STOCHASTIC FINITE MODEL UPDATING OF A UNIDIRECTIONAL ISOLATION BRIDGE UNDER BIDIRECTIONAL EARTHQUAKES

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Abstract

Accurate mechanical characterization of civil engineering structures after construction remains challenging due to the unique complexities of each structure, including geometric configurations, imperfect design modeling assumptions, soil conditions, and pervasive uncertainties in actual operational environments. Leveraging actual measurements, structural health monitoring (SHM) has emerged as a promising approach to validate structural designs, detect changes in structural states, and predict future performance. In seismic isolation bridges, despite the spatial nature of ground motions, a considerable number of bridges in Japan are designed with unidirectional isolation in the longitudinal direction and a fully fixed condition in the transverse direction. Consequently, seismic design and simulations are typically conducted independently in each direction, raising concerns about whether these bridges perform as intended during earthquakes. This study presents a case study of an isolation bridge equipped with a long-term earthquake monitoring system, focusing primarily on its bidirectional seismic behavior, using a unified SHM analysis framework. Data from the January 1, 2024, Noto Peninsula earthquake are analyzed. Following data collection from this event, a simulation-based analysis was conducted to evaluate the validity of the unidirectional design assumptions and identify sources of discrepancies. Subsequently, by modeling the bidirectional nonlinear behaviors of mechanical components contributing to these discrepancies, Bayesian stochastic model updating was employed to address both epistemic and aleatoric uncertainties. Finally, incorporating the updated uncertainties of the bidirectional bridge model and considering varying earthquake intensities, the probability of functional deterioration in future seismic events was predicted.

***Keywords**: Isolation Bridge; Earthquake; Seismic design; Stochastic model updating; Structural health monitoring*