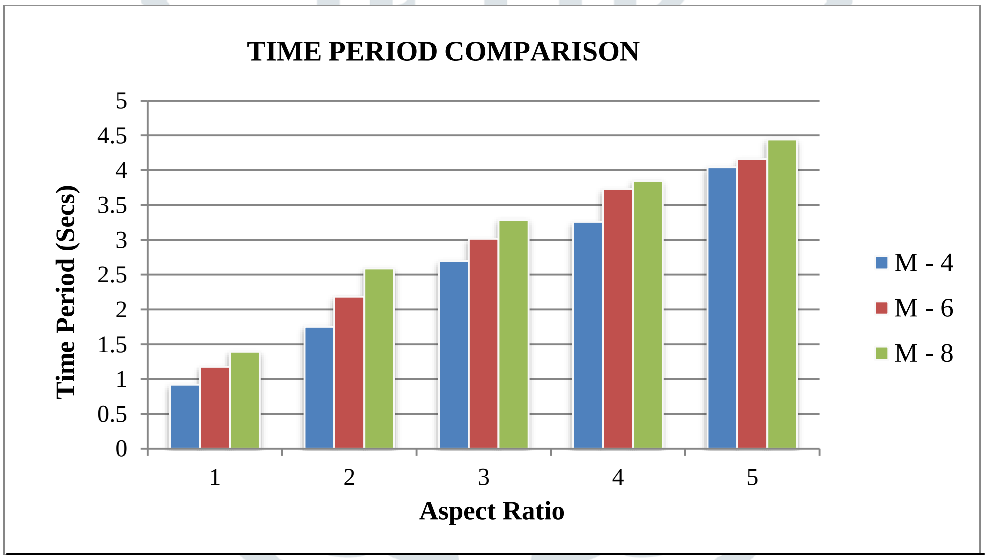

Fig.6. Time Period Results

It is observed that with the increase in the module size increases the modal time period i.e. the system is more stiffer for module-4 compared to module-6 and module-8.

3.2 Maximum Base Shear

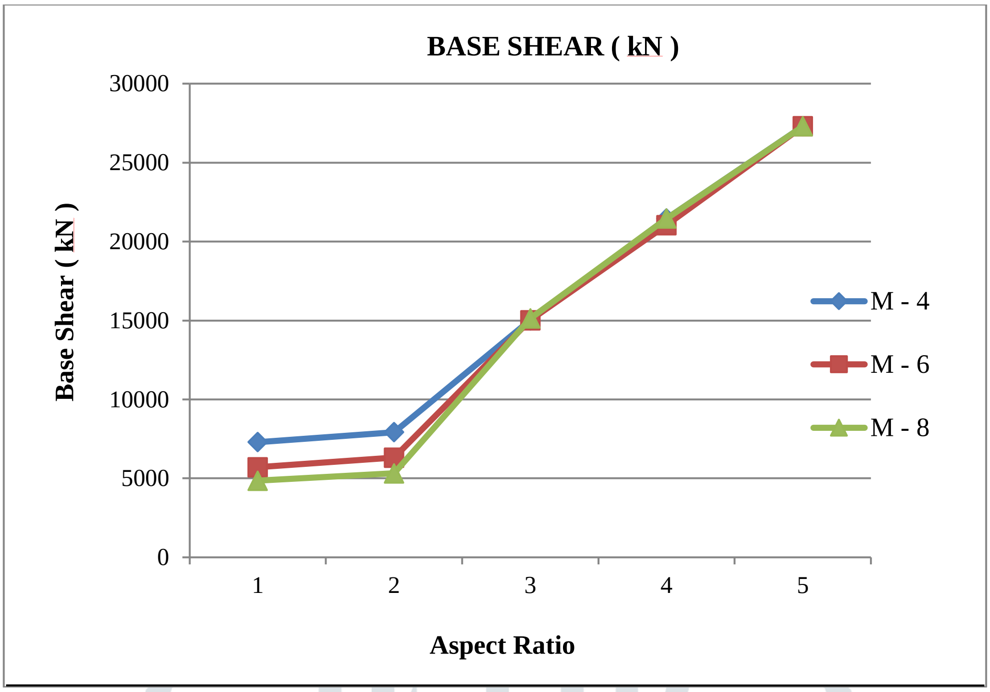

Fig.7. Base Shear Results

4-Storey Module Diagrid system is stiffer than the other module, it attracts more lateral force and hence it has more base shear up to 24 storey buildings. After 24 storeys, static wind loads takes hold and becomes governing forces and the base shear is governed by static wind loads. Thus after 24 storeys the base shear for is observed to be similar.

3.3 Maximum Storey Displacement

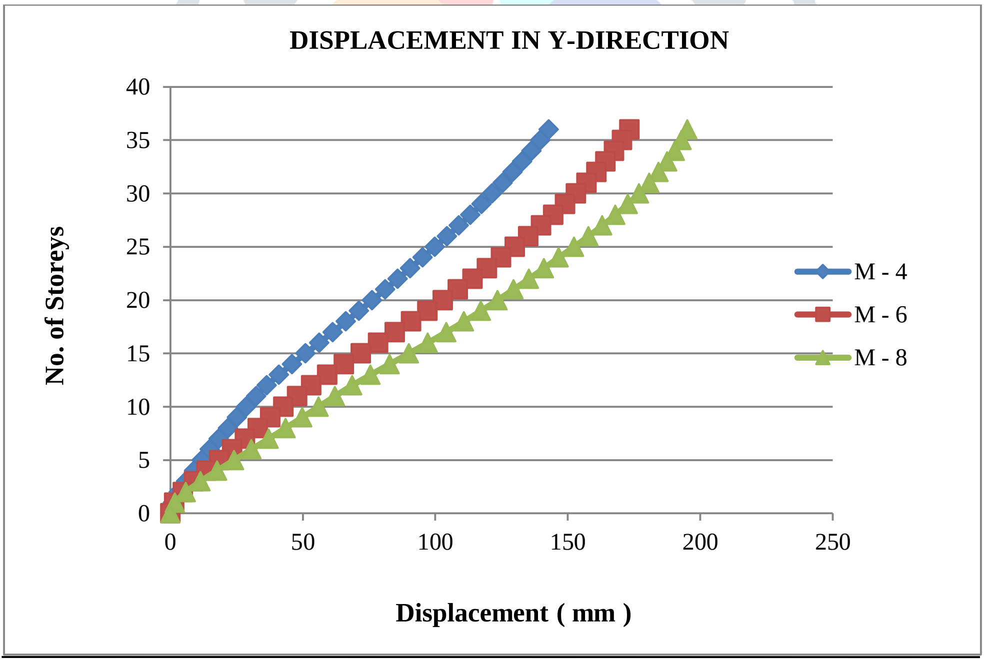

Fig.8. Maximum Storey Displacement Results

From results it is observed that the displacement of all models is less for 4-storey module size. As the area obstructing the wind decreases with the increase in module size the lateral displacement of the sructure increases.

3.4 Storey Drift Ratio

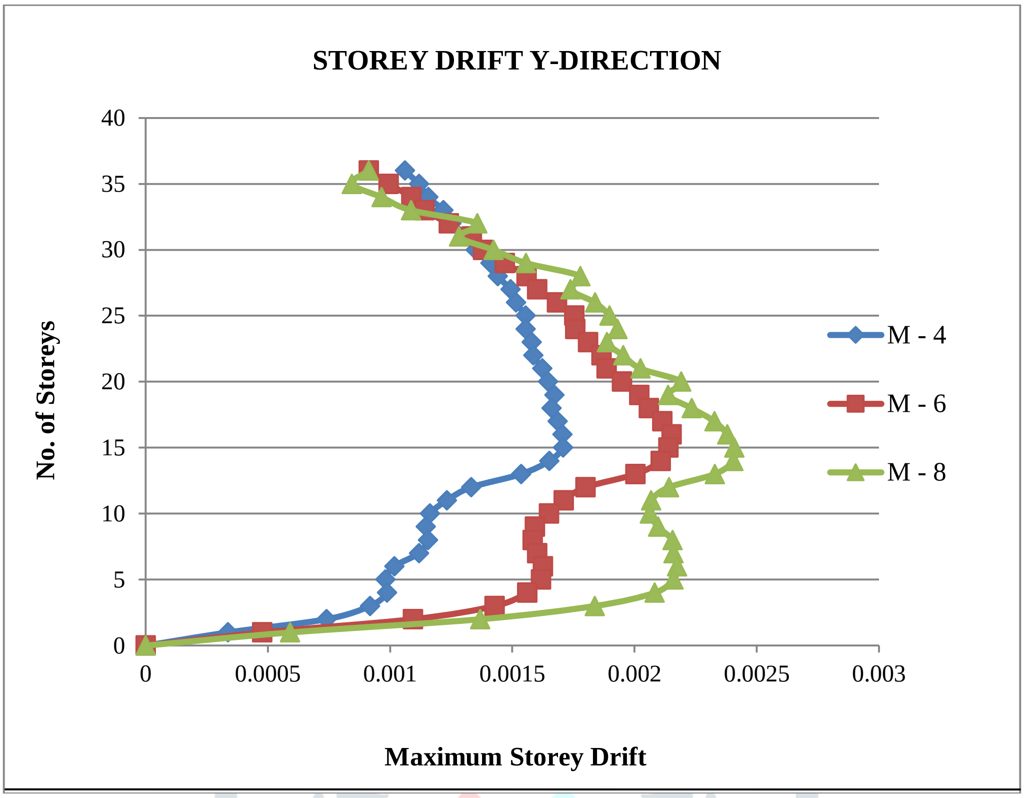

Fig.9. Storey Drift Ratio Results

From the results obtained the storey drift was much higher for 8-storey Module as compared with other models. 4-storey Module has the minimum value of storey drift compared with other models.

IV. CONCLUSION

From the above results it is concluded that diagrid serves as the efficient lateral force resisting system. Diagrid structural system has emerged as a better solution for lateral load resisting system in terms of lateral displacements, steel weight and stiffness. It is stiff enough to resist wind forces upto higher heights. As the module height increases building becomes flexible and resistance to wind decreases. Aspect ratio 3 can be marked as the point of transition for diagrid structures where wind forces are becoming predominant over earthquake forces. It was concluded from analysis of various models that 4-storey module acts as the most effective module size.

REFERENCES

[1] Ali, Mir M., and Sum Moon Kyoung. “Structural Developments in Tall Buildings: Current Trends and Future Prospects.” Architectural Science Review, 2007: 205-223.
[2] Boake T. M , “ Diagrids, the new stability system : combining architecture with engineering” ,University of Waterloo 2013 .
[3] Boake T. M, “ The Emergence of the diagrid – It's all about the node”, International Journal of High rise buildings vol. 5, 293-304, 2016.
[4] Elena, Mele, Maurizio Toreno, Brandonisio Giuseppe, and De Luca Antonello. “Diagrid structures for tall buildings: case studies and design considerations.” The Structural Design Of Tall And Special Buildings, 2014: 124-145.
[5] Elena, Mele, Toreno Maurizio, Brandonisio Giuseppe, and De Luca Antonello. “Diagrid Structures for Tall Buildings: Case Studies and Design Consideration.” The Structural Design of Tall and Special Buildings, 2014: 124-145.
[6] Giovanni, Maria Montuori, Mele Elena and De Luca Antonello, “ Design criteria for diagrid tall buildings : Stiffness versus strength ”, The structural design of tall and special buildings, 2013.
[7] Jani, Khushbu D., and Paresh V. Patel. “Design of Diagrid Structural System for High Rise Steel Buildings as per Indian Standards.” Structures Congress 2013 © ASCE 2013, 2013: 1070-1081.
[8] Jani, Khushbu, and Paresh V. Patel. “Analysis and Design of Diagrid Structural System for High Rise Steel Buildings.” Procedia Engineering, 2012: 92-100.
[9] Kim, J., Y. Jun, and Lee Ho. “Seismic Performance Evaluation of Diagrid System Buildings.” 2nd Speciality Conference on Disaster Mitigation, 2010.

[10] Kim, Jong Soo, Young Sik Kim, and Seung Hee Lho. “Structural Schematic Design of a Tall Building in Asan using the Diagrid System.” CTBUH 2008 8th World Congress. Dubai, 2008.
[11] Kwon, Kwangho, and Jinkoo Kim. “Progressive Collapse and Seismic performance of Twisted Diagrid Buildings.” International Journal of High-Rise Buildings, 2014: 223-230.
[12] Kyoung, Soon Moon, J. Connor Jerome, and E. Fernandez John. “Diagrid Structural Systems for Tall Buildings: Characteristics and Methodology for Preliminary Design.” The Structural Design of Tall and Special Buildings, 2007: 205-230.
[13] Kyoung, Sun Moon. “Diagrid Structures for Complex-Shaped Tall Buildings.” Procedia Engineering, 2011: 1343-1350.
[14] Kyoung, Sun Moon. “Diagrid Structures for Complex-Shaped Tall Buildings.” Advanced Materials Research, 2012: 1489-1492.
[15] Mir, Ali M., and Kyoung Sun Moon. “Structural Developments in Tall Buildings: Current Trends and Future Prospects.” Architectural Science Review, 2007: 205-223.
[16] Moon, K. “Design and Construction of Steel Diagrid Structures.” NSCC, 2009.
[17] Moon, Kyoung Sun. “Comparative Evaluation of Structural Systems for Tilted Tall Buildings.” International Journal of High-Rise Buildings, 2014: 89-98.
[18] Moon, Kyoung Sun. “Diagrid Structures for Complex-Shaped Tall Buildings.” Procedia Engineering, 2011: 1343-1350.
[19] Moon, Kyoung Sun. “Optimal Grid Geometry of Diagrid Structures.” Architectural Science Review, 2008: 239- 251.
[20] Moon, Kyoung Sun, Jerome J. Connor, and John E. Fernandez. “Diagrid Structural Systems For Tall Buildings: Characteristics And Methodology For Preliminary.” The Structural Design Of Tall And Special Buildings, 2007: 205-230.
[21] Zhang, Chonghou, Feng Zhao, and Yansheng Liu. “Diagrid tube structures composed of straight diagonals with gradually varying angles.” The Structural Design Of Tall And Special Buildings, 2010: 283-295.

Indian Standard Codes

[22] “IS 1893 (Part 1) : 2016.” Criteria For Earthquake Resistant Design Of Structures. Bureau of Indian Standards.
[23] “IS 800:2007.” General Construction In Steel - Code Of Practice. Bureau of Indian Standards.
[24] “IS: 875 - 2015.” Code Of Practice For Design Loads (Other Than Earthquake) For Buildings And Structures. Bureau of Indian Standards.