A Proposal of Cable-stayed Bridge Composed of Steel Girder and Concrete Girder for Progress in Aerodynamic Stability and Seismic Performance

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Summary

The Ikina Bridge spans the strait between the islands of Ikina and Sashima in Ehime prefecture, Japan. Since the particular geographic conditions at the bridge site of the Ikina Bridge pose certain problems in terms of balancing the bridge dynamically across the span length, a composite cable-stayed bridge structure combining light-weight steel girders and heavy concrete girders is adopted to ensure the correct dynamic balance. While steel girders and prestressed concrete (PC) girders are joined near the main towers in conventional composite cable-stayed bridges, in the Ikina Bridge, the PC girder ranges are expanded to positions approximately 1/4 of the main span length from each of the main towers, where they are joined to the steel girders in order to improve not only the workability and economic efficiency of the Ikina Bridge, but also the wind resistance. A main girder design that achieves excellent economic efficiency by taking simple and rational wind-pressure countermeasures was selected, and the wind resistance was verified through wind-tunnel tests. In addition, H-shaped concrete main towers are adopted due to their excellent wind-resistance and durability as well as their conformance to the narrow road width condition. Sufficient aseismatic performance of the concrete main towers is ensured by reducing the self-weight by adopting a hollow cross-section and reducing cross-sectional forces by allowing minor plastic deformations in the connecting beams at the top of the H-shaped main towers. Note that this bridge is the first composite cable-stayed bridge in Japan in which stay-cables are anchored diagonally at both steel and concrete girders along the main span.

Keywords: cable-stayed bridge; composite girders of steel and concrete; concrete tower; aerodynamic stability method; aseismatic performance.

1. Design of the Main Girders

We pursued the adoption of a main girder shape that could ensure sufficient stability against wind pressure for the long-span bridge, with low ratios between the center span and road width, through simple and inexpensive countermeasures against wind pressure. As a result of verifying stability against the wind pressure of the basic cross-section in wind tunnel tests, it was found that the concrete girders satisfy the standards while the steel girders require separate countermeasures against wind pressure. Next, we examined countermeasures to be taken for the steel girders and as shown in Fig. 1. we confirmed that it is possible to ensure sufficient stability against wind pressure by adding both horizontal plates B and C while the Ikina Bridge is still in the intermediate status, and then remove horizontal plate B when the bridge is completed, leaving only horizontal plate C. Note that horizontal plate C is an effective countermeasure both when the Ikina Bridge is in intermediate state and when is it is completed, and it is safe to say that we succeeded in finding a rational countermeasure.

2. Design of the Main Towers

To determine the shape of the main towers, we compared the 3 most commonly used shapes in past cable-stayed bridges, H, A and inverted-Y, and adopted the H-shaped main tower design. In addition, we noted that the role of horizontal connecting beams set at the top of the main towers is crucial only during an earthquake. We thus allowed minor damage to the connecting beams in the design in order to suppress the cross-sectional forces in the main towers as well to improve aseismatic performance and reduce cost. In terms of the concern over damage to the connecting beams, we confirmed from the result of the FEM analysis shown in Fig. 2 that, by setting appropriate haunches, damage to the connecting beams will be concentrated in the haunches and will not advance further, and that the fracture morphology of the connecting beams can be controlled via flexural yielding.

3. Conclusion

The specifications of the Ikina Bridge are shown in Fig. 3. The Ikina Bridge adopts the following specifications to achieve a rational plan that excels in economic efficiency.

1) In spite of the given conditions where securing stability against wind pressure is difficult, we verified simple and rational countermeasures against wind pressure through wind tunnel tests and succeeded in keeping the required cost for countermeasures against wind pressure down to 0.3% of the main girder construction cost.

2) We treated the horizontal connecting beams of the main towers as dampers of cross-sectional forces applied to the main towers in the event of an earthquake and succeeded in reducing the bending moments applied to the main towers by up to 58%. By doing so, we achieved both improvement of the aseismatic performance and a reduction of the cost.

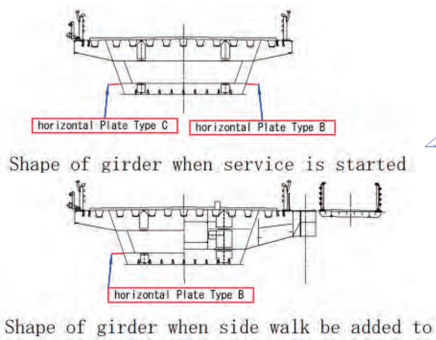
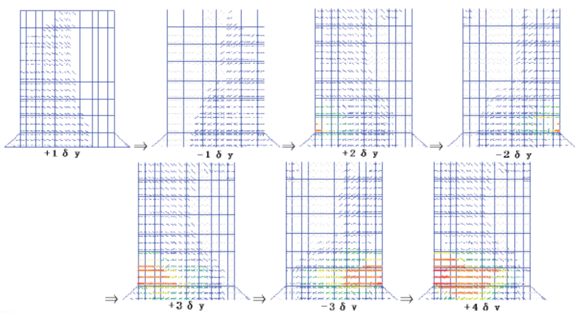


Fig.1 Location of horizontal plates



Colors	Blue	Green	Yellow	Orange	Red
strain	0.0≦ε<0.2	0.2≦ε<0.35	0.35≦ε<0.5	0.5≦ε<1.0	1.0≦ε

Fig.2 Results of FEM analysis

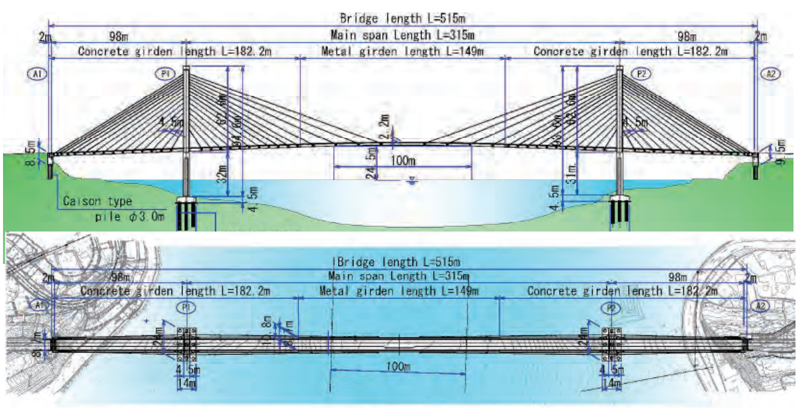


Fig. 3 The IKINA bridge