Engineering Structures 33 (2011) 696–705

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Fragility analysis of track-on steel-plate-girder railway bridges in Korea

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ARTICLE INFO

Article history:
Received 12 March 2009
Received in revised form
27 September 2010
Accepted 29 September 2010
Available online 27 October 2010

Keywords:
Track-on steel-plate-girder bridges
Railway bridges
Seismic risk
Fragility curves

ABSTRACT

More than 40% of the bridges in conventional Korean railway lines are track-on steel-plate-girder (TOSPG) bridges. They are characterized by a superstructure consisting of railway tracks sitting directly on steel plate girders without any ballast system. Most of these bridges have been designed with little or no consideration given to seismic loading. In this paper, seismic fragility curves of TOSPG bridges in Korea are developed. Fragility curves are developed first for the components, by using the probabilistic seismic demand model. The developed component fragility curves show that the bearings are the most vulnerable components of the TOSPG bridges against seismic loading. On the other hand, the piers are much less vulnerable, although they contain no reinforcing bars. This is because the superstructure mass is very light, and therefore horizontal loading transferred from the superstructure to the piers is minimal. A generic damage measure is introduced for measuring the system-level damage of structures out of the component-level damages. The system fragility curves are then developed, using the generic damage measure. Finally, representation of seismic risk in terms of expected seismic losses is demonstrated. This demonstration shows how the fragility analysis is utilized for risk assessment and support in decision-making.

1. Introduction

Ensuring the seismic resistance of railway bridges is an important issue for a transportation network, because the loss of functionality of railway bridges could result in severe disruption of the railway line, as no redundant routing systems generally exist. Therefore, the seismic performance of railway bridges should be focused on minimizing the time required for restoration of the functions after a seismic event.

Seismic design or retrofitting of a structure requires the determination of a target seismic resistance level of the structure. The target seismic resistance level for the design of a new structure is, in general, determined such that it complies with current seismic codes. For seismic retrofitting of an existing structure, however, it would be rational to determine the target resistance level, considering both future seismic losses expected for a specified time period and the cost required for the retrofitting. The expected future seismic losses can be obtained from a risk analysis that considers both the frequency and consequences (i.e., damage or losses) of the seismic events associated with the structure. In regions of low to moderate seismicity, the frequency of significant seismic events is relatively low. On the other hand, structural systems in these regions tend to be less prepared against seismic loading, and therefore the severity of potential seismic consequences in these regions would be greater than those in regions of high seismicity. The overall risk, considering both the frequency and the consequences, can be obtained from a seismic risk analysis and used as a basis for making decisions on seismic design or structural retrofitting. Fragility analysis could be effectively used for seismic risk assessment of structures because it provides the probability-based information for seismic damage of the structures, which allows seismic loss estimation and decision making for seismic risk reduction [1].

Track-on steel-plate-girder (TOSPG) bridges are some of the most common structural types of bridges in conventional Korean railway lines (as opposed to high-speed railway lines). According to the inventory analysis [2], more than 40% of the bridges in conventional Korean railway lines are TOSPG bridges. Most of these bridges were constructed prior to the 1970s and therefore were designed with little or no consideration for seismic loading. TOSPG railway bridges are characterized by a superstructure consisting of railway tracks sitting directly on the steel plate girders without any ballast system (Fig. 1). In addition, almost all the TOSPG railway bridges in Korea have gravity-type concrete piers with no reinforcing bars. These characteristics make TOSPG bridges distinct not only from highway bridges but also from other types of railway bridges.

As mentioned earlier, TOSPG railway bridges in Korea are designed typically without consideration of seismic loading. In

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doi:10.1016/j.engstruct.2010.09.028