Investigation of Wind Influence to Prevent Dew Condensation in Steel Bridges by Using CFD Technique

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1. INTRODUCTION

Dew condensation is an important factor in the occurrence of bridges corrosion and contributor to the deterioration of protective coating. Therefore, it is important to prevent from occurrence of dew condensation in steel bridges. In this study, the wind influence to prevent dew condensation was investigated by using computational fluid dynamics (CFD) technique, and the investigation outcome confirmed the validity of proposed technique to a certain extent.

2. OVERVIEW OF SITE OBSERVATION

In this study, the steel girder temperature, air temperature and relative humidity were obtained at Toyokuni bridge. The measurement has been conducted since November 2018. In addition, the wind speed was measured from the nearest meteorological observatory (Inabu) for this bridge. Fig. 1 shows the bridge overview, this bridge is located in the northeast of Aichi prefecture, which is a steel girder bridge with length of 180m, and was built 1997.

3. FIELD MEASUREMENT

Fig. 2(a) and Fig. 2(b) show the evaluation results of dew condensation based on the temperature and relative humidity obtained in the bridge using sensors. The dew condensation occurred in December 11, and did not occur in December 6. However, the girder temperature is lower the dew point temperature in both days, which is supposed to be dew. The investigation revealed, although the girder temperature is lower than the dew point, the dew may or may not occur. This is thought to be due to higher wind speed in December 6. Fig. 3(a) and Fig. 3(b) show the wind speed in both days respectively.

4. SIMULATION OVERVIEW

The main purpose of simulation is to confirm the validity of the wind influence on prevention of dew condensation under the same condition of real bridge. In this study, the computational fluid dynamics (CFD) is used to perform a heat coupled simulation between gas and solid. Fig. 4 shows the simulation overview, the simulation was carried out based on the winter data obtained by field measurement and the same condition was applied. Here, one of the three parameters such as; wind speed, wind direction and steel plate shape were changed, and fixed the others Then the dew condensation was investigated based on the view point of wetting time. In order to determine the dew condensation, a water droplet with 1mm diameter was set to the wall surface. It is considered to be dry condition whether the droplet size is either equal or smaller than 1mm, and consider dew condition if it is greater than 1mm.

4.1 Relation between wind speed and dew condensation

A simulation was carried out to investigate the relation between wind and dew condensation through setting different wind speed value. The wind speed was changed from 0, 0.3, 3 and 12 m/s, which act vertically on the steel plate, and the wetting time was investigated. According to Fig. 5 the wetting time decreased as the wind speed increases which clearly confirm the wind influence on prevention of dew condensation.

4.2 Relation between wind direction & dew condensation

Here, a simulation was conducted to investigate the relation between wind direction and dew condensation by considering the wetting time. The wind speed was set to 12m/s, and the wind direction changed from 0º, 45º, 60º and 90º with respect to steel plate, and the difference in the wetting time was investigated. According to Fig. 6 the wetting time become shorter as the wind direction approach to horizontally, and the wetting time reduced to 45% when the wind direction with respect to steel plate is changed from vertical to horizontal.

Additionally, Fig. 7 shows the wind distribution around steel plate. According to the figure the wind speed is weak at the center of steel plate when the wind act in the vertical direction. Therefore, the exchange of heat energy to the center part decrease. Also as the angle of the wind direction to the steel plate approach to inclined, the wind distribution tends to becomes uniform. Therefore, it is considered that dew condensation equally dried, and it can be further uniformed when it approach to totally horizontal.

Fig. 1: Show the Toyokuni bridge overview

Keywords: Steel bridge, prevention of dew condensation, CFD, maintenance management.
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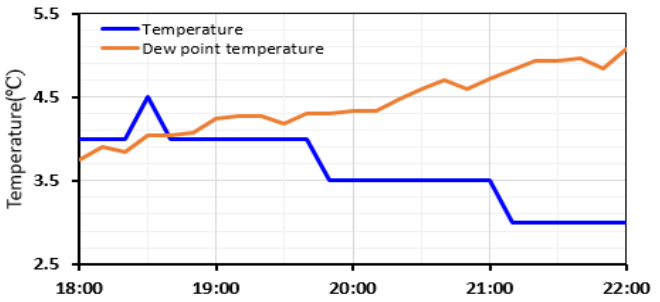
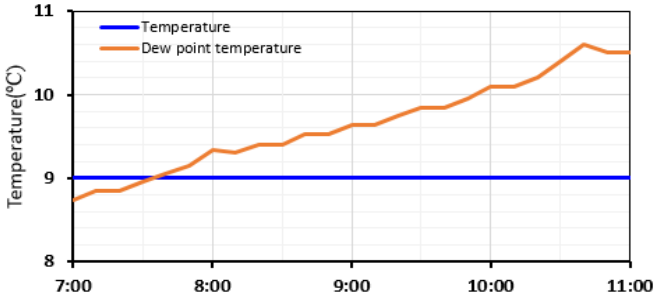
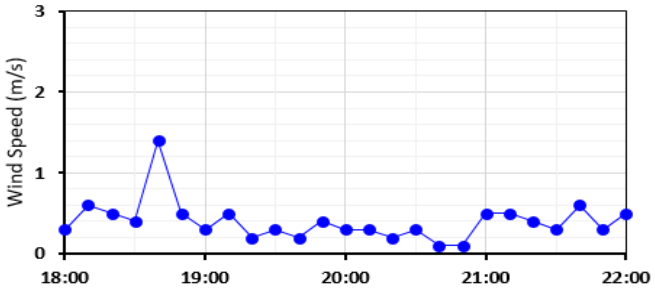


(a) December 11

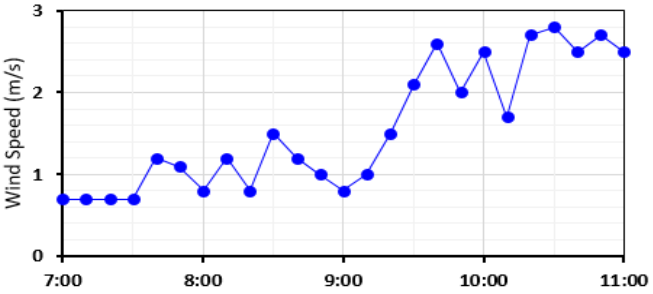


(b) December 6

Fig. 2: Comparison of girder and dew point temperature



(a) Wind speed on December 11



(b) wind speed on December 6

Fig. 3: Show the wind Speed at Toyoukni bridge

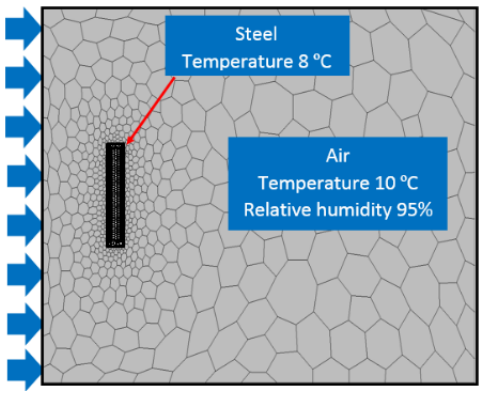


Fig. 4: Shows the simulation overview

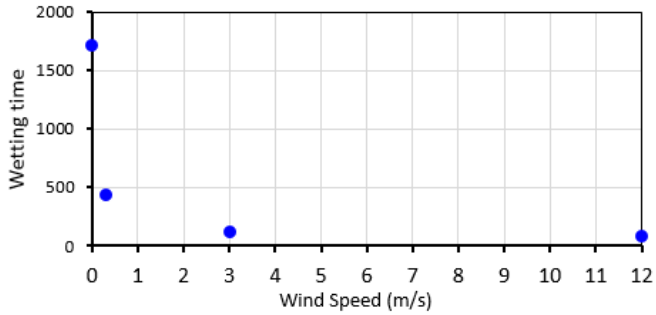


Fig. 5: Relationship between wind speed and wetting time

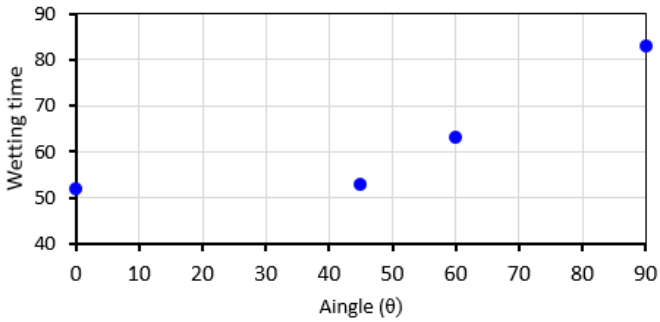
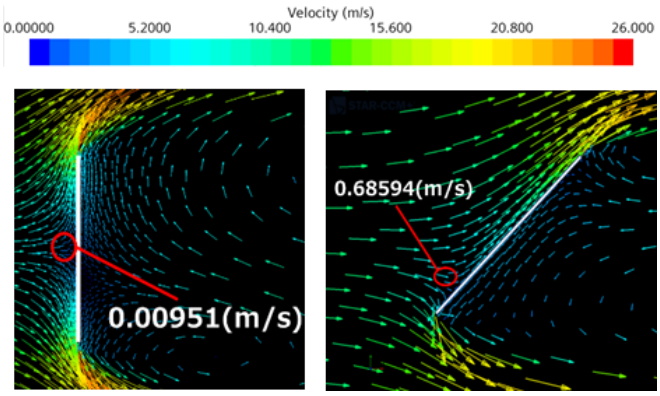


Fig. 6: Relationship between wind direction and wetting time



(a) Vertical direction (b) 45° direction

Fig. 7: Show the wind speed distribution

5. CONCLUSIONS

The corrosion caused by dew condensation is a challenging issue for steel bridges. The study aimed to investigate wind influence to prevent dew condensation. The study can be summarized as following:

1) It was confirmed through field measurements, that dew condensation may or may not occur in the environment where the dew condensation is possible to occur. In addition, it is depended on the wind speed.
2) It was confirmed that the higher wind speed caused further prevention of dew condensation compare to low wind speed.
3) The prevention effect of dew condensation was higher when the wind direction is applied parallel to the surface of steel plate.