

UNIVERSITI TEKNOLOGI MARA

**DYNAMIC CHARACTERIZATION
AND OPTIMIZATION OF POT
BEARINGS IN BRIDGES USING
FINITE ELEMENT ANALYSIS**

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ABSTRACT

Bridge bearings are crucial components of the overall bridge structure. Among all the bearings used for bridges, pot bearings are a commonly used type of bridge bearing. Pot bearings support the bridge superstructure and allow it to move independently of the supporting elements, such as piers and abutments. Investigating the dynamic behavior of pot bearings is challenging due to the complexity of the bearing, which consists of several materials. It requires advanced modeling techniques that are typically expertise demanding, time consuming, and often proprietary to manufacturers. Therefore, this research aims to determine the dynamic properties of pot bearings, optimize their finite element (FE) models, and develop a reliable framework for assessing and enhancing the dynamic behavior of pot bearings under harmonic loading in bridge system. Experimental and FE modal analysis were employed to extract dynamic properties, while response surface method (RSM) and direct method optimization were used to refine material parameters, ensuring close agreement between numerical and experimental results. The optimized pot bearing model was subsequently integrated into harmonic response simulations to evaluate the bridge system's dynamic performance using FE analysis. From the modal analysis, discrepancies between the FE and experimental results were identified, with relative errors of up to 43.9% observed in the natural frequencies, necessitating model refinement. Despite these discrepancies, the mode shapes exhibited good agreement between the two methods. To address these errors, the pot bearings were updated and optimized to achieve the best FE model that closely aligns with experimental results. Design parameters such as Young's Modulus and Poisson's Ratio were systematically adjusted to minimize discrepancies between FE and experimental results. The RSM approach outperformed the direct method, achieving significantly reduced relative errors. The total relative error was reduced from 43.9% to 8.42% using RSM, compared to 11.16% with the direct method. The optimized pot bearing model obtained through RSM was then used to evaluate its performance in a bridge application under harmonic loading conditions. The results showed that the bridge equipped with optimized pot bearings exhibited improved performance, with significantly reduced displacement at the bridge mid span compared to the bridge with non-optimized pot bearings. For all modes, the maximum deformation of the optimized bridge system was reduced by up to 17% compared to the non-optimized bearings. In conclusion, this study highlights the critical role of pot bearing optimization in improving the dynamic performance of bridge structures. A reliable framework for assessing and enhancing the dynamic behavior of pot bearings under harmonic loading was successfully developed through the integration of numerical simulations, experimental validation, and advanced optimization techniques. This framework provides a robust and efficient approach for accurately modeling and evaluating pot bearing performance, contributing to safer and more resilient bridge systems.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Bridge infrastructure is a critical component of national development, facilitating economic growth, regional connectivity, and public mobility (Kaiser & Barstow, 2022). A considerable number of bridges constructed during the rapid infrastructure expansion of past decades are now approaching or exceeding their intended service life (Omar & Nehdi, 2018; Jiang et al., 2023). The deterioration of key structural components, particularly bridge bearings, poses significant safety risks and challenges to long term maintenance (Razak & Ng, 1998; Chang, 2009).

Bridge bearings are essential elements that transfer loads between the bridge superstructure and substructure while allowing controlled movement. Among various types of bearings, pot bearings are extensively used in bridges due to their ability to support high vertical loads and accommodate rotational and translational movements (Shiau et al., 2008; R Arunkiliyal et al., 2017). These bearings typically consist of confined elastomeric pads within a steel pot and sliding surfaces, allowing relative movement between the superstructure and substructure. However, the functional lifespan of pot bearings is considerably shorter than that of the bridge, making them more prone to wear, damage, and performance degradation under dynamic loads such as heavy traffic, seismic vibrations, and wind actions (Wang et al., 2020).

The significance of pot bearings has driven researchers to study their behavior and improve their design. A thorough understanding of isolator characteristics is essential for designing effective base isolation systems (Kelly, 1997). Recent research has focused extensively on the foundations, superstructures, and substructures of bridges (Melcer & Valašková, 2022; Velniciuc & Bujoreanu, 2023; Mansour et al., 2024). However, despite the critical role of bearings and their potential to contribute to the collapse of entire bridges or structural systems, comprehensive research particularly in the area of simulation and modeling of bearing behavior remains limited (Jabbareh Asl et al., 2014).

Simulation becomes crucial in such complex and unpredictable real world problems. It allows engineers to learn about system behavior without direct physical