Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 156 (2016) 140 – 147

Procedia Engineering

www.elsevier.com/locate/procedia

9th International Conference „Bridges in Danube Basin 2016“, BDB 2016

Probabilistic modelling of bridge safety based on damage indicators

Barbara Heitner[a,b]*, Eugene J. OBrien[b], Franck Schoefs[c], Thierry Yalamas[a], Rodrigue Décatoire[a], Cathal Leahy[d]

[a]Phimeca Engineering, 34 Rue Sarlieve, Cournon-d'Auvergne, 63100, France
[b]School of Civil Engineering, University College Dublin, Newstead, Belfield, Dublin 4, Ireland
[c]Research Institute of Civil Engineering and Mechanics, Université de Nantes, 1 Rue de la Noë BP 92101, 44321, Nantes cedex 3, France
[d]Roughan O'Donovan Innovative Solutions, Arena House, Arena Road, Sandyford, Dublin 18, Ireland

Abstract

This paper introduces the various aspects of bridge safety models. It combines the different models of load and resistance involving both deterministic and stochastic variables. The actual safety, i.e. the probability of failure, is calculated using Monte Carlo simulation and accounting for localized damage of the bridge. A possible damage indicator is also presented in the paper and the usefulness of updating the developed bridge safety model, with regards to the damage indicator, is examined.

Peer-review under responsibility of the organizing committee of BDB 2016

Keywords: Reliability; Safety; Bridges; Probabilistic; Bayesian Updating; Damage Indicator

1. Introduction

Probabilistic assessment of bridges has been the subject of various studies in recent decades [1][2][3][4]. It has been widely accepted that evaluating an existing bridge according to the standards and codes used for new structures can lead to unnecessary demolition or repair, and thus to high economic cost and an increase in the associated environmental impact. Using a probabilistic way and understanding the realistic risks related to the state of the bridge helps to avoid unnecessary costs and emissions. Nevertheless, decreasing the level of uncertainty is beneficial and so in the present paper a probabilistic model is presented that incorporates data, which can be obtained through bridge monitoring.

* Corresponding author. Tel.: +33789044595.
E-mail address: heitner@phimeca.com

Peer-review under responsibility of the organizing committee of BDB 2016
doi:10.1016/j.proeng.2016.08.279

1.1. Bridge Safety models

In several studies in the literature, researchers developed a complete or partial bridge safety model based on probabilistic assessment of load and/or resistance. The main focus of these studies however varies widely. Rocha et al. [1] focus on the safety assessment of short span railway bridges for identifying critical train speeds and the associated probability of failure. Hajializadeh et al. [2] primarily study the effect of spatial correlation of both load and resistance on the probability of failure of concrete road bridges. The principal aim in Zhou et al. [3] is to quantify the effect of projected traffic growth on the time-dependent reliability of a reinforced concrete (RC) bridge, accounting for structural deterioration caused by chloride induced corrosion. Marsh & Frangopol [4] also concentrate on the deterioration model of an RC bridge deck but improve the model by incorporating corrosion rate sensor data.

These works can also be distinguished through the simplifications, idealizations and the application levels. In the present work both load and resistance of a one-directional (single lane) bridge are modelled in a probabilistic context, accounting for localized damage and the bridge safety is found by combining them and calculating the probability of load exceeding capacity. The structural model of the bridge is greatly simplified and loads other than dead and traffic loads are ignored, since the emphasis is placed on the probabilistic assessment, the introduction of damage and the global methodology.

1.2. Bayesian updating

Bayesian updating is a powerful technique for combining a probabilistic model with a limited volume of information from measurement to enhance the existing model. It has already been used for several different problems in the field of structural engineering, such as for estimating bridge characteristic load effects [5], for prediction of the effects of corrosion on RC beam bearing capacity [6] or for updating either fatigue reliability of steel structures [7] or degradation of RC structures [8] using non-destructive test data. In the framework of this paper, a simple deflection-based damage indicator (DI) will be used as the measurement data for updating the bridge safety model and thus for obtaining a better measure of the actual condition of the studied RC bridge. It is acknowledged that more realistic damage indicators exist – deflection is used here simply to demonstrate the concept.

2. Initial bridge safety model

2.1. Resistance model

The resistance of the bridge is defined as the bending moment capacity of an RC deck cross-section. This resistance is calculated using both deterministic and random variables for the geometric, concrete and steel reinforcement properties. The incorporated random variables (explained in section 4) and their descriptions have been taken from the literature [9][10][11][12]. The bridge is represented by a simplified 1D beam model. Spatial variability is not accounted for along the length of the beam, however localized damage is introduced.

2.2. Dead load model

As for the resistance, the dead load model incorporates random variables that can be defined according to findings reported in the literature (e.g. after Akgül [13]). It accounts for the weight of concrete and the surface asphalt layer. Other bridge equipment is not taken into account as the corresponding load and its variation are relatively small. It can also be noted here that other loads, such as wind, thermal and seismic, are not considered in the current study.