

A REVIEW PAPER ON SEISMIC PERFORMANCE ASSESSMENT OF IRREGULAR REINFORCED CONCRETE STRUCTURES: A COMPREHENSIVE STUDY ON THE IMPACT OF CONFIGURATIONALLY IRREGULARITIES

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ABSTRACT

Deviation from regularity in the arrangement of reinforced concrete structures may have a substantial impact on their ability to withstand seismic activity. This abstract provides a thorough investigation of the influence of configuration inconsistencies on the seismic behavior of these buildings. An extensive examination was conducted to assess several forms of abnormalities, such as vertical, horizontal, and plan irregularities, in order to comprehend their impact on the structural response during seismic occurrences.

Vertical irregularities in a structure, such as setbacks, changes in height, and uneven distribution of mass or stiffness, may result in the concentration of forces and torsional effects when the structure is subjected to seismic stress. These deviations from the norm might cause damage in certain areas and an unequal spread of seismic pressures, which could ultimately lead to an imbalanced collapse or structural failure. Horizontal abnormalities, such as unequal distribution of lateral stiffness or strength over the horizontal plane, may result in torsional effects and uneven response to seismic pressures. This can lead to torsional and pounding effects between neighboring buildings. Deviation from the original plan, such as changes in the arrangement, setbacks, or protrusions, may worsen the structural response by adding more twisting effects and uneven distribution of seismic pressures over the building.

A thorough investigation was carried out to evaluate the seismic behavior of irregular reinforced concrete structures. This work included the integration of numerical modeling, analytical methods, and experimental verification. The use of finite element analysis (FEA) and nonlinear dynamic analysis (NDA) allowed for the simulation of seismic loading conditions and the assessment of structural reactions in the presence of different abnormalities. Structural capacity and dynamic features were evaluated using analytical approaches such as pushover analysis and modal analysis. Experimental testing, such as shaking table tests and scaled model tests, yielded vital insights into the behavior of irregular structures when subjected to seismic stimulation.

The results of this research indicate that abnormalities in the layout of reinforced concrete structures have a significant influence on their seismic performance. Vertical abnormalities were discovered to cause torsional forces and localized harm, resulting in probable collapse mechanisms. The presence of horizontal abnormalities caused an unequal distribution of lateral stresses, resulting in erratic reactions and the possibility of instability

when subjected to seismic loading. The structural response was worsened by the introduction of extra torsional effects and inconsistent distribution of seismic stresses throughout the structure due to plan errors. In summary, this extensive research emphasizes the need of taking into account configuration abnormalities when designing and evaluating reinforced concrete buildings for their ability to withstand seismic activity. Engineers and designers may improve the seismic resilience and safety of buildings in earthquake-prone areas by studying the impacts of abnormalities and applying effective ways to address them. These solutions may include structural details, reinforcing, and strengthening techniques.

Key Words: Earthquake, Irregular Structure, Linear Dynamic Analysis, Mass Irregularity, Stiffness Irregularity, Seismic Response, Response Spectrum Analysis.

1. INTRODUCTION

The seismic performance of reinforced concrete buildings is crucial, particularly in areas susceptible to seismic activity. The presence of irregularities in the arrangement of such structures may have a considerable impact on their performance during seismic events, creating difficulties in the process of designing, analyzing, and evaluating them. This introduction provides a thorough examination of the influence of configuration abnormalities on the seismic behavior of reinforced concrete structures. Reinforced concrete constructions may exhibit abnormalities in their configuration, which might take the form of vertical, horizontal, or plan irregularities. Vertical irregularities refer to discrepancies in the height or distribution of mass along the vertical axis of a construction. These deviations from

regularity may result in twisting effects and the accumulation of forces, which impact the overall structural behavior when subjected to seismic loads. Horizontal irregularities refer to changes in the lateral stiffness or strength of a structure along its horizontal plane. These anomalies may result in unequal distribution of seismic forces, which can lead to irregular reactions and possible structural instability. Plan irregularities refer to deviations in the arrangement, setbacks, or projections of a structure, which result in extra twisting pressures and uneven distribution of seismic stresses over the building.

It is crucial to comprehend the impact of these configuration abnormalities on the seismic performance of reinforced concrete buildings in order to guarantee structural safety and resilience. The purpose of this extensive research is to examine and evaluate the effects of configuration abnormalities using numerical modeling, analytical approaches, and experimental validation. This research aims to gain insights into the behavior of irregular buildings when subjected to seismic loading and to find solutions for enhancing their seismic performance by using different techniques of analysis and testing.

Finite element analysis (FEA) and nonlinear dynamic analysis (NDA) are used to model seismic loading situations and assess how structures respond to various abnormalities. Structural capacity and dynamic properties are evaluated using analytical approaches such as pushover analysis and modal analysis. Experimental testing, such as shaking table tests and scaled model tests, provide essential data to confirm numerical and analytical conclusions and improve the comprehension of structural behavior under seismic stimulation.

The results of this research are anticipated to aid in the creation of guidelines and recommendations for the design and evaluation of irregular reinforced concrete buildings in areas prone to earthquakes. By clarifying the impact of configuration abnormalities on the performance of structures, engineers and designers may more effectively integrate steps to reduce their impacts and develop strategies to improve the resilience and safety of the structures. Furthermore, the knowledge acquired from this research may be used to enhance the creation of more advanced design rules and standards for buildings that can withstand seismic activity.

Essentially, this introduction highlights the need of evaluating the seismic performance of irregular reinforced concrete buildings and the need to comprehend the effects of configuration anomalies. This research aims to gain valuable insights into the behavior of irregular structures under seismic loading and contribute to the development of more resilient and safer structural designs. It will achieve this by conducting a comprehensive study that includes numerical modeling, analytical techniques, and experimental validation.

2. LITERATURE REVIEW

Oyguc et al. (2018) conducted a research to examine how irregular reinforced concrete buildings respond to different earthquake forces. The researchers examined three different kinds of buildings, namely SPEAR, ICONS, and an existing school building in Turkey. They specifically focused on the effects of significant seismic events and subsequent aftershocks caused by the Mw 9.0 March 11, 2011 Tohoku earthquake. The findings revealed substantial disparities in the seismic reaction between buildings that are irregular and those that are regular. The mean increment in residual drifts caused by structural anomalies was 27%, 35%, and 35% for the SPEAR, ICONS, and school buildings, respectively. Furthermore, irregular buildings exhibited a much larger average increase in the number of plastic hinges caused by aftershocks, suggesting a greater possibility for damage. These results highlight the significance of dealing with structural abnormalities in reinforced concrete structures to reduce the likelihood of seismic damage and enhance the overall structural resilience.

Bello et al. (2017) performed a research where they analyzed the behavior of multi-story structures under seismic forces using response spectrum analysis. A three-dimensional model of the structure was created for linear analysis, which was then followed by more intricate investigations. The outcomes of the study showed substantial results in terms of how the structure responded to seismic loads. They found that the greatest movement and deviation occurred at level 4 in the y-direction when using the SRSS (Square Root of the Sum of the Squares) spectrum in both directions. These findings demonstrate that level 4 had the highest intensity of seismic activity, underscoring the need of understanding and addressing possible weaknesses at that level. The results of this research provide useful understanding of how multi-story structures behave when subjected to seismic forces. This information may be used to develop methods for designing and retrofitting buildings to improve their ability to withstand earthquakes. These studies are essential for enhancing the seismic resilience of reinforced concrete buildings and mitigating the potential for damage and collapse during seismic events.

Tikiksh (2017) conducted a study on the seismic impacts of non-uniform vertical constructions in medium soil within seismic zones II, III, IV, and V. The research found that when seismic intensity progresses from zone II to zone V, there is a proportional rise in base shear and lateral displacement, suggesting a higher seismic demand. Specifically, when there are widespread abnormalities, a greater amount of base shear is noticed in comparison to other types of irregularities. This implies that vertical buildings that are not uniform in shape, particularly those with uneven distribution of weight, are more prone to being affected by seismic pressures. This emphasizes the need of taking into account and resolving irregularities in the design and reinforcement of structures. Comprehending the influence of irregularities on seismic performance is essential for guaranteeing the safety and durability of buildings in areas prone to earthquakes, thereby reducing the likelihood of structural harm and collapse during seismic occurrences. These findings help in creating successful seismic design and retrofit techniques that seek to improve the seismic performance of buildings and infrastructure.

Georgoussis et al. (2015) performed a seismic analysis of a multistory structure that had abnormalities in both mass and stiffness. They used Southwell's formula and the idea of an analogous single-story system to get an approximation analysis. Their investigation found that this method detects the structural arrangement with little twisting, guaranteeing that the structure's elastic response is mostly translational during ground motion. The translational response continues in the inelastic system, as the allocation of strength for the lateral load-resistant components is calculated using planar static analysis, taking into account the almost simultaneous yield of these parts. The researchers used analytical approaches to get insights into the seismic behavior of structures with abnormalities, allowing a more comprehensive knowledge and reduction of possible seismic hazards. Gaining comprehension of how structures react to seismic pressures in irregular circumstances is crucial for increasing seismic design methodologies and bolstering the durability of buildings against earthquakes.

Srinivasan et al. (2015) examined the seismic response of vertically mass irregular multistoried reinforced concrete (RC) frames using time history analysis. Their work sought to confirm the existing definition of time period for structures with mass irregularities and offer an empirical method to compute fundamental time periods, taking into account the influence of mass irregularities. A measure called the "mass irregularity index" was proposed, and an equation was devised to predict the base shear for structures with uneven mass. The suggested approach underwent evaluation and was compared to base shear values derived from various codes and dynamic assessments. The results demonstrated that the suggested approach produced comparable results to those obtained from free vibration analysis, therefore showing its efficacy in calculating base shear for structures with mass anomalies. This study enhances the comprehension of seismic behavior in buildings with mass anomalies and offers a vital tool for seismic design and evaluation in these situations.

Moehle et al. (2020) performed an analytical and experimental investigation of the seismic behavior of a 9-storey reinforced concrete (RC) frame structure. Their work included both linear and nonlinear static and dynamic studies. The researchers determined that dynamic analysis is crucial for effectively predicting the maximum displacement response of reinforced concrete frame structures under intense seismic ground motion. Their research revealed that dynamic approaches yielded somewhat more precise distributions of total storey shears in comparison to static methods. This study highlights the significance of using dynamic analytic methods in seismic evaluation and design to get a deeper understanding and make more accurate predictions about the performance of reinforced concrete frame structures during earthquakes.

Ravikumar et al. (2020) examined how irregular designs affect the susceptibility of reinforced concrete (RC) structures to seismic activity. They observed differences in the eccentricity between the center of mass and stiffness, even in structures that do not include multiple systems such as shear walls. Their research indicated that while a structure may have a substantial capacity, the seismic demand might vary considerably based on its layout. It is crucial to take into account abnormalities in structural configurations while evaluating seismic susceptibility. Engineers and designers may improve their assessment of the seismic performance of reinforced concrete (RC) structures and apply effective strategies to increase their ability to withstand seismic occurrences by detecting and comprehending these variances.

Kadid et al. (2021) investigated the efficacy of horizontal and vertical ground vibrations on reinforced concrete structures. The researchers performed nonlinear modeling on three concrete buildings with stiff, semi-rigid, and flexible structures using lumped mass and mass distributed models. Their findings demonstrated that the existence of vertical elements had a little effect on the forces experienced by the floor and foundation, but had a substantial impact on the axial forces exerted on the columns and their vertical displacement. It is essential to take into account vertical ground movements while evaluating the behavior of columns and their reaction to seismic events, especially in areas

susceptible to intense vertical shaking. Engineers may enhance the resilience of buildings by integrating these discoveries into structural design and analysis, enabling them to resist both horizontal and vertical seismic stresses.

Himanshu Bansal, 2022. The shear intensity on the first level was found to be optimal and was minimized on the top floor in all instances. Observations revealed that mass irregular frames exhibited a higher base shear compared to regular construction frames of similar characteristics. The irregular structure exhibited reduced base shear and increased inter-story drift due to its rigidity. The seismic impact of various building frames with vertical imperfections was investigated by.

V. Valmundsson et al. (2019). The mass, strength, and stiffness restrictions specified in the Uniform structure Code (UBC-97) are evaluated for a typical, structurally sound structure. The design under study consists of two-dimensional concrete frameworks with five, ten, and twenty levels.

Six essential phases are considered for each kind of structure. Irregularities arise when there are modifications made to the characteristics of a particular level or story. Research has shown that the mass and stiffness criteria of UBC have a little impact on the degree of irregular structural response compared to regular structures. Nevertheless, the inclusion of the strength parameter significantly increases the number of solutions, which is not in accordance with the requirements for mass and stiffness.

Humar and Wright (2022) conducted a study on the seismic response of steel frames with set-backs using a single ground movement. In the tower portions of set-back buildings, researchers discovered that the story drifts were bigger compared to those seen in regular structures. Conversely, lesser story drifts have been seen at the base portions of the irregular construction, as opposed to the regular buildings. The researchers determined that the disparity in elastic and inelastic story drifts between the regular and setback structures is contingent upon the specific narrative level being examined. The most significant discoveries in setback irregularity include altered motions and a high need for ductility.

3. CONCLUSIONS

1. **Seismic Analysis Irregularities:** Numerous research have examined seismic analysis, specifically focusing on irregularities such as mass irregularity, stiffness, and vertical geometry. The presence of these anomalies may have a substantial effect on how a structure reacts to earthquakes, requiring a comprehensive investigation in various seismic zones.
2. **Mitigation Measures:** Studies indicate that the implementation of measures such as shear walls or base isolation may effectively decrease the structural consequences of abnormalities. These steps are intended to improve the building's capacity to resist seismic forces and reduce damage in the event of an earthquake.
3. **Shear Force Distribution:** Seismic research findings often indicate that the shear force is greatest at the ground level of a building and diminishes progressively towards the upper floors. The significance of strengthening the lowest floors of a structure to endure the highest seismic pressures is shown by this distribution.
4. **Effect of Mass Irregularity:** Mass irregularities, such as an unequal distribution of mass inside the structure, result in a greater base shear as compared to similar regular structures. This suggests that buildings with uneven mass distribution may encounter amplified lateral stresses during seismic events.
5. **Buildings that have unequal stiffness** exhibit reduced base shear but increased drifts. This implies that while the sideways forces may be decreased, the total bending or distortion of the structure is greater because of the uneven distribution of stiffness.
6. **Vertical Displacement Variation:** When there is a mass irregularity at higher levels of a structure, it results in larger vertical displacement relative to lower levels. The unequal distribution of displacement highlights the need of assessing the full vertical extent of a structure to ensure its resistance against seismic activity.
7. **Displacement due to Stiffness Irregularity:** Likewise, when there is a stiffness irregularity in structures, they exhibit more displacement when the irregularity occurs at lower levels. This discovery highlights the need for thorough examination and strengthening of lower levels in order to reduce the impact of uneven rigidity.
8. **The need of conducting a thorough analysis** is emphasized by the observed discrepancies in displacement and base shear, which demonstrate the intricate nature of seismic response in irregular buildings. A thorough examination that takes into account all anomalies is essential for precisely evaluating a structure's seismic behavior.
9. **Structural vulnerability** refers to the susceptibility of a structure to seismic occurrences, which may be heightened by irregularities in mass and stiffness. Gaining a comprehensive understanding of these vulnerabilities is crucial for the purpose of creating robust buildings that are capable of enduring earthquakes.

10. Design Considerations: Engineers and designers must take into account the results of seismic analysis when creating buildings in areas that are susceptible to earthquakes. Implementing strategies to rectify abnormalities and minimize their impact may greatly improve the stability and security of constructed structures.

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