The Analysis of The Cable Crane In The Large Span Bridge

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Abstract. Jinsha river bridge is the biggest span suspension bridge under construction across the canyon. The analysis of the cable crane is of vital importance. The parabola theory of three spans is used in this paper to design the selection and installation of the sag of the track cable and hoisting cable. At last, the result is used to guide the design of the structure. The calculation results can provide the reference to the design of cable crane in the large span bridge in the future.

Introduction

The main part of Jinsha river bridge is a twin towers suspension bridge. The mainspan is 1386*m* and rise-span ratio is 1/10. The theoretical spans is 330*m*+1386*m*+205*m*. The horizontal distance between main cable is 27*m*. The theoretical sag of the main cable in the mid-span is 138.6*m*. Cable crane hoisting is used for the main girder construction. The direction of the erection is from the mid-span to both side of the bridge. The beam is divided to 127 sections that contains 124 standard beam sections and 3 special beam sections. The length of the standard beam section is 10.8*m*.

In order to ensure the safety and construction schedule in the process of hoisting construction of the main beam, it is using the scheme of the cable crane. The theoretical lifting capacity is 150*t*.

M.X. Ran and H.S. Xu[2] worked on the design of the cable crane of the Beipan River Bridge based on the three spans parabola theory. X.G. Li e.t.[3] introduced the cable crane applicated in the Qingshui River Bridge. As the first cable crane in the thousand meter scale, the project solved many problems. X.T. Deng e.t.[4] put their attention on the finite element analysis on the Wujiang River in the Pengshui city. G.R. Zheng e.t.[5] analyzed the characteristics of cable crane. The process itself of the economy, the construction efficiency, process maturity are analyzed in their study. W.D. Liu e.t.[6] optimized the details of the bridge design. J. Yao[7] introduced the situation of the construction of the Sidu River Bridge. S.Z. Yang e.t.[8] summarizes the construction design process of the cable crane of the Egongyan Suspension Bridge.

The Design of The Cable Crane

The Overall Design

The mid-span of the cable crane is 1380*m*. It is consist of the anchorage, the tower, the track cable, the hoisting cable and the pulling cable.

The design of the track cable

Because of the reason that the span of the Jinsha river bridge is relatively large and the terrain and environment are complex, the traditional calculation formula of the track cable based on the theory of the single span parabola can not meet the needs of construction precision and it need further study. Hongsheng Xu e.t.[1] took all the three span into consideration and got the state equations of the track cable tension, as shown in Equs.(1) and (2)

$$H_x^3 + aH_x^2 - b = 0 \tag{1}$$

Where

$$\begin{aligned} a &= \frac{E_k A\cos^3\beta}{24K_1H_{\max}^2}(K_1+K_2) - H_{\max} \\ &\quad - \varepsilon\Delta t E_k A\cos\beta \\ b &= \frac{E_k A\cos^3\beta}{24K_1}\Big[K_4 \\ &\quad + \frac{12(L-x)x}{L\cos^2\beta}Q_x(Q_x+K_5)\Big] \\ K_1 &= \frac{L_1}{\cos\beta_1} + \frac{L}{\cos\beta} + \frac{L_3}{\cos\beta_3} \\ K_2 &= \frac{3Q_{\max}^2L}{\cos^2\beta} + \frac{3Q_{\max}qL^2}{\cos^3\beta} \\ K_3 &= \frac{q_1^2L_1^3}{\cos^4\beta_1} + \frac{q^2L^3}{\cos^4\beta} + \frac{q_2^2L_2^3}{\cos^4\beta_2} \\ K_4 &= \frac{q_{x1}^2L_1^3}{\cos^4\beta_1} + \frac{q_x^2L^3}{\cos^4\beta} + \frac{q_{x2}^2L_2^3}{\cos^4\beta_2} \\ K_5 &= \frac{q_xL}{\cos\beta} \end{aligned} \tag{2}$$

Define H as the horizontal component of cable tension in mid-span; L and β are the distance and the slope angle of the line across two endpoints of the track cable. Q and q are the concentrated load and the uniform load imposed on the track cable in mid-span. E_k is the measured elastic modulus of steel wire rope. Q_x , q_{x1}, q_{x2} and q_{x3} are the concentrated load and the uniform load in the second state when the car moved from the tower of x. A and ε are the cross-sectional area and the linear expansion coefficient of the steel wire rope.

The Design of The Track Cable

Defined $T_{\max}$ as the maximum tension of the track cable in mid-span, and its approximate value can be got from Equs.(3) (4) and (5), as following

$$H_{\max} = \frac{qL^2}{8f_{\max}\cos\beta} + \frac{Q_{\max}L}{4f_{\max}} \tag{3}$$

$$V = \frac{qL}{2\cos\beta} + \frac{Q}{2} \pm Htg\beta \tag{4}$$

$$T_{\max} = \sqrt{H_{\max}^2 + V^2} \tag{5}$$

The maximum concentrated load $Q_{\max}$ can be got from the lifting weight and the sling weight, and it has a value of 140t. The predetermined work sag f_{max}= 71.4m. The uniform load imposed on the track cable in mid-span q=3.758 kN/m. From Equs.(3) (4) and (5), we can get H_{max}=19432.61KN, V=3304.294KN and T_{max}=19711.5KN. The number of track cable can be got, as following

$$n > \frac{\mu T_{\max}}{[T]} = 14.16 \tag{6}$$

Where n is the number of track cable and take an integer for 15. [T] =1670kN is the breaking force of the steel wire rope. μ=1.2 is the dynamic amplification factor.

The Calculation of The Erection Sag of The Track Cable

When the the number of track cable is confirmed, the accurate value of q can be got. Then the accurate value of H_{max} can be got from Equ.(3). Defined H_0 as the horizontal component of tension when the track cable in mid-span is in installation conditions. The erection sag of the track cable f_0 can be got from Equ.(3) when the values of the Q and H are confirmed. The difference between the theoretical and measured value can be shown as Tab.1.

Table 1. The erection sag of the track cable

	f_0 (m)	Error(%)	T_0 (KN)	Error (%)
The theoretical value	58.8	-2.3	15346.7	2.4
The measured value	60.2		14989.8	

The Design of The Hoisting Cable

There are four root hoisting ropes. Defined Q_s as weight imposed on a piece of rope, and Q_S= Q_{max}/4= 35t. S is the loading coefficient of the hoisting cable, and S= 0.119. The safety coefficient of the largest tensile of the hoisting cable can be got as following

$$\frac{[T]}{Q_s S} = 15.56 > K = 5 \tag{7}$$

Where [T] is the breaking force of the hoisting cable, and its value is 648KN.

Conclusion

The cable crane of the Jinsha river bridge is analyzed in this paper. Different from the traditional theory, the parabola theory of three spans is used in this paper. The track cable and the hoisting cable are designed based on the theory. The error between the theoretical value and the measured value meet the accuracy requirement of the construction.

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