HAZARD-RESISTANT PERFORMANCE OF HIGHWAY GIRDER BRIDGES UNDER EARTHQUAKE–LANDSLIDE CASCADING HAZARDS BASED ON INTEGRATED ANALYTICAL MODEL

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Extended Abstract

Earthquake-induced cascading landslides in geologically complex mountainous regions pose a substantial threat to the structural safety of reinforced concrete (RC) highway bridges. This study carried out the research on the hazard resistance and residual vertical capacity of RC bridges under the cascading hazards of earthquakes and landslides. An integrated analytical framework of RC bridges under the cascading hazards of earthquakes and landslides was first developed. In this analytical framework, the disaster scenario was integrally modelled through two sequential steps based on restart technology to trace the progressive accumulation of plastic damage, to capture the temporally and spatially continuous nature of cascading events. The pile foundation and superstructure were modelled as an integrated system, and SSI was accounted for by combining the direct method with a secondary program to capture systemic progressive failure mechanisms. The pushdown analytical method was employed for the entire post-disaster bridge to assess its overall vertical bearing capacity and quantify its residual vertical bearing load. Subsequently, based on the developed integrated analytical framework, numerical models of a typical RC highway bridge were established to analyse the hazard-resistant performance under cascading hazards. The main conclusions are summarized as follows:

(1) Under single landslide impact, RC highway bridges primarily exhibit a punch-shear failure mode, whereas under earthquake-landslide cascading hazards, the failure mode transitions to local buckling-bending failure. Pre-existing seismic damage significantly alters the subsequent dynamic response of the bridge subjected to landslide impact. Under the single landslide impact scenario, the peak vertical displacement of the girder induced by landslide impact reached 606 mm, whereas the corresponding value under the cascading hazard scenario was 395 mm, representing a difference of 53.4%.

(2) Post-disaster pushdown analyses indicate differences in vertical failure modes under different hazard scenarios. Bridges subjected to a single earthquake mainly exhibit buckling failure, while bridges subjected to a single landslide are dominated by inclined fracture failure. Bridges under cascading earthquake-landslide hazards exhibit a combined inclined fracture and buckling failure mode. In terms of residual vertical bearing load, bridges after cascading hazards show lower values than after single earthquake hazards, but higher than after single landslide hazards. Specifically, the peak vertical loads following the disaster for models subjected only to seismic effects, only to landslide effects, and to combined seismic and landslide effects were 151.6 MN, 49.2 MN, and 75.4 MN, respectively.

(3) Parameter analysis indicates that landslide-dependent parameters—particularly the impact angle—have a significant influence on the dynamic response of bridges under cascading hazards. As the landslide impact angle increases, the vertical displacement response of the pier cap increases significantly. The peak impact force also shows an increasing trend as the angle of the landslide impact increases. Specifically, when the impact angle increases from 15° to 45°, the peak impact force rises from 3170 kN to 5719 kN (with an intermediate value of 3917 kN at 30°), representing an 80.4% increase. Composite failure modes involving inclined fracture and buckling dominate in pushdown analysis; however, an increase in the relative impact angle results in a critical shift in the dominant failure mechanism, leading to significant out-of-plane instability.

Keywords: *Highway girder bridge; Hazard-resistant performance; Earthquake–landslide cascading hazards; Residual vertical load-bearing; Integrated analysis.*