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Structural Comparison of Diagrid Building with Tubular Building

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***Abstract*— Today's tall building concept is rooted in architectural features of building geometry along with stiffness and lightness. Hence, architectural concept and structural concept must go hand in hand. Based on this many lateral load resistance systems have been developed. Tubular system is the latest technology in this area. Recently, the high rise building technology relies on this system. Diagrid is another latest invention in this area, which is a mutation of Tubular system. Diagrid is a better choice, where Tubular system failed to fulfil the requirements, especially in the case of complex geometries. In this paper the Diagrid and Tubular buildings are compared in order to study the structural efficiency of both type of buildings. For this purpose, comparison is made among different models of Diagrid building and respective models of Tubular building. 24, 30, 36, 42, 48, 54, 60, 66 storey models of both Diagrid and Tubular buildings are generated in ETABS2015 software and analysed. The loads are taken from IS: 875 – 1987. The earthquake load is applied as per 1893-2002. The analysis results are compared in terms of 'Displacement', 'Storey drift', 'Time period' and 'Storey shear'. The values of these parameters of Tubular building are found to be larger than that of Diagrid building under same loading condition. The comparison of analysis results revealed that the Diagrid building is structurally more efficient than the Tubular building.**

Keywords—Diagrid Building; Tubular Building; Lateral Load Resistance; Tall Building

I. INTRODUCTION

The complex geometries of buildings along with high cost of land emphasis the need for considering architectural ideas and structural concepts hand in hand. As the building height increases, the lateral load resistance system is more important than the gravity load resistance system. There are a number of lateral load resistance systems, such as Moment resisting frame system, Braced frame system, Shear wall system, Advanced structural forms-tubular systems. In these the tubular system is found to be more efficient both in terms of reduction in self weight and better lateral load resistance [3]. They are made with strong exterior frame to resist lateral loads, allowing the interior frame to take only the gravity loads. The distance between the interior and the exterior is spanned with beams or trusses and intentionally left column free. This maximizes the effectiveness of the perimeter tube by transferring some of the gravity loads within the structure to it and increases its ability to resist overturning due to lateral loads. Diagrid or Exo diagonal system is a new concept in lateral load resistance of high rise buildings. These are the latest mutation of tubular structure, in which tubes are arranged diagonally across the building perimeter [3]. i.e. the columns are placed in an inclined position to make a triangular structural configuration, so that all the loads acting on the diagrid will get distributed as axial forces; rather than bending or shear [4]. Tubular configuration utilize overall building plan dimension to counteract the overturning moment. But this potential bending efficiency is not fully achievable because of shear deformation that arise in the building webs. On the other hand the diagrid systems, which provide shear resistance and rigidity by means of axial action in the diagonal members, rather than bending moment in beams and columns, allows for a nearly full exploitation of the theoretical bending resistance [3].

Today's building technology prefer tubular concept for high rise buildings. But diagrid is also an important lateral load resistance system, which can be used for complex geometries of building. Hence, in this study the diagrid building and tubular building are compared in order to reveal the structural advantages of diagrid building, if any, over the tubular building, so that to add the importance of diagrid as a lateral load resistance system. For the comparison eight models of diagrid building and eight models of tubular building are generated in ETABS2015 software. The number of stories is taken as the criteria for the selection of models. 24, 30, 36, 42, 48, 54, 60 and 66 storey models are used for the study.

II. RELATED WORKS

A. Optimum Angle of Diagrid Structural System [1]

This work has been done by Nishith B. Panchal et.al. This paper involves the modeling of diagrid structures of 24, 36, 48 and 60 stories. The diagrid structure of each storey height is designed with diagonals placed at various uniform angles as well as gradually changing angles along the building height in order to determine the optimal uniform angle for each structure with a different height and to investigate the structural potential of diagrids with changing angles. In this paper, the comparison study of 24-storey, 36-storey, 48-storey and 60-storey of diagrid structural system with a diagrid angle 50.2°, 67.4°, 74.5° and 82.1° is presented. The comparison of analysis of results in terms of top storey displacement, storey drift, time period, angle of diagrid and steel and concrete consumption are included in this paper. From the study it was observed that the Diagrid angle in the region of 65° to 75°

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provides more stiffness to the diagrid structural system which reflects the less top storey displacement, storey drift, time period and storey shear. It also indicates economy in terms of consumption of steel and concrete.

B. Analysis and Design of Diagrid Structural System for High Rise Steel Buildings [2]

This is the work done by Khushbu Jani and Paresh V. Patel. The analysis and design of 36 storey diagrid steel building is presented in this paper. A regular floor plan of 36 m × 36 m size is considered for the study. The modeling and analysis of structural members have been done in ETABS software. All structural members are designed as per IS 800:2007 considering all load combinations. Dynamic along wind and across wind are considered for analysis and design of the structure. Load distribution in diagrid system is also studied for 36 storey building. Similarly, analysis and design of 50, 60, 70 and 80 storey diagrid structures are also carried out. The analysis results are compared in terms of time period, top storey displacement and inter-storey drift. From the study it is 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 peripheral diagonal columns. So, internal columns need to be designed for vertical load only. Lateral and gravity load are resisted by axial force in diagonal members on periphery of structure, which make system more effective.

III. MODELLING AND ANALYSIS

Building models of plan 32 m x 32 m are generated in ETABS2015. The storey height is 3.8 m. Four interior columns are used for carrying a part of gravity load. In the present study models of both the diagrid buildings and tubular buildings are modelled. The models of various number of storey ie, 24, 30, 36, 42, 48, 54, 60, 66 are generated in ETABS 2015, which are represented by D1, D2, D3, D4, D5, D6, D7, D8, T1, T2, T3, T4, T5, T6, T7 and T8. Here 'D' represents, diagrid building model and 'T' represents tubular building model. The digits '1 to 8' represents the number of storey from 24 to 66 respectively.

In the diagrid models the peripheral diagonals are placed at 8 m spacing. The diagonal angle is kept uniform for each model. The end conditions for diagonals are assumed as pinned and the support conditions as fixed. 6-storey diagrid module is used for modelling. Based on the 6-storey module the diagonal angle provided is 70.6°.

In tubular building models columns are placed at closer spacing of 4 m on outer periphery of the building. In order to model these buildings, the member sections are kept same as that of diagrid building for the purpose of comparison. Then the analysis results of two types of buildings are compared in terms of displacement, storey drift, time period and storey shear.

The characteristic strength of concrete and steel are taken as 40N/mm^2 and 415N/mm^2 respectively. The design of building models have been done based on Indian Standards. The design dead load and live load are taken from IS: 875 (Part 1) – 1987 [7] and IS: 875 (Part 2) – 1987 [8] respectively. The live load assigned on roof level is 1.5KN/m^2 and that on typical floor level is 2KN/m^2. The earthquake loads are taken from IS: 1893-2002 [5]. The earthquake design is based on zone III. Zone factor of 0.16, Importance factor of 1, Soil type II and response reduction factor 5 are adopted as per IS 1893 (Part 1): 2002 [5]. The design wind load is computed based on location Calicut, Wind speed 39 m/s, Terrain category 2, Structure class B, Risk Coefficient 1 and Topography factor 1 as per IS: 875 (Part 3) – 1987 [9]. The models are generated in ETABS 2015 software and linear static analysis have been done.

The structural plan used for the present study is given in the Fig.1. The member sections used for diagrid building models and tubular building models are given in Table I and Table II. Initially, preliminary member sections are assumed and modelling and analysis have been done by using ETABS 2015 software. The member sections are revised for failed members. The Table 1 and Table 2 represents the revised member sections for diagrid and tubular models presented in this study. The member sections of tubular building are kept same as that of diagrid building for the purpose of comparison so that the variation in results can be studied under same building configuration and loading condition. The models D-1 and T-1 used for the study are shown in Fig.2. Similarly, all other models are also generated in ETABS2015 software.

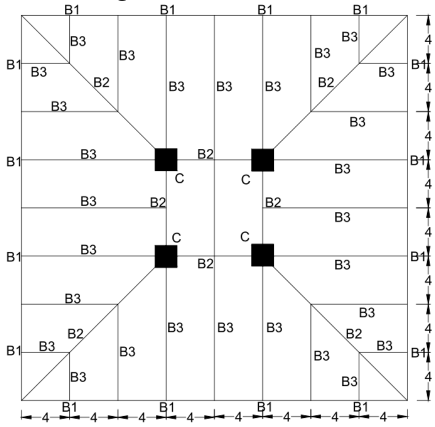

Fig. 1. Structural plan.

TABLE I. MEMBER SECTIONS FOR DIAGRID MODELS

Model	Member Section				
	Beam			Column	Diagrid
	B 1	B 2	B 3		
D 1	300X500	300X1000	300X500	1200X1200	500X500
D 2	300X500	300X1000	300X500	1250X1250	540X540
D 3	300X500	300X1000	300X500	1380X1380	600X600
D 4	300X500	300X1000	300X500	1510X1510	660X660
D 5	300X500	300X1000	300X500	1650X1650	690X690
D 6	300X500	300X1000	300X500	1790X1790	720X720
D 7	300X500	300X1000	300X500	1900X1900	760X760
D 8	300X500	300X1000	300X500	2200X2200	810X810

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TABLE II. MEMBER SECTIONS FOR TUBULAR MODELS

Model	Member Section				
	Beam			Column	
	B 1	B 2	B 3	Core	Peripheral
T 1	300X500	300X1000	300X500	1200X1200	500X500
T 2	300X500	300X1000	300X500	1250X1250	540X540
T 3	300X500	300X1000	300X500	1380X1380	600X600
T 4	300X500	300X1000	300X500	1510X1510	660X660
T 5	300X500	300X1000	300X500	1650X1650	690X690
T 6	300X500	300X1000	300X500	1790X1790	720X720
T 7	300X500	300X1000	300X500	1900X1900	760X760
T 8	300X500	300X1000	300X500	2200X2200	810X810

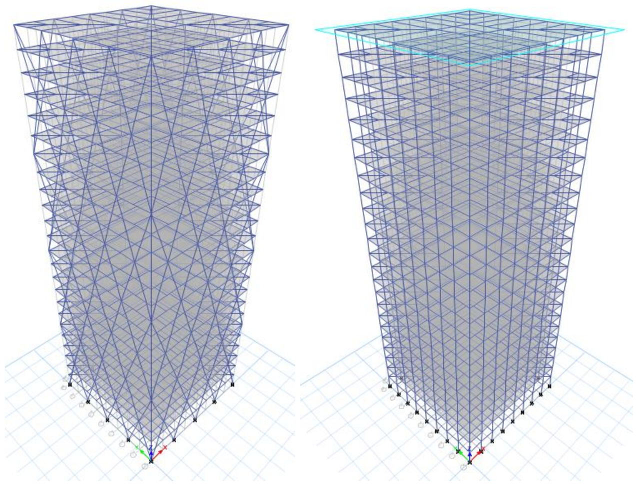

Fig. 2. Model D-1 and T-1.

IV. ANALYSIS RESULTS

A. Displacement

The Diagrid building models and Tubular building models are compared in terms of displacement in the Fig.3. The results are considered under WINDX load case.

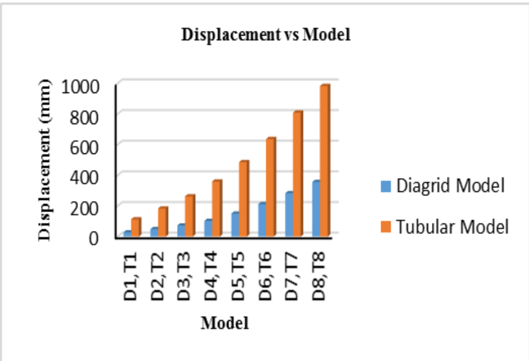

Fig. 3. Displacement results of Model D and T.

The two types of models are compared under WINDX load case. The displacement of tubular models are found to be more than that of diagrid models. For example, the maximum displacement of model D-1 is 28mm. The maximum displacement obtained for model T-1 is 113.2mm.i.e. the maximum displacement of model T-1 is 304.3% more than that of model D-1. While, the maximum displacement of model T-8 is only 175.9% more than that of model D-8. i.e the variation in displacement values is found to decrease from 24 storey model to 66 storey model. Though the variation in displacement decreases from lower to higher models, the displacement of tubular building is found to be of very large value while comparing with the diagrid model results.

As per code IS: 456-2000 [6], clause: 20.5, page no. 33, the maximum top storey displacement due to wind load should not exceed H/500, where H is the total height of the building. Both the building models satisfy this criteria. But the lateral displacement of tubular building model is very larger than that of diagrid building model. i.e. the tubular building model displaces more than that of diagrid model under same load.

B. Storey Drift

The storey drift values of Diagrid building models and Tubular building models are compared under EQ X load case in the Fig.4.

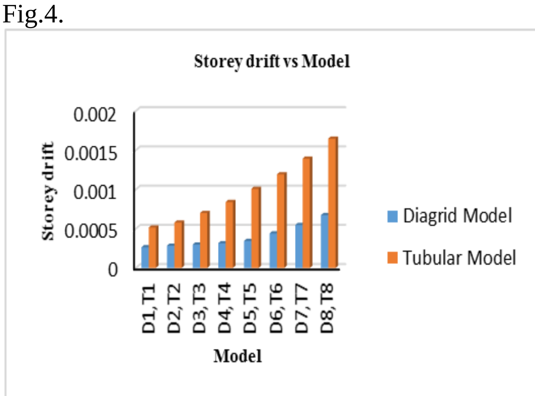

Fig. 4. Storey drift results of Model D and T.

While comparing the storey drift under EQ X load case, the values are found to increase from lower to higher models for both type of buildings. The storey drift value of tubular building is found to be more than that of diagrid building. For model D-1 the maximum storey drift value is 0.000263 and that of model T-1 is 0.000514. Similarly, for all other models the storey drift value of tubular building is very larger than that of diagrid building. The maximum storey drift of model T-1 is 95.4% more than that of model D-1. The variation in storey drift is found to increase upto 48 storey model and reaches 192.7%, then the variation decreases for the remaining three models. For 66 storey building, the variation is 144.7%.

For earthquake load, as per code IS: 1893-2002 [5], clause: 7.11.1, page no: 27, the storey drift in any storey due to minimum specified lateral force with partial load factor of 1.0 should not exceed 0.004 times storey height that is H/250, where H is thestorey height in meter. The storey drift values are found to be within the permissible limit.

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C. Time Period

The modal analysis results of Diagrid building and Tubular building are compared in Fig.5. The time period for twelve mode shapes are considered for each model.

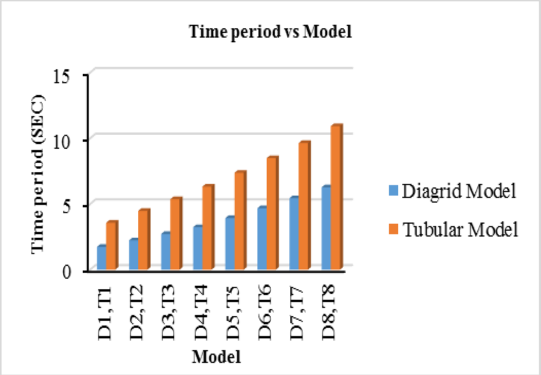

Fig. 5. Time period results of Model D and T.

The time period increases from lower to higher models for both type of building models. While comparing the two models, it is clear that the time period of tubular building models are larger than that of diagrid building model. For model D-1 the maximum time period is 1.74sec and that of model T-1 is 3.579sec. Similarly, the time period of tubular building is more than that of diagrid building for all other models also. The maximum time period of model T-1 is 105.7% more than that of model D-1. This variation in time period decreases from lower to higher models and reaches to 74.1%. The building natural time period is obtained from the equation;

$$T = 2\ \Pi * \sqrt{(m/k)} \qquad (1)$$

Where, 'T' is the time period, 'm' is the mass, 'k' is the stiffness. i.e. the time period can be related to the stiffness of the building. Since the time period of tubular building is more than that of daigrid building, it's stiffness will be less than that of diagrid building.

D. Storey Shear

The storey shear of models of both the diagrid building and that of tubular building are compared under WINDX load case in the Fig.6.

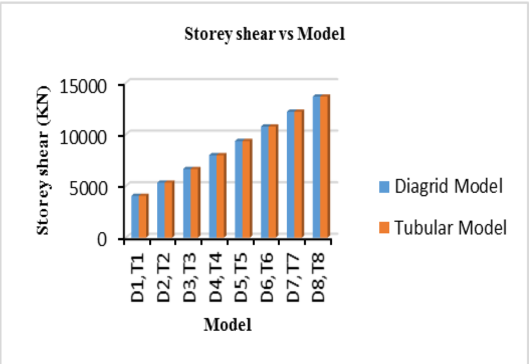

Fig. 6. Storey shear results of Model D and T.

The storey shear values increases while moving from lower models to higher models for both type of buildings. i.e. the maximum storey shear increases when the height of the building increases. While comparing both the types of building models, the storey shear are found to be almost same for respective models.

V. CONCLUSION

The models of Diagrid building and Tubular building have been generated in ETABS2015 software. The analysis and design have been carried out based on Indian Standards. For the sake of comparison the member sections and loading conditions are kept the same for both the type of models.

The comparison of analysis results reveales that the displacement, storey drift and time period of tubular building is greater than that of Diagrid building under same member sections and loading condition. The storey shear is found to be almost the same for both type of buildings. Many of the members of Tubular building have been failed while analyzing under the same loading conditions as that of Diagrid models. On the other hand the Diagrid models are found to resist these loads effectively by their axial action. It implies that the member sections of tubular building has to be increased or it has to be strengthened by some other means to carry the same amount of load.

The variation in analysis results of Diagrid and Tubular building decreases while moving to higher models. It indicates that these lateral load resistance systems are best suited for high rise buildings. Hence, the study on the selected models indicates that, the Diagrid building is structurally more efficient than Tubular building.

REFERENCES

[1] Nishith B. Panchal, Dr. V. R. Patel, Dr. I. I. Pandya, "Optimum Angle of Diagrid Structural System", International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869, Volume-2, Issue-6, June 2014

[2] Khushbu Jani , Paresh V. Patel , "Analysis and Design of Diagrid Structural System for High Rise Steel Buildings", Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference on Engineering (NUiCONE 2012), SciVerseScienceDirect, Procedia Engineering 51 (2013) 92- 100

[3] Maurizio Toreno, Raffaele Arpino, Elena Mele, Giuseppe Brandonisio and Antonello De Luca, "An Overview on Diagrid Structures for Tall Buildings", Journal of SEWCMarch 2012

[4] Kyoung-Sun Moon, Jerome J. Connor and John E. Fernandez, "Diagrid Structural Systems for Tall Buildings: Characteristics and Methodology for Preliminary Design", Published online in Wiley Interscience (www.interscience.wiley.com). DOI:10.1002/tal.311, Struct. Design Tall Spec. Build. 16, 205–230 (2007)

[5] IS: 1893(Part-I)-2002. Criteria for Earthquake Resistant Design of Structures. Bureau of Indian Standard, New Delhi.

[6] IS:456-2000. Plain and Reinforced Concrete- Code of Practice (Fourth Revision), Bureau of Indian Standard, New Delhi.

[7] IS: 875(Part-1)-1987. Code of practice for design loads (other than earthquake)for buildings and structures, Dead loads, unit weights of building materials and stored materials. Bureau of Indian Standard, New Delhi.

[8] IS: 875(Part-2)-1987. Code of practice for design loads (other than earthquake)for buildings and structures, imposed loads. Bureau of Indian Standard, New Delhi.

[9] IS: 875(Part-3)-1987. Code of practice for design loads (other than earthquake) for buildings and structures, wind loads. Bureau of Indian Standard, New Delhi.