SHM of Bridges and Buildings: Prestress Force Identification and Deterioration Assessment

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Abstract

Bridges and buildings are vital elements of infrastructure networks in any country. Regarding bridge structures, prestressed concrete bridges have been increasingly constructed due to their superior strength compared to ordinary concrete bridges. The main concern of engineers is to ensure the prestress force, which significantly contributes to the overall strength of the bridge. Besides, buildings are seriously exposed to weather over their lifespans, while structural maintenance is hardly performed due to high cost and limited accessibility. Therefore, assessment of deterioration in a timely manner is critical to ensure the serviceability of the building and to inform maintenance planning. This paper presents recent developments in Queensland University of Technology for prestress force identification in bridges and deterioration assessment in buildings using structural health monitoring (SHM) technologies.

In the first scheme, prestress force (PF) in box-girder bridges is examined by three different methods using moving force (MF) technique, simplified analytical model and ultrasonic stress evaluation, respectively. The first study presents a synergic identification method to identify PF and MF simultaneously. The principle of this method is to transform the PF into an external pseudo-load using virtual distortion method. The PF and MF are then estimated by using Duhamel integral. The second study proposes a simplified modeling approach to predict PF from measured vibration responses. Herein, the technique idealizes the top slab of box girder bridges using boundary characteristic orthogonal polynomials for accurate dynamic analysis. The PF is then predicted using an inverse approach based on plate theory. The third study develops a non-destructive testing technique to predict PF from ultrasonic waves travelling along the concrete surface. The study theoretically investigates relative change in wave velocity due to PF and uses this knowledge to inversely estimate the applied PF. Results on a lab-scaled box girder indicate good accuracy of all three methods in PF identification. Selection of these methods for applications depends on the availability of loading information, measurement data and calibration information at zero-stress state.

The second scheme presents a comprehensive deterioration assessment method based on the reconstruction of vibration responses. Firstly, an improved autoregressive (AR) time-series approach is proposed to effectively reconstruct acceleration responses by incorporating a data normalization technique and an optimal model order (OMO) estimation technique. Secondly, a method to detect deterioration is developed using the statistical hypothesis of chi-square variation test for model residuals. Thirdly, a Fisher-criterion-based algorithm is used to estimate the locations of deterioration. Results from two numerical studies of 3-storey and 20-storey buildings illustrate high capability of the method on detecting and locating deterioration. In addition, validation results on a real building using monitoring data of three years demonstrate the feasibility of the method in real applications.

Keywords: Prestress force, box-girder bridges, moving force, plate transform, ultrasonic, buildings, deterioration, time-series, AR model, best model order.