International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 06 | Jun 2024 www.irjet.net p-ISSN: 2395-0072

COMPARATIVE STUDY OF SEISMIC BEHAVIOR OF THE RC FRAME STRUCTURE WITH PRECAST CONCRETE AND NORMAL CONCRETE

Rajat Pratap Shahi[1], Mr. Ushendra Kumar[2]

[1]Master of Technology, Civil Engineering, Lucknow Institute of Technology, Lucknow, India
[2]Head of Department, Department of Civil Engineering, Lucknow Institute of Technology, Lucknow, India

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Abstract - *The present research paper aims to conduct a comprehensive comparative analysis of three precast structural models under dynamic loading conditions, in accordance with the guidelines stipulated in IS 1893 Part 1:2016. In this investigation, four models have been formulated using the ETABS Software. In the initial model, the beam, column, and slab are all fabricated from concrete with an M25 grade. Transitioning to the second model, the beam and column are constructed using M40 grade concrete, while the slab is comprised of M25 grade concrete. The third model incorporates beam and slab elements with M40 grade concrete, while the column is erected utilizing M25 grade concrete. By employing dynamic analysis techniques, the response of each model to seismic forces is evaluated to determine their respective efficiency and vulnerability. Key parameters such as natural frequencies, mode shapes, and structural displacements are analyzed to assess the seismic performance of each structural configuration. Through extensive numerical simulations and analytical evaluations, this research paper seeks to elucidate the impact of distinct structural components on the overall seismic response of precast concrete structures. The findings derived from this comparative analysis can inform the development of optimal design strategies aimed at enhancing the seismic resilience of precast concrete constructions, thereby significantly advancing seismic engineering practices. This study is of paramount importance as it provides invaluable insights into the performance characteristics of different precast structural models under dynamic loading scenarios. It emphasizes the importance of considering various factors, such as natural frequencies and mode shapes, when designing structures intended to withstand seismic events or similar natural disasters. By identifying areas requiring enhancement in current design methodologies through this comparative analysis, engineers can devise more effective approaches that improve the safety and durability of precast concrete structures during seismic events.*

Key Words: Seismic behaviour, reinforced concrete frame, precast concrete, normal concrete, earthquake resistance, ductility, stiffness, strength, energy dissipation, construction techniques, seismic resilience.

1.PRECAST CONCRETE STRUCTURE

Precast concrete structures have emerged as a fundamental component of contemporary construction due to their adaptability, resilience, and effectiveness. Originating in ancient Rome, where early forms of precast concrete were utilized for aqueducts and temples, the technique truly advanced in the early 20th century with progress in concrete technology. Following World War II, there was a notable surge in the utilization of precast concrete, particularly in Europe, as countries prioritized swift urban reconstruction. Presently, the fabrication of precast concrete elements takes place in controlled settings, ensuring top-notch quality and uniformity. This approach diminishes construction schedules, reduces on-site labor, and enables enhanced design flexibility, as elements can be shaped into various forms and sizes. Precast concrete finds extensive application in building construction, infrastructure undertakings, and urban expansion, encompassing bridges, tunnels, and stadiums. Technological progressions, such as high-performance concrete, 3D printing, and automation, have further expanded its utilization. Despite challenges like transportation and initial expenses, the long-term advantages frequently surpass these obstacles. The future of precast concrete appears promising with an increasing focus on sustainable methodologies, integration with Building Information Modeling (BIM), and continual material innovations, solidifying its status as an increasingly indispensable component of the construction sector.

2.PRINCIPLE OF THE PRECAST CONCRETE

The concept of precast concrete entails the process of pouring concrete into a reusable mold or form, subsequently curing it in a regulated setting, then transporting it to the construction site and hoisting it into position. This technique affords meticulous oversight of the quality and consistency of the concrete elements, thereby augmenting their resilience and longevity. Precast concrete can be crafted in a diverse array of shapes and dimensions, rendering it adaptable for various construction purposes. Moreover, this method substantially diminishes on-site construction duration and labor expenses, given that the concrete components are primed for immediate installation upon delivery. The controlled manufacturing environment also curtails waste and environmental repercussions, rendering precast concrete a sustainable option for contemporary construction endeavors.

3.PRECAST CONCRETE IN REAL LIFE PROJECT

Precast concrete is extensively employed in practical applications due to its efficiency and versatility. In the construction of tall buildings, for example, precast concrete panels serve both structural and aesthetic purposes, presenting a durable and visually appealing facade. In infrastructure projects like bridges and highways, precast concrete elements such as beams, girders, and slabs ensure swift construction and enduring performance. Moreover, in residential developments, precast concrete is utilized for constructing components like walls, floors, and staircases, offering rapid assembly and consistent quality. Its usage extends to commercial buildings, parking structures, and even stadiums, highlighting its adaptability to diverse construction requirements while improving the efficiency, safety, and eco-friendliness of projects.

4.APPLICATION OF SOFTWARE IN THIS RESEARCH

ETABS, also known as the Extended Three-Dimensional Analysis of Building Systems, is a highly advanced software tool that is widely used in the field of civil engineering. Created by Computers and Structures, Inc. (CSI), this software provides engineers with a robust platform for modeling, analyzing, and designing a wide range of intricate structures. ETABS is especially proficient in conducting both linear and nonlinear static and dynamic studies, allowing engineers to accurately evaluate how a structure reacts to different types of loads. Its versatility extends to the design of steel and concrete buildings, highlighting its flexibility and efficiency in tackling the intricate challenges of contemporary engineering projects. Over time, ETABS has evolved into an essential tool within the industry, empowering engineers to improve productivity and ensure the safety of structures in various applications and scenarios.

5.INDIAN STANDARD CODE IN THIS RESEARCH WORK

In India, the guidelines and regulations for the design and construction of reinforced concrete (RC) frame structures are established by a series of Indian Standard (IS) codes published by the Bureau of Indian Standards (BIS). The primary code governing RC structures is IS 456: 2000, which sets out the fundamental principles for working with plain and reinforced concrete. Additionally, IS 875 (Parts 1 to 5) offers detailed instructions on various types of loads that need to be taken into account during structural design, such as dead loads, imposed loads, wind loads, snow loads, and special loads. When it comes to ensuring that structures are able to withstand seismic forces, IS 1893 (Part 1): 2016 lays down the specific criteria that must be met for earthquake-resistant design. It is essential for engineers and architects in India to adhere to these codes to guarantee the safety and stability of RC frame structures in the country.

6.ANALYSIS OF MODELS

In the course of this research project, we have utilized Time History Analysis to analyze four different models that have been created in the ETABS Software. Time History Analysis is a crucial methodology used in the field of seismic engineering and earthquake-resistant design. This technique involves conducting dynamic structural analysis by replicating the actual ground motion experienced during historical earthquakes. Unlike traditional analytical methods, Time History Analysis does not rely on simplified or approximate representations of seismic forces. Instead, it accurately computes the structure's response throughout the entire duration of recorded ground motion. By utilizing Time History Analysis, engineers are able to provide a comprehensive and precise assessment of how structures react to dynamic seismic forces during an earthquake. This approach is particularly beneficial for evaluating the performance of structures with complex geometries or those located in regions prone to intense seismic activity. Through this detailed analysis, engineers are able to gain a more precise understanding of how these structures will behave in the event of an earthquake.

7.GRADE OF THE MATERIAL

In this particular section, we will be exploring the various materials that are utilized in the construction of the models, as well as delving into their respective grades. The information pertaining to these materials and grades can be found in the table provided below. This table serves as a comprehensive guide for understanding the composition and quality of the materials employed in the models. By examining this detailed breakdown, we can gain a clearer insight into the materials used and their corresponding grades, allowing for a more thorough understanding of the overall construction process.

Table-1: Grade of Material

Serial Number	Material with Grade	Application in the Models
01	M25 Grade of Concrete	Use as Normal Concrete in the Models
02	Fe500, Fe415 Grade of Steel	Used in Beam and Column
03	M40 Grade of Concrete	Use as Precast Concrete

7.1.View of Model

The details view of these four models aregiven below:

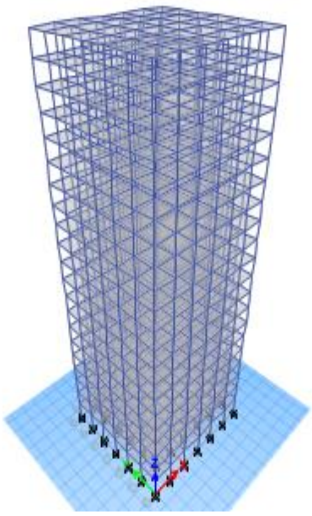

Figure-1: 3D View of the Model.

8.RESULT AND ANALYSIS

In this chapter of the result and analysis, we will analyse the result after analysis of these four models by using the etabs software. Here we have taken the parameter of the analysis of these models are:

1. Base Shear of the Models
2. Storey Displacement due to lateral Load on the models.
3. Natural Period of the Models

8.1.BASE SHEAR

According to IS 1893 Part 1 (Indian Standard Code of Practice for Earthquake Resistant Design of Structures), the primary factor in determining the seismic forces acting on a structure during an earthquake is the base shear. This factor represents the total lateral force exerted on the base of the structure as a result of ground motion. The calculation of base shear takes into account the mass of the structure and the acceleration of the ground motion. It is used in the design of the structure's lateral load-resisting systems, such as shear walls, bracing systems, and moment-resisting frames. The calculation of base shear considers various factors, including the seismic zone of the structure, its importance, the response reduction factor, and the structure's natural period of vibration. These factors help determine the level of seismic forces that the structure must be able to withstand. Base shear plays a critical role in earthquake-resistant design by ensuring that the structure can withstand the expected seismic forces and provide the necessary safety for its occupants. Adhering to the guidelines outlined in IS 1893 Part 1 is essential for accurately determining the base shear and designing structures that can effectively withstand seismic events.

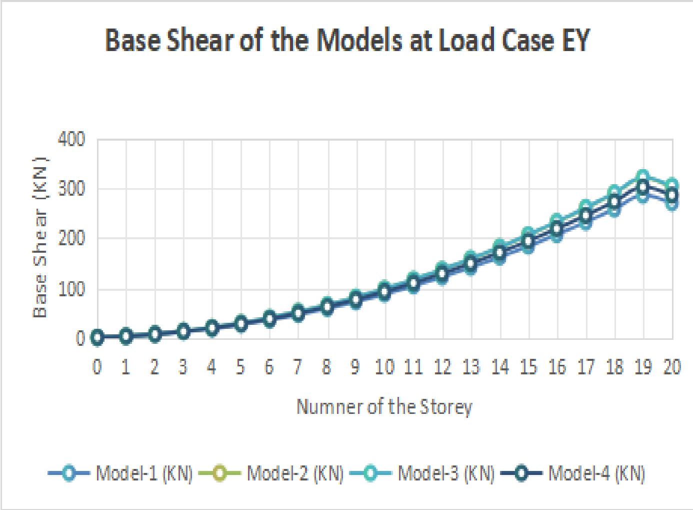

Figure-2: Base Shear of the Model at Load Case EY.

8.2.NATURAL PERIOD

The fundamental period of a structure is a crucial parameter that indicates the minimum natural period of vibration that the structure will experience when subjected to external forces. This period is influenced by a variety of factors, including the mass, stiffness, and overall geometry of the structure. According to the IS Code 1893 part-1:2016, structures with a height of up to G+20 should have a natural period falling within the range of 0.05 seconds to 2.00 seconds. For structures with a height of up to G+30, the period should be greater than 3.00 seconds. Detailed information, including a table and graph illustrating the natural period, can be found below for further reference and analysis.

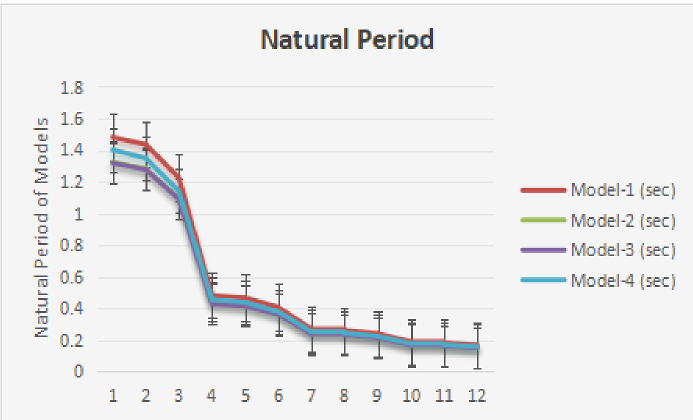

Figure-3: Natural Period.

8.3.MAXIMUM STOREY DISPLACEMENT

According to the guidelines set forth in IS 1893 (Part 1):2016, the permissible storey displacement is determined by both the seismic zone in which a structure is located and its structural type. The standard outlines specific limits for buildings with ductile detailing as opposed to those without such detailing. As per IS Code 1893 part-1: 2016, the maximum allowable storey displacement is set at H/250, where H represents the total height of the structure in millimeters. For example, in the scenario of a G+20 reinforced concrete building with a total height of 63500mm, the storey displacement must not exceed 254mm in order to comply with the regulations. These provisions are crucial in ensuring the safety and stability of structures during seismic events, and adherence to these guidelines is essential for structural integrity and public safety.

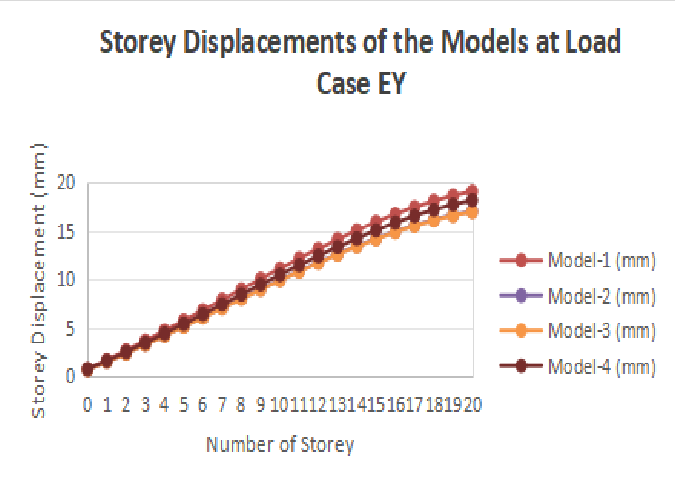

Figure-4: Maximum Storey Displacement at the load Case EY.

9.CONCLUSION

In this chapter of the conclusion, four models were analyzed using Time History Analysis in the ETABS software. The base shear of the models at load case EX showed the maximum value in model-3 and the minimum in model-01. Model-03 had 0.427 percent higher base shear than model-02 and 11.08 percent higher than model-01. The natural period of the models indicated that model-01 had the maximum natural period and model-03 had the minimum. The values of the natural period fell within the range specified by IS Code 1893 part1:2016. The storey displacement of the models at load case EX showed the maximum in model-01 at 18.412 mm and the minimum in model-03 at 16.375 mm. Model-01 had an 11.06 percent higher storey displacement compared to model-03. The values of storey displacement at load case EY were similar for all models.

REFERENCE

1. Algamati, M., Al-Sakkaf, A., Abdelkader, E. M., & Bagchi, A. (2023). Studying and analyzing the seismic performance of concrete Moment-Resisting frame buildings. CivilEng, 4(1), 34–54. https://doi.org/10.3390/civileng4010003

2. Al-Saffar, D. H., Dawood, M. B., & Habeeb, G. M. (2023). Experimental study of the structural behavior of Non-Prismatic reinforced concrete frame using different types of concrete under static and repeated load. Research Square (Research Square). https://doi.org/10.21203/rs.3.rs-2820190/v1

3. Arastu, M., & Moin, K. (2023). Seismic analysis of reinforced concrete frame using shake table test. Journal of Applied Engineering Sciences, 13(1), 23–26. https://doi.org/10.2478/jaes-2023-0004

4. Aykanat, B., Arslan, M. E., & Şen, A. (2023). Effects of different wall openings on the cyclic behavior of aerated concrete block infilled RC frames. Periodica Polytechnica. Civil Engineering/Periodica Polytechnica. Civil Engineering (Online). https://doi.org/10.3311/ppci.21798

5. Cao, Y., & Yang, Z. (2022). Seismic damage evaluation of Beam-Column joints in monolithic precast concrete frame structures. Materials, 15(17), 6038. https://doi.org/10.3390/ma15176038

6. Chen, Q., Qin, Y., Xie, Y., & Yang, C. (2023). Seismic performance of a new precast concrete frame joint with a built-in disc spring. Scientific Reports, 13(1). https://doi.org/10.1038/s41598-023-32447-1

7. Hasibuan, S. a. R. S., Ma'arif, F., & Praja, B. A. (2023a). Non-Linear Behavior of Reinforced Concrete Frame Structure with Vertical Irregularities. International Journal of Innovative Research in Computer Science & Technology, 11(1), 45–51. https://doi.org/10.55524/ijircst.2023.11.1.10

8. Hasibuan, S. a. R. S., Ma'arif, F., & Praja, B. A. (2023b). Non-Linear Behavior of Reinforced Concrete Frame Structure with Vertical Irregularities. International Journal of Innovative Research in Computer Science & Technology, 11(1), 45–51. https://doi.org/10.55524/ijircst.2023.11.1.10

9. Huang, Y., Wu, Q., & Tang, T. (2022). Seismic Performance and Design of the Fully Assembled Precast Concrete Frame with Buckling-Restrained Braces. Buildings, 12(11), 1818. https://doi.org/10.3390/buildings12111818

10. Işık, E., Hadzima-Nyarko, M., Bilgin, H., Ademović, N., Büyüksaraç, A., Harirchian, E., Bulajić, B., Özmen, H. B., & Hosseini, S. E. A. (2022). A comparative study of the effects of earthquakes in different countries on target displacement in Mid-Rise Regular RC structures. Applied Sciences, 12(23), 12495. https://doi.org/10.3390/app122312495

11. Ma, C., Zheng, X., & Zhu, Z. (2023). Seismic behavior of precast column with energy-dissipating bars and unbonded prestress: Physical and numerical investigations. Research Square (Research Square). https://doi.org/10.21203/rs.3.rs-2742556/v1

12. Mehta, V., & Chey, M. H. (2022). Seismic performance and assessment of RC framed structure with geometric irregularities. Asian Journal of Civil Engineering, 24(2), 479–496. https://doi.org/10.1007/s42107-022-00513-0

13. Nour, A., Bourdim, S. M. E., & Hassaine, M. I. E. T. (2023). Evaluation of the Seismic Behavior of RC Buildings through the Direct Modeling of Masonry Infill Walls. Buildings, 13(7), 1576. https://doi.org/10.3390/buildings13071576

14. Parekh, D., Suthar, J., & Purohit, S. (2022). Seismic performance of RC plane frame building Irregular in Mass. ASPS Conference Proceedings, 1(1), 711–717. https://doi.org/10.38208/acp.v1.572

15. Sadeq, S. F., Muhammad, B. R., & Al-Zuheriy, A. J. (2022). Seismic behaviour of RC building located in Erbil, Iraq and strengthening by using steel frame sections precast Bolt-Connected Steel-Plate reinforced concrete. IOP Conference Series. Earth and Environmental Science, 961(1), 012012. https://doi.org/10.1088/1755-1315/961/1/012012

16. Sococol, I., Mihai, P., Petrescu, T., Nedeff, F., Nedeff, V., & Agop, M. (2022). Analytical Study Regarding the Seismic Response of a Moment-Resisting (MR) Reinforced Concrete (RC) Frame System with Reduced Cross Sections of the RC Beams. Buildings, 12(7), 983. https://doi.org/10.3390/buildings12070983

17. Sococol, I., Mihai, P., Petrescu, T., Nedeff, F., Nedeff, V., Agop, M., & Luca, B. (2022). Numerical Study Regarding the Seismic Response of a Moment-Resisting (MR) Reinforced Concrete (RC) Frame Structure with Reduced Cross-Sections of the RC Slabs. Buildings, 12(10), 1525. https://doi.org/10.3390/buildings12101525

18. Soureshjani, O. K., & Nouri, G. (2022). Seismic assessment and rehabilitation of a RC structure under mainshock-aftershock seismic sequences using beam-column bonded CFRP strategy. Bulletin of Earthquake Engineering, 20(10), 4989–5016. https://doi.org/10.1007/s10518-022-01382-3

19. Sutar, S., & Patil, R. D. (2023a). Comparative Study on Seismic Behaviour of RC Structure with Framed Tube Structure and Shear Wall for Different Stories. Research Square (Research Square). https://doi.org/10.21203/rs.3.rs-3090596/v1

20. Sutar, S., & Patil, R. D. (2023b). Evaluating the seismic behavior of RC structures: A comparative study of framed tube and shear wall systems for varying numbers of stories. Research Square (Research Square). https://doi.org/10.21203/rs.3.rs-3090596/v2