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DYNAMIC TESTING METHOD FOR PRESTRESSING OF SIMPLY SUPPORTED STRUCTURES

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Abstract

By theoretical analysis**,** this paper discusses the prestressing of simply supported structures through testing the frequency of the simply supported structure. This method can be applied after moulding or once using, and can obtain the valid prestress of simply supported structures after some prestress loss. This paper proposes a new method to calculate total tensile force after a prestressed structure makes a number of prestressed losses by testing the frequency of the structure. This method is a nondestructive examination method and it is convenient for detecting presstressing force. It also can be used to detect the value of prestressed loss, guide prestressed construction, and research of prestressed loss. It therefore, has broad application prospects for structural quality testing, construction, and scientific research.

FORWARD

A prestressed concrete member can delay the component cracking, improve the crack resistance and stiffness of components, and achieve the effect of savings in steel and reducing support. It overcomes the drawbacks of reinforced concrete, but also creates conditions for the introduction of high-strength materials [1]. Because of its obvious advantages, prestressed concrete are widely used in various fields of civil engineering, such as the prestressed hollow floor, roof covering girder, roof truss, crane beam, pool, oil tank, and atomic pile in industry and civil architecture. Prestressed concrete has also been widely applied in ridges, water resources, marine and port projects, especially simply supported structure.

Prestressed effectiveness depends on a effective compressive prestresses which are established in prestressed concrete, and the effective compressive prestress is carried out by tension of prestressing tendon. At present, the maximal stress value that prestressing tendons reach in the process of tension, is the stress value which total tension stress instructed by tension equipment, divided by the area of the prestressing tendon is considered as tension control stress. Tension stress reduces gradually in the process of constructing and using prestressed concrete structures. The prestressed losses will affect the prestressed result. To correctly analyze and estimate various prestressed losses, and to explore measures of reducing these losses, using appropriate tension control stress is an important problem in the physical design , construction, and scientific research of prestressed concrete.

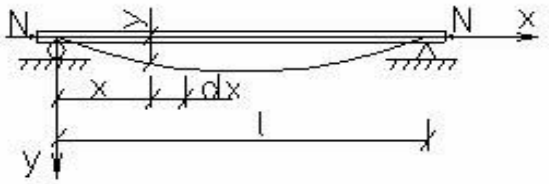
Many factors induce prestressed losses , such as shrinkage and creep of concrete, and the relaxation of steel. These losses also change with the passage of time and constant environment alteration. These factors are interrelated and interdependent. Therefore, calculating and determining prestressed loss values accurately is a very complex task. In engineering design, the total prestressed loss value of concrete members can be considered as a superposition of

the prestressed loss value caused by a variety of factors. To the specific structure, there are different combinations with different technologies. Reference to the specification [2], the loss value of pretension structures is at least 100 N / mm^2 that of post-tension structures is at least 80N / mm^2. This accounts for a considerable proportion of prestress. They have different effects for different components.

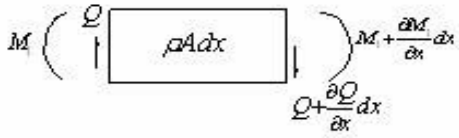
Detecting reinforcement stress after prestressing force loss to control the tension in the construction process is difficult in many cases, especially in post-tensioned structures, and the testing method is complicated[3].This paper presents a test method which can detect the frequency of constructure to obtain the prestress of simply supported structures. This method can be used after the structural shaped and even during construction. It can detect the effective prestress of simply supported structures after prestressing losses. This method is simple and can produce good results.

BASIC PRINCIPLE

As shown in Figure 1 a, simple supported beams vibrate breadwise in a symmetry plane. The span length of the beam is *l* the cross-sectional area is *A*, the inertia moment is *It,* the mass density is *ρ,* the elastic ratio is *E,* the flexural rigidity is *EI,* the axial force is *N*, the shear of cross-section variable is *Q,* the flexural forque of cross-section *is M*, and the deflection in lateral direction is *y.*



(a) schematic of simple beam



(b) schematic of vibration analysis of simple beam

Figure 1. Schematic of simply supported structure.

Obviously, the moment of cross-section is composed of two parts: One is M_1 produced by the lateral load[4] . In the circumstances of free vibration, M_1 is produced by inertia force. Two is *Ny* produced by axial force *N* , so

$$M = M_1 + Ny \qquad (1)$$

As shown in figure 1, the simply supported beam that is not bearing the axial force is intercepted a micro-length *dx* in the coordinate x. Available from equilibrium conditions:

$$Q = \frac{\partial M_1}{\partial x} \qquad (2)$$

$$\frac{\partial Q}{\partial x} = \rho A \frac{\partial^2 y}{\partial t^2} \qquad (3)$$

By material mechanical, the relationship between flexural torque of cross-section M and horizontal deflection of beam Y is that :

$$M = -EI \frac{\partial^2 y}{\partial x^2} \qquad (4)$$

Put equality (2), (3), (4) into (1), it can be obtain differential equation of lateral vibration of beam baring the axial force :

$$\frac{\partial^2}{\partial x^2}(EI \frac{\partial^2 y}{\partial x^2}) + N \frac{\partial^2 y}{\partial x^2} = -\rho A \frac{\partial^2 y}{\partial t^2} \qquad (5)$$

To prismatic beam, upper equation (5) turn into:

$$EI \frac{\partial^4 y}{\partial x^4} + N \frac{\partial^2 y}{\partial x^2} = -\rho A \frac{\partial^2 y}{\partial t^2} \qquad (6)$$

By separation of variables, it is available differential equation of vibration mode function. Put it into the boundary conditions, it can obtain natural frequency ω_i of lateral vibration of the beam baring axial force:

$$\omega_i = \eta_{\alpha i} \omega_{0i} \qquad i = 1, 2, 3, \cdots\cdots \qquad (7)$$

In the equation, $\eta_{\alpha i}$ is the influence coefficient of of axial force to frequency.

$$\eta_{\alpha i} = \sqrt{1 - \frac{N}{N_{ci}}} \qquad (8)$$

N_{ci} is the ultimate axial force of Number *i* destabilization.

$$N_{ci} = \frac{i^2 \pi^2 EI}{l^2} \qquad (9)$$

ω_{0i} is the Number *i* natural frequency of horizontal vibration of simply supported beam that is not beard axial force

$$\omega_{0i} = \frac{i^2 \pi^2}{l^2} \sqrt{\frac{EI}{\rho A}} \qquad (10)$$

It can be seen from the equation (7):

(1) when axial force N is pressure, influence coefficient $\eta_{\alpha i}$<1, which means that frequencyω_i is reduced.

(2) When $N = N_{ci}$, $\eta_{\alpha i}$=0 , the frequencyω_i =0。

(3) The more serial number of vibration modal, the more $\eta_{\alpha i}$ close to 1, which means that axial force have small impact on high vibration mode.

(4)There is corresponding relationship between the frequency ωi and axial force N of simple structure.

TESTING METHOD

It is available from equtaion (7) :

$$\frac{N}{N_{ci}} = 1 - \frac{\omega_i^2}{\omega_{0i}^2} \qquad i = 1, 2, 3, \cdots\cdots \qquad (11)$$

when i=1

$$\frac{N}{N_{c1}} = 1 - \frac{\omega_1^2}{\omega_{01}^2} \qquad (12)$$

when i=2

$$\frac{N}{N_{c2}} = 1 - \frac{\omega_2^2}{\omega_{02}^2} \qquad (13)$$

It is available from equation (9), （10）:

$$N_{c2} = 4\, N_{c1} \qquad （14）$$

$$\omega_{02} = 4\, \omega_{01} \qquad （15）$$

Put into (12), （13）:

$$\omega_{01}^2 = \frac{1}{48}(4\omega_2^2 - 16\omega_1^2) \qquad (16)$$

It is also available from equation (9), （10）:

$$N_{c1} = \frac{l^2}{\pi^2}\rho A\, \omega_{01}^2 \qquad (17)$$

Put equation（16）、（17）into equation (12), （13）:

$$N = \frac{l^2}{48\pi^2}\rho A(4\omega_2^2 - 64\omega_1^2) \qquad (18)$$

By equation (18), we can infer the axial force that the structure bears, according to the measured frequency ω1、ω2 of structures and physical dimension.

The effective compressive prestress of a prestressed concrete member can be simplified. It can be calculated by total tensile force that is axial force [1] [2], and the effective compressive prestresses can be obtained by measuring axial force.

Adopt free vibration or resonance method to test frequency [5]. Test equipment will be installed in the measured samples during the test. Using a sensor amplifier, a dynamic signal analyzer, and other equipment to test the vibration response curves, at the same time measure stimulation. The phase-frequency curve and amplitude frequency curve can be obtained by analyzing, and solving the natural frequency character of specimen system.

ANALYSIS OF METHOD

According to this method, the test can be carried out after the structure is complete, so it is applicable for a pretensioned system and a post-tensioning method, especially the post-tensioning method. Because the reinforcement (or wire) is in the channels, and only the anchorage device shows on the outside, it is difficult to adopt other measures to test the tensile force of reinforcement. Many methods [3] cannot do that, such as tensimenters, tensometers, and so on. However, this method recommended by this paper is very simple. More importantly, this method can measure the total tensile force that is the number of prestressed losses.

This method can be widely applied to measure the tensile force of prestressing tendons of various tensile anchorages (screw terminal anchorage, blunt anchorage), and also can test lots of prestress losses of various anchorage in the process of construction.

Prestress losses can be divided into six item in the specification [2] : ① prestress loss caused by the deformation of tensile anchors and contraction of prestressing tendon; ② prestress loss caused by the friction between the prestressing tendons and the channel inwall; ③ prestress loss caused by the difference in temperature between tensile reinforcements and the equipment bearing tensile force during concrete heating conservation; ④ prestress loss caused by stress relaxation of prestressing tendons; ⑤ prestress loss caused by concrete shrinkage and creep; ⑥ prestress loss caused by parial extruding of concrete in annular component whose reinforcing bars configurated spiral steel. In the above six prestressed losses, item ⑥ is the only belonged to special components, and the post-tensioning method haven't ③ items.

For post-tensioning methods, it can obtain the total tensile force of partial prestressing tendon of items ①②④and ⑤. And for the pretensioned system, it can obtain the total tensile force of partial prestressing tendon of items ①②④and ⑤. For the post-tensioning method, detection is possible immediately after anchor, items ① and ② are excluded from the checkout value because they have a greater variability during construction. Therefore, it has good results in controlling the pretressing force.

For the post-tensioning method, if prestressed loss is detected, such as items □□, measure the frequency of the structure. Adopting this method can obtain the results of items □□, and the results can guide the construction of prestressed tension.

This method is a nondestructive examination method. Because its advantage of test equipment legerity, shorter test time, facilitating census and repeated tests, it can be used to test the quality of precast elements. It also has broad prospects for construction and scientific research.

CONCLUSION

This paper proposes a new method to calculate total tensile force after prestressed structure makes a number of prestress losses by testing the frequency of the structure. This method is a nondestructive examination method and it is convenient for detecting presstressing force. It also can be used to detect the value of prestressed loss, guide prestressed construction, and research prestress loss. Therefore, it has broad application prospects for structural quality testing, construction, and scientific research.

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