International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 12 | Dec - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Analysis & Design of G+20 Building on a Slopy Ground by Using Staad Pro

G. Uma Mahesh[1], Mr.Dr. G. Srikanth[2]

[1]*M.Tech Scholar, Department of Civil Engineering, Siddhartha Institute of Technology and Sciences (SITS), Hyderabad, India .*

(umamahesh2553@gmail.com)

[2]*Assistant Professor and Head of the Department (HOD), Department of Civil Engineering, Siddhartha Institute of Technology and Sciences (SITS), Hyderabad, India (gsrikanth.civil@siddhartha.co.in)*

---***---

Abstract -
This study focuses on the **analysis** and **design** of RCC multi-storeyed **G+14 framed buildings** with both **regular** and **irregular plans**, using **STAAD Pro** software. The objective is to **model** and analyze the buildings under **seismic loads** through **equivalent static analysis**. Key areas of study include the comparison of **regular and irregular building configurations** and the impact of **shear walls** on **seismic performance**. The research investigates the **structural behavior**, including **displacement**, **stress distribution**, and **stability** of buildings subjected to **lateral seismic loads**, with a focus on buildings **with and without shear walls**. The findings reveal significant differences in the **structural responses** between the two configurations, highlighting the importance of shear walls in improving **seismic resistance**. The study concludes that shear walls enhance the **structural integrity** and reduce **lateral displacements**, providing recommendations for designing safer buildings in **seismic zones**. The research aims to offer valuable insights for **effective design strategies** to ensure safety and **minimize seismic damage** in **multi-storeyed RCC buildings**.

Keywords: RCC, multi-storeyed, G+14 framed buildings, regular and irregular plans, STAAD Pro, seismic loads, equivalent static analysis, shear walls, structural behavior, displacement, stress distribution, stability, seismic resistance, seismic zones, structural integrity, effective design strategies.

1.INTRODUCTION

Lateral loads, primarily in the form of horizontal forces, are critical considerations in the design of high-rise buildings. These forces, often generated by environmental factors such as wind and seismic activity, become increasingly significant as building height increases. In multi-storeyed structures, particularly those located in seismic zones, the type of lateral load-resisting system chosen plays a vital role in determining the building's response to such forces. The selection of an appropriate lateral system depends on factors such as the structural configuration, material availability, and economic feasibility, all of which must be carefully considered during the design process.

Among the various natural disasters, earthquakes stand out as one of the most unpredictable and destructive events, leading to catastrophic loss of life and property. Over the past few decades, numerous devastating earthquakes, such as the 2001 Bhuj earthquake in India, the 2005 Kashmir earthquake, and the 2011 Japan earthquake, have caused widespread destruction. These events have underscored the urgent need for earthquake-resistant design in buildings. The failures of engineered structures during such disasters often result from inadequate seismic design and construction practices, particularly in developing countries, where the quality of earthquake-resistant measures remains insufficient.

During an earthquake, buildings experience lateral forces due to ground motion, leading to shear forces at the base and potential structural damage. The dynamic response of a building during seismic events is influenced by its mass, stiffness, and natural period. A building's ability to resist seismic forces depends on its design to safely transfer these forces to the foundation and mitigate the impact through energy absorption. The fundamental principle behind earthquake-resistant design is to ensure that buildings can withstand such forces without suffering catastrophic failure, thereby protecting human life and minimizing economic losses.

This study aims to explore the behaviour of RCC framed buildings under seismic loading and emphasizes the importance of implementing effective earthquake-resistant measures to improve structural safety.

1.2 Necessity of the Project

In seismic-prone areas, ground motion during an earthquake occurs randomly in both horizontal and vertical directions, radiating from the epicenter. These accelerations induce vibrations in structures, generating inertial forces that can lead to significant damage if not properly accounted for in the design. The ability of a building to withstand these forces and maintain stability, strength, and serviceability during an earthquake is crucial for ensuring the safety of occupants and the preservation of the structure. Therefore, designing buildings to resist seismic forces is essential for mitigating the risks associated with earthquakes.

This thesis addresses the necessity of understanding the seismic behavior of G+14 RCC multi-storeyed framed buildings, both with regular and irregular plan configurations. The study uses STAAD Pro software to model and analyze these structures under seismic loading conditions. By conducting linear static analysis (Equivalent Static Analysis), the thesis evaluates critical parameters such as lateral displacement, base shear, shear forces, and bending moments in beams and columns. These parameters are essential for assessing the structural response to seismic events, highlighting the importance of considering both regular and irregular building plans in seismic design. The findings of this research will help improve the earthquake-resistant design of multi-storey buildings, enhancing their resilience in the face of seismic hazards.

1.3 OBJECTIVES OF THE STUDY

1.To model RCC G+14 multi-storey framed buildings with both regular and irregular plan configurations using STAAD Pro software.

2.To analyze the seismic response of RCC G+14 multi-storey framed buildings with regular and irregular plans under equivalent static analysis conditions.

3.To compare and evaluate the analysis results of both regular and irregular plan building models subjected to seismic loads.

4.To assess the seismic performance of RCC G+14 multi-storey framed buildings with and without shear walls under lateral seismic forces.

2.Theory and methodology

STAAD Pro is a leading software for structural analysis and design, extensively used for various types of buildings, water tanks, steel and concrete structures, and portal frames. It enables the modeling, analysis, and design of multi-story buildings, taking into account various load combinations such as dead, live, and seismic loads. This software is equipped with powerful 3D object-based modeling and visualization tools, allowing engineers to efficiently generate and analyze complex structural models. It integrates the entire engineering design process, from conception to the production of schematic drawings.

STAAD Pro's capabilities include both linear and nonlinear analysis, with advanced tools for dynamic response analysis, considering factors like construction sequencing and time-dependent effects such as creep and shrinkage. The software supports a wide range of materials, including steel, concrete, and composite beams and columns, and is equipped for designing structural elements like shear walls, steel connections, and base plates. It allows for rapid analysis of large models using the SAP Fire 64-bit solver, making it suitable for complex structures. Additionally, STAAD Pro provides detailed reports, graphic displays, and schematic construction drawings, making it a comprehensive solution for structural engineers involved in both residential and commercial building design.

2.Theory and Methodology

Earthquakes and Structural Design Considerations

Earthquakes result from the sudden release of energy within the Earth's crust, creating seismic waves that cause ground vibrations. These vibrations impact structures, potentially causing damage or collapse, especially during significant tectonic events. The **Elastic Rebound Theory** explains this process, where strain energy builds up in the Earth’s crust and is released through ruptures when the material's resilience is exceeded. The forces generated by earthquakes are dynamic and unpredictable, causing both vertical and horizontal movements in buildings. Lateral forces from earthquakes trigger shear and overturning moments in structures, which can lead to deformation, commonly referred to as "racking."

To mitigate earthquake damage, buildings must be designed to resist seismic loads, which include both dead loads (self-weight) and live loads (temporary or moving forces). Structural elements like **shear walls** play a critical role in resisting lateral forces. Earthquake-resistant structures are designed to withstand various levels of seismic activity, from minor tremors to severe shaking, without collapsing. Effective seismic design aims to reduce structural vulnerability and prevent loss of life during earthquakes.

In practice, **STAAD Pro** software is commonly used for the analysis and design of earthquake-resistant structures, allowing engineers to model buildings and apply dynamic load analysis to ensure safety and stability under seismic conditions. This software incorporates advanced modeling tools for various structural systems, facilitating efficient earthquake-resistant design.

2.1 Methodology

In the analysis of the G+14 storey framed building, several load combinations are considered to evaluate the building’s behavior under different conditions, as outlined by the Limit State of Collapse method. The load combinations are derived based on the Indian Standard Codes IS 1893: 2016 and IS 456:2000. The primary load combinations for this study include 1.5 times the sum of Dead Load (DL) and Live Load (LL), as well as combinations of DL with Earthquake loads in the X and Z directions, both in positive and negative directions. For instance, combinations like 1.5(DL + LL), 1.5(DL + EQX +ve), and 1.5(DL + EQZ -ve) are used for earthquake analysis. Additionally, combinations considering the live load in conjunction with earthquake loads such as 1.2(DL + LL + EQX +ve) and 1.2(DL + LL + EQZ -ve) are also applied. Other combinations, like 0.9DL + 1.5EQX +ve and 0.9DL + 1.5EQZ -ve, account for more extreme earthquake loading scenarios.

To calculate these loads numerically, the dead load (DL) for each floor is estimated based on the thickness of the slab and the material density. The slab thickness is 150 mm, and the density of reinforced concrete is 24.9926 kN/m³. This gives a dead load of approximately 3.749 kN/m² for each floor slab. The live load (LL) is considered to be 3 kN/m² for the floors, based on the requirements for educational institutions per IS 875: Part 2, 1987, and 1.5 kN/m² for the roof. These loads are combined with earthquake loads for different directions to assess the building’s response to lateral forces. The earthquake load is calculated using the Response Spectrum method, incorporating the fundamental period of the building, which is calculated to be 0.714 seconds, and the seismic parameters of the building’s location.

The seismic load, or base shear, is calculated by multiplying the total seismic weight of the building by the spectral acceleration for the seismic zone, with the building located in Seismic Zone II. The total seismic weight is the sum of the dead load and live load, with each floor contributing to the total load. The seismic coefficient for Zone II is 0.10, as per IS 1893: 2016, and the building’s response to seismic forces is considered using the fundamental period. Base shear is determined through the where WW is the total seismic weight, SaS_a is the spectral acceleration, and gg is the acceleration due to gravity (9.81 m/s²).

With these load combinations and numerical values in place, the structural analysis of the building is performed using STAAD Pro software. The analysis is conducted for the combined effects of dead load, live load, and seismic loads to ensure the building meets the safety and performance standards under seismic conditions, as stipulated in the relevant IS codes. This comprehensive approach ensures that both gravity and lateral loads are considered in the design and evaluation of the building.

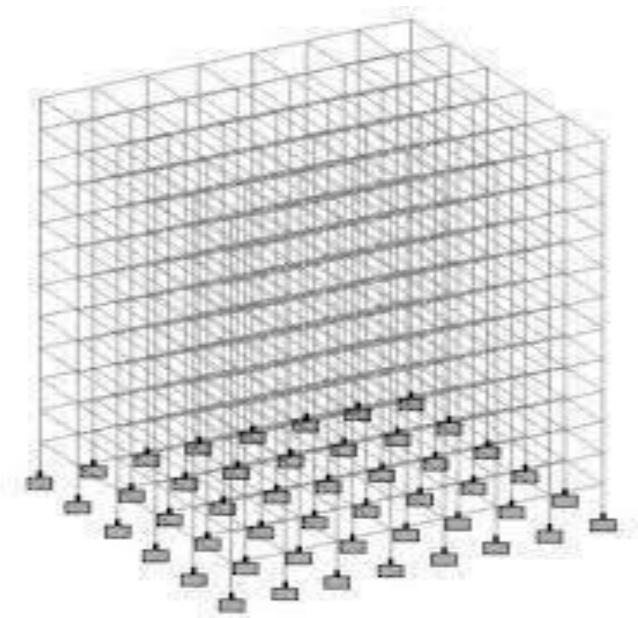


Fig.1.13D View of Model -1 (Building with plan regular)

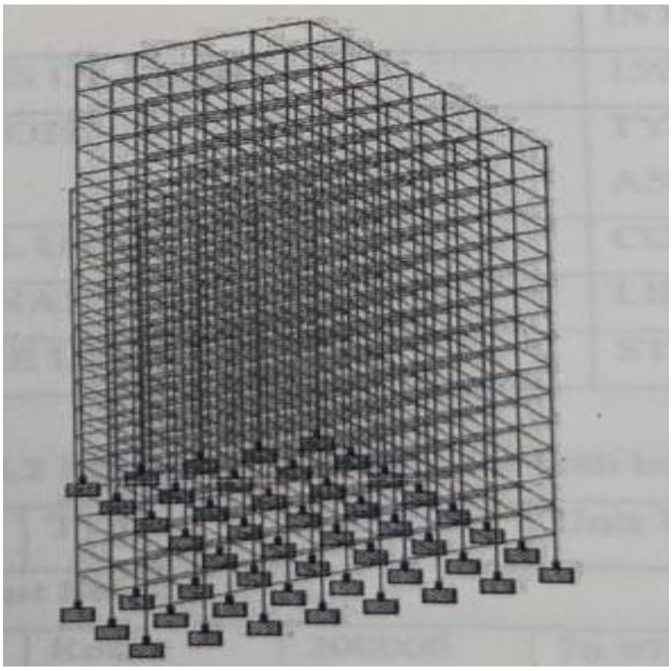


Fig.1.2 3D View of Model -2 (Building with plan irregular)

3. RESULTS AND DISCUSSIONS

3.1 LATERAL DISPLACEMENT

The lateral displacement of the G+14 storey building has been calculated in both the X and Y directions under seismic load conditions. The results for the lateral displacement of each storey are provided in the table for both directions.

In the X-direction, the displacement increases with height, reaching 52.14 mm at the 14th storey and reducing as we move towards the ground level. At storey 13, the displacement is 50.52 mm, and it continues to decrease gradually until reaching the ground level with a displacement of 1.27 mm. This reduction in displacement at lower levels is typical, as the base provides more restraint compared to the upper floors.

Similarly, in the Y-direction, the displacement follows a similar trend, with the maximum displacement observed at the 14th storey (55.67 mm) and decreasing to 1.52 mm at the ground level. The displacement at storey 13 is 54.22 mm, and at lower storeys, it gradually reduces until reaching the first storey, where it is 5.48 mm.

Notably, the displacement patterns in the upper storeys show a higher degree of movement compared to the lower storeys. The lateral displacements in the X-direction are generally lower than those in the Y-direction across most of the building's height, indicating that the building is more responsive to lateral forces in the Y-direction. These displacement values are essential in ensuring the building's performance under seismic loading, helping to verify whether the structure meets the design criteria for lateral displacement as per seismic codes.

3.2 The comparison of lateral displacement for Building Model 1 with a regular plan in the X and Z directions under seismic loads shows a clear trend of decreasing displacement as we move from the top to the ground level in both directions.

In the X-direction, the maximum lateral displacement occurs at the 14th storey, with a value of 19.83 mm, and gradually reduces as we move down to the ground level, where the displacement reaches 0.68 mm. The reduction in displacement is consistent across all storeys, with storey 13 at 19.17 mm, storey 12 at 18.41 mm, and so on. At the first storey, the displacement is 2.03 mm, and at the ground level, it is 0.68 mm.

In the Z-direction, the displacement values are slightly higher than in the X-direction across all storeys. At the 14th storey, the displacement reaches 23.59 mm, and decreases down to 0.91 mm at the ground level. Similar to the X-direction, the displacement decreases progressively as the storeys move downward, with storey 13 at 22.73 mm and storey 12 at 21.69 mm, and so on.

Overall, the lateral displacement in the Z-direction is higher than in the X-direction, indicating the building's greater response to seismic forces along the Z-axis. Both directions show a gradual decrease in displacement as the height of the building decreases, which is typical for framed structures under seismic loading.

3.3 BASE SHEAR

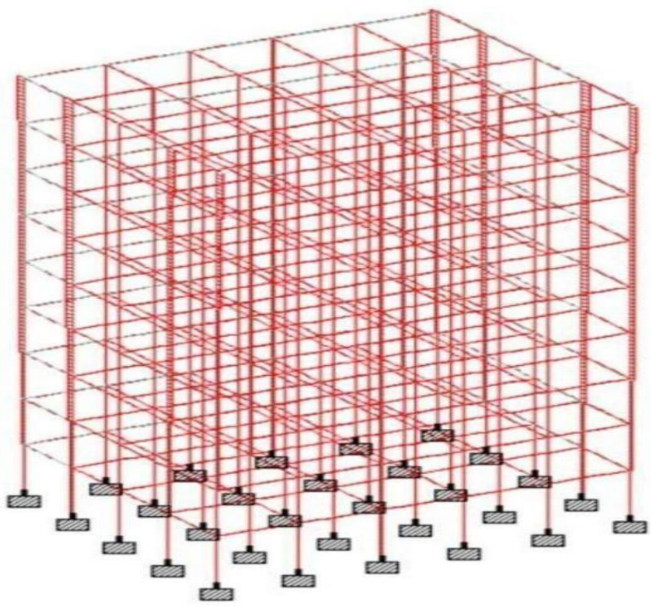
Base shear is the total horizontal force acting at the base of a structure due to seismic activity. It is directly proportional to the weight of the building. The values of base shear for both models were calculated through static analysis. For Model 1, which has a regular plan, the base shear value is 2657.27 kN. In contrast, Model 2, with an irregular plan, experiences a lower base shear value of 2033.48 kN. This difference highlights the influence of building configuration on seismic force distribution, with irregular plan structures generally experiencing lower base shear.

3.4 BENDING MOMENT IN BEAMS AND COLUMNS

Fig.3.Bending moment in beams of Building Model 1

The analysis of maximum bending moments in the beams of the building models reveals the effect of different load combinations. For the load combination 1.5(DL+LL), which accounts for dead load (DL) and live load (LL), the maximum bending moments vary across the beams, with the highest values reaching up to 621.21 kN-m. This represents the bending moments experienced by beams under normal loading conditions. In contrast, for the combination 1.2(DL+LL+EQZ+), which also incorporates seismic forces in the Z-direction (EQZ+), the maximum bending moments are generally lower, with values ranging between 1096.01 kN-m and 496.96 kN-m. This indicates that the seismic loads contribute significantly to the bending moments in the beams, especially when compared to the standard dead and live load combination. Lastly, for the load combination 1.5(DL+EQZ), where only seismic loads in the Z-direction are considered along with dead load, the maximum bending moments show a similar trend, although there are some notable variations, with the highest values observed at 1220.93 kN-m. The comparison of these results suggests that the beams experience the highest bending moments when subjected to seismic forces, highlighting the importance of considering seismic loads in structural design. These variations in bending moments are crucial for the structural integrity and safety of the building under seismic conditions.

The analysis of the maximum bending moments in the columns of both building models under various load combinations reveals interesting insights. For the load combination 1.5(DL+LL), which includes dead and live loads, the maximum bending moments range from 44.23 kN-m to 176 kN-m. These values are relatively low compared to the seismic load combinations, indicating that the columns primarily resist vertical loads under typical conditions. In contrast, the combination 1.2(DL+LL+EQZ+), which includes seismic forces in the Z-direction, shows a significant increase in bending moments, with values reaching up to 2221.61 kN-m. This highlights the substantial impact of seismic forces on the columns, making them the critical elements under earthquake conditions.



The highest bending moments are observed under the load combination 1.5(DL+EQZ+), with values reaching as high as 2721.75 kN-m in some cases. This indicates that the columns experience the most significant bending under seismic forces alone, with some values exceeding those from the other load combinations. The variation in bending moments across the columns suggests that the structural response is heavily influenced by the distribution of seismic forces, which can cause significant localized effects. These findings emphasize the importance of designing columns to withstand large seismic bending moments, ensuring the stability and safety of the building during an earthquake.

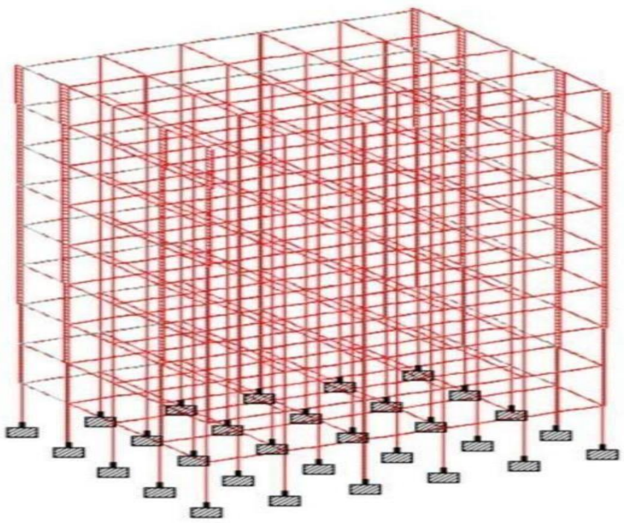


Fig.4 Bending moment in columns of building model

The maximum bending moments in the columns of both building models under different load combinations reveal critical insights into the structural behavior under various loading conditions. For the load combination 1.5(DL+LL), which accounts for dead and live loads, the maximum bending moments are relatively moderate, with values ranging from 44.23 kN-m to 176 kN-m. However, when seismic loads are considered, significant increases are observed. In the 1.2(DL+LL+EQZ+) load combination, which includes seismic forces in the Z-direction, the bending moments rise substantially, reaching up to 2221.61 kN-m.

The most pronounced increase in bending moments occurs under the 1.5(DL+EQZ+), where the seismic load alone leads to bending moments as high as 2721.75 kN-m. These values highlight the severe effect of seismic forces on the column behavior. Additionally, the variation in bending moments across different columns indicates that the response to seismic forces is not uniform, with some columns experiencing significantly higher stresses than others. This emphasizes the need for careful consideration of seismic forces in the design process to ensure that the columns can withstand the large bending moments generated during an earthquake, maintaining the overall stability and safety of the structure.

4. CONCLUSION

The results from the analysis of two building models subjected to seismic loads provide valuable insights into the structural response under different load combinations. The maximum lateral displacements observed at the top storey level for Model 1 were 52.14 mm in the X-direction and 55.67 mm in the Z-direction. For Model 2, the displacements were significantly lower, with values of 19.83 mm in the X-direction and 23.59 mm in the Z-direction. Additionally, the base shear was higher for Model 1 (2657.27 kN) compared to Model 2 (2033.48 kN), highlighting the direct correlation between building mass and base shear.

Regarding bending moments in beams, Model 1 exhibited a reduction of up to 32.16% for the load combination of 1.5(DL+EQZ+) compared to 1.5(DL+LL). In contrast, Model 2 showed lower bending moments across all load combinations. In columns, Model 1 demonstrated a significant increase in bending moments, with a 1562.13% rise for the load combination 1.2(DL+LL+EQZ+) compared to 1.5(DL+LL), emphasizing the effect of earthquake loads.

Notably, Model 1 showed a reduction in shear forces in beams and columns, especially under the load combination of 1.2(DL+LL+EQZ+), with a 24% decrease in shear force for beams. These results underline the importance of considering multiple load combinations in the design phase to optimize structural performance.

Future studies should incorporate nonlinear dynamic analysis and explore soil-structure interaction to further enhance the accuracy and resilience of buildings in seismic zones.

Reference

1. Chandurkar, P. P. (2013). *Seismic Analysis of RCC Building with and Without Shear Wall*. International Journal of Modern Engineering Research (IJMER), Vol. 3, Issue 3, pp. 1805–1810. ISSN: 2249-6645.

2. Gauri, G. Kakpure, and Mundhada, A. R. (2017). *Comparative Study of Static and Dynamic Seismic Analysis of Multistoried RCC Buildings by ETAB*. International Journal of Engineering Research and Application, Vol. 7, Issue 5 (Part 5), pp. 06–10. ISSN: 2248-9622.

3. GS Hiremath (2014). *Effect of Change in Shear Wall Location with Uniform and Varying Thickness in High Rise Building*. International Journal of Science and Research, Volume 03, October 2014.

4. Harne, V. R. (2014). *Comparative Study of Strength of RC Shear Wall at Different Location on Multi-Storied Residential Building*. International Journal of Civil Engineering Research, Vol. 5, No. 4, pp. 391–400. ISSN: 2278-3652.

5. IS 456: 2000. *Indian Standard Plain and Reinforced Concrete Code of Practice (Fourth Revision)*. Bureau of Indian Standards, New Delhi.

6. IS 875 (Part 1, 2, and 5): 1987. *Indian Standard Code of Practice for Design Loads (Other than Earthquake) for Building and Structures*. Bureau of Indian Standards, New Delhi.

7. IS 1893 (Part 1): 2016. *Criteria for Earthquake Resistant Design of Structures*. Bureau of Indian Standards, New Delhi.

8. Karnale, A. K. B., & Shinde, D. N. (2015). *Comparative Seismic Analysis of High Rise and Low Rise RCC Building with Shear Wall*. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 9, September 2015.

9. Ugale, A. B., & Raut, H. R. (2014). *Effect of Steel Plate Shear Wall on Behavior of Structure*. International Journal of Civil Engineering Research, Vol. 5, No. 3, pp. 295–300. ISSN: 2278-3652.