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Structural Stability Analysis of Bridge Structure Using FEA

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ABSTRACT- In the current research, the dynamic analysis of bridge structure is conducted to determine the natural frequency and mode shape. The dynamic analysis is conducted using ANSYS FEA simulation package. The critical regions of high deformation and energy states are determined. The analysis revealed the presence of several dominant vibration modes, each associated with distinct deformation patterns and nodal patterns. These findings shed light on potential vulnerability zones and areas of concern that may be susceptible to resonance and excessive vibrations during bridge operation. Understanding these critical modes is vital for designing appropriate damping and vibration control measures to ensure the bridge's long-term stability and safety.

KEYWORDS- Bridge, modal, vibration, FEA, ANSYS FEA

I. INTRODUCTION

The primary objective of a bridge is to effectively transfer vertical forces, whether they are concentrated or distributed, in a controlled manner. Bridges are structures characterized by their elongated form, supported by two abutments or piers. The two supports responsible for providing structural stability to the wooden components of the sample bridge exhibit a straightforward design. The support must possess sufficient strength to effectively sustain the structure. In general, it is recommended to minimize the length of gaps. However, under certain circumstances where a valid justification exists, it may be acceptable to have a longer duration for a gap.

Figure 1: Bridge Structure [1]

Bridges are an integral component of contemporary road infrastructure. The bridge design is shown in figure 1. However, individuals may not universally perceive or interpret them in a consistent manner. Bridges are constructed using a variety of materials, resulting in different types of bridge structures. The majority of individuals who traverse this bridge during their commute or other travels are often unaware of its existence. The individuals direct their gaze towards the roadblock situated on the opposite side. The initial bridge construction proved to be relatively straightforward due to its utilization of stepping stones.

II. LITERATURE REVIEW

Jerome F. Hajjar et al [1] this research provides a concise summary of the key findings from a field test conducted in Duluth, Minnesota. The test involved subjecting a hybrid steel I-girder bridge with multiple spans and a horizontal bend to a significant live load. This study involved the utilization of eight 320KN cars on the bridge, which were subjected to a total of 43 steady loading scenarios and 13 dynamic loading scenarios. Subsequently, the ultimate data were juxtaposed with those obtained from a study on linear elastic grillage. The comparison between the results obtained from the field tests and the grillage computer model is conducted to assess the bridge's structural response under significant stress conditions. A total of thirteen dynamic tests were conducted on a two-girder, five-span continuous horizontally bent composite steel structure. These tests involved the application of a cumulative load of 320kN, distributed among eight cars. The field study revealed dynamic effect factors that exceeded the values specified in the code.

Edward et al. [2] the study involved a comparison between predicted values derived from Canadian highway bridges and distribution factors directly determined for the overall bridge model. According to design standards, it has been determined that the code numbers assigned to the elastic and inelastic states are lower by 22% and 33% respectively, when compared to the appropriate values for the highest moment in an interior-loaded frame. The present release provides a comprehensive overview of the findings obtained upon the conclusion of the study. The deflection of the beam gradually increases under load, with the exception of when it is being unloaded close to its maximum capacity. The three girders appeared nearly identical at any location along the bridge. Evidence suggests that a plastic hinge materialised at the midpoint of each of the three girders, coinciding with the final load. The moment of the loaded frame was determined using the CSA guidelines. The CSA S6 standard provides numerical values and cautionary statements regarding the load capacity or estimated moment that a loaded frame can support.

Zhuet. al. [3] the CSi Bridge Design tool is utilized to compare the design and analysis of single-cell and four-cell post-tensioned box girder bridges with IRC and AASHTO Loading. Through a comparative analysis of the outcomes generated by the fundamental operations of this programme, one can ascertain the optimal course of action. The design technique and detailed study of single- and four-cell box girders in relation to IRC and AASHTO loads can also be acquired. The implementation of the CSi Bridge software resulted in a reduction in the number of cables, the magnitude of force required to tension the cables, and the depth of the beam. After analyzing the data, it can be concluded that the single-cell prestressed concrete beam is the optimal and economically efficient choice for the double-lane Indian national. The safety code of the IRC does not provide a higher level of safety compared to the AASHTO code. Upon comparing the IRC and AASHTO codes, it becomes evident that the AASHTO numbers offer a higher degree of cost-effectiveness.

Neut et al. [4] the concept of steel concrete buildings is a widely used construction method in the industry. This approach combines the strength and durability of steel with the versatility and stability of concrete. Steel concrete buildings are designed to withstand various environmental conditions and provide long-lasting structural integrity. The construction of I-girder bridges employ a two-stage optimization approach for enhancing and refining the finite element model's design. The initial stage of the refining process involves the utilization of five widely recognized metaheuristic methods. There exist three distinct search algorithms, namely the backtracking search algorithm (BSA), the search group algorithm (SGA), and the imperialism competitive algorithm (ICA). The selection of the optimal method in the study was determined through the evaluation of five contemporary optimization algorithms, taking into account the knowledge gained from this assessment.

Víctor et. al. [5] this study examines the load-carrying capacity of prestressed concrete box girders based on the standards set by the Indian Road Congress (IRC:6) and the Code of Practice for Concrete Bridges (IRC:1/2). It adds to existing research on this topic. The study of box girder bridges involved the utilization of CSI Bridge Wizard. After careful consideration, it was determined that the inactive load, shear force, and bending moment exhibited significantly greater magnitudes compared to the remaining loads. Based on the findings of the live traffic study, it is deemed more crucial to prioritize the presence of a single lane of IRC 70R and class A, as opposed to three lanes solely consisting of class A. Upon conducting tests, it has been determined that the displacement resulting from various loads, also known as loading conditions, remains comfortably within the limits specified by the International Residential Code (IRC). The observation reveals that the maximum deflection of the beam occurs primarily in the vertical direction, specifically in the vicinity of the midpoint of the span.

Galamboset al [6] this study provides a comprehensive analysis of the impact of various factors on the free vibration response of bent composite-steel girder bridges, elucidating the nature of these factors. The mode forms and their corresponding basic frequencies can be determined through a comprehensive parametric analysis. Throughout the entire study, a total of 336 bridges, encompassing both straight and bent structures, were utilized. The ABAQUS software is utilized for conducting computer simulations of structures under analysis to determine their fundamental frequencies. An increase in the curve ratio or spread results in a decrease in the basic frequency. The quantity of girders and the spacing between them have a relatively minimal impact on the fundamental frequency. However, it is generally observed that the fundamental frequency tends to decrease as the distance between girders increases and the number of girders in the structure increases. Increasing the number of girders will result in an eventual increase in both the basic frequency and the span-to-curvature ratio.

Prajwal et. al. [7] this study aims to compare the performance of AASHTO and IRC standards when subjected to significant loads on single-cell and four-cell beams during the construction of a bridge's framework. The IRC category AA is utilized to define the structural load composition for box girders. The AASHTO code is subsequently implemented. The AASHTO code is preferred over the IRC code due to its enhanced safety features. As the depth of the beam decreases, the pretensioning force and the number of wires also decrease. It is indisputable that the AASHTO code offers a more cost-effective solution compared to the IRC.

III. OBJECTIVES

In the current research, the dynamic analysis of bridge structure is conducted to determine the natural frequency and mode shape. The dynamic analysis is conducted using ANSYS FEA simulation package. The critical regions of high deformation and energy states are determined.

IV. METHODOLOGY

The methodology for vibration analysis involves different steps i.e. modelling, meshing, applying structural boundary conditions and running simulation. The CAD design of bridge structure is shown in figure 2.

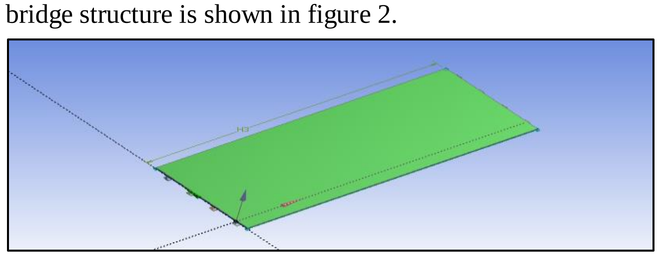

Figure 2: CAD Model of Bridge Structure

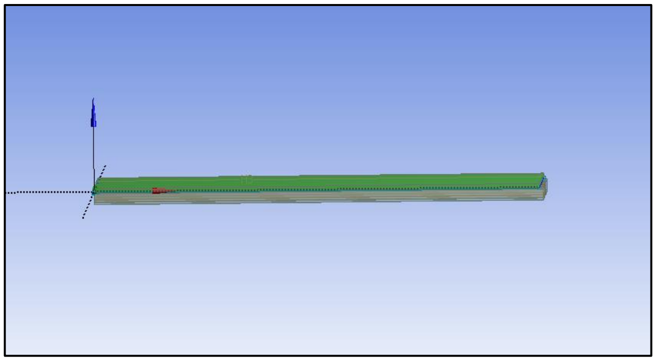

Figure 3: Front View Design of Bridge Structure

The modelling process involves sketching and extruding. The sketch is developed of rectangular shape along with girder cross section. The developed model of bridge structure is shown in figure 3.

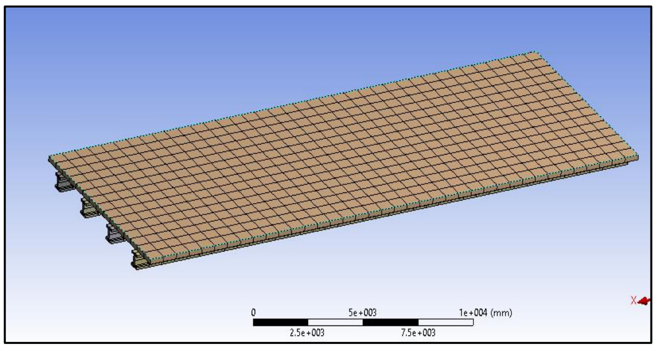

Figure 4: Meshed Model of Bridge Structure

After modelling, the model is discretized wherein the CAD design is converted in to elements and nodes as shown in figure 4. The meshing is non uniform type with hexahedral element shape combined with tetrahedral element type.

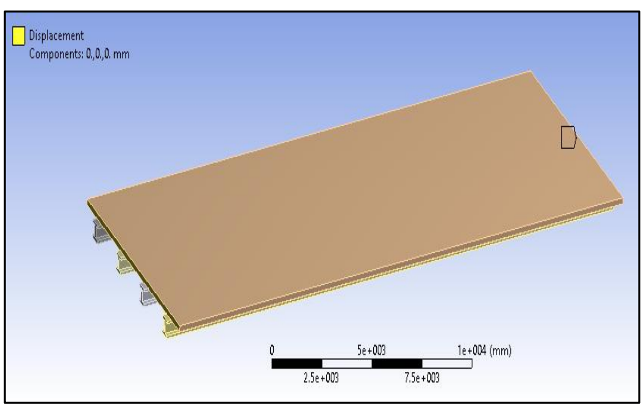

Figure 5: Structural Boundary Conditions

After meshing, the structural boundary conditions are defined which include application of fixed support at both the ends of the bridge structure and no external loads are applied as shown in figure 5. The solver settings are defined to determine natural frequencies.

V. RESULTS AND DISCUSSION

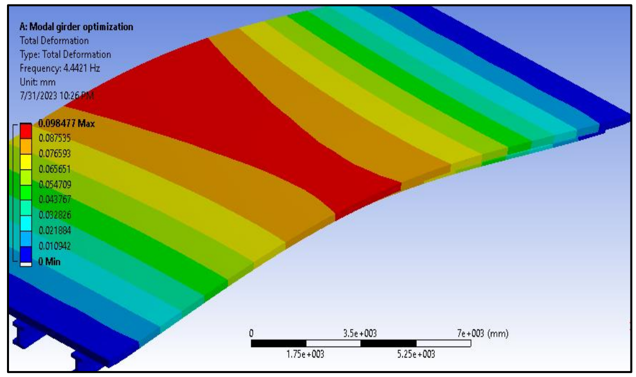

Figure 6: 1st Natural Frequency

In the 1st mode of vibration, the energy is higher and maximum deformation is obtained along the vertical direction as shown in figure 6.

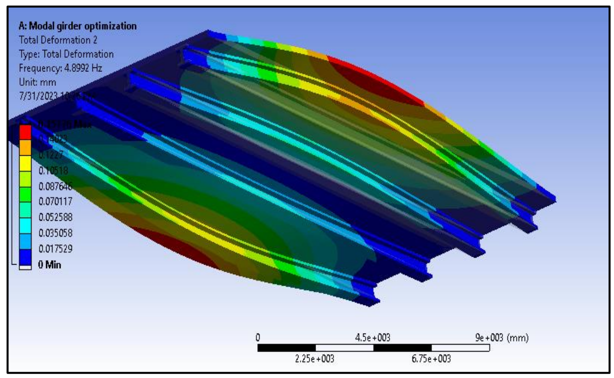

Figure 7: 2nd Natural Frequency

In the 2nd mode of vibration, the energy is higher and maximum deformation is obtained along the torsional direction as shown in figure 7.

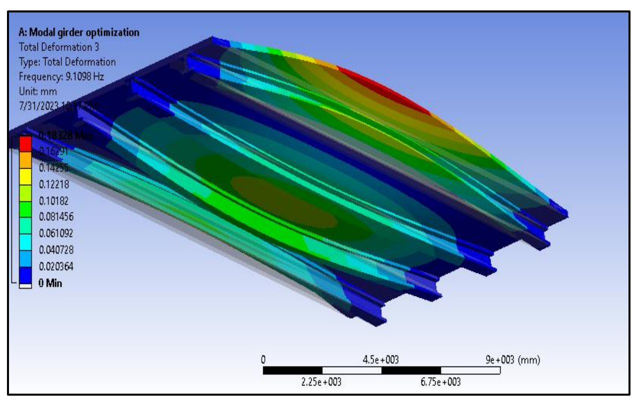

Figure 8: 3rd Natural Frequency

In the 3rd mode of vibration, the energy is higher and maximum deformation is obtained along the torsional direction as shown in figure 8.

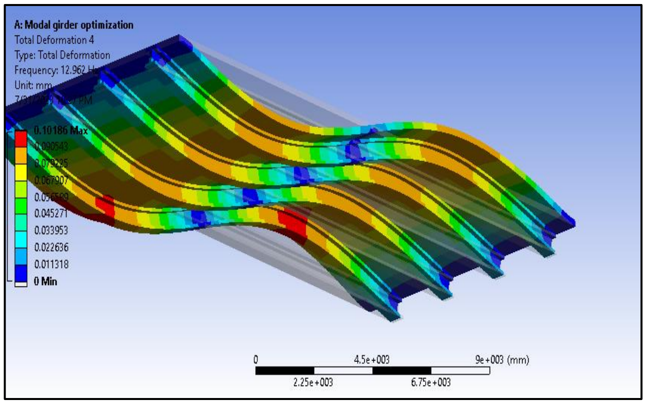

Figure 9: 4th Natural Frequency

In the 4th mode of vibration, the energy is higher and maximum deformation is obtained along the torsional direction. The maximum deformation is obtained at various regions as represented in red coloured region. These regions are susceptible to damage as shown in figure 9.

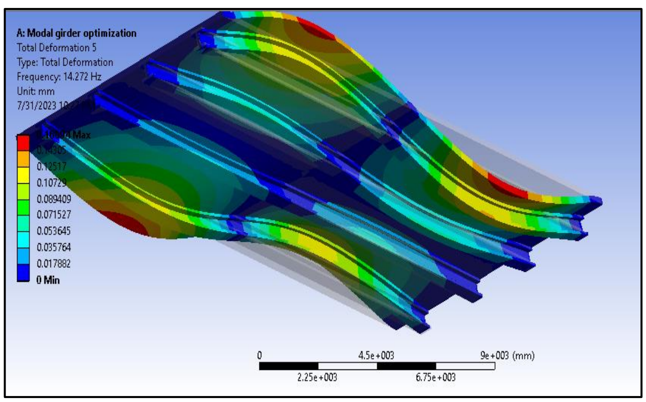

Figure 10: 5th Natural Frequency

In the 5th mode of vibration, the energy is higher and maximum deformation is obtained along the torsional direction. The maximum deformation is obtained at various regions as represented in red coloured region as shown in figure 10.

VI. CONCLUSION

The modal analysis conducted on the I-shaped girder bridge structure has provided valuable insights into its dynamic behavior and vibration characteristics. Through this study, we have successfully identified the natural frequencies and corresponding mode shapes of the bridge, which are crucial in understanding its structural integrity and performance under various loading conditions. The analysis revealed the presence of several dominant vibration modes, each associated with distinct deformation patterns and nodal patterns. These findings shed light on potential vulnerability zones and areas of concern that may be susceptible to resonance and excessive vibrations during bridge operation. Understanding these critical modes is vital for designing appropriate damping and vibration control measures to ensure the bridge's long-term stability and safety.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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