TOWARD A FURTHER UNDERSTANDING OF RAIN-WIND INDUCED VIBRATION THROUGH EXPERIMENTAL WORKS

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1. INTRODUCTION

Rain wind induced vibration of cable has been observed on many cable-stayed bridges, not only in Japan but also all over the world. The combination of rain flow and wind can cause large amplitude cable vibrations of stay cables at low frequencies. These vibrations occurred typically when rain and moderate wind speeds (8–15m/s) combined in the direction angled 20° to 60° to the cable plane, with the cable declined in the direction of the wind. The frequencies were low, typically less than 3 Hz. The peak amplitudes were very high, in the range of 0.25 to 1.0 m, violent movements resulting in the clashing of adjacent cables observed in several cases. In addition, Matsumoto at el (1995) found that the divergent response could be found, because the formation of the upper rivulet at a certain location on the cable surface or the generation of the axial flow behind a yawed cable causes a negative slope of the lift force coefficient. Besides that, field of observations has shown that rivulets of water running down the upper and lower surfaces of the cable in rainy weather were the essential component of this aeroelastic instability. The water rivulets changed the effective shape of the cable and moved as the cable oscillated, causing cyclical changes in the aerodynamic forces, which led to the wind feeding energy into oscillations. The wind direction causing the excitation was approximately 45° to the cable plane. The particular range of wind velocities that caused the oscillations appears to be that which maintained the upper rivulet within a critical zone on the upper surface of the cable.

2. WIND TUNNEL TEST

The wind tunnel test was carried out in a wind tunnel circuit of the Yokohama National University, and the size of the working section is 1.3m width x 1.3m height. The maximum wind speed is up to approximate 24m/s. WTT was conducted on an elastically supported section model of a stay cable. The supporting system of cable model is 1-DOF in the vertical direction. Cable model with length 1.8m was tested to observe the response characteristics under artificial rivulet (Fig 1) and Rain Simulator System (Fig. 3). Apart from that, rain-wind induced vibration control method has been considered in this study.

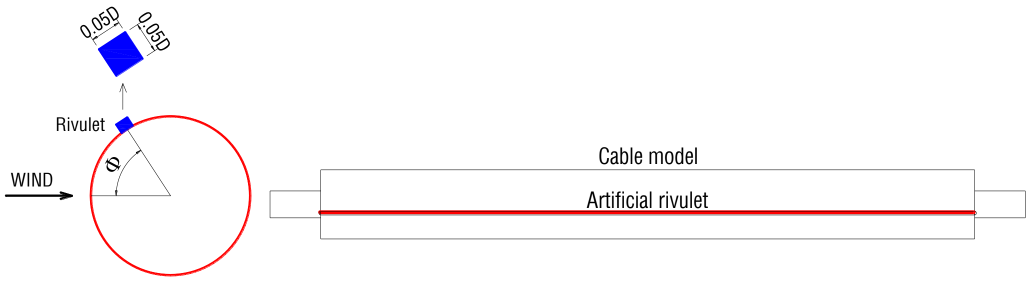

Fig.1 Rivulet position

3. CABLE GALLOPING DUE TO ARTIFICIAL RIVULET

3.1 Cable Galloping due to artificial rivulet

In present work, the critical angle of rain rivulet on the cable and the level of effect of rivulet to the vibration of cable are clarified. Based on the actual observation and the heritage of the past researchers, the upper rain flow was simulate by artificial rivulet which the width and thickness is 4x4mm equivalent to 0.05Dx0.05D. From the researches of Bosdogianni and Olivari (1996) and Gu et al. (2002), it is noted that the shapes of rivulet insignificantly affected to the cable response. In this experiment, five different positions of the rivulet locating relatively to the cable model were tested at 45^0, 55^0, 60^0, 75^0, 90^0 respectively. In this test, the Scruton number is approximate 15 and natural frequency equals to 1.15Hz. From Fig 2, it can be seen that the relative angle of rivulet (Φ) from 45 to 60 degree showed the most critical. The divergence galloping started from 50 to 70 of reduced wind speed and the most dangerous position of rivulet are 45 degree, 55 degree, and 60 degree respectively. This mean the critical rivulet zone is around 45-60 degree compare to 40 to 50 of S. Zhan at el (2008). Consequently, artificial rivulet contributes much in changing the effective cable aerodynamics and cause cyclical changes in the aerodynamic forces which led to oscillations. The yawed angle of 0 degree and 30 degree were also examined.

Keywords: Artificial rivulet, Rain simulator, Cable vibration, Rain-wind
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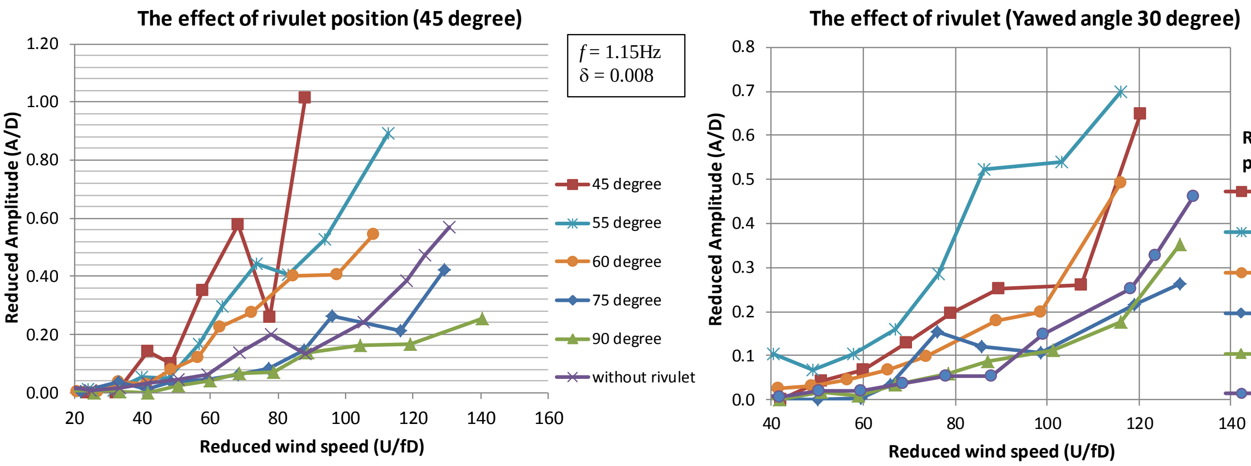

Fig. 2 Rivulet position

3.2 Experiments with Rain simulation system

In this wind tunnel test, cable model was fixed in the wind tunnel with the rain simulator and it was support in the direction same to Fig. 3. The cable model was arranged in a wide range of wind relative angle in order to check the effect of rain-wind interaction. The detailed of this experiment result as well as proposed control methods will be presented in full presentation.

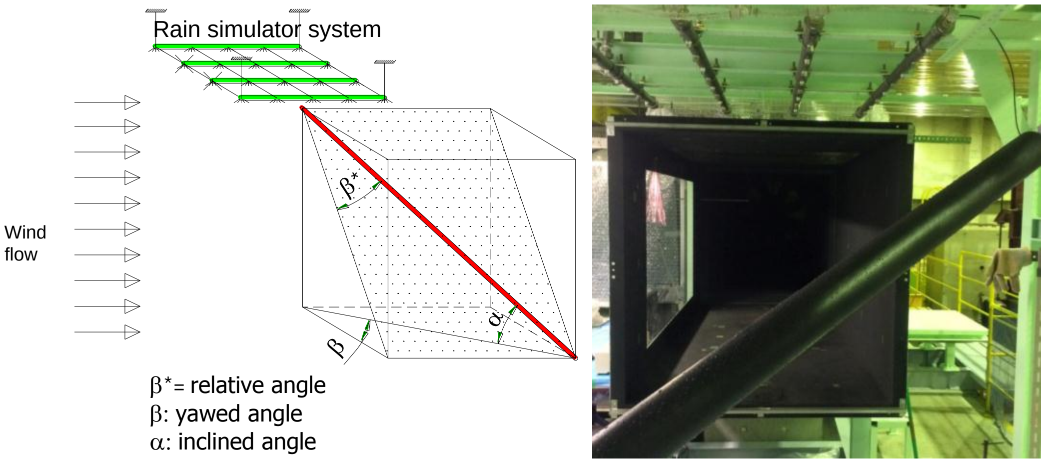

Fig. 3 The Wind tunnel test with rain simulator

8. CONCLUSIONS

In the present work, experiments were conducted for cable model by varying cable angle. Reliability of the work is judged by comparing to before publications. Many different cases of cable were considered. Under each case, the responses of cable due to effect of rain-wind are different. Up to now, the following conclusions have been figured out:

- Cable responses are extremely sensible with the position of artificial rivulet. The rain rivulet not only increases amplitude but also makes the divergence galloping happen at not so high wind speed.
- Secondly, the rain simulator system could simulate the nearly same condition of the bridge field. It also confirmed that the great effect of rain wind interaction to the cable vibration.

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