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Dynamic analysis of a bridge repaired by CFRP: Experimental and numerical modelling

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ABSTRACT

A significant number of existing reinforced-concrete bridges all over the world require maintenance and repair. Hence, the need for a rapid evaluation procedure for the diagnosis of existing bridges. This paper presents the application of a dynamic analysis methodology for structural evaluation of reinforced-concrete bridges. The methodology is based on the application of ambient vibrations non-destructive testing method and the identification of the structure total response using finite element method. A case study of a three span reinforced concrete bridge in a strong seismic activity area in the north of Algeria is analysed. The ambient vibration testing was carried out on the bridge, before and after its repair by the application of carbon fibre composites. The tests were conducted using an acquisition system made up of four accelerometers with three components placed at specific locations on the bridge. The finite element model gave comparable results to the experimental ambient vibrations tests. The modal parameters of the bridge before and after repair were identified by this in situ testing. The application of composite material to strengthen the structure increases the transverse rigidity of the structure and thus its modal frequency.

1. Introduction

A significant number of existing reinforced-concrete bridges require maintenance and repair. In Algeria there are more than 4850 road bridges of which more than 40% require repair. Many of these structures have suffered cracking and various damages during their life span [1]. The causes of these damages are either due to errors in design, detailing, calculation or construction and also due to ageing and fatigue. In addition, Algeria is located in a high activity earthquake zone and its infrastructure is often damaged by seismic actions. Therefore, there is a need to evaluate and diagnosis these structures in order to repair and strengthen them when necessary. Bridge inspection is currently conducted mainly based on visual inspection and hence there is a need to improve bridge assessment techniques. The evaluation procedure should be a quick method that could detect any damage at its early stage and propose repair and/or strengthening method to reinstate the initial transverse rigidity of the structure and improve its performance and durability. The non-destructive testing methods (NDT) that permit the evaluation of the materials properties and the performance of the structure without interfering with its use and without affecting its carrying capacity are the most recommended for this kind of evaluation. The mostly used NDT techniques are optical fibres, ambient excitation or forced vibrations [2].

Vibrations testing on bridges are not recent and several studies are reported by various researchers and testing laboratories [3]. This technique has gained recently a widespread use for structural evaluation. This technique could be divided into two main categories: the category of testing by measurement of inputs generally called "measured-input testing" intended for large structures such as stayed-girder bridges, suspension bridges or structures with large lattice road surface, and a second category known as "ambient testing" intended for medium and small scale structures, such as reinforced concrete or steel beam bridges with reinforced concrete slab deck [4].

Ambient vibration testing could be applied using excitation by vehicles. For bridges with heavy traffic that cannot be interrupted, another form of ambient vibration testing is applied which is that of the excitation of the circulating traffic itself on the structure in use that could be associated with other sources of ambient excitation such as wind. This type of excitations was applied on 57 large bridges in California in 1982. Ambient excitation by wind and waves as well as pedestrians was also applied on the Oakland

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Fig. 1. Overview of the bridge.

Fig. 2. A view of pile degradations.

Bay Bridge and the Golden Gate Bridge of San Francisco [2]. The main objective of the ambient excitation tests is the determination of the modal parameters such as Eigen frequencies, the distortion and the damping coefficients of the structures.

Most ambient excitation tests for the structural evaluation of bridges were carried out to check the numerical modelling and comparing it with the experimental data and also to monitor changes in the modal properties due to changes in the structural conditions after induced defects [2–6]. However, the application of such test method on rehabilitated and strengthened structures remains scarce.

The objective of this paper is the structural evaluation of an old three span reinforced concrete bridge in Algeria before and after strengthening by a carbon fibre composite material. The tested bridge is described as well as the instrumentation used. The effect of the composite materials on the modal characteristics of the structure by using ambient excitations testing was quantified.

2. Case study

2.1. Description of the structure

The structure is a road bridge crossing Oumazer River located near the old city of Tipaza at about 80 km west of Algiers. The area is situated in a strong seismic activity zone classified as zone III [7]. The bridge is a hyperstatic three span bridge built in 1927. The deck consists of a reinforced concrete slab supported by four reinforced concrete longitudinal beams, while the infrastructure is made up of two piles each made of four posts connected by shear walls, and two supports (Fig. 1). The geometrical characteristics of the bridge are:

- Total length 70.0 m.
- Length of access span 15.0 m.
- Intermediate span 40.0 m.
- Length of road surface 6.0 m.
- Length of shoulders 1.0 m.
- Height of pile 10.0 m.

2.2. Diagnosis of degradation

The degradations are visible on the bridge structural elements, with cracking in the concrete cover and corrosion of the reinforcement in the beams and piles (Fig. 2). Corrosion of the piles affected the concrete cover with a loss of steel and concrete section probably due to the aggressive marine environment. The diagnosis also reveals cracks inclined at 45° near the support of the main beams indicating an increase in shear stress mainly due to road traffic increase. These damages were probably exacerbated by the

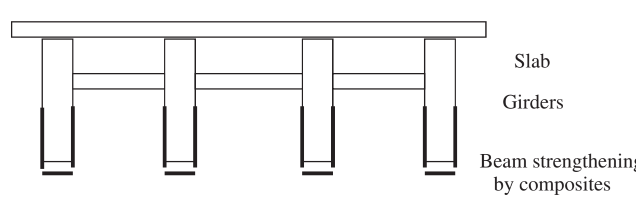

Fig. 3. Applications of carbon fibres CFRP on the bridge beams.