Galloping stability studies of steel box hanger of arch bridge by CFD numerical simulation

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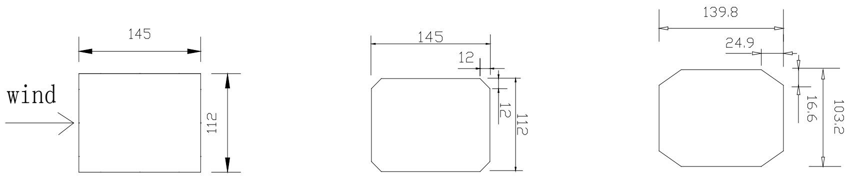
Abstract A slight change in section geometry will result in a great change in galloping stability of the structure. This paper studies galloping stability of three schemes of steel box hanger of one arch bridge by two numerical methods.For the first method:Calculate drag and lift coefficients at different wind attack angle by commercial computational fluid dynamics software FLUENT, judge galloping stability through Glauert-Den Hartog criterion and calculate galloping critical wind speed by formula.For the second method:Establish two-dimensional fluid-structure interaction numerical model to calculate galloping critical wind speed by secondary development of FLUENT.According to time histories of vertical displacements, we can judge galloping stability and obtain galloping critical wind speed. The results of two numerical methods are in agreement with the wind tunnel test.Chamfered rectangular cross-section B is better than rectangular cross-section and chamfered rectangular cross-section A for galloping stability.

Keywords Steel box hanger of arch bridge,Glauert-Den Hartog criterion,Drag and lift coefficient, Galloping critical wind speed, Fluid-structure interaction.

1.1 Introduction

The hanger of a steel truss arch bridge is made of a steel box whose side length is above 1m and the maximum length is above 50m.Three cross-sectional schemes of wind tunnel test model are shown in Fig.1.1.The wind is blowing from left to right.This paper studies galloping stability of three cross-sectional schemes of wind tunnel test models by two numerical methods.



(1)Rectangular (2)Chamfered rectangular A (3)Chamfered rectangular B

Fig.1.1 Cross section of wind tunnel test model (unit:mm)

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1.2 First method

1.2.1 Numerical simulation principle

By using the software FLUENT, drag and lift coefficients are calculated at different wind attack angles. According to Glauert-Den Hartog criterion,we know whether galloping would happen. If galloping happens, calculate galloping critical wind speed according to the formula $U = -4m\omega\zeta / \rho H(\dot{C}_L + C_D)$ (1).

1.2.2 Numerical simulation results

Results of first method are shown in Table 1.1.

Table 1.1 Results of first method

Cross-section	Method	C_D	$\dot{C}_L$	$C_D + \dot{C}_L$	U (m/s)
Rectangular	FLUENT	2. 081	−3. 866	−1. 785	8.0
	Wind tunnel test	1. 959	−4. 020	−2. 061	7.0
Chamfered rectangular A	FLUENT	1.256	-3.2	-1.944	7.4
	Wind tunnel test	1.235	-3.040	-1.805	7.9
Chamfered rectangular B	FLUENT	0.93	positive	positive	No galloping
	Wind tunnel test	0.942	positive	positive	No galloping

1.3 Second method

1.3.1 Numerical simulation principle

The governing structural equation for one-degree-of -freedom heaving mode is shown as (3).The governing equations of the incompressible flow are the continuity equation and the Navier-Stokes equations as (4),(5).

$m\ddot{y} + c_h\dot{y} + k_h y = F_h$ (2) $\nabla \cdot \overline{V} = 0$ (3) $\frac{\partial \overline{V}}{\partial t} + (\overline{V} \cdot \nabla)\overline{V} = -\frac{1}{\rho}\nabla p + \mu\nabla^2\overline{V}$ (4)

Solve equations (3)(4), obtain pressure and velocity around object.Then calculate aerodynamic force acting on the object and extract lift force into vibration equation (2).Solve the vibration equation by Newmark method.Then simulate object move through dynamic mesh technique.This can be achieved by secondary development of FLUENT.

1.3.2 Numerical simulation results

Results of second method are shown in Table 1.2.

Table 1.2 Results of second method (m/s)

Cross-section	Rectangular	Chamfered rectangular A	Chamfered rectangular B
FLUENT	8~10	7~8	No galloping
Wind tunnel test		6.5	No galloping

1.4 Conclusions

By numerical simulation and wind tunnel test can we get following conclusions:

1.A slight change in the section geometry will result in a great change in aerodynamic characteristics of the structure.

2.The results of galloping stability by two numerical methods are roughly in agreement with wind tunnel test.