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"Comparative Evaluation of Conventional RC Structure and Diagrid Framed Structure in Severe Seismic Zones"

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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. The lateral load-resistant system becomes more important than the gravity load-resistant system as the building's height grows. Because they are improved in terms of cost, appearance, and performance, it is crucial to specify lateral load resistant systems in high-rise buildings in terms of shear walls, bracing, base isolation techniques, diagrid framed structures, etc. Nonetheless, the diagrid structural system has gained popularity recently because of its effectiveness and the attractive appearance that its distinctive geometric arrangements offer. The regular building with the configuration of lateral load resisting systems has been the subject of a comparative review analysis in this work. The availability of a diagrid structural system for performance comparison has also been examined. Building models with the diagrid structural module performed better in terms of maximum story displacement, story stiffness, story drift, base shear, and time period, according to the patterns of the results. However, the diagrid structural system appears to be cost-effective for high-rise structures. In this study, a comparison analysis was performed on a regular building located in a severe seismic zone as per IS 1893:2016. Different models of G+11 story buildings were developed using standard moment resistant frames, shear walls at various locations, and the supply of a diagrid structural system to compare their performance using the ETABS software. The building's dimensions and structural data are maintained constant for comparison purposes. Based on the results, it was concluded that building models with the diagrid structural module have better performance in terms of maximum story displacement, story stiffness, story drift, base shear, and time period; however, the diagrid structural system appears to be more expensive for such medium-rise buildings.

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

1. INTRODUCTION

The development of skills has made our lives easier and more self-sufficient than they were in the past, but it has also led to the demand for additional housing space to accommodate the expanding population. 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.

Diagrid structures' horizontal strength engages both static and dynamic loads, causing reactions for exposed and across-wind loads in both directions. In the across-wind route, vortex shedding causes a lot more lateral movement than in the windward course. Generally, Stiffer structures are less likely to have the vortex regularity locking on a modular recurrence because the critical regularity of a design raises the needed wind velocity to produce a lock-in condition. Because of their increased lateral rigidity, diagrid structures are less likely to lock in than traditional building systems.

In order to mitigate the impacts of seismic load (also known as lateral load) operating on a structure, a shear wall is a basic framework composed of fixed panels. Shear walls must be constructed to withstand two well-known loads: seismic and wind. 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 resistance of a shear wall to horizontal lateral loads (wind and earthquake). When the shear wall is sufficiently strong, these horizontal forces are passed to the next component in the heap underneath them.

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. Although there are other kinds of constructions, the shear wall structure system is the most widely utilized. The diagrid structural system is one of the structural systems that uses less material than other structural systems. This article compares the shear wall and diagrid structural systems. In earthquake zone V, both structures undergo dynamic analysis in ETABS. The sole purpose of the ETABS analysis of the constructions is to determine which is more stable, economical, and sustainable in seismic zone V.

2. Structural System in High Rise Building

Large amounts of energy and greenhouse gasses are consumed in high-rise buildings, such as concrete constructions, which generate more carbon dioxide. for engineers to select a high-performance structural system that minimizes floor-to-floor height, uses less material, and has a service core, all of which improve the sustainability and design quality of tall buildings [4]. There are two types of structural systems: outside structural systems and interior structural systems. A high-rise structural system's component distribution must be categorized because it serves as the building's main lateral load-resisting mechanism. When the lateral load is resisted by the structure's perimeter, the system is classified as an external structure. The system is classified as an internal structural system if the load is resisted by the building's interior. Because structural durability and design flexibility extend the life of the structure, they also extend the life of the structural system. cut down on building construction to save energy and carbon emissions. It is theoretically possible that a structural system built for 100 years could be twice as sustainable as one built 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 production of shear force and bending moment in joints and frame members is the main way that rigid frame action resists the lateral forces produced. Lateral stiffness of the structure is caused by the rigidity of the frame and joints.

2.2 Shear Wall System –

Shear walls, also known as reinforced or steel paneled walls, are a type of lateral load-resisting system that is developed from the foundation all the way to the top of the structure. Shear walls use cantilever action to withstand lateral loads. The location of the shear walls determines their efficacy or performance.

2.3 Diagrid Structural System

A perimeter frame structure known as a "diagrid" is composed of diagonal members that combine to form a diamond-shaped element that inherits a triangle 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 investigate the effects of the Diagrid structural system and compare it to the Shear wall and rigid frame systems.

2. Determine the impact of lateral forces on the diagrid structural system.

3. To understand the seismic loading behaviour of RC structures with various plan configurations, both with and without a diagrid.

4. To investigate the performance of buildings using diagrid systems vs traditional frame structures in terms of maximum story displacement, story drift, base shear, and time period.

5. To compare the economics of the system for a medium-rise building subjected to lateral loading.

4. METHODOLOGY –

The primary goal of the research was to examine the behavior of high-rise structures equipped with diagrid systems. For comparison, we used a shear wall system and a moment resisting frame system. The shear walls are placed in different locations to allow for behavioral comparisons. For the analysis, G+12 storey Diagrid, Shear wall, and Moment resisting frame structures are simulated in India's zone V, as described by IS 1893(Part1):2016. The RSA technique was used to analyze a total of four models, and the models compared in this study are listed below:

Details of Models:

Model 1 – Conventional RC G+12 building with dimension of 30 m x 30 m.

Model 2 –RC G+12 building with dimension of 30 m x 30 m. using shear wall at the core center of the building.

Model 3 –RC G+12 building with dimension of 30 m x 30 m. using shear wall at the outer periphery corner of the building.

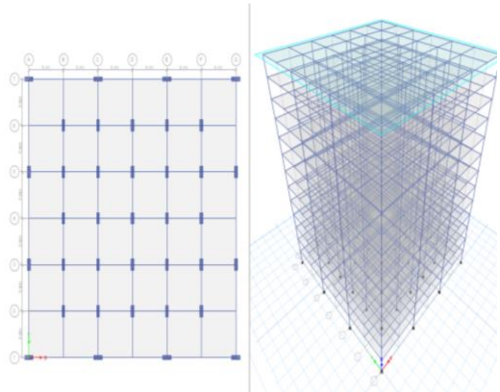
Model 4 –RC G+12 building with dimension of 30 m x 30 m. using diagrid structural system at the outer periphery of the building.

For analysis purposes, the slab, columns, and beams' dimensions are maintained constant. Additional information utilized for analysis came from IS 1893:2016.

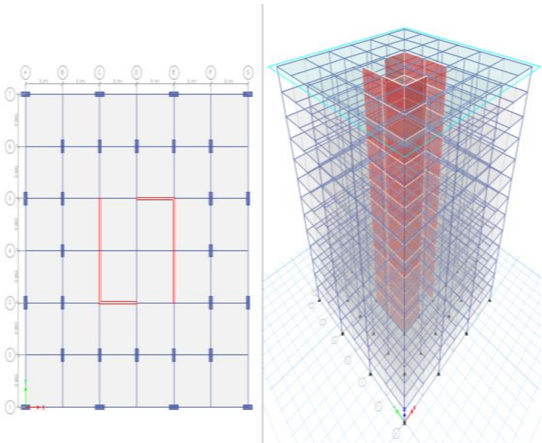
General Properties	
No. of storeys	G+12
Typical Storey Height	3.5 m.
Size of Column	400 mm x 1200 mm
Size of Diagrid structural system	400 mm x 1200 mm
Size of Beam (internal)	300 mm x 600 mm
Size of Beam (external)	300 mm x 1000 mm
Thickness of Slab	150 mm.
Thickness of Core Wall	200 mm.

Material Properties	
Grade of Concrete	M 30
Grade of Steel Rebar	Fe 550
Type of Loading	
Wall Load	10 KN/m
Live Load	3 KN/m^2
Floor Finishing	1.5 KN/m^2
Seismic Details (IS 1893:2016)	
Seismic Zone	V
Zone Factor	0.36
Importance Factor	1
Type of Soil	II - Medium
Building Type (R)	5 (SMRF)

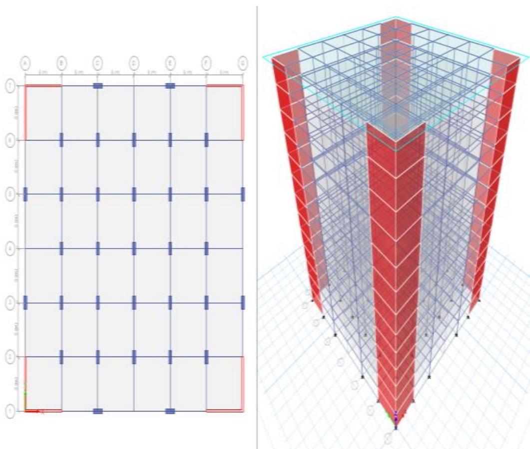
Model 1 –



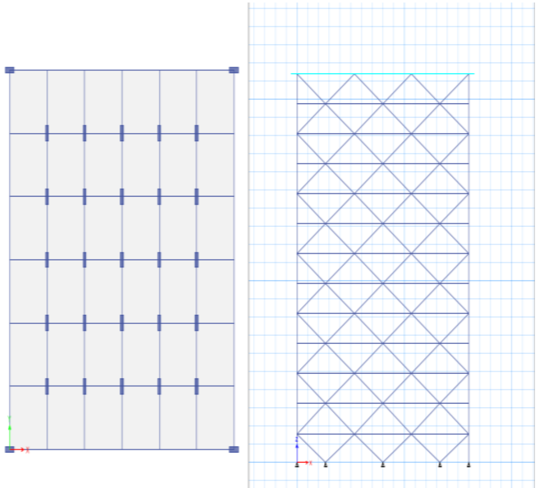
Model 2 –



Model 3 –



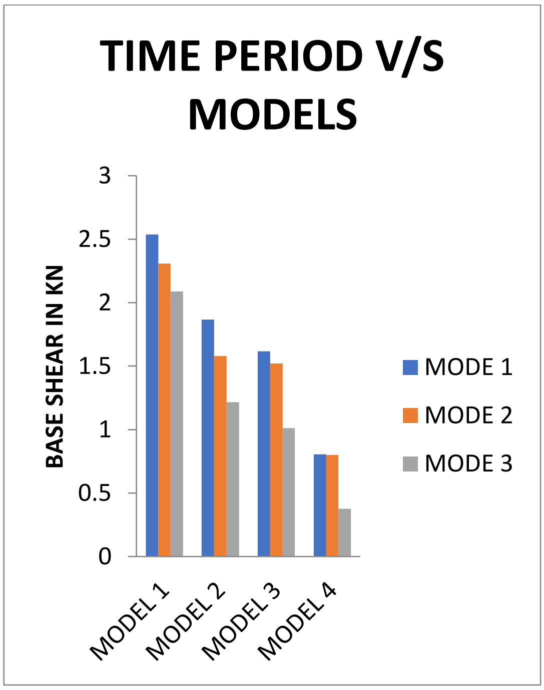
Model 4 –



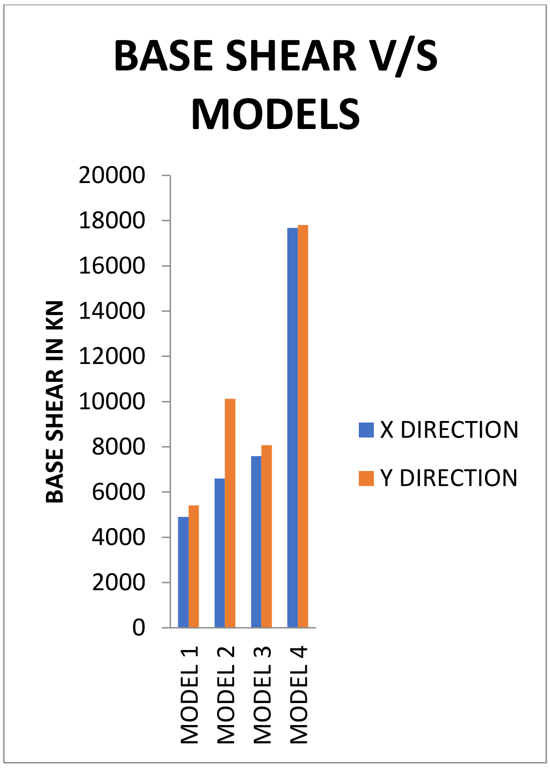
5. RESULTS –

Here are the outcomes of many building models. Response Spectrum (Linear Dynamic) analysis is the method used. For several model types, the values of base shear and the results of drift and displacement in both directions were displayed.

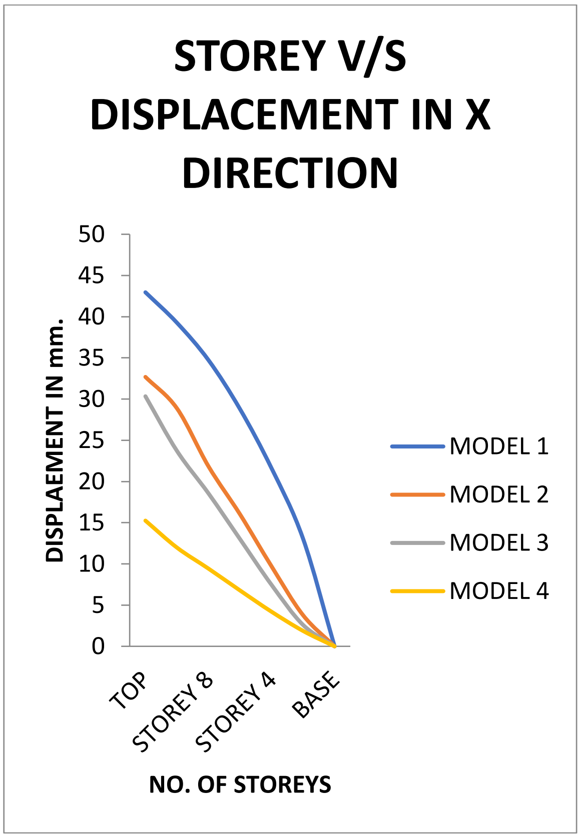
TIME PERIOD –

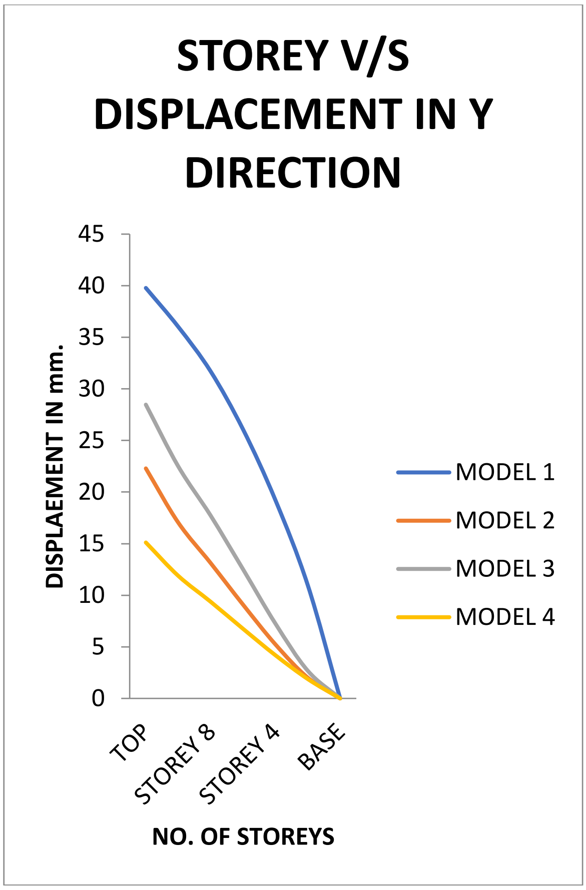


BASE SHEAR

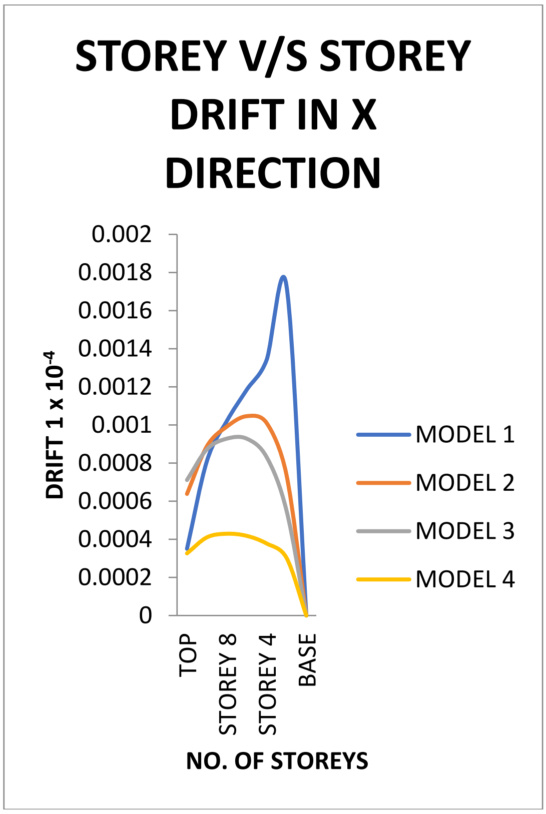


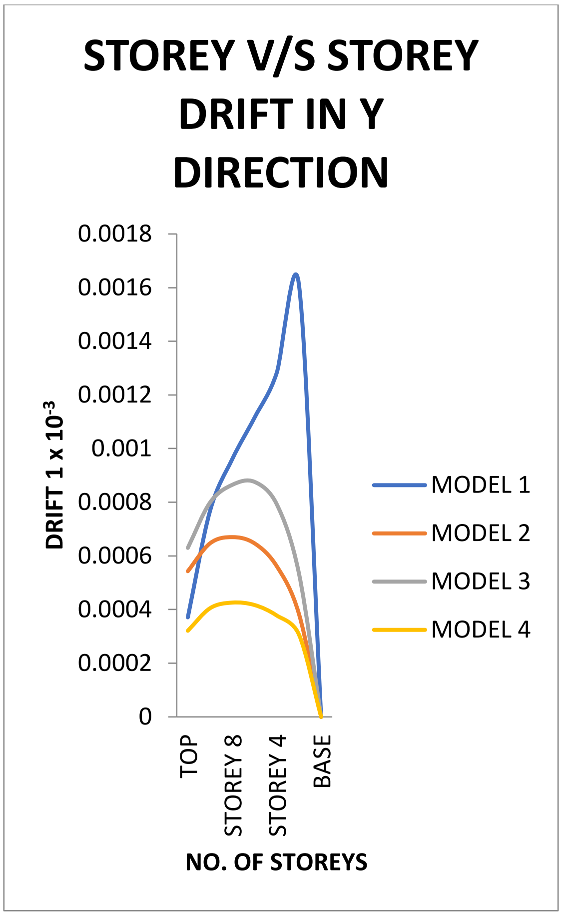
DISPLACEMENT -



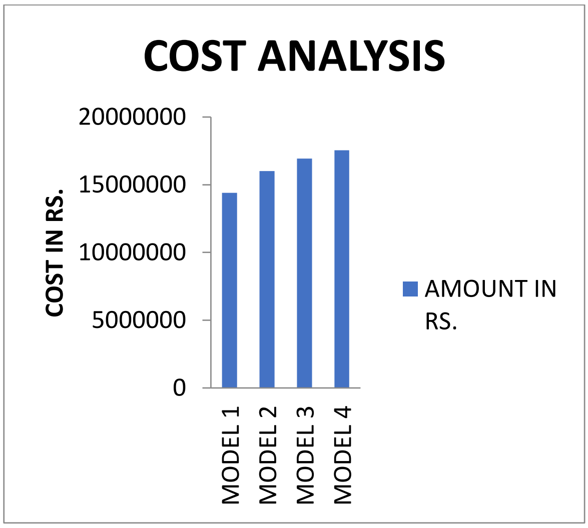


STOREY DRIFT -





COST ANALYSIS –



6. Conclusion –

Several models were examined and created in this study to withstand the lateral load on medium-rise structures. The ETABS software models and analyzes the 30 x 30 m layout with a 40 m height. The following conclusions are drawn from the results:

- As the structure height increases, the lateral load resisting system's ability to withstand gravity loads is improved above that of the traditional frame system.
- Taking into account all of the data, we can say that the building with the diagrid frame pattern outperformed every other model in terms of drift, time period, and storey displacement.
- The time period is lowered by up to 42% when using the Diagrid Structural System instead of a traditional construction.

- When compared to a traditional structural system, the diagrid structural system also minimizes the storey displacement by up to 33%.
- Compared to a traditional structural system, the storey drift for a diagrid structural system can be reduced by up to 29%.
- The diagrid system's value base rises by up to 90% when compared to the conventional system because of the outside columns' inclination, which ultimately results in larger columns.
- Because it is 20% less expensive than a diagrid system, it is noticed that structures with shear walls at the corners are efficient and cost-effective in these medium-rise buildings. However, as compared to a typical frame structure, the diagrid structure has a far lower chance of failing due to strong earthquake vibrations. Therefore, it can be used for high-rise buildings in seismically active areas where corner shear walls are insufficient.

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