第 I 部門

Reducing airborne sea salt adhesion amount on bridge girders by aerodynamic devices

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1. Introduction

In order to achieve effective maintenance and enhanced structural durability it is necessary to control corrosion of bridges. One major cause of corrosion in bridge structures is airborne sea salt adhesion and since Japan is surrounded by the sea, the effect of airborne sea salt on structural performance degradation due to steel corrosion is a serious problem. Basically, sea salt particles are transported by the wind and cause corrosion by being deposited on bridge girders. The objective of this study is to reduce airborne sea salt adhesion amount on an I-beam girder bridge consisting of eight girders by employing aerodynamic devices to change the wind flow pattern around the bridge deck and eventually reduce wind velocity.

2. Airborne sea salt adhesion amount estimation

Two-dimensional steady state flow field around the bridge deck is first simulated by employing the *k-ε* turbulent model of RANS equations.

Airborne sea salt adhesion amount around the bridge girders is then estimated according to the improved concentration flux method that takes into account adhesion of sea salt particles by inertial collision and diffusion action with consideration of gravity.

$$Q = C \cdot \left(V_n + V_s \cos\theta\right) \cdot \Delta t + C \cdot \int_0^{\Delta t} \sqrt{\frac{D}{\pi t}}\, dt \quad (1)$$

Q: Adhesion amount (mg/m^2), *C*: airborne salinity concentration (mg/m^3), *Vn*: wall normal wind speed (m/s), *Vs*: settling velocity of sea salt particles by gravity (m/s), θ: wall inclination angle (rad), *D*: diffusion coefficient (m^2/s)

Meteorological data (wind speed, wind direction) and airborne salinity concentration collected from previous research on Amadori Bridge in Wakayama prefecture are used.

3.Target bridge

The original bridge deck used in current research is shown in Fig. 1.

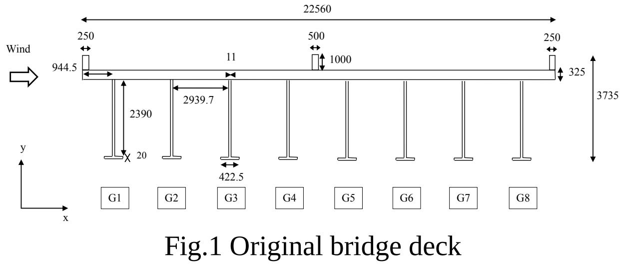

Fig.1 Original bridge deck

4. Aerodynamic devices

Aerodynamic countermeasure devices are installed on the original bridge deck with the strategy to reduce *x* and *y* components of time averaged wind velocity. First the effect of noise barriers installed on both ends of the bridge is investigated as shown in Fig. 2. Next, horizontal plates which exist on bridges as facilities for passage of electric cables and drainage pipes are investigated by being installed on girders facing upstream or downstream as shown in Fig.3. Vertical plates are then installed on the upstream edge of the flange of G1 so as to change the flow separation point. Finally, a combination of vertical plate on G1 and horizontal plates facing downstream from G5 to G8 is investigated as shown in Fig 4.

Installed horizontal plates denoted by HP, are defined as follows: HP(Girder, direction; length of plate).

Installed vertical plates denoted by VP, are defined as follows: VP(Girder; length to edge; length of plate).

Length of plate is abbreviated as LP and length to edge as LE. LF stands for length of flange of the original bridge deck. LE and LP are both described in terms of LF. All installed plates have the same thickness as the flange of the original bridge deck, which is 20mm.

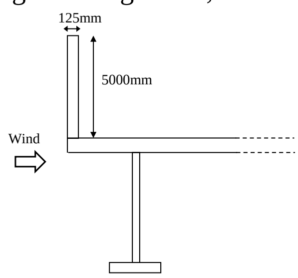

Fig.2 Installation of noise barriers

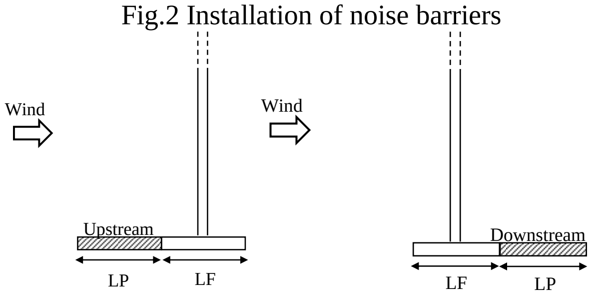

Fig.3 Horizontal plates facing upstream or downstream

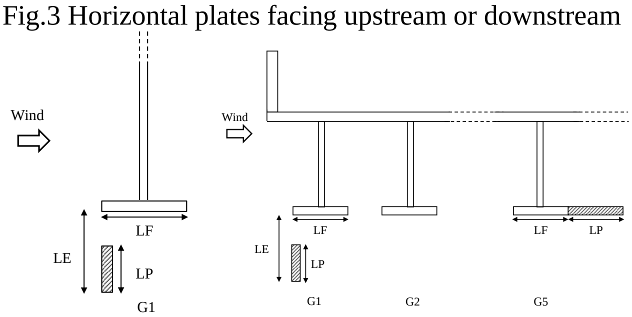

Fig. 4 Vertical plate on G1 and a combination of vertical plate and horizontal plates from G5 to G8

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5. Results

To assess increase or decrease in sea salt adhesion amount, the sea salt adhesion amount integrated over the span of each girder is calculated and ratio to the sea salt adhesion amount integrated over the span of the original bridge deck girders computed. Total sea salt adhesion amount corresponds to sea salt adhesion amount added from G1 to G8. The sea salt adhesion amount of the original bridge deck is set to 1. A ratio below 1 indicates decrease in sea salt adhesion amount. Vice versa is true. The results are shown in Fig. 5.

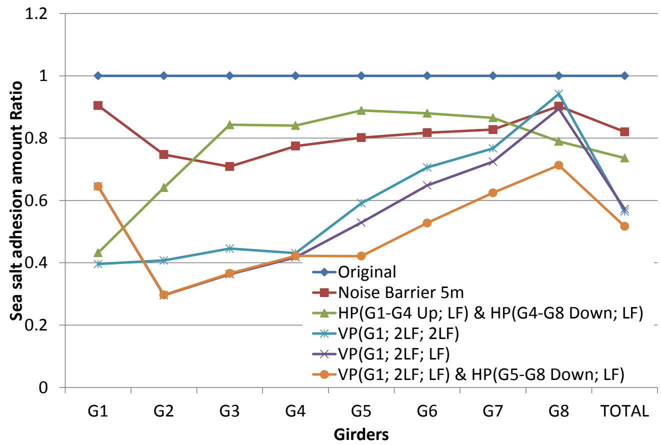
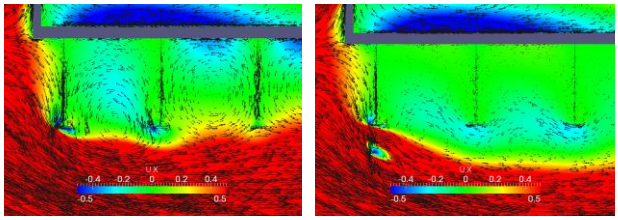


Fig. 5 Sea salt adhesion amount ratio in comparison to the original bridge deck after application of aerodynamic devices

According to the plot, a noise barrier of 5m installed on both ends of the bridge deck reduces total airborne sea salt adhesion amount by about 20%. Horizontal plates of length LF facing upstream on the upstream side of the bridge deck and downstream on the downstream side of the bridge deck, HP(G1-G4 Up; LF) & HP(G4-G8 Down; LF), reduce total airborne sea salt adhesion amount by 27%. A full-length vertical plate on the upstream edge of the flange of G1 with length to edge LE equal to 2LF and length of plate equal to 2LF, VP(G1; 2LF; 2LF), decreases total sea salt adhesion amount by 43%. The same applies to a vertical plate on the upstream edge of the flange of G1 with length to edge LE equal to 2LF and a slit of length LF created by a length of plate equal to LF, VP(G1; 2LF; LF).

For the combination of a vertical plate of length LF with a slit of LF on the upstream edge of the flange of G1 and horizontal plates of length LF facing downstream on the downstream side of the bridge deck, VP(G1; 2LF; LF) & HP(G5-G8 Down; LF), total airborne sea salt adhesion amount is reduced by about 48%. Compared to the case with no horizontal plates on the downstream side of the bridge deck, VP(G1; 2LF; LF), the total sea salt adhesion amount is lowered further by 5%. Therefore horizontal plates installed facing downstream on the downstream side of the bridge deck further reduce the total sea salt adhesion amount by 5%. Contour vector diagrams in comparison to the original bridge deck are shown in Fig.6.



a) Original bridge deck b) Combination VP & HP

Fig. 6 Comparison of contour vector diagrams of time averaged wind velocity in the *x* direction from G1 to G3 between the original bridge deck and the bridge deck with a combination of vertical and horizontal plates VP(G1; 2LF; LF) & HP(G5-G8 Down; LF)

According to the vector diagrams, an anticlockwise wind circulation flow is observed from G1 to G3 of the original bridge deck. The concentration of velocity vectors is also high hence high velocity is expected. After installation of a combination of vertical and horizontal plates, VP(G1; 2LF; LF) & HP(G5-G8 Down; LF), on the upstream side of the bridge deck wind circulation flow between the girders is significantly lowered by the vertical plate and very little circulation flow is observed between girders hence low wall-normal wind velocity and low sea salt adhesion amount. On the downstream side of the bridge deck, wind circulation flow is same as the original bridge deck in the anticlockwise direction however absolute values of time averaged wind velocity are lower hence low sea salt adhesion amount.

6. Conclusions

The following conclusions are drawn:

1) Installation of noise barriers and sound proof walls is recommended on bridges since airborne sea salt adhesion amount can be reduced.
2) By changing the positioning and orientation of horizontal plates for passage of electric cables and drainage facilities on bridges, airborne sea salt adhesion amount can be reduced.
3) Installing vertical plates on bridges can lower flow separation and circulation flow leading to decreased wall-normal wind velocity therefore low airborne sea salt adhesion amount.
4) A combination of vertical plate on the upstream side of the bridge deck and horizontal plates facing downstream on the downstream side of the bridge deck can further reduce total airborne sea salt adhesion amount by about 5%.

References

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