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AERODYNAMIC DESIGN OF KWANGYANG SUSPENSION BRIDGE WITH MAIN SPAN 1545M

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1 INTRODUCTION

The Kwangyang Bridge will connect Kwangyang City through Myodo Island to Yeosu City where the Expo shall be held at 2012. The main span length has been determined as 1545m to ensure the safety of heavy ship traffics in Kwangyang Harbor. The Kwangyang and Yeosu area is located in south seashore of Korean peninsula which is typhoon prone region at summer. Present paper summarizes the details of aerodynamic issues in the design of the Kwangyang Bridge.

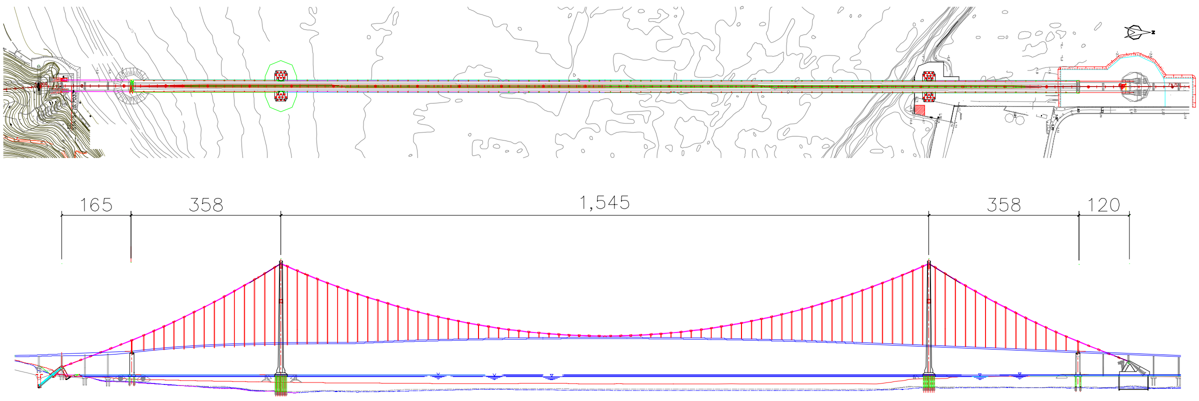


Figure 1: General layout of Kwangyang Bridge.

2 AERODYNANMIC DESIGN PROCEDURE

General procedure for aerodynamic design of Kwangyang Bridge is given in Fig. 2. In the first stage of design, preliminary cross sectional shape of the girder was derived based on the design code and computational fluid-structural interaction analysis. Wind climate analysis was also performed in conjunction with basic design.

The cross sectional shape of main girder was gradually modified from the section model tests with three different scales to maximize aerodynamic stability and to minimize drag force. Global analysis combined structural model and aerodynamic data were carried out to provide necessary data for the detail design. Finally the aerodynamic stability was confirmed from the full bridge tests for completion as well as construction stage.

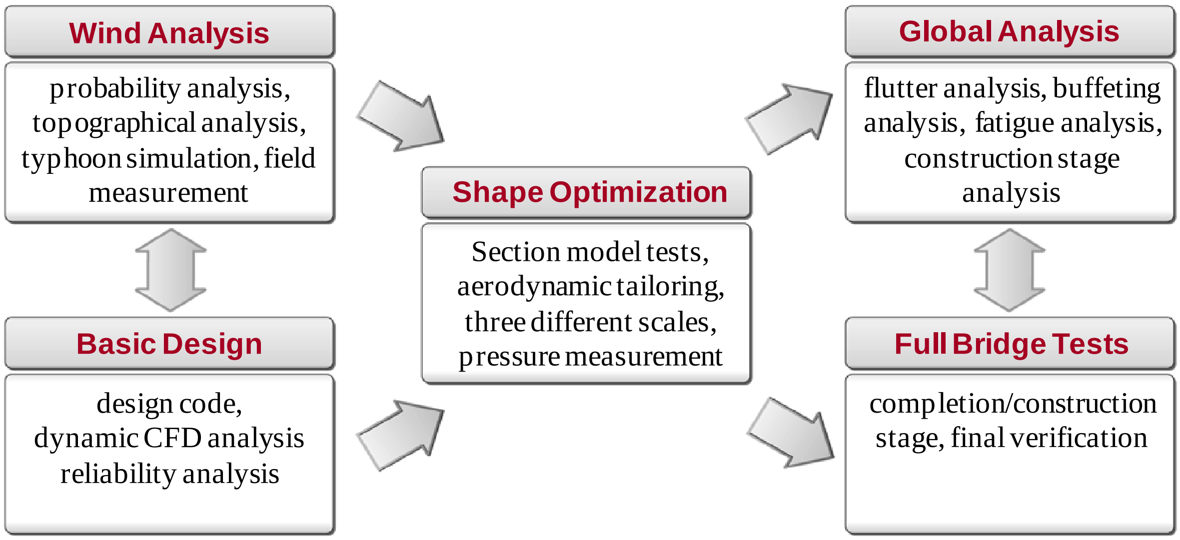


Figure 2: General procedure for aerodynamic design.

3 WIND CLIMATE STUDY

Wind data of two weather stations within 20km of the bridge site were used for estimating the design wind speed from the probability analysis based on extreme distribution. The estimated basic wind speeds for 200 years return period were different almost 25% from each other. Additional efforts were given to predict actual wind velocity at the site.

Basic wind speed was predicted again from Monte Carlo based typhoon simulation. Moreover computational wind field analysis for topographical model near the bridge site and short time field measurement for calibration of the numerical model were performed. However the wind speed estimated from four different ways were divided into two groups, and the conservative result was adopted finally.

The 10 minute averaged basic wind speed at 10m height was 40.4m/s, and design wind speed was 62.5m/s at girder height. Critical wind velocity for aerodynamic instability was evaluated from the reliability analysis. The safety factor corresponding to reliability index 4.0 was 1.3, and critical wind velocity became 81.6m/s consequently. Wind monitoring from 50m high tower has initiated from 2006 in order to acquire actual wind information at bridge site.

4 OPTIMIZATION OF GIRDER SHAPE

4.1 Girder shape

Basic cross section for main stiffening girder started from the ordinary single steel box section shown in Fig. 3(a). However, it was found that single box might not be feasible for main girder of Kwangyang Bridge which required critical wind velocity over 80m/s. Based on the experience of aerodynamic design of long span cable-supported bridges such as Messina[1], Xihoumen[2], Stonecutter[3] et al., twin box section shown in Fig. 3(b) was adopted to ensure the stability.

The girder shape was improved from section model tests with 1/100 and 1/70 scale models at the wind tunnels of Hyundai Engineering and Construction Company. Gap size between twin boxes was minimized to 4.3m which is the smallest among such kind of girders. Although flutter onset velocity of the section in Fig. 3(c) exceeded 120m/s, it was inevitable to modify the cross section because of severe vortex-induced vibration. The edge shape and angle of bottom flange were modified again, and then the section shown in Fig. 3(d) was found after the iterative tests.

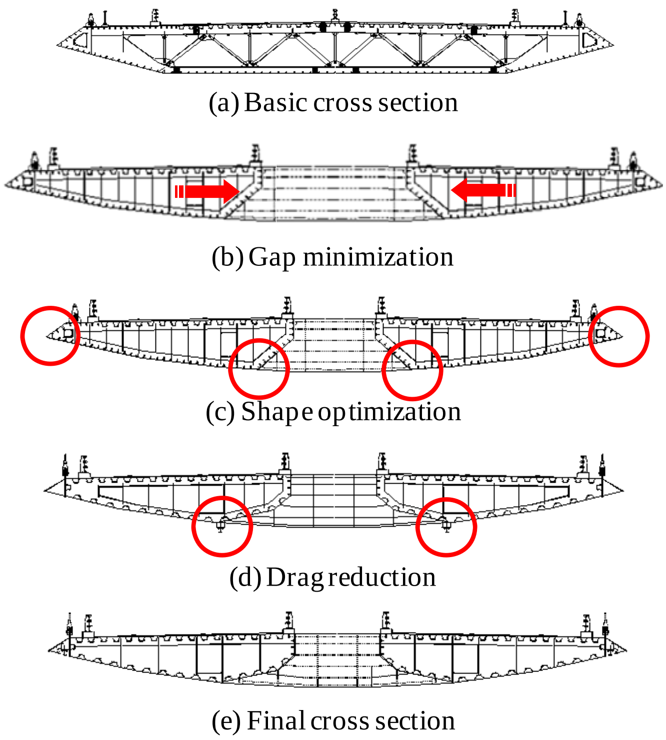


Figure 3: Modification of cross sectional shapes

Even though the cross section with gantry crane rails at its bottom flange showed good aerodynamic performance, drag force acting on girder was significantly increased because of the rails. After several trials such as placing the rails at various positions or attaching a flow guide vane used in Stonecutter Bridge[3], the final solution was burying the crane rails inside the edge fairing as shown Fig. 3(e) and Fig. 4.

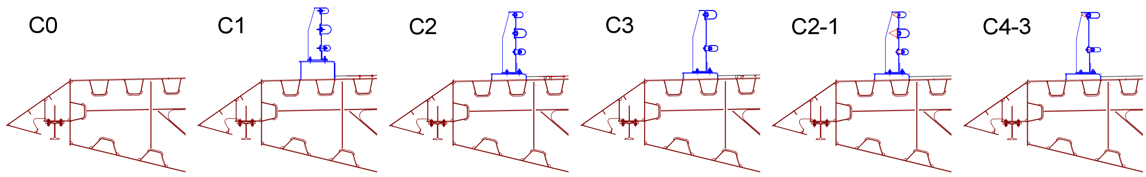


Figure 4: Variations of curb and railing.

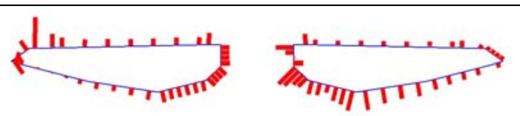
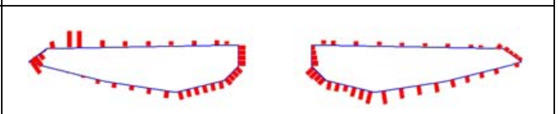
Section	C0	C2
C_p (mean)		
drag	176%(windward) - 76%(leeward)	78%(windward) + 22%(leeward)

Table 1: Mean pressure and drag force distributions.

4.2 Curb and railing

The effects of curb and railing on flutter onset velocity and drag force were studied from the 1/30 scale model tests. Fig. 4 shows the various curbs and railings used at the tests. It was found that drag coefficient of the section without curb and railing was just half of the section with curb and railing. However various combinations of curbs and railings might not affect to reduce the drag coefficients. The finally adopted combination was C2 in Fig. 4.

The wind pressures were measured at 74 pressure taps on the deck surface. As shown in Table 1, curb and railing affect the pressure distribution and contribute to share the drag force at windward and leeward decks.

5 VERIFICATION OF AERODYNAMIC STABILITIES

The aerodynamic stabilities were checked from the 1/165 scale full aeroelastic bridge model tests at the wind tunnel of University of Tokyo. Damping ratios of the model were mostly less than 0.4% to critical damping.

The tests were done for completion and construction stage under smooth and turbulent flow. The results in Fig. 6 showed that dynamic instabilities were not observed within wind speed 100m/s. Small amplitude vortex-induced vibration in vertical mode which was already seen at the section model tests was disappeared at turbulent wind.

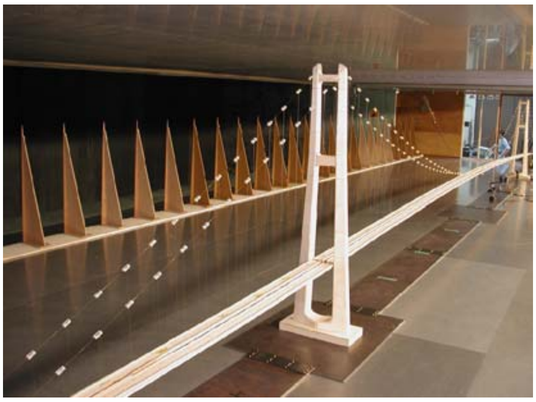


Figure 5: Full bridge model test.

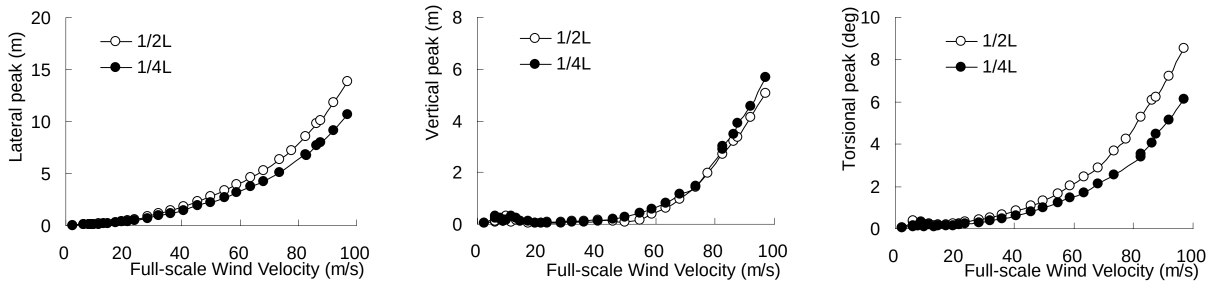


Figure 6: Dynamic responses of full bridge model test at completion stage.

6 CONCLUSIONS

A series of wind tunnel tests and analysis were performed in order to investigate possible aerodynamic problems of Kwangyang Bridge. The results show that any instabilities or undesirable vibrations might not be observed at the bridge.

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