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

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Abstract - *This comprehensive review paper delves into a detailed comparative analysis of the seismic behavior of reinforced concrete (RC) frame structures that are built using precast concrete as opposed to traditional cast-in-situ concrete. The growing demand for efficient and durable construction methods has brought to light the numerous potential benefits of precast concrete, including faster construction times, improved quality control, and cost-effectiveness. However, the seismic performance of these structures is a crucial factor to consider, especially in areas prone to earthquakes. By synthesizing existing research, this study aims to assess the differences in seismic response between precast and conventional concrete RC frames. Various key parameters such as ductility, stiffness, strength, and energy dissipation are thoroughly examined through an in-depth analysis of experimental findings and numerical simulations. The results suggest that precast concrete frames have the potential to exhibit similar seismic performance to their cast-in-situ counterparts, but specific challenges related to design and construction need to be addressed to ensure their effectiveness under seismic forces. The paper provides valuable recommendations for future research endeavors and practical guidelines for engineers and construction professionals to enhance the seismic resilience of precast RC structures. By taking into account these insights, it is possible to further optimize the performance and safety of precast concrete frame buildings in seismic-prone areas.*

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

1.HISTORY

The comparative analysis of the seismic response of reinforced concrete (RC) frame structures constructed with precast concrete and conventional (cast-in-situ) concrete has undergone significant evolution over time, mirroring advancements in construction technology and seismic engineering. In the early 20th century, RC structures were predominantly cast-in-situ, encountering challenges related to quality control and construction efficiency. The introduction of precast concrete brought about improvements in quality control and construction speed, albeit raising concerns regarding joint performance during seismic events. As seismic design principles and building codes matured in the mid-20th century, researchers began systematically comparing the two construction methodologies. Initial investigations often favored cast-in-situ concrete due to its monolithic characteristics. Nevertheless, progress in precast technology during the 1990s and 2000s, such as the utilization of high-performance concrete and enhanced connection techniques, bolstered the seismic performance of precast frames. Contemporary research utilizes advanced modeling and testing techniques, demonstrating that properly engineered precast RC frames can rival or even surpass the seismic performance of cast-in-situ frames. Building codes now offer detailed recommendations for both construction approaches in seismic zones, ensuring safety and performance. Practical applications in earthquake-prone regions showcase the feasibility of both methods, reflecting a nuanced perspective in ongoing comparative analyses.

2.RC FRAME STRUCTURE

Reinforced concrete (RC) frame structures are a widely used construction method globally for a diverse range of buildings, such as residential, commercial, and industrial projects. These structures are composed of a framework consisting of horizontal beams and vertical columns that are interconnected to create a grid-like structure. This design is specifically engineered to bear both vertical loads, like the weight of the building and its contents, and horizontal loads, such as wind or seismic forces. To strengthen the concrete, reinforcement materials like steel bars or mesh are incorporated within the concrete to enhance its tensile strength, as concrete alone is not as strong under tension. The adaptability and resilience of RC frame structures make them an excellent option for constructing multi-storey buildings, as they can be tailored to various architectural styles and can endure substantial stress over time. Furthermore, the fire-resistant and sound insulating qualities of concrete add to the appeal of using RC frame structures in modern construction practices. The combination of strength, versatility, and durability makes RC frame structures a preferred choice for a wide range of construction projects across the globe.

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Figure-1: RC Frame Structure.

2.1.Load Transfer Mechanism in RC Frame Structure

In a reinforced concrete (RC) frame structure, the load transfer mechanism functions by strategically distributing forces throughout the framework to uphold stability and structural soundness. Initially, vertical loads, encompassing the building's weight, occupants, and furnishings, are borne by the beams, which subsequently transmit these forces to the columns. The columns then convey these loads downwards to the foundation, guaranteeing their uniform dispersion into the ground. Horizontal loads, such as those induced by wind or seismic forces, are effectively managed by the sturdy connections between beams and columns. These connections allow the frame to act as a cohesive unit, dispersing the forces evenly across the structure. The amalgamation of reinforced concrete's tensile and compressive strengths plays a pivotal role in this mechanism. The steel reinforcement embedded within the concrete combats tensile forces, while the concrete itself withstands compressive forces. This harmonious interaction between materials and structural components ensures efficient load transfer and dissipation, thus upholding the building's stability and safety in the face of diverse loading scenarios.

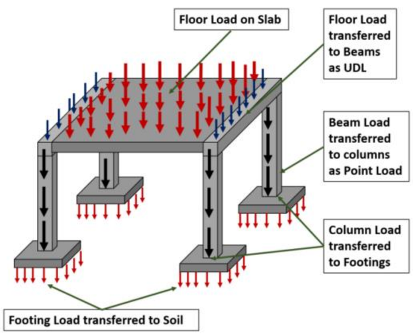

Figure-2: Load Transfer Mechanism in RC Frame Structure.

3.PRECAST CONRETE

Precast concrete is a building material created by pouring concrete into a reusable mold, which is subsequently cured in a controlled setting, transported to the construction site, and then hoisted into position. This technique enables the fabrication of intricate forms, guaranteeing superior quality and consistency among components. The utilization of precast concrete presents numerous benefits, such as decreased construction duration, heightened resilience, and greater oversight of the building process. It is frequently employed for architectural elements like panels, beams, columns, and flooring, offering a flexible and effective answer to contemporary construction requirements. Precast concrete comes in various types, each serving specific construction needs. Here are some of the common types of precast concrete:

3.1. Precast Beams

These are used to support loads in buildings and bridges. They come in different shapes and sizes, such as T-beams, L-beams, and inverted T-beams.

3.2.Precast Columns

These vertical structural elements are designed to carry loads from beams and slabs to the foundation. They can be round, square, or rectangular.

3.3. Precast Floors and Slabs

These include hollow core slabs, solid slabs, and double tees, which are used for constructing floors and roofs. They provide strength, stability, and quick installation.

3.4.Precast Walls

These are used for both structural and non-structural purposes. Types include solid walls, sandwich panels with insulation, and cladding panels for decorative purposes.

3.5.Precast Stairs

These are pre-fabricated steps that can be quickly installed at the site, ensuring uniformity and precision.

3.6.Precast Piles

These are driven or placed into the ground to provide foundational support for structures. They are particularly useful in areas with poor soil conditions.

3.7.Precast Bridge Components

These include girders, deck slabs, and parapets, which are used in bridge construction to expedite the building process and ensure quality control.

4.NORMAL CONCRETE

Normal concrete, also known as conventional concrete or traditional concrete, refers to the most commonly used type of concrete in construction. It is made from a mixture of cement, water, aggregates (such as sand and gravel), and often admixtures for specific properties.

5.PRECAST CONCRETE AND NORMAL CONCRETE ON THE BASIS OF THE GRADE OF THE CONCRETE

In accordance with the Indian Standard IS 456:2000, concrete grades for precast and normal concrete are classified similarly but with specific considerations for each type. Normal concrete, which is typically used for onsite casting, generally ranges from grades like M15 to M50, depending on the structural requirements of the project. On the other hand, precast concrete, which is specifically designed for prefabricated elements, often utilizes higher grades such as M40 and above to ensure its durability against handling, transportation, and installation stresses.

Quality control in precast production is of utmost importance, with a strong focus on ensuring uniformity and durability to meet the specific demands of the project. While both types of concrete adhere to the standards set by IS 456:2000, precast concrete tends to lean towards higher strength grades to ensure that the structural integrity is maintained throughout its entire lifecycle. This emphasis on higher strength grades in precast concrete is crucial in ensuring the longevity and performance of the precast elements.

6.BENEFIT OF PRECAST AND NORMAL CONCRETE

Precast concrete and cast-in-place concrete each present distinct advantages depending on the specific requirements of a construction project. Precast concrete, fabricated in controlled environments off-site, offers numerous advantages. Firstly, it expedites construction progress as precast elements can be manufactured simultaneously with on-site preparations, thereby significantly reducing overall project timelines. Secondly, precast components are renowned for their consistent quality as a result of strict factory-controlled conditions, ensuring enhanced durability and reliability. Thirdly, off-site production minimizes on-site disturbances and enhances safety by decreasing the necessity for extensive formwork and scaffolding.

On the contrary, cast-in-place concrete provides its own unique benefits. One significant advantage is its adaptability to intricate architectural designs and irregular shapes, given that it can be poured directly into formwork on-site. This approach enables adjustments and modifications during the casting process, making it easier to accommodate last-minute changes or corrections compared to precast elements. Furthermore, cast-in-place concrete eliminates transportation costs and logistical complexities associated with large precast elements, rendering it more cost-effective for smaller projects or those with less predictable design requirements.

The selection between precast and cast-in-place concrete predominantly hinges on project specifics such as timeline, design intricacy, and budget limitations. Each approach offers distinct advantages to construction, providing tailored solutions to address the requirements of various building scenarios.

7.LITERATURE REVIEW

In this section of the literature review, we have sudied previous research work based on the normal concrete and precast concrete in the different type of the structure, and summary of previous research works are given below:

Batuhan & Mehmet: This study explores the impact of infilled reinforced concrete (RC) frames with varying configurations of window and door openings when exposed to cyclic loads. The research indicates that the placement and quantity of openings significantly influence the behavior and failure patterns of the RC frames. It was specifically observed that both the position and quantity of openings directly affect the structural response and failure mechanisms of the frames. Moreover, the study emphasizes that an increase in the aperture ratio leads to a reduction in the load-carrying capacity and energy dissipation ability of the RC frames. Thus, meticulous consideration and appropriate design of window and door openings are imperative to ensure the overall performance and stability of infilled RC frames under cyclic loading conditions.

Saurabh & Rahul: This article provides an in-depth comparative analysis of the seismic performance of reinforced concrete (RC) structures using framed tube systems versus shear walls across various numbers of stories. By employing the ETABS software, the study aimed to assess the efficacy of these structural systems in withstanding seismic and wind loads. The results indicated that the framed tube structure displayed superior resistance to lateral loads when compared to the shear wall structure. Moreover, the framed tube system exhibited a notable decrease in maximum storey drift, emphasizing its effectiveness in reducing the impact of seismic forces on the building. The research emphasizes the significance of selecting the appropriate structural system to bolster the overall seismic resilience of RC structures.

Satur & Patil: Within this academic manuscript, a comprehensive examination was carried out to juxtapose the seismic efficacy of framed tube and shear wall reinforced concrete (RC) structures utilizing the Response Spectrum Method (RVM). The primary objective of the investigation was to evaluate the structural response of reinforced concrete edifices during seismic events. The results unveiled that the framed tube configuration showcased superior seismic endurance in comparison to the shear wall arrangement. Framed tube frameworks manifested exceptional earthquake resistance and structural dependability, accentuating their efficacy in withstanding seismic loads. This study emphasizes the significance of selecting suitable structural systems to optimize the overall seismic performance of buildings.

Aman et al: This article provides an in-depth analysis of the behavior displayed by a non-prismatic concrete frame when exposed to various types of concrete under static and cyclic loads. The research conducted included a detailed assessment involving variations in concrete types, specifically steel fiber reactive powder concrete (SF-RPC), alongside modifications in loading conditions (static and cyclic). It was noted that SF-RPC exhibited superior compressive strength when compared to standard concrete, while GF-RPC demonstrated higher flexural strength. Additionally, GF-RPC was observed to significantly improve the first crack load more than traditional concrete. These results highlight the substantial influence that different concrete types can exert on the structural performance of non-prismatic concrete frames under varying loading conditions.

John et al: The research detailed in this article delved into examining the influence of design parameter variations on the behavior of precast, assembled columns using a fiber-beam element model. A pivotal discovery of the study was that augmenting the proportion of unbonded post-tensioned tendons (UPT) emerged as a noteworthy factor in enhancing the energy-dissipating capacity of the precast columns. Furthermore, the application of high-strength concrete was determined to be efficacious in mitigating damage and residual deformation post-seismic events. It was underscored that the ratio of unbonded post-tensioned tendons and energy-dissipating bars holds a pivotal role in the overall efficacy of the columns. These findings underscore the critical importance of meticulously considering design parameters to bolster the seismic resilience of precast structures.

Chen et al: This article introduces a pioneering precast concrete frame beam-column connection that surpasses the conventional grouting sleeve connection. The innovation integrates a disc spring device at the beam end, greatly enhancing the joint's ductility. In contrast to traditional precast connections, which excel in bearing capacity but lack ductility, this new connection with the integrated disc spring device demonstrates exceptional seismic performance. The incorporation of the disc spring device not only enhances the connection's flexibility but also ensures superior resistance to seismic forces, making it a viable solution for structures located in high-risk seismic zones. Overall, this innovative design signifies a remarkable progression in the realm of precast concrete construction, offering enhanced performance and safety in the event of seismic occurrences..

Arastu & Khalid: In this investigation, a building model one-quarter the size of a standard reinforced concrete (RCC) framed structure underwent testing on a shake table. The primary objective of the study was to analyze the failure modes present in the column-beam connections of the RCC frame. The outcomes of the experiments revealed the earthquake-resistant characteristics of the RCC frame. More precisely, the researchers identified distinct failure modes in the column-beam connections, offering significant insights into the structural response of the building during seismic events.

Algamati et al: In the research paper presented, an in-depth investigation of seismic response spectrum analysis is carried out on a complex multi-degree-of-freedom system situated in the vibrant metropolis of Vancouver. The study specifically examines the influence of seismic waves, notably earthquakes, on the edifices within the city. The research delves into the average displacement and base shear that these structures endure when confronted with such seismic forces. It is observed that the utilization of 3D software proves to be more accurate and dependable in seismic analysis in contrast to conventional 2D software. Additionally, it is emphasized that the scenarios applied in the study strictly conform to the regulations stipulated in the NBCC 2015 Code, ensuring that safety standards are not only met but surpassed. This exhaustive analysis provides valuable insights into the structural response to seismic events, ultimately contributing to the continuous endeavors to bolster seismic resilience in urban settings like Vancouver.

Changkal et al: In this scholarly article, the primary focus was on utilizing an incremental dynamic analysis (IDA) method to comprehensively model the complete mechanical behavior history of short columns. The IDA curves were scrutinized, along with the distribution of interfloor displacement angles and the limit state of vertex displacement in frames, in order to delve into the seismic responses of structures. The research revealed that reinforced concrete (RC) frames with short columns constitute a vulnerable layer, ultimately compromising seismic performance. Conversely, the incorporation of ECC short columns was demonstrated to improve seismic performance, albeit still falling short when compared to standard frames. This study illuminates the significance of considering various column types in the design and analysis of structures to ensure their resilience against seismic events.

Nour at al: The research paper examines the analysis of multiple 3D models using the nonlinear static (pushover) method, focusing on the implications of including or excluding masonry infill walls. The results emphasize that neglecting these walls, and instead depending on indirect modeling based on assumptions regarding seismic behavior factors or utilizing the macro-modal approach, can lead to a flawed comprehension of the seismic performance of structures. Conversely, direct modeling of masonry infill walls is demonstrated to reduce time periods and improve the overall stiffness of the building. Failure to integrate these walls in the modeling process may result in a significant decrease in the building's stiffness and resistance. This highlights the critical importance of accurately representing masonry infill walls in structural analyses to guarantee the integrity and safety of buildings during seismic events.

Yang: In this scholarly article, the authors investigate the optimal method for evaluating the structural effects of earthquakes using closed-form solutions. Their objective is to differentiate the results derived from this approach from those generated through numerical modeling methods. It is essential for the seismic design of concrete structures to meet the minimum design standards to guarantee their safety and resilience in the event of an earthquake. Additionally, the research underscores the unique seismic characteristics displayed by subterranean structures compared to frame constructions, underscoring the necessity of customized design approaches for each structure type.

Parekh et al: This article delves into a 10-story Reinforced Concrete (RC) Moment Resisting Frame building exhibiting vertical irregularity stemming from mass discrepancies. The structural analysis of the building is carried out in accordance with Indian standards, particularly IS 1893(Part-1):2016 and IS 456, for the purpose of modeling and analyzing its structural integrity. A comparative study is conducted on the seismic response of the building in contrast to a conventional structure with a similar layout. The adherence to Indian standards in the modeling and analysis stages ensures that the structural design complies with the requisite safety protocols and seismic performance criteria. Through an exploration of the impact of vertical irregularities on the seismic behavior of the building, valuable insights can be gleaned regarding the response of structures under dynamic loading conditions. This research contributes to the continuous endeavors aimed at enhancing the seismic resilience of buildings situated in high-risk zones, thereby bolstering the safety and stability of structures in anticipation of potential seismic occurrences.

Olvera et al: This paper conducts a comprehensive comparative analysis of two prevalent structural design concepts in the Ecuadorian construction industry: concealed beams versus drop beams. The research centers on assessing these design concepts based on their financial implications, structural stability, and resistance to seismic activity. The investigation revealed that concealed beam configurations displayed unfavorable interstory displacements, while drop beam configurations adhered to the acceptable displacement limits. Surprisingly, there was no significant difference in costs between the two design alternatives. The results of this study highlight the significance of selecting the appropriate structural design strategy to ensure the safety and cost-effectiveness of construction projects in Ecuador.

Vikas & Chandra: The study presented in this paper explores the influence of geometric anomalies on reinforced concrete (RC) frame structures located in seismic zone IV. Through the utilization of the sophisticated software STAAD Pro, an extensive investigation was conducted to examine the repercussions of such irregularities. The research revealed that structures featuring geometric irregularities tend to exhibit heightened time displacement in comparison to their regular counterparts. This occurrence consequently leads to an amplified dynamic response and alterations in the structural performance of RC frame structures. In essence, the research underscores the importance of addressing geometric irregularities in the design and assessment of RC frame structures to guarantee their structural soundness and resilience in earthquake-prone regions.

Bing et al: This paper presents an innovative precast concrete frame beam-column joint that integrates high-strength reinforcement. The research conducted simulated reversed cyclic loading tests on two precast connections and one cast-in-place connection to assess the seismic performance of the new precast joint. The outcomes revealed that YZ1 showcased superior ultimate displacement and ductility in contrast to the cast-in-place connection. Conversely, YZ2 displayed insufficient ductility and energy dissipation capabilities when compared to the other connections. These results emphasize the advantages of implementing the proposed precast connection in earthquake-resistant structures.

Scocol et al: This article provides a comprehensive analysis of a mathematical model for a moment-resisting reinforced concrete frame, which has been meticulously scrutinized through a comparative approach. The emphasis is on demonstrating the efficacy of the transverse cross-section reduction method when implemented in reinforced concrete slabs. By employing this technique, it becomes apparent that seismic energy dissipation can be effectively controlled and directed towards designated areas, thereby bolstering the overall structural strength and functionality of the slabs in seismic scenarios.

8.CONCLUSION

This comparative study examined the seismic behavior of reinforced concrete (RC) frame structures, specifically comparing precast concrete with normal concrete. The research found that precast concrete demonstrated superior ductility and energy dissipation, resulting in lower lateral displacement and inter-story drift, thanks to its high-quality joints. Additionally, precast construction allows for quicker assembly and reduced maintenance costs, although the initial expenses may be higher. Furthermore, precast structures are considered sustainable due to lower emissions and material waste, providing benefits in terms of construction efficiency and overall performance. When deciding between precast and normal concrete, factors such as seismic risk, project timeline, budget constraints, and environmental impact should all be taken into consideration. It is important to weigh the advantages and disadvantages of each option to determine the most suitable choice for a particular project. Future research should concentrate on optimizing connections in precast systems and exploring hybrid solutions for earthquake-resistant construction. By focusing on these areas, advancements can be made in enhancing the overall seismic performance and durability of structures built using precast concrete.

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