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Drag Force Coefficients of the Double-deck Truss Girder of Cable-stayed Bridges

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SUMMARY:
Compared with the current research, it is more difficult to determine the drag force coefficients of more complex sections. Generally, the drag force coefficients of the main girder can be calculated according to its form projection area. However, due to the frame structure of the truss bridge, it is difficult to determine the resistance and to establish bridge model accurately, either experimentally or numerically. To select the drag force coefficients of a truss bridge conveniently and quickly, the method of combining wind tunnel tests and numerical simulation is adopted. Find a way to simplify the model while ensuring accuracy. The variation law of the drag force coefficients is explored, and it is found that the drag force coefficients change with the wind attack angle in the form of a quadratic parabola. The empirical formula is obtained by numerical fitting, which can quickly calculate the drag force coefficients of the truss bridge.

Keywords: wind tunnel tests, numerical simulations, double-deck truss girder

1. GENERAL INSTRUCTIONS

Because the form of the truss is changeable and complex, it is difficult to calculate the drag force coefficient of the bridge girder. Therefore, a simplified calculation method is found to study the variation law of the drag force coefficient of the truss. Firstly, the drag force coefficient is obtained through the wind tunnel test, and the feasible simplified model is found by the method of numerical simulation. By changing the truss structure, the drag force coefficient of the truss under different forms is calculated to find out its change law. It provides a more convenient and quick reference for the designer.

2. Wind tunnel test and Numerical simulation

2.1. Research background

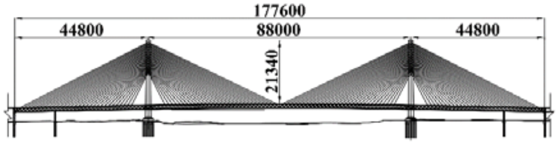

Fig.1 Bridge elevation arrangement

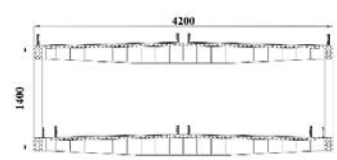

Fig.2 Cross-sectional view of the girder

This study takes asea-crossing bridge into consideration as the engineering background. The bridge is a long-span double-layer truss cable-stayed bridge with a span of 1776m (the main span is 880m).

The truss is symmetrically arranged, the cross-section of the main girder is a rectangular frame structure, the truss is 14m in height and 42.2m in width, and the crossbeam is fish-bellied. Fig 1 and Fig 2 show the elevation layout of the bridge and the section view of the girder (unit: cm).

2.2 Wind tunnel test

The force balance used in the test is a rod-type 5-component strain balance developed by China Aerodynamic Research Center. The segmental force measurement model is required to be similar to the shape of the actual bridge and has sufficient stiffness. The segmental model of the main girder is composed of a measuring section and a two-dimensional end plate, and the α mechanism is connected with the model. The test model is arranged as shown in figure 3 below.

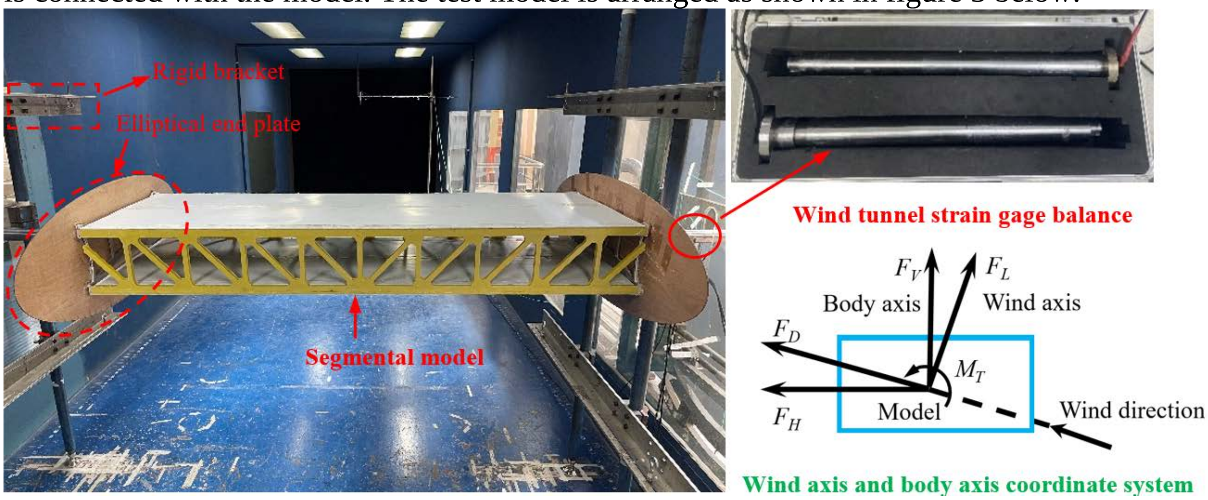

Fig.3 Experimental set-up

2.3. Numerical simulation

The three-dimensional simulation segmental model is established by using SpaceClaim in Ansys. In order to facilitate the calculation, the model under construction stage is simplified and shown in Figure 4. Mesh used for calculated is shown in Figure 5.

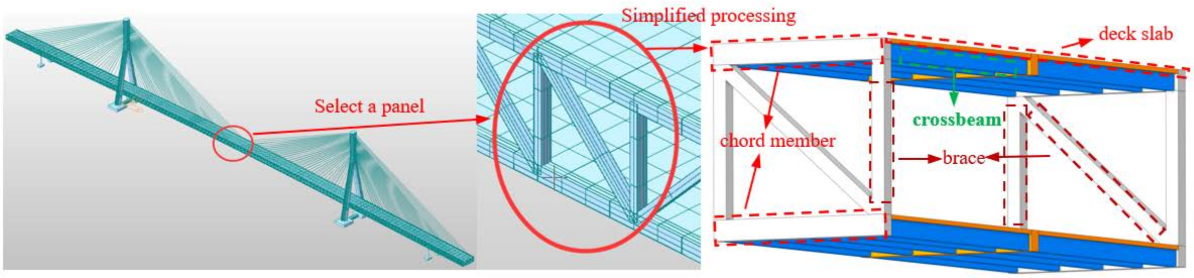

Fig.4 Simplified schematic of the model

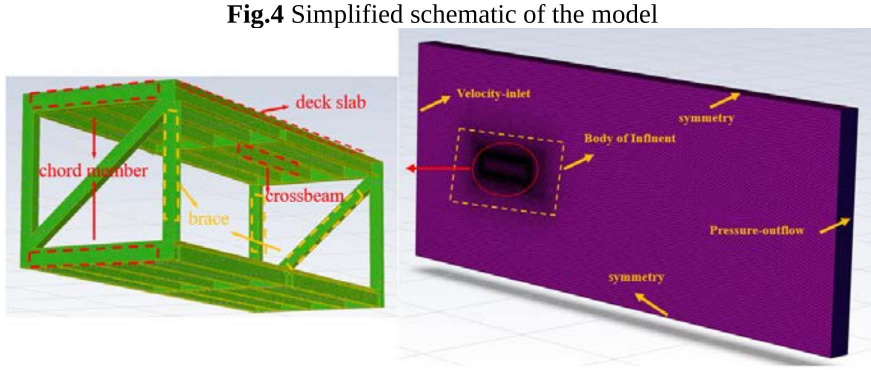

Fig.5 Mesh for model

2.4. Comparison between numerical simulation and wind tunnel test results

Figure 6 shows the comparison between the experimental data and the numerical simulation data. From Figure 6, it can be found that the test data and the numerical simulation data fit well, which proves that the single intersegmental truss can be used to calculate the truss aerostatic coefficients.

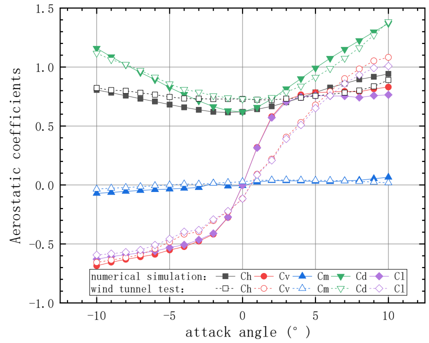

Fig.6 Comparison of wind tunnel test and numerical simulation results

Comparing the limits specified in the code with the measured results, it is found that the drag force coefficient given by the specification is close to that in the wind axis coordinate system at the angle of wind attack of-10 °or 8 °, but far exceeds the drag force coefficient in the body axis coordinate system. There is still a maximum of 50% surplus.

The drag force coefficients of the main girder of the double-layer truss bridge are 0.731 and 0.708 respectively from the test and numerical simulation calculation in this paper. The data is fitted and the following formula is obtained.

$$\begin{cases} C_h = 0.005\alpha^2 + 0.01\alpha + 0.7 \\ C_d = 0.013\alpha^2 + 0.02\alpha + 0.015 \end{cases} \quad (1)$$

In the formula: α is the number of wind attack angles, in degrees.

3. Effect of characteristic size on drag force coefficient of the main girder

3.1. Working condition setting

In order to study the influence of the real area ratio on the drag force coefficient of truss girder, the height and width of internodes are taken as variables. The change law of real area ratio caused by the change of its length is studied. And it is used to explore the changing law of the drag force coefficient of the main girder.

Tab. 1 Condition table of double-deck truss bridge with different actual area ratio

Condition	Model height /m	Model length /m	Model width /m	*AH=HL* /m^2	*AV=BL* /m^2	The area of truss /m^2	Actual area ratio
C1-1	14	7.8	43	109.2	335.4	56.8	0.52
C1-2	14	11.3	43	158.2	485.9	69.6	0.44
C1-3	14	13.8	43	193.2	593.4	79.2	0.41
C1-4	14	18.2	43	254.8	782.6	96.8	0.38
C1-5	14	21.6	43	302.4	928.8	108.9	0.36

3.2. Numerical simulation results

The simulation results of the drag force coefficient of the main girder with the change of internode width are shown in Figure 7. Generally speaking, it was thought that the greater the real area ratio, the greater the drag force coefficient of the main girder of the truss bridge. However, the results of numerical simulation for the change of internode width show that due to the change of internode width, the drag force coefficient of the main girder of a double-layer truss bridge decreases at first and then increases with the increase of real area ratio.

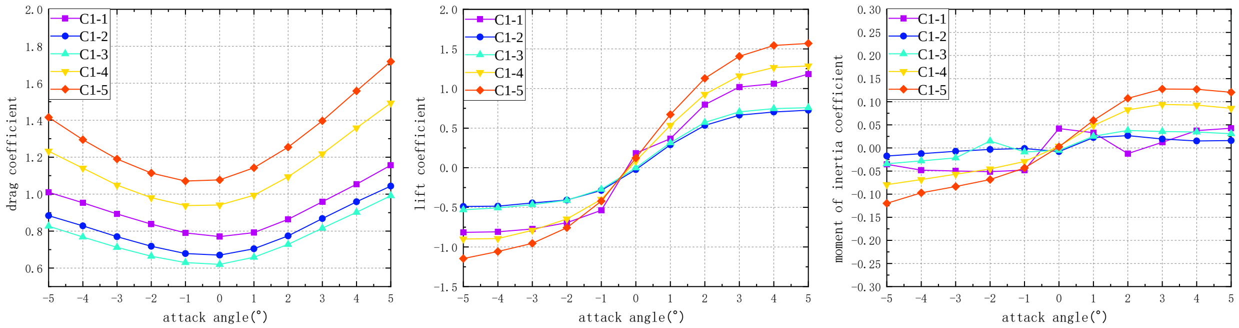

Fig.7 Aerostatic coefficients of double-deck Truss Bridges with different Internode widths

5. CONCLUSIONS

Through the wind tunnel force measurement test and three-dimensional numerical simulation of a proposed long-span double-layer truss bridge, the influence of truss layout on the drag force coefficient is studied, and the following conclusions are obtained.

1. The numerical simulation using an internode truss is close to the experimental results, which proves that the truss drag force coefficient can be calculated more accurately and quickly by using an internode truss.

2. Through wind tunnel test and numerical simulation, it is found that the transverse drag force coefficient of double-layer truss bridge is similar to the quadratic function at different wind angles of attack. According to its variation law, a drag force coefficient fitting formula for the main girder of a double-layer truss bridge with the change of wind attack angle is obtained by the numerical fitting method.

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