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Behavioral Analysis of G+9 Reinforced Concrete Buildings with Different Structural Configurations under Severe Seismic Conditions

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Abstract- Seismic performance of mid-rise reinforced concrete buildings is strongly influenced by structural configuration, regularity, and the adopted lateral load-resisting systems. This study presents a comparative seismic behavior analysis of a G+9 reinforced concrete building founded on soft soil and located in Seismic Zone V as per IS 1893 (Part 1):2016. Three structural configurations are considered: (i) a regular symmetrical building with bracing and base isolation, (ii) an irregular hybrid building with bracing and base isolation, and (iii) an irregular building with bracing but without base isolation. Numerical modeling and dynamic analysis are carried out using ETABS software. The structural response is evaluated in terms of storey displacement, storey drift, storey shear, base shear, and overturning moment under critical seismic load combinations. The results indicate that structural regularity significantly enhances stiffness and reduces displacement and overturning effects, while base isolation effectively reduces seismic forces and inter-storey drift at the cost of increased overall displacement. For irregular buildings, the combined use of bracing and base isolation provides superior seismic performance, offering an optimal balance between force reduction, deformation control, and structural safety.

Keywords: Seismic analysis, G+9 RC building, base isolation, bracing system, irregular structures, ETABS.

I. INTRODUCTION

Rapid urbanization and scarcity of land in metropolitan areas have led to the widespread construction of mid-rise and high-rise buildings. As building height increases, seismic forces become a dominant design consideration, especially in regions classified under high seismic zones. Structural irregularities arising from architectural, functional, or economic constraints further aggravate seismic vulnerability by causing uneven distribution of mass, stiffness, and strength.

Past earthquake events have repeatedly demonstrated that irregular buildings are more prone to excessive damage and collapse compared to regular configurations. To mitigate seismic risk, modern lateral load-resisting systems such as braced frames, shear walls, diagrid systems, and base isolation techniques are increasingly adopted. Among these, base isolation is recognized as an effective seismic protection strategy that decouples the superstructure from ground motion, thereby reducing force demand.

The present study focuses on evaluating the seismic behavior of a G+9 reinforced concrete building with different structural configurations under severe seismic conditions. A comparative assessment is carried out to understand the influence of structural regularity, bracing, and base isolation on key seismic response parameters.

II. STRUCTURAL IRREGULARITY AND SEISMIC RESPONSE

Structural irregularity refers to non-uniform distribution of mass, stiffness, or geometry along the height or in the plan of a building. Plan irregularities such as re-entrant corners, torsional irregularity, diaphragm discontinuity, and offsets out of plane lead to eccentricity between the center of mass and center of rigidity, resulting in torsional effects during seismic excitation. Vertical irregularities, including soft storeys, mass irregularity, setbacks, and floating columns, cause abrupt changes in force flow and concentration of stresses at critical levels.

Irregular structures exhibit amplified seismic response due to uneven load paths, increased storey drift, and stress concentration. These effects can lead to premature failure of structural components, reduced ductility, and increased base shear and overturning moments. Therefore, advanced seismic analysis methods and effective lateral load-resisting systems are essential for the safe design of irregular buildings in high seismic zones.

III. BASE ISOLATION SYSTEM

Base isolation is a seismic control technique in which flexible isolator units are installed between the superstructure and foundation. These isolators increase the fundamental time period of the structure and provide additional damping, thereby reducing seismic force transmission. Commonly used isolators include laminated rubber bearings and lead-rubber bearings. While base isolation significantly reduces storey shear, base shear, and drift demands, it increases overall lateral displacement due to enhanced flexibility at the base.

IV. LITERATURE REVIEW

Arvish Panchal, Aakash Suthar (2025) The diagrid system is one of the most structurally efficient and aesthetically pleasing solutions for tall buildings. Such systems are being used more and more in modern construction. Yet, in present literature, detailed knowledge about structural behavior and seismic design requirements necessary to provide optimal response under different earthquake zones is still missing. Studies have been performed for the creation of more efficient performance-based approaches and to analyze the seismic reliability of diagrid structural systems. Seven models, which differ in size, angle, storey height, and density, with a typical floor arrangement, have been modeled using ETABS software for the analysis of diagrid structural systems of tall steel buildings that are subjected to lateral load under seismic zones II, III, IV, and V.

Pooja (Year-2025) - A major advancement in modern architecture is represented by diagrid structures, in which structural effectiveness is combined with visual appeal. The term “diagrid” is derived from “diagonal grid,” which is used to describe a grid-patterned framework composed of diagonal elements. Diagrids are not considered to be as stable as conventional orthogonal grid systems, since dependence is not placed on horizontal beams and vertical columns. Instead, lateral stresses and gravity loads are managed by the diagonal elements, through which a strong and flexible structure is created that is regarded as highly efficient. Owing to this efficiency, more creative architectural expressions and greater design freedom are enabled.

Komal Burele, M.R. Nikhar (2022) The design and analysis of structures are greatly affected by earthquakes. An ample amount of work is needed in the analysis and design of a structure under different loading conditions if done manually, but using software can analyze and design any kind of structure very easily. For evaluating the stability of a building in a seismic region, the performance of conventional structural buildings with plan defects and Diagrid Structural Buildings is compared utilizing STAAD PRO software. The probability of collapse in high-rise buildings is increased because of the high loads brought on by earthquakes and winds. The possibility of failure in such multistory buildings can be minimized using lateral load-resisting systems. Modeling is done on an irregular plan in the research, and C-shaped and L-shaped plans are taken into account for non-regular building shapes.

The structure consists of a twelve-story frame structure with a total height of 36 meters, and each floor is equipped with a storey height of 3 meters. In this research, a preliminary comparison between the diagrid structural system and the conventional frame structural system has been made for C-Type and L-Plan separately, and then a follow-up comparison between the two plans in total. Multiple parameters such as storey drift, absolute displacement, base shear, moment, and axial forces have been taken into consideration while different models were compared for earthquake load cases.

The structural analysis and design software uses the acronym STAAD PRO. According to IS 800:2007, M40-grade concrete and Fe-500 steel were used. The load combinations were calculated as per IS 1893:2002, and the analytical process was executed using the live load and the linear response method as per IS 875. For analysis purposes, earthquake zone 4 was chosen. There were variations in the results between floors when the diagrid was attached to the floor system. The base shear capacity of the diagrid structure was found to be less compared to that of the bare frame. Since the diagonal system resulted in minimum values of absolute displacement, storey drift, moment, and axial force, it was illustrated from the results that the system will be able to resist lateral loads better compared to a normal frame.

Devender Kumar Sutha, and Sabhilesh Sing (2020) A comparative study between irregular steel structures with and without diagrids has been made based on the seismic conditions suggested by IS 1893:2016. For the purpose of analysis, an irregular 2B + G + 18-story steel structure with a plan size of 15 m × 15 m, located in zone IV with average soil conditions, is considered. The modeling and analysis have been performed using ETABS 2019 software. All the structural elements have been designed as per IS 456:2000. Both the structures have been analyzed and checked considering dynamic analysis, lateral wind forces, and load combinations as per the requirements of the I.S. code. The building models have been analyzed using the ETABS 2019 program to determine base responses, storey stiffness, storey forces, maximum storey displacement, and maximum storey drift.

M. Vhanmane, M. Bhanuse (Year 2020) - Because of the high growth of the population and the increasing price of land, construction work has been enhanced to a high degree. As the height of the building increases, however, resistance to lateral loads must be improved, and this mechanism is more important than the structural response to gravity loading. Shear walls, rigid frames, wall-frame systems, braced tube systems, tubular systems, and outrigger systems are generally utilized to resist lateral loads. The application of diagrid structures in high-rise steel construction, as compared to traditional construction methods, has been analyzed as the aim of the dissertation project. In this research work, the analysis of high-rise structures involving a diagrid system has been discussed.

The dynamic response of high-rise buildings with diagrid systems has been studied by employing a square plan of 32 m × 32 m. According to IS 800:2007, all the structural elements, viz., beams and columns, are analyzed by taking into account all possible combinations of loads. Likewise, models of G+40, G+60, and G+80 storeys with diagrid system have been analyzed.

Comparative study of parameters like storey shear, storey displacement, and storey drift has also been discussed in this research work. Modeling and analysis of structural members have been done with the help of ETABS software. Compared to traditional buildings, a diagrid structure is seen to minimize the amount of steel used, as a column-free building is achieved. Additionally, diagrid buildings are seen to be aesthetically appealing from various angles. The overall performance, expression, and stability of the diagrid system are proven to be improved, and the stiffness of diagrid structures is seen to be higher compared to other structural systems.

V. METHODOLOGY

A G+9 reinforced concrete building located on soft soil in Seismic Zone V is considered for analysis. The building is modeled and analyzed using ETABS software in accordance with IS 1893 (Part 1):2016 and relevant Indian standards.

Structural Models

Three analytical models are developed:

- **Model I:** Regular symmetrical building with bracing and base isolation
- **Model II:** Irregular hybrid building with bracing and base isolation
- **Model III:** Irregular building with bracing without base isolation

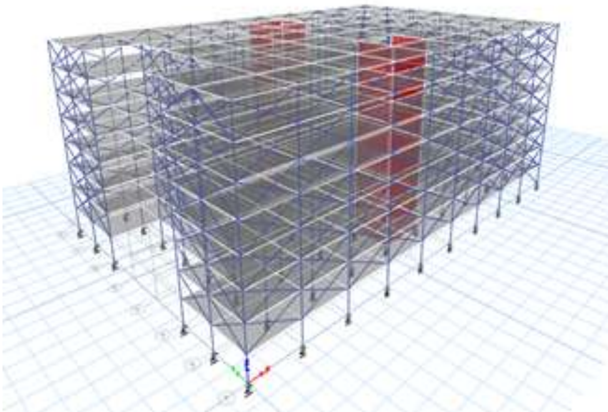

Figure 5.1 3D View of Model I

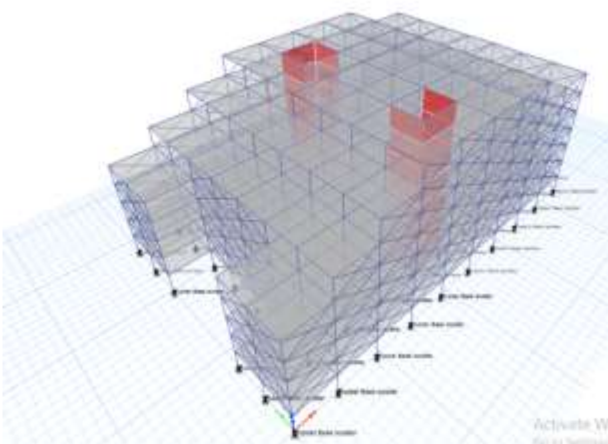

Figure 5.2 3D View of Model II

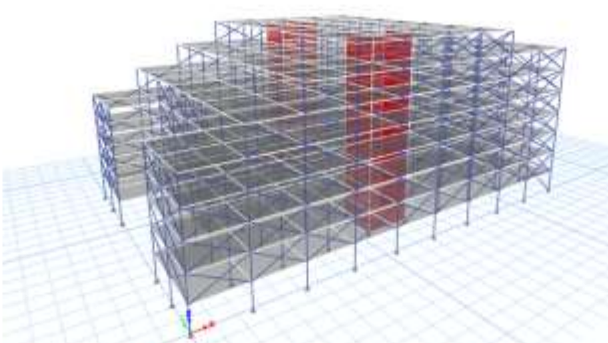

Figure 5.3 3D View of Model III

Analysis Procedure

Dynamic analysis is performed using the response spectrum method. Critical seismic load combinations are applied, and the structural response is evaluated in terms of storey displacement, storey drift, storey shear, base shear, and overturning moment.

VI. RESULTS AND DISCUSSION

Storey Displacement

For all models, lateral displacement increases with height and reaches a maximum at the top storey, which is consistent with typical bending behavior under lateral loads. Model I exhibits the least displacement due to its regular configuration and uniform stiffness. Model II shows the highest displacement owing to the flexibility introduced by base isolation. Model III demonstrates moderate displacement, where bracing improves stiffness but irregularity limits effective control.

Storey Drift

Storey drift results indicate that Model II performs best in limiting inter-storey deformation, highlighting the effectiveness of base isolation in reducing drift demand. Model III records the highest drift values due to irregularity and the absence of base isolation, while Model I shows intermediate performance.

Storey Shear and Base Shear

Model I experiences the highest storey shear and base shear, reflecting greater force attraction due to higher stiffness. Model II shows the lowest seismic forces, confirming the efficiency of base isolation systems. Model III lies between the two.

Overturning Moment

Overturning moments increase from the top towards the base for all models. Model III consistently exhibits the highest overturning moments, indicating higher vulnerability to overturning effects. Model II shows reduced overturning demand compared to Model III, while Model I records the lowest values due to structural regularity.

VII. CONCLUSIONS

Based on the comparative seismic analysis of G+9 buildings with different structural configurations, the following conclusions are drawn:

1. Structural regularity significantly enhances stiffness and reduces displacement, storey shear, and overturning moments.
2. Base isolation effectively reduces seismic forces and storey drift but increases overall lateral displacement.
3. Irregular buildings without base isolation exhibit higher drift and overturning demand, indicating increased seismic vulnerability.
4. The combined use of bracing and base isolation provides the most efficient seismic performance for irregular buildings, ensuring safety, comfort, and force reduction under severe seismic conditions.

Future Scope

The scope of the present study can be extended by:

- Investigating taller buildings (G+15 and above) to study height effects on seismic response.
- Performing nonlinear pushover and time-history analyses to capture inelastic behavior.
- Using real earthquake ground motion records for more realistic seismic assessment.
- Evaluating alternative isolation and energy dissipation devices.

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