SEISMIC PERFORMANCE AND RESILIENCE ENHANCEMENT OF STEEL BRIDGE PIERS IN CORROSIVE ENVIRONMENTS

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Extended Abstract

Steel bridge piers are important substructures in highway and railway bridges because they combine high strength, low self-weight, and favorable deformability. However, for piers operating in marine, deicing-salt, industrial, or humid environments, corrosion gradually reduces plate thickness, changes local imperfection patterns, weakens material properties, and accelerates local buckling and fracture during earthquakes. Therefore, their seismic performance and post-earthquake functionality should be evaluated as time-dependent quantities governed by environmental exposure, corrosion morphology, member instability, and system-level traffic demand.

This study investigates the seismic performance deterioration and resilience enhancement of steel bridge piers in corrosive environments. A research framework combining theoretical analysis, refined numerical simulation, and parametric study is developed. The framework covers corrosion modelling of steel materials, deterioration of member behavior, and life-cycle performance assessment and retrofit. The intended application includes both condition assessment of existing piers and durability-informed design of new piers. The main research contents are summarized as follows:

(1) A refined numerical simulation method for corroded steel and a time-dependent seismic assessment theory for steel bridge piers are established. A multi-platform collaborative simulation framework is developed by integrating environmental parameters, evolution of corrosion characteristics, and degradation of material constitutive properties. Based on this framework, the deterioration mechanisms of circular hollow-section and H-shaped steel bridge piers are clarified. The influence of end-region corrosion is emphasized because this region is closely

related to plastic hinge formation and local buckling. The coupled effects of corrosion ratio, corrosion height, and geometric parameters are quantified. Practical prediction methods are proposed for the horizontal ultimate bearing capacity, buckling half-wavelength, and biaxial compression-bending interaction curves considering service time.

(2) A ductility-oriented retrofit technique for corroded steel bridge piers is proposed. To avoid the excessive strength amplification associated with conventional strengthening methods, an embedded contact-type longitudinal stiffener system is developed. The system introduces free-end plates with controllable gaps into conventional stiffeners. Under small to moderate deformation, the retrofit components have limited participation, whereas under large deformation, contact action is activated to compensate for capacity loss induced by corrosion and seismic damage. Thus, the method achieves limited strength increase, significant ductility improvement, and reduced demand transfer to foundations. The enhancement mechanism, failure modes, and effects of key design parameters are identified, and prediction models for ultimate strength and displacement are established.

(3) A multi-level and multi-parameter assessment framework integrating seismic performance and traffic functionality is developed for corroded steel bridge piers. The framework establishes a time-dependent assessment matrix that directly links pier-level displacement damage indices with bridge-level residual vertical bearing capacity and post-earthquake traffic capacity. Five resilience states are defined to describe the coupled structural and functional condition of the bridge system. Parametric analyses are conducted to quantify the effects of corrosive environment, corrosion type, and pier geometry on the residual vertical bearing capacity over the service life, and corresponding prediction formulae are developed for this functional index.

Overall, this study develops a integrated methodology for life-cycle seismic assessment and resilience enhancement of steel bridge piers exposed to corrosion. The proposed corrosion simulation method, strength and stability prediction approaches, ductility-oriented retrofit technique, and performance-function assessment matrix provide theoretical and technical support for safety evaluation, retrofit design, and life-cycle seismic design of steel bridge piers in aggressive environments.

Keywords*: Steel bridge pier; corrosive environment; time-dependent seismic performance; seismic retrofit; ductility enhancement; resilience assessment*