GAUSSIAN PROCESS REGRESSION DRIVEN RAPID LIFE-CYCLE BASED SEISMIC FRAGILITY AND RISK ASSESSMENT OF LAMINATED RUBBER BEARINGS SUPPORTED HIGHWAY BRIDGES SUBJECTED TO MULTIPLE UNCERTAINTY SOURCES

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Extended Abstract

Bridges exposed to natural environments are affected by various deterioration factors during their service life, prompting heightened concerns regarding the potential time-dependent reduction in durability. For reinforced concrete (RC) highway bridges implemented with laminated rubber bearings (LRBs), the accurate assessment of seismic performance is affected by several main factors: structural attributes, corrosion of steel rebars in RC columns, thermal oxidative aging of inherent rubber in the LRBs, the replacement of LRBs, and the time-dependent seismic hazard level at the bridge site. Although log-space linear regression is a common method for estimating fragility curves, the probabilistic seismic demand model (PSDM) and probabilistic structural capacity model (PSCM) of deteriorated bridge components may not exhibit homoscedastic log-linearity. Furthermore, expanding seismic fragility surfaces and seismic risk curves in the temporal dimension requires a considerable computational cost due to the extensive nonlinear analyses involved, which has not been well addressed in current studies.

To fill this gap, this study proposes a life-cycle based seismic fragility and risk assessment framework for LRBs supported RC bridges, as shown in Figure 1. The proposed methodology accounts for multiple uncertainties, including the deterioration mechanisms of bridge components during their life cycles and the replacement intervals for LRBs. The core innovation of this framework is the application of Gaussian process regression (GPR), a nonparametric machine learning algorithm, to effectively construct the PSDM and PSCM of deteriorated bridge components. By avoiding simplified assumptions like homoscedasticity, GPR is able to capture the nonlinearity and heteroscedasticity characteristics inherent in the demand and capacity estimates.

Within this framework, time-dependent seismic fragility surfaces are established for both the bridge components and the overall bridge system. Following this, a life-cycle based seismic risk analysis is conducted based on a non-homogeneous Poisson process to quantify the coupled time-dependent effects of structural deterioration and site seismic hazards. This probabilistic method is capable of assessing the seismic risk on both a newly built bridge over its design service life and a deteriorated bridge for its remaining service life.

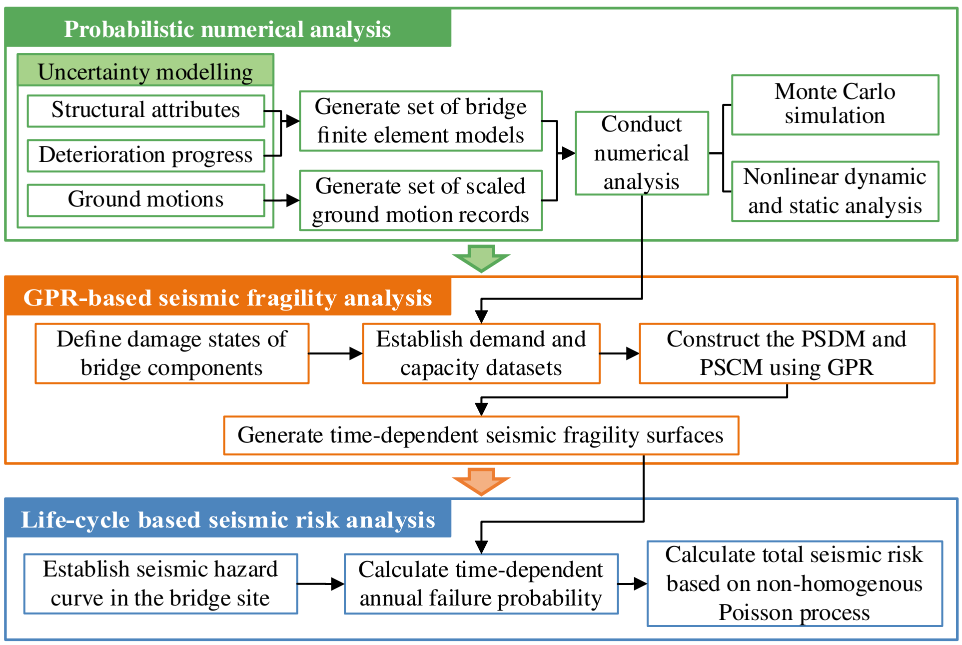

Figure 1- Details of the proposed life-cycle-based seismic fragility and risk assessment framework.

To exemplify the proposed framework, a typical three-span LRBs supported highway bridge located in a coastal region was selected as a case study. The probabilistic numerical analysis incorporated uncertainties related to structural geometry, material properties, deck mass, structural damping, ground motions, and deterioration progress sourced from material degradation and LRB replacement.

The results of the study indicate that utilizing GPR leads to a significantly reduced number of nonlinear analysis cases required to generate time-dependent seismic fragility surfaces and seismic risk curves. Consequently, the proposed framework substantially improves the accuracy and efficiency of life-cycle based seismic

performance assessments when uncertainties of structural attributes, deterioration progress, and seismic hazards are taken into consideration.

Keywords*: Gaussian process regression; Seismic fragility and seismic risk; Reinforced concrete bridge; Laminated rubber bearing; Multiple uncertainties.*