ABSTRACT

Bridges, as the principal elements of a highway transportation system, play a vital role in reducing traffic congestion. Understanding the seismic performance of highway bridges is imperative for maintaining a reliable and efficient transportation network. Earthquake vulnerability is one of the major factors threatening the functionality of highway bridges, particularly the ones located in high-risk seismic zones. The experience of recent earthquakes (e.g., Northridge earthquake in 1994, Kobe earthquake in 1995, and Chile earthquake in 2010) revealed that bridges, with geometric irregularities or inconsistencies in configuration, have a higher probability of damage in comparison with the regular, straight bridges. Although previous studies have explored the seismic analysis of different types of bridges, there is a lack of research concentrating on the effect of various types of geometric irregularities on the seismic response of the bridges. This study aims to address this deficiency by focusing on the effect of skew angle, as a geometric irregularity, on the seismic response of a bridge, and to propose a simplified approach for seismic response evaluation of skewed bridges.

Skewed bridges are commonly constructed in response to complex geometric constraints that necessitate using skew-angled abutments. As a result, the eccentric passive resistance of the abutment backfill initiates and promotes the in-plane rotation of superstructure’s deck and ultimately causes the unseating of the superstructure leading the skewed bridge to collapse. The post-earthquake investigation of skewed bridges showed serious damage caused by displacement or unseating of the bridge deck. Several research efforts evaluated the seismic response of skewed bridges. Although these studies indicated that the class of skewed bridges experiences larger demands including column forces and larger deck displacement, they are limited to specific case studies on failed bridges and they considered a single bridge model. This research study concentrates on developing a simplified approach for taking into account the effect of skew on estimating the seismic response of bridges.

As a case study, a typical two-span, single-frame, concrete box-girder bridge designed in post-1990 design era was selected to illustrate the approach. Deterministic parameters (Ramanathan, 2012) were selected for the numerical modeling. For an accurate numerical analysis, three-dimensional model of the bridge was developed in OpenSees. The incorporation of skew into the analytical modeling of straight bridges necessitates various modifications including recently developed modeling procedures based on the experimental and numerical studies of (Shamsabadi & Rollins, 2014) and (Kaviani, Zareian, & Taciroglu, 2012). Nonlinear Time History Analysis (NLTHA) was performed on the selected bridge with skew angles of 0° (straight), 15° (low), 30° (medium), 45° (high), and 60° (very high), and using the Baker’s suite of 160 ground motions. The results of this analysis provide the peak seismic response of each of the components of a bridge. The peak responses are commonly used to develop probabilistic seismic demand models (PSDMs) which are regression models expressing the relationship between the

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seismic demands and the ground motion intensities. In this study, $S_{a,1.0}$s (i.e., the spectral acceleration at 1.0 second) was chosen as the measure of the ground motion intensity since it is the optimal intensity measure for the box-girder bridges. Based on this regression models, the median value of the seismic demand can be estimated for specific ground motion intensities. This study provides a simplified approach using a mathematical optimization algorithm to derive a general form of PSDMs for the skewed bridge. This general form provides a decent approximation of the median responses of the bridge for any desired skew angles within the range of low to very high (0° to 60°).

The results of this study indicate that the responses of skewed bridges are prominently governed by the skew angle, and the presented approach provides an estimation of the seismic demand model of a bridge by taking the effect of skew angle into account. Moreover, comparison of the fragility curves indicates that the probability of exceeding a damage state is increasing along with the skew angle.

REFERENCES


Ramanathan, K. N. (2012). Next generation seismic fragility curves for California bridges incorporating the evolution in seismic design philosophy.
