

INTISARI

Jembatan Joglo merupakan jembatan kereta baru di kota Surakarta dengan konfigurasi struktur yang unik karena berupa struktur rangka pipa baja menerus sepanjang tiga bentang dengan bentang utama 120 meter dan dua bentang samping masing-masing 65 meter. Menurut Permen PUPR No.10 Tahun 2022, Jembatan Joglo dikategorikan sebagai jembatan khusus yang memerlukan evaluasi kinerja struktural lebih ketat karena risiko terjadi kegagalan struktural sangat besar. Selain itu, perilaku struktur jembatan kereta berbeda signifikan dibandingkan jembatan biasa karena menerima beban dinamis kereta dengan *impact* yang besar, dan setiap kereta melintas, beban lokomotif akan selalu maksimal. Oleh karenanya, analisis memerlukan acuan standar perkeretaapian yang komprehensif.

Pada penelitian ini, analisis kinerja struktur jembatan dilakukan berbasis elemen hingga dari pemodelan skala global struktur hingga skala lokal pada sambungan. Model global struktur dianalisis menggunakan program *Midas Civil* dengan idealisasi *frame element* sementara sambungan dimodelkan sebagai *shell element* pada program *Midas FEA NX*. *Output* dari analisis global di antaranya: deformasi akibat suhu dan beban kereta, karakteristik dinamik struktur, reaksi tumpuan, rasio tegangan aktual terhadap tegangan izin, dan nilai *Demand Capacity Ratio*. *Output* dari analisis sambungan di antaranya: tegangan prinsipal, kuat fatik, dan tegangan von Mises.

Berdasarkan hasil analisis elemen hingga didapatkan hasil-hasil sebagai berikut: Tumpuan mengalami translasi longitudinal hingga 126 mm akibat pengaruh suhu. Sementara akibat beban kereta, struktur mengalami lendutan pada bentang utama sebesar 97,59 mm (<120 mm) dan pada bentang samping sebesar 38,18 mm (<65 mm). *Mode 1* (Transversal, $T=0,88$ detik) dan *mode 2* (vertikal, $T=0,837$ detik). Rasio $f_{torsi}/f_{vertikal}$ sebesar 3,033 ($\geq 2,5$) sehingga terhindar dari risiko bahaya interaksi aeroelastik. Menurut reaksinya, tumpuan P11-A-R menerima beban vertikal mencapai 29344,73 kN dan *uplift* sebesar 7225,46 kN, sementara tumpuan P9-L menerima beban gempa mencapai 34365,83 kN. Rasio tegangan aktual terhadap tegangan izin menunjukkan elemen di puncak struktur memiliki rasio tertinggi sebesar 1,16. Nilai *DCR* menunjukkan hal serupa pada kondisi Kuat, elemen di puncak struktur memiliki nilai tertinggi sebesar 0,941 sementara pada kondisi Ekstrem gempa, nilai *DCR* pada elemen di sekitar pilar P9 mencapai 1,94. Pada sambungan tumpuan, tegangan fatik diperoleh sebesar 55,26 MPa (kategori C, $S_{rfat} = 69$ MPa) dan tegangan von Mises sebesar 361,56 MPa. Pada sambungan puncak, tegangan fatik diperoleh 109,07 MPa di ujung *top chord* (detail kategori B, $S_{rfat} = 110$ MPa), 96,98 MPa di pertemuan batang diagonal (kategori C, $S_{rfat} = 69$ MPa), dan tegangan von Mises sebesar 389,41 MPa. Sehingga diperlukan inspeksi intensif, perawatan, rencana perkuatan pada sambungan puncak di masa mendatang.

Kata kunci: Jembatan kereta khusus, rangka pipa baja, analisis elemen hingga, tegangan fatik, tegangan *von mises*,

ABSTRACT

The Joglo Bridge is a newly constructed railway bridge located in Surakarta, featuring a unique configuration consisting of a continuous steel tubular truss structure spanning three spans, with a main span of 120 meters and two side spans of 65 meters each. According to the Ministry of Public Works and Housing Regulation (*Permen PUPR*) No. 10 of 2022, the Joglo Bridge is classified as a special bridge that requires a more rigorous structural performance evaluation due to its high potential risk of structural failure. Moreover, the structural behaviour of a railway bridge differs significantly from that of a conventional highway bridge because it is subjected to dynamic train loads with substantial impact effects, where the locomotive loads are always near their maximum during every passage. Therefore, the analysis must refer to a comprehensive railway bridge design standard.

In this study, the structural performance evaluation was conducted using finite element analysis (FEA), encompassing both global and local scales. The global model of the bridge was analysed using Midas Civil, idealized with frame elements, while the local connection models were analysed using Midas FEA NX with shell elements. The outputs of the global analysis include deformations due to temperature and train loads, dynamic characteristics of the structure, support reactions, the ratio of actual to allowable stresses, and the Demand Capacity Ratio (DCR). Meanwhile, the outputs of the local connection analysis include principal stresses, fatigue strength, and von Mises stresses.

Based on the finite element analysis results, the following findings were obtained: the supports experienced longitudinal translation up to 126 mm due to temperature effects. Under train loading, the structure exhibited deflections of 97,59 mm (<120 mm) on the main span and 38,18 mm (<65 mm) on the side spans. The first two vibration modes were identified as transverse ($T = 0,88$ s) and vertical ($T = 0,837$ s) modes. The torsional-to-vertical frequency ratio of 3,033 ($\geq 2,5$) indicates that the structure is free from aeroelastic interaction risk. In terms of reactions, the P11-A-R support carried a vertical load of 29.344,73 kN with an uplift of 7.225,46 kN, while the P9-L support experienced seismic forces up to 34.365,83 kN. The stress ratio analysis showed that elements near the top chord had the highest ratio of 1,16. The DCR values presented a similar trend, where at Strength Condition, the top chord elements reached 0,941, while at Extreme Seismic Condition, elements around pier P9 reached 1,94. For the connection analysis, the support joint exhibited a fatigue stress of 55,26 MPa (detail category C, $S_{rfat} = 69$ MPa) and a von Mises stress of 361,56 MPa. At the top chord joint, the fatigue stress reached 109,07 MPa at the end of the top chord (detail category B, $S_{rfat} = 110$ MPa) and 96,98 MPa at the diagonal intersection (category C, $S_{rfat} = 69$ MPa), with a von Mises stress of 389,41 MPa. Therefore, intensive inspection, maintenance, and strengthening plans for the top chord joints are recommended for future operation.

Keywords: Unique Railway Bridge, steel pipe truss, finite element analysis, fatigue stress, von mises stress