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Seismic Performance of Highway Bridges with Partially Self-Centering Isolation Bearings against Near-Fault Ground Motions

Authors : Shengxin Yu

Abstract : Earthquakes can cause varying degrees of damage to building and bridge structures. Traditional laminated natural rubber bearings (NRB) exhibit inadequate energy dissipation and restraint, particularly under near-fault ground motions, resulting in excessive displacements in the superstructure. This paper presents a composite natural rubber bearing (NFUD-NRB) incorporating two types of shape memory alloy (SMA) U-shaped dampers (UD). The bearing exhibits adjustable features, predominantly characterized by partial self-centering and multi-level energy dissipation, facilitated by nickel-titanium-based SMA (NiTi-SMA) and iron-based SMA (Fe-SMA) UDs. The hysteresis characteristics of NFUD-NRB can be tailored by manipulating the configuration of NiTi-SMA and Fe-SMA UDs. Firstly, the proposed bearing's geometric configuration and working principle are introduced. The rationality of the modeling strategy for the bearing is validated through existing experimental results. Parameterized numerical simulations are subsequently performed to investigate the partially self-centering behavior of NFUD-NRB. The findings indicate that NFUD-NRB can attain the anticipated nonlinear behavior and deliver adequate energy dissipation. Finally, the impact of NFUD-NRB on improving the seismic resilience of highway bridges is examined using the OpenSees software, with particular emphasis on the seismic performance of NFUD-NRB under near-fault ground motions. System-level analysis reveals that bridge systems equipped with NFUD-NRBs exhibit satisfactory residual deformations and higher energy dissipation than those equipped with traditional NRBs. Moreover, NFUD-NRB markedly mitigates the detrimental impacts of near-fault ground motions on the main structure of bridges.

Keywords : partially self-centering behavior, energy dissipation, natural rubber bearing, shape memory alloy, U-shaped damper, numerical investigation, near-fault ground motion
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