Influence of Design Practices and Climate Change Effects on the Seismic Fragility and Life-Cycle Cost of Highway Bridges

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Abstract

Over the past several decades seismic design practices of highway bridges have undergone a considerable change from typical non-seismic design to adoption of modern ductile detailing principles. Despite such advances in structural design, bridge structures around the globe continue to be exposed to deteriorating agents from the surrounding atmosphere. The ill effects of these environmental stressors are likely to be further compounded from potential climate change scenarios as the bridge continues to age along the service life. For bridges across different design era that are exposed to unfavorable environmental conditions, climate change settings, and simultaneously situated in moderate to high seismic zones, a renewed systematic assessment of seismic fragility and life-cycle cost is required. These estimates will facilitate informed decision making and efficient channeling of monetary resources for structural upgrade and repair. In this context, the present study proposes a novel framework to compare the lifetime seismic losses of highway bridges considering earthquakes hazard, seismic design era, aging effects, and global warming due to climate change. The proposed framework is demonstrated on a non-seismically designed case-study multi-span continuous (MSC) concrete girder bridges located within Central and Southeastern United States. This bridge comprises of multiple bridge components that are also prone to the adverse effects of environmental degradation. Results reveal substantial deviation in lifetime seismic losses and fragility when expected future climate changes are neglected.

Keywords: Seismic life-cycle cost analysis; seismic fragility; chloride-induced deterioration; climate change effects; climate change projections.

1 Introduction

Refurbishment, maintenance, construction, repair, and replacement decisions for civil infrastructure systems may have an impact for up to 200 years. Therefore, it is imperative to consider future climatic circumstances while making decisions on building upkeep or during the design stage, as well as the related financial commitments. This may be primarily attributed to the long-term passive effects of climate change on the performance of reinforced concrete (RC) structures (Wang et al. 2010, Stewart et al. 2011). In light of the aforementioned findings, modern researchers, including TRB (2014), Dong & Frangopol (2016), Frangopol et al. (2017), and Li et al. (2020), among others, investigate frameworks to assess the economic loss costs of highway bridges under multiple hazards that take climate change effects into account. Recently, Mortagi & Ghosh (2020) explained how important it is to take climate change into account when developing ageing

https://doi.org/10.2749/newdelhi.2023.0257

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