

Pembangunan Jalan tol Yogyakarta – Bawen merupakan proyek strategis nasional sehingga struktur jembatan harus memiliki durabilitas yang tinggi serta efisien. Struktur *pier head* tipe *hammerhead single pier* pada P38 akan direncanakan menerima beban pelebaran lajur di masa depan. Namun, penggunaan material baja untuk tendon rentan terhadap korosi dan kehilangan gaya prategang yang besar sehingga berpotensi mengurangi umur layan struktur. Perancangan ini bertujuan untuk memberikan alternatif desain *pier head* menggunakan tendon *Carbon Fiber Reinforced Polymer (CFRP)* dan memberikan perbandingan kinerja yang ditinjau dari aspek tegangan saat transfer dan masa layan, kapasitas lentur, geser, torsi, serta efisiensi biaya konstruksi.

Perancangan dilakukan dengan memodelkan struktur menggunakan perangkat lunak Midas Civil. Pemodelan memperhitungkan *time-dependent material* yang mengacu pada CEB FIP 2010, serta kriteria perancangan berdasarkan SNI 8973:2021 dan AASHTO LRFD *Bridge Design Specification* edisi ke 10 tahun 2024. Analisis dilakukan dengan mendefinisikan *construction stage* untuk kondisi transfer, layan pra-pelebaran (0-20 tahun), dan pasca-pelebaran (30-100 tahun).

Hasil menunjukkan bahwa struktur eksisting mengalami tegangan tarik yang melampaui batas izin pada saat pasca-pelebaran yang memiliki distribusi tegangan setelah LOP sebesar 77-82%, sedangkan perancangan ulang memiliki distribusi tegangan setelah LOP sebesar 86-93% sehingga memenuhi syarat batas tegangan dan aman dari retak sampai akhir umur rencana. Kapasitas penampang CFRP terutilitasi secara optimal pada tahanan lentur dengan nilai *Demand Capacity Ratio (DCR)* sebesar 0,59 serta memiliki kinerja tahanan geser dan torsi yang sebanding dengan baja. Dalam segi ekonomi, hasil perancangan ulang dengan tendon CFRP menghasilkan penghematan biaya konstruksi sebesar 32,91% pada sebuah *pier head* akibat reduksi volume tendon dan baja tulangan yang signifikan. Dapat disimpulkan bahwa tendon CFRP dapat menjadi alternatif solusi untuk meningkatkan stabilitas kinerja struktur jangka panjang dan efisiensi biaya.

Kata kunci: *pier head*, CFRP, beton prategang, sistem pascatarik, efisiensi biaya

ABSTRACT

The construction of the Yogyakarta – Bawen toll road is a national strategic project, so the bridge structure must be highly durable and efficient. The hammerhead single pier pier head structure at P38 will be designed to accommodate future lane widening loads. However, the use of steel for tendons is susceptible to corrosion and significant loss of prestressing force, which could potentially reduce the service life of the structure. This design aims to provide an alternative pier head design using Carbon Fiber Reinforced Polymer (CFRP) tendons and provide a performance comparison in terms of stress transfer and service life, flexural, shear, and torsional capacity, as well as construction cost efficiency.

The design was carried out by modeling the structure using Midas Civil software. The modeling took into account time-dependent materials referring to CEB FIP 2010, as well as design criteria based on SNI 8973:2021 and AASHTO LRFD Bridge Design Specification 10th edition 2024. The analysis was conducted by defining the construction stage for transfer conditions, pre-widening service (0-20 years), and post-widening service (30-100 years).

The results show that the existing structure experienced tensile stress that exceeded the allowable limit during the post-widening period, with stress distribution after LOP around 77-82%, while the redesign was able to have stress distribution after LOP around 86-93%, thus meeting the stress limit requirements and ensuring safety from cracking until the end of the design life. The CFRP cross-section capacity was optimally utilized in flexural resistance with a Demand Capacity Ratio (DCR) value of 0.59 and had shear and torsional resistance performance comparable to steel. Economically, the redesign with CFRP tendons resulted in a 32.91% reduction in construction costs on a pier head due to a significant reduction in tendon and reinforcing steel volume. It can be concluded that CFRP tendons can be an alternative solution to improve long-term structural performance stability and cost efficiency.

Keywords: pier head, CFRP, prestressed concrete, post-tensioning system, cost efficiency