Effects of gap distance on VIV of a parallel cable-stayed bridge

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The effects of gap distance on vortex-induced vibration of two parallel section models are studied in a wind tunnel. Since two section models have similar cross-section and dynamic properties, the position whether the deck is located in upstream or downstream is the most significant difference between two decks in this study. Wind velocity at the beginning of the vibration of the downstream deck is affected by vortices from upstream deck. This is connected with separation flows from upstream deck through flow field observation.

Keyword: parallel bridge, vortex-induced vibration, particle image velocimetry, gap distance

1. INTRODUCTION

The vibrational vulnerability of bridge deck to vortex critically increases when two decks are located closely in a parallel disposition. This sort of phenomenon is observed and reported in previous researches[1),2)]. Since one of the critical parameters, which affects the vortex-induced vibration (VIV) of a parallel bridge, is the gap distance between two adjacent bridge decks, this study investigates the effect of gap distance on VIV of the two bridge decks identical to the previous researches with a series of wind tunnel tests.

2. EXPERIMENTAL SETUP

Every experiments were carried out in an Eiffel-type wind tunnel operated by the Department of Civil and Environmental Engineering at Seoul National University.

Since two section models are same with those used in the previous papers[1),2)], the detail geometry and dimensions of two sections are omitted in this paper. Two section models have similar shape and aspect ratio. The upstream is referred to B2 and the downstream deck is referred to B1, respectively hereafter.

Figure 1 shows the experimental setup. For the dynamic tests, two section model were mounted on spring-supported systems. The vertical and torsional displacements of both models were measured by 8 (4 for each section model) laser sensors. In this study, the gap distance and wind velocity are used in non-dimensional forms as L/D and V/nD, where L is the open gap distance between two sections, D is the depth of B2, V is the upcoming wind velocity and n is the motional frequency of section. It is noted that n is changed corresponding to the sections or modes of motion.

The setup parameters are summarized in Table 1. As meaningful torsional vibration were not observed during the entire experiments, the torsional setup parameters are omitted. Two bridges have similar vertical frequencies but B2 is slightly lower. The damping ratios were set to a minimum level for a better observation of vibrations. The Stcruton numbers of two sections are defined with the depths of each section model.

Averaged flow field in specific phase of one entire period[3)] were obtained by a high-resolution PIV system with a trigger generator which was synchronized with the vertical vibration of B2.

3. RESULTS AND DISCUSSIONS

Vortex-induced vibration (VIV) is well known for its resonance phenomenon with a limited amplitude. Flow crossing a structure alternately rolls up behind the structure with the vortex shedding frequency which is proportional to the mean wind velocity. The shedding vortex tuned to a natural frequency of the structure causes VIV in a specific velocity. For the sake of convenience, the specific velocity in which the vortex

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shedding frequency is identical to the nature frequency of the structure is designated as “resonant velocity”, hereafter. In a different manner, the minimum wind velocity causing VIV on a specific section is designated as “outset velocity”.

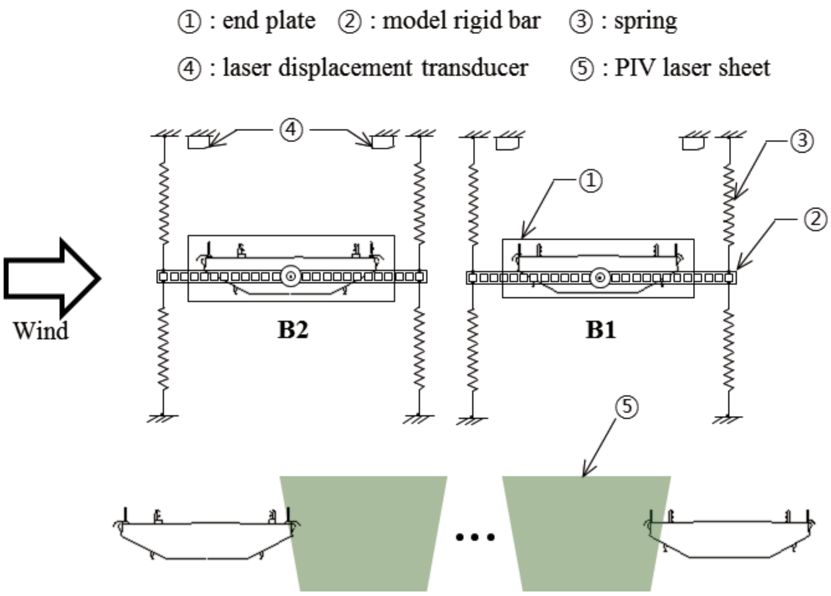

Figure 1: The experimental setup

Table 1: Captions should be centered above tables.

Parameters	B2	B1
Length (m)	0.900	0.900
Breadth (m)	0.353	0.329
Depth (m)	0.076	0.078
Mass (kg/m)	6.874	5.400
Vertical frequency (Hz)	5.096	5.875
Vertical damping ratio (%)	0.1	0.1
Scruton number	12.0	8.9

Figure 2 shows measured resonant velocities and outset velocities with various gap distances. The resonant velocity of B2 marked by black dots is derived by the vortex shedding frequency measured by a hot-wired anemometer while two sections are fixed, i.e. the sections are restrained to vibrate. The outset velocities are naturally obtained while the sections are free to vibrate. VIVs of B2 are observed at the gap distance of 2.1 or more. The outset velocity of B2 marked by squares are well matched with the resonant velocity in all cases.

Interesting points are observed on B1, the downstream deck. Since B1 has a different Strouhal number with B2, outset velocity of B1 should be different with the resonant velocity of B2. According to the results, it is true for only small gap distances. The outset velocities of B1 are also matched with the resonant velocity of B2 for large gap distances. It implies that B1 is affected by the vortices from B2 instead of the Strouhal number of itself. The gap distances of 2.5 to 4.0 seem to be a transient region. At this region, B1 is controlled by its Strouhal number as long as B2 is fixed, but it disappears while B2 is oscillating. PIV results at the transient gap distance show that the separation flows from the windward edge of B2 directly cross over the gap so re-separation at the windward edge of B1 does not occur as shown in figure 3. As separation flows comes into the gap area for further gap distances, re-separation occurs at the windward edge of B1.

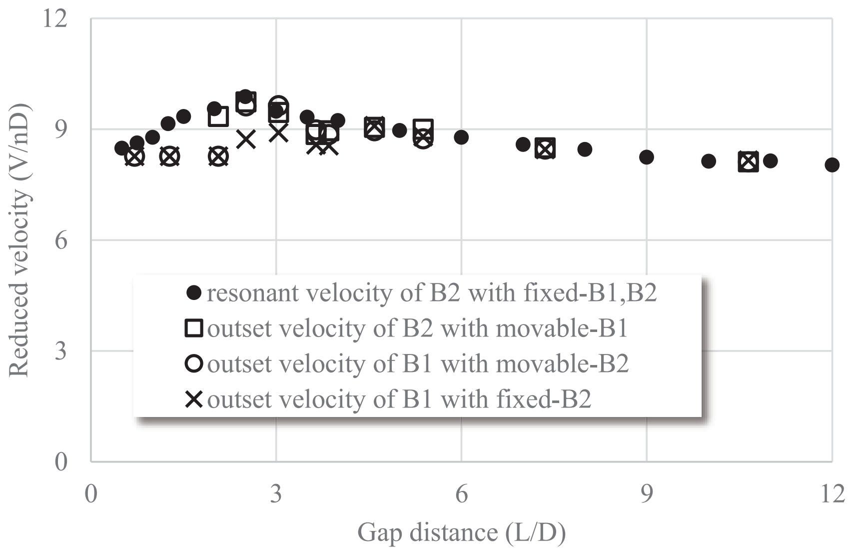

Figure 2: The resonant velocity and the outset velocities according to the gap distances

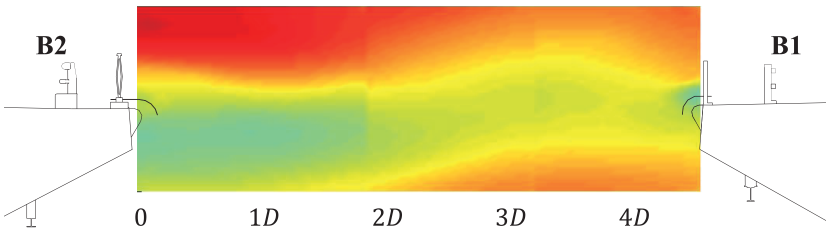

Figure 3: Magnitude of velocity distribution in the gap (red: higher velocity, blue: lower velocity)

4. CONCLUSION

VIV characteristics of two parallel section models with various gap distances are studied. Wind velocities of VIV of both decks are controlled by the vortex shedding frequency of upstream deck as long as the gap distance is larger than 4.6D. The motion of upstream deck is also important factor for the downstream deck as long as re-separation at the downstream deck does not occur.

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