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Fatigue Damage Identification in Precast Truss Girders Using Relative Wavelet Entropy

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Abstract

An experimental implementation of a relative wavelet entropy (RWE)-based structural damage identification technique (DIT) is presented. The technique is capable of detecting and localizing structural damage, as well as estimating its severity, without the need for any data to be collected from undamaged (reference) state of structure. The bases of this reference-free DIT are: (1) structural damage changes the energy distribution of bridges' vibrational signals; (2) these changes are detectable by means of discrete wavelet transforms (DWTs); and (3) the detected changes can be quantified using spectral entropy. The efficacy of the proposed RWE-based DIT in identification of structural damage has been verified through its application on a precast bridge truss girder system tested under fatigue loading. The girder consists of glass fibre-reinforced polymer (GFRP) tubes filled with concrete reinforced and connected to pretensioned top and bottom concrete chords by double-headed GFRP bars.

Keywords: bridges; fatigue; damage identification; FRP; relative wavelet entropy; vibration.

1 Introduction

Bridges are designed and built to be safe against failure, and to perform satisfactorily during their service life. Over the past few decades, however, they have been deteriorating at an alarming rate due to aging, inadequate maintenance, adverse environmental conditions, and constantly growing transportation demand. Corrosion of reinforcing steel is the major source of deterioration of concrete bridges. Cracking of concrete reduces the structural stiffness and expedites corrosion of the steel.

Recently, fibre-reinforced polymers (FRPs) have been replacing steel in reinforced concrete structures to mitigate the durability problems caused by corrosion of steel and to enhance their structural performance [1]. Nevertheless, the performance of hybrid FRP-concrete bridges can be affected by various types of damage caused by excessive loading and extreme events. To ensure both safety and serviceability of bridge structures, robust damage identification techniques (DITs) are needed. Despite all the advanced development of current DITs, the following problems related to the structural evaluation of bridges have been historically difficult to solve:

1. Most of current DITs are designed for specific types of structure and are limited to identifying a particular type of damage [2].
2. It is not practical to interrupt the normal operations of bridges in order to perform dynamic excitation tests [3].
3. Even if dynamic tests could be performed, the varying operational and environmental conditions of the bridges lead to changes in their measured dynamic responses. These changes may result in false-positive damage indication (i.e. indication of damage while none actually exists) [4].

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