Static Structural Analysis of a Bridge

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ABSTRACT

Pedestrian bridges represent critical components of urban infrastructure, facilitating safe and efficient movement for pedestrians while alleviating traffic congestion. This abstract provides an overview of a rigorous static structural analysis performed on a pedestrian bridge, with a primary focus on evaluating its stability and strength under various static loading conditions. The investigation employs state-of-the-art engineering methodologies, including finite element analysis (FEA), structural modelling, and material characterization, to comprehensively assess the structural performance of the bridge.

Keywords: Finite Element Analysis (FEA), Static structural analysis, urban infrastructure.

I. INTRODUCTION

Pedestrian bridges play a pivotal role in urban infrastructure, alleviating traffic congestion and fostering safe and sustainable urban environments. These elevated walkways facilitate pedestrian movement over roads, railways, and other obstacles, contributing to reduced pollution and improved mobility. To ensure their long-term safety and usability, a thorough static structural analysis is essential.

Static structural analysis assesses a pedestrian bridge's stability and strength under various static loads, including pedestrian traffic, dead loads, and environmental forces such as wind and temperature effects. This evaluation relies on advanced engineering techniques, including finite element analysis (FEA), structural modelling, and material characterization.

FEA enables engineers to simulate real-world conditions and predict potential stress concentrations, identifying areas prone to deformation or failure. Consequently, this analysis optimizes bridge design, construction, and maintenance, aligning with urban planning goals to create safer and more resilient pedestrian environments.

In the following discussion, we will delve into the components and methodologies involved in static structural analysis, emphasizing its crucial role in enhancing the performance and longevity of pedestrian bridges in urban landscapes.

II. LITERATURE REVIEW

Research Paper1: The paper proposes a multi-level strategy to enhance load-carrying capacity predictions of concrete bridges. Initial estimates on a tested prestressed concrete girder bridge were often 25%-78% of failure load due to misjudged shear failure. Nonlinear finite element analysis significantly improved accuracy (within 4% deviation), demonstrating the strategy's efficacy while emphasizing the need for guidelines and bridge-specific data.

Research Paper2: The paper presents a numerical solver coupling structural analysis and fluid dynamics to simulate bridge failures, addressing the challenge of hydrodynamics-soil-structure interactions. It introduces advanced sediment stress models validated against field data, enabling accurate analysis of intricate interactions in extreme hydrological scenarios.

Research Paper3: This study employs Finite Element Method (FEM) for Transient Structural Health Monitoring (SHM) of intact and damaged test bridges with similar physical characteristics. Analysis of non-linear behaviour changes due to various loading conditions, including parameters like stresses, deformation, and strain, offers insights into structural condition monitoring. This approach allows simulation of real-world bridge behaviour for enhanced safety assessment.

Research Paper4: The Paderno Bridge, a vital arch-bridge spanning the Adda River in northern Italy, links Milan and Bergamo provinces since 1889. A comprehensive method is outlined for evaluating the condition of deteriorated historical steel bridges. Through analytical, mechanical, and structural evaluations, critical areas of concern are identified via finite-element analysis. Fatigue reliability assessment and traffic predictions suggest potential service extension of 10 years, with retrofitting recommendations highlighted.

Research Paper5: This paper introduces an innovative finite element (FE) model within ANSYS for assessing coupled flutter in lengthy bridges. Employing a user-defined Matrix27 element, aero elastic forces are simulated with wind effects using reduced wind velocity and flutter derivatives. The model facilitates damped complex eigenvalue analysis to identify decay rates and damped vibration frequencies. Validated through case studies, the approach empowers engineers to analyse flutter instability in cable-supported bridges using ANSYS.

These research papers have significantly aided our project by providing valuable insights and methodologies, ultimately contributing to the attainment of our desired results.

III. NUMERICAL MODEL

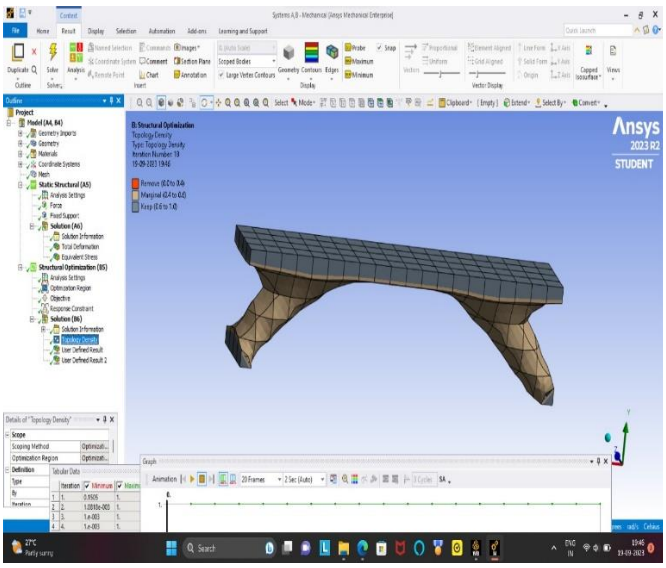

Figure 1: Model of the Bridge

III. Methodology

Geometry Preparation:

1. Launch ANSYS and access Design Modeller: Start ANSYS and open the Design Modeller, which is a tool for creating and modifying geometry.

2. Create a rectangle on the XY plane representing the bridge section: In Design Modeller, draw a rectangle on the XY plane. This rectangle should represent the cross-section of your bridge.

3. Define dimensions of the bridge section: Specify the dimensions (length, width, and height) of your bridge section within the software. Ensure that these dimensions accurately reflect the physical properties of your bridge.

4. Extrude the rectangle to create the 3D bridge model: Use the extrusion tool to extend your 2D rectangle into a 3D model that represents the entire bridge structure. This will give your model thickness and depth.

Mesh Generation:

1. Enter the Modelling environment: Transition from Design Modeller to the modelling environment within ANSYS where you can work with the mesh.

2. Generate a mesh for the bridge model using the generated geometry: Create a mesh over the 3D bridge model. Meshing divides the model into smaller elements to facilitate analysis. You can use various meshing methods such as tetrahedral, hexahedral, or other elements depending on your requirements.

3. Set an element size for the mesh (e.g., 0.01 units): Specify the size of the finite elements used in the mesh. This value can affect the accuracy and computational requirements of your analysis. Smaller elements generally provide more accurate results but require more computational resources.

4. Update and refine the mesh as needed for accuracy: Inspect and refine the mesh to ensure it adequately represents the bridge's geometry. You may need to adjust the mesh density in critical areas to capture stress concentrations or other important details.

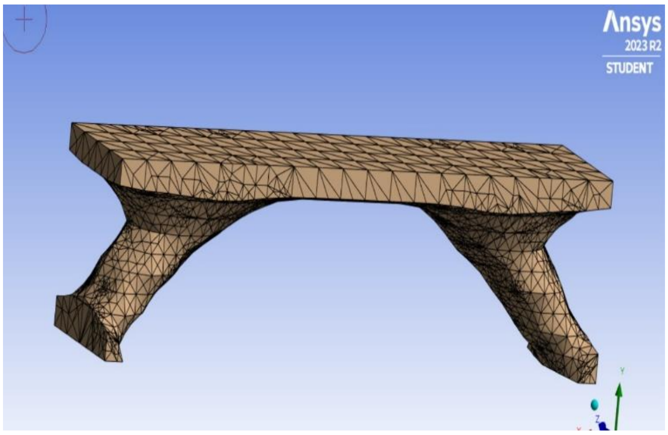

Figure 2: Mesh Generation

Boundary Conditions:

1. Navigate to the Static Structural analysis: Transition to the Static Structural analysis environment within ANSYS, where you will define and apply boundary conditions and loads.

2. Apply fixed supports to appropriate locations of the bridge model and apply external forces: Specify the locations where the bridge is anchored or supported (fixed supports). Additionally, apply external forces such as loads or constraints that simulate real-world conditions, like the weight of pedestrians or vehicles.

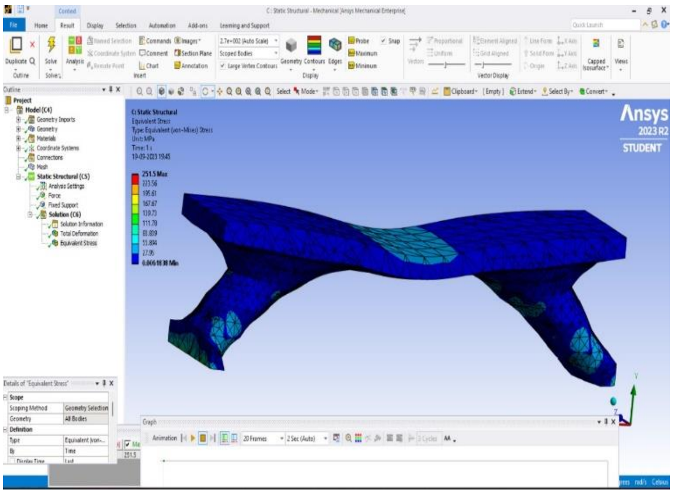

Figure 3: Boundary Condition and Analysis

Solution and Analysis:

1. Insert a deformation plot to observe the total deformation of the bridge under the applied loads: Define the type of results you want to visualize, such as deformation. Deformation plots will help you understand how the bridge structure responds to the applied loads.

2. Begin the solution process to compute the deformation and stress distribution: Initiate the analysis to compute the deformation, stress distribution, and other relevant engineering parameters for your bridge model. ANSYS will perform numerical simulations and provide you with results that can help you assess the structural integrity and behaviour of your pedestrian bridge under the specified conditions.

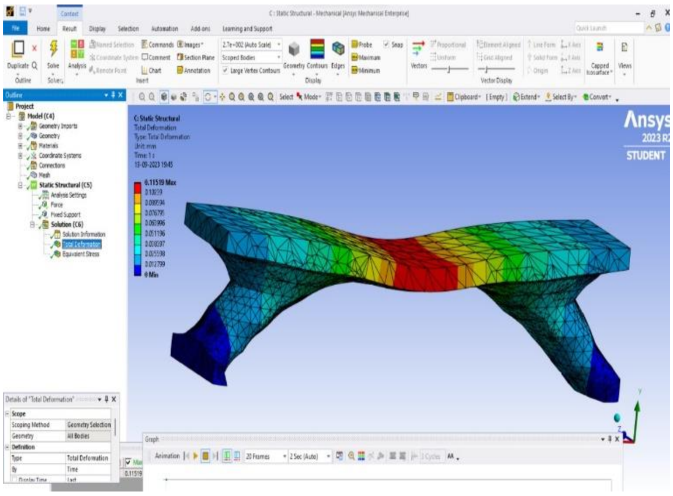

Figure 4: Solution and Analysis

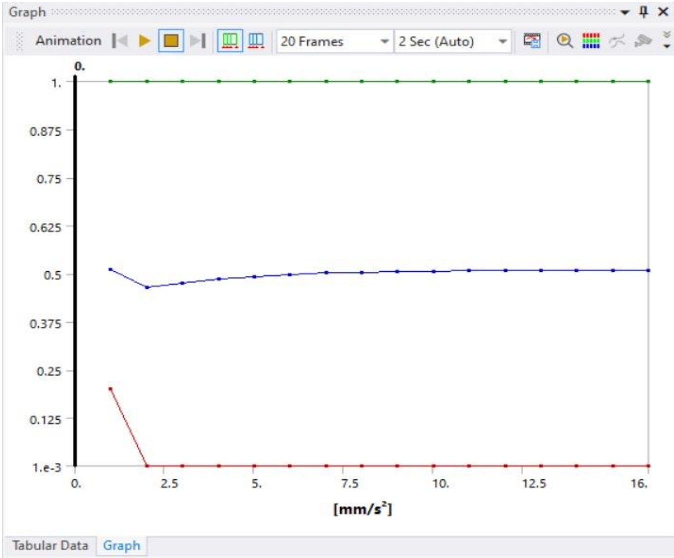

Figure 5: Graph for Case 1, a sample line graph using colours which contrast well both on screen and on a black-and-white hardcopy

Throughout this process, it's essential to validate and verify your model against physical testing or established engineering standards to ensure the accuracy and reliability of your analysis results.

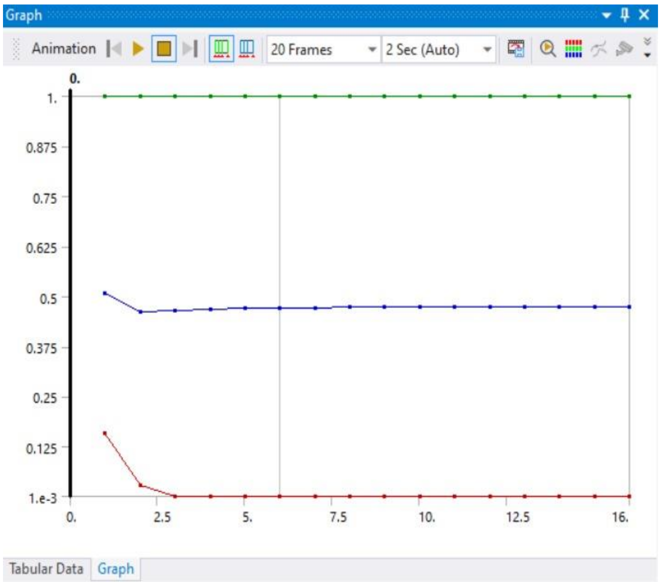

Figure 6: Graph for Case 2, a sample line graph using colours which contrast well both on screen and on a black-and-white hardcopy

IV. RESULT AND DISCUSSION

The results and inferences drawn from a static structural analysis of a pedestrian bridge are paramount for ensuring the bridge's safety, durability, and performance. Through rigorous analysis, engineers uncover valuable insights into the behaviour of the structure under various loads and environmental conditions. These results include stress and strain distribution, deflection, displacement, safety factors, and load redistribution throughout the bridge. Engineers scrutinize these outcomes to make critical inferences regarding the bridge's structural integrity, safety assurance, load-bearing capacity, and compliance with engineering standards. Furthermore, resonance and vibrations induced by pedestrian traffic or environmental factors are assessed to guarantee user comfort and safety. Based on these inferences, engineers can recommend structural modifications, design optimizations, and maintenance strategies.

V. CONCLUSION

In conclusion, the static structural analysis of pedestrian bridges is an indispensable step in ensuring the safety and reliability of these essential urban infrastructure components. Through meticulous examination of stress distribution, deflections, safety factors, and load-bearing capacity, this analysis empowers engineers to make informed decisions regarding design improvements, structural optimizations, and necessary maintenance strategies. The inferences drawn from such analyses not only contribute to the longevity and resilience of pedestrian bridges but also play a vital role in enhancing urban connectivity, mitigating traffic congestion, and fostering sustainable urban environments. As cities continue to grow and evolve, the knowledge gained from static structural analyses remains instrumental in the pursuit of safer, more efficient, and more accessible pedestrian pathways, enriching the lives of urban residents and visitors alike.

VI. REFERENCES

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