INTISARI

Jembatan pelengkung diagonal merupakan salah satu tipologi struktur jembatan dengan karakteristik unik dan kompleks akibat konfigurasi geometrik spasial yang asimetris, sehingga distribusi gaya menjadi lebih kompleks dan respons struktur terhadap pembebanan dinamik menjadi lebih sensitif. Karakteristik tersebut menyebabkan perilaku dinamis yang berbeda dibandingkan jembatan konvensional dan menuntut pendekatan analisis lanjutan dalam evaluasi respons seismik. Hingga saat ini, kajian respons dinamis jembatan pelengkung diagonal di Indonesia masih terbatas, terutama yang menggunakan analisis *nonlinear time history*. Penelitian ini bertujuan mengevaluasi karakteristik dinamis dan kinerja seismik jembatan pelengkung diagonal dengan sistem isolasi seismik berbasis *Lead Rubber Bearing* (LRB) melalui studi kasus Jembatan Mungkid pada ruas Tol Yogyakarta–Bawen dengan total panjang bentang 97.88 m.

Analisis dilakukan menggunakan pemodelan berbasis *finite element* dengan perangkat lunak Midas Civil, yang mencakup *gravity load*, analisis modal, dan analisis *nonlinear time history*. Analisis dengan *gravity load* digunakan untuk meninjau respons elemen struktur pada kondisi layan, analisis modal untuk memperoleh bentuk mode getar, periode alami, dan partisipasi massa modal, sedangkan analisis *nonlinear time history* digunakan untuk mengevaluasi respons seismik struktur. Analisis *nonlinear time history* dilakukan menggunakan tujuh pasang rekaman gempa yang disesuaikan terhadap respon spektrum desain pada lokasi jembatan sesuai SNI 2833:2016. Sistem isolasi LRB dimodelkan secara *nonlinier* untuk merepresentasikan perilaku histeretik dan mekanisme disipasi energi.

Hasil analisis menunjukkan bahwa respons dinamis jembatan pelengkung diagonal didominasi oleh mode translasi dengan periode fundamental sebesar 1.728 detik, serta partisipasi massa kumulatif yang melampaui 50% pada tiga mode awal, sementara kontribusi rotasi muncul pada mode-mode berikutnya. Analisis statik memperlihatkan bahwa seluruh elemen struktur atas, meliputi girder, hanger, dan pelengkung, memiliki nilai *Demand–Capacity Ratio* (DCR) yang memenuhi kriteria pada kondisi layan. Selanjutnya, hasil analisis *nonlinear time history* menunjukkan bahwa elemen utama struktur berperilaku elastis tanpa terbentuknya sendi plastis. Rasio simpangan maksimum pilar tercatat sekitar 0.13% pada arah-X dan 0.03% pada arah-Y, yang mengindikasikan tingkat kinerja *Fully Operational* sesuai (NCHRP,2013). Perpindahan maksimum pada sistem isolasi LRB berada dalam kisaran 70–125.78 mm pada arah-X dan 96–148.65 mm pada arah-Y, masih berada di bawah kapasitas desain sebesar 225 mm, serta LRB mampu mendisipasi energi gempa sebesar 67.6%.

Berdasarkan hasil tersebut, penerapan sistem isolasi seismik berbasis *Lead Rubber Bearing* pada jembatan pelengkung diagonal menghasilkan respons dinamis struktur yang tetap berada dalam batas kapasitas elemen dan dapat digunakan sebagai rujukan teknis awal bagi evaluasi kinerja seismik jembatan dengan konfigurasi geometrik yang asimetris.

Kata kunci: Jembatan Pelengkung Diagonal, *Non-Linear Time History*, *LRB*

ABSTRACT

Diagonal arch bridges represent a bridge structural typology with unique and complex characteristics arising from asymmetric spatial geometric configurations, which result in more intricate force distributions and heightened sensitivity of structural response under dynamic loading. These characteristics lead to dynamic behavior that differs from that of conventional bridge systems and therefore require advanced analytical approaches for seismic response evaluation. To date, studies addressing the dynamic response of diagonal arch bridges in Indonesia remain limited, particularly those employing nonlinear time history analysis. This study aims to evaluate the dynamic characteristics and seismic performance of a diagonal arch bridge equipped with a Lead Rubber Bearing (LRB)–based seismic isolation system through a case study of the Mungkid Bridge on the Yogyakarta–Bawen Toll Road, with a total span length of 97.88 m.

The analysis was conducted using a finite element–based numerical model developed in Midas Civil, encompassing gravity load analysis, modal analysis, and nonlinear time history analysis. gravity load analysis was employed to examine the structural response of individual elements under serviceability conditions, while modal analysis was used to determine mode shapes, natural periods, and modal mass participation ratios. Nonlinear time history analysis was performed to evaluate the seismic response of the bridge system. The seismic input consisted of seven pairs of ground motion records scaled to match the design response spectrum at the bridge site in accordance with SNI 2833:2016. The LRB isolation system was modeled using nonlinear elements to accurately represent its hysteretic behavior and energy dissipation mechanism.

The results indicate that the dynamic response of the diagonal arch bridge is predominantly governed by translational modes, with a fundamental period of 1.728 seconds and cumulative modal mass participation exceeding 50% within the first three modes, while rotational contributions become evident in higher-order modes. Static analysis results show that all superstructure components, including girders, hangers, and arch ribs, satisfy serviceability requirements, as reflected by Demand–Capacity Ratio (DCR) values within acceptable limits. Furthermore, the nonlinear time history analysis demonstrates that the primary structural elements remain in the elastic range throughout seismic excitation, with no formation of plastic hinges. The maximum pier drift ratios are approximately 0.13% in the longitudinal (X) direction and 0.03% in the transverse (Y) direction, indicating a Fully Operational performance level in accordance with NCHRP (2013). The maximum displacements of the LRB isolation system range from 70–125.78 mm in the X direction and 96–148.65 mm in the Y direction, remaining below the design displacement capacity of 225 mm, while the LRB system is capable of dissipating up to 67.6% of the seismic input energy.

Based on these findings, the implementation of a Lead Rubber Bearing–based seismic isolation system in a diagonal arch bridge results in a well-controlled dynamic structural response that remains within the capacity limits of all structural components. The outcomes of this study may therefore serve as an initial technical reference for the seismic performance evaluation of bridges with asymmetric geometric configurations.

Keywords: Diagonal Arch Bridge, Non-Linear Time History, LRB