



Seismic performance of railway hollow piers with semi-hinged column-footing connections: Numerical simulation and implementation guidelines

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Abstract

Rounded rectangular hollow tall piers are commonly used in high-speed railway bridges. However, their large sectional dimensions result in oversized capacity-protected members, such as pile foundations, incurring challenges in cost and seismic force control. To address this issue, semi-hinged (SH) column-footing connections have been proposed to reduce the forces transmitted to connecting structural elements and were experimentally compared with the traditional monolithic column-footing connections. Nevertheless, a systematic understanding of key design parameters and a practical seismic design procedure remains insufficiently explored. This study presents a numerical investigation on the seismic behavior of SH bases and provides guidelines for their practical application. Advanced finite element (FE) models of the typical piers with SH connections were developed in ABAQUS and calibrated against experimental data. Seventeen additional SH pier models with different cross-sectional area ratio, mortar bed strength, mortar bed height, and inner longitudinal connection bar ratio were also cyclically analyzed to evaluate the influence of these design parameters on seismic performance. Based on the parametric outcomes, a seismic design procedure for SH piers, in accordance with the capacity protection philosophy, was proposed. The design procedure was split into a simplified explicit force calculation approach and a rigorous cyclic assessment of energy dissipation and ductility capacities. In the force calculation, SH pier designed shears were determined using a strength-reduction factor ($=0.8$) multiplied by the yield capacity of monolithic piers, while the foundation and pile designs do not account for overstrength capacity. A detailed

design example of the SH pier is provided for illustration, indicating that piers designed using this procedure can meet the requirements for both frequent and rare earthquakes. The study not only clarifies the role of critical SH design parameters but also provides a practical and code-compatible design methodology for railway hollow piers in seismic regions.

Keywords: *Railway bridge piers, Semi-hinged connections, Seismic performance, Finite element, Capacity protection*