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Modal analysis of KRK bridge by using ANSYS Workbench

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Abstract. The modal analysis of KRK bridge is presented in this paper. The solid model and finite element model of KRK bridge are established by ANSYS WORKBENCH 2023 R2. The model is a whole, not made up of multiple parts. Due to the limited finite element number of WORKBENCH, there may be some deviation between the model studied in this paper and the reality. The mass of the model used in this paper is consistent with reality. The modal analysis is carried out under the boundary condition that the bottom of the bridge column is fixed and the two ends are not fixed. The model does not shift in any direction. The aim is to find six modes that have their own natural frequencies and modal modes. The natural frequency of the model is obtained, and the resonance and collapse of the model are avoided during use.

Keywords: Modal analysis, Vibration mode, ANASY WORKBENCH.

1. Introduction

The KRK Bridge is a dual-purpose road and pipeline bridge in Croatia. The entire bridge was completed in 1980 and consists of two sections with a span of 390 meters (mainland to Sveti Marco Island) and 244 meters (Sveti Marco Island to KRK Island). The two Bridges are 235 meters apart and connected by a 96 meters long road on the island of Sveti Marco. The bridge floor is 11.4 meters wide, and there are 17 pipelines (oil, water, industry) under the bridge floor. Its wide span ratio is only 1/30, which is a unique design feature of the bridge. The arch has a single-box, three-chamber section and is assembled from both ends with prefabricated components on the cantilever until they meet at the midpoint. The main arch, with a span of 390 meters, is extended by inclined piers with pillars, and its foundation is constructed with semi-floating pneumatic caissons [1].

This research report focuses on a modal analysis of the KRK Bridge in Croatia with the ANSYS Workbench program. Using ANSYS, different conditions were tested on the narrow, two-span bridge. Specifically, a finite element model was constructed via ANSYS Workbench to analyze the change of different modes at various vibration frequencies.

2. Background

In addition, despite being exposed to a harsh marine environment for over forty years with a designed concrete cover thickness of only 2.5 cm, the reinforced concrete structure of KRK Bridge remains in good condition. The local marine environment undergoes frequent changes, with strong winds carrying sea spray in the southern region and during winter months. The Mediterranean climate has average wind speeds of twenty kilometers per hour and occasionally reaches wind speeds characteristic of tropical

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depressions. The bridge is able to withstand the volatile weather conditions in the Adriatic Sea in part due to the quality of concrete used during construction in its frame.

The region surrounding the KRK Bridge is affected by the subtropical high pressure and the oceanic westerly belt, and therefore, has less precipitation in summer and more precipitation in winter. In summer, the region averages approximately 12.5 days of rain, less than the average of 14.9 days in other months. In the winter and spring, precipitation is more frequent [2].

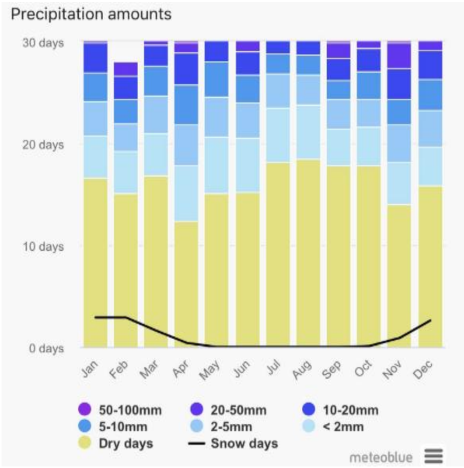

Figure 1. Precipitation amount within KRK bridge.

The temperature in this region is relatively suitable throughout the year. Although there are differences in summer and winter temperatures, extreme temperature events are rare. The daily maximum temperature from July to September averages higher than 15°C, with sporadic days where the temperature measures higher than 30°C. The temperature in winter is relatively mild. Though frost can be prevalent in winter, the maximum temperature was almost always above -5°C.

Additionally, wind speeds in summer are generally slow—lower than 38km/h. However, in the winter, gusts measuring higher than 61km/h are frequent. There are two types of prevailing winds on Krk Island—Southwest (SW) and Northeast (NE). The color change of the polar coordinates from green to yellow indicates the distribution of the wind speed in the direction of the wind. The time for the NE wind speed to exceed 38km/h is as high as 48 hours, far exceeding the 7 hours the SW wind takes. The slow SW wind in winter brings warm and moist air to the region, leading to the unique seasonal characteristics of mild and rainy weather [3].

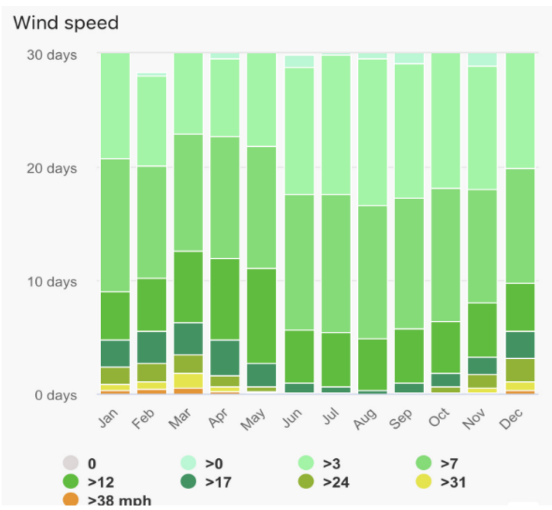

Figure 2. Wind speed within KRK bridge.

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3. Methodology

The modal of KRK Bridge is modeled by ANSYS Workbench. In addition, although the KRK Bridge has two spans, there is little impact between them. Therefore, only longer spans are modeled.

Although multiple drawings of the bridge were found during the literature review, it was difficult to determine which one was the most accurate. Many of them are inconsistent in size, and some have messy designs. It can also be challenging to read measurements of some components and details, such as beams, pillars, gutters, and sewer systems. In the original model, there were many errors, such as abnormal extrusion, incorrect size of some parts, inaccurate definition of inter-edge conditions, etc. However, through multiple tests using ANSYS, the model was refined to perfection.

Finally, some difficulties were also encountered before the final testing of the model. For example, there were several failures during the model import process. The error message here is rather vague. After repeated attempts, the team concluded that the model in ANSYS was too elaborate, that there were too many finite element units for the computer to handle, and that the boundary conditions were not fully defined due to the complexity of the model. After several adjustments, this conclusion was confirmed:

- Some beams (joists and bearers) are removed.

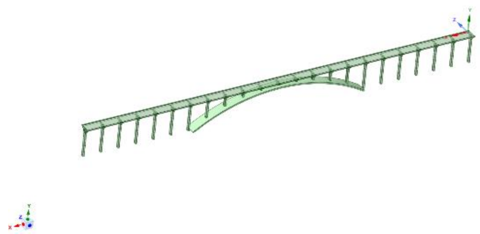

Figure 3. Modal of KRK bridge.

- The deck of the bridge is simplified to model only the minimum number of sidewalks.

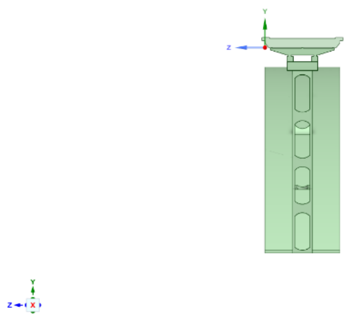

Figure 4. Side of the model.

- Make sure that each bridge column is correctly connected to the bridge arch and deck, and remove raised parts.

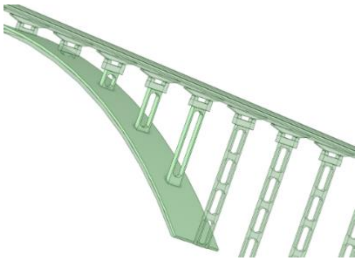

Figure 5. Columns of the modal.

- Set the correct boundary conditions at the bottom of the bridge column.

4. Simulation Analysis

4.1. Grid

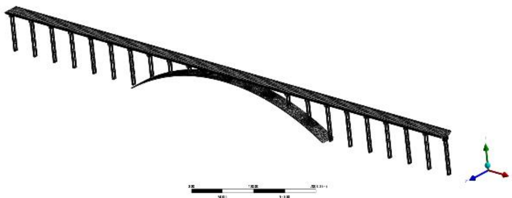

Figure 6. Grid modal.

Firstly, the established model is imported, and the number of nodes and units are obtained by free mesh division in ANSYS. Therefore, the finite element calculation model is established. By changing the cell size of the grid, a different number of nodes can be obtained. This data will be used in later calculations.

4.2. Volume

The volume of the model can be measured at this interface after the grid is generated.

4.3. Boundary condition

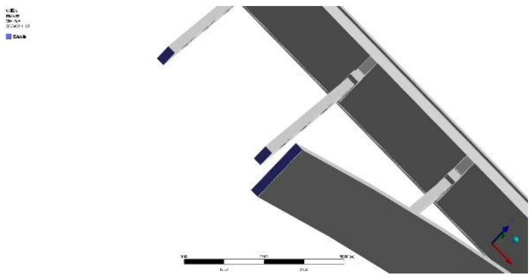

Figure 7. Bottom of the modal

The degree of freedom of the model is restricted by setting the boundary conditions. Fixed supports (blue part in the fig.7) were set up on the underside of the bridge columns to determine the direction of the force on the bridge and to ensure that it does not move randomly.

4.4. Data

Back on the toolbar page, the materials used in the engineering data, the data of Young's modulus, Poisson's ratio, the volume modulus, and the shear modulus were all determined.

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4.5. Density

The desired building mass of 41977000kg was divided by the volume of 1.0801*10^(5)m^3 to get a density of 388.64kg/m^3. The input density ensures that the result of the subsequent operation is correct.

4.6. Deformation

After saving the data, we returned to the model page, clicked on the total deformation based on the original grid model, and changed the pattern to 1 to 6 respectively. The deformation results of 6 different aspects are obtained.

4.7. Deformation Results

Finally, the basic frequency of 0.26Hz is obtained by changing the cell size of the grid repeatedly. We selected one of the results to evaluate the six total deformations respectively to obtain the deformation process.

First-order constraint mode Shaping mode: The whole bridge oscillates along the Z axis.

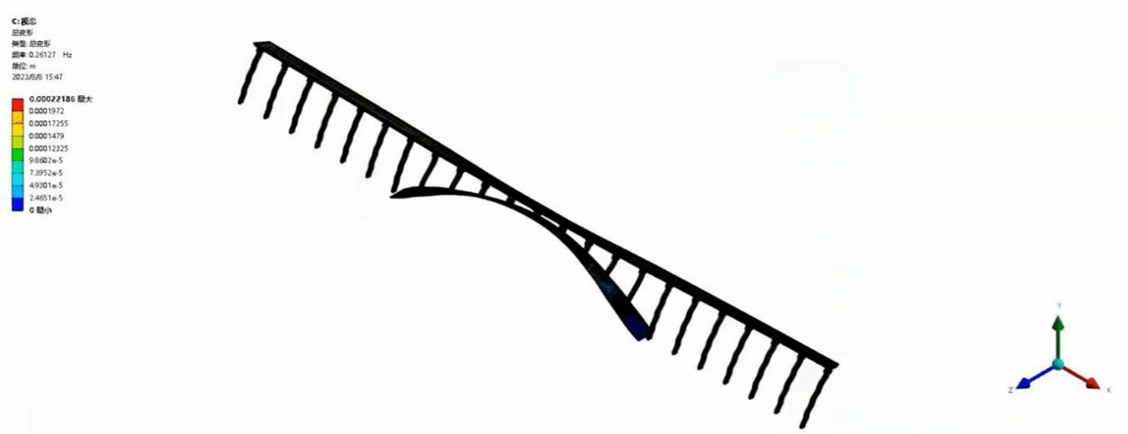

Figure 8. First-order constraint mode Shaping mode

Second order constraint mode Shaping mode: The two sides of the bridge are twisted clockwise and counterclockwise along the X-axis, respectively.

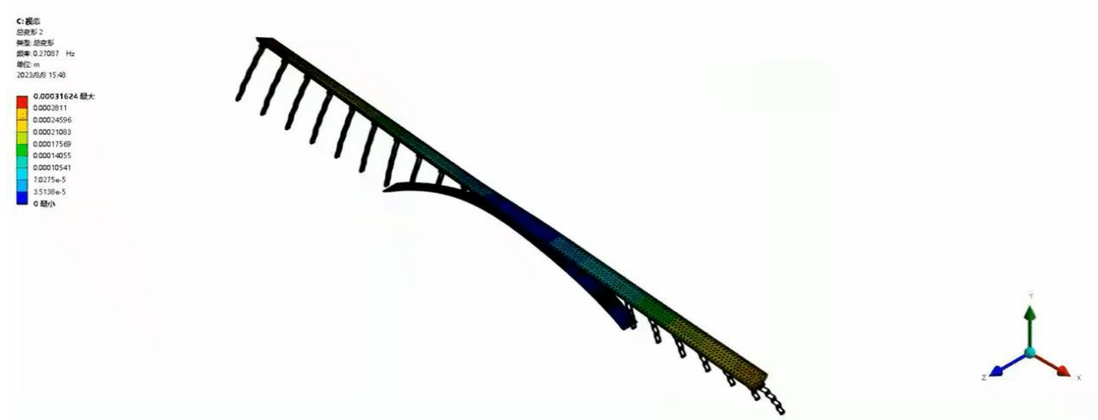

Figure 9. Second order constraint mode Shaping mode.

Third order constraint mode Shaping mode: both sides of the bridge swing in the same direction along the z axis and twist.

Figure 10. Third order constraint mode Shaping mode.

Fourth order constraint mode Shaping mode: The bridge twists up and down along the y axis and swings along the x axis.

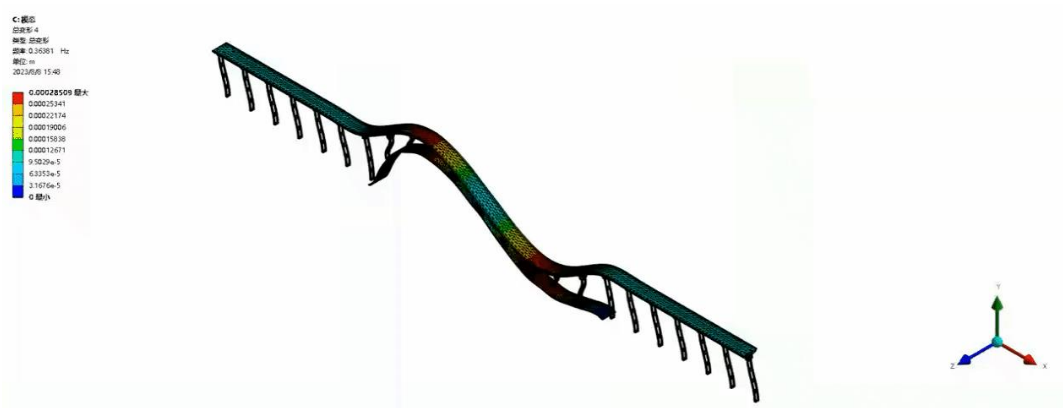

Figure 11. Fourth order constraint mode Shaping mode.

Fifth-order constraint mode Shaping mode: The bridge is twisted up and down along the y axis, both sides are twisted clockwise and counterclockwise along the x axis, and the whole oscillates along the Z axis.

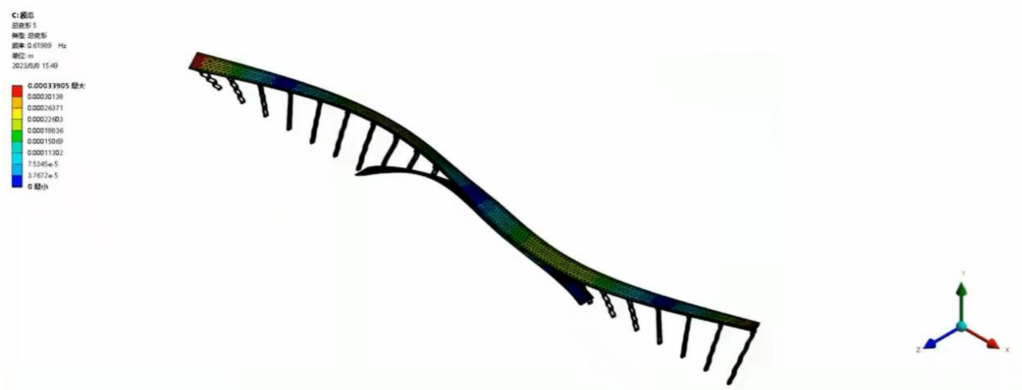

Figure 12. Fifth-order constraint mode Shaping mode.

Sixth-order constraint mode Shaping mode: The bridge is twisted up and down along the Y-axis.

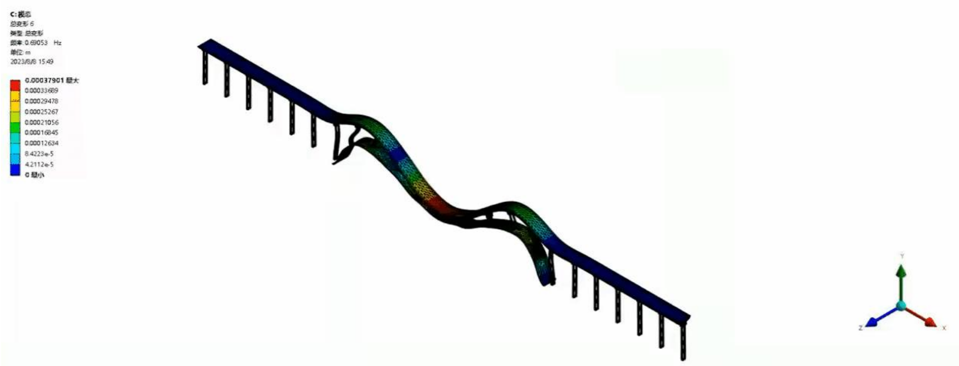

Figure 13. Sixth-order constraint mode Shaping mode.

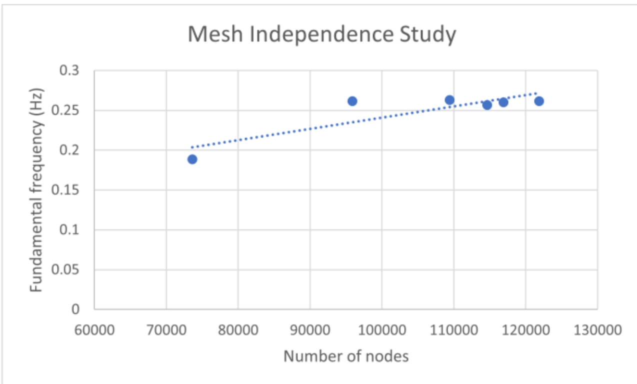

Figure 14. Mesh Independence Study.

5. Conclusion

The present study conducts modal analysis of the KRK Bridge in Croatia using ANSYS Workbench. Mesh independence of the bridge model is investigated in ANSYS, and an appropriate mesh size for analysis is determined. Maximum normalized deformation of the bridge is analyzed with six different natural frequencies ranging from 0.26Hz to 1.69Hz. In grid independence study, fundamental frequency of the bridge tends to stabilize as number of nodes increases. Due to finite element limitations in WORKBENCH, the model used in this paper differs somewhat from reality, which may introduce some bias into conclusions drawn herein. For more accurate results, both ends of the model can be fixed and effects of wind and temperature can be added.

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