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Effects of separation distance on VIV of parallel bridges in adjacent disposition

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ABSTRACT

A series of wind tunnel tests were conducted to study the effects of separation distance on VIV of parallel bridge. Total 13 cases of gap distance from 1.1 to 4.7 were studied. The intensive cases contribute to find the critical distances that behaviors of bridges sudden change. This paper introduces the results and discusses them.

1. INTRODUCTION

Aerodynamic behaviors of parallel bridge decks are known to be different with that of single case. In case of vortex-induced vibration (VIV), separation distance between two decks was studied as an important parameter in Kimura et al. (2008). The paper introduces the results with only 4 gap distances. Behaviors of decks are, however, protean with small change of gap, especially when they are in adjacent disposition. Moreover, the certain critical distance in which the behavior suddenly changes was observed by a series of wind tunnel tests.

2. WIND TUNNEL TESTS

Two test sections with similar shape and bluffness are shown in Fig. 1. Sectional parameters are included in Table 1.

2.1 Test setup

Two decks were set on each spring-supported system while S2 positioned at upstream. Non-dimensional parameters were used, the center to center distance between two decks, X, is divided by B, the breadth of S2. It is same description in Kimura's. Other setup parameters are summarized in Table 1. Both models have 2-DOFs, heaving and torsion, but torsional parameters were given unrealistic values to

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avoid torsional VIV appears in the region of interest wind speeds. Scruton number (Sc) is defined as follows:

$$Sc = \frac{2m\delta}{\rho D^2} \tag{1}$$

where m is the mass per unit length, δ the logarithmic decrement for heaving motion, ρ the air density and D the depth of bridge deck.

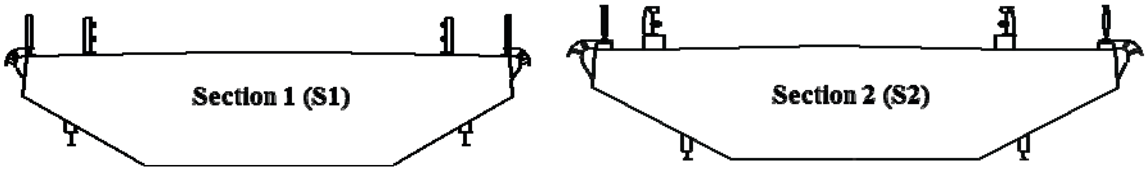

Fig. 1 Test sections

Table. 1 Sectional parameters

Parameters	S1	S2
Breadth (mm)	329.0	353.0
Depth (mm)	78.0	76.0
B/D ratio	4.2	4.6
Heaving frequency (Hz)	5.9	5.1
Scruton number for heaving motion	9.1	12.4

2.2 Results

This study focuses on the interactions in adjacent two bridges thus total 13 cases were conducted with X/B=1.1, 1.2, 1.4, 1.5, 1.6, 1.7, 1.8, 2.0, 2.1, 2.5, 3.3, 4.1 and 4.7. The entire results are categorized into 3 phases according to gap distance. Wind speeds – amplitudes curves for a representative case of each phase are drawn in Fig. 2 to 4. For the comparison, results of each deck in single disposition are shown in Fig. 5. The figures show the standard deviations of dynamic response according to the wind speeds. Y-axis indicates reduced amplitudes which is normalized by the depth of S2 while X-axis is the reduced wind speed normalized by the heaving frequency and the breadth of S2. Note that the results of S1 are normalized by same values of S2 in order to draw both results from each section on one axis.

1st phase is defined as gap distance is below 1.2. In this extremely closed disposition, upstream deck is silent although it has VIV in single bridge state. VIV of S1 shows similar amplitudes with that of single state but appears at higher wind speed. Changes of wind speed can be explained by difference of Strouhal number. It is reported by Seo et al. (2013) and Kim et al. (2013) that parallel bridges have different Strouhal number with that of single deck. However, further study is carried out to explain the reason of VIVs occurring in broad wind speeds.

2nd phase appears within X/B=1.4 to 2.0. It is the phase that the interactions between two bridges strongly appear. S2 vibrates first at low wind speeds. S1 begins to vibrate when the amplitude of S2 so decreases that the lock-in phenomenon disappears. During the lock-in of S2, VIV of S1 does not develops well since the vortex-shedding frequency (VSF) synchronizes the natural frequency of S2. After VSF is unlocked from S2, lock-in jump to the natural frequency of S1 and VIV of S1 largely occurs. One type of flow seems to govern two decks thus VIVs of both decks do not appear in same time. The VIVs are amplified by the interactions in both decks and the maximum amplitudes are observed in this phase.

3rd phase begins over the gap distance 2.5. As gap distance is further, the interaction effects on upstream deck quickly disappear and the state converse to single case. Downstream deck, however, differently behaves in the even farthest cases. It means that downstream bridge keep to be under upstream deck's influence. Two decks are not bonded tightly like phase 2 so that VIVs of both decks occurs in a same time.

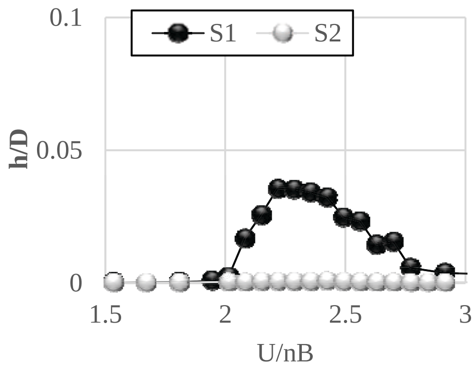

Fig. 2 V-A curves of X/B=1.1

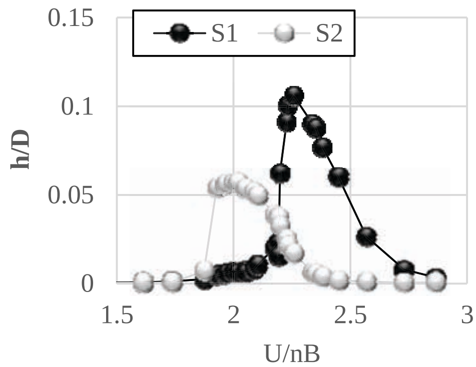

Fig. 3 V-A curves of X/B=1.8

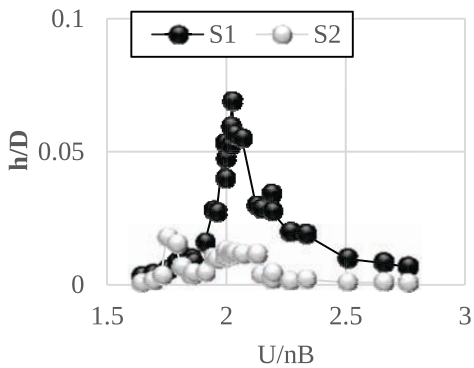

Fig. 4 V-A curves of X/B=3.3

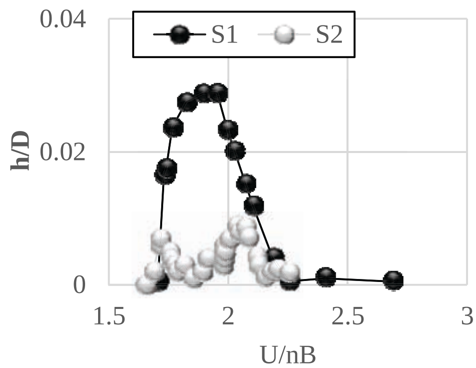

Fig. 5 V-A curves of each deck in single disposition

3. CONCLUSIONS

With intensive wind tunnel tests about separation distance in adjacent parallel bridge, it is confirm that gap is very sensitive parameter for VIV of parallel bridges. Gap distance keeps changing wind speeds and amplitudes of VIVs. There are, furthermore, critical points that behaviors of decks sudden change. One exists within X/B=1.2-1.4 and another point locates within X/B=2.1-2.5. Especially, interactive VIVs strongly occurs between two critical points. Over 2nd critical point, upstream bridge lose interaction effect and converse to single case.

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