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

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1. Introduction Hot-dip Al coating (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. Many ancillary facilities of steel structures, such as guardrails and platforms, were coated by Al coating. These Al coated steel structures also contact concrete directly in some places. Al is an amphoteric metal that can be dissolved in acid and alkaline environments. The pH of concrete made based on Portland cement range from 12.5 to 13.8.[1)] Whether Al coated steel structures can be used in contacting concrete is still unclear. This study evaluated the effect of an alkaline environment of concrete on the hot-dip Al coated steel plate according to the electrochemical and atmospheric exposure tests.

2. Test method In the past research, the open circuit potential (OCP) was measured for the potential changes with pH changing is shown in Fig.1. When the pH was over 12.10, the Al coating dissolved behavior was obvious by the reflection of a rapid decline of OCP.[2)] Hence, the surface pH of the concrete was measured during the hardening process until the age reached 28 days. Four groups of specimens were carried out to ensure the repeatability of the test. Hot-dip Al coated steel structures are usually used in the ancillary facilities of bridge substructures. 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 highway 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 is 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 steel 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). In the test group, Al coating contacted the concrete directly; the other controlled group was isolated the Al coating and concrete by PTFE sheet. The purpose of the PTFE sheet was to isolate Al coating and concrete. Moreover, ensure the corrosion behavior of Al coating can’t be affected by the concrete.

3. Test results The surface pH changing of concrete hardening process is shown in Fig.3. As age goes by, the surface pH of concrete has a decreasing tendency. In the past research, the Al coated steel bar was immersed into the fresh concrete. The bubble-shaped cavity is formed on the interfacial surface of Al coating and concrete by the cross-section observation. It is concluded that Al coated steel members will have a dissolution behavior and cause adhesion decreasing when contact the fresh concrete.[3)] After the first three days, the pH value is lower than 12.10. When the pH is less than 12.10, the Al coating contact with the concrete, the dissolve behavior will not occur. With the passage of ages, the surface pH of the hardened concrete is nearly 11. In this case, the Al coating can be used in hardened concrete. The long-term corrosion behavior of Al coating contact with the concrete is verified by the atmospheric exposure test in Kyoda and UR. The environment data of two exposure sites were compared; the main factor is the rain-washing effect. The exposure test of Kyoda, the specimens were in a dry environment and

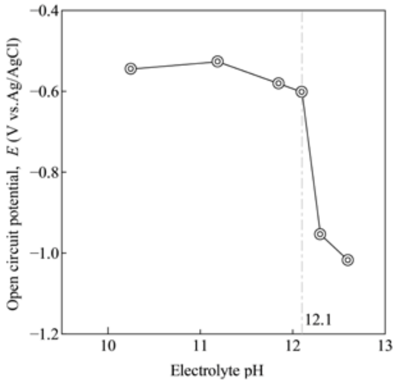


Fig.1 The variation of OCP with the change of pH for the Al coating.

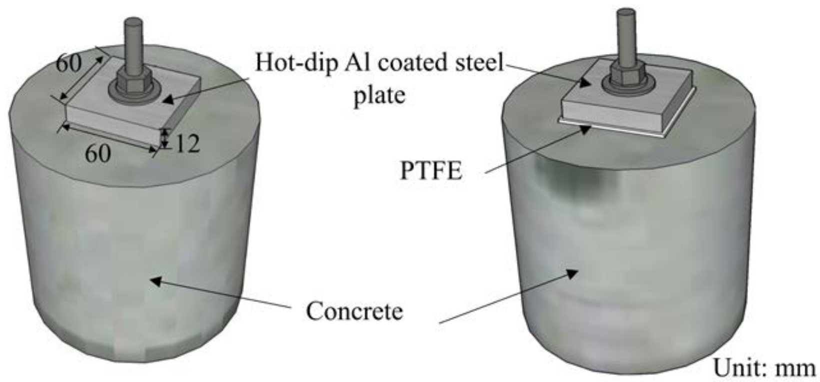


Fig.2 The schematic diagram of exposure test specimen.

Table 1 The environmental data of two exposure sites

Exposure site	Temperature T (°C)	Humidity RH (%)	Amount of Airborne salt w (mdd)	Offshore distance d (m)	Yearly Average precipitation P (mm/day)	Rain washing effect
Kyoda	22.7	82.9	0.5	30.0	5.3	Without
UR	22.9	81.5	0.3	2.3×10^3	5.2	With

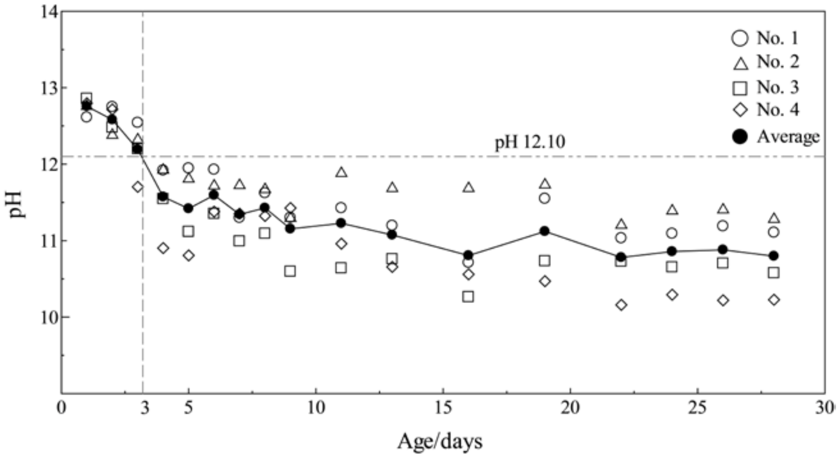
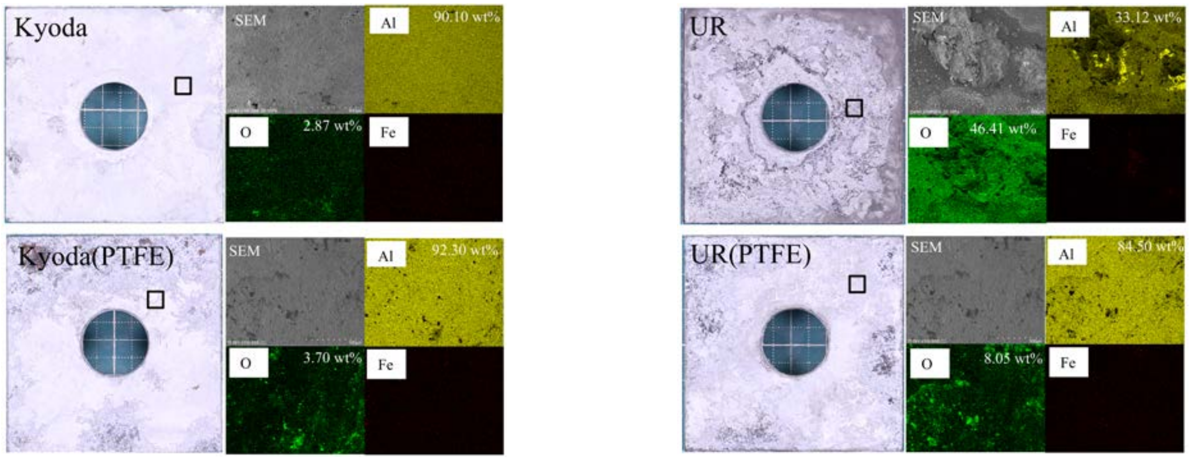


Fig.3 The surface pH changing of concrete with the curing age.



(a) Kyoda (b) UR

Fig.4 The EDX analysis on the surface of contact concrete part after atmospheric exposure test in Kyoda and UR.

without rainy-washing effect. For the UR, the Al coating contact concrete in the stagnant water environment due to the rainy-washing effect. The rainwater can enter the crevice between steel plate and concrete because of not a tight connection between them. This behavior also causes a weakly alkaline environment under the impact of water passing through the surface of the concrete. For the Al coating contact with PTFE case, the PTFE sheet can isolate the Al coating from concrete and the stagnant water environment. After one year's atmospheric exposure test, the EDX analysis was shown in Fig.4. From the surface observation, the direct connection specimen in Kyoda, PTFE specimens in Kyoda and UR, the surface is still complete and can't find some corrosion behavior. The high concentrate of element Al and less concentrate of element O also stated that the contact corrosion behavior of Al coating and hardened concrete does not occur basically. As the specimen in UR that contacts concrete directly, the concentration of element Al has an apparent decrease, and element O has an inevitable increase. However, the increase of element O is not caused by the deterioration of Al due to the distribution of elements is not same. Because of the arbitrariness of each point in the analysis, the few points can't reflect all, overall judgment is more important. In general, both Kyoda and UR, the element Fe still can't be detected by the surface analysis. In both the case of contact directly and PTFE, no matter in Kyoda or UR, the corrosion behaviors were similar, and no significant difference can be found. It is concluded that the Al coating layer is still complete, and the corrosion behavior only has a little phenomenon on the outermost Al layer. The Fe-Al intermetallic layer and the bottom steel substance are still completely protected. When the Al coated steel members contact concrete in the atmospheric environment, the hardened concrete will not cause the deterioration behavior on Al coating.

4. Summary 1) After the first three days, the pH of hardening concrete is less than 12.10, and from this time, the hardening concrete has no deterioration behavior on Al coating. 2) The Al coating contact the hardened concrete, both in the dry and rainy-washing effect caused stagnant environment, concrete will not cause the corrosion behavior on Al coating.

References 1) G.Plusquellec, M.R. Geiker and J. Lindgard: Determination of the pH and the free alkali metal content in the pore solution of concrete, Cement and Concrete Research, Vol.-96, pp.13-26, 2017 2）八木孝介，貝沼重信，山下和也，石原修二，井上大地，橋本幹雄：アルカリ性水溶液中における溶融アルミニウムめっきの腐食挙動に関する電気化学的検討， 土木学会第 73 回年次学術講演会講演概要集, I -035, pp.69-70, 2018.3）3）山下和也，貝沼重信，石原修二，井上大地，橋本幹雄：溶融アルミニウムめっきのコンクリート接触部における腐食挙動に関する基礎的検討， 土木学会第 74 回年次学術講演会講演概要集, I -407, pp.1-2, 2019.