Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 82 (1999)

Artikel: Application of simultaneous identification of tension and flexural rigidity at once to the bridge cables

Autor: Yamagiwa, Ichiro / Utsuno, Hideo / Endo, Koji

DOI: https://doi.org/10.5169/seals-62166

Application of Simultaneous Identification of Tension and Flexural Rigidity at once to the Bridge Cables

Ichiro YAMAGIWA
Researcher
Kobe Steel, Ltd
Kobe, Japan

Hideo UTSUNO
Senior Researcher
Kobe Steel, Ltd
Kobe, Japan

Koji ENDO
Researcher
Kobelco Res. Inst. Inc.
Kobe, Japan

Kenichi SUGII
General Manager
Kobe Steel, Ltd
Kobe, Japan

Abstract

A new vibration method to simultaneously identify the tension T and the flexural rigidity EI of the cable is examined. This vibration method using natural frequencies of the cable's bending vibration is used for measuring the tension of the cable during erection of cable-stayed bridges. In the practical equation of the usual vibration method, the tension of the cable is estimated by using the first or second natural frequency. In this new vibration method, the plural higher mode natural frequencies, which are usually ignored, are raised by hammer striking, and using their frequencies the tension and the flexural rigidity are identified simultaneously. (Picture1, Fig.1)

Applying the theory of the one-dimensional beam's bending vibration with the tension to the vibration of the cable, a simple equation is analytically derived from the frequency equation for the fixed boundary condition:

$$f_i^2 = \frac{\pi^2 EI}{4\rho A L^4}\left(i - \frac{\phi}{\pi}\right)^4 + \frac{T}{4\rho A L^2}\left(i - \frac{\phi}{\pi}\right)^2 \quad (1), \qquad \tan\phi = -\frac{4\pi f_i}{T}\sqrt{\rho AEI} \quad (2)$$

where i = mode number, fi = natural frequency (mode number = i), = density, A = sectional area, L = length of cable.

In this equation the square of the natural frequency can be written as a function of the fourth power of mode i plus the second power of mode i. Using this equation we can identify the tension and the flexural rigidity from the coefficient of the term of the second power or the fourth power of the mode i by least-squares fitting and the iteration technique. (Fig.2)

If the boundary conditions are known, the tension and the flexural rigidity can be accurately identified. Assuming the unknown boundary conditions like the actual bridge cable, the limit of precision was quantitatively investigated by a numerical simulation. As a result it was found that the limit of the precision of tension and flexural rigidity was decided by the following parameter.

$$\xi = \sqrt{\frac{T}{EI}} \cdot L \quad (3)$$

With higher values of , the precision of tension is also higher. (Table1)

Fig.3 shows the result of the experiment using a test piece of cable for the known boundary condition. The vertical axis is the ratio of the estimated tension to the measured tension by the load cell. It shows that we can identify the precision of the tension to less than 1% in this method.

Fig.4 shows the result of the experiment with the actual bridge cable. Assuming the tension of the

hydraulic jack is correct, the precision of tension is less than 8% in this method. This result agrees with the numerical simulation. This precision is sufficient in practical use for the cable erection.

The Advantages of this method compared with the usual method are as follows:

1) In the usual method, a preliminary test using a test piece of cable is necessary because the value of the flexural rigidity EI is necessary for calculation of the tension T. However, in this new method, a preliminary test is not necessary because the tension T and the flexural rigidity EI are calculated simultaneously during the erection.
2) If special order natural frequency(e.g. first order, second order) is not raised, the tension can be estimated due to the use of plural natural frequencies. Moreover, the effect of sag in the first natural frequency is avoided.
3) Discrimination between the cable's natural frequency and the noise peak frequency is simple because of the regulation of plural natural frequencies.

Therefore, in this new vibration method, the judgement of the measurement is brief and speedy so that the tension T can be quickly identified during the erection of a cable-stayed bridge.

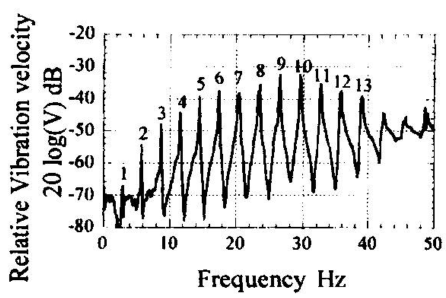

Figure1: Frequency analysis of cable vibration

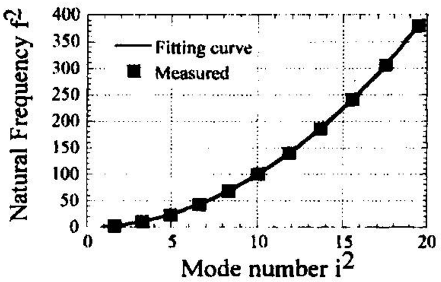

Figure2: Least-squares fitting for natural frequencies

		ξ			
		10	30	50	100
EL	6-10	11.5%	9.6%	7.5 %	4 %
	16-20	5.5%	5.2%	4.8 %	3.5 %
	26-30	3.55%	3.5%	3.3%	2.8 %
T (1-5)		70 %	15 %	8 %	4 %

Table 1: Precision of T and EI

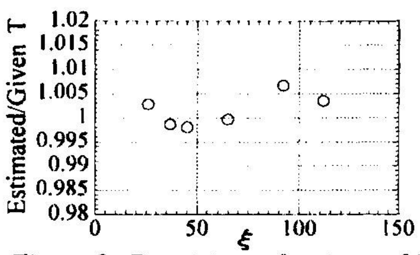

Figure3: Precision of estimated T

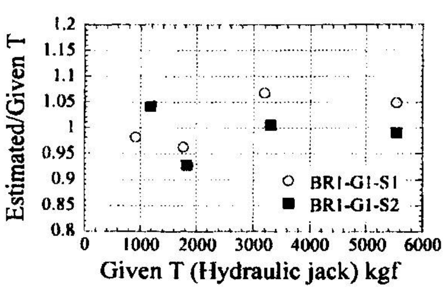

Figure4: Precision of estimated T