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SEISMIC MECHANISM AND PERFORMANCE OF EXISTING DOUBLE-COLUMN BRIDGE PIERS RETROFITTED BY ROCKING SELF-CENTERING CONCEPT

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Extended Abstract

Bridges serve as critical hubs and lifeline infrastructures within the transportation system, whose seismic performance and post-earthquake resilience directly determine the efficiency of post-disaster rescue and economic recovery. With the improvement of seismic design philosophies, fortification criteria, and structural detailing requirements for bridges, several highway bridges designed in accordance with the 1989 seismic code fail to meet the current codes. These bridges may exhibit deficiencies, such as insufficient seismic resistance and excessive residual displacements after an earthquake.

At present, most existing retrofitted technologies for improving bridge seismic performance are developed based on ductility-based or seismic isolation theories. Although these methods can enhance structural seismic capacity, they result in poor post-earthquake recoverability, large residual displacements, and difficult post-quake restoration. Therefore, this paper proposes a seismic retrofitted method based on the rocking self-centering concept. By installing additional rocking self-centering piers between existing double-column piers or retrofitting existing double-column bridge piers by rocking columns, the seismic performance and post-earthquake recoverability of existing bridge piers can be effectively improved.

Combining quasi-static tests, numerical simulations, and theoretical analysis, this study investigated the seismic mechanism and performance of existing double-column bridge piers retrofitted by the rocking self-centering concept. The main research contents are outlined as follows:

(1) A seismic retrofitting methodology for existing double-column piers was proposed. Specifically, a rocking self-centering system composed of rocking

columns, unbonded prestressing tendons, and replaceable buckling-restrained dampers is installed between existing double-column piers. Similarly, the existing double-column bridge piers are widened via rocking columns, so as to enhance the seismic performance and post-earthquake recoverability of in-service bridge piers.

(2) Quasi-static tests were conducted on existing double-column bridge piers retrofitted by the rocking self-centering concept. Three specimens were designed, namely the original double-column (D-CIP), the specimen with additional rocking self-centering piers installed between original double-column piers (D-Z), and the specimen of original double-column piers widened by rocking column (D-T). Quasi-static tests were carried out to analyze key seismic indicators, including capacity, hysteretic behavior, energy dissipation capacity, and residual displacement. Experimental results validate the feasibility of the proposed retrofitting concept and reveal the seismic enhancement mechanisms, damage evolution processes, and failure modes of rocking-retrofitted piers.

(3) Finite element analyses were carried out on the original double-column bridge piers and the piers retrofitted by the rocking self-centering concept. The accuracy of the finite element model was verified by experimental results. The influence of key parameters on the seismic performance of retrofitted piers was further analyzed, such as prestress of rocking piers, cross-sectional area of dampers, axial compression ratio, and pier reinforcement ratio. The results show that increasing prestress can reduce the residual displacement of retrofitted piers. Increasing the cross-sectional area of dampers can effectively improve the lateral capacity and energy dissipation.

(4) Based on the failure stages and critical mechanical states of existing double-column bridge piers retrofitted with a rocking self-centering concept, a mechanical analysis model considering the nonlinear mechanical behavior at the contact region of rocking piers is established on the basis of Winkler elastic foundation beam theory. The analytical results derived from the proposed model are in good agreement with experimental data and possess high calculation accuracy, which can provide a theoretical foundation for the seismic retrofitting design of existing double-column piers using the rocking self-centering concept.

Keywords: *Seismic bridge; rocking self-centering; seismic enhancement mechanisms; finite element analysis; mechanical analytical model*