Analysis Of Curved Perimeter Diagrid Lateral System

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***Abstract*— In recent years, the number of tall buildings being constructed has been rapidly increasing worldwide. Some buildings have been constructed with triangular exterior structural members, known as diagrid systems, which have been developed for structural effectiveness and architectural aesthetics. Selecting a curved structural system for tall building design involves many complex factors, such as wind behavior, structural efficiency , behavior of building due to wind.**

This paper presents various design and analysis strategies to mitigate wind-induced structural motions of tall buildings. The impact of recently-emerging relatively stiff structural systems, such as diagrids, is investigated. Recently diagrid structural system is adopted in tall buildings due to its structural efficiency and flexibility in architectural planning. Compared to closely spaced vertical columns in the framed tube, diagrid structure consists of inclined columns on the exterior surface of building. Analysis of 30 storey diagrid with core as shear wall building is presented. A curved perimeter plan is considered. ETABS software is used for modelling and analysis of structural members. All structural members are designed as per IS 800:2007 considering all load combinations. Along wind is considered for analysis and design of the structure. Load distribution in diagrid system is also studied for 30 storey building. Analysis results in terms of time period, top storey displacement and inter-storey drift is presented in this paper.

Keywords*— *Diagrid, Curved perimeter, analysis of structure, High rise buildings.

I. INTRODUCTION

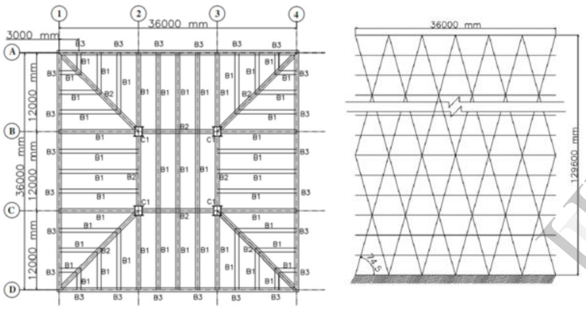
The rapid growths of urban population and consequent pressure on limited space have considerably influenced the residential development of city. The high cost of land, the desire to avoid a continuous urban sprawl, and the need to preserve important agricultural production have all contributed to drive residential buildings upward. As the height of building increases, the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. The lateral load resisting systems that are widely used are: rigid frame, shear wall, wall-frame, braced tube system, outrigger system and tubular system. Recently, the diagrid structural system is widely used. Since the application of the curved perimeter diagrid structural system for the unusual shape and site constraints of the Cyclone Tower in Asan (Korea),University of Cincinnati Athletic Center lead to the initial design of a perimeter diagrid lateral system. The Guangzhou International Financial Center designed by Wilkin-son Eyre has been topped out at the height of 437 meters, and the Lotte Super Tower designed by Skidmore, Owings and Merrill will soar into the skyline of Seoul with its height of 555 meters. To-day's prevalent use of diagrids in tall buildings is due to their structural efficiency and aesthetic potential. For a very tall building, its structural design is generally governed by its lateral stiffness. Compared to conventional orthogonal structures for tall buildings such as framed tubes, diagrid structures carry lateral wind loads much more efficiently by their diagonal member's axial action. In Korea, the diagrid system has been considered in projects for the Cyclone Tower in Asan, Lotte Super Tower in Seoul and Future-Ex in Daejeon. However, lack of studies on connection shape and node connection details makes it hard to employ the system to the buildings. So therefore, connection details should be suggested and developed in order to promote the application of the system and the generalization of the connections with secured safety should backup its application through structural performance evaluation and reliability verification for the connection details which have been suggested so far. In this study, the structural safety of the node connections in circular steel tube diagrid system which has been considered in the Cyclone Tower in Korea.

Fig (1): Cyclone Tower in Asan, (Korea)[1]

II. RELATED WORK

A. Analysis and Design of Diagrid Structural System for High Rise Steel Buildings[1]

Due to inclined columns, lateral loads are resisted by axial action of the diagonal compared to bending of vertical columns in the framed tube structure. Diagrid structures generally do not require core because lateral shear can be carried by the diagonals on the periphery of building. Analysis and design of 36 storey diagrid steel building is presented. A regular floor plan of 36 m × 36 m size is considered. ETABS software is used for modelling and analysis of structural members. All structural members are designed as per IS 800:2007 considering all load combinations. Dynamic along wind is 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 is carried out. Comparison of analysis results in terms of time period, top storey displacement and inter-storey drift is presented in the paper. 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 internal columns and peripheral diagonal columns. So, internal columns need to be designed for vertical load only.



Fig(2) : Floor plan and elevation details[1].

B. Diagrid Structural Systems for Tall Buildings: Charact - -eristics And Methodology For Preliminary Design [2]

Skyscrapers today are irregular-shaped, to the city landmarks and function as vertical cities to enable the efficient use of land. Diagrid structural systems are emerging as structurally efficient as well as architecturally significant assemblies For tall buildings. The paper presents a simple methodology for determining preliminary member sizes. The methodology is applied to a set of building heights ranging from 20 to 60 stories, and parameters for the optimal Values of the grid geometry are generated for representative design loadings. These values are shown to be useful For architects and engineers as guidelines to preliminary design. Associated architectural and constructability issues of diagrid structures are also discussed here. This study examined the influence of the diagonal angle on the behavior of diagrid type structures. It was found that, for 60-story diagrid structures having an aspect ratio of about 7, the optimal range of Diagrids angle is about 65° to 75°.

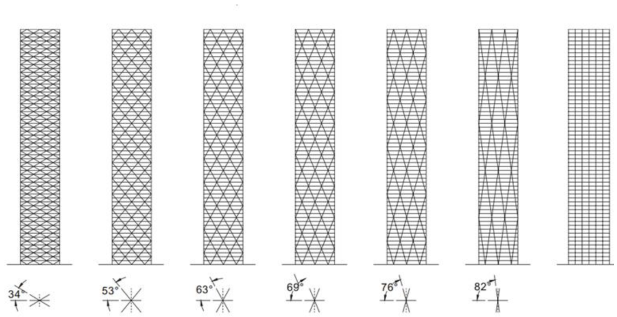


Fig (3): 60-story structures with various diagonal angles[2].

III. PROPOSED WORK

For all the studies, square shaped structures are taken. Hence, the structure is directly withstanding the wind force and circular shaped structures are also similar to the analysis of building. In this case the attempt is made to study the analysis of curved perimeter diagrid lateral system is studied with considering all types of load cases and load combinations as per IS 800-2002. The diagrids are perimeter structural configurations characterized by a narrow grid of diagonal members which are involved both in gravity and in lateral load resistance. Diagonalized applications of structural steel members for providing efficient solutions both in terms of strength and stiffness are new, however nowadays a renewed interest in and a widespread application of diagrid is registered with reference to large span and high rise buildings, particularly when they are characterized by complex geometries and curved shapes, sometimes by completely free forms.

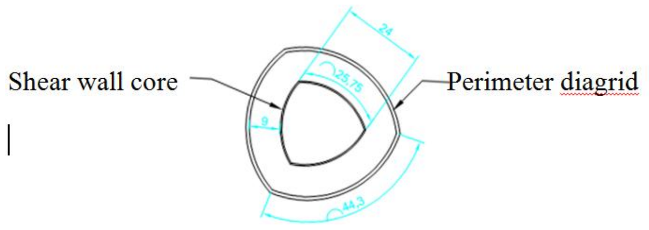
1. Analysis of 30 storey diagrid structure

1.1. Building configuration

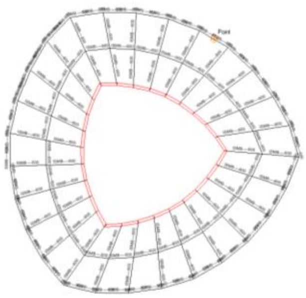
The 30 storey tall building is having 43.3 m external and 25.75m internal plan dimension. The storey height is 3.6 m. The typical plan and section are shown in Fig. In diagrid structures, pair of braces is located on the periphery of the building. The angle of inclination 700 is kept uniform throughout the height. The inclined columns are provided at five meter spacing along the perimeter. The interior frame of the diagrid structures is provided with the core shear wall of 400mm thick. The design dead load is automatically assigned in the software as self weight and live loads on floor slab as 2.5 KN/m2 is taken and the floor finish as 1.5KN/m2 from IS 875(part-2) -1987 [8]. The dynamic along wind loading is considered based on the basic wind speed of 33 m/sec (appendix A) and terrain category II as per IS:875 (part-3)-1987[9]. probability factor or risk coefficient factor K1as 1.05 (for Important buildings and structures/towers), terrain, height and structure size factor k2as1.2248, topography factor Ks as 1.0 (for upward wind slope less than 300)

The design earthquake load is computed based on the zone, Considered zone-III factor of 0.16 (Dharwad), medium soil, importance factor of 1.0 and response reduction factor of 5.0 From IS 1893-20002[5].

1.2. Building key plan and details



Fig(4): Proposed key plan of diagrid



Fig(5): sectional view

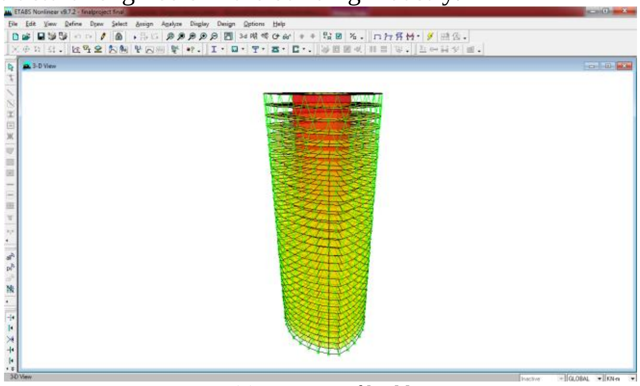
Table (1): Geometric parameters of the structure

Description		Value
Height of Diagrid structure		109.5 m
Number of story		30
Floor to floor height		3.6m
core Shear wall thickness		400mm
Internal perimeter beam distance		2.5m
External perimeter beam distance		5m
Diagrid column spacing		5m
Inclined angle of diagrid		70^0
Diagrid module		4 storey
All beams		ISMB 600
Diagrid Columns	1st to 20th floor	450mm pipe 25mm thick[1]
	21st to 30th floor	375mm pipe 12mm thick[1]

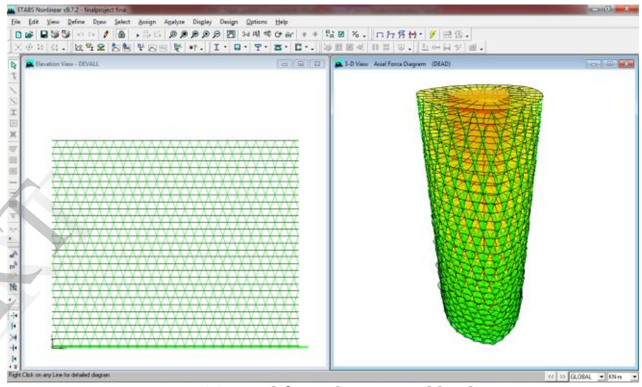
2. Modeling and Analysis of diagrid structure

Modeling, analysis and design of diagrid structure are carried out using ETABS software. For linear static and dynamic analysis the beams and columns is modelled by beam elements and braces are modelled by truss elements. The support conditions are assumed as hinged. All structural members are designed using IS 800:2007[6]. Secondary effect like temperature variation is not considered in the design, assuming small variation in inside and outside temperature.

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building systems. ETABS Version 9 features an intuitive and powerful graphical interface coupled with unmatched modelling, analytical, and design procedures, all integrated using a common database. Although quick and easy for simple structures, ETABS can also handle the largest and most complex building models, including a wide range of nonlinear behaviors, making it the tool of choice for structural engineers in the building industry.



Fig(6): 3D view of building



Fig(7): axial force due to Dead load

3. *Analysis Output*

Analysis Results of following values were obtained from ETABS software and collected to excel and then made the Chart of results.

- Time period
- Storey Displacements
- Storey Drifts
- Storey Shear

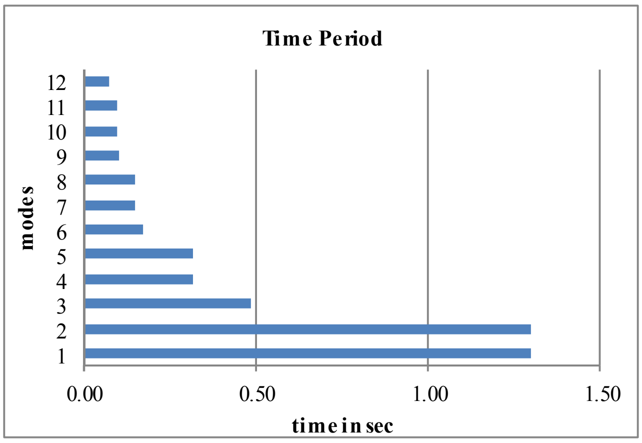


Fig (8): Time period for different mode shapes

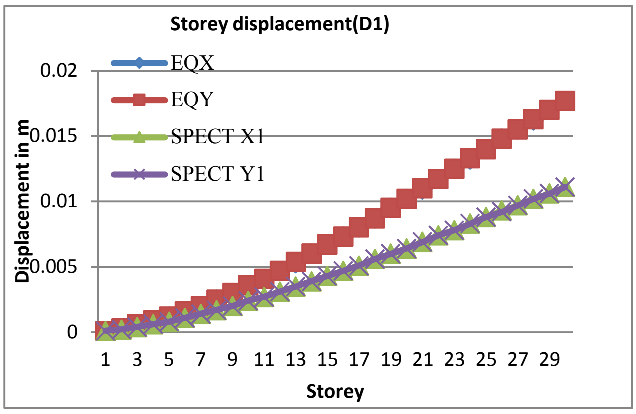


Fig (9): Storey displacement due to earthquake loads

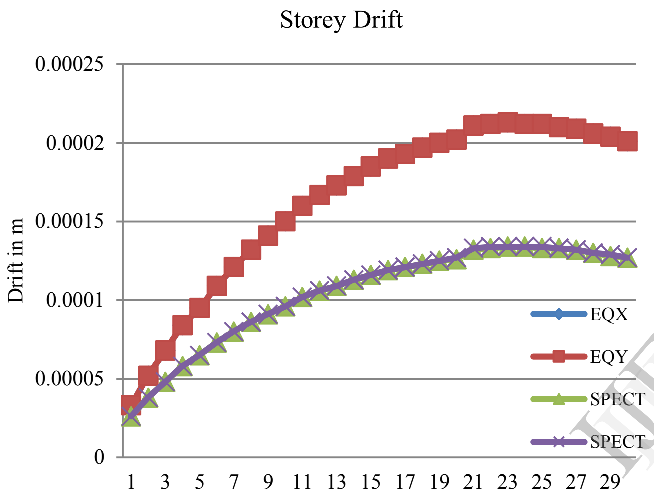


Fig (10): Storey drift due to static and dynamic earthquake loads

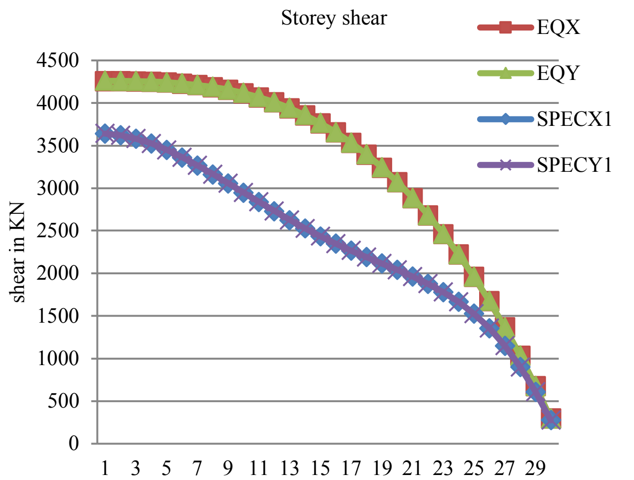


Fig (11): Storey shear due to static and dynamic earthquake loads

Table (2): Total loads on structure

Sl no	Type of load	Value in kN
1	Total Wind load	5739
2	Total earthquake in X-direction	4829
3	Total earthquake in Y-direction	4388
4	Total live load(LL+FF)	129990
5	Total Dead load	312837

IV. CONCLUSION

In this paper, analysis and design of 30 storey diagrid steel building with shear wall core is presented in detail. A curved perimeter floor plan of 43.3 m external and 25.75m internal dimension is considered. ETABS9 software is used for modeling of structure in non linear static and response spectrum analysis. All structural members are designed using IS 800:2007[6] considering all load combinations. Load distribution in diagrid system is also studied for 30 storey building. The storey response time period, storey displacement, inters storey drift and total storey displacement is obtained from response spectrum analysis, gives the lesser values when compared to static analysis. The inter storey drift is maximum between 22 and 23 storey in the static and response spectrum earthquake load combinations. The shear wall is provided more stability to the structure to resist the seismic loads and along wind speed. The total load acting on the each storey due to lateral and gravity loads are calculated.

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