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Study on the Effect of Variation in Number of Panels on Natural Frequency

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ABSTRACT

This study examines how the natural frequency and mode shapes of truss bridges are affected by changes in the number of panels. The Damped DOF system and ABAQUS were used to examine three distinct panel configurations (8, 10 and 12 panel) using a steel frame bridge as a case study. The results show that bridges with fewer panels exhibit lower natural frequencies, while those with more panels have higher frequencies due to increased stiffness. Furthermore, the mode shape analysis indicates that bridges with fewer panels experience greater deformations, potentially impacting their dynamic performance. This research emphasizes the importance of optimizing the number of panels in bridge design to enhance both stiffness and dynamic force resistance. Future research may explore the influence of other structural parameters on natural frequency and mode shape.

Keywords: bridges, frequency, mode, panel, stiffness

1. Introduction

Truss bridges are one type of bridge that uses the most widely used steel material [1]. The natural frequency of the is one of the parameters that influence the construction process [2][3][4]. The natural frequency is the frequency at which the structure vibrates naturally and is an important prerequisite for analyzing the feasibility of bridges [2][3][4]. The natural frequency of bridges is influenced by several factors, one of which is internal factors in the form of plate thickness, position, mass, bridge geometry, the relative ratio of prestress to the total weight of the structure, bridge length, bridge height, bridge width, and bridge span length [5][6][7].

These internal factors are also factors that affect the stiffness of a bridge, so bridge stiffness is also one of the factors that affect the natural frequency of a bridge [8][9][10][11][12]. In [13], Malekjafarian altered the Malahide Bridge's span to make it stiffer than other bridges. As a consequence, the bridge's natural frequency value increased, indicating that the more rigid the bridge, the higher its natural frequency value. In addition to the above factors, bridge stiffness, especially on truss bridges, is also influenced by the number of panels used [14]. The bridge's natural frequency will also be impacted by the quantity of panels employed [15][16].

Based on this theory, the goal of this study is to reexamine how changes in the number of panels affect the bridge's natural frequency. This is so that it is known more clearly the effect caused so that the determination of the number of bridge panels when designing the bridge can be done properly. So that a more proportional bridge design can be obtained in resisting dynamic forces.

2. Method

2.1 Research Sample

The sample of this research is a steel frame bridge, namely the Sei Belawan Bridge (Tj. Selamat Bridge) located on Jalan Graha Tanjung Anom, Tanjung Anom Village, Pancur Batu District which can be seen in Figure 1 with the bridge type *Warren*. The number of research samples consists of three research samples with the same bridge length and the same profile dimensions but with a different number of panels. The first sample is a bridge with 10 panels, the second sample is a bridge with 8 panels, and the third sample is a bridge with 12 panels. This research sample can be seen in Figure 2. In Figure 3 you can see the side view of the Sei Belawan Bridge. In Figures 4-6 are pictures of research samples. Figure 4 shows the original design of the Sei Belawan Bridge, which had ten panels. Figure 5 shows a bridge with eight panels that has the same height and span length as the Sei Belawan Bridge. Twelve panels make up the bridge in Figure 6, which has the same span length and height as the previous one.

Figure 1 The Belawan Bridge's Location

2.2 Type of Research

This research uses a quantitative approach which is a scientific study in which parts of the phenomenon and their relationships are systematized and the development of mathematical models, theories, or hypotheses related to the phenomena that occur is the goal of quantitative research [17].

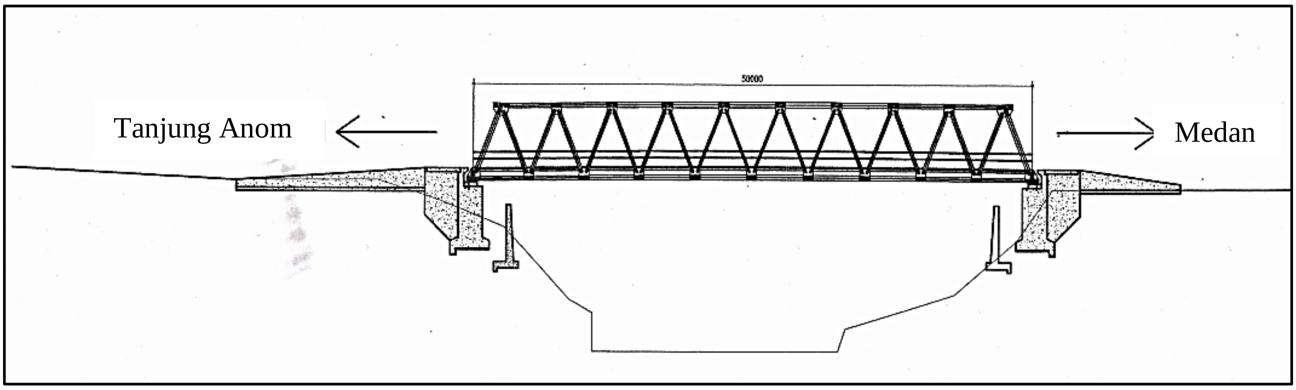


Figure 2 Sei Belawan Bridge research sample

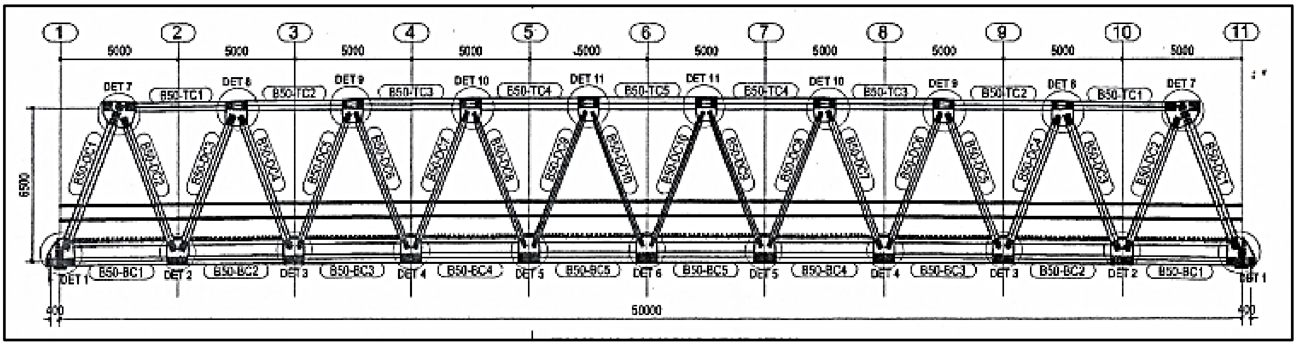


Figure 3 Side view of Sei Belawan Bridge

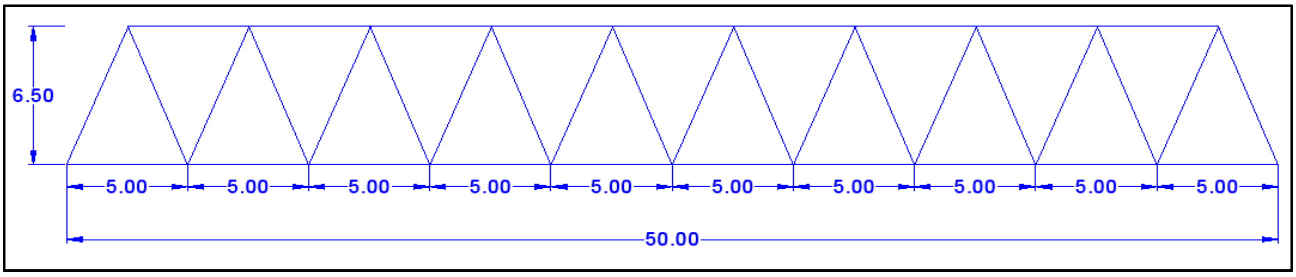


Figure 4 Bridge with 10 panels

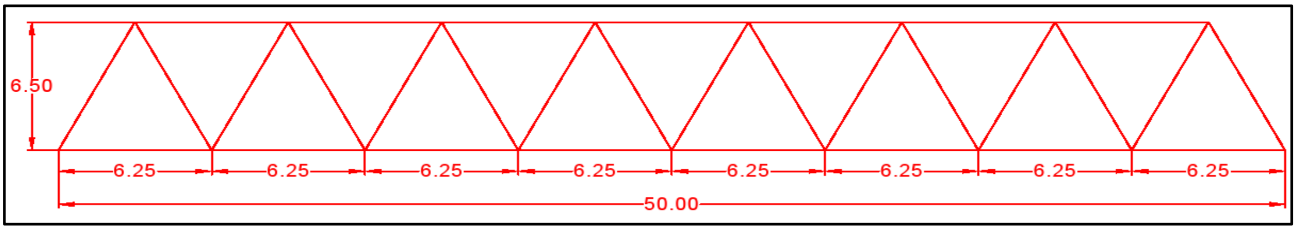


Figure 5 Bridge with 8 panels

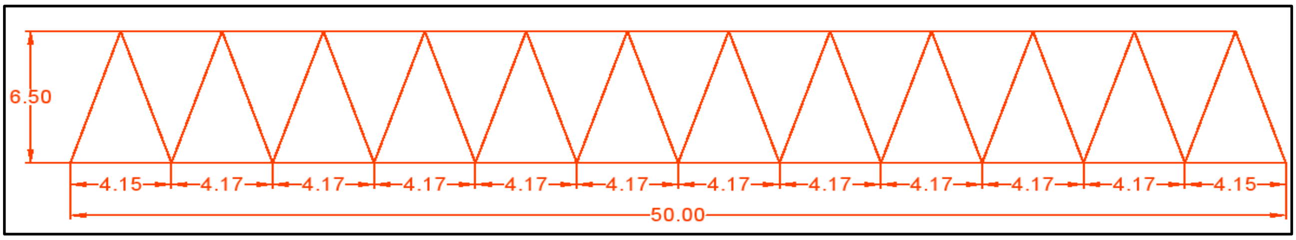


Figure 6 Bridge with 12 panels

2.3 Data Processing

This research goes through several stages of data processing starting with analyzing the stiffness matrix, mass matrix, and natural frequency on bridges with 10 panels, 8 panels, and 12 panels using two methods namely Damped-DOF System and ABAQUS software. After that, the analysis findings are compared according to the number of panels employed in order to ascertain the impact of different panel counts.

3. Results and Discussion

3.1 Natural Frequency Using Damped-DOF System

Natural frequency using damped DOF system with 10 panels has a value of 23.727 rad/sec. For bridges with a total of 8 panels, the natural frequency is 21.067 rad/s. And the natural frequency for bridges with 12 panels has a value of 25.687 rad/sec. Natural frequency using ABAQUS with 10 panels has a value of 23.649 rad/sec. For bridges with a total of 8 panels, the natural frequency is 20.979 rad/s. And the natural frequency for bridges with 12 panels has a value of 25.498 rad/sec.

3.2 Mode Shapes of the Bridge

An essential component of the natural frequency is the mode shape, which is also used to analyze the natural frequency's magnitude. The resulting mode shapes of the bridge with 10 panels using the Damped-DOF System and ABAQUS can be seen in Figure 7. The resulting mode shapes of the bridge with 10 panels using the Damped-DOF System and ABAQUS can be seen in Figure 8. And then, in addition to analyzing the magnitude of the natural frequency, the mode shape is an integral part of the natural frequency. The mode shapes generated by the bridge with 10 panels using the Damped-DOF System and ABAQUS can be seen in Figure 9.

3.3 Comparison of Natural Frequency Based on Number of Panels

The research shows that the natural frequency of a system with less than 10 panels is smaller, whereas the natural frequency of a system with more than 10 panels is bigger. From this comparison, it can be seen that the fewer the number of panels, the smaller the natural frequency, while the greater the number of panels, the greater the natural frequency. This comparison can be seen in Table 1 and Table 2.

From the percentage error, it can be seen that, when the number of panels is reduced, the natural frequency value will also decrease. Vice versa, when the number of panels is increased, the natural frequency value will also increase. According to G.-W. Chen et al. [18], Grigorjeva [19], Ju & Lin [20], Malekjafarian [13], Matsuoka et al. [11], Siekierski [21], and Tarozzi et al. [12], stiffness has an impact on the natural frequency value; the higher the bridge stiffness, the higher the natural frequency value, and the lower the bridge stiffness, the lower the natural frequency value. Bridges with 8 panels have lower stiffness than bridges with 10 panels and 12 panels.

This is because the frame used is less and longer compared to the bridge with 10 panels and 12 panels. Therefore, the bridge with 8 panels has a lower natural frequency value compared to the bridges with 10 panels and 12 panels. The bridge with 12 panels has a higher stiffness compared to the bridges with 8 panels and 10 panels, because the frame used is more and shorter. Therefore, compared to bridges with 8 and 10 panels, the bridge with 12 panels has a larger natural frequency value.

3.7 Comparison of Mode Shapes Based on the Number of Panels

From the analysis results, a comparison of mode shapes based on the number of panels used was obtained using the Damped-DOF System and ABAQUS. This comparison can be seen in Figures 10 and 11. Based on Figure 10, it shows that the most striking difference in the mode shape is found in the bridge with 8 panels. The mode shape of the bridge with 8 panels appears significantly larger compared to the bridges with 10 and 12 panels. Meanwhile, the bridge with 12 panels has a mode shape that is larger than that of the bridge with

10 panels but smaller than that of the bridge with 8 panels. Figure 11 reaches the same conclusion as Figure 10, where the bridge with 12 panels has a mode shape that is larger than that of the bridge with 10 panels but smaller than that of the bridge with 8 panels.

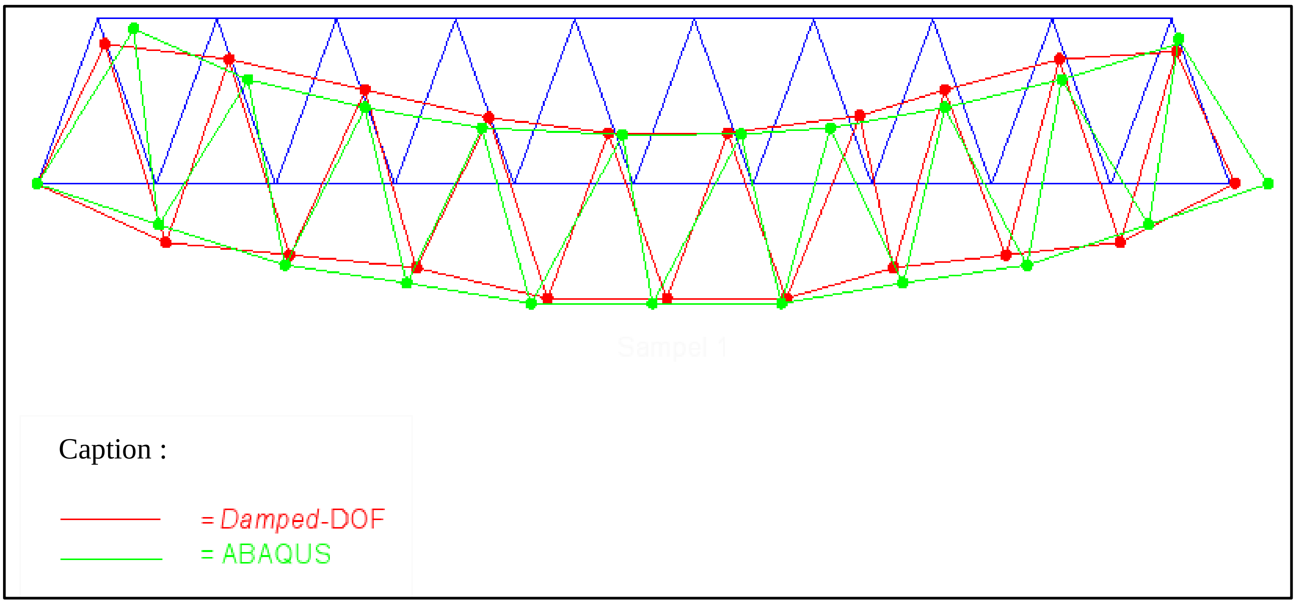


Figure 7 The modal shape of a bridge with 10 panels using a Damped-DOF System and ABAQUS.

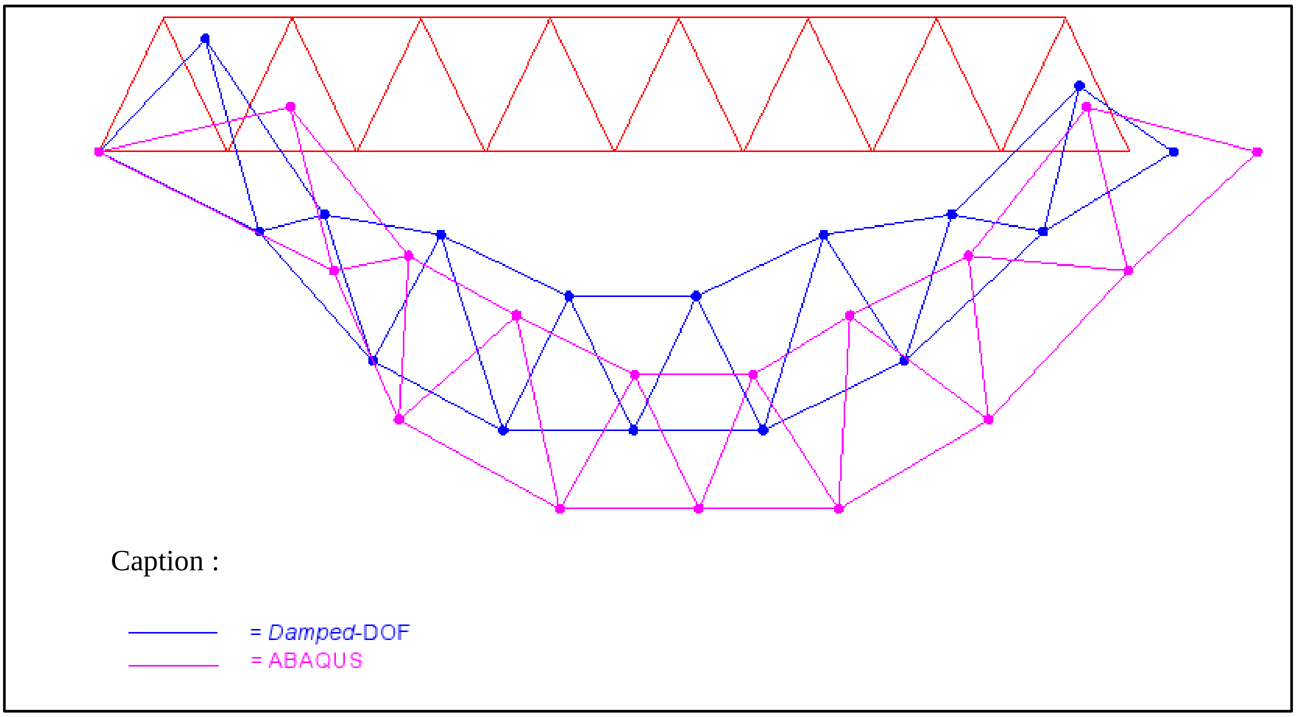


Figure 8 The modal shape of a bridge with 8 panels using a Damped-DOF System and ABAQUS.

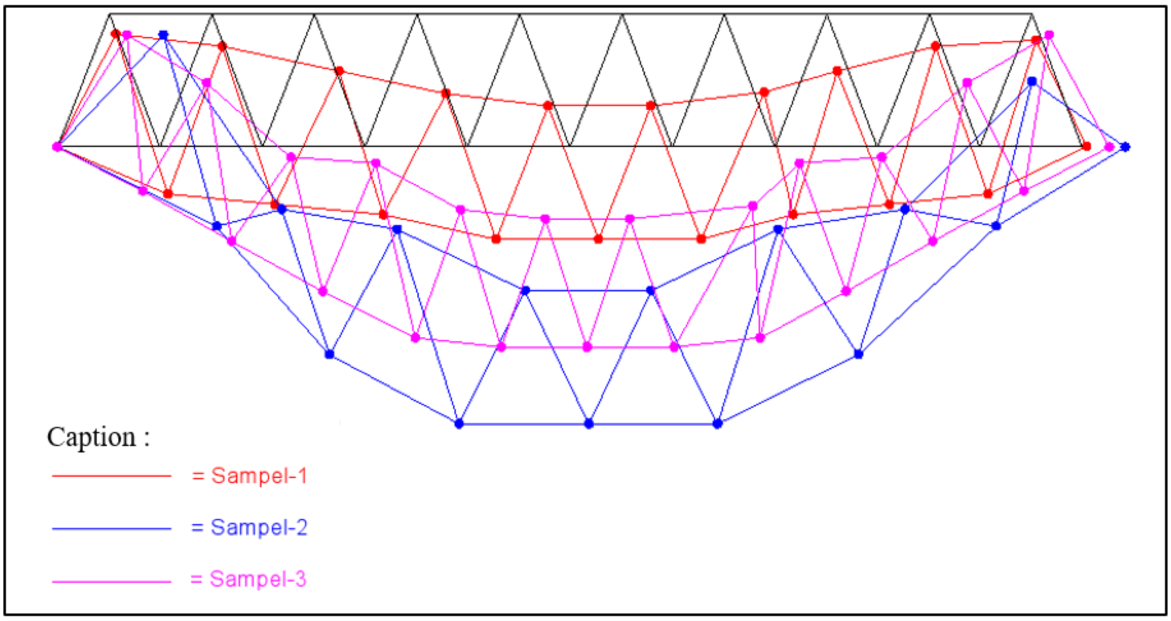


Figure 9 The modal shape of a bridge with 12 panels using a Damped-DOF System and ABAQUS.

Table 1 Natural frequency percentage comparison based on panel number using the Damped-DOF System.

	8 Panel	10 Panel	12 Panel
8 Panel		-0.1263	-0.2193
10 Panel	0.1121		-0.0826
12 Panel	0.1799	0.076	

Tabel 2 Natural frequency percentage comparison based on panel number using the ABAQUS

	8 Panel	10 Panel	12 Panel
8 Panel		-0.1274	-0.2156
10 Panel	0.1130		-0.0782
12 Panel	0.1774	0.0725	

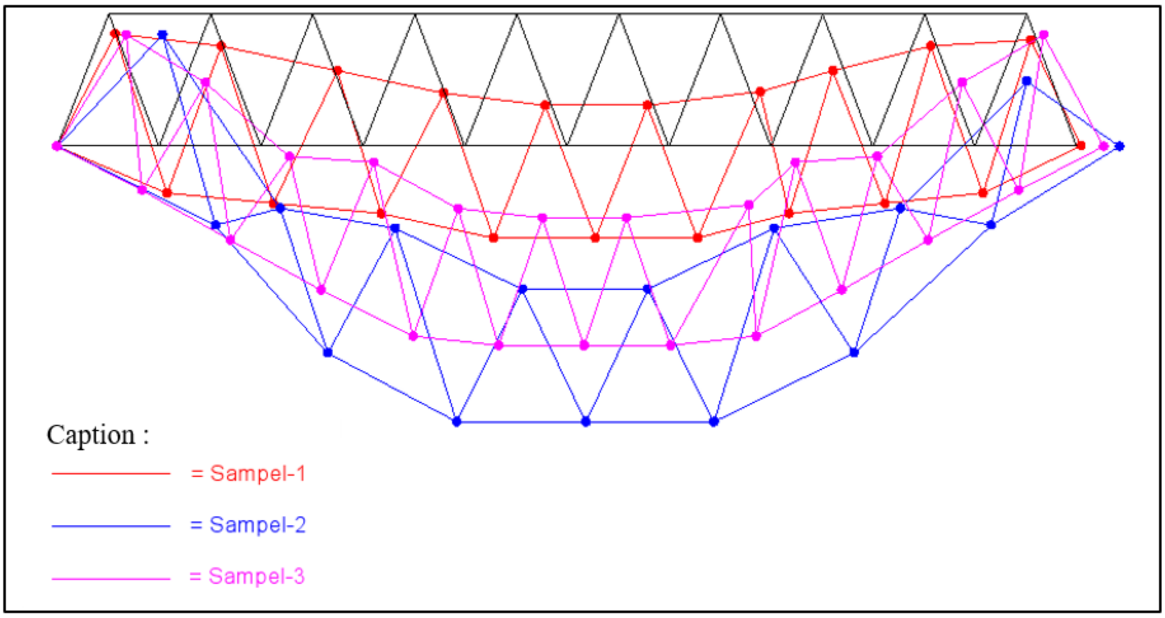
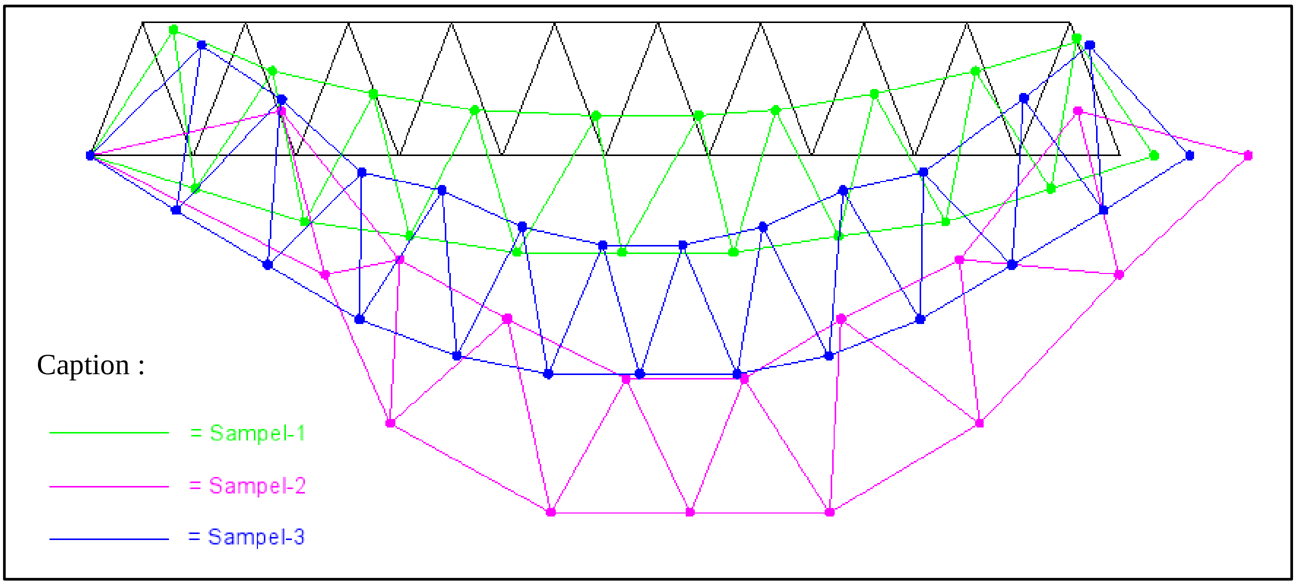


Figure 10 Comparison of the modal shapes of bridges with 10 panels, 8 panels, and 12 panels using the Damped-DOF System.



Gambar 11 Comparison of the modal shapes of bridges with 10 panels, 8 panels, and 12 panels using the ABAQUS.

4. Conclusion

This study found that the number of panels in a truss bridge has a substantial effect on its natural frequency and mode shape. Bridges with fewer panels, such as the 8-panel type, have lower natural frequencies, whereas 12-panel designs have higher frequencies. This variance is caused by the additional stiffness that comes with having more panels, which correlates directly with a higher natural frequency.
Moreover, the mode shape analysis revealed that bridges with fewer panels experience larger deformations, impacting their dynamic performance. Therefore, in designing truss bridges, careful consideration must be given to the number of panels to optimize both stiffness and natural frequency, ensuring the structure's ability to withstand dynamic forces. Future studies could explore other design factors such as material variations or the influence of external forces to further enhance bridge performance.

5. Acknowledgement

The Damped-DOF system and ABAQUS software were used in this study to investigate how changing the number of panels affected a truss bridge's natural frequency and mode shape. That means the impact of additional structural characteristics on the natural frequency and mode shape can be investigated in future studies.

6. Conflict of Interest

The study's authors, whose names are shown below, attest to the absence of any conflicts of interest.

Muhammad Zaki Chairuman

If more than 10 authors are present, this form may be photocopied. The precision and comprehensiveness of the previously stated information support this declaration:

Author’s name	Author’s signature
Muhammad Zaki Chairuman	

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