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Investigation for corrosion characteristic of structural members on unpainted weathering steel bridge

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ABSTRACT

Severe corrosion damages have been reported in some of uncoated weathering steel bridges in an early stage of service. In this study, to investigate the corrosivity of structural members on uncoated weathering steel bridge, atmospheric exposure tests were carried out for 1 year using monitoring steel plates (MSP). In addition, atmospheric corrosion environment were also monitored by temperature and humidity sensor, corrosion monitoring (ACM) sensors, etc. The results of exposure test and the monitoring indicates that the corrosivity of north-side members on lower chord members was greater than those of south-side members. It is because that the corrosion damage was caused by the airborne sea salt, time of wetness for rainfall, mist and condensation.

1. INTRODUCTION

To properly maintain steel structures, it is important to investigate the corrosivity of structural member. Thus, progress and effect of corrosion damage on steel members and maintenance method against corrosion should be suggested, but predicted corrosion damage and useful maintenance methods do not go far enough until now. In a previous study about corrosion damages in steel structure, it has been usually conducted to verify their corrosion durability and corrosion environment, etc. using measuring the corrosion loss for anti-corrosive techniques as atmospheric exposure test and accelerated exposure test. However, it cannot evaluate the corrosivity of steel member. In this study, to investigate the corrosivity of structural member on weathering steel bridge, atmospheric exposure tests was carried out for 1 year using monitoring

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steel plates (MSP) and corrosion monitoring sensors (ACM). This paper shows main factor for corrosion damage and investigation the corrosivity on lower chord members.

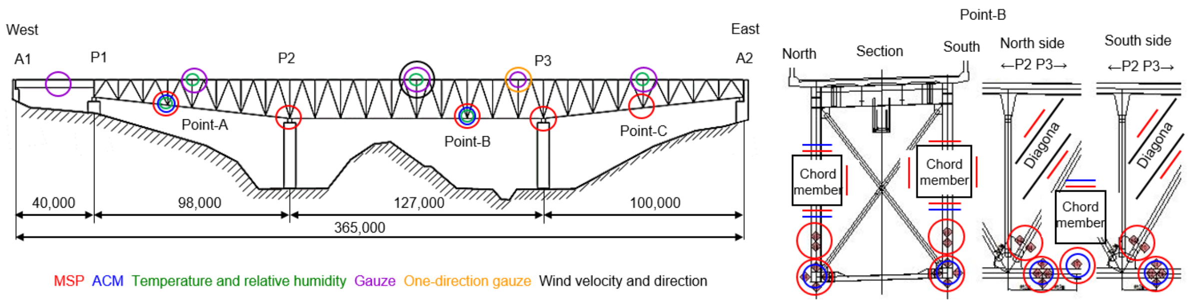


Fig. 1 Target bridge and installed location of specimens and monitoring devices

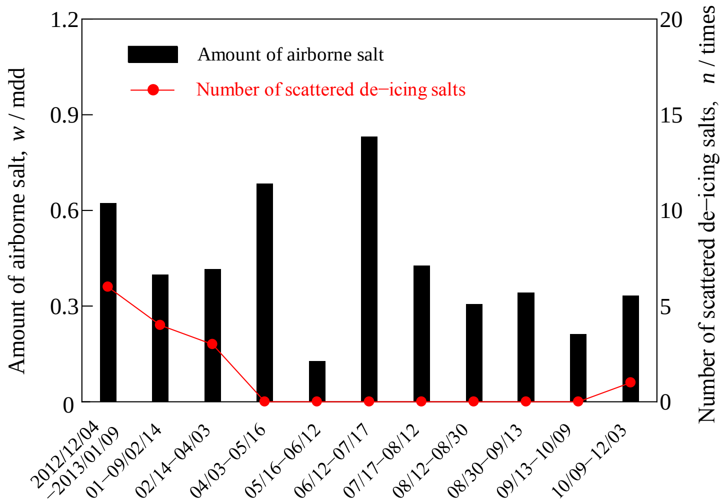
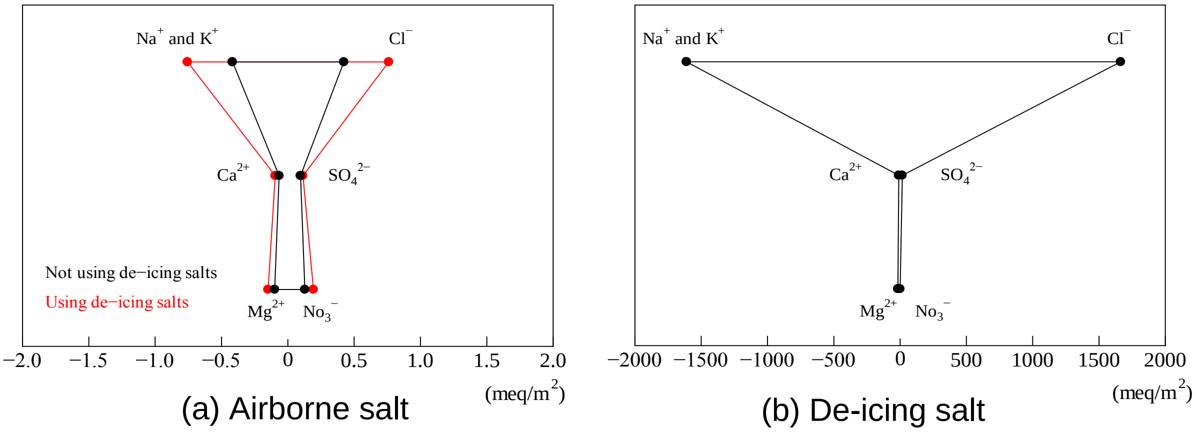


Fig. 2 Amount of airborne salt *w* and number of scattered de-icing salts *n* in the bridge

2. ATMOSPHERIC EXPOSURE TEST

To examine the corrosivity in weathering steel member depending on atmospheric environments, atmospheric exposure test was conducted for 1 year considering Japanese weather fluctuation throughout the four seasons. In case of corrosion problem, amount of airborne sea salt, moisture and sand puddle and their interaction and effect are important factors, the test was held on the unpainted weathering steel deck truss bridge in Kagoshima, Japan, which is about 5km away from the west coastline. Fig. 1 shows the target bridge and installed positions of specimens and monitoring devices. The temperature, relative humidity, wind velocity and direction, and airborne sea salts were measured to identify the corrosion environment with the thickness change of corrosion steel plate. In case of ratio of airborne salinity for important factor in corrosion



(a) Airborne salt (b) De-icing salt

Fig. 3 Components of salt in airborne salts and de-icing salts

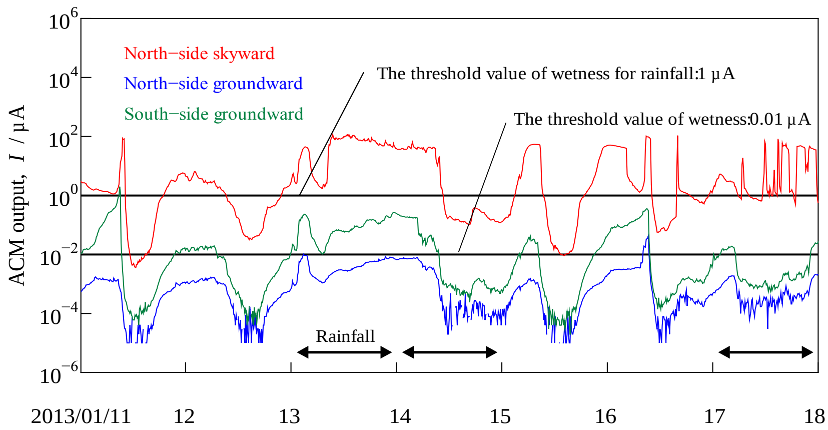
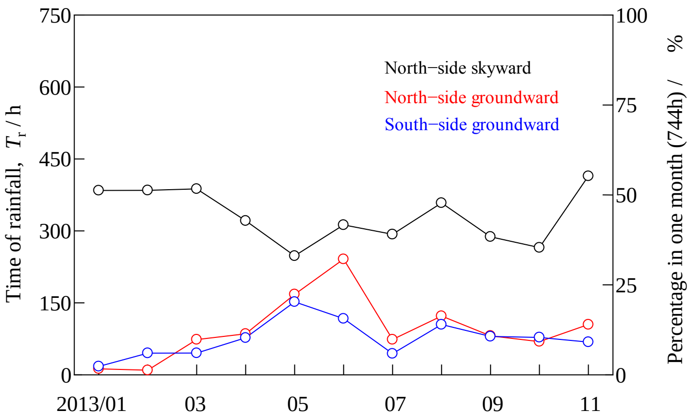


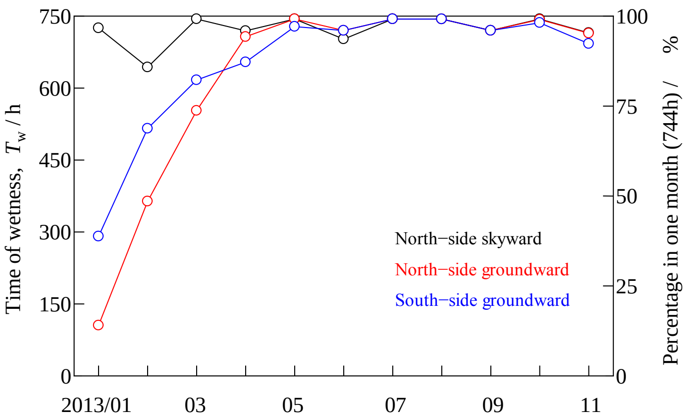
Fig. 4 ACM output *I* in lower chord members of point-B

environment, it was analyzed using dry gauze method (JIS (Japanese Industrial Standard) Z 2382).Steel plates specified in JIS G 3114 SMA490W were used. And their dimension are 60×60×3mm. In addition, output of ACM sensor was measured for 1 year during December 2012 to 2013.

The corrosivity of structural members on the bridge was evaluated by the thickness of corrosion product layer $t_{r,mean}$ and the mean corrosion depth d_{mean} of MSP. The thickness of corrosion product were measured by electromagnetic coating thickness gauge (Measuring range : 0 to 8mm, Resolution : 1μm (0 to 999μm), 10μm (1 to 8mm)). It was measured more than 11 times for the center position considering measurement error. d_{mean} on corroded surface was calculated by weight loss method after removal of the rust for each corrosion specimen. The evaluated mean corrosion depth $d_{mean,eva}$ was calculated on the basis of $t_{r,mean}$. In addition, the rainfall time T_r and time of wetness T_w were calculated based on measured ACM sensor (Shinohara 2005). And anion (Cl^-, NO_3^-, SO_4^{2-}) or cation (Na^+, Ca^{2+}, Mg^{2+}) of airborne salt formed on gauze were analyzed by ion chromatography method.

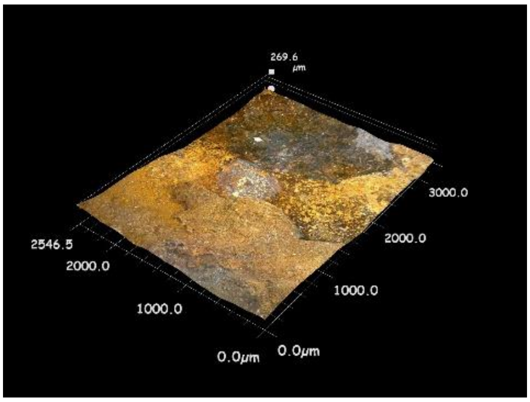


(a) Time of rainfall T_r

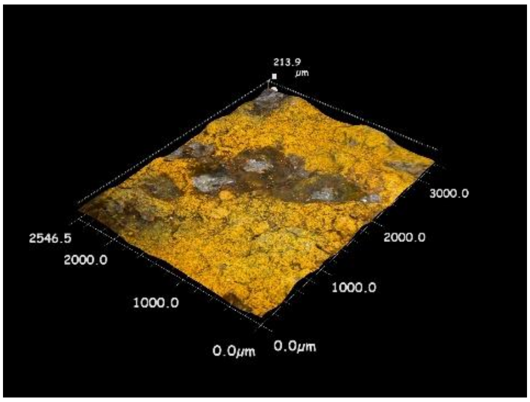


(b) Time of wetness T_w

Fig. 5 Time of rainfall T_r and time of wetness T_w calculated on *I* in lower chord members of point-B

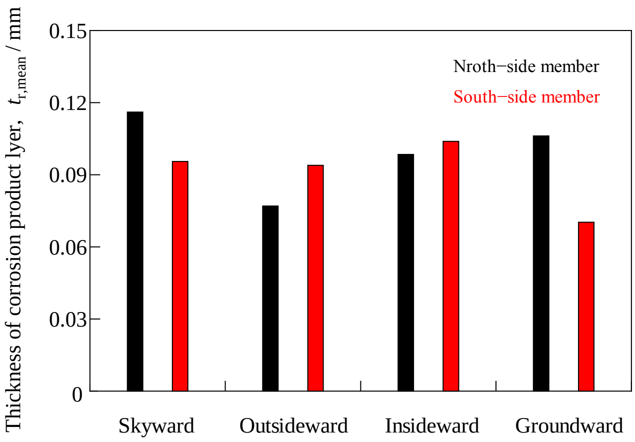


(a) Skyward

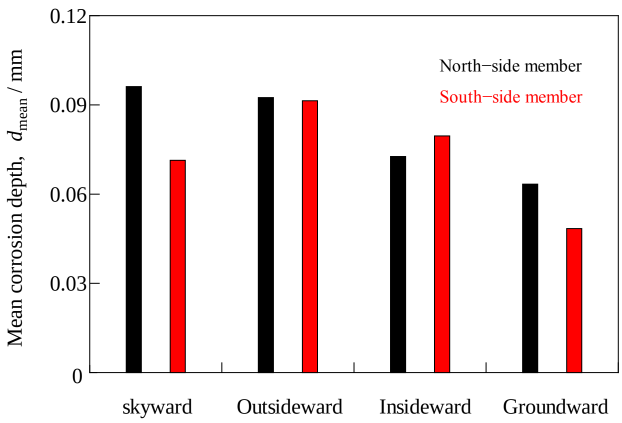


(b) Groundward

Fig. 6 Corrosion product surface on north lower chord members in point-B



(a) Thickness of corrosion product layer $t_{r,mean}$

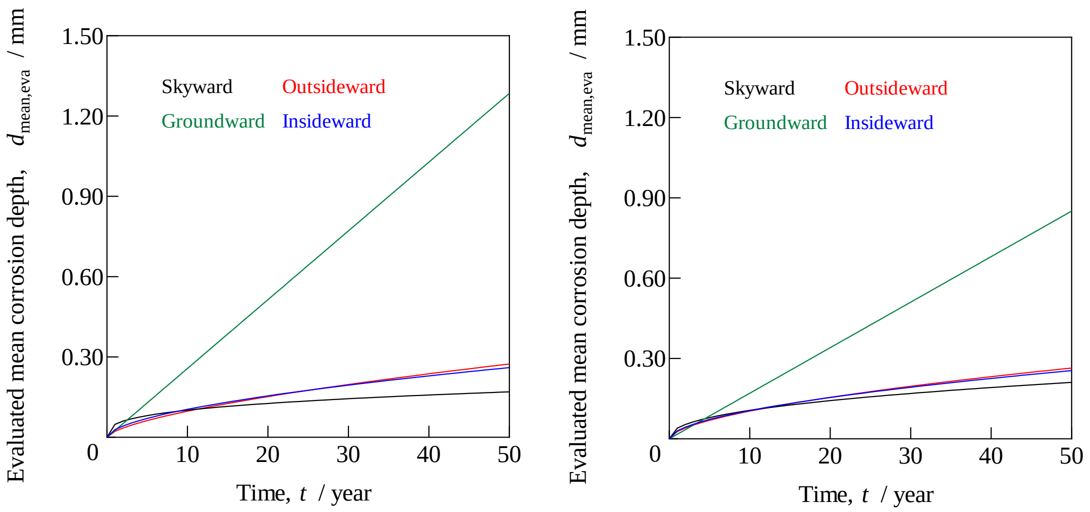


(b) Mean corrosion depth d_{mean}

Fig. 7 Thickness of corrosion product layer $t_{r,mean}$ and mean corrosion depth d_{mean} on lower chord members in point-B

Table 1 Terms of rainfall effect and airborne salt adhering and accumulating on each member in lower chord members in point-B

Member	Rainfall efect	Adhered and accumulated airborne salt
Skyward	Stagnant water	Without
Insideward	With	Without
Outsideward	With	Without
Groundward	Without	With



(a) North-side member

(b) South-side member

Fig. 8 Evaluated mean corrosion depth $d_{mean,eva}$ on lower chord members in point-B

3. TEST RESULTS AND DISCUSSIONS

In south-side member of point-A, the average temperature and relative humidity were 17°C and 75% under exposure period, respectively. The measured temperature and relative humidity were similar with those of other monitoring member. Fig. 2 shows amount of airborne salt *w* and number of scattered de-icing salts *n* in the center of span and piers of bridge. *w* is higher than 0.05mdd under the limit value to use an uncoated weathering steel (Public Works Research Institute of Ministry of Construction 1993), it can be affected on the corrosion damage in the bridge. Fig. 3 shows components of salt in airborne salt and de-icing salts. From the ion chromatography analysis, the airborne salt contains the Mg^{2+} and Ca^{2+}, but de-icing salts not contain. The proportion of Na^{+}+K^{+} and Cl^{-} to components of airborne salt was larger than de-icing salts with winter season. Therefore, airborne salts in the bridge were caused by sea salts, and it was affected by using de-icing salts in season.

Figs. 4 and 5 show ACM result and measured rainfall time T_r and time of wetness T_w on lower chord members in point-B. In Fig. 4, 1μA was the threshold value of wetness for rainfall and 0.01μA is the threshold value of wetness (Shinohara 2005). In case of rainfall, I of skyward was more than 1μA, but those of groundward was less than 1μA. T_r on skyward is longer than groundward, it was that skyward was effect of wash-away by rainfall. In case of April to November 2013, T_w of skyward and groundward showed about 90 to 100%. It can to be seem that skyward and groundward in chord member were always wet condition for rainfall, mist and condensation.

Fig. 6 shows the corrosion product surface of MSP on north-side lower chord member in point-B. The roughness of corrosion product surface on skyward was smooth by comparison with groundward. Fig. 7 shows the thickness of corrosion product layer $t_{r,mean}$, and the mean corrosion depth d_{mean} of MSP on north-side lower chord member in point-46. On skyward and groundward, $t_{r,mean}$ and d_{mean} of north member were larger than those of south-side member. It shown to be similar tendency with ACM sensor and thickness of corrosion product. From the test results, the corrosivity of north-side members on lower chord members was larger than those of south-side members in point-B.

Evaluated mean corrosion depth $d_{mean,eva}$ of MSP on lower chord members in point-B is shown in Fig. 8. On calculating $d_{mean,eva}$, the term of rainfall effect and airborne salt adhering and accumulating was assumed based on w, I and structure. Table 1 shows the term on each member. $d_{mean,eva}$ of skyward and sideward suddenly increases for first years, thereafter rate of this increase is small. On the other hand, $d_{mean,eva}$ of groundward increases also linearly. Therefore, it seems that the corrosivity of groundward is greater than those of skyward and sideward in lower chord members of point-B.

4. SUMMARY

In this study, the corrosivity of structural member on unpainted weathering steel deck truss bridge was investigated using monitoring steel plates (MSP) and corrosion monitoring (ACM) sensors. The main results obtained in this study are shown below.

1) Corrosion damage in the bridge was caused by airborne sea salts and a long time of wetness due to rainfall, mist and condensation.
2) Airborne salts in the bridge was derived from sea salts, and it was affected by using de-icing salts in snow season.
3) In the lower chord member, the corrosivity of north-side member was higher than south-side member, and those of groundward were more than skyward and sideward.

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