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SUPPRESSION OF AEROELASTIC VIBRATION OF SHALLOW RECTANGULAR PRISM DUE TO ITS HORIZONTAL PLATES ON BOTH ENDS

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ABSTRACT: *The aerodynamic vibration of bridges in the strong wind is always brought into question. Therefore, aerodynamic measures to suppress aerodynamic vibration are necessary. For suppression device of aerodynamic vibration, there is technique to install the additional members such as fairing, flap and horizontal plate. The author paid his attention to the horizontal plate which is simple structure and highly effective to suppress aerodynamic vibrations in the additional members. However, at the present time, detail mechanism is not yet elucidated on suppressing aerodynamic vibration. Therefore, the examination of basic section was conducted at first to obtain the basic effect of horizontal plate on suppression of aerodynamic vibration. The flow visualization was carried out to obtain flow behavior around the model with horizontal plate of arbitrary width which was installed at the various positions on the sidepiece of model. As a result, it was confirmed that installing horizontal plate in the appropriate position controls the generation of separated vortex that is regarded as a factor to cause aerodynamic vibration. In addition, aerodynamic response of one degree of freedom in torsional vibration was carried out. The torsional flutter was suppressed in the case of horizontal plate with the appropriate position.*

Keywords: Rectangular prism, Horizontal plate, Flutter, Separated flow, Wind tunnel test

1. INTRODUCTION

In the current bridge design, aerodynamic stability of bridge has been investigated for most bridges after a structural section shape was determined. In these cases, aerodynamic stability of bridge has been secured by installing additional members such as fairing, flap and horizontal plate as suppression device of aerodynamic vibration. In the present study, author's attention was paid to horizontal plate which was one of the additional members for suppressing aerodynamic vibration. It has some advantages that the structural shape is simple and that suppression of aerodynamic vibration is relatively effective. However, a study about the horizontal plate is hardly performed in the past. Therefore, the shallow rectangular section with side ratio 5 (B/D=5) was used in the present paper, which is often used for a bridge girder. The suppression effect of the horizontal plate was examined by changing both the length and the installation position of the horizontal plate.

2. EXPERIMENTS

2.1 Flow visualization

Figure 1 shows the cross section of used model for flow visualization. Figure 2 shows enlargement of corner portion of the model. The test section of wind tunnel is 400mm×400mm. The size of rectangular section model was B/D = 5 (B=150mm, D=30mm). The model is made of permeable acrylic plate. Flow visualization was conducted by smoke wire method. Since there was a limitation on the available wind velocity in smoke wire method to take clear photos, wind speed of V = 0.6 m/s was used in the experiment. The cases of flow visualization were cases of basic section , with horizontal plate of θ=15 deg., 25 deg., 35 deg., and 45 deg. in b/D = 0.33 (b=10mm)

2.2 Aerodynamic response in torsional vibration

Table 1 shows experimental conditions of model in aerodynamic response in torsional vibration. The test section of the wind tunnel is 1780mm×910mm for measurement of aerodynamic response. The size of model used in the aerodynamic response test was B/D=5 (B=300mm, D=60mm). Experimental cases of aerodynamic response in torsional vibration were the case of basic section, with horizontal plate of 15 deg., 25 deg., 35 deg. and 45 deg. in b/D = 0.17, 0.33, 0.50 (b=10mm, 20mm, 30mm, respectively).

In the current bridge design, the investigation of aerodynamic stability of bridge is performed after a structural section is determined. In the current design process, the aerodynamic stability of bridge is secured by installing additional members such as fairing, flap and horizontal plate as suppression device of vibration. In the present study, the horizontal plate was dealt with as the additional member. It is said that the horizontal plate has big merits that its structure is simple and that it is highly effective for suppression of aerodynamic vibration. However, a study about the horizontal plate is hardly performed in the past. Therefore, the shallow rectangular prism with B/D=5 was used as the typical bridge section, and the size and installing position of horizontal plate were changed.

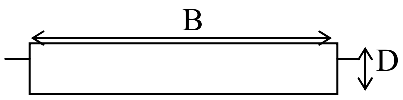


Figure 1: Outline of model

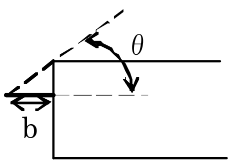


Figure 2: Close up of corner

Width of model : B(mm)	300
Depth of model : D(mm)	60
Mass per unit length : m(N·sec^2/m^2)	4.95
Mass moment of inertia per unit length : I(N·m·sec^2/m)	0.0679
Torsional frequency : f_θ(Hz)	2.59
Structural damping ratio in torsion : δ_θ	0.007～0.009

Table 1: Experimental condition

3. EXPERIMENTAL RESULTS

3.1 Flow Visualization

Figure 3 shows flow visualization around various cross sections at rest. Figure 3 (1) shows flow behavior of basic cross section in which the separated vortex occurs, and size of separation is larger than other cases. Flow behavior of the cases withθ=15deg. and 45deg.

(Figure 3 (2) and Figure 3 (5)) is almost similar to that of basic cross section. On the other hand, size of separation of the cases with θ=25deg. and 35deg. (Figure 3 (3) and Figure 3 (4)) is extremely smaller than those of basic cross section, cases withθ=15deg. and 45deg.. Furthermore, separated vortex does not occur definitely on upper surface in these cases (θ=25deg., 35deg.).

Figure 4 shows plots the path of separation flow to compare the path of separation of the experimented cases each other. The horizontal axis indicates the distance x from leading edge and vertical axis indicates the distance y from upper surface of the model to the separation flow path. They are normalized by width B and depth D of the model, respectively. Table 2 shows maximum value of y/D in each cross section. The maximum value of y/D in cases with θ =15 deg. and 45 deg. is smaller by only 20-30% than that of basic cross section. The maximum value of y/D in cases with θ =25deg. and 35deg. is smaller by about 50-60% than that of basic cross section. Therefore, the cases with θ =25deg. and 35deg. are expected to be more stable on aerodynamic vibration than basic section and the cases with θ =15 deg. and 45 deg.

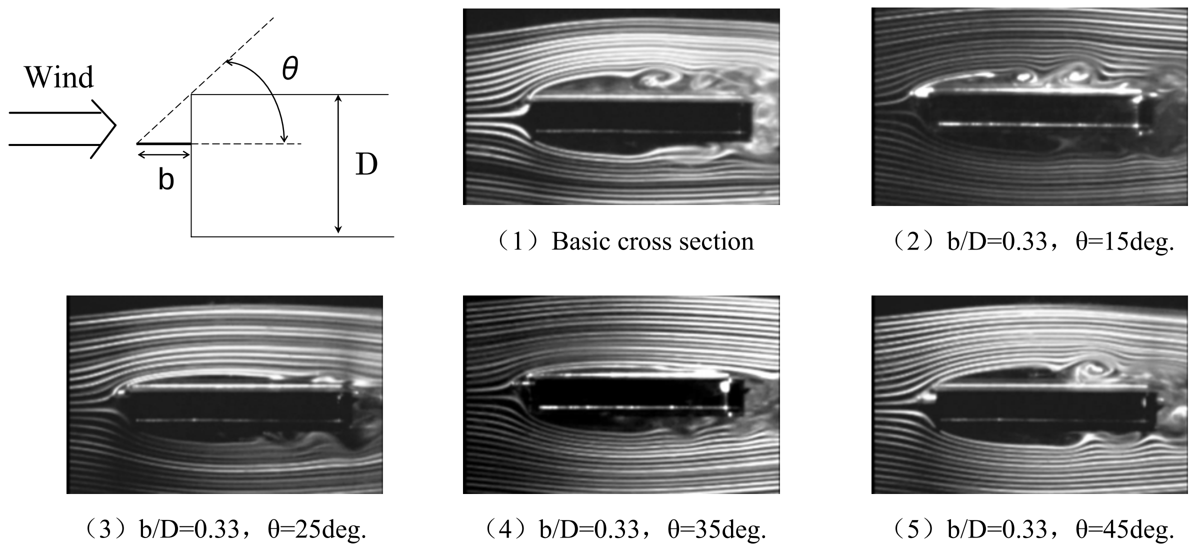
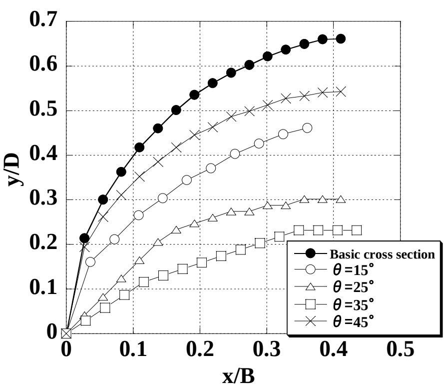


Figure 3: Visualization image



x: Distance from front corners-cut square part

B: Width of model

y: Distance from the model top surface to separated flow

D: Depth of model

Figure 4: Separated flow comparison figure

	Maximum value of y/D
Basic cross section	0.66
θ =15°	0.46
θ =25°	0.30
θ =35°	0.23
θ =45°	0.54

Table 2: Maximum value of y/D in each cross section

3.2 Aerodynamic response of torsional vibration

Figures 5, 6 and 7 show aerodynamic torsional responses in cases of b/D=0.17, b/D=0.33, and b/D=0.50, respectively. The flutter speed of the case flutter occurred was in the vicinity of flutter onset wind velocity Vr=6.0 of the basic section. In the case of b/D=0.17, the aerodynamic responses of the cases with θ =15 deg. and 25 deg. had almost similar tendency to that of the basic cross section. Therefore, the effect of the horizontal plate for the cases of b/D=0.17 with θ =15 deg. and 25 deg. is not recognized enough for improving aerodynamic instability of basic section. On the other hand, the flutter did not occur in the case of θ =35 deg. and 45 deg. In the case of b/D=0.33, the flutter occurred in the vicinity of Vr=10.0 in only the case of θ =15 deg. Although the flutter did not occur in the case of θ =45 deg., the double amplitude grew up to 5 deg. in the higher wind velocity region than Vr=12.0. In contrast, the flutter did not occur in the case of θ =25 deg. and 35 deg. Therefore, the effect of horizontal plate was also recognized enough for the cases of θ =25 deg. and 35 deg. In the case of b/D=0.50. The flutter occurred in the vicinity of Vr=9.0 in only the case of θ =45 deg. In contrast, the flutter did not occur in the case of θ =15 deg., 25 deg. and 35 deg. Therefore, the effect of horizontal plate was recognized enough in the cases of θ =15 deg., 25 deg. and 35 deg.

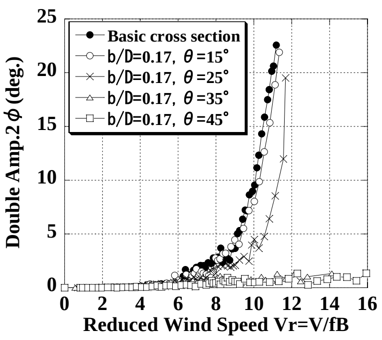


Figure 5: Aerodynamic torsional response in b/D=0.17

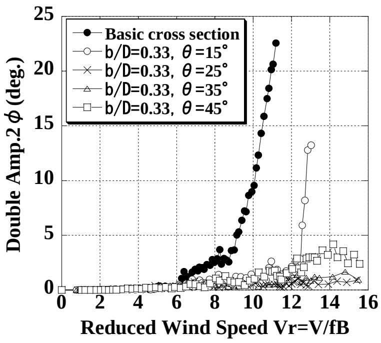


Figure 6: Aerodynamic torsional response in b/D=0.33

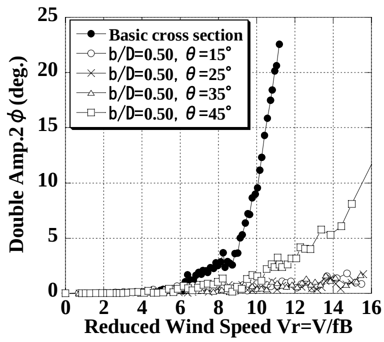


Figure 7: Aerodynamic torsional response in b/D=0.50

4. CONCLUSION

From the result of flow visualization, it was predicted that the aerodynamic instability could be improved by installing horizontal plate of b/D = 0.33 with θ = 25 deg. and 35 deg. The prediction from flow visualization was confirmed by conducting wind tunnel test for aerodynamic response in 1-D.O.F. torsional vibration. In the cases of b/D = 0.33 with θ = 25 deg. and 35 deg., the flutter was not observed as shown in Figure 6. The aerodynamic instability was observed in the cases of θ = 15 deg. and 45 deg. This also was predicted from the results of flow visualization. In addition, it was confirm that flutter did not occur at θ =35 deg. in the length of the horizontal plate of all three kinds.

It is concluded that the horizontal plate investigated in the present paper is useful to improve aerodynamic instability of shallow rectangular prism of B/D = 5 when the horizontal plate has the dimension of b/D=0.33 and θ =35 deg.

In future, the mechanism of horizontal plate how aerodynamic instability is improved will be clarified by observing detail flow behavior through PIV method.