EVALUATION OF WIND RESISTANCE OF PARALLEL PC EXTRADOSED BRIDGE (HIMIYUME OHASHI BRIDGE)

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1. Introduction

Himiyume Ohashi Bridge on the Nagasaki Expressway consists of two extradosed bridges (Phase I and Phase II) running parallel. Structurally, they are made of PC slabs with corrugated steel webs, continuously laid over three spans (Fig.1 and Photo.1). Considering that the bridge is put in unfavorable structural conditions for wind resistance, we evaluated the wind resistance of the bridge, taking into account the airflow characteristics at the location of the bridge.

The wind resistance of the parallel bridges was evaluated by confirming through a wind tunnel test that the resonant amplitude of over-excitation (vibration amplitude of vertical reflection is less than the structural allowable amplitude).

The specifications of the bridge are shown in Table-1 and Photo-1. Figure-1 shows the general drawing of the bridges.

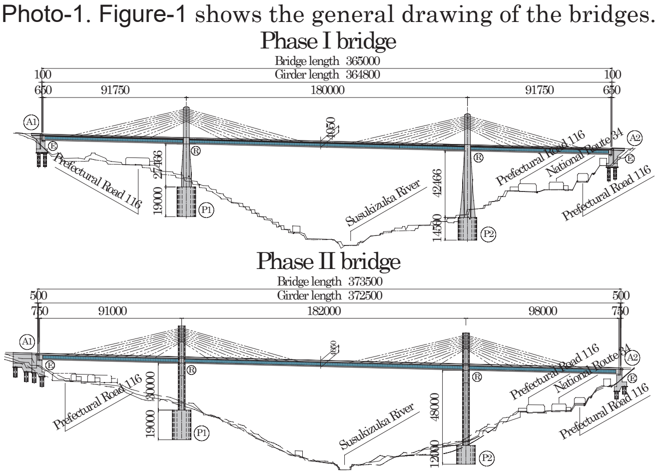

Figure-1 Specifications of the bridges

Photo-1 Himiyume Ohashi Bridge

Table-1 Specifications of the bridges

Length／Span lengths	Phase I: 365.0m / 91.8＋180.0＋91.8m Phase II: 373.5m / 91.0＋182.0＋98.0m
Girder height	D = 4.05m
Total width	B = 12.95m(Phase I), 12.60m(Phase II)
Center-to-center distance	W = 22.9m (Center of Pier 1 ~ Pier 2)
Construction method	Cantilever erection method

2. Evaluation process for wind-resistance performance

First, wind velocity in a construction site of Himiyume Ohashi Bridge was observed in order to determine airflow conditions, attack angle and turbulent intensity for wind tunnel test. Then, wind tunnel test was conducted using sectional model of girders which were design based on eigenvalue analysis results of whole bridge models. Finally, safety of girders oscillation due to vortex-induced vibration was evaluated by comparing resonance amplitude of the vibration obtained by the wind tunnel test with allowable amplitude estimated by structural analysis.

3. Wind tunnel test

The experimental specimen was a rigid partial model with a length of 2.7 m and a scale of 1/18 which was cut out of the longitudinal section in the axis direction of the bridge (Photo-2). Figure-2 shows relationships between the girders and definitions of wind direction and attack angle. The center-to-center distance of girders was simulated at the center of span between Pier 1 to Pier 2 where the vertical deflection of girder is maximum value.

The models supported at both ends by springs were given one degree of freedom toward vertical direction. The structural damping (hereinafter referred to as “logarithmic decrement”) was based on the result of vibration examination conducted after the completion of Phase I, and was adjusted by electromagnetic damper in the test.

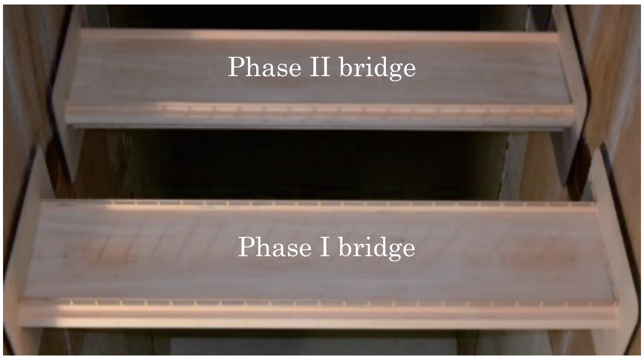

Photo-2 Model of wind tunnel test

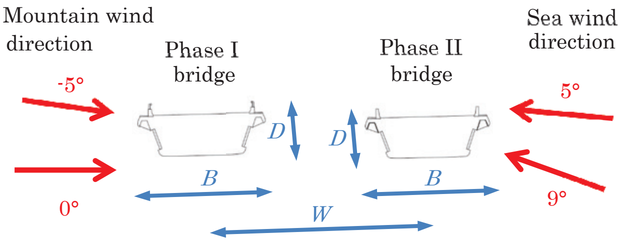

Figure-2 Wind directions and angles of attack for the wind tunnel test

4. Results of the wind tunnel test

As a result, the resonance amplitude of the windward bridge was less than half of the single bridge. On the other hand, the resonance amplitude of the leeward bridge presented a typical angle of incidence characteristic. At the angles of incidence of -5° and 5°, the amplitude was larger than that of the single bridge.

For the leeward bridge (Phase I bridge) with sea wind direction/5° angle of incidence which have the largest resonance amplitude recorded, the dynamic response characteristics were compared for different airflow conditions (Figure-3). The resonance amplitude in the uniform flow condition was 29.1 cm, while the resonance amplitude in the condition of the "turbulent flow" (Iu ≒ 8%) was 21.2 cm, and a 27 % decrease from the uniform airflow was confirmed.

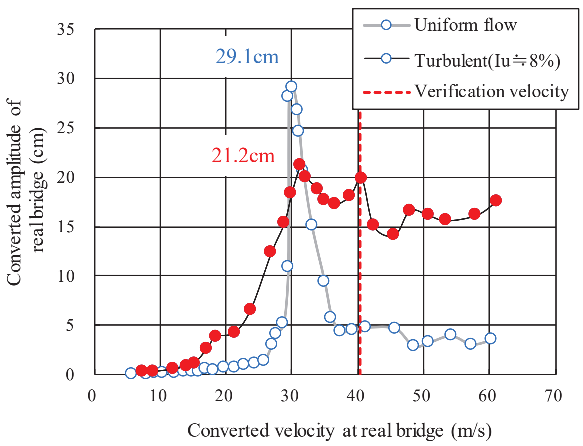

Figure-3 Dynamic response characteristics of leeward bridge (Phase I)

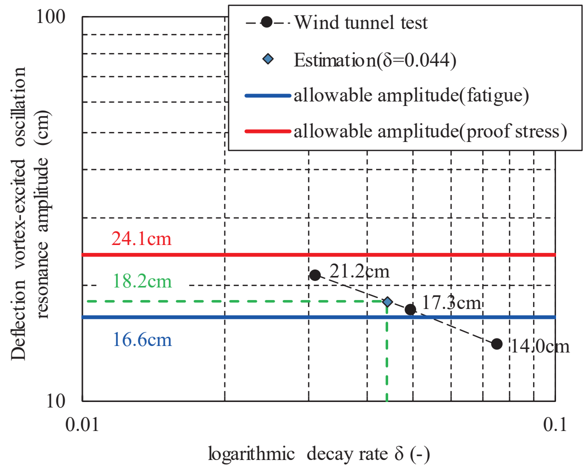

Figure-4 Relationship between logarithmic decay rate and resonance amplitude of leeward bridge (Phase I)

5. Evaluation of wind resistance

Figure-4 shows the relationship between the logarithmic decay factor δ and the resonance amplitude of vortex excitation for the leeward bridge under a turbulent flow (Iu ≒8%) producing vortex excitation, with the sea side wind direction and at an angle incidence of 5°. The logarithmic decay rate used for the wind resistance evaluation was determined to be δ = 0.044 for the actual bridge vibration measurement during the construction of the Phase I bridge. The estimated resonance amplitude was 18.2 cm, less than 24.1 cm, a calculation value from the fractural resistance at the moment the tensile reinforcement stress reaches the allowable level.

On the other hand, this wind tunnel test value was 18.2 cm, exceeding the fatigue verification amplitude 16.6 cm which corresponds to 2 million vibration repetitions. From the allowable number of repetitions obtainable from the stress acting in the girder and the predicted number of vibration repetitions considering the frequency of wind velocities of resonance range, we calculated the cumulative damage degree, which was much less than a unity.

From this result, the integrity of the structure was proved in terms of both fatigue verification and wind resistance.

Key Words : extradosed bridge, parallel bridge, wind tunnel test, wind resistance design

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