Engineering Structures 33 (2011) 2861–2869

Contents lists available at ScienceDirect

Engineering Structures

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

Testing and long-term monitoring of a curved concrete box girder bridge

Hugo C. Gomez [a,*], Paul J. Fanning [b,1], Maria Q. Feng [a,2], Sungchil Lee [a]

[a] *Department of Civil & Environmental Engineering, University of California-Irvine, Irvine, CA 92697-2175, USA*
[b] *School of Architecture Landscape & Civil Engineering, Newstead Building, Belfield, University College Dublin, Ireland*

ARTICLE INFO

Article history:
Received 18 August 2010
Received in revised form
16 February 2011
Accepted 25 May 2011
Available online 7 July 2011

Keywords:
Bridge
Test vehicle
Natural frequencies
Long-term monitoring
System identification
Ambient vibration
Curved concrete box girder

ABSTRACT

Capital investment in national infrastructure is significant. The need to maintain and protect critical infrastructure links has led in recent years to significant developments in the area of structural health monitoring. The objective is to track a structure's long-term performance, typically using sensors, and to successively compare the most recently measured responses with prior response history. During construction of the West Street On-Ramp, a curved concrete box girder bridge, located in the city of Anaheim (California), eleven accelerometers were permanently installed on its bridge deck. The associated data acquisition system was configured to record once a specified threshold acceleration response was exceeded; during the period 2002–2010 a total of 1350 datasets including six earthquakes, for each of the eleven sensors, were acquired. This automatically acquired data was supplemented, during the summer of 2009, with responses measured during controlled vehicle tests. Six accelerometers were additionally installed on the frame of the weighed test vehicle. This paper presents the findings of the analyses of these measured data sets and serves to inform owners and managers as to the potential feedback from their instrumentation investment. All response histories were analyzed using frequency domain techniques for system identification. Extraction of the modal characteristics revealed a continuous reduction, of approximately 5%, in the first three natural frequencies over the period of the study. The measured responses from the vehicle sensors are discussed in the context of identifying the potential for bridge frequency measurement using instrumented vehicles.

1. Introduction

Long-term continuous monitoring programs are increasingly used to track structural integrity and to identify at what time, if any, structural intervention might be required. The timely undertaking of combined preventative and essential maintenance strategies results in reduced total life cycle costs [1]. Additionally, Orcesi et al. [2] argue that coupling traditional life-cycle management techniques with structural health monitoring will enable even more accurate identification of optimum maintenance strategies for a range of limit states. Long-term continuous or intermittent monitoring provides the best method for understanding and quantifying the actual loading environment and corresponding bridge responses [3].

Long-term monitoring programs serve different objectives and take different forms. Refs. [4–6] are review papers which define the ultimate goal of structural health monitoring as damage detection. A significant body of literature discusses shifts in natural frequencies and attempts to link these to various structural deterioration mechanisms. Specifically in the area of bridges Choi et al. [7] and Guan et al. [8] discuss the variation in natural frequencies detected from vibration data measured during a 2-year period. Soyoz and Feng [9] reported a 5% decrease in the frequency of the first mode of vibration for a bridge over a 5-year monitoring period. Salawu [10] and Farrar et al. [11] discuss the variability of modal parameters due to environmental effects such as changes in temperature, humidity, amount of traffic, etc. and other researchers have studied the deterioration of bridge decks with special emphasis on the contribution of reinforcement corrosion [12–16].

In long-term monitoring practice, bridge vibration response time-histories are extensively used to extract modal parameters, i.e. natural frequencies, modal shapes and damping ratios. The advent of output only system identification algorithms has enabled modal parameters to be extracted from ambient responses without knowledge of the excitation force [17]. Both time domain and frequency domain output-only system identification algorithms are available; frequency domain algorithms are more popular due to their simplicity [18]. The frequency domain decomposition (FDD) technique [19] has since been widely used for system identification of bridges [9,20–23].

---

[*] Corresponding author. Tel.: +1 949 300 4079.
E-mail addresses: gomezh@uci.edu (H.C. Gomez), paul.fanning@ucd.ie (P.J. Fanning), mfeng@uci.edu (M.Q. Feng), sungcl@uci.edu (S. Lee).

[1] Tel.: +353 1 716 7777x3220.

[2] Present address: The Henry Samueli School of Engineering, University of California-Irvine, Irvine, CA 92697-2175, USA. Tel.: +1 949 378 8666.

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.05.026