INTISARI

Penelitian ini dilatarbelakangi oleh kebutuhan penguatan konektivitas wilayah kepulauan, khususnya di Provinsi Maluku, yang memerlukan infrastruktur jembatan bentang panjang yang aman dan stabil terhadap beban angin. Jembatan *cable-stayed* dipilih karena mampu mencapai bentang besar dengan efisiensi material, namun rentan terhadap fenomena aerodinamik seperti *flutter* dan *vortex-induced vibration* (VIV). Permasalahan utama penelitian ini ialah bagaimana pengaruh variasi lebar dek terhadap respons dinamis jembatan, khususnya frekuensi alami, deformasi struktur, gaya kabel, dan kestabilan aerodinamik. Penelitian ini bertujuan mengevaluasi efek rasio lebar terhadap panjang bentang (B/L) pada jembatan *cable-stayed* tipe I girder komposit. Kebaruan penelitian terletak pada integrasi analisis numerik berbasis Midas Civil dan *Computational Fluid Dynamics* (CFD) untuk menilai perilaku struktural dan aerodinamik secara simultan pada studi kasus Jembatan Merah Putih di Kota Ambon.

Metode penelitian dilakukan melalui pemodelan elemen hingga menggunakan Midas Civil 2024 dan simulasi aliran angin tiga dimensi menggunakan *Cradle* CFD versi akademik. Empat variasi lebar dek dianalisis, yaitu 9 m, 14 m, 21,5 m, dan 24 m pada bentang utama 150 m serta dua side span 75 m. Analisis mempertimbangkan kecepatan angin 4, 8, 12, dan 25 m/s dengan sudut datang angin 0°, −6°, −9°, dan −12°, serta dievaluasi mengacu pada SNI 1725:2016 dan Pedoman 02/P/BM/2022.

Hasil penelitian menunjukkan bahwa peningkatan lebar dek menurunkan frekuensi lentur pertama dari 0,731 Hz menjadi 0,664 Hz, sementara rasio torsi–lentur (ft/fb) berada pada kisaran 1,34–1,39 yang masih di bawah batas 2,5. Displacement vertikal maksimum mencapai 17,23 mm pada lebar 24 m. Gaya kabel tertinggi tercatat sebesar 4.320 kN, sedangkan gaya lateral maksimum mencapai 157,52 kN pada kecepatan angin 25 m/s. Secara keseluruhan, rasio B/L antara 0,09–0,11 direkomendasikan sebagai rentang optimal untuk keseimbangan kekakuan struktural dan stabilitas aerodinamik.

Kata kunci: jembatan *cable-stayed*, I-girder komposit, frekuensi alami, *Computational Fluid Dynamics* (CFD), stabilitas aerodinamik

ABSTRACT

This study examines the structural and aerodynamic stability of a cable-stayed bridge with a composite I-girder deck under variations in deck-width-to-span ratio (B/L), motivated by the need to strengthen inter-island connectivity in archipelagic regions such as Maluku Province. Long-span cable-stayed bridges are efficient for spanning coastal straits, yet are susceptible to aerodynamic phenomena including flutter and vortex-induced vibration (VIV), which may compromise serviceability and structural safety. The primary objective of this research is to evaluate how variations in deck width affect the natural frequencies, structural displacements, cable forces, and aerodynamic stability of the bridge. The novelty of this study lies in its integrated assessment of structural and aerodynamic responses using finite element modeling and Computational Fluid Dynamics (CFD) on a real Indonesian long-span bridge, the Merah Putih Bridge in Ambon.

The research methodology combines numerical structural analysis using Midas Civil 2024 and three-dimensional external flow simulation using Cradle CFD (academic version). Four bridge deck width configurations—9 m, 14 m, 21.5 m, and 24 m—were analyzed on a 150 m main span with two 75 m side spans. Wind speeds of 4, 8, 12, and 25 m/s and wind attack angles of 0°, −6°, −9°, and −12° were considered. Evaluation criteria followed SNI 1725:2016 and the Indonesian Road and Bridge Design Guidelines No. 02/P/BM/2022.

The results indicate that increasing deck width reduces the first bending frequency from 0.731 Hz to 0.664 Hz, while the torsional-to-bending frequency ratio (ft/fb) remains between 1.34 and 1.39, below the aerodynamic stability threshold of 2.5. The maximum vertical displacement reached 17.23 mm at the 24 m deck width. The highest cable force observed was 4,320 kN, and the maximum lateral wind force was 157.52 kN at 25 m/s. Overall, a B/L ratio between 0.09 and 0.11 offers an optimal balance between structural stiffness and aerodynamic stability.

Keywords: cable-stayed bridge, I-girder composite, natural frequency, Computational Fluid Dynamics (CFD), aerodynamic stability