INVESTIGATING LATERAL RESPONSE VARIATIONS IN REINFORCED CONCRETE FRAMES WITH DIFFERENT TYPE OF CONCRETE

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Abstract - *This research paper presents a comparative analysis of four precast structural models subjected to dynamic loading, following IS 1893 Part 1:2016 guidelines. Using ETABS software, we developed four models with varying concrete grades: the first with all elements (beam, column, and slab) in M25-grade concrete; the second with beams and columns in M40-grade and the slab in M25-grade; the third with all elements in M40-grade; and the fourth with beams and slabs in M40-grade and columns in M25-grade. Through dynamic analysis, we evaluated each model's seismic response, focusing on parameters like natural frequencies, mode shapes, and structural displacements. The study reveals the impact of different concrete grade combinations on the seismic performance of precast structures, providing insights to enhance their design and resilience against seismic forces.*

Key Words: Lateral response, Reinforced concrete frames, Concrete types, Seismic performance, Structural resilience, Precast Concrete.

1.INTRODUCTION

Reinforced concrete (RC) frames have been a cornerstone of structural engineering, known for their durability, strength, and adaptability in various applications. Traditionally, normal concrete (NC) has been used in RC frames due to its accessibility and established performance characteristics. However, with advancements in construction techniques, precast concrete (PC) has gained traction for its efficiency in reducing on-site construction time, minimizing material wastage, and offering enhanced quality control. Despite these advantages, the lateral response of RC frames, a critical factor in ensuring structural stability during dynamic loading scenarios such as earthquakes and wind forces, may vary significantly between normal and precast concrete. This variation stems from differences in material properties, construction joints, and the inherent structural continuity of the two systems. Understanding these differences is essential to optimize design strategies and ensure safety, particularly in high-seismic or load-intensive environments. This research seeks to bridge the knowledge gap by investigating and comparing the lateral response variations in RC frames constructed with NC and PC.

2. REINFORCED CONCRETE (RC) FRAMES IN STRUCTURAL ENGINEERING

Reinforced concrete frames are fundamental to modern structural engineering, providing the primary load-bearing skeleton for a wide range of buildings and infrastructure. RC frames owe their widespread adoption to their versatility, combining the compressive strength of concrete with the tensile strength of steel reinforcement. This synergy allows for enhanced load-carrying capacity and durability, making them a standard choice for both residential and commercial structures. The behavior of RC frames under various loading conditions, particularly lateral forces such as wind and seismic activity, is pivotal in ensuring their safety and functionality.

2.1.Traditional Use of Normal Concrete (NC)

Normal concrete has long been the default material for constructing RC frames due to its availability, ease of handling, and predictable mechanical properties. It is typically mixed and poured on-site, which facilitates construction in varied conditions but can also lead to inconsistencies in quality due to environmental or operational variables. Despite these challenges, NC remains a robust material, particularly in static or low-dynamic loading environments. However, its performance under lateral loading, where stiffness, ductility, and energy dissipation become critical, demands meticulous design considerations.

2.2.Emergence of Precast Concrete (PC)

Precast concrete introduces a paradigm shift in construction practices by manufacturing concrete components off-site under controlled conditions. These precast elements are transported to the construction site and assembled, resulting in faster project timelines, reduced labor costs, and superior quality control. PC has garnered increasing interest for its potential to address urbanization-driven construction demands efficiently. However, PC systems differ structurally from NC systems due to the presence of construction joints and connectors, which can influence the overall lateral behavior of the frame.

2.3.Significance of Lateral Response in Structural Stability

The lateral response of a structure—its behavior under horizontal forces like seismic loads or wind pressures—is a critical determinant of safety and serviceability. In RC frames, this involves parameters such as lateral stiffness, strength, and ductility, which ensure that the structure can withstand dynamic loading without experiencing catastrophic failure. NC and PC systems inherently respond differently to such loads due to differences in continuity, material homogeneity, and connection integrity. The integrity of these responses is particularly vital in high-risk zones where lateral loads are predominant.

3.CHALLENGES AND THE NEED FOR COMPARATIVE ANALYSIS

Despite their growing adoption, precast concrete systems remain under-researched compared to conventional normal concrete systems, particularly in terms of their lateral response in RC frames. Construction joints in PC frames can act as potential weak points, raising concerns about stiffness degradation and displacement under cyclic or dynamic loading. In contrast, NC systems, while structurally continuous, may lack the precision and uniformity that PC systems offer. A systematic comparative analysis of these two materials is essential to understand their relative performance, inform design decisions, and guide the development of standards that optimize both safety and efficiency in RC frame construction.

By dissecting these aspects, the background provides a robust foundation for the research, highlighting the importance of lateral response and the necessity of this comparative study.

4.LITERATURE REVIEW

4.1.Overview of Reinforced Concrete Frames

Reinforced concrete (RC) frames are one of the most widely used structural systems due to their ability to withstand both vertical and lateral loads effectively. These systems combine steel reinforcement for tensile strength and concrete for compressive strength, creating a durable and versatile construction method. Common applications include residential buildings, commercial structures, and infrastructure projects such as bridges and tunnels.

4.2.Advantages of Normal Concrete and Precast Concrete

Normal concrete (NC) in RC frames provides flexibility in construction, allowing on-site customization. This adaptability makes it ideal for complex designs or retrofitting in constrained environments.

Precast concrete (PC), on the other hand, offers factory-controlled quality, reducing defects and enhancing durability. Its modular nature accelerates construction timelines and minimizes material wastage. However, PC systems face challenges in achieving monolithic structural continuity, and construction joints may act as weak points under certain loading conditions (Bogdan et al., 2021).

4.3.Lateral Response in Structural Systems

The lateral response of RC frames is a critical performance metric, particularly under seismic and wind loads. Lateral stiffness, ductility, and energy dissipation capabilities define a structure's ability to withstand horizontal forces without significant deformation or failure.

4.3.1.Factors Influencing Lateral Responses

- Material Properties: The strength, stiffness, and damping characteristics of the concrete and reinforcement play a significant role in determining the lateral response (Dolce et al., 2007).
- Construction Techniques: The assembly method—whether in-situ casting for NC or modular assembly for PC—affects joint performance and overall stability (Filippou & Issa, 1988).
- Load Distribution and Connections: In precast systems, connections such as dowels, welding, and bolting significantly influence the lateral performance compared to NC, which benefits from seamless continuity (Bogdan et al., 2021).

4.3.2.Role of Material Properties and Construction Techniques

Studies have highlighted that material homogeneity in NC contributes to better energy dissipation under cyclic loads. However, PC systems, despite their modular advantages, may experience localized stress concentrations at joints, impacting their ductility and stiffness under lateral loading (Zameeruddin & Sangle, 2016).

4.4.PRECAST CONCRETE IN STRUCTURAL DESIGN

4.4.1.Recent Advancements

The development of high-performance precast materials, such as self-compacting concrete and fiber-reinforced composites, has enhanced the applicability of PC in RC frames. Innovations in connection design, such as hybrid steel-concrete joints, have also improved the seismic resilience of PC systems (Mosallam, 2000).

4.4.2.Studies Comparing Precast and Conventional Concrete Systems

Recent comparative studies have demonstrated that while PC systems excel in construction speed and environmental benefits, they require more sophisticated engineering for joint integrity to match the monolithic behavior of NC (Bogdan et al., 2021). Similarly, the lateral response of PC systems, when designed with advanced joint technologies, can rival that of NC in seismic zones, but at a higher upfront cost (Dolce et al., 2007).

5.METHODOLOGY

In this section of the methodology, we will study about the materials, details the models, method used for the analysis of the models, details view of the models, and load acting on the models.

5.1.Load on the Models.

There are four models which created with the help of the ETABS Software and subjected to the different type of the loading such as the self-weight of the structure, imposed load on the models, finishing load on the models as well as seismic load in Both X as well as Y-Direction by the Indian Standard Code 1893 part1:2016.

5.2: Indian Standard Code

In this research work, we have used different Indian Standard Code for different purpose such as for the self weight of the structure used IS 875 part-1, for the imposed load on the structure used IS 875 part2, for the RCC work used IS 456, and for the earthquake load used IS 1893 part-1.

5.3.Software

ETABS (Extended Three-Dimensional Analysis of Building Systems) is a powerful structural analysis and design software widely used for multi-story buildings. It integrates modeling, analysis, and design capabilities for steel, concrete, and composite structures. Known for its user-friendly interface, ETABS supports seismic, wind, and dynamic load simulations, making it ideal for designing high-rise buildings and ensuring compliance with international codes and standards.

5.4.Method of Analysis

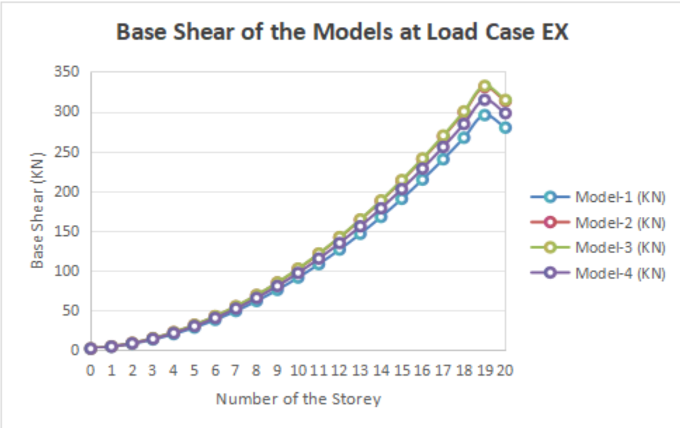
Time history analysis in ETABS is a dynamic analysis technique used to evaluate the structural response of buildings under time-dependent loads, such as earthquakes or other transient forces. It involves applying ground motion records or synthetic time histories to simulate real-world conditions. This method captures detailed behavior like displacement, acceleration, and internal forces, providing insights into the structure's performance during seismic events.

6.ANALYSIS OF RESULT

In this section, we will analyse the result which come after analysis of these four models in the etabs software by using the dynamic analysis, the result are given below at the different parameter:

6.1.Lateral force on the Model

As per IS 1893 Part 1 (Indian Standard Code of Practice for Earthquake Resistant Design of Structures), the fundamental parameter to ascertain the seismic forces acting on a structure during an earthquake is the base shear. This parameter signifies the overall lateral force applied to the base of the structure due to ground movement. The calculation of base shear involves the consideration of the structure's mass and the acceleration of the ground movement. It is utilized in the design of the structure's lateral load-resisting systems, including shear walls, bracing systems, and moment-resisting frames. The value of the lateral force are given below at the load case EX:

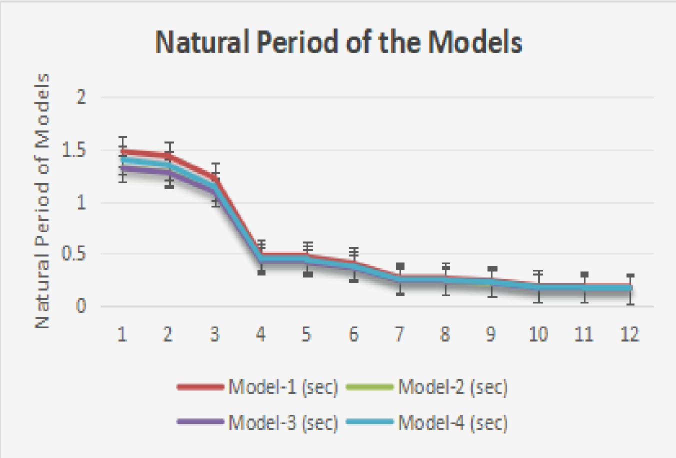


Graph-1: Base Shear at the load Case EX.

From the above graph, we can see that maximum value is existing in the model-3.

6.2.Fundamental Period of the Models

The fundamental period of a structure denotes the minimum natural period of vibration experienced by the structure under external forces. This period is determined by various factors such as the mass, stiffness, and geometry of the structure. As per IS Code 1893 part-1:2016, the natural period for structures up to G+20 should fall within the range of 0.05 seconds to 2.00 seconds, while structures up to G+30 should have a period exceeding 3.00 seconds. The table and graph depicting the natural period are provided below for reference.

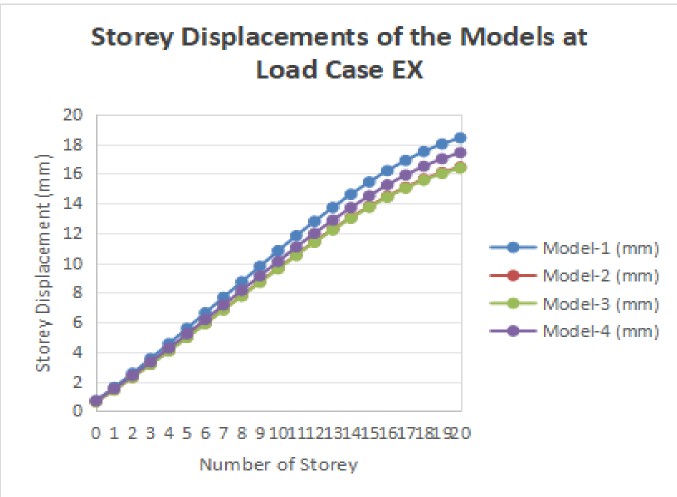


Graph-2: Fundamental Period of the Models

From the above graph, we can see that maximum value of the fundamental period is in the model-1.

6.3.Lateral Displacement of Models

As per the provisions of IS 1893 (Part 1):2016, the permissible storey displacement is contingent upon the seismic zone and the structural type. The standard delineates distinct thresholds for structures with ductile detailing and those without. In accordance with IS Code 1893 part-1: 2016, the maximum allowable storey displacement must not exceed H/250, where H represents the overall structure height in millimeters. For instance, in the case of a G+20 reinforced concrete edifice with a total height of 63500mm, the storey displacement should not surpass 254mm. The graph of the lateral displacement at the load case EX are given below:



Graph-3: Storey Displacements of the Models at Load Case EX.

From the above graph of the lateral displacement, the maximum value is in the model-1 at the load case EX.

7.CONCLUSION

In this section of the conclusion, we have studied the result of four models which are analyzed in the ETABS software by using the Time History Analysis. As we have discussed in the above section, we have taken those parameter, and on the basis of those parameter, we will analyze the result of the models:

With reference to the graph of the base shear of the models at the load case EX, the maximum value on the model-03 (where beam, column, and slab are build with M40 grade of the concrete), and minimum in the model-01 (where beam, column, and slab is build with M25 grade of the concrete). The value of base shear of the model-03 is 12.465 percent higher than model-01 at the top floor of the structure.

With reference to the graph of the natural period of the models, model-01 have maximum natural period as compared to the all models, and minimum natural period in the model-03. 12.443 percent higher natural period in the model-01 as compared to the model-03. We can see that the value of the natural period within the range according to IS Code 1893 part1:2016.

With reference to the graph of storey displacement of the models at the load case EX, the maximum storey displacement in the model-01 that is 18.412 mm, and minimum in the model-03 that is 16.375 mm. The 12.440 percent high storey displacement in the models-01 as compared to the model-03. Similarly all value of the storey displacement at the load case EY for all models.

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