© July 2026 | IJIRT | Volume 13 Issue 2 | ISSN: 2349-6002

Comparative Analysis of Lightweight and Normal Concrete RC Buildings Under Seismic Loads in Zone-II And Zone-V Using ETABS

Rajkumar S [1], Dr G.Arunkumar [2]
[1]PG Student, Structural Engg, Government college of engineering, Salem
[2] Associate professor, Dept of Civil Engg, Government college of engineering, Salem

***Abstract*—The increasing demand for earthquake-resistant and sustainable buildings has encouraged the use of lightweight concrete in structural engineering. This study presents a comparative analysis of a G+5 reinforced concrete building constructed using conventional concrete and lightweight concrete under seismic loading. Both models were developed in ETABS with identical geometry and loading conditions and analyzed for Seismic Zone II and Zone V in accordance with relevant Indian Standard codes. The structural performance was evaluated based on base shear, storey displacement, and storey drift. The results indicate that the lightweight concrete building experienced significantly lower base shear due to its reduced self-weight, while only a slight increase in storey displacement and drift was observed. All response parameters remained within acceptable design limits. The findings demonstrate that lightweight concrete can effectively reduce seismic forces without compromising structural safety, making it a suitable alternative for medium-rise reinforced concrete buildings in earthquake-prone regions. This study highlights the potential of lightweight concrete to improve seismic performance while promoting sustainable construction practices.**

***Index Terms*—Lightweight Concrete; Reinforced Concrete Building; ETABS; Seismic Analysis; Base Shear; Storey Drift; Storey Displacement; Earthquake Resistant Design**

I. INTRODUCTION

Rapid urban development and increasing population have accelerated the construction of multi-storey reinforced concrete buildings throughout the world. Modern buildings must not only satisfy strength requirements but also exhibit adequate resistance against lateral loads generated by earthquakes and wind. These lateral forces significantly influence structural stability, serviceability, and overall safety, particularly in regions prone to seismic activity. Consequently, structural engineers continuously seek innovative materials and design approaches capable of reducing earthquake-induced damage while maintaining structural reliability.

Among the various loads acting on a building, seismic forces are particularly critical because they originate from the inertia developed by the structure during ground motion. Since inertia force is directly proportional to the structural mass, heavier buildings generally experience greater earthquake forces. Therefore, reducing the self-weight of reinforced concrete structures has become an effective approach to improve seismic performance and reduce the demand on structural members and foundations.

Lightweight concrete has gained considerable attention in structural engineering because of its reduced density compared with conventional concrete. Besides lowering dead load, lightweight concrete offers improved thermal insulation, fire resistance, and easier handling during construction. The reduction in structural mass directly contributes to lower seismic forces, making lightweight concrete particularly suitable for buildings located in earthquake-prone regions. Although lightweight concrete may exhibit slightly lower stiffness than conventional concrete, appropriate structural design can effectively compensate for this limitation while preserving satisfactory performance.

Recent advances in computational structural engineering have enabled engineers to evaluate complex building behaviour accurately using sophisticated analysis software. ETABS is among the most widely adopted software packages for analysing reinforced concrete buildings because it integrates three-dimensional modelling, load assignment, code-based seismic analysis, wind analysis, and structural design within a single platform. Its capability to predict storey response, member forces, base shear, and lateral displacements makes it particularly suitable for evaluating the behaviour of multi-storey buildings under various loading conditions.

The present investigation evaluates the structural response of a G+5 reinforced concrete building modelled using both normal concrete and lightweight concrete under identical loading conditions. The study compares the performance of both structural systems under seismic loading corresponding to Zone II and Zone V while also considering wind effects. The comparison is primarily based on structural response parameters such as base shear, storey displacement, and storey drift, thereby providing insight into the influence of reduced structural mass on earthquake-resistant building performance.

II. LITERATURE REVIEW

1). “Seismic performance of lightweight concrete structures” N.V.Vandanapu et.al (2018) Summary: This study investigates the seismic response of multi-storey reinforced concrete buildings constructed using lightweight concrete. The research compares structural parameters such as base shear, storey displacement, and storey drift with conventional concrete structures. Results indicate that lightweight concrete reduces overall structural mass, thereby lowering seismic forces. However, slight increases in displacement were observed due to reduced stiffness.

2). “Seismic Performance Study of RC Columns Strengthened by Full Lightweight Ceramsite Concrete: Experiment and Simulation” Y.Zhang,L.Wang et.al (2025) Summary: This paper presents both experimental and numerical investigations on reinforced concrete columns strengthened using lightweight ceramsite concrete. The study evaluates seismic performance under cyclic loading conditions. Results show improved ductility, energy dissipation capacity, and crack control in strengthened columns. Finite element simulations validated experimental observations. The research demonstrates that lightweight concrete materials can enhance structural performance during earthquakes. The findings highlight the suitability of lightweight aggregate concrete for seismic retrofitting and strengthening applications.

3). “Experimental and Numerical Investigation on Post-Fire Seismic Performance of Lightweight Aggregate Reinforced Concrete Beams” H.Li,X.Chen et.al (2022) Summary: This research evaluates the seismic behavior of lightweight aggregate reinforced concrete beams subjected to post-fire conditions. Both laboratory experiments and numerical modeling were conducted to assess load-carrying capacity and ductility under cyclic loading. The study observed that lightweight aggregate concrete maintains acceptable seismic performance even after thermal exposure. Though stiffness slightly reduced, structural integrity remained within safe limits. The paper emphasizes the durability and resilience of lightweight concrete elements under combined fire and earthquake scenarios.

4). “Seismic Performance of RC Columns with Different Degrees of Earthquake Damage Strengthened Using Full Lightweight Ceramsite Concrete” J.Liu, Z.Zhao et.al (2025) Summary: This paper investigates the strengthening of earthquake-damaged RC columns using lightweight ceramsite concrete. Experimental cyclic loading tests were conducted to measure improvements in load capacity and ductility. The results indicated significant enhancement in seismic resistance after strengthening. Lightweight concrete contributed to reduced additional dead load while improving structural efficiency. The study concludes that lightweight concrete materials can be effectively used in rehabilitation and retrofitting of seismic-damaged structures.

5). “Effect of Lightweight and Low-Strength Concrete on Seismic Performance of Shear Walls” R.K.Singh,S.K.Jain et.al (2015) Summary:This study investigates the influence of lightweight and low-strength concrete on the seismic response of reinforced concrete shear walls. Analytical and numerical models were used to compare lateral displacement, drift, and energy dissipation capacity. Results revealed that lightweight concrete reduces base shear due to lower structural mass, but stiffness reduction slightly increases displacement. The study highlights the need for proper design modifications when using lightweight materials in seismic zones. The findings are significant for understanding mass-stiffness interaction in earthquake engineering.

III. BUILDING DESCRIPTION

The building selected for analysis is intended to represent a typical medium-rise reinforced concrete residential structure commonly adopted in urban regions.

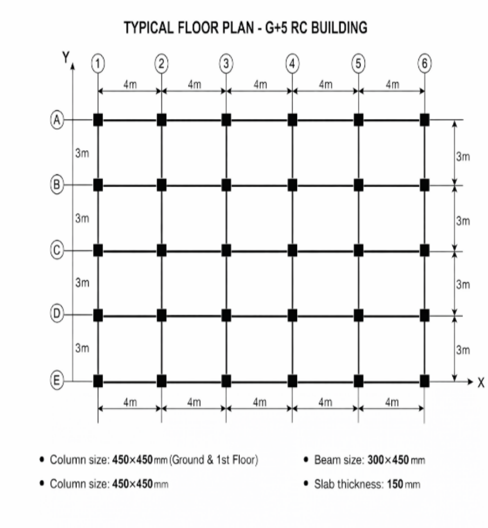

Figure 1 Floor plan

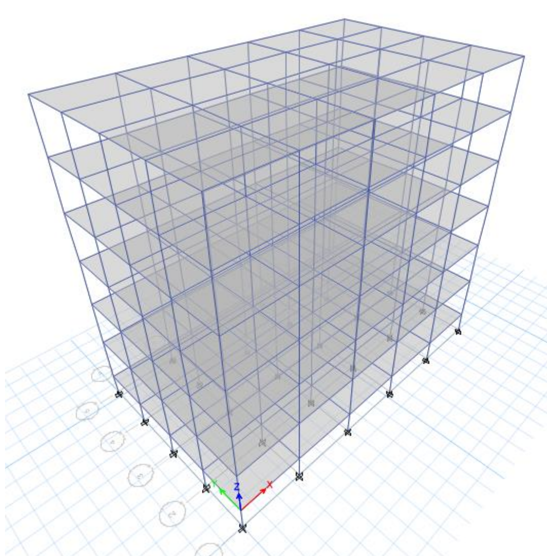

Figure 2 Three dimensional (3D) view

Table 1 Building details

Parameter	Value
Building Type	Residential
Structural System	Reinforced Concrete Moment Resisting Frame
Number of Storeys	G + 5
Analysis Software	ETABS
Analysis Method	Linear Static Analysis
Concrete Types	Conventional Concrete & Lightweight Concrete
Seismic Zones	Zone II and Zone V
Applicable Codes	IS 456:2000, IS 875, IS 1893 (Part 1)

The same structural configuration was maintained for both models so that the comparison accurately reflects the influence of concrete density on the structural response.

IV. STRUCTURAL ANALYSIS

Following completion of modelling, linear static analysis was performed for both structural systems.
The analytical comparison focused on:

- Base Shear
- Maximum Storey Displacement
- Maximum Storey Drift

These parameters provide a clear understanding of the influence of lightweight concrete on global structural behaviour. Because the structural mass is lower in the lightweight concrete building, a reduction in inertia forces was anticipated according to Newton's Second Law.

BASE SHEAR: Base shear is the total horizontal seismic force acting at the base of the structure during earthquake loading. It is one of the most important parameters in seismic analysis.

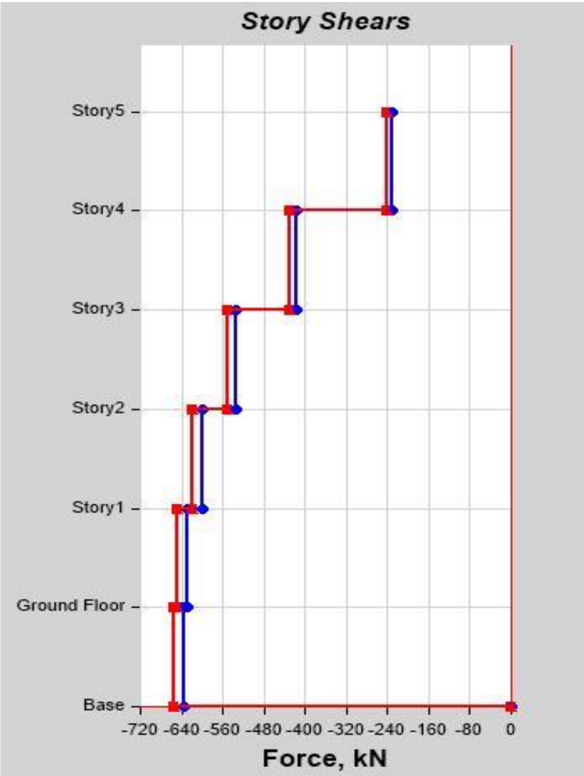

Figure 3 Base Shear – Normal concrete (Zone II)

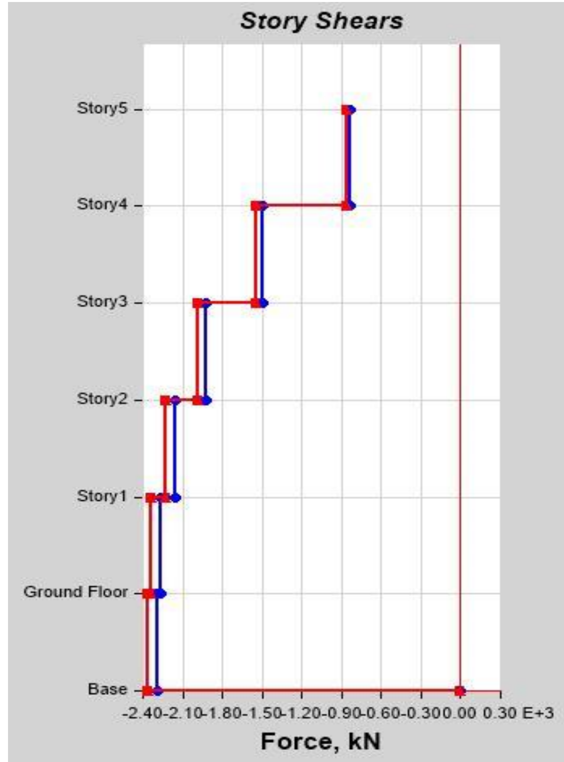

Figure 5 Base Shear – Normal concrete (Zone V)

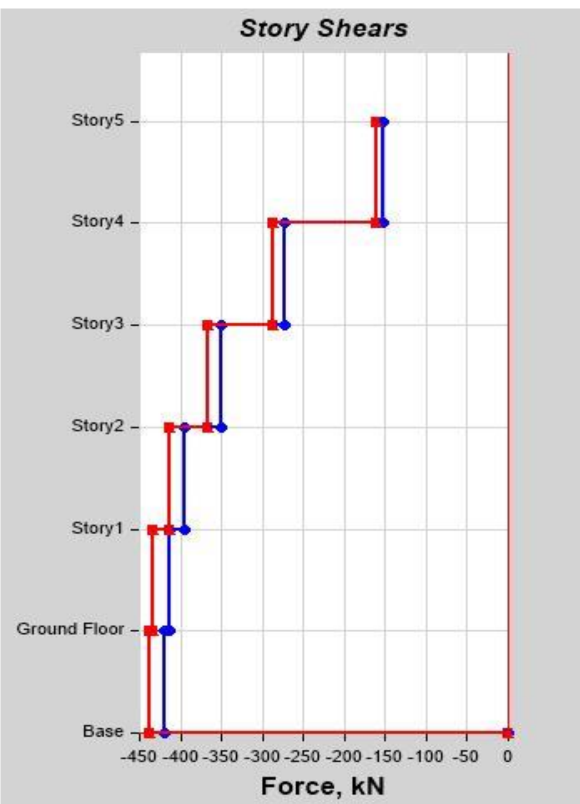

Figure 4 Base Shear – Lightweight concrete (Zone II)

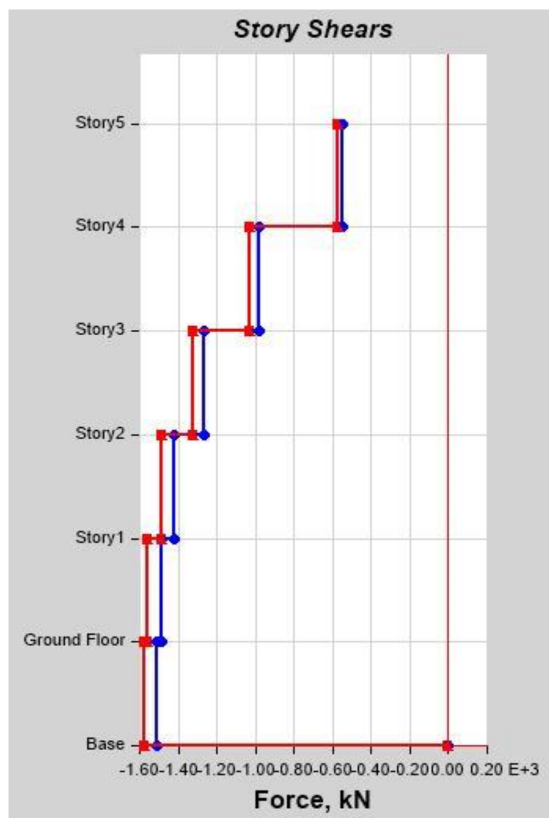

Figure 6 Base Shear – Lightweight concrete (Zone V)

Table 2 Base shear comparison

Seismic Zone	Conventional Concrete	Lightweight Concrete
Zone II	636.692 kN	418.538 kN
Zone V	2292 kN	1507 kN

These results confirm that lightweight concrete effectively reduces earthquake forces acting on the building.

STOREY DISPLACEMENT: Storey displacement refers to the lateral movement of each floor level due to seismic and wind loads. Excessive displacement may affect structural safety and serviceability.

Figure 7 Storey Displacement – Normal concrete (Zone II)

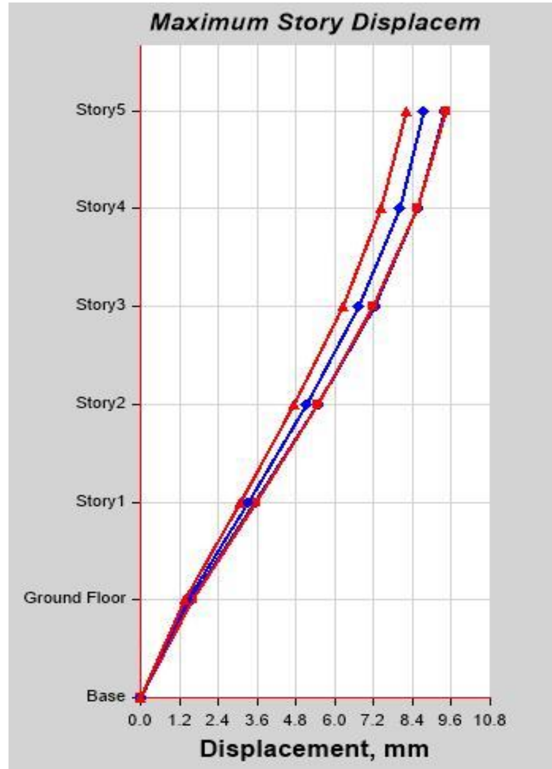

Figure 8 Storey Displacement – Lightweight concrete (Zone II)

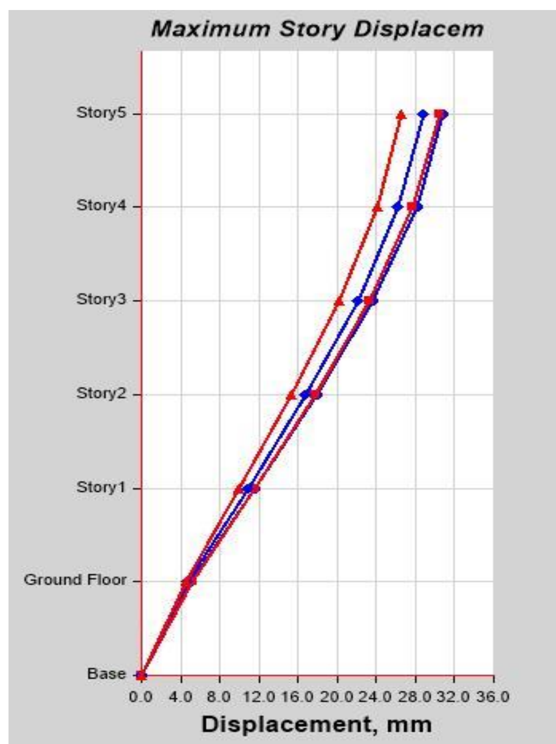

Figure 9 Storey Displacement – Normal concrete (Zone V)

Figure 10 Storey Displacement – Lightweight concrete (Zone V)

Table 3 Storey displacement comparison

Seismic Zone	Conventional Concrete	Lightweight Concrete
Zone II	8.546 mm	8.754 mm
Zone V	30.765 mm	31.514 mm

Although the lightweight concrete model experienced slightly higher displacement, the increase is very small. This behaviour is expected because lightweight concrete reduces structural stiffness to some extent while simultaneously reducing seismic forces. Despite the slight increase, the displacement values remained within acceptable serviceability limits.

STOREY DRIFT: Storey drift is defined as the relative lateral displacement between two consecutive floors of a building. It is an important parameter in earthquake-resistant design.

Figure 11 Storey Drift – Normal concrete (Zone II)

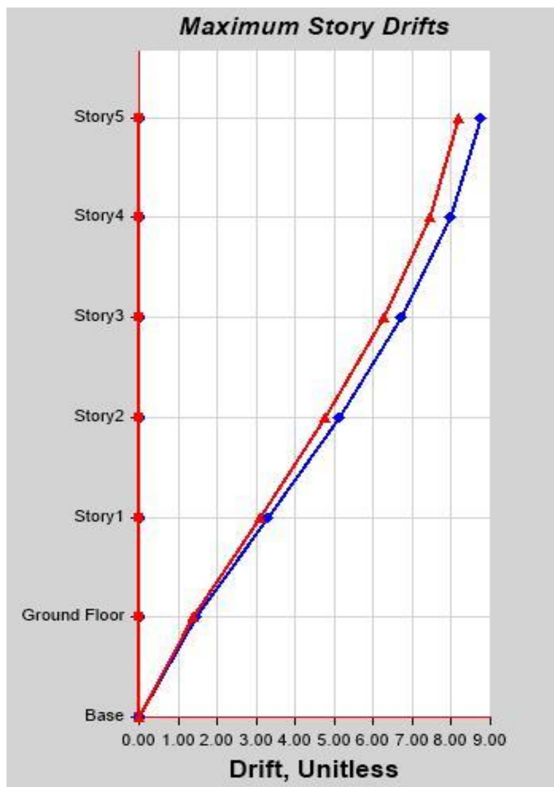

Figure 12 Storey Drift – Lightweight concrete (Zone II)

Figure 13 Storey Drift – Normal concrete (Zone V)

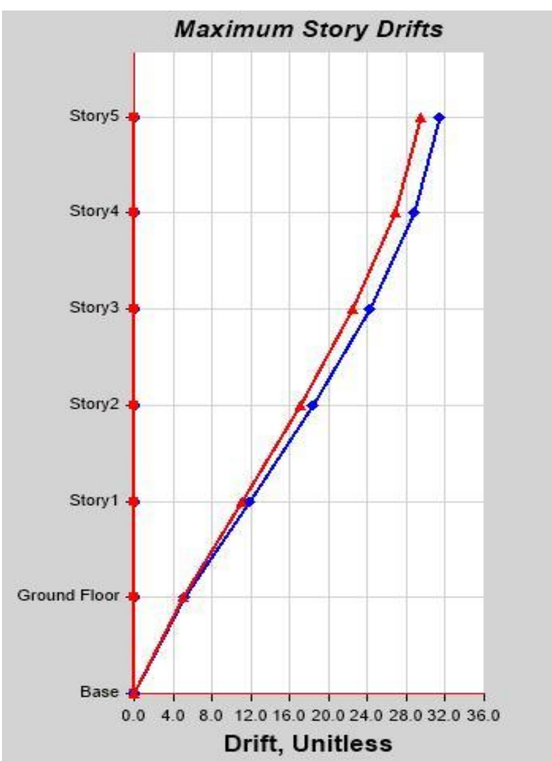

Figure 14 Storey Drift – Lightweight concrete (Zone V)

Table 4 Storey drift comparison

Seismic Zone	Conventional Concrete	Lightweight Concrete
Zone II	7.9899 mm	8.7538 mm
Zone V	28.7636 mm	31.5136 mm

The lightweight concrete model exhibited a marginal increase in storey drift. However, the drift remained within the permissible limits prescribed by IS 1893.The slight increase is compensated by the considerable reduction in seismic force, making lightweight concrete an attractive alternative for earthquake-resistant construction.

V. RESULTS AND DISCUSSION

This project focused on the comparative analysis of a G+5 reinforced concrete building using normal concrete and lightweight concrete under seismic and wind loading conditions using ETABS software. The structural behaviour of the building was studied by evaluating important parameters such as base shear, storey displacement, and storey drift.
The analysis results obtained from ETABS were carefully compared to understand the effect of reduced structural weight on the seismic performance of the building.

Table 5 Comparison between normal concrete and lightweight concrete

DESCRIPTION	ZONE II		ZONE V	
	Normal Concrete	Lightweight Concrete	Normal Concrete	Lightweight Concrete
Base shear (kN)	636.7	418.5	2292	1507
Storey Displacement(mm)	8.55	8.75	30.77	31.51
Storey Drift	0.0008	0.0009	0.0029	0.0031

Table 6 Parameter comparison between NC & LWC

Parameter	Normal concrete	Lightweight concrete
Structural weight	Higher	Lower
Base shear	Higher	Lower
Seismic force	Higher	Reduced
Structural efficiency	Moderate	Better

The analytical investigation clearly demonstrates the structural advantages of lightweight concrete under seismic loading. The reduction in concrete density significantly decreases the overall seismic weight of the building. Since earthquake force is directly proportional to structural mass, the resulting base shear decreases considerably. The ETABS analysis revealed reductions of approximately one-third in base shear for both seismic zones. Although storey displacement and storey drift increased slightly, the increase remained within acceptable design limits. This behaviour is consistent with previous research, where reduced stiffness accompanies lower structural weight. From an engineering perspective, the slight increase in displacement is acceptable because the substantial reduction in earthquake force decreases demands on beams, columns, and foundations. Consequently, lightweight concrete offers a balanced combination of safety, economy, and sustainability. Furthermore, reducing dead load also decreases foundation reactions and reinforcement demand, potentially leading to cost savings in large-scale construction projects. The analytical findings therefore indicate that lightweight concrete can be successfully adopted in medium-rise buildings located in earthquake-prone regions.

VI. CONCLUSION

The present study investigated the comparative structural behaviour of a G+5 reinforced concrete building constructed using conventional concrete and lightweight concrete under seismic loading conditions using ETABS. Identical structural geometry, member dimensions, loading conditions, and boundary conditions were maintained for both analytical models to ensure that the observed differences in structural response were solely attributable to the variation in concrete density.

The analytical results demonstrated that the lightweight concrete building exhibited a substantial reduction in base shear compared with the conventional concrete building. In Zone II, the base shear decreased from 636.692 kN to 418.538 kN, while in Zone V it reduced from 2292 kN to 1507 kN. These reductions clearly indicate the beneficial effect of lowering the seismic mass of the structure.

The maximum storey displacement and storey drift of the lightweight concrete model were observed to be slightly higher than those of the conventional concrete model. However, the increases remained within acceptable design limits prescribed by the relevant Indian Standards. The slight increase in lateral deformation is outweighed by the significant reduction in seismic demand, making lightweight concrete a structurally efficient alternative for earthquake-resistant buildings.

Overall, the investigation confirms that lightweight concrete offers an effective means of reducing seismic forces while maintaining satisfactory structural performance. In addition to improved earthquake resistance, the reduction in dead load contributes to more economical structural members and foundations, improved sustainability, and enhanced construction efficiency. The study therefore concludes that lightweight concrete is a promising material for medium-rise reinforced concrete buildings located in seismic regions and has considerable potential for future structural applications.

REFERENCES

[1] Vandanapu, N.V., & Krishnamurthy, M. (2018) - Seismic Performance of Lightweight Concrete Structures.

[2] Zhang, Y., & Wang, L. (2025) - Seismic Performance Study of RC Columns Strengthened by Full Lightweight Ceramsite Concrete: Experiment and Simulation.

[3] Li, H., & Chen, X. (2022) - Experimental and Numerical Investigation on Post-Fire Seismic Performance of Lightweight Aggregate Reinforced Concrete Beams.

[4] Mohamed, M.A., & El-Sayed, K.M. (2024) - Damage Detection of Lightweight Concrete Dual Systems Reinforced with GFRP Bars under Various Seismic Intensities.

[5] Shaik Akhil Ahamed, K.V. Pratap, Aug (2020) – Dynamic analysis of G+20 multi storied building by using shear walls in various locations for different seismic zones by using ETABS analysis

[6] Md. Foisal Haque & et.al,Jan (2025) – Seismic performance evaluation of multi-storied RC structure by non linear static analysis

[7] Ajay Namdev, Dr. Rajeev Chandak, June (2023) – Studyon seismic analysis of high-rise buildings using ETABS software

[8] Liu, J., & Zhao, Z. (2025) - Seismic Performance of RC Columns with Different Degrees of Earthquake Damage Strengthened Using Full Lightweight Ceramsite Concrete.
[9] ElGawady, M.A., & Mohamed, A.S. (2023) - Seismic Performance Evaluation of Plastered Cellular Lightweight Concrete Block Masonry Walls.
[10] Sun, Q., & Yang, T. (2022) - Experimental Seismic Analysis of Steel-Reinforced Lightweight Concrete Columns with Cross-Shaped Steel Section.
[11] Singh, R.K., & Jain, S.K. (2015) - Effect of Lightweight and Low-Strength Concrete on Seismic Performance of Shear Walls.
[12] IS 456:2000, Plain and Reinforced Concrete – Code of Practice, Bureau of Indian Standards, New Delhi, India.
[13] IS 875 (Part 1):1987, Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures – Dead Loads, BIS, New Delhi.
[14] IS 875 (Part 2):1987, Code of Practice for Design Loads (Other than Earthquake) – Imposed Loads, BIS, New Delhi.
[15] IS 875 (Part 3):2015, Wind Loads on Buildings and Structures, BIS, New Delhi.
[16] IS 1893 (Part 1):2016, Criteria for Earthquake Resistant Design of Structures, BIS, New Delhi.
[17] IS 10262:2019, Concrete Mix Proportioning – Guidelines, BIS, New Delhi.