Structural and Pulse coupled seismic design for piers with SMA in near-fault regions : probabilistic assessment of peak demand and residual performance

J. Zhong(1),(2), K. Wang(1), H. Wang(2),*

(1) *Professor, Hefei University of Technology, jzhong@hfut.edu.cn*

(2) *master's student, Hefei University of Technology, 2023110759@mail.hfut.edu.cn*

(3) *Professor, Southeast University, wanghao1980@seu.edu.cn*

Abstract

Post-earthquake residual drift control of reinforced concrete (RC) piers constitutes a critical challenge in the seismic design of near-fault bridges. Superelastic shape memory alloy (SMA) and engineered cementitious composite (ECC) offer novel solutions for enhancing plastic hinge zone performance due to their self-centering characteristics and high ductility. However, previous studies have inadequately evaluated the influence of pulse-like ground motion (PLGM) on SMA-RC designs, neglected the integration of dual seismic response indexes and economic factors, and only qualitatively described the performance of ECC — thereby limiting their practical application in near-fault seismic zones. This study proposes a comprehensive method for balancing peak seismic demand and residual performance and economic efficiency through structure-pulse coupled seismic design, using SMA-ECC hybrid-reinforced piers (SERC) as a case study. First, an artificial neural network (ANN)-driven predictive model correlating structural parameters, pulse characteristics with residual drift is established. Second, a dual-control probabilistic seismic fragility system (considering during-earthquake maximum drift (MD) and post-earthquake residual drift (RD)) is constructed by synthesizing structural parameters, pulse characteristics, response analyses, and capacity evaluations. Finally, a pulse-period-sensitive SMA content optimization function is formulated based on probabilistic seismic hazard integration (PSRCR),incorporating SMA economic indicators. Results demonstrate that SMA-ECC hybrid reinforcement significantly reduces the seismic fragility of piers, with the optimal SMA content exhibiting an initial increase followed by a decrease as the pulse period (T_P) extends. Furthermore, incorporating economic indicators of SMA, an effective range of recommended values is provided to facilitate practical seismic design. This approach offers a streamlined framework for engineers to ensure bridge safety and economic efficiency in near-fault regions.

Keywords: *Residual drift; Machine learning; Repair cost ratio; Pulse-like ground motions*