System Identification and Finite Element Model Updating of a Multi-Span Railway Bridge with Uncertain Boundary Conditions

Mathias Torp, Jakob Braaten Johnsen, Emrah Erduran

Dept. of Civil Engineering and Energy Technology, Oslo Metropolitan University, Norway

Contact: emrah.erduran@oslomet.no

Abstract

This study presents the implementation of a sensitivity-based finite element model updating process on a 48.6 m long, multi-span, reinforced concrete railway bridge located in Stange, Norway. Lack of documentation and uncertainties surrounding the boundary conditions combined with unrealistic dynamic response obtained from dynamic analysis using a finite element model based on the design drawings prompted the need for monitoring of the vibrations on the bridge followed by identification of modal properties and development of an updated finite element model which can more accurately represent the as-built structure.

For this purpose, the railway bridge was instrumented and vibration data from operational conditions was collected. Using the covariance- driven stochastic subspace identification method, the modal properties of the bridge were identified from the recorded vibrations. Comparison of the identified mode shapes with those obtained from the documentation-based initial finite element model showed significant discrepancies depicting the shortcomings of the initial model. A comprehensive sensitivity analysis and iterative finite element model updating was undertaken with a specific focus on the boundary conditions to obtain a FE model that can replicate the observed behaviour. As a result, the correlation between the observed and computed mode shapes were increased to 89% from 61% and the average error in the first four natural frequencies was reduced to 10% from 23%. Comparison of the initial and updated finite element models highlighted the significance of the boundary conditions on the dynamic behaviour of the bridge.

Keywords: Dynamic behaviour; railway bridge; modal identification; monitoring; finite element model updating; boundary conditions

1 Introduction

The assessment and verification of an existing bridge requires detailed finite element analysis of the bridge under generic or specific loading conditions. The accuracy of the analysis results, and thus the assessment of the bridge, is directly impacted by the capability of the developed finite element model to simulate the actual behaviour of the bridge. However, finite element models are generally based on design drawings and material specifications, which may not necessarily reflect the as-built conditions [1]. As a result, the results obtained from a finite element model that is based on these drawings and material properties often fail to match the actual behaviour of the bridge [2]. One of the most widely used methods to overcome this shortcoming is to conduct vibration measurements on the bridge, identify its modal parameters and calibrate the finite element model to match the identified behaviour [1, 2].

Calibrating the finite element model, while useful for every structure, is crucial for structures with high uncertainties regarding its structural properties. This article presents the calibration of a