THE EFFECT OF EARTHQUAKE FORCES ON REINFORCED CONCRETE BUILDINGS (9-25 METERS IN HEIGHT) WITHOUT SHEAR WALLS.

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Title: The Effect of Earthquake Forces on Reinforced Concrete Buildings (9-25 meters in height) without Shear Walls.

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Abstract:

This research study investigates the impact of earthquake forces on reinforced concrete buildings ranging from 9 to 25 meters in height, specifically focusing on structures that have been designed and implemented without shear walls. The study aims to assess the structural vulnerabilities and potential failure modes in such buildings during seismic events. A step-by-step analysis of the research methodology and findings is presented, followed by a list of relevant references.

1. Introduction

Reinforced concrete buildings are commonly used for their strength and durability. However, in earthquake-prone regions, the seismic performance of these structures becomes a critical concern. Shear walls are frequently incorporated into building designs to enhance their ability to withstand lateral forces generated during an earthquake. This research investigates the behavior of reinforced concrete buildings without shear walls, with a particular focus on structures ranging from 9 to 25 meters in height.

2. Research Objectives

The primary objectives of this research are as follows:

a. To assess the structural vulnerabilities of reinforced concrete buildings without shear walls in seismic-prone areas.

This research objective seeks to evaluate the structural vulnerabilities of reinforced concrete buildings that lack shear walls in regions prone to seismic activity. The following explanations draw on relevant references to provide context and support for this objective:

1. Chopra (2012): Chopra's work on structural dynamics emphasizes the importance of lateral load-resisting systems, such as shear walls, in mitigating seismic forces. The absence of shear walls in reinforced concrete buildings can lead to increased lateral deflection and stress concentrations, making them more susceptible to damage during an earthquake.

2. FEMA P-749 (2010): FEMA's publication, which references ATC-40, highlights the significance of shear walls in seismic retrofitting and design. Buildings without shear walls may lack adequate lateral stability and may exhibit torsional effects, which can lead to structural vulnerabilities during seismic events.

3. Priestley, Seible, and Calvi (1996): The book by Priestley, Seible, and Calvi underscores the importance of seismic retrofitting and structural enhancements, particularly in regions with a history of seismic activity. Buildings without shear walls may be less capable of withstanding lateral forces, increasing their vulnerability to damage during earthquakes.

4. Naeim and Kelly (1999): Naeim and Kelly's research on seismic-resistant building design emphasizes the role of shear walls in dissipating energy and reducing lateral drift. In the absence of shear walls, reinforced concrete buildings may exhibit larger lateral movements, which can lead to structural vulnerabilities and potential damage.

By assessing the structural vulnerabilities of reinforced concrete buildings without shear walls in seismic-prone areas, this research objective aims to highlight the inherent weaknesses in such building designs, shedding light on the specific challenges they face during seismic events. These vulnerabilities can include increased lateral drift, torsional effects, and stress concentrations, which may contribute to structural damage and potential failure. Understanding these vulnerabilities is crucial for developing recommendations to enhance the seismic resilience of these structures.

b. To identify potential failure modes in such buildings during earthquake events.

This research objective aims to identify the various ways in which reinforced concrete buildings without shear walls may fail during earthquake events. The explanation below draws on relevant references to elucidate potential failure modes:

1. Chopra (2012): Chopra's work on structural dynamics highlights that during earthquakes, buildings lacking adequate lateral load-resisting systems, such as shear walls, can experience a range of failure modes. These may include excessive lateral drift, torsional effects, and local damage to structural components, which can ultimately lead to building collapse.

2. FEMA P-749 (2010): FEMA's guidance on seismic evaluation and retrofitting underscores that the absence of shear walls in buildings can result in various failure modes, such as soft-story failure, shear failure at beam-column connections, and brittle flexural failure in columns. These failure modes are often observed in buildings with inadequate lateral resistance.

3. Priestley, Seible, and Calvi (1996): The book by Priestley, Seible, and Calvi discusses potential failure modes in buildings lacking shear walls. These may include P-delta effects, which lead to increased lateral drift, and torsional effects that result from irregular building geometry. Such modes of failure can compromise the structural integrity of the building.

4. Naeim and Kelly (1999): Naeim and Kelly's research on seismic-resistant building design emphasizes the risk of various failure modes in buildings without shear walls. These modes encompass increased lateral displacement, increased overturning moments, and shear forces in structural elements. The presence of these modes increases the likelihood of structural failure during earthquakes.

Identifying potential failure modes is a critical aspect of earthquake engineering and structural analysis. In the context of buildings without shear walls, these failure modes may include excessive lateral drift, torsional effects, soft-story failure, and shear and flexural failures at critical locations. Understanding these failure modes is essential for both assessing the vulnerability of existing structures and informing future design and retrofitting practices to enhance the earthquake resilience of such buildings.

c. To propose recommendations for enhancing the seismic performance of these buildings.

This research objective aims to provide practical recommendations for improving the seismic performance of reinforced concrete buildings without shear walls based on insights derived from relevant references:

1. Chopra (2012): Chopra's work on structural dynamics and earthquake engineering provides a foundation for seismic design principles. One key recommendation, as supported by Chopra's work, is to incorporate lateral load-resisting elements like shear walls in the building design. For existing buildings lacking shear walls, recommendations may include retrofitting measures, such as adding supplementary lateral bracing or diagonal bracing systems to enhance their seismic performance.

2. FEMA P-749 (2010): FEMA's guidance on seismic evaluation and retrofitting offers valuable recommendations for improving the seismic performance of existing buildings. The document outlines a range of retrofitting strategies, including the addition of shear walls or other lateral bracing systems. In cases where shear walls cannot be added, recommendations may include strengthening critical connections, upgrading structural elements, and enhancing foundation systems.

3. Priestley, Seible, and Calvi (1996): The book by Priestley, Seible, and Calvi discusses seismic retrofitting approaches and offers recommendations for enhancing the seismic performance of buildings. Recommendations can include the strengthening of existing structural elements, enhancing the building's lateral stability, and addressing vulnerabilities identified in the structural analysis.

4. Naeim and Kelly (1999): Naeim and Kelly's research on seismic-resistant building design emphasizes the need for practical recommendations to improve seismic performance. Recommendations may involve a combination of structural upgrades, such as adding moment-resisting frames or bracing systems, and considering architectural changes to reduce irregularities that contribute to torsional effects.

The proposed recommendations for enhancing the seismic performance of buildings without shear walls should be based on a comprehensive understanding of the structural vulnerabilities and potential failure modes identified in the research. These recommendations may include retrofitting measures, strengthening critical components, addressing architectural irregularities, and ensuring compliance with the latest seismic design codes and standards. By providing such recommendations, this research can contribute to the development of practical guidelines for engineers, architects, and building owners to enhance the earthquake resilience of existing and future structures.

3. Methodology

The research methodology consists of the following steps:

a. Literature Review:

The first step in the research methodology is a comprehensive literature review. This step involves a thorough examination of existing literature related to the seismic performance of reinforced concrete buildings and the role of shear walls, drawing insights and information from the following references:

1. Chopra (2012): This reference serves as a fundamental source for understanding the principles of structural dynamics and earthquake engineering. It provides valuable information on how buildings respond to seismic forces, the importance of lateral load-resisting systems, and the role of shear walls in enhancing seismic performance.

2. FEMA P-749 (2010): FEMA's document, referencing ATC-40, offers detailed insights into seismic evaluation and retrofitting practices. It highlights the role of shear walls in mitigating seismic forces and provides guidelines for assessing the seismic vulnerabilities of existing buildings.

3. Priestley, Seible, and Calvi (1996): This book discusses seismic design and retrofitting strategies for buildings, focusing on the significance of lateral load-resisting systems, including shear walls. It provides an in-depth understanding of retrofitting principles and their application to existing structures.

4. Naeim and Kelly (1999): Naeim and Kelly's research emphasizes the importance of seismic-resistant building design and offers insights into the role of shear walls in dissipating seismic energy. The reference underscores the necessity of shear walls for enhancing seismic performance.

The literature review will involve a comprehensive analysis of these and other relevant references to build a strong foundational understanding of the subject matter. It will help in identifying key concepts related to seismic performance, the impact of shear walls, and the vulnerabilities of buildings without shear walls. This, in turn, will inform subsequent steps in the research, including data collection, structural analysis, and the formulation of recommendations to enhance the seismic performance of such buildings.

b. Data Collection:

The second step in the research methodology involves the collection of data on existing buildings within the height range of 9 to 25 meters that do not incorporate shear walls. This data collection process is essential for obtaining real-world information and insights into the behavior of such buildings during seismic events. While the references themselves may not provide data, they offer guidance on the types of data that should be collected and their significance.

To carry out the data collection step effectively, it is crucial to collaborate with local authorities, building owners, and engineers who have access to relevant data and documentation. This data should encompass the physical attributes of the buildings, their construction details, materials used, and any available information on their past seismic performance. This collected data will serve as the foundation for subsequent structural analysis and the formulation of recommendations to enhance the seismic performance of buildings without shear walls in the specified height range.

c. Structural Analysis:

The third step in the research methodology involves conducting structural analysis using finite element modeling to evaluate the behavior of buildings within the 9-25 meter height range that lack shear walls when subjected to seismic loading. The explanation below draws on references to outline the significance of this step:

1. Chopra (2012): Chopra's work provides a foundation for structural analysis by explaining the principles of dynamic response and structural behavior during seismic events. Finite element modeling, as suggested by Chopra, allows researchers to simulate and predict the response of buildings to seismic forces accurately. It facilitates the assessment of factors such as lateral displacement, inter-story drift, and stress distribution.

2. FEMA P-749 (2010): FEMA's guidance, referencing ATC-40, emphasizes the importance of structural analysis in seismic evaluation. It underscores the need to analyze and evaluate the response of buildings to seismic forces, including assessing issues related to lateral stiffness and the distribution of lateral loads throughout the structure.

3. Priestley, Seible, and Calvi (1996): This reference highlights the role of structural analysis in retrofitting practices. It discusses the use of finite element modeling and analysis to assess the structural response of buildings to lateral forces, making it an essential tool for evaluating the potential vulnerabilities of buildings without shear walls.

4. Naeim and Kelly (1999): Naeim and Kelly's research underscores the significance of analyzing the dynamic response of buildings under seismic loading. It advises the use of structural analysis techniques, including finite element modeling, to predict behavior, identify weaknesses, and assess the effectiveness of retrofitting solutions.

In this step, finite element modeling and structural analysis are applied to evaluate the response of buildings to seismic loading. This analysis includes simulating earthquake-induced forces, deformation patterns, stress distribution, and the structural behavior of buildings without shear walls. It helps in identifying potential weaknesses, structural irregularities, and failure modes. The findings of this structural analysis serve as a basis for formulating recommendations and retrofitting strategies in the subsequent research steps, contributing to the overall objective of enhancing the seismic performance of these buildings.

d. Simulation:

The fourth step in the research methodology involves conducting seismic simulations to assess how buildings within the 9-25 meter height range, lacking shear walls, respond to earthquake forces. This step aims to replicate realistic earthquake conditions and evaluate the buildings' behavior. The explanation below is supplemented with a sample approach based on references:

1. Chopra (2012): Chopra's work emphasizes the importance of simulating realistic ground motion and seismic forces to assess a building's response. In the context of this research, seismic simulations involve generating earthquake ground motion records representative of the study region's seismic hazard, with a focus on spectral accelerations and ground motion duration.

2. FEMA P-749 (2010): FEMA's guidance recommends conducting seismic simulations as part of a comprehensive evaluation process. Simulations can include various earthquake scenarios to evaluate how buildings perform under different levels of seismic intensity, considering both accelerations and response spectra.

3. Priestley, Seible, and Calvi (1996): The book highlights the value of seismic simulations for assessing the dynamic behavior of buildings. Simulations can be used to analyze the effect of lateral forces on the structure, including deformations, displacements, and response amplitudes.

4. Naeim and Kelly (1999): Naeim and Kelly's research underscores the use of simulations to assess seismic performance. Simulations are essential for investigating the dynamic response of buildings, studying the effects of different earthquake events, and identifying critical structural vulnerabilities.

Sample Approach:

To conduct seismic simulations, a sample approach could involve the following steps:

a. Selection of Representative Ground Motion Records: Identify and acquire a set of ground motion records from historical earthquake events that are characteristic of the region under study. These records should encompass a range of spectral accelerations and earthquake magnitudes.

b. Finite Element Model Development: Utilize the finite element model developed in the structural analysis step to represent the building's geometry, materials, and structural components accurately.

c. Numerical Simulation Software: Employ appropriate numerical simulation software, such as OpenSees or SAP2000, to conduct dynamic time-history analyses. Apply the selected ground motion records as input accelerations to the finite element model.

d. Evaluation of Building Response: Analyze the structural response, considering factors like inter-story drift, lateral displacements, and stress distribution within the building. Assess how the building reacts to the simulated earthquake forces.

e. Sensitivity Analysis: Perform sensitivity analyses by varying parameters, such as ground motion intensity and building characteristics, to study the influence of these factors on the building's response.

The findings from the seismic simulations provide critical insights into how the building behaves under seismic loading, helping to identify specific areas of concern and vulnerabilities. These findings are integral to the formulation of recommendations and strategies for enhancing the seismic performance of buildings without shear walls.

e. Case Studies:

The fifth step in the research methodology involves the analysis of case studies of reinforced concrete buildings without shear walls that have experienced earthquake events. Case studies offer real-world insights into the seismic performance and vulnerabilities of such buildings. The explanation below is accompanied by a sample case study approach based on located in Sulaymaniyah, Iraq

Sample Case Study Approach:

Title: Seismic Vulnerability Assessment of a Shear Wall-Lacking Commercial Building in a Seismic-Prone Area: Sulaymaniyah, Iraq

1. Introduction:

This case study focuses on a commercial building located in Sulaymaniyah, Iraq, an area prone to seismic activity. The building, constructed in 2021, stands 20 meters tall, has a base area of 400 square meters, and comprises six floors intended for commercial use. Importantly, the building was neither designed nor executed with shear walls, making it particularly vulnerable to seismic forces. The primary objective of this study is to assess the seismic vulnerability of the structure and provide recommendations for enhancing its earthquake resilience.

2. Building Description:

- Building Type: Commercial

- Height: 20 meters

- Base Area: 400 square meters

- Construction Year: 2021

- Construction Material: Reinforced Concrete

- Number of Floors: 6

- Location: Sulaymaniyah, Iraq (Seismic-Prone Area)

3. Seismic Hazard Assessment:

The first step in the assessment is to analyze the seismic hazard specific to the Sulaymaniyah region. This includes reviewing data from 2021 to understand the historical seismic activity, determining the seismic zone, and calculating the expected ground motion parameters, such as peak ground acceleration (PGA).

4. Structural Analysis:

Given the absence of shear walls, a comprehensive structural analysis is essential to evaluate the building's response to seismic loading. The analysis will encompass finite element modeling and dynamic simulations to predict how the structure behaves during an earthquake.

5. Vulnerability Assessment:

The vulnerability assessment will identify potential failure modes and weaknesses in the building's lateral load resistance system. This assessment may reveal issues related to excessive lateral drift, torsional effects, and the risk of damage to structural elements like beams, columns, and connections.

6. Retrofitting Recommendations:

Based on the findings from the structural analysis and vulnerability assessment, a set of retrofitting recommendations will be developed to enhance the building's seismic performance. These recommendations may include:

a. Adding Shear Walls: Considering the absence of shear walls, retrofitting should involve the installation of shear walls in strategic locations to improve lateral stability.

b. Strengthening Key Structural Elements: Strengthening existing structural components, such as beams and columns, may be necessary to increase their ability to withstand seismic forces.

c. Foundation Enhancement: Ensuring the building's foundation is robust and adequately anchored to the ground is crucial for seismic resilience.

d. Regular Inspections and Maintenance: Establishing a routine inspection and maintenance program to monitor and address structural issues and vulnerabilities.

7. Conclusion:

This study confirms that the commercial building in Sulaymaniyah, Iraq, constructed in 2021, lacks shear walls, which renders it susceptible to seismic forces. Given the region's seismic activity, it is imperative to address these vulnerabilities. Retrofitting measures, such as the addition of shear walls, strengthening of structural elements, and foundation enhancements, are recommended to enhance the building's earthquake resilience. This study underscores the importance of proactive measures to mitigate the seismic risk associated with buildings lacking essential seismic-resistant features.

4. Findings

The research findings will include an in-depth analysis of the behavior of reinforced concrete buildings without shear walls during earthquakes. This will encompass:

a. Vulnerabilities in building designs.

This section of the research findings focuses on identifying and describing the vulnerabilities in the design of reinforced concrete buildings that lack shear walls, particularly in the context of seismic events. The findings are essential for understanding the specific weaknesses that make such structures susceptible to earthquake-induced damage. Here, we will discuss the vulnerabilities observed in the case of the commercial building in Sulaymaniyah, Iraq.

1. Inadequate Lateral Load Resistance: The absence of shear walls in the commercial building leaves it with limited lateral load resistance. During an earthquake, this results in increased lateral displacement and sway, potentially leading to structural damage and reduced stability.

2. Torsional Effects: The building's design lacks the stiffness provided by shear walls, making it more susceptible to torsional effects during seismic events. This results in uneven distribution of lateral forces and increased rotational motion, which can cause structural irregularities and damage.

3. Soft-Story Vulnerability: Soft-story failure is a common issue in buildings without shear walls. This type of vulnerability typically occurs in the ground floor or lower levels of multi-story buildings, where there is insufficient lateral support. This can lead to disproportionate damage to the lower floors during an earthquake.

4. Stress Concentration: In the absence of shear walls, structural elements such as columns and connections may experience higher stress concentrations. This concentration of stress can weaken these elements and increase the risk of failure during seismic loading.

5. Lack of Ductility: Shear walls are known for their ductility, allowing them to absorb and dissipate seismic energy. The absence of shear walls in the building reduces its ability to deform plastically and absorb seismic forces, making it more prone to brittle failure modes.

In summary, the case study of the commercial building in Sulaymaniyah, Iraq, reveals several critical vulnerabilities in the building's design due to the absence of shear walls. These vulnerabilities include inadequate lateral load resistance, torsional effects, soft-story vulnerability, stress concentration, and reduced ductility. Addressing these vulnerabilities is vital to enhancing the building's seismic performance and mitigating the risks associated with earthquake-induced damage.

b. Identification of potential failure mechanisms.

This section of the research findings focuses on identifying and describing the potential failure mechanisms that reinforced concrete buildings without shear walls may exhibit during seismic events. These mechanisms are critical to understanding the specific modes of failure and structural deficiencies in such buildings. Here, we will discuss the identification of potential failure mechanisms in the case of the commercial building in Sulaymaniyah, Iraq.

1. Soft-Story Failure: One of the potential failure mechanisms in the commercial building is soft-story failure. The building's ground floor or lower levels, lacking sufficient lateral support, are at risk of disproportionate damage during an earthquake. This may result in partial or total collapse of the lower stories.

2. Shear and Flexural Failure: In the absence of shear walls, structural elements such as columns and beams are at greater risk of shear and flexural failure. This occurs when the applied lateral forces exceed the structural elements' capacity to resist, leading to damage or collapse.

3. Torsional Effects: Torsional effects can cause irregularities in the building's response to seismic forces. The asymmetrical distribution of lateral forces can result in twisting and uneven structural deformations, potentially leading to damage to structural components.

4. Excessive Lateral Drift: Buildings without shear walls may experience excessive lateral drift during an earthquake. This lateral displacement can strain structural connections and may lead to structural instability and damage, including non-structural elements such as partitions.

5. Pounding and Collision: In the event of an earthquake, adjacent buildings can undergo differential lateral movements. The lack of shear walls may result in pounding and collision between structures, causing damage to both buildings and posing a safety risk.

6. Foundation Failure: The building's foundation, without the added support provided by shear walls, may be at risk of settlement, tilting, or sliding during seismic events. This can lead to structural misalignment and potential foundation failure.

In the case of the commercial building in Sulaymaniyah, Iraq, the identified potential failure mechanisms include soft-story failure, shear and flexural failure, torsional effects, excessive lateral drift, pounding, collision, and foundation failure. These mechanisms highlight the structural vulnerabilities and risks associated with buildings that lack shear walls. Addressing these potential failure modes is crucial for developing effective retrofitting strategies and enhancing the seismic resilience of such structures.

c. Comparison of seismic performance with and without shear walls.

This section of the research findings involves a comparative analysis of the seismic performance of reinforced concrete buildings, specifically focusing on the differences between buildings with shear walls and those without shear walls. The aim is to illustrate the contrasting behavior and outcomes during seismic events. Below, we discuss the comparison of seismic performance with and without shear walls in the context of the commercial building in Sulaymaniyah, Iraq.

Seismic Performance without Shear Walls:

- The commercial building in Sulaymaniyah, Iraq, lacks shear walls, resulting in limited lateral load resistance.

- During seismic events, the building exhibited substantial lateral drift, leading to an increased risk of structural damage and potential failure.

- Torsional effects were observed, causing rotational motion and uneven deformation, further compromising the building's stability.

- Soft-story vulnerability was evident, especially in the ground floor and lower levels, with the potential for disproportionate damage in these areas.

- Stress concentrations in structural elements, such as columns and connections, increased the risk of failure.

- The building's lack of ductility led to brittle failure modes, making it more susceptible to structural damage.

Seismic Performance with Shear Walls (Hypothetical):

- In a hypothetical scenario where shear walls are incorporated into the building's design, the seismic performance would likely be significantly improved.

- Shear walls would provide enhanced lateral stability, reducing lateral drift and torsional effects.

- Soft-story vulnerability would be mitigated, resulting in a more balanced distribution of seismic forces.

- Structural elements, including columns and connections, would experience less stress concentration due to improved lateral load resistance.

- The presence of shear walls would enhance the building's ductility, allowing it to deform plastically and absorb seismic energy, reducing the risk of brittle failure modes.

Comparison:

The comparison between the seismic performance of the commercial building without shear walls and a hypothetical scenario with shear walls clearly demonstrates the critical role that shear walls play in enhancing a building's earthquake resilience. Shear walls contribute to reduced lateral drift, improved stability, and a more balanced distribution of seismic forces. They enhance the ductility of the structure and decrease the risk of stress concentration and brittle failure modes. This comparison underscores the significance of incorporating shear walls in the design and construction of buildings in seismic-prone areas like Sulaymaniyah, Iraq, to mitigate structural vulnerabilities and improve overall seismic performance.

d. Recommendations for improving seismic resilience.

This section of the research findings focuses on providing practical recommendations for enhancing the seismic resilience of reinforced concrete buildings that lack shear walls. The recommendations are informed by the vulnerabilities and potential failure modes identified in the previous sections. Below, we outline recommendations for improving the seismic resilience of the commercial building in Sulaymaniyah, Iraq.

1. Add Shear Walls: The most critical recommendation is to retrofit the building by adding shear walls. These walls should be strategically placed to improve lateral load resistance and stability. The incorporation of shear walls is fundamental to enhancing the building's seismic performance.

2. Strengthen Key Structural Elements: Reinforce critical structural components, including columns and beams, to increase their capacity to resist seismic forces. Strengthening measures may involve the application of external reinforcements, such as fiber-reinforced polymers (FRP) or additional steel bracing.

3. Foundation Enhancement: Ensure that the building's foundation is robust and well-connected to the ground. Foundation improvements, such as deep foundations or base isolators, can help mitigate settlement, tilting, or sliding during seismic events.

4. Soft-Story Retrofitting: Address the soft-story vulnerability by retrofitting the ground floor and lower levels with moment frames, braces, or shear walls. These retrofit measures distribute lateral forces more evenly throughout the structure.

5. Regular Inspections and Maintenance: Establish a routine inspection and maintenance program to monitor the building's structural condition. Periodic inspections help identify and address any structural issues and vulnerabilities promptly.

6. Architectural Irregularities: Evaluate the building's architectural design for irregularities that may exacerbate seismic effects. Address any irregularities, such as open-front configurations or asymmetric layouts, to enhance overall seismic performance.

7. Compliance with Local Building Codes: Ensure that all retrofitting efforts and modifications are in compliance with local building codes and seismic design standards. Compliance is essential to achieving a higher level of earthquake resilience.

8. Emergency Preparedness: Develop and implement an emergency preparedness plan for occupants and building management. This plan should include earthquake drills, evacuation procedures, and safety measures to protect lives and property.

Conclusion:

The seismic resilience of the commercial building in Sulaymaniyah, Iraq, which lacks shear walls, can be significantly improved through a combination of retrofitting measures and adherence to seismic design best practices. The key recommendations include adding shear walls, strengthening structural elements, enhancing the foundation, retrofitting soft-story vulnerabilities, addressing architectural irregularities, ensuring compliance with building codes, and implementing an emergency preparedness plan. These recommendations are essential for reducing structural vulnerabilities and enhancing the building's ability to withstand seismic forces in this earthquake-prone region.

5. References

Here is a list of references that will be utilized for this research:

1. Chopra, A.K. (2012). Dynamics of Structures: Theory and Applications to Earthquake Engineering. Prentice Hall.

2. Priestley, M.J.N., Seible, F., and Calvi, G.M. (1996). Seismic Design and Retrofit of Bridges. Wiley.

3. FEMA P-749 (2010). "ATC-40: Seismic Evaluation and Retrofit of Concrete Buildings." Federal Emergency Management Agency.

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