Load Carrying Capacity Assessment of Prestressed Concrete Beam Bridge from Structural Forced Vibration Response

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1. Introduction

Nowadays, with the aging of thousands of highway bridges, the problems on how to assess their physical condition for bridge maintenance and management attractes more and more attentions. Since the prestressed concrete (PC) beam bridge is the most generally adopted bridge type for highway bridge, it is thus very important to develop a fast test method to evaluate structural condition, especially the load carrying capacity, for this type of bridge in a non-destructive way. The prestress force is critical for crack resistant load carrying capacity of PC beam bridges. The problem is that commonly used non-destructive evaluation (NDE) techniques (e.g. visual inspection, acoustic emission technique, ultrasonic inspection technique) cannot be used for prestress force identification..

To meet this requirement, structural vibration test is proposed in this paper. Using structural vibration response measurements collected from a bridge excited by artificially generated forces or ambient excitations, prestress force can be identified using sensitivity-based optimization Method. And then, the crack resistant load carrying capacity can be assessed according to the remaining prestress force in the beam..

This paper proposes such a procedure for the PC simply supported beam bridges eccentrically prestressed with straight tendons using structural forced vibration response. The model of the beam is as shown in Figure One:

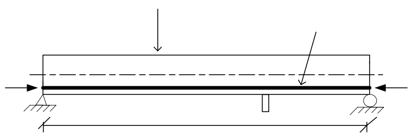

Figure 1

2. Methodology

The forward mapping from structural prestress force to forced vibration responses is analytically derived firstly in time domain. Special focus is put on derivation of the geometrical stiffness matrix for an eccentrically prestressed PC beam. In this paper, the prestress bars are simulated by one axial force and one bending moment, as shown in Figure Two, both of which would have effects on the stiffness matrix of the beam.

The stiffness matrix for the eccentrically prestressed beam consists of three parts: the global elastic stiffness matrix, the geometric stiffness matrix caused by axial prestress force T, and the geometrical stiffness matrix caused by bending moment $B = T \times e$,

$$K = \overline{K} - K_G + K_B = \sum_{i=1}^{N} \left(\overline{k}^i - k_G^i + k_B^i \right)$$

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The inverse mapping technique to identify the prestress force from structural forced vibration response is then presented by solving a sensitivity based optimization problem. The sensitivity matrix is first got by differentiating the EOM by prestress force T. Obtaining response-prestress-force sensitivity S, the prestress force ΔT can then be determined from the sensitivity analysis based optimization,

According to the identified prestress force, the crack resistant load carrying capacity of the PC bridges can be assessed. For bridges in services, its loads consist of both live loads and dead loads. To calculate the normal stress of the PC beam sections, three types of force, the live load, the dead load and the prestress force, should be considered. The load carrying capacity would vary with the changes of the prestress force. The prestress force is actually the primary factor which would determine the crack resistant load carrying capacity.

$$M_l \le [\frac{N_y}{A_i} + \frac{N_y e}{W_i} - \frac{B_{di}}{W_i} - N_l \times (\frac{1}{A_p} + \frac{e}{W_p}) + \sigma_{cs}] \times W_p - B_{ds}$$

3. Numerical Study

A numerical study on a typical PC highway bridge, the Qinglong-River Bridge on Beijing-Qinghuangdao Highway, is conducted. The bridge is a simply-supported PC slab bridge with 20 spans. Each span is of 25 m long. Four straight prestress tendons are tensioned at the bottom of the beam. Based on this numerical study, the eccentrical prestressing effects on structural dynamic properties are checked firstly (as shown in Fig. 3 and 4). After that, structural forced vibration responses under impulse, harmonic and white noise random excitations are calculated for the load carrying capacity assessment purpose. The results shown that the proposed identification method is efficient; the identified results are accurate.

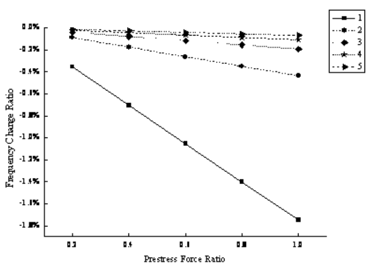

Figure 3: *Effects of prestress force magnitude on natural frequencies*

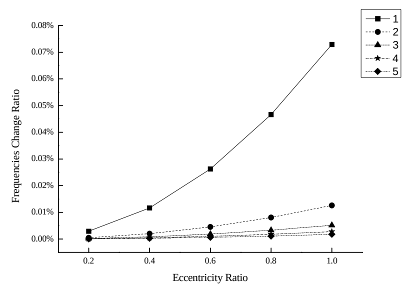

Figure 4: *Effects of eccencitivity on natural frequencies*

4. Conclusions

The results verified the proposed method is of great accuracy for the identification of structural prestress forces and workable for assessing the crack resistant load carrying capacity for highway PC bridges. Further researches on how to extend the proposed technique for model-free output-only prestress force identification are ongoing and will be reported in the future.

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