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SEISMIC FRAGILITY ASSESSMENT OF CURVED STEEL BOX-GIRDER BRIDGES

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Bridges are one of the most important and vulnerable components of any transportation system in the world of today. Curved box-girder bridges are a common type of highway bridges, which are usually constructed at an interchange that allow traffic to move from one highway to another. The generation of vulnerability functions in the form of fragility curves is a common approach for assessing bridges seismic vulnerability. The current study presents the effect of geometric parameters such as horizontal curvature, and column height on the seismic response and fragility of curved multi-frame steel box girder bridges. The model is used to perform a set of nonlinear incremental dynamic analyses for a ground motion suite to compute the fragility function of components and system. Moreover, multiple levels of each geometric parameter are determined to identify the effect of geometry. Median value modification factors are proposed to scale fragility curves to account for the deck radius effects. Although the curved superstructure can be very effective in resisting seismic loading (increase in the overall lateral stiffness), the inherent eccentricity between centers of mass and stiffness in the bridges causes increased in-plan rotation of the superstructure in comparison to a comparable straight bridge. Parametric studies on the seismic response of curved bridges have been conducted by several researchers (Abdel-Salam & Heins, 1988; Linzell & Nadakuditi, 2011; Wu & Najjar, 2007). Their results indicate that the radius of curvature had the most significant impact on the seismic performance of curved steel I-girder bridges. Additionally, a few studies have been recently carried out for developing seismic fragility curves of horizontally curved steel I-girder bridges (AmiriHormozaki et al., 2015; Minavand & Ghafory-Ashtiany, 2019; Seo & Linzell, 2012). Figure 1 illustrates analytical models of the bridge components. Iranian bridges have different pier types such as hammerhead piers, single, and multicolumn rigid frame piers or bents. Multicolumn bents are the most common type based on an in-depth review of bridge plans for the bridge classes considered in this study. Because the deck is assumed to remain elastic during seismic excitations, linear elastic beam-column elements are assigned to it. The bridge curvature has been shown to increase coupled longitudinal and transverse responses; therefore, the spine model with lumped masses along longitudinal centerline of the bridge may not capture real response. Consequently, this deficiency is resolved by distributing the mass in the transverse direction along rigid elements. To capture the spread of plasticity in the column elements, columns are modeled with fiber sections assigned to nonlinear beam-column elements, with constitutive models assigned to each fiber for steel and concrete with the same confinement. Rigid links are then used to connect the columns to the deck to transfer moments and forces. Reinforcing steel is modeled code material provided by OpenSEES which uses the Menegotto and Pinto (Lupoi et al., 2006) model to include isotropic strain hardening. Finally, fragility curves are assessed based on HAZUS concepts. It is concluded from Table 1 that the median value of the fragilities for a curved multiframe box-girder bridge at the complete damage state is 28, 33, 42, 48, and 57% of those for straight bridges with bridge radii of 0.5, 1, 1.5, 2, and 3L, respectively, in which L is the bridge length. However, applying these modification factors may not be consistent with the bridges fragility trend for various bridge types, leading to an underestimate or overestimate in the fragility median values.

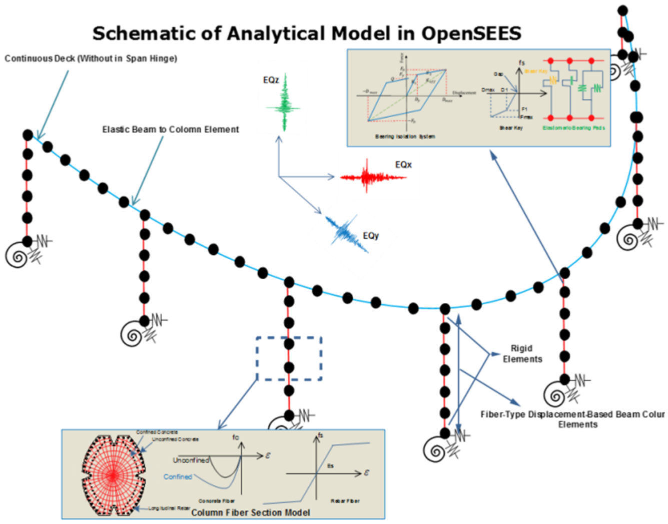

Figure 1. Schematic of Analytical Model of curved Bridge in Opensees.

Table 1. Fragility Median Value Modification Factors for Curved Multiframe Steel Box-Girder Bridges.

Limit states	**Radius**					
	0.5 L	L	1.5 L	2 L	3 L	Straight
Slight	0.48	0.59	0.63	0.68	0.75	1.00
Moderate	0.42	0.44	0.54	0.57	0.66	1.00
Extensive	0.32	0.33	0.42	0.48	0.59	1.00
Complete	*0.28*	*0.33*	*0.42*	*0.48*	*0.57*	*1.00*

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