Tension Force Estimation of Cables in Cable Supported Bridges with Considering Initial Curvature Shortening Effect

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Summary

In the maintenance of cable-supported bridges, estimating cable tension is the most important procedure. For this procedure, some formulas have been used. However, the results estimated using these formulas are not accurate because they was developed using a variety of assumptions. The major reason for the inaccuracy of existing formulas is the neglect of the initial curvature shortening effect. As the slenderness ratio of the cable increases, this effect is strengthened. If the cable is supported by the immovable ends, the stretching force induced by the initial curvature shortening effect results in a tension force to the cable. In this paper, a new method is proposed to increase accuracy in estimating the total tension force of the cable. The total tension force is calculated with considering the initial deflection curve, the initial curvature shortening effect, and the nonlinear oscillation of the cable. The verification result for a cable-stayed bridge showed that the initial curvature shortening effect should be considered to estimate the total tension force of the cable and that the new method gives more rational estimates compared with the existing formulas.

Keywords: Cable-stayed bridge; Suspension bridge; Cable tension; Natural frequency

1. Introduction

The vibration method can be used to estimate cable tension regardless of the construction status, cable diameter, and number of strands in the cable. Shinke et al. [1], Zui et al. [2], Utsuno et al. of Kobe Steel, Ltd. [3], and Mehrabi and Tabatabai [4] proposed the estimation formulas that can account for the flexural rigidity effects of the bridge cables in tension force calculations. Ren et al. [5] also proposed a practical formula for rapid calculation considering only the cable sag effect or only the cable bending stiffness effect. The bridge cables can be treated as axially loaded beams because of their flexural and axial rigidities. The free vibrations of axially loaded beams under gravity effects were studied by Shih et al. [6] and Hughes and Bert [7]. They considered the initial deflection of the beam that occurs due to the gravity effect. This effect is closely related to the curvature shortening effect. If immovable ends are assumed at the supports, the curvature shortening occurrence is restrained. Zaslavsky [8] investigated the curvature shortening distance and the reaction at immovable ends for changes in the support position. In this paper, a new estimation method for calculating the tension force of bridge cables with considering the curvature shortening effect is presented. To verify the effectiveness of the new estimation method, this paper also included the estimation result about the tension forces of a cable-stayed bridge.

2. Static deflection of the bridge cable

The differential equation for the static deflection of the bridge cable to account for the curvature shortening effect can be described as follows:

$$\frac{d^2 w_s}{dx^2}\left(EI\frac{d^2 w_s}{dx^2}\right)-\left[N_a+\frac{EA}{2L}\int_0^L\left(\frac{dw_s}{dx}\right)^2 \mathrm{d}x\right]\frac{d^2 w_s}{dx^2}=q \quad \left(q=\rho g A\right) \tag{1}$$

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