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Dynamic Analysis of Bridge using Techniques of FEM

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Abstract- This research focuses on the free vibration analysis of bridges utilizing the powerful Finite Element Analysis (FEA) simulation software, ANSYS. Bridges play a critical role in transportation infrastructure, and understanding their dynamic behavior under free vibrations is essential for ensuring structural integrity and safety. The study employs ANSYS to model and simulate the vibrational response of a bridge structure subjected to natural excitations, such as wind or seismic events. The investigation aims to characterize the fundamental modes of vibration, eigen frequencies, and mode shapes of the bridge, providing valuable insights into its dynamic behavior. The results obtained from the ANSYS simulations contribute to optimizing bridge design, enhancing resilience against dynamic forces, and ultimately advancing the field of structural engineering. This research underscores the significance of FEA simulations in comprehensively assessing the dynamic performance of bridges, with potential applications in improving structural design practices and ensuring the longevity and safety of these critical infrastructure elements.

Keywords- Bridge, structural analysis, damage

I. INTRODUCTION

A bridge is a carefully designed structure that is built to connect two points, such as a road, a ravine, or a body of water, while allowing for uninterrupted passage underneath. The main goal of this undertaking is to ensure the successful overcoming of an obstacle. It is likely that the first bridges constructed by Homo sapiens used a basic design consisting of support and cross beams. It is likely that these bridges were first built using sliced hardwood timbers or logs, but later on, stones were also used [1]. The Romans were pioneers in the use of arches for bridge construction. Cement was used to address the structural integrity issues found in different parts of the stone bridge. Different bridge designs were used to match the specific purpose of each bridge. Various factors, such as the bridge's topography, composition, and financial constraints, were considered during the development of these designs.

II. LITERATURE REVIEW

The researchers Jeong-Tae Kim et al. [1] studied the detection of deterioration in bridge structures using vibration response monitoring. A thorough analysis was conducted to assess the exact position, extent, and effects of the damage caused by temperature, with the vibration level as the basis for evaluation.

A study conducted by Brownjohn et al. [2] examined the vibration analysis of the Humber Bridge in Hong Kong. The damage was detected using various advanced techniques [2]. The research findings have shown that these systems are viable for fracture detection and monitoring.

The study conducted by Whelan et al. [3] centered on the surveillance of bridge structural health. Health monitoring systems use sensors to detect fractures. The study concluded that utilizing stochastic SSI subspace identification techniques to estimate modal parameters solely from output experimental data is more favorable compared to the frequency domain decomposition (FDD) method. However, it is important to note that this approach requires additional computational effort and involves subjectivity in identifying the system poles.

The study conducted by Wardhana and Hadipriono et al. [4] focused on analyzing the susceptibility of bridges to various operational and environmental factors. The analysis primarily focuses on environmental concerns, erosion, and corrosion. Additionally, it considers overburden as one of the operational variables. A significant number of incidents, accounting for 73% of the total, were caused by overburden. This factor played a major role in the failure of bridges, as indicated by the data.

Objectives

The objective of current research is to investigate the vibration characteristics of bridge structure using different materials. The modal analysis of bridge structure is conducted using ANSYS simulation package. The materials investigated in the research is concrete material, silicone rubber and neoprene rubber. The mode shapes, natural frequency and mass participation factor is evaluated for different bridge materials.

III. METHODOLOGY

In order to ascertain the natural frequency and mode shape for the first, second, and third natural frequencies, a FEA model study is performed on the bridge structure. There are several steps to the analysis.

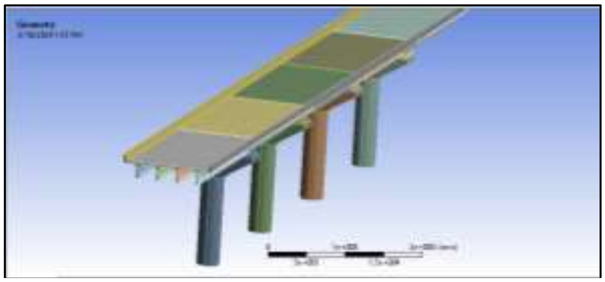

Figure 1: Imported model of bridge structure

The bridge construction is designed in accordance with the figure 1 schematic. We examine the bridge structural model for surface patches and geometric flaws.

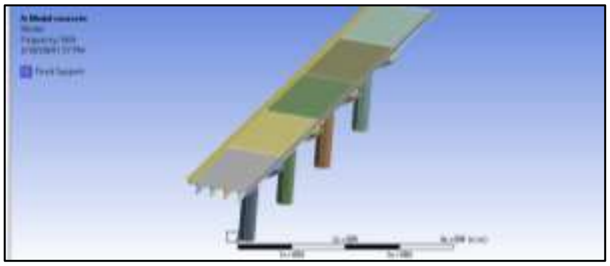

Figure 2: Loads and boundary condition for modal analysis

The structure is subjected to the boundary conditions in order to perform modal analysis. The base of the construction is applied with fixed support under modal analysis.

A sparse matrix solver is used to execute the FEA simulation, and many iterations are performed.

IV. RESULT & DISCUSSION

The mass participation factor, natural frequency, and mode shape for silicone rubber, neoprene rubber, and concrete are determined from the FEA study.

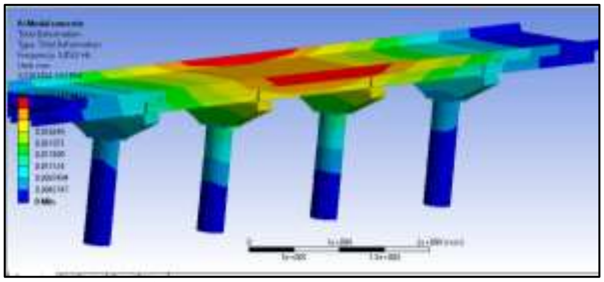

Figure 3: 1st frequency mode shape for concrete

The bridge crash barrier zone, where the magnitude of deformation is.034mm, is where the highest deformation is seen for bridge decks made of concrete and the first natural frequency mode shape.

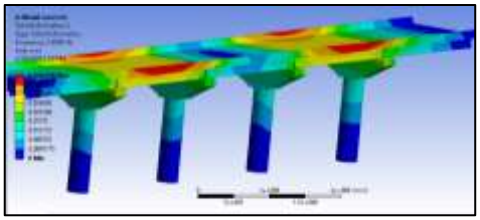

Figure 4: 2nd frequency mode shape for concrete

The bridge crash barrier zone exhibits the highest deformation, with a magnitude of.031mm, for bridge decks made of concrete material and the second natural frequency mode shape.

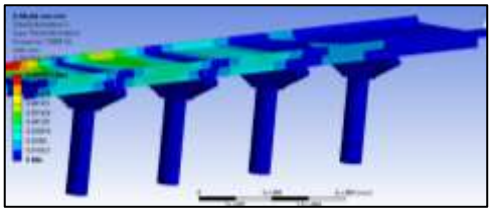

Figure 5: 3rd frequency mode shape for concrete

The greatest deformation of a bridge deck made of concrete with a third natural frequency mode shape is measured in the bridge crash barrier zone, where the magnitude of deformation is.084mm.

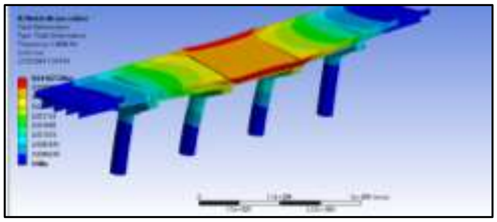

Figure 6: 1st frequency mode shape for silicone rubber

The bridge crash barrier zone exhibits the most deformation, with a magnitude of.038mm, for bridge decks made of silicone rubber and the first natural frequency mode shape.

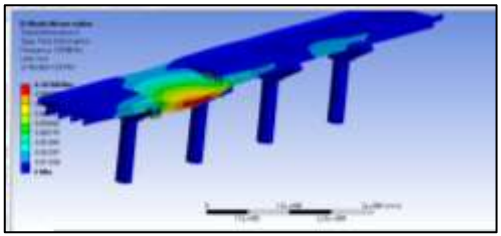

Figure 7: 2nd frequency mode shape for silicone rubber

The bridge crash barrier zone, where the magnitude of deformation is.98mm, is where the largest deformation is recorded for bridge decks made of silicone rubber and the second natural frequency mode shape.

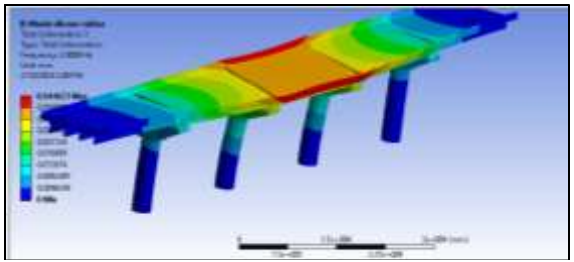

Figure 8: 3rd frequency mode shape for silicone rubber

The bridge crash barrier zone, where the magnitude of deformation is.040mm, is where the largest deformation is recorded for bridge decks made of silicone rubber and the third natural frequency mode shape.

III. CONCLUSION

Using finite element analysis (FEA) to evaluate the vibration properties of bridge structures is a highly advantageous pursuit. An analysis technique called modal analysis is used to evaluate the mode shapes and natural frequencies of the bridge, which is made up of silicone rubber, neoprene rubber, and concrete. Mode analysis is a procedure that identifies the key areas experiencing significant deformation.

Based on the analysis of the concrete material, it was found that the impact barrier was the critical area. This area experienced the highest deformation and was susceptible to amplitude accumulation during resonance.

Based on the modal analysis of the silicone rubber material, it was found that the collision barrier was the most critical area. This area experienced the highest deformation and was susceptible to amplitude accumulation during resonance.

The modal analysis reveals that the neoprene rubber material undergoes significant deformation in the bearing zone, while the impact barrier and bridge structure experience only minimal distortion.

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