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ENHANCING SEISMIC ANALYSIS OF BRIDGES THROUGH SOIL-STRUCTURE INTERACTION

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Abstract - Seismically isolated bridge structures are widely employed as a crucial measure for mitigating the destructive effects of earthquakes. The effectiveness of these isolation systems relies not only on the properties of the bridge structure but also on the interaction between the structure and the underlying soil. The understanding of soil-structure interaction (SSI) plays a vital role in designing and assessing the performance of seismically isolated bridges. This project aims to investigate the influence of SSI on seismically isolated bridge structures by considering variations in soil types under different ground motion scenarios.

To achieve this objective, the study will employ numerical modelling techniques and advanced analysis tools. First, a comprehensive literature review will be conducted to identify and summarize the key parameters affecting SSI in seismically isolated bridges. These parameters include soil stiffness, damping characteristics, and nonlinear soil behaviour. Subsequently, a numerical model representing a seismically isolated bridge system will be developed, considering different soil types commonly encountered in bridge engineering, such as sandy soil, clayey soil, and layered soil profiles.

isolated bridge structures, facilitating the development of more accurate design guidelines and improved assessment methodologies.

Key Words: Soil-structure interaction, Ground motions, Numerical modelling, Dynamic response

1.INTRODUCTION

Bridges serve as essential components of modern infrastructure, connecting communities, facilitating trade, and enabling efficient transportation. However, these critical structures are vulnerable to seismic hazards, posing a substantial risk to their integrity and functionality. To ensure the resilience and safety of bridges in regions prone to earthquakes, it is imperative to employ advanced engineering techniques that consider the intricate interplay between the bridge's superstructure and the underlying soil. This intricate interaction, known as Soil-Structure Interaction (SSI), is pivotal in determining the bridge's response to seismic forces and warrants comprehensive exploration and understanding.

Historically, seismic analysis of bridges has predominantly centered on the bridge's superstructure, often neglecting the influence of the surrounding soil. However, recent advancements in structural engineering and geotechnical research underscore the significance of incorporating SSI effects into seismic analysis. By accounting for the dynamic interaction between the bridge and the supporting soil, engineers can develop more precise models that reflect the realistic behavior of bridges during seismic events. This approach enables the enhancement of seismic analysis and the formulation of more resilient bridge designs capable of withstanding severe seismic disturbances.

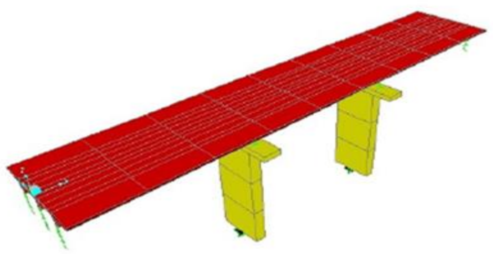
This paper aims to delve into the pivotal role of Soil-Structure Interaction in elevating the seismic analysis of bridges. It will scrutinize various factors that impact this interaction, encompassing soil characteristics, bridge design attributes, and seismic ground motion characteristics. Additionally, this paper will illuminate the advantages stemming from the inclusion of SSI in bridge analysis, including heightened accuracy in predicting structural responses, improved comprehension of load transfer mechanisms, and the potential for optimizing bridge design and retrofitting strategies.

The discussion will also encompass cutting-edge computational tools and modeling techniques that have emerged in recent years to faithfully simulate SSI. These tools empower engineers to conduct more sophisticated seismic analyses that consider not only the dynamic response of the bridge superstructure but also the underlying soil, empowering them to make well-informed decisions regarding bridge design, retrofitting, and maintenance.

2. Body of Paper

The existing bridge, situated in Beed along National Highway No. 211, spans over the Bindusara River. This bridge boasts dimensions of 42 meters in length and 7.95 meters in width, featuring a structure comprised of three continuous reinforced concrete girders. The superstructure, on the other hand, is constructed with a 300 mm deep reinforced concrete deck slab, which is supported by the three reinforced concrete girders, each with a depth of 1100 mm. The bridge's solid piers, measuring 4.0 meters in width and 1.0 meter in thickness, rest securely on a stable soil stratum. In the bridge modeling process, the deck is represented using thin shell elements, while the girders and piers are modeled as frame elements. For further accuracy, elastomeric bearings are modeled as linear-type links, and elastomeric isolators are represented as rubber isolator-type link elements.

Figure 1 illustrates the bridge model analyzed using CSI bridge.



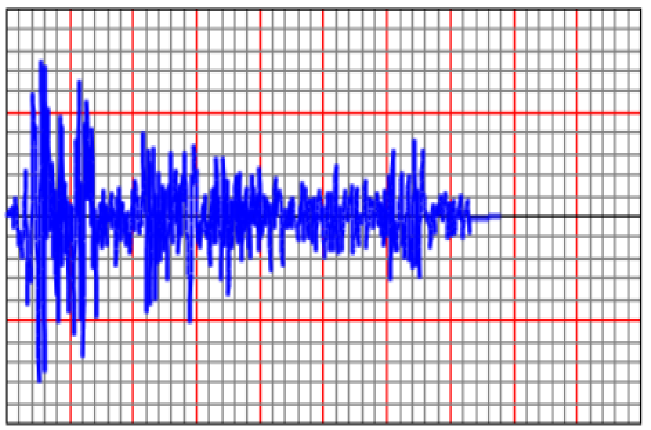
In the present study, our initial focus centers on modeling and analyzing the first bridge employing conventional elastomeric bridge bearings. Subsequently, we gather and examine the results obtained from this analysis. Following this, we undertake a pivotal step by substituting these conventional elastomeric bearings with elastomeric isolation bearings, conducting a comprehensive analysis, and subsequently comparing the results.

The fundamental distinction between conventional elastomeric bearings and elastomeric isolation bearings lies in their horizontal flexibility, with the latter being notably more flexible in the horizontal direction while maintaining the same vertical stiffness. This increased horizontal flexibility, combined with specific damping characteristics, serves as the foundation for achieving the desired isolation effects within the system.

The enhanced horizontal flexibility of the elastomeric isolation bearings acts as a mechanism that restricts the transmission of substantial earthquake forces from the piers to the superstructure. Conversely, the damping properties of these bearings play a crucial role in dissipating seismic energy, thereby effectively reducing the overall design displacement experienced by the bridge.

2. Methedology

This project employs a comprehensive methodology to investigate the effects of soil-structure interaction on the seismic response of bridges. Beginning with an in-depth literature review, the study establishes a foundation by examining existing theories and methodologies in this field. Clear objectives are then defined to address specific aspects, including the impact of different soil types, bridge configurations, and seismic loading conditions. Representative bridge models are carefully selected, encompassing various types, materials, and geometries to ensure the study's applicability to real-world scenarios. Soil characterization involves rigorous testing to determine key properties such as shear modulus and damping ratio, essential for accurate modeling. Advanced numerical simulations, utilizing finite element analysis software, are employed to model the selected bridges and simulate their behavior under seismic loading, with a particular emphasis on incorporating realistic soil-structure interaction effects. Parametric studies explore the sensitivity of the system to variations in soil stiffness, foundation type, and bridge geometry. Complementing these simulations, scaled physical models of the bridges undergo experimental testing, providing validation and capturing insights that may elude numerical analyses alone.



Time (sec) v/s acceleration graph

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3.RESULTS AND DISCUSSION

After performing time history analysis of bridge, seismic response of bridge is scrutinized and compiled results are presented in following

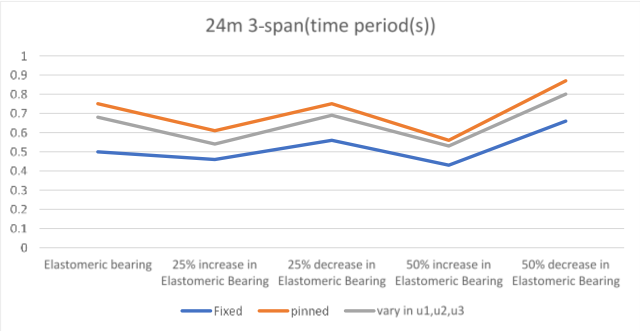

TABLE 3: Results of TIME PERIOD

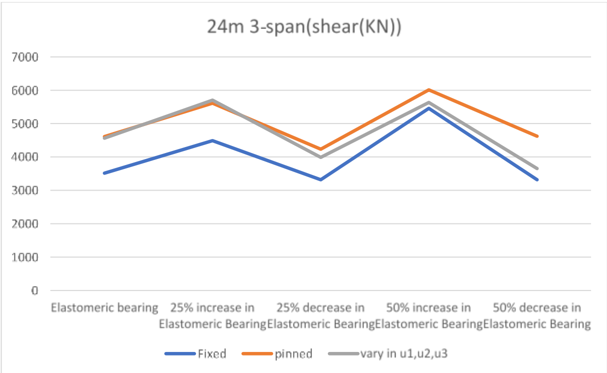

TABLE 4: Results of SHEAR

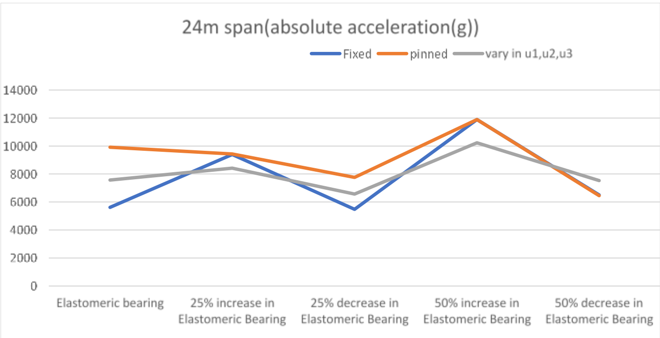

TABLE 5: Results of ABSOLUTE ACCELERATION

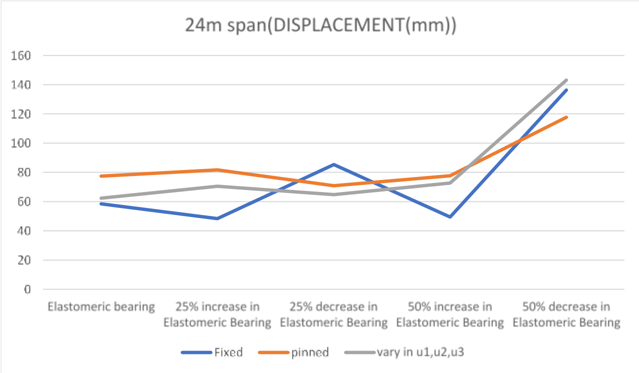

TABLE 6: Results of DISPLACEMENT

In above Table Significant increase in fundamental time period,acceleration and shear while decrease in the displacements is observed due to horizontal flexibility of elastomeric isolator and resultant change in seismic response is reduction in absolute acceleration of deck and base shear in pier values.

3. CONCLUSIONS

The investigation into the effects of soil-structure interaction on the seismic response of bridges has provided valuable insights into the dynamic behavior of these structures under earthquake loading. Through a combination of numerical simulations and experimental testing of scaled models, the project has shed light on the significance of considering soil-structure interaction in seismic design.

The results highlight the intricate relationship between the bridge and underlying soil conditions, emphasizing the need for accurate modeling in seismic analysis. The observed effects on structural response and performance underscore the importance of incorporating soil-structure interaction considerations in the design process. The findings contribute to advancing our understanding of bridge behavior during earthquakes and have implications for the development of more robust and reliable seismic design codes for bridges.

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