# Wind-resistance design of Zhangjinggao south channel bridge: a suspension bridge with 2300m main span

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**SUMMARY:**
Zhangjinggao south channel bridge is situated in the central area of the Yangtze River Delta Economic Zone, and it is a 2300m span suspension bridge with a streamlined box girder. Therefore, the wind-resistance design of the bridge becomes challenging work. A series of 1:50 scale sectional models wind tunnel tests were conducted to find a novel aerodynamic configuration that can suppress flutter and vortex-induced vibration (VIV), and the final aerodynamic configuration design has a horizontal stabilizer at the both rostra side and vertical stabilizers at the central deck and the middle of the bottom. The results of the 1:25 scale sectional test confirmed the measurements to suppress VIV. The full-bridge aeroelastic model with a 1:196 scale finally provided a result that the aero-static divergent speed and flutter onset speed exceeded the criteria speed both in the laminar flow and turbulent flow. Furthermore, the 1:100 scale aeroelastic model test of the 350m high tower verified that the steel-concrete composited structure was a cheerful aerodynamic design without VIV and galloping.

*Keywords: suspension bridge, wind tunnel tests, aeroelastic model, flutter, VIV*

## 1. GENERAL INSTRUCTIONS

The Zhangjinggao south channel bridge is a two-span suspension bridge having a main span length of 2300 m and side span lengths of 717 m. The superstructure is composed of a streamlined box steel girder having an overall width of 51.7 m and a central height of 4.5m. The final aerodynamic configuration design has a horizontal stabilizer at the rostra and vertical stabilizers at the deck and bottom. The road deck carries wind barriers along the entire length of the suspended spans attached at the outer edges of the maintenance walkways. The superstructure is supported by two 350 m tall steel-concrete composited towers. Figure 1 shows the general arrangement of the bridge, and Figure 2 shows the cross-section of the girder that was verified by a series of wind tunnel tests, including sectional model tests and full-bridge aeroelastic model tests. The final aerodynamic design of the bridge satisfied the requirement of the criterion.

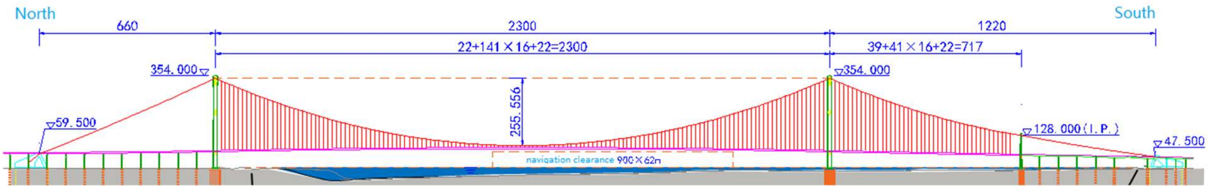


**Figure 1**. The general arrangement of the bridge.

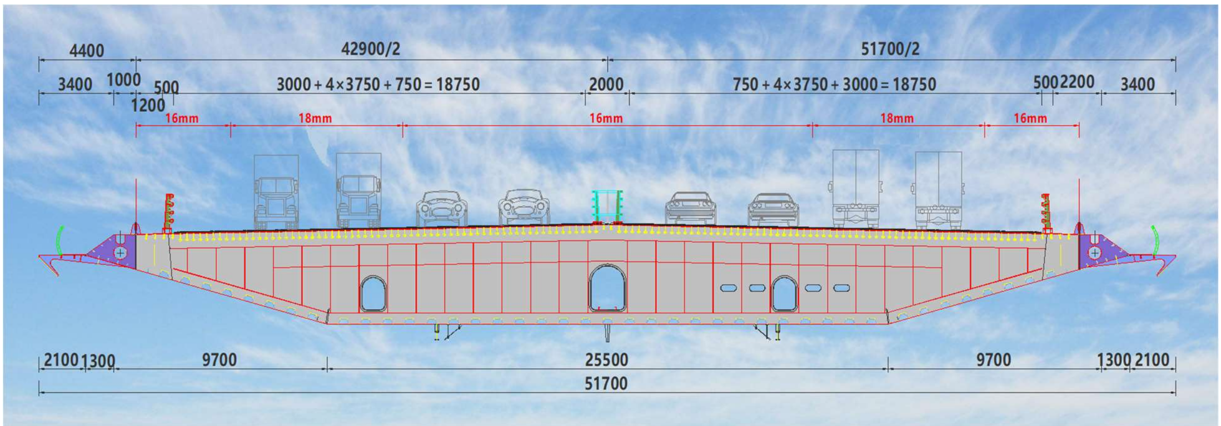


**Figure 2.** Cross section of the girder

## 2. WIND TUNNEL TESTS OF THE GIRDER

### 2.1. 1:50 sectional model free vibration wind tunnel test

The test was conducted in the XNJD-1 wind tunnel of Southwest Jiaotong University. The scale ratio of the sectional model is 1:50 made of wood, and the length is 2.1m. The test model is suspended on the rigid bracket by eight springs, forming a 2D vibration system that can move vertically and rotate around the model's axis, shown in Fig. 3. End plates are provided at both ends of the model to eliminate the interference of the end flow. The critical flutter wind speeds obtained by the sectional model wind tunnel test are shown in Table 1. The mode combination is the first vertical symmetrical mode and the first torsional symmetrical mode.

**Figure 33.** Free vibration wind tunnel test for flutter (1:50 scale).

**Table 1.** Critical flutter wind speed (VS1: 0.0821Hz, 51.83t/m, and TS1:0.1583Hz, 12258.1 tm$^2$/m).

| Angle of attack(°) | -3° | 0° | 3° |
|---|---|---|---|
| Critical flutter wind speed(m/s) | 63.5 | 64.1 | 63.3 |

VS1 and TS1 represent the first symmetrical vertical and torsional mode.

## 2.2. 1:25 sectional model for VIV

The 1:25 free vibration sectional model test for VIV was conducted in the XNJD-3 wind tunnel of Southwest Jiaotong University, with a length of 3.9m, only to obtain the VIV performance of the same section in detail. The results confirmed that the aerodynamic configuration of the girder, which was mainly for flutter, also can eliminate the VIV, shown in Figure 4.

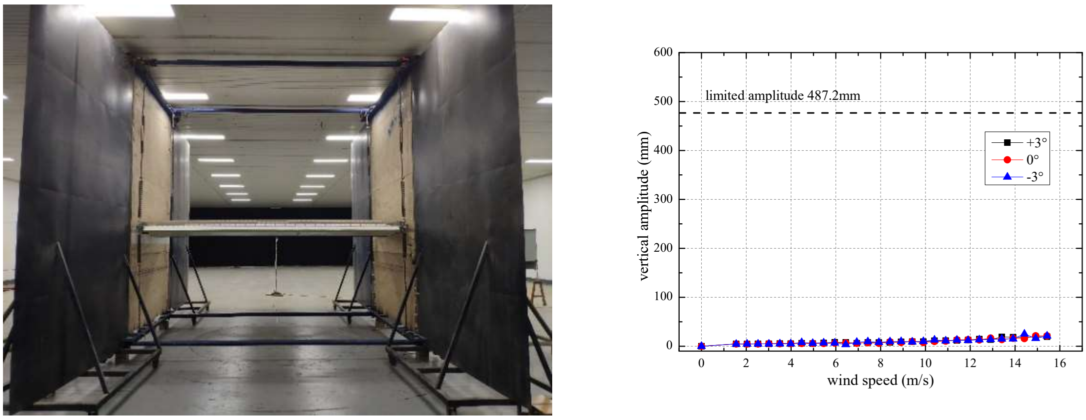


**Figure 4.** Free vibration wind tunnel test for VIV (1:25 scale)..

## 2.3. 1:196 full-bridge aeroelastic model wind tunnel test

The test was conducted in the XNJD-3 wind tunnel of Southwest Jiaotong University. The scale ratio of the model is 1:196, and the whole length is close to 22.0m. The aeroelastic model of the completed bridge comprises girders, towers, cables, hangers, barriers, railing, etc. The girder and the towers are composed of the metal spine assembly and the external claddings. The cable is simulated by steel wire, and the hanger is simulated by fine metal wire. For the railing, only their geometric shapes are simulated. The critical flutter wind speeds obtained by the full-bridge aeroelastic model wind tunnel test are shown in Table 2. At all angles of attack, the critical flutter wind speeds exceed the criteria speed.

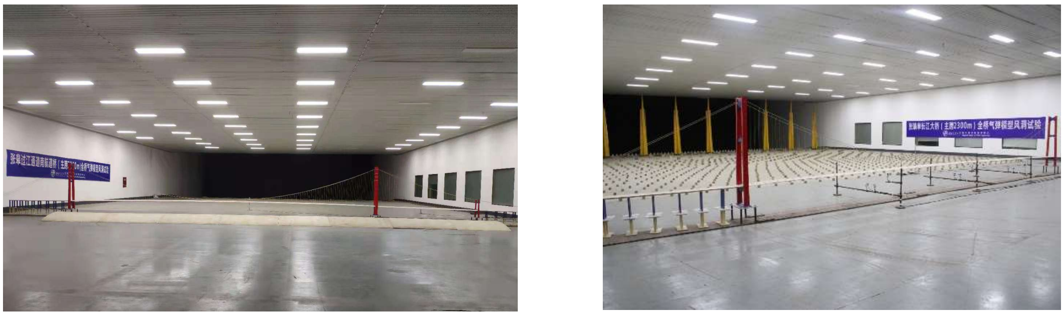

**Figure 5.** Full-bridge aeroelastic model wind tunnel test (left: laminar flow, right: turbulent flow).

**Table 2.** Critical flutter wind speed of the full-bridge aeroelastic model.

| Angle of attack(°) | -3° | 0° | 3° |
|---|---|---|---|
| Critical flutter wind speed(m/s) | 66.4 | 68.2 | 65.5 |

## 3. AEROELASTIC MODEL TEST OF THE TOWER

The tower was modelled using a frame of aluminum spine coated by external claddings made of light wood. The aluminum spine was used to provide the necessary stiffness and the additional mass to assure the mass similitude by using soft lead. The damping adjustment was realized using rubber tape strips, and the position was defined via a trial and error process to obtain the desired damping ratio. The test photo and the results in the tower model's laminar flow are shown in Fig.6. The results indicated that there is no VIV and galloping was observed in the test at various yaw angles, and the RMS displacement of the top at the design wind speed is 75mm .

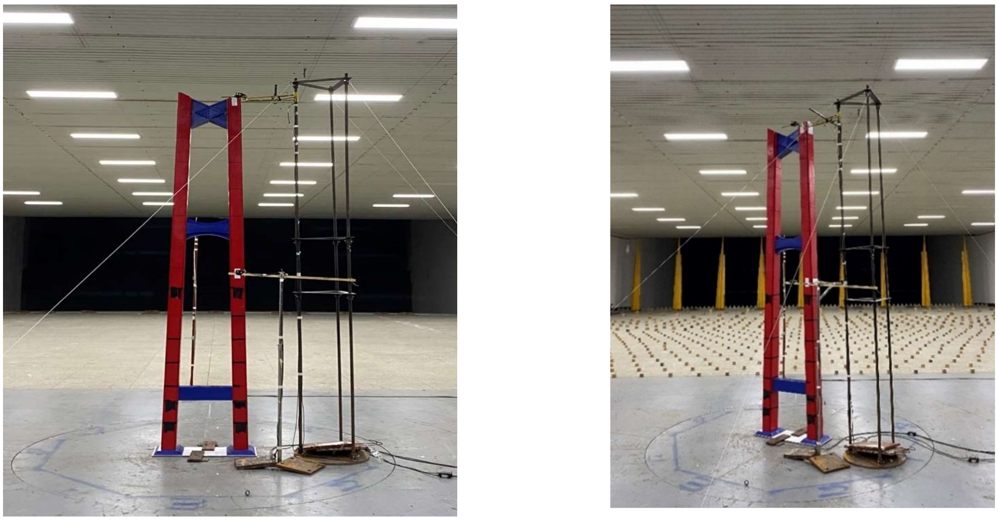

**Figure 5.** The aeroelastic model wind tunnel test of the tower.

## 4. CONCLUSIONS

The sectional model and the full aeroelastic model wind tunnel tests described in this paper were carried out to verify the bridge's wind-resistance design in the completed stage through measurement of the susceptibility to flutter/galloping instability and vortex shedding excitation. As a result, the following conclusions can be made:

No matter in turbulent flow and in laminar flow, no divergent instability (aero-static divergent and flutter) for the bridge girder at 0° and ±3° wind attack angle was found within the tested wind speed range, <65m/s (laminar flow) and <80m/s (turbulent flow).No matter in turbulent flow and in laminar flow, from 0° to 90° yaw angles, there is no VIV and galloping for the bridge tower was found within the tested wind speed range, <60m/s.


**REFERENCES**

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