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"Comparative Evaluation of Conventional RC Structure and Diagrid Framed Structure in Severe Seismic Zones" - A Literature Review

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Abstract—

The rapid urban population expansion has resulted in a shortage of space in cities, and the expensive cost of land has already compelled developers to prioritize high-rise structures. As the building's height increases, the lateral load-resistant system becomes more crucial than the gravity load-resistant system. It is essential to specify lateral load resistant methods in high-rise buildings, such as shear walls, bracing, base isolation techniques, diagrid framed structures, etc., because they are enhanced in terms of cost, appearance, and performance. However, due to its efficiency and the appealing appearance that its unique geometric arrangements provide, the diagrid structural system has become more and more popular in recent years. In this work, a comparative review analysis has been conducted on a normal building that has lateral load resisting systems installed. It has also been investigated whether a diagrid structural system is available for performance comparison. The patterns of the data showed that building models with the diagrid structural module performed better in terms of maximum story displacement, story stiffness, story drift, base shear, and time period. For high-rise buildings, the diagrid structural system seems to be more affordable.

Keywords: Conventional RC Structure, Shear wall, Diagrid Structural System, Seismic Analysis, Drift, Displacement, Base Shear.

1. Introduction

Our lives are now easier and more self-sufficient than they were before thanks to skill development, but the growing population has also increased demand for greater dwelling space. With a population of over 7.9 billion, we now face greater needs and demands in our daily lives. Engineers must concentrate on tougher, sustainable, economical, lighter, and creative rapid development methods due to space constraints and environmental preservation. High-rise buildings are the constructions that minimize environmental damage and meet the requirement for more people to live in less spaces. One such method used in high-rise structures is the diagrid construction, where the upward parts are positioned to support both horizontal and gravity loads.

The horizontal strength of diagrid structures engages both static and dynamic stresses, resulting in both directional reactions for exposed and across-wind loads. Compared to the windward track, vortex shedding results in significantly higher lateral movement in the across-wind path. Because the crucial regularity of a design increases the required wind velocity to create a lock-in condition, stiffer structures are generally less likely to have the vortex regularity locking on a modular recurrence. Compared to conventional building systems, diagrid structures are less prone to lock in due to their higher lateral rigidity.

A shear wall is a simple framework made up of fixed panels that is used to lessen the effects of seismic load, sometimes referred to as lateral load, acting on a structure. Shear walls are able to withstand lateral loads proportional to their height. Usually, applied loads are moved to the wall via a diaphragm, authority, or drag part. Examples include CMU (masonry), cement, and wood. The ability of a shear walls to withstand horizontal lateral loads, such as earthquake and wind. These horizontal forces are transferred to the component underneath them in the heap when the shear wall is strong enough.

Shear walls, which protect the aforementioned roof or floor from undesired side effects, also offer sidelong stability. A properly hardened shear wall will prevent people from escaping their backs by enclosing the floor and rooftop. In a similar vein, properly hardened structures will usually experience less non-structural damage.

The requirement for living in cramped quarters can be met by high-rise buildings, which have no negative environmental effects. The shear wall structure system is the most commonly used, while there are different types of constructions. Compared to other structural systems, the diagrid system is one of the ones that uses less material. The diagrid and shear wall structural systems are contrasted in this article. Both structures are dynamically analyzed in ETABS in earthquake zone V. Finding out which construction is more stable, cost-effective, and sustainable in seismic zone V is the only goal of the ETABS analysis.

2. Building Structure in a High-Rise Structure

High-rise structures, like concrete ones, utilize a lot of energy and produce a lot of greenhouse gases, including carbon dioxide. for engineers to choose a high-performance structural solution that reduces floor-to-floor height, has a service core, and uses less material—all of which enhance tall building sustainability and design quality [4]. Outside structural systems and inside structural systems are the two categories of structural systems. Since a high-rise structural system is the primary lateral load-resisting mechanism of the building, its component distribution needs to be characterized. The system is categorized as an exterior structure when the perimeter of the structure resists the lateral load. If the interior of the building resists the load, the system is categorized as an internal structural system. Design flexibility and structural durability increase the lifespan of the structural system because they prolong the life of the structure. Reduce building construction to reduce carbon emissions and energy use. A structural system constructed for 100 years would, in theory, be twice as sustainable as one constructed for 50, 30, or 20 years.

2.1 Special Moment Resisting Frame –

A rigid frame, as used in structural engineering, is the load-bearing framework made up of curved or straight parts joined by primarily rigid connections that prevent member movements at their joints. The primary mechanism by which rigid frame action resists the lateral forces generated is through the creation of shear force and bending moment in joints and frame elements. The rigidity of the frame and joints results in lateral stiffness of the structure.

2.2 Shear Wall System –

From the foundation to the top of the structure, shear walls—also referred to as reinforced or steel paneled walls—are a kind of lateral load-resisting system. Cantilever action is used by shear walls to support lateral stresses. The effectiveness or performance of the shear walls is determined by their position.

2.3 Diagrid Structural System

A "diagrid" is a type of perimeter frame structure made up of diagonal members that come together to create a diamond-shaped element that inherits a triangular module or configuration. Together, the diagrid and the RC core increase the structure's rigidity by resisting shear and acting as a cantilever. This system's primary benefit is that it can withstand lateral loads more effectively than other systems. Additional benefits of this system include redundancy, which allows it to shift the weight from one section of the structure that fails to another, lower steel consumption, a column-free exterior, no façade requirements, and a high level of aesthetics and beauty. Examples of diagrid buildings are as follows:

Fig.2 Hearst Tower, New York

g 3. Poly International Plaza, Beijing

3. OBJECTIVES OF THE STUDY

The primary goals of the current investigation are as follows:

1. To evaluate the rigid frame, shear wall, and diagrid structural systems' performance.
2. To investigate how lateral forces, affect the diagrid structural structure.
3. To comprehend how RC structures, behave under seismic loads with and without diagrid systems using various plan configurations.

4. Literature Review

The analysis and construction of such structures with various lateral load-resisting systems, both static and dynamic, have been the subject of several studies. The findings also point to the challenges that high-rise buildings face when designing for seismic activity. The methods used, findings, and a few of the data from earlier investigations have all been covered here. The application of such lateral load-resisting components in multi-story buildings has been the subject of numerous research studies.

"Chandurkar and Pajgade, 'Seismic Analysis of RCC Building with and Without Shear Wall ', International Journal of Modern Engineering Research (IJMER), pp. 1805–1810, 2013" investigated the effect of the shear wall on the G+9 building of four models by doing a dynamic study on the structure using ETABS. Four models with multiple shear wall positions were analyzed in order to compare displacement, story driftness, % Ast in column, amount of concrete needed, amount of steel needed, and overall cost needed for all models. They discovered that changing the shear wall's placement would affect the model's performance. They discovered that placing shear walls in strategic places significantly lowers earthquake-related displacements and minimizes drift in the structure.

"Nischay J, M.R. Suresh, "Comparative study of the performance of Tall Structures with Diagrid and Shear wall Systems Subjected to Seismic loading", International Research Journal of Engineering and Technology (IRJET), Volume: 03, Issue: 07, Jul-2016" worked on how tall constructions behaved when the diagrid systems were the main component that could withstand lateral loads. Three different symmetrical plan shapes—square, octagonal, and circular—were taken into consideration. Three distinct storey heights—30 stories, 45 stories, and 60 stories—were modeled for each design. The octagon plan had the lowest lateral displacement, while the circular plan had the largest, according to a comparison of various plan shapes, including square, octagon, and circular, for the diagrid system. With a 36.72% decrease in lateral displacement compared to the shear wall model, the octagonal shape model was shown to be the most effective model with diagrid for 60 stories.

"Viraj Baile, Dr.A.A. Bage, "Comparative Study of Diagrid Simple Frame and Shear wall system", International Journal of Engineering Research and Application (IJERA), Volume-7, Issue: 07, (Part -2) July 2017" The investigation focused on comparing the shear wall, basic frame, and diagrid systems. Twelve models in all were examined, ten of which were shear wall systems with various placements, one of which was a diagrid and the other a basic frame. To achieve the ideal location for the placement or design of shear walls, they were supplied as tubes at the hollow core, in the center of the edges, L-shaped at the corners, and C-shaped at the core. The dynamic analysis in ETABS was conducted using response spectrum analysis. The findings showed that while Diagrid is lighter and more effective as a lateral load-resisting system, it is more affordable than other variants.

"Mahdi Hosseini, Prof.N.V. Ramana Rao, "Dynamic analysis of High-rise structures under different type of Reinforced concrete Shear wall for an Earthquake resistant building" IJIRAE- International Journal of Innovative Research in Advanced Engineering, Issue 22 January 2017" have conducted a close examination of a 52-story hyperbolic round steel diagrid basic framework that has been repaired at the focal center using steel propped outlines and a shear divider. In essence, this work had two models with a focus divider system and a moving floor zone. The two models' diagrid channel part is located on the exterior periphery. Zone II and Zone III are the two specific seismic zones for which these models are examined.
"Kumar, 'Seismic behavior of buildings with shear wall', International Journal of Engineering Research & Technology (IJERT), 6(11), pp. 1–5. 2018" Using ETABS to do dynamic analysis in compliance with the IS code on a five-story structure. By moving the shear wall in zone five, dynamic analysis was performed on different building models to compare displacement, shear, and acceleration in the X and Y directions. It was found that shear walls may react to seismic activity more efficiently.

"Shankar, B. and Priyanka, M. V (2018) 'Comparative Study of Concrete Diagrid Building and Conventional Frame Building Subjected to Seismic Force', pp. 1078 – 1082" conducted an investigation comparing the effects of the diagrid's length and angle to the traditional system for both diagrid and conventional structures with comparable plan sizes and story heights. The Equivalent Static Analysis method is used to analyze structures. It was found that a diagrid structure has a smaller lateral displacement than a conventional structure. The story shear and base shear of the diagrid system are found to be the highest when compared to the conventional construction. Because drift decreases with increasing structure altitude, the diagrid system has been shown to be important for high-rise buildings.

"Mohammad Rafi Uzzama, Sita Hemanth, "Analysis of high raised structures in different seismic zones with diagrid and Shear walls using e-tabs", International Journal of Advance Research and Innovative Ideas in Education (IJARIIE), Volume-6, Issue: 01, 2018" worked on the analysis and design of shear and diagrid walls that were subjected to seismic loads. Both of the 18-story buildings were planned and examined for various seismic zones. A standard 20 × 20 m layout was taken into consideration, with a base story of 2 m and a storey height of 3.5 m. The structure was examined using ETABS 2015, and findings such as base shear, storey displacement, and storey drift were examined. It is determined that the constructions with diagrids are more efficient than those with shear dividers.

"Ravikiran, H.R. Shyam Prasad, "Comparative Study on the seismic behaviour of Diagrid structure and Shear wall structure in different seismic zones", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 7, Issue: 06, Jun 2019" - 893-part 1), compared the seismic behavior of diagrid and shear wall systems for each zone. The ETABS 2015 program was used to conduct the response spectrum analysis. For the study, 16-story diagrid and shear-walled buildings with the same internal structural elements, such as beams and columns, and the same proportions were modeled. The results of the study indicate that shear walls are more efficient in reducing the building's acceleration when seismic vibrations are taken into consideration, while diagrids are an effective lateral load-resisting system when it comes to displacements.

"Thota Sai Charan, Dumpa Venkateswarlu, Rayi Chandra Shekar, "Design and Analysis of Diagrid and Shear Wall Structures Subjected to Seismic Loads", International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-8, Issue-11, September 2019" Seismic analysis of symmetrical diagrid and shear divider structures with G+30 story buildings and a 36 m x 36 m arrangement region was the primary focus of the investigation. Three seismic zones (Zone III, Zone IV, and Zone V) were examined in these models. ETABS 2016 software was used to display and examine the structure. The product used a shear divider and diagrid framework to build the structure model, which was decomposed for the reaction range and time history technique.

"Mr. Abhishek Admane1 Prof. Sharif H. Shaikh2 COMPARATIVE STUDY OF DIAGRID STRUCTURE WITH CONVENTIONAL BUILDING HAVING DIFFERENT HEIGHTS International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 08 Issue: 06 | June 2021 www.irjet.net p-ISSN: 2395-0072" This research examines the design and nonlinear behavior of mid-to-high-rise steel diagrid structures. Tale drift, time length, base share, and displacement in diagrids are compared to similar moment resistant frames and concentrically braced frames. To enhance nonlinear behavior and raise the collapse load potential of diagrid structures in high seismic locations, practical design guidelines are proposed utilizing virtual work/energy diagrams and nonlinear seismic analysis using ETABs for G+7, G+11, and G+16.

"Srinitthe Kamlecar1 , Dr. Shrihari Saduwale2 , Vithal Biradar3 Comparative Study On Diagrid, Rigid Frame and Shear Wall Structural Systems in High Rise Buildings International Journal of Advances in Engineering and Management (IJAEM) Volume 4, Issue 9 Sep. 2022, pp: 1152-1160 www.ijaem.net ISSN: 2395-5252" This work compares the shear wall system, rigid frame system, and diagrid system. Two different plan configurations—square and octagon—have been used to model and analyze a rigid frame building, an 18-story diagrid building, and a building with shear wall systems. To find out which technology is better at sustaining lateral loads, a total of six structures have been modeled and investigated. ETABS has been applied to analysis and modeling. The dynamic analysis is performed using the Response Spectrum Method. According to Indian Standards, all loading and inspections are provided. Time period, base shear, storey displacement, and storey drift are among the variables considered in the analysis..

"Mr. Rishav Jaiswal[1] and Mr. Ankit Mahajan[2] Comparative analysis of building with shear wall & diagrid structure ICASF-2022 IOP Conf. Series: Earth and Environmental Science 1110 (2023) 012033 IOP Publishing doi:10.1088/1755-1315/1110/1/012033" - A comparison of structures with different lateral load-resisting systems has been carried out. Five different G+9-story building models with shear walls and diagrid structures have been made in order to compare how well they operate. In compliance with IS 1893:2016, the design for seismic zone V and medium soil condition is analyzed using ETABS software. The building is unaltered save for the lateral load-resisting system. The patterns of the data show that building models with a shear wall and diagrid module combination perform better in terms of maximum story displacement, story stiffness, story drift, base shear, and time period.

"Arbaz Ahmad Lone 1 Er. Gurpreet singh.2 Jagdish Chand 3 COMPARATIVE STUDY ON DYNAMIC ANALYSIS OF DIAGRID BRACINGS AND SHEAR WALL IN DIFFERENT LOCATIONS IN TERMS OF SUSTAINABILITY USING ETABS ICASF-2022 IOP Conf. Series: Earth and Environmental Science 1110 (2023) 012054 IOP Publishing doi:10.1088/1755-1315/1110/1/012054" This article examined the diagrid and shear wall systems to ascertain which structural system is more economical, sustainable, and capable of supporting lateral loads for buildings located in earthquake zone V. The construction in question is 25 m by 25 m, has 30 floors, a total height of 91 m, and a plan area of 625 m2. According to IS 1893:2016, all of the buildings are modeled and examined using ETABS software; they are all presumed to be situated in seismic zone V, with a significance factor of 1.5. Structural elements include basic period (T, seconds), story drift, base shear, lateral displacement, and overturning moment influence the building's response.

"**Darpan Kapre1 , Dr. N. G. Gore2 Structural Analysis of the Performance of the Diagrid System with and without Shear Wall International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538 Volume 11 Issue V May 2023- Available at www.ijraset.com"** The current study aims to investigate the behavior and performance of diagrid structural systems with and without shear walls under lateral loads—like wind and earthquake—that may occur during the building's lifetime. In this work, a specific G+70-story, C-shaped, high-rise Diagrid building with and without shear walls is modeled using ETABS software. The static and dynamic behavior of these models are analyzed in three different zones, namely Zone III, Zone IV, and Zone V, where the basic wind speeds are 44 m/s, 47 m/s, and 50 m/s, respectively. Equivalent Static analysis, Response Spectrum Method (dynamic analysis), and Static Wind analysis are all carried out.

5. Conclusion –

These conclusions must be drawn from the various researchers' studies on the Diagrid Structural System. The following are the inferences drawn from the points:

a. The number of external elements in the structure has decreased due to the diagrid system's structural effectiveness and arrangement.
b. Because there are fewer external columns, less material is used, which is beneficial for the sustainability of the structural system.

c. Period, overturning moment, base shear, and narrative drift are some of the outcomes. Diarid structures are much less prone to collapse following an earthquake due to intense vibrations than shear wall systems.
d. Lateral load resisting technologies, such shear walls and the diagrid system, improve the structure's performance under seismic and wind loads by increasing stiffness when employed in tall structures. It has been found that high-rise buildings perform better seismically when diagrid systems are added.
In general, diagrid structures perform better as lateral load-resisting systems than shear walls and moment-resisting frames.

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