Engineering Structures 33 (2011) 1267–1276

Contents lists available at ScienceDirect

Engineering Structures

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

Load rating of concrete-deck-on-steel-stringer bridges using field-calibrated 2D-grid models

Ahmet Turer [a,*], Bahram M. Shahrooz [b]

[a] Civil Engineering Department, Structural Mechanics Lab., Middle East Technical University, 06531 Ankara, Turkey

[b] Department of Civil and Environmental Engineering, University of Cincinnati, 765C Baldwin Hall, OH 45221, USA

ARTICLE INFO

Article history:
Received 18 August 2009
Received in revised form
5 January 2011
Accepted 6 January 2011
Available online 7 February 2011

Keywords:
Bridge
Rating
Modeling
Calibration

ABSTRACT

This paper presents and discusses issues related to structural identification, calibrated model-based load rating, and sensitivity of rating to the analytical model, along with experimental studies conducted on an existing concrete-deck-on-steel-stringer bridge. The proposed model-updating procedure uses collected dynamic data (mode shapes, modal frequencies, and order of modes) as well as static deformed shape information. Two-dimensional (2D) grid models were developed to successfully simulate the transverse load transfer mechanisms between girders, torsional flexibility, and effects of skewed bridge architecture. The rating results obtained from the 2D-grid models were close to 3D-FEM-based evaluation, while simplified 1D bar models had serious shortcomings. Grouping the parameters of the analytical model at different stages of model calibration enhanced the speed and convergence success of the objective function. Although cross-braces are considered as non-structural members, they have been found to be the most critical members of the selected bridge during rating studies. Failure of cross-braces deemed to alter the load transfer mechanism between girders and possibly resulting in the premature failures of interior girders.

1. Introduction

Bridges are potentially the weakest links of a healthy transportation system. According to 2005 bridge inventory statistics in USA, about one quarter of all bridges (156,177 bridges out of 594,616 nationwide) [1] are structurally deficient and/or functionally absolute, while USA can be considered as one of the relatively good examples regarding bridge safety considering other countries around the globe. As recent unfortunate bridge collapses have bitterly reminded the society, evaluation and categorization of the bridge conditions is a major task and should be given high importance (e.g. I-35W Mississippi River bridge in Minnesota, August 1, 2007 [2] and Harp Road bridge Oakville, Washington, 15 August 2007 [3,4]). Large numbers of bridges often times make the evaluation and categorization process an unmanageable task. Visual inspection methods have known shortcomings such as visual limitations, indirect and often uncertain correlation between appearance and actual structural condition, subjectivity of the evaluator due to his/her level of experience, variations in the mood—personal emotional state of the evaluator affecting the evaluation, and even weather conditions during bridge evaluation. Therefore, a robust and objective evaluation method is needed to assess the existing condition of bridges, which would preferably be based on field measured objective data and adequate level of analytical modeling. The field-calibrated analytical model-based objective load rating of bridges would not only eliminate false negative and false positive errors – such as identifying a healthy bridge as deficient, or a deficient bridge as healthy – but also allows bridge engineers to conduct correct ordering and prioritization of bridges that need repair work and strengthening. Different aspects of bridge load rating have been studied in the past [5], including time dependency, reliability, and probabilistic approaches [6,7]. This paper discusses general concepts on field-calibrated analytical model-based load rating, putting emphasis on different levels of analytical modeling (1D, 2D, 3D models) on the load rating sensitivity. An overview of load rating methods is presented and implementation is shown using an actual sample bridge.

1.1. Overview of bridge load rating

Bridge load rating utilizes a normalized unitless value which quantifies the remaining capacity of a bridge, after its self-weight, in terms of standard live loads. Dynamic impact factors and different load factors are used during rating. The standard truck

* Corresponding author. Tel.: +90 312 210 5419; fax: +90 312 210 7991; GSM: +90 533 655 7665.

E-mail addresses: aturer@metu.edu.tr (A. Turer), shahrobm@ucmail.uc.edu (B.M. Shahrooz).

URL: http://www.ce.metu.edu.tr/~aturer/ (A. Turer).

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.01.004