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A Review on Seismic Analysis of Irregular Plan of Diagrid Structure on Sloping Ground

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Abstract - Modern tall buildings often use diagrid systems due to their potential for both architectural aesthetics and structural efficiency. Diagrid systems are more structurally efficient than other systems such as braced systems. When a structure can withstand both gravity and lateral load, it is considered stable. Therefore, it is important to design it using structural software such as E-tabs, Staad Pro, etc., to verify certain structural conditions and implementations as per IS standards. The review report takes into account factors such as dead load, live load, floor finish load, wind load, and seismic load as the acting loads.

***Key Words*: Dia-Grid Structure, Structural Design, Seismic Load, E-tabs, Staad pro.**

1. INTRODUCTION

The current trend shows that the population is growing rapidly, resulting in limited space for new constructions in the city. To accommodate this growth, tall buildings are necessary. The diagrid system is a cost-effective solution that can efficiently resist lateral forces and support gravitational loads. When designing tall structures, it is crucial to consider the lateral loads that can be caused by wind and earthquakes. An inclined column positioned at the periphery of the structure makes the diagrid system a better option for resisting lateral loads. In contrast, diagonal braces in a conventional system can create wall-like structures with widely spaced columns.

People living in areas with no flat land are forced to build their homes on hilly terrain. Even though building on hills comes with advantages like great views, natural ventilation, natural drainage, and additional space from lower floor levels, rapid urbanization has led to an increase in the population of hilly regions. As a result, the construction of high-rise buildings has become necessary. However, designing structures on sloping ground is quite different from designing structures on level land due to the changes in mass and stiffness of the building as it rises and spreads.

Figure 1: I-Lab Corporate Office, Hyderabad, India

The term "diagrid" is a combination of diagonal and grid, used to describe a structural system that uses triangulation to achieve coherence. This system consists of single-thickness members that are joined together at the floor edge beams. The loads, such as weight density and sideways force, are accepted and distributed in a highly distributed manner by multiple members and directions throughout its configuration, resulting in triangulated member evolution.

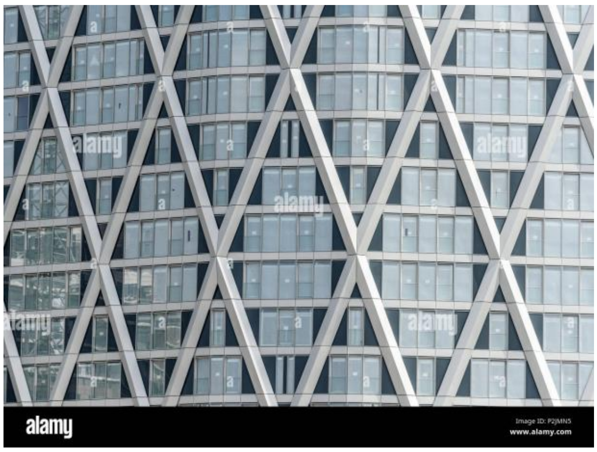

Figure 2: Diagrid Structure

The characteristics of a building, such as its mass and stiffness, change as it rises and spreads. Therefore, designing a structure on sloping ground can be significantly different from designing one on level ground. For any high-rise building on a sloping or flat surface, a unique structural system is required. As a building gets taller, the system that can withstand lateral loads becomes more important than the one that can withstand gravitational stresses. The most commonly used sideways load resisting systems include shear walls, rigid frames, wall frames, outrigger systems, braced tube systems, and tubular systems. In recent years, the diagrid structural system has gained popularity.

1.2 Objective

- To investigate the seismic loading of a diagrid structure with plan irregularity on sloping ground.
- To determine the optimum angle for various irregular geometry of diagrid structures on different sloping ground angles.
- Analyse the performance of the Diagrid structure with various parameters such as story drift, story displacement, and base shear.
- To investigate the differences in structural response caused by earthquake motions in various Indian seismic zones.
- The primary goal of designing an earthquake-resistant structure is to ensure that the structure has enough ductility to withstand lateral loads.
- To analyse diagrid structure using E-tabs software.

2. Literature Review

[1] Saurabh Babhulkar, Kuldeep R Dabhekar, S.S. Sanghal, Isha P. Khedikar, "Comparative Study of Seismic Behavior of Diagrid Structure with Conventional Structure" IOP Conference Series: Materials Science and Engineering (2021)

This report presents an analysis and design of a 24 m x 24 m building with a total plan area of 576 m^2. The building has 15 stories, each with a height of 3.2 m. The report focuses on three types of structures: diagrids with two modules, diagrids with four modules, and diagrids with six modules. The two-story module has a corner-to-corner angle of 50.19°, the four-story module has an angle of 67.38°, and the six-story module has an angle of 74.475°. To conduct the analysis, the response spectrum method was used with Staad Pro software.

According to the peak storey graph, the conventional structure has a significantly lower peak storey shear than the diagrid structure, 4-module diagrid structure, and 6-module diagrid structure. The conventional structures have a lower base shear value than the diagrid structures, which have a higher base shear value. The diagrid structure is more efficient than other structures because it requires less concrete and steel, depending on the conditions.

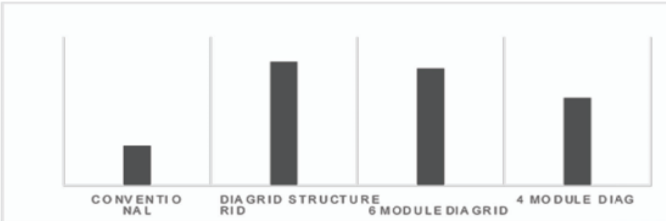

Figure 2.1 (a): Base Shear[1]

[2] Chittaranjan Nayak, Snehal Walke, and Suraj Kokare "Optimal Structural Design of Diagrid Structure for Tall Structure" ICRRM 2019 – System Reliability, Quality Control, Safety, Maintenance and Management, pp. 263–271, (2020)

The paper discusses the model of braced tube structures and diagrid structures with circular, square, and rectangular plans. The rectangular plan measures 54 m x 24 m, the square plan measures 36 m x 36 m, and the circular plan has a diameter of 40.62 m. The story height of each structure is 60 m, with a height of 3.0 m for each story. The paper compares the earthquake and wind analysis results of both braced tubes and diagrid structures. Using Etabs software calculates the story displacement, story drift, and base shear.

According to the analysis, diagrid structures exhibit less story displacement and storey drift than braced tube structures during earthquakes. However, the base shear of the diagrid structure is higher than that of the braced tube structure. In wind analysis, diagrid structures also show less storey displacement and storey drift than braced tube structures. In the case of braced tube structures, circular plans perform better than square or rectangular plans. Conversely, square plans perform better than circular or rectangular plans for diagrid structures. In terms of storey displacement and storey drift values, diagrid structures have the lowest values, whereas the base shear values are the highest as compared to braced tube structures. Therefore, it can be concluded that diagrid structures perform better than braced tub structures.

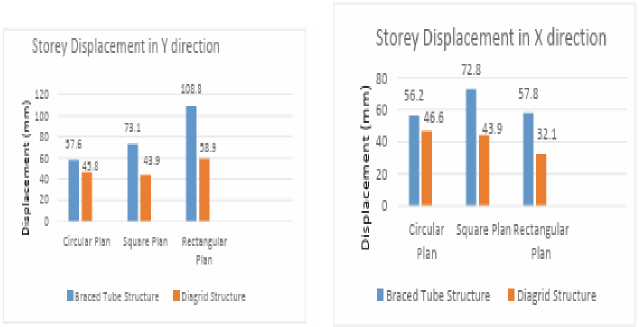

Figure 2.2 (a): Storey Displacement[2]

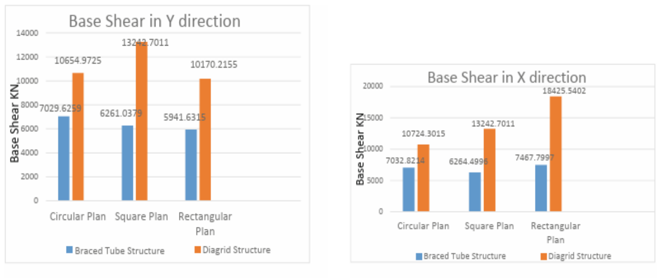

Figure 2.2 (b): Base Shear[2]

[3] Merry James and Neeraja Nair "Seismic Performance Analysis of Vertically Irregular Structure with Diagrid" National Conference on Structural Engineering and Construction Management (2019)

The 36-story tall building has a plan dimension of 36 m x 36 m, according to this paper. Each storey has a height of 3.6 meters. All the structural members of the building are designed using IS 800-2007 code. From the 18th floor to the top, the building has asymmetrical setbacks by removing the corners. The angle of the diagrid is calculated for different module heights of 2-story, 4-story, 6-story, and 18-story based on the height and spacing of the diagrid. The angle of a 2-story diagrid is 50.2 degrees, a 4-story diagrid is 67.5 degrees, a 6-story diagrid is 74.5 degrees, and an 18-story diagrid is 84.4 degrees. The seismic analysis of all models is performed using Etbas software with the help of time history analysis.

According to a time history analysis of a symmetric model, a diagrid structure with an angle of 67.22° outperforms other angles in terms of maximum displacement and drift. For this particular diagrid, the maximum displacement and story drift are lower compared to other angles. As the diagrid angle increases, the base shear and structural weight decrease progressively. However, the structural weight has only been slightly reduced since all models have the same member sizes.

Type	Modal analysis	Time history analysis			
	Time period (s)	Max displacement (mm)	Max drift	Base shear (kN)	Structural weight (kN)
D2	2.45	42.6	0.000613	5454.04	18.78×10^4
D4	2.48	33.97	0.000594	5343.64	18.57×10^4
D6	2.78	8.86	0.000732	4750.08	18.48×10^4
D18	4.46	89.51	0.00164	3304.0	18.48×10^4
Conventional model	6.374	72.68	0.002261	3206.42	17.84×10^4

Table 2.3 (a): Analysis Result[3]

[4] Chetan S.Patta, Prof. Smt. Varsha Gokak "Analysis of diagrid structure with irregularity" International Research Journal of Engineering and Technology (2018)

In this paper, the authors analyze the diagrid structure with plan irregularity for seismic loading. Three models are considered: square plan, C-type plan, and L-type plan layout. All plans have a G+16 story structure. The structures are modelled in ETABS software, with each story height at 3.6 m. The study compares parameters such as base shear, time period, storey drift, and quantity of material consumed.

Based on the results, it has been observed that the L-type diagrid structure is more efficient in terms of base shear, storey displacement, storey stiffness, and storey drift. On the other hand, the C-type diagrid structure is more efficient in terms of top-storey shear. Additionally, the C-type diagrid structure consumed less material than the L-type diagrid structure. Overall, the performance of the L-type diagrid structure is more efficient.

[5] Mangesh Vhanmane and Maheshkumar Bhanuse "Study of Behavior of High-Rise Buildings with Diagrid Systems" SPRINGER Nature Singapore Pte Ltd. (2021)

This work analyzes the behaviour of diagrid structures with 30, 60 and 80 floors, taking into account lateral forces caused by wind loads and earthquakes, following the Indian code. The diagrid structures are modelled and analyzed using ETABS software. Response spectrum analysis is used for earthquake loads. The paper examines four different cases with diagonal angles of 56.18°, 66.2°, 71.33° and 75.4° for each diagrid structure, with 4, 6, 8, and 10-storey modules respectively. The results are evaluated in terms of storey shear, storey displacement, and storey drift.

According to the results, the storey displacement and drifts are less in G+40 and G+60 storey buildings with a storey module of 6, and in G+80 storey buildings with a storey module of 8. Therefore, module 6 with a diagrid angle of 66.2° is suitable for G+40 and G+60 storey buildings, and module 8 with a diagrid angle of 71.33° is suitable for g+80 storey buildings. Additionally, the results suggest that the diagrid angle ranging between 65° and 72° is best suited for heights ranging between 120 and 240 meters.

[6] Shylaja N, Ashwini R M and Babu E R "Seismic Analysis of Diagrid Structure on Sloping Ground" IOP Conference Series: Materials Science and Engineering (2019)

This paper describes the design and analysis of a 12-story diagrid structure and a conventional building on sloping ground, with a plan dimension of 24m x 24m and a storey height of 3.5m. All structural members were designed using IS:800-2007 and the modeling and analysis were carried out in ETABS software. Additionally, a 48-story structure was modelled with varying ground slopes and diagrid angles. Response spectrum analysis was used for dynamic analysis of models by varying the diagrid angle to 53.47°, 60.94°, 69.67°, 74.47°, and 79.5°.

The diagrid building displays less lateral displacement and storey drift when compared to a conventional building on sloped ground. Additionally, the storey stiffness and base shear of diagrid is higher than that of a conventional building. The seismic weight of diagrid structure is significantly less than that of a conventional building. This is due to the lightweight materials that are used for the diagrid, which provide a high level of strength. For a 15° slope of the ground, the optimum angle of diagrid is 60.94°, and for a 25° slope of the ground, the optimum angle is 69.67°. Diagrid buildings have a more pleasing appearance compared to conventional buildings.

3. CONCLUSIONS

The literature review above compares the diagrid structure models and braced frame models with a traditional frame model. It takes into account structural irregularities and also alters the H/B ratio and diagrid angle. Studies are conducted using response spectrum analysis and time history analysis with the aid of ETABS and STAAD Pro software. Based on the research, it is determined that:

- The diagrid structural model has more stiffness than the simple model as the top displacement is less in it.
- Vertical irregularities in diagrid structures result in less top-story displacement, making the diagrid structure more stable there.
- The diagrid angle should vary according to the model's height.
- A diagrid system is a better solution for lateral load, flexibility and economy in terms of material consumption.
- An ideal diagrid angle for heights ranging from 120 to 240 m is between 61° to 72°. However, the diagrid construction with a 67.22° angle is better than other angles regarding maximum displacement and drift.
- On sloping ground, the diagrid structure is more efficient than the conventional structure, and the optimum diagrid angle is between 60-75°.

REFERENCES

[1] Saurabh Babhulkar, Kuldeep R Dabhekar, S.S. Sanghal, Isha P. Khedikar, "Comparative Study of Seismic Behavior of Diagrid Structure with Conventional Structure" IOP Conf. Series: Materials Science and Engineering 1197 (2021) 012049 doi:10.1088/1757-899X/1197/1/012049

[2] Chittaranjan Nayak, Snehal Walke, and Suraj Kokare "Optimal Structural Design of Diagrid Structure for Tall Structure" Springer Nature Singapore Pte Ltd. 2020 V. K. Gunjan et al. (Eds.): ICRRM 2019– System Reliability, Quality Control, Safety, Maintenance and Management, pp. 263–271, 2020. https://doi.org/10.1007/978-981-13-8507-0_39

[3] Merry James and Neeraja Nair "Seismic Performance Analysis of Vertically Irregular Structure with Diagrid" Springer Nature Switzerland AG 2020 K. Dasgupta et al. (eds.), Proceedings of SECON'19, Lecture Notes in Civil Engineering 46, https://doi.org/10.1007/978-3-030-26365-2_55

[4] Chetan S.Patta, Prof. Smt. Varsha Gokak "Analysis of diagrid structure with irregularity" International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 08 Aug 2018

[5] Mangesh Vhanmane and Maheshkumar Bhanuse "Study of Behavior of High-Rise Buildings with Diagrid Systems" Springer Nature Singapore Pte Ltd. 2021 M. C. Narasimhan et al. (eds.), Trends in Civil Engineering and Challenges for Sustainability, Lecture Notes in Civil Engineering 99, https://doi.org/10.1007/978-981-15-6828-2_19

[6] Shylaja N, Ashwini R M and Babu E R "Seismic Analysis of Diagrid Structure on Sloping Ground" IOP Conf. Series: Materials Science and Engineering 1255 (2022) 012008 doi:10.1088/1757-899X/1255/1/012008