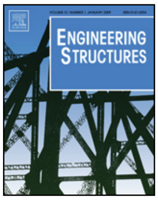
Engineering Structures 33 (2011) 786–795

Contents lists available at ScienceDirect

Engineering Structures

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



A design method for seismically isolated bridges with abutment restraint

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ARTICLE INFO

Article history:
Received 2 July 2010
Received in revised form
24 September 2010
Accepted 1 December 2010
Available online 6 January 2011

Keywords:
Seismic isolation of bridges
Transverse seismic response
Partial restraint
Visco-elastic model

ABSTRACT

Seismic isolation is a commonly used technique for protecting new and existing bridges. It usually consists of introducing isolation bearings between the superstructure and the substructures in order to decouple their motion and reduce the force demand due to the earthquake action. This paper deals with partially restrained seismically isolated continuous bridges, which are a particular class of isolated bridges whose transverse motion is restrained at the abutments.

In this study a method is proposed for the preliminary design of these systems, which can be applied to both new and existing bridges. The dynamic problem is described in a variational form in order to obtain a simplified solution based on a pre-fixed transverse deformed shape of the deck. The objective of the design procedure is to control the internal actions on the piers by means of an appropriate configuration of the isolation bearings. Simple formulas for estimating the forces transmitted to the abutments and the superstructure transverse curvature demand are also derived, which account for the contribution of higher modes of vibration.

Validation studies are undertaken for different bridge configurations, in order to assess the ability of the simplified method to control the force demand at the piers.

1. Introduction

In the last three decades the introduction of seismic isolation devices between the superstructure and substructures has become a widely used tool for the protection and retrofit of bridges in seismic areas [1,2]. The basic aims of the seismic isolation of bridges are (a) decoupling the movement of the substructures from that of the superstructure, (b) increasing the fundamental period of the bridge and thus shifting the fundamental frequency of vibration to a range where the energy content of the earthquake is reduced and (c) providing additional sources of damping. There are however some drawbacks to using isolation bearings on pier and abutment tops. In some situations, the period shift due to isolation may lead to excessive displacements of the deck. Moreover, bridge isolation requires the use of expensive bidirectional joints at the abutments in order to accommodate superstructure displacements. These aspects may lead to the choice of restraining the transverse motion of the superstructure at the abutments, in both seismically isolated [1,3–5] and non-isolated bridges [6–8]. The seismic response of isolated bridges with transverse restraint at abutments, also called "partially restrained seismically isolated" (PRSI) bridges in [5], is significantly different from that of fully isolated bridges, with isolation bearings placed both at the piers and abutments. In PRSI bridges, two different load paths may be identified under transverse seismic excitation. The first path involves the abutments and superstructure, which under inertia forces shows significant bending, while the second path involves the piers/bearings system. The assumption of rigid displacement of the superstructure, which simplifies the design of fully isolated bridges, is not applicable to the case of PRSI bridges. Moreover, the period elongation effect may at times be limited in partial isolation. In fact, an upper bound to the fundamental period of vibration is given by the fundamental period of the superstructure free to move at the piers, which behaves as a beam simply supported at the abutments. Furthermore, in the case of dissipative isolation bearings, the global dissipation capacity of PRSI bridges may be reduced as a result of the strain energy contribution due to deck elastic deformation. This structural solution is however often adopted thanks to its capability to involve the highest number of substructures in resisting the inertia forces and to avoid the use of expensive bidirectional joints at the abutments.

To date, many simplified models and procedures have been proposed for the analysis and design of fully isolated bridges [6,9,10]. These methods are mainly based on a rigid behaviour of the superstructure in the transverse direction, which usually yields the same isolator characteristics in the case of piers with equal height. In PRSI bridges, however, the deck shows a bending deformation in the transverse direction so that the rigid model

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0141-0296/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2010.12.002