SEISMIC RESILIENCE ENHANCEMENT OF BRIDGES USING NOVEL DAMPING ADAPTIVE PENDULUM ISOLATION SYSTEM

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Extended Abstract

Seismic isolation is a particularly effective strategy to mitigate seismic damage and enhance seismic resilience of engineering structures. The friction pendulum (FP) system with spherical sliding surface, which features the friction damping and re-centering capabilities, has been widely employed in engineering structures. Due to the constant radius of curvature, the shifting of the friction pendulum bearing may introduce the uplift of the superstructure, which shows unfavorable influence on the service performance and vehicle safety. As an effective measure to accommodate the thermal movements, the pure-friction sliding isolator accommodates thermal and lateral displacements in a simple and natural way without uplift behavior or any inconveniences related to the curved sliding surface of the friction pendulum. However, the pure-friction isolator without recentering capacity may introduce large peak displacement under earthquakes. On the other hand, to enhance the damping capacity and adaptability, the variable friction isolators, in which the damping characteristics vary with the increase of the displacement amplitude, have been investigated. It is an effective strategy to mitigate the peak displacement of the girder and protect the bridge from girder unseating under strong earthquakes. However, due to the adaptive damping characteristics, the recentering demand may increase as the displacement amplitude increases, the adaptability of the variable friction pendulum isolator under service loadings and earthquakes needs to be improved.

To address the shortages, a novel damping adaptive pendulum isolator (DAPI) is developed to update the adaptability and seismic resilience of bridges. The DAPI integrates the advantages of variable friction sliding isolator to enhance the adaptive damping capacity and improved friction pendulum bearing to address the bearing movements. The hysteretic behavior of the DAPI is modeled in OpenSees platform,

and the prediction accuracy of the DAPI model is further validated using experimental results. Based on the experimentally validated model, case studies are conducted to analyze and evaluate performance enhancement effect of the DAPI system for bridges compared to the improved friction pendulum system. Finally, the feasibility of using SMA damper to enhance the recentering performance of DAPI system is demonstrated.

In this study, a numerical model of the DAPI is developed, and the accuracy is validated through comparison with experimental results. The seismic performance of a bridge equipped with DAPI system is investigated through a case study considering various isolation periods. The effectiveness of employing SMA dampers to improve recentering capability is also examined. Compared to the improved FP system, the bridge with DAPI system achieves a maximum reduction in peak girder displacement of 26.6% under GM-1 and 38.6% under GM-2. However, this comes with an increase in peak permanent isolator displacement by 72.4% under GM-1 and 60.0% under GM-2. A maximum increase of 27.1% in base force at the middle pier under GM-1 is also observed (Fig. 1). Despite the increase in base forces, the maximum pier drift remains well below the equivalent yield drift. The case study further reveals that incorporating SMA dampers is both feasible and effective in enhancing the recentering capacity of the DAPI system. The permanent isolator displacement is significantly reduced by 41.2% under GM-1 and 45.4% under GM-2. Meanwhile, the seismic demand increment in piers is slight. Moreover, the DAPI system with SMA dampers outperforms the improved FP system in mitigating the permanent isolator displacement.

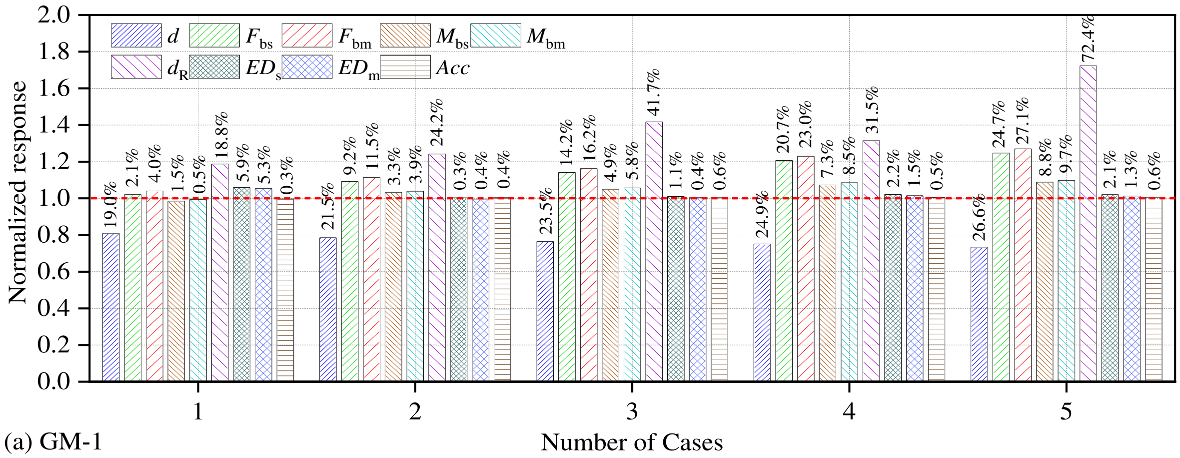

Fig. 1. Variations of the normalized responses of DAPI system

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