AERODYNAMIC COUNTERMEASURE DEVICES TO REDUCE AIRBORNE SEA SALT ADHESION ON BRIDGE GIRDERS

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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. Sea salt particles are transported by blowing 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 wall-normal 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 conforming to the improved concentration flux method [1] that takes into account adhesion of sea salt particles by inertial collision and diffusion action with consideration of gravity according to Eq.(1).

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

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)

For sea salt adhesion amount estimation, meteorological data (wind speed, wind direction) and airborne salinity concentration acquired from previous research on Amadori Bridge in Wakayama prefecture are used [2].

3.Target bridge

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

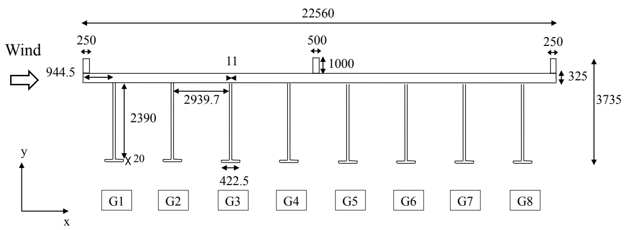


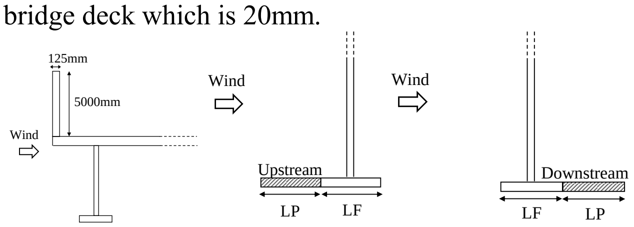
Fig.1 Original bridge deck (all dimensions in mm)

4. Aerodynamic countermeasure 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 on airborne sea salt adhesion amount 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 while facing either upstream or downstream as shown in Fig.2. A vertical plate is then installed on the upstream edge of the flange of the most upstream girder, G1, to alter the flow separation point. Following up the results of horizontal and vertical plates, a combination of vertical plate on G1 and horizontal plates facing downstream from G5 to G8 is investigated as shown in Fig 3.

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 installed plates is abbreviated as LP and length to edge as LE. LF stands for length of flange of the original bridge deck which is 422.5mm. 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.



a) Noise barrier b) Horizontal plates

Fig.2 Installation of noise barriers and horizontal plates

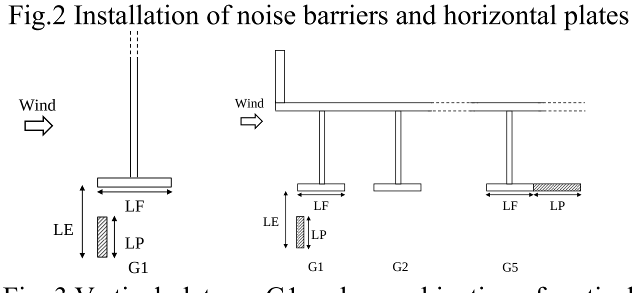


Fig. 3 Vertical plate on G1 and a combination of vertical plate on G1 with horizontal plates from G5 to G8

5. Results

To determine increase or decrease in sea salt adhesion amount, the airborne sea salt adhesion amount integrated over the span of each girder is calculated and

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ratio to the airborne 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 summed up 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. Obtained results are as shown in Fig. 4.
According to the plot, a noise barrier of 5m installed on both ends of the bridge deck reduces total sea salt adhesion amount by about 20%. Horizontal plates of length LF set facing upstream from G1 to G8, HP(G1-G8 Up; LF), reduce total sea salt adhesion amount by about 20%. The same applies to horizontal plates set facing downstream, HP(G1-G8 Down; LF). Altering the orientation of horizontal plates to face 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), reduces total 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).

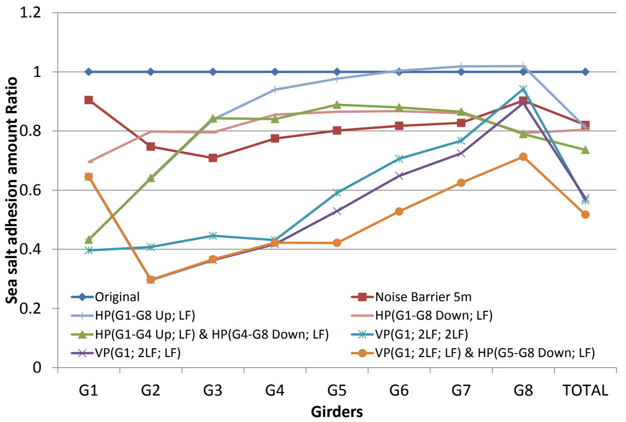
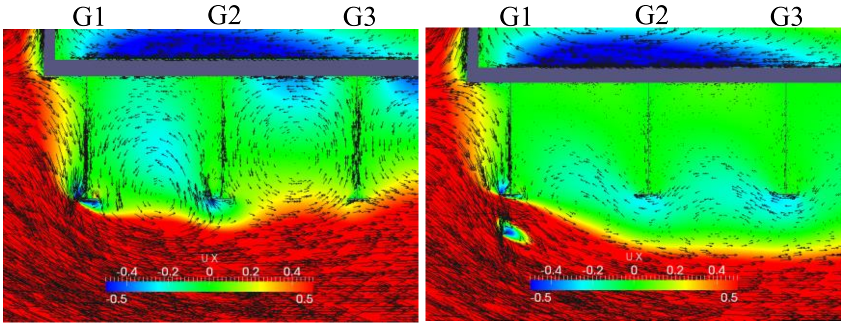


Fig. 4 Sea salt adhesion amount ratio in comparison to the original bridge deck after application of aerodynamic countermeasure devices

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 further lowered 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%.



a) Original bridge deck b) Combination VP & HP

Fig. 5 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)

Contour vector diagrams in comparison to the original bridge deck are shown in Fig.5.
According to the vector diagrams above, 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 wall-normal wind velocity. 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 airborne sea salt adhesion amount. On the downstream side of the bridge deck, wind circulation flow is same as the original bridge deck towards the anticlockwise direction however absolute values of time averaged wind velocity are lower hence low airborne 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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