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Seismic Fragility Assessment of Continuous Integral Bridge Frames with Variable Expansion Joint Clearances

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Abstract : Fragility analysis is an effective tool for the seismic vulnerability assessment of civil structures in the last several years. The design of the expansion joints according to various bridge design codes is almost inconsistent, and only a few studies have focused on this problem so far. In this study, the influence of the expansion joint clearances between the girder ends and the abutment backwalls on the seismic fragility assessment of continuous integral bridge frames is investigated. The gaps (ranging from 60 mm, 150 mm, 250 mm and 350 mm) are designed by following two different bridge design code specifications, namely, Caltrans and Eurocode 8-2. Five bridge models are analyzed and compared. The first bridge model serves as a reference. This model uses three-dimensional reinforced concrete fiber beam-column elements with simplified supports at both ends of the girder. The other four models also employ reinforced concrete fiber beam-column elements but include the abutment backfill stiffness and four different gap values. The nonlinear time history analysis is performed. The artificial ground motion sets, which have the peak ground accelerations (PGAs) ranging from 0.1 g to 1.0 g with an increment of 0.05 g, are taken as input. The soil-structure interaction and the P-Δ effects are also included in the analysis. The component fragility curves in terms of the curvature ductility demand to the capacity ratio of the piers and the displacement demand to the capacity ratio of the abutment sliding bearings are established and compared. The system fragility curves are then obtained by combining the component fragility curves. Our results show that in the component fragility analysis, the reference bridge model exhibits a severe vulnerability compared to that of other sophisticated bridge models for all damage states. In the system fragility analysis, the reference curves illustrate a smaller damage probability in the earlier PGA ranges for the first three damage states, they then show a higher fragility compared to other curves in the larger PGA levels. In the fourth damage state, the reference curve has the smallest vulnerability. In both the component and the system fragility analysis, the same trend is found that the bridge models with smaller clearances exhibit a smaller fragility compared to that with larger openings. However, the bridge model with a maximum clearance still induces a minimum pounding force effect.

Keywords : expansion joint clearance, fiber beam-column element, fragility assessment, time history analysis
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