Corrosion Behavior of Hot-dip Al Coated Steel Plate Contact with Concrete in the Atmospheric Environment

Kyushu University Student member ○ Y. Gao Kyushu University Fellow member S. Kainuma
Kyushu University Regular member M. Yang Mitsui E&S Machinery Co. Regular member S. Ishihara
Shinko Alumer Industries Co., Ltd. Regular member M. Hashimoto
Sumitomo Mitsui Construction Steel Structures Engineering Co., Ltd. Regular member D. Inoue

1. Introduction Hot-dip Al coating is an effective method to protect steel structures from a corrosive environment. It is one of the most economical protection methods for coating large tonnages of steel. Especially in humid, marine, and industry atmosphere[1]. Many ancillary facilities of concrete structures, for example, guardrails, platforms, these steel structures were coated by hot-dip Al coating. The actual case of Al coating contact with concrete was shown in Fig. 1. Al is an amphoteric metal, can be dissolved in both acid and alkaline environments. The pH of concrete made based on Portland cement range from 12.5 to 13.8. The rain-washing effect can cause the stagnant water environment between coating and concrete. In this situation, the alkaline environment on the surface of concrete will occur due to the combined factors of alkalinity of concrete and stagnant water environment. This study evaluated the effect of an alkaline environment of concrete on the hot-dip Al coated steel plate according to atmospheric exposure tests.

2. Test method Hot-dip Al coated steel members are usually used in the ancillary facilities of bridge substructure. In order to simulate the actual situation of long-term contact between Al coated steel members and concrete. The atmospheric exposure tests were carried out for one year at Kyoda (Lat.26˚32'N, Long.127˚57'E) and Univ. of the Ryukyus (Lat.26˚15'N, Long.127˚46'E). Kyoda, located under the viaduct of the city road at about 30m distance from the west coastline, where has no rain-washing effect; University of the Ryukyus (denoted as UR) with rain-washing effect. The environment data of each exposure site was shown in Table 1. The schematic diagram of the test specimen is shown in Fig. 2. The specimen consists of three parts, concrete (water: 154 kg/m^3, cement: 285kg/m^3, sand: 783 kg/m^3, gravel: 1087kg/m^3, w/c=0.54), bolt, and hot-dip Al coated plate. The concrete base (Φ150mm, Height: 150mm) and Al coated steel plate (JIS G 3106 SM490A 60×60×12mm) were fixed by a bolt (M12×125mm). The bolt consists of a screw, washer, and nut. In this test, two sets of tests were set up. One is the Al coated steel plate contact with concrete directly, the other is the steel plates didn't contact with concrete and isolated by the poly tetra fluoroethylene (PTFE). After one-year exposure test, the corrosion produces of groundward of Al coated steel plates were analyzed by XRD.

3. Test results The hot-dip Al coated steel plates after exposure test were shown in Fig. 3. The skyward of Al coated steel plate was exposed to the atmospheric environment, the groundward contacted with the concrete or PTFE sheet. After completely isolated by the PTFE sheet, the Al coated plate was not affected by the concrete. For the skyward, the corrosion behavior of Kyoda was more serious than that of UR due to no rain-washing effect for the adhered airborne sea salt. No rainy-washing effect will cause more airborne sea salt accumulation and this effect can accelerate the corrosion rate. However, the groundward of the specimens, UR has a certain corrosion due to the rainy accumulation in the crevice of steel plate and concrete, it also formed an alkaline environment. Furthermore, Kyoda did not show serious corrosion behavior. The pH of hardening concrete decreased comparing with the fresh concrete[2]. In this case, Al coating did not show dissolution due to the pH value was not reach that can be dissolved. The analysis of corrosion products by XRD was shown in Fig. 4. Except for Al and Al_2O_3, some kinds of compounds consisted of Ca and Al, such as $CaAl(OH)_2$ and $Ca_2Al_2O_5 \cdot 8H_2O$ can be found in groundward of Kyoda. In the weakly alkaline and no stagnant water environment, the Al_2O_3 film and compound of Ca and Al will firmly be attached to the interface of steel

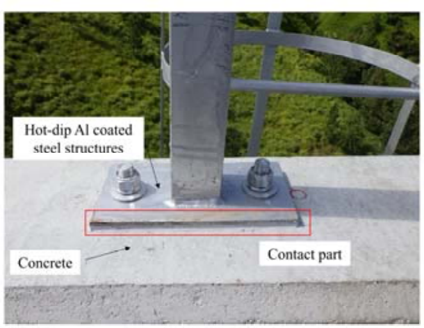


Fig. 1 The actual situation of hot-dip Al coated structures contact with concrete

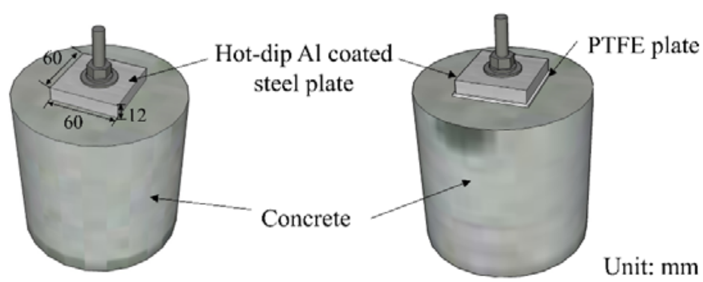
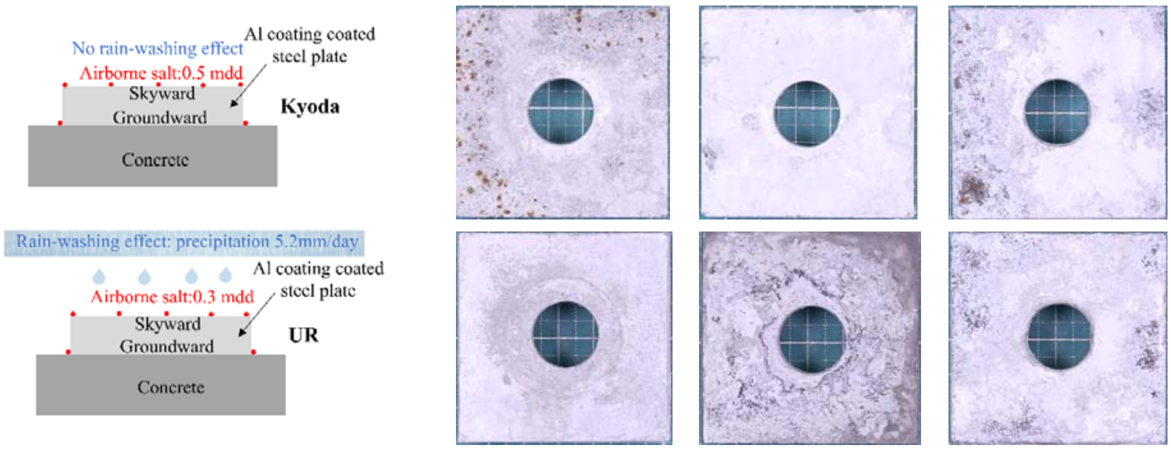


Fig. 2 The schematic diagram of test specimen

Table 1 The Environmental Data of Two Exposure Sites

Exposure site	Temperature T (°C)	Humidity RH (%)	Amount of Airborne salt w (mdd)	Offshore distance (m)	Yearly Average precipitation (mm/day)	Rain washing effect
Kyoda	22.7	82.9	0.5	30.0	5.3	No
UR	22.9	81.5	0.3	2.3×10^3	5.2	Yes



Environment condition Skyward Groundward Groundward (PTFE)

Fig. 3 The Corrosion Behavior of Al Coated Steel Plate after Exposure Test

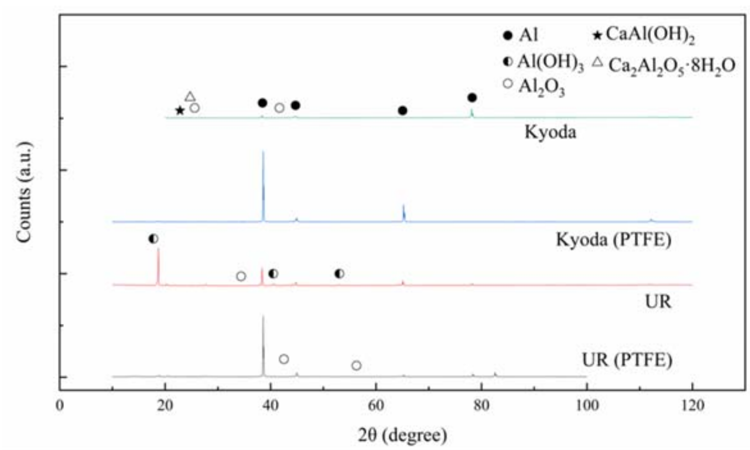


Fig. 4 The XRD analysis of the groundward surface of Al coated steel plate after exposure test

plate and concrete and have a certain protection effect to Al coating. In addition, after the exposure test, the steel plate and concrete were also hard to be separated, so the close adhesion also make the concrete play a shielding role on the steel plate. In the comparative test carried out with PTFE, after the test, the adhesion between PTFE sheet and concrete is very poor, the airborne salt and rainy (if have rainy-washing effect) can be penetrated into the crevice of steel plate and concrete and easily cause the corrosive environment. That is the reason why the steel plate specimens with PTFE, the corrosion behavior usually occurs around the edge of plate. As for Kyoda, the corrosion behavior of steel plate with PTFE was more serious than that of contact with concrete directly. Hence, concrete can provide a certain protection to Al coating in dry environment. On the contrary, as for UR, the opposite conclusion was obtained, the corrosion behavior of that contact with concrete directly was more obvious. The groundward of UR without PTFE is the most serious corrosion part in this test, through the composition analysis of corrosion products, $Al(OH)_3$ can be found, this indicated that the stagnant environment can occur more serious corrosion compare with the other situation. The corrosion products of contact parts that have PTFE were similar, consist of Al, Al_2O_3. The Al_2O_3 film can have a natural protection effect, Al_2O_3 composites exhibited excellent corrosion resistance in chloride environment than alkaline environment, this is also one of the factors that the corrosion behavior of groundward of UR was more serious than PTFE[3].

4. Summary 1) In the dry environment, the hot-dip Al coating contact with concrete, the concrete can provide certain protection to Al coating by formation the complex calcium-aluminum compounds. 2) In the stagnant water environment, the corrosion behavior of Al coating contact with concrete will be accelerated. 3) After one-year exposure test, no matter in dry or stagnant water environment, the corrosion behavior is not serious, the Al coating film is also complete and still can provide the protection effect to steel structures. For the hardened concrete, the Al coating contact with concrete, the alkaline environment cause by concrete will not have serious effect on Al coating.

References 1) R. W. Richards and R. D. Jones: Metallurgy of Continuous Hot-dip Aluminizing, International Materials Reviews, Vol.-39, No.5, pp.191-212,1994. 2) A. Behnood, Van Tittelboom K, De Belie N: Methods for Measuring pH in Concrete: A review, Construction and Building Materials, Vol.-105, pp.176-188, 2016 3) K. K. Alaneme and M. O. Bodunrin: Corrosion Behavior of Alumina Reinforced Aluminium (6063) Metal Matrix Composites, Journal of Minerals and Materials Characterization and Engineering, Vol.-10, No. 12, pp. 1153-1165, 2011