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PERFORMANCE-BASED SEISMIC DESIGN OF TALL BUILDINGS WITH SOIL-STRUCTURE INTERACTION

By

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ABSTRACT

This research delves into the critical aspect of seismic design for tall buildings by incorporating the dynamic interplay between soil and structure. The seismic performance of tall buildings is a paramount concern in earthquake-prone regions, necessitating innovative approaches to enhance resilience and safety. This study adopts a performance-based seismic design methodology, considering the complex interaction between tall building structures and the underlying soil strata. The research begins by comprehensively reviewing existing seismic design practices, highlighting the limitations of conventional methods that often overlook the dynamic influence of soil-structure interaction (SSI). Subsequently, a thorough investigation into the seismic response characteristics of tall buildings is conducted, emphasizing the importance of accurately capturing the dynamic behavior induced by soil-structure interaction. The study employs advanced numerical simulations and finite element analysis to model the intricate relationship between tall buildings and the underlying soil layers. The findings underscore the significance of incorporating SSI effects in the design process to optimize the seismic performance of tall structures. Furthermore, the research proposes a performance-based seismic design framework that integrates soil-structure interaction parameters, considering both structural and non-structural components. A case study is presented to validate the proposed methodology, employing real-world data from a seismic-prone region. The results showcase the effectiveness of the performance-based approach in enhancing the seismic resilience of tall buildings, thereby reducing the potential for damage and ensuring occupant safety during seismic events. This research contributes to advancing the field of seismic design by providing a comprehensive framework for incorporating soil-structure interaction in the design process of tall buildings. The proposed methodology offers a nuanced understanding of the dynamic response of tall structures to seismic forces, enabling engineers and designers to optimize building performance and enhance overall seismic resilience in regions prone to earthquakes.

INTRODUCTION

The seismic design of tall buildings stands as a paramount challenge in regions prone to earthquakes, necessitating a nuanced understanding of the dynamic interaction between soil and structure. This study delves into the intricate realm of Performance-Based Seismic Design (PBSD) for tall buildings, with a particular focus on incorporating Soil-Structure Interaction (SSI) effects. As urbanization continues to drive the proliferation of tall structures in earthquake-prone zones, the need for innovative design methodologies becomes increasingly evident.

Conventional seismic design approaches often oversimplify the complex dynamics involved in the interaction between tall buildings and the underlying soil layers. By adopting a performance-based approach, this research seeks to address these limitations and contribute to the development of robust design frameworks that prioritize both structural integrity and occupant safety. Historically, seismic design practices for tall buildings have predominantly adhered to prescriptive codes that provide guidelines based on simplified assumptions and empirical relationships.

1. Background:

Tall buildings are integral components of modern urban landscapes, embodying architectural and engineering marvels. However, their structural response to seismic forces is complex, influenced not only by the inherent characteristics of the building itself but also by the dynamic interactions with the underlying soil. Traditional seismic design codes often provide generalized guidelines, falling short in capturing the intricacies of tall building behavior under seismic loading. Recognizing this limitation, Performance-Based Seismic Design emerges as an innovative paradigm, focusing on achieving predefined performance objectives rather than adhering strictly to prescriptive rules.

2. Significance of Soil-Structure Interaction:

The interaction between tall buildings and the supporting soil foundation plays a pivotal role in shaping their seismic response. Soil-Structure Interaction (SSI) introduces additional complexities, influencing factors such as natural frequencies, damping, and lateral displacements. Neglecting these interactions can lead to conservative or, conversely, underestimated seismic designs. Therefore, a comprehensive understanding of SSI is imperative for accurate seismic assessment and efficient design strategies for tall buildings.

3. Objectives of Performance-Based Seismic Design:

The primary objectives of Performance-Based Seismic Design include enhancing the safety, functionality, and resilience of tall buildings during and after seismic events. Unlike conventional approaches, PBSD enables engineers to explicitly define and achieve desired performance levels, considering factors such as structural integrity, occupant safety, and post-earthquake functionality. The integration of soil-structure interaction within this framework aims to address the specific challenges posed by the geological conditions beneath these tall structures.

4. Methodological Advances:

The methodology for Performance-Based Seismic Design integrates cutting-edge analytical tools, advanced structural modeling techniques, and realistic soil-structure interaction models. Incorporating incremental dynamic analysis, pushover analysis, and probabilistic seismic hazard assessments, this approach provides a holistic understanding of the seismic performance of tall buildings. Iterative optimization processes allow for the refinement of structural and foundation designs, ensuring a balance between performance objectives and economic feasibility.

5. Research Gap and Motivation:

Despite the advancements in seismic design methodologies, a research gap exists in the comprehensive understanding and integration of soil-structure interaction in the performance-based design of tall buildings. This study aims to bridge this gap by offering a detailed exploration of the seismic behavior of tall structures, considering the dynamic interplay with the underlying soil. By doing so, it aspires to contribute valuable insights, practical guidelines, and a robust framework that can inform future seismic design practices for tall buildings in seismically active regions.

Tall structures, characterized by their increased flexibility and potential for dynamic amplification, exhibit unique behaviors during seismic events. The coupling of these structures with the underlying soil introduces additional complexities, as the dynamic properties of the soil significantly influence the overall response. The first phase of this research involves an in-depth investigation into the seismic behavior of tall buildings, emphasizing the need to capture the dynamic effects induced by soil-structure interaction.

The proposed methodology offers a comprehensive and adaptable approach to seismic design, ensuring that tall structures are not only structurally sound but also capable of withstanding seismic events with minimized damage and enhanced occupant safety. As urban landscapes continue to evolve, the findings of this study hold significant implications for the development of resilient structures in earthquake-prone regions.

The Need for Performance-Based Seismic Design:

Recognizing the shortcomings of conventional approaches, there has been a paradigm shift towards performance-based seismic design. This approach emphasizes achieving predefined performance objectives, such as limiting structural damage and ensuring life safety, rather than adhering strictly to prescriptive code provisions. Performance-based design allows for a more nuanced consideration of the dynamic interactions between the building and the underlying soil. In the context of tall buildings, performance-based seismic design becomes imperative to account for the diverse range of structural configurations and soil conditions. By adopting a performance-based approach, engineers can tailor the design to meet specific performance goals, considering factors like occupant safety, repair costs, and functionality post-earthquake.

SCOPE

Advanced Engineering Practices:

The scope of this research extends to the development and promotion of advanced engineering practices in the field of seismic design for tall buildings. By incorporating soil-structure interaction into performance-based design, the study aims to introduce a more sophisticated and accurate approach that reflects the dynamic realities of seismic events.

Optimization of Seismic Resilience:

The research seeks to contribute to the optimization of seismic resilience in tall buildings. The incorporation of soil-structure interaction parameters in the design process aims to enhance the overall performance of tall structures during earthquakes. This optimization encompasses not only structural components but also considers the impact on non-structural elements critical for the building's functionality and occupant safety.

Applicability to Diverse Structures:

The scope of the research is designed to be broad and applicable to diverse tall building structures. Whether the buildings have varying heights, different structural systems, or are situated in regions with distinct soil conditions, the proposed performance-based seismic design framework is intended to provide a versatile and adaptable solution.

Influence on Building Codes and Standards:

The findings of this research have the potential to influence and shape building codes and standards related to seismic design. As the proposed methodology demonstrates its efficacy through case studies and validation, it may serve as a basis for updating or refining existing codes to better address the complexities of soil-structure interaction in tall buildings.

Practical Implementation in Seismic-Prone Regions:

The scope extends to the practical implementation of the developed framework in real-world scenarios, particularly in seismic-prone regions. Engineers and designers in these regions can leverage the research outcomes to enhance the seismic performance of tall buildings, thereby contributing to increased safety, reduced damage, and improved overall resilience in the face of seismic events.

AIM

Enhancing Seismic Safety:

The primary aim of this research is to contribute to the enhancement of seismic safety for tall buildings. By incorporating soil-structure interaction in the performance-based design, the study aims to develop strategies that improve the overall structural response to seismic forces, ultimately ensuring the safety of occupants and minimizing potential damage during earthquakes.

Developing Comprehensive Design Framework:

The research aims to develop a comprehensive performance-based seismic design framework specifically tailored for tall buildings. This framework will consider not only the structural elements but also the dynamic interaction with the underlying soil, providing a holistic approach to seismic design that can be applied across various architectural configurations and soil conditions.

Optimizing Resilience and Functionality:

The aim is to optimize the seismic resilience of tall buildings beyond structural considerations. The research seeks to address the functionality of buildings during and after seismic events, emphasizing the importance of non-structural components. By doing so, the study aims to minimize downtime and ensure that tall buildings remain operational and functional post-earthquake.

Guiding Future Design Practices:

The research aspires to guide future design practices in seismic-prone regions, influencing how engineers approach the seismic design of tall buildings. By presenting a nuanced understanding of soil-structure interaction and its impact on tall structures, the study aims to shape design methodologies that prioritize both structural integrity and overall building performance.

Contributing to Sustainable Urban Infrastructure:

The overarching aim is to contribute to the development of sustainable urban infrastructure in seismic-prone areas. The research endeavors to provide insights and solutions that enhance the seismic resilience of tall buildings, promoting safety and sustainability in the face of seismic challenges and supporting the continued growth of urban environments.

OBJECTIVE

Evaluate Current Seismic Design Practices:

The primary objective is to conduct a comprehensive review and evaluation of existing seismic design practices, with a specific focus on tall buildings. This includes an examination of the limitations of conventional methods in addressing soil-structure interaction and understanding how current practices may fall short in ensuring the seismic resilience of tall structures.

Investigate Seismic Response Characteristics:

To analyze the seismic response characteristics of tall buildings, considering factors such as building height, structural systems, and soil properties. This objective aims to quantify and understand the dynamic behavior of tall structures under seismic loading, emphasizing the importance of accurately capturing the interaction between the building and the underlying soil.

Develop a Performance-Based Design Framework:

The research aims to develop a comprehensive performance-based seismic design framework specifically tailored for tall buildings. This includes formulating methodologies that integrate soil-structure interaction parameters, providing a nuanced approach to seismic design that goes beyond structural considerations to encompass both structural and non-structural components.

Utilize Numerical Simulations for Validation:

To employ advanced numerical simulations and finite element analysis for modeling the dynamic interaction between tall buildings and the underlying soil. This objective involves validating the proposed performance-based design framework through rigorous numerical simulations, ensuring its effectiveness and accuracy in capturing the complexities of soil-structure interaction.

Validate the Framework Through a Case Study:

Validate the developed design framework through a real-world case study in a seismic-prone region. This involves applying the proposed methodology to actual data from a tall building in a seismic zone, demonstrating its applicability, efficacy, and its potential to enhance the seismic resilience of tall structures in practical engineering scenarios.

NOVELTY

The novelty of the proposed research lies in its pioneering approach to advancing seismic design methodologies for tall buildings by explicitly addressing the intricate dynamics of soil-structure interaction. While traditional seismic design practices focus predominantly on structural elements, this study introduces a groundbreaking perspective by incorporating the often-overlooked influence of the underlying soil on tall building behavior during seismic events. The research novelty stems from its commitment to developing a comprehensive performance-based seismic design framework tailored specifically for tall structures. By leveraging advanced numerical simulations and finite element analysis, the study aims to model and understand the dynamic interplay between the building and the soil, considering factors such as soil stiffness, damping properties, and their impact on the overall seismic response. Furthermore, the research introduces a paradigm shift by emphasizing the optimization of seismic resilience beyond structural considerations. The proposed framework aims to address the broader spectrum of a tall building's response to earthquakes, encompassing both structural and non-structural components. This holistic approach to performance-based seismic design for tall buildings, considering the complex and dynamic nature of soil-structure interaction, represents a novel contribution to the field, with implications for improving safety and sustainability in seismic-prone regions.

LITERATURE REVIEW

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"Nonlinear analysis of plane frames under earthquake excitation." Bulletin of the Seismological Society of America, 69(2), 581-601:
The paper presents a study on the nonlinear analysis of plane frames under earthquake excitation. Nonlinear analysis is crucial for capturing the behavior of structures beyond the elastic range during seismic events.

2. ASCE 4-98 (1998)."Seismic Analysis of Safety-Related Nuclear Structures and Commentary." ASCE 4-98 provides guidelines for the seismic analysis of safety-related nuclear structures. It outlines specific criteria and methods for ensuring the safety and integrity of structures in nuclear facilities under seismic loading.

3. ASCE 7-16 (2016)."Minimum Design Loads and Associated Criteria for Buildings and Other Structures." ASCE 7-16 is a standard that provides the minimum design loads for buildings and other structures, including seismic loads. It outlines the criteria for designing structures to withstand various environmental loads, including earthquakes.

4. ASCE 41-17 (2017)."Seismic Evaluation and Retrofit of Existing Buildings."
ASCE 41-17 is a critical standard that outlines procedures for evaluating and retrofitting existing buildings for seismic performance. It provides guidelines for seismic assessment and retrofitting strategies, ensuring the safety of structures during earthquakes.

5. ATC-40 (1996)."Seismic Evaluation and Retrofit of Concrete Buildings."
ATC-40 is a guideline that outlines procedures for the seismic evaluation and retrofit of concrete buildings. It provides a systematic approach for assessing the seismic vulnerability of existing concrete structures and implementing retrofit measures.

6. Bernal, D., and Carr, A.J. (2010)."Simplified and efficient soil-structure interaction models for seismic analysis of buildings."
This paper proposes simplified and efficient models for soil-structure interaction in seismic analysis. Efficient models are essential for large-scale analyses, providing a balance between accuracy and computational feasibility.

7. Chopra, A.K., and Goel, R.K. (2002)"A modal pushover analysis procedure for estimating seismic demands for buildings."
   This paper introduces a modal pushover analysis method, which is a nonlinear static procedure, to estimate seismic demands for buildings. It provides an alternative approach to the conventional linear static analysis, offering a more realistic representation of the structure's response to seismic forces..

8. Dall'Asta, A., and Ragni, L. (2009)."Seismic behavior of structures with soil-structure interaction: Experimental results."
   The paper presents experimental results on the seismic behavior of structures considering soil-structure interaction. Experimental data from physical models are crucial for validating analytical models and improving our understanding of dynamic interactions.

9. Dazio, A., Beyer, K., and Kuehn, N. (2014)."Soil-Structure Interaction Effects on the Seismic Response of Reinforced Concrete Buildings."
   This paper explores the effects of soil-structure interaction on the seismic response of reinforced concrete buildings. It provides insights into the dynamic interaction between the building and the soil, offering valuable information for seismic design considering realistic site conditions.

10. FEMA P695 (2009)."Quantification of Building Seismic Performance Factors."
    FEMA P695 provides guidelines for quantifying seismic performance factors for buildings. It plays a crucial role in the development of performance-based seismic design procedures, offering a standardized approach to evaluate the seismic performance of structures.

11. Hall, J.F., and Heaton, T.H. (1996)."Near-source ground motion and its effects on flexible buildings." The paper investigates near-source ground motion and its effects on flexible buildings. Understanding the characteristics of ground motion near earthquake sources is vital for accurately predicting structural responses.

12. Kalkan, E., and Kunnath, S.K. (2006)."Displacement-Based Assessment of Seismic Performance of Buildings." The paper introduces a displacement-based assessment method for evaluating seismic performance. It emphasizes the importance of displacement as a more reliable measure than traditional force-based approaches for predicting structural damage and assessing overall performance.

13. Katsanos, E.I., and Sextos, A.G. (2013)."Seismic vulnerability of structures and infrastructure: Soil-structure interaction effects." This paper explores the seismic vulnerability of structures and infrastructure with a focus on soil-structure interaction effects. It contributes insights into the potential risks and vulnerabilities associated with dynamic soil-structure interaction.

14. Kramer, S.L. (1996). "Geotechnical Earthquake Engineering."
"Geotechnical Earthquake Engineering." Prentice Hall:
Kramer's book serves as a fundamental resource for geotechnical earthquake engineering. It covers various aspects of soil-structure interaction, providing a comprehensive understanding of the geotechnical aspects influencing seismic response.

15. Krawinkler, H., and Miranda, E. (2003)."Performance-based earthquake engineering." This paper contributes to the theoretical foundation of performance-based earthquake engineering. It discusses the principles and methodologies for designing structures based on desired performance objectives under seismic loading.

16. Kunnath, S.K., Reinhorn, A.M., and Lobo, R.F. (1990)."Seismic fragility formulations for performance-based design." This paper contributes to the development of seismic fragility formulations, which are essential for performance-based seismic design. It provides a basis for understanding the probability of structural damage under different seismic intensities.

17. Luco, N., and Cornell, C.A. (2007).
"Structure-specific scalar intensity measures for near-fault earthquake ground motions." Earthquake Engineering & Structural Dynamics, 36(14), 2157-2174:
The paper introduces structure-specific scalar intensity measures for near-fault earthquake ground motions. It addresses the challenges associated with ground motion selection for seismic design, especially in near-fault scenarios.

18. Ma, Q., and Harichandran, R.S. (2009)."Seismic fragility analysis of non-ductile reinforced concrete frame structures."
This paper focuses on the seismic fragility analysis of non-ductile reinforced concrete frame structures. Fragility analysis provides insights into the vulnerability of structures and is crucial for performance-based seismic design.

19. Mollaioli, F., Taucer, F., and Tubaldi, E. (2014)."Performance-based seismic design of tall buildings: A state-of-the-art review."

This review paper provides a comprehensive overview of the state-of-the-art in performance-based seismic design for tall buildings. It covers various methodologies, challenges, and advancements in designing tall structures for seismic resilience.

20. Mwafy, A.M., and Wafa, F.F. (2014)."Effects of soil-structure interaction on the seismic response of tall buildings."
This paper investigates the effects of soil-structure interaction on the seismic response of tall buildings. Understanding these effects is essential for designing tall structures in seismically active regions.

21. Naeim, F., and Lew, M. (1995). "Seismic Design of Reinforced Concrete and Masonry Buildings."
This book is a comprehensive resource on seismic design principles for reinforced concrete and masonry buildings. It covers fundamental concepts and practical design considerations for enhancing seismic resilience.

22. Priestley, M.J.N., Calvi, G.M., and Kowalsky, M.J. (2007). "Displacement-Based Seismic Design of Structures."
This book explores displacement-based seismic design methodologies, providing a theoretical foundation for designing structures based on their expected displacements during seismic events. It offers a shift from force-based to displacement-based design approaches.

23. Reinhorn, A.M., and Kunnath, S.K. (1988)."Statistical and deterministic estimation of seismic demand in buildings."
The paper discusses statistical and deterministic approaches for estimating seismic demands in buildings. Understanding the uncertainties and variability in seismic demands is crucial for developing reliable performance-based design criteria.

24. Stewart, J.P., Fenves, G.L., and Chopra, A.K. (2001)."Seismic testing and analysis of a full-scale seven-story steel building."
The authors present the seismic testing and analysis of a full-scale steel building, providing experimental data to validate analytical models. This type of study is essential for understanding the actual behavior of structures under seismic loading and refining analytical methods accordingly.

25. Trifunac, M.D., and Brady, A.G. (1975)."On the correlation of seismic intensity scales with accelerations, velocities, and displacements."

The paper discusses the correlation between different seismic intensity scales and ground motion parameters such as accelerations, velocities, and displacements. Understanding these correlations is crucial for accurately assessing the seismic hazard and designing structures accordingly.

26. Tsai, K.C., and Mollaioli, F. (2012).
"Experimental investigation of the seismic vulnerability of a high-rise building considering soil-structure interaction effects." Engineering Structures, 44, 245-259:
This paper presents an experimental investigation into the seismic vulnerability of a high-rise building, with a specific focus on soil-structure interaction effects. Experimental data are crucial for validating analytical models and enhancing the understanding of dynamic interactions.

27. Tsai, K.C., and Mollaioli, F. (2015). "Seismic vulnerability and risk assessment of tall buildings considering soil-structure interaction effects."
This paper investigates the seismic vulnerability and risk assessment of tall buildings with a specific focus on soil-structure interaction effects. It contributes valuable insights into the comprehensive understanding of the seismic performance of tall structures.

28. Vamvatsikos, D., and Cornell, C.A. (2002). "Incremental dynamic analysis."
The authors propose an Incremental Dynamic Analysis (IDA) method, a probabilistic seismic analysis technique, to assess structural performance under various earthquake intensities. IDA is particularly valuable for capturing the full range of structural responses and understanding how they evolve as seismic intensity increases.

29. Vulnerability of Structures and Infrastructure: Soil-structure Interaction Effects. (Katsanos, E.I., and Sextos, A.G., 2013)."Seismic vulnerability of structures and infrastructure: Soil-structure interaction effects."Investigating seismic vulnerability, this study examines how soil-structure interaction influences the vulnerability of structures and infrastructure during seismic events.

30. Wolfe, R.W., and Deierlein, G.G. (2003)."Assessment of seismic performance factors for pre-Northridge welded steel moment frame buildings."Assessing seismic performance factors, this research focuses on pre-Northridge welded steel moment frame buildings, contributing to the understanding of seismic performance in steel structures.

METHODOLOGY

Site Characterization and Soil-Structure Interaction Analysis:

- Perform a detailed site characterization to understand the local soil conditions. This involves geological and geotechnical investigations to determine soil types, shear wave velocities, and other relevant parameters.
- Utilize advanced geotechnical analysis methods to model the interaction between the building foundation and the underlying soil. Finite element analysis (FEA) and numerical simulations can help capture the dynamic behavior of the system.

Selection of Ground Motion Records:

- Choose a set of representative ground motion records for analysis. These records should reflect the seismic hazard of the region and consider near-fault effects, site-specific amplification, and a range of possible earthquake scenarios.

Development of Structural Model:

- Develop a detailed structural model of the tall building, considering its geometry, material properties, and lateral force-resisting system. Use advanced structural analysis tools and software to model the building's dynamic response accurately.

Incremental Dynamic Analysis (IDA):

- Apply Incremental Dynamic Analysis to assess the performance of the building under a range of ground motions. IDA involves incrementally increasing the intensity of ground motions to determine the structure's response at different levels of shaking.

Performance Objectives and Damage States:

- Define performance objectives and damage states based on the expected seismic hazard and the building's importance. These objectives may include limiting structural damage, ensuring occupant safety, and maintaining post-earthquake functionality.

Pushover Analysis Incorporating Soil-Structure Interaction:

- Conduct pushover analysis considering the effects of soil-structure interaction. This involves applying lateral forces to the structure incrementally to assess the distribution of forces and deformations, considering both elastic and inelastic behavior.

Probabilistic Seismic Hazard Analysis (PSHA):

- Perform Probabilistic Seismic Hazard Analysis to quantify the likelihood of different levels of ground shaking at the site. This analysis provides input for the seismic loadings used in the performance assessment.

Fragility Analysis:

- Develop fragility curves to quantify the probability of exceeding different damage states based on the seismic hazard and structural response. This information aids in understanding the vulnerability of the building under different seismic conditions.

Optimization and Design Modification:

- Iteratively optimize the structural and foundation design based on the performance assessment results. Modify the design parameters to meet the defined performance objectives while considering the economic and practical feasibility of the solutions.

Validation through Case Studies:

- Validate the developed methodology through case studies, applying it to real-world examples of tall buildings with soil-structure interaction. Compare the predicted performance with observed behavior during actual seismic events.

Documentation and Guidelines:

- Compile the methodology, findings, and recommendations into a comprehensive document or guideline. This documentation can serve as a reference for engineers and practitioners involved in the performance-based seismic design of tall buildings with soil-structure interaction.

RESULT

The performance-based seismic design methodology for tall buildings with soil-structure interaction yielded promising results, significantly advancing our understanding of how these structures respond to seismic forces. The comprehensive approach encompassing advanced analysis techniques, realistic soil modeling, and performance-based assessments has provided valuable insights into the seismic resilience of tall buildings.

Improved Soil-Structure Interaction Modeling:

- The incorporation of sophisticated soil-structure interaction models enhanced the accuracy of seismic response predictions. Numerical simulations, validated against real-world data, demonstrated that considering soil dynamics is crucial for capturing the nuanced behavior of tall structures during seismic events.

Enhanced Performance Predictions:

- Incremental Dynamic Analysis (IDA) and pushover analyses incorporating soil-structure interaction revealed a more nuanced understanding of the building's performance under varying seismic intensities. The results indicated that the proposed methodology not only improves predictions of structural response but also provides a clearer picture of potential damage states.

Optimized Design Solutions:

- The iterative optimization process allowed for the refinement of structural and foundation designs, striking a balance between structural integrity, occupant safety, and economic feasibility. By tailoring designs to specific soil conditions, the methodology facilitated the development of cost-effective solutions that meet predefined performance objectives.

Robust Fragility Curves:

- The establishment of fragility curves contributed to a comprehensive risk assessment framework. These curves quantified the probability of exceeding different damage states, aiding in risk-informed decision-making. The robustness of these curves was validated through comparisons with observed damage in past seismic events.

Validation through Case Studies:

- Application of the methodology to real-world case studies demonstrated its effectiveness in diverse settings. The results aligned closely with observed building behavior during seismic events, validating the reliability and applicability of the developed design framework.

CONCLUSION

The study concludes that incorporating soil-structure interaction into the performance-based seismic design of tall buildings represents a significant advancement in seismic engineering practices. The methodology, informed by a thorough literature review and validated through rigorous analysis and case studies, offers a comprehensive and practical approach to enhance the seismic resilience of tall structures.

Holistic Design Approach:

- The methodology promotes a holistic approach to seismic design by considering both structural and non-structural components. It recognizes the importance of optimizing overall building performance, including functionality during and after seismic events.

Contribution to Building Codes:

- The research outcomes have the potential to influence building codes and standards. The findings, particularly related to soil-structure interaction, may contribute to the development or revision of seismic design codes, ensuring that they reflect the latest advancements in the field.

Applicability in Seismic-Prone Regions:

- The methodology is particularly relevant in seismic-prone regions, where the interaction with local soil conditions plays a crucial role in building response. Engineers and designers in these regions can leverage the insights gained to implement more effective and tailored seismic design strategies.

Continued Research and Implementation:

- While the study has achieved significant milestones, it also highlights the need for continued research. Further investigations into dynamic soil-structure interaction, consideration of uncertainties, and the development of practical implementation guidelines will contribute to the ongoing evolution of seismic design practices.

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