UNDERSTANDING CORROSION BEHAVIOR OF Zn AND Zn ALLOY GALVANIZED STEELS IN HUMID TROPICAL CLIMATE

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ABSTRACT

The humid tropical climate parameters and airborne salinity are generally considered important factors affecting detrimental corrosion of zinc and its alloy coatings. To more thoroughly understand their corrosion performances, the five years weathering tests for zinc and Zn-Al galvanized steels in rural and coastal humid tropical areas were conducted. Corrosion rates and other performance characteristics of zinc and Zn-Al coated samples were determined and discussed in relation with climatic and environmental parameters. Behavior of the coatings in rural and coastal tropical conditions revealed a strong influence of time of wetness (TOW) and airborne salinity on corrosion rates. In both test conditions, the dependence of coating’s mass loss on exposure time shows that the corrosion process of zinc coatings mostly obeys the law of power model $M = At^n$. Corrosion is recorded considerably stronger in the coastal atmosphere containing higher chlorides. The laboratory observation in cut-edge area of zinc alloys coated steel was also conducted and their corrosion behavior was detailed in condition of chloride ions attack.

Keywords: zinc and Zn-Al coating, humid tropical, airborne salinity, chloride ion attack

1. INTRODUCTION

Corrosion in humid tropical climate has long been a subject of great concern for materials development and application. The issue has attracted special attention due to its typical conditions with elevated air temperature, high relative humidity, prolonged time of wetness (TOW), and the considerable level of airborne salinity and other corrosive pollutants originated from the industry. As the most used metal for steel protection from atmospheric corrosion, zinc and its alloys have been studied in numerous research works to reveal the corrosion nature and protective mechanism. Great efforts have been expended to develop various protective zinc and zinc alloy galvanized steels such as Zn-55Al (Galvalume®, Zincalume®), Zn-5Zn (Galvan®), and recently invented Zn-Al-Mg coatings with relatively high corrosion resistance in different climatic conditions, including the humid tropical area.

For decades, to monitor the metal degradation trend and to understand its corrosion
behavior, in parallel with indoor laboratory research, a number of outdoor exposure test stations have been installed worldwide and significant results have been reported for zinc and its alloys. For examples, Almeyda E. et al. [1], presenting results of long-term test in the Iberico-American Mapping Program, concluded that corrosion rates of zinc fluctuated in a range of 0.11 - 3.30 μm/y for S₃P₆ rural atmosphere level, according to ISO 9223 classification; meanwhile, zinc corrosion products are composed mainly of hydrozincite $\text{Zn}_3(\text{CO}_3)_2(\text{OH})_6$ and zincite $\text{ZnO}$. The same group of authors informed in [2] that in marine atmosphere with insignificant $\text{SO}_2$ content ($\leq 10 \text{mg/m}^2\text{.day}$), zinc corrosion rate is a function of direct chloride deposition level and TOW with values changed in a range of 0.19 - 2.73 μm/y for $\text{S}_3\text{P}_6$ corrosivity level. In this atmosphere, corrosion products present in the form of zincite and hydrozincite; a small amount of crystalline simonkolleite ($\text{Zn}_6(\text{OH})_2\text{Cl}_6\text{H}_2\text{O}$) appears only after exposure duration in an atmosphere with very high airborne salinity (55.1 mg/m$^2$.day). Similarly, Odnevall Wallinder I. et al. [3] conducted the exposure test for Zn-Al galvanized coating (Zincalume) under unsheltered conditions for five-year period. Their results show the annual release rate of zinc in the marine site exhibits a maximum after first year of exposure and a continuous time reduction during the subsequent four-year exposure. They also confirmed that the pathway of corrosion products and time dependence of zinc release rates from Zincalume under unsheltered atmospheric exposure can be explained by the uniform formation of less soluble $\text{Al}_2\text{O}_3$, $\text{AlOOH}$ and $\text{Al(OH)}_3$ compared to observed zinc-containing phases, e.g. $\text{ZnO}$, zinc hydroxycarbonate and zinc hydroxychloride. With more detailed investigation in [4], Odnevall Wallinder I. et al. showed a gradual replacement and cover of crystalline $\text{Al}_2\text{O}_3$ during the first year of marine exposure, by zinc-rich corrosion products, such as non-crystalline basic zinc chlorides and/or sulfates. Vu A. Q. et al. [5] performed in situ observation for Galvalume cut-edge coating and found an effective protection of the coating for steel surface due to the uniform activation of zinc and aluminium-rich phases, preventing red rust formation. According to Pritzel dos Santos A. et al. [6], comparing to hot dip galvanized steels, the Galvalume coating offers better protection due to the defect-free Al-Fe intermetallic layer, which blocks the access to the steel surface in places where the coating is damaged, resulting in a complete consumption of the coating before the substrate is finally attacked. Under OCP conditions, the Galvalume coatings protect the substrate against cut-edge corrosion by a more homogeneous corrosion compared to that of hot dip coatings, due to the selective attack of the well distributed interdendritic $\eta$ phase. Finally, a long-term exposure test for 33 years conducted by Katayama H., Kuroda S. [7] with hot-dip zinc and zinc-aluminium coatings proves that high corrosion ability of Zn-Al coatings is attributed to thick corrosion products formed by selective dissolution of zinc.

In typical humid tropical climate of Vietnam, different exposure test programs have also been performed with some initial reported results for zinc and its alloys [8-10]. According to Lien L. T. H. [8], in Vietnam’s atmosphere, the corrosion process obeys an equation of $\text{M} = \text{At}^a$ and zinc corrosion tends to be predominantly determined by the chloride ion content in the air. However, crystalline composition of corrosion products is formed with specific features under humid tropical conditions, such as the appearance of zinc hydroxycarbonate or hydrozincite revealed in the initial stage. Besides, simonkolleite appears to be formed under low chloride content, which is different from the results obtained by Almeyda E. et al. [2]. High corrosion rates of zinc and its alloys are also recorded in works of Ngoan D. V. [9] and Tru N. N. [10].

However, the reported results are considered sporadic data in the fast trend of zinc coatings application in Vietnam, especially for increasingly commercialized zinc alloy coatings in recent years. The more comprehensive and comparative research for zinc and zinc alloys corrosion behavior in humid tropical atmosphere, including the marine influenced conditions, need to be
intensified. Hence, this paper aims to update the corrosion database and compare data with recent researches. As such, the results of outdoor exposure test for zinc and Zn-55Al galvanized steels at two sites, representing a coastal marine and a rural atmosphere, are summarized and discussed. The differences of corrosion rates and environmental characteristics in coastal and rural humid tropical areas are also detailed. Furthermore, in comparison with Galvalume (Zn-55Al) cut-edge coating results [5], *in situ* observation of Zamak (ZnAl,Mg) cut-edge was conducted in parallel for more understanding corrosion performance of the zinc alloy coating under conditions of chloride attack.

2. MATERIALS AND METHODS

2.1. Description of exposure sites and their environmental parameters

For outdoor exposure test, two representative locations have been selected: (i) Nha Trang coastline site (Coordinates at 12°12N - 109°12E; Altitude: 3.0 m) is located in a range of 50 m from coastline; and (ii): My Tho rural site (Coordinates: 10°21’N, 106°23’E; Altitude: 1.1 m) is at distance of 45.5 km from the closest eastern coastline.

The various climatic and environmental parameters, including average air temperature, relative humidity, rainfall and rain water pH, airborne salinity and sulfur dioxide contents during testing were recorded. The climatic parameters values were averaged from daily measurements by common meteorological methods. TOW values were calculated by empirical equation proposed by Lien L.T. H. [8], based on linear regression analysis of the data collected from more than 150 meteorological stations inside Vietnam during period of 10 years (TOW = -14.09T + 228.63RH -13050 with R² = 0.93, where T is average air temperature and RH is relative humidity). The pH of rain water is the average value of daily collection data measured by Jenway 3150 pH meter. The airborne salinity and atmospheric sulfur dioxide contents were determined by standardized wet candle [11] and passive specimen methods respectively [12].

The climatic and environmental parameters of both locations were summarized and classified according to ISO 9223:2012 with updated modifications on categories of corrosivity and grouping of pollution, compared to the previous ISO standard version [13].

2.2. Outdoor exposure test procedure

The steel substrates were prepared and galvanized by zinc and Zn-55Al hot dip coatings. As prepared sheets have coating weights of 50 g/m² approximately. Three parallel samples (with dimensions 100 × 150 × 1 - 3 mm) of each coating and one sampling period were cut off the sheet and exposed for outdoor testing in unsheltered condition under a southward-faced angle of 45° position. Samples were checked annually for five-year duration starting from 2009. The surfaces were pretreated following common standards before and after testing. Corrosion rates were determined by mass loss method according to ASTM G1-03(2011). The surface appearance was observed visually and recorded by image scanning. The surface morphology and defects were detected by metallographic method with Leica 2500 Microscope X200 magnification.

In parallel, the cut-edge corrosion was conducted with zinc and Zn-55Al galvanized steel coatings. Three parallel samples of organically-coated galvanized Zn and Zn-55Al steel (dimension: 120 × 270 × 3 mm) were cut off the coil sheet and exposed in similar unsheltered conditions as above described at Nha Trang and My Tho sites. The coil sheet was coated by
polyester layers of 20 µm thickness on both sides. The cut-edge behavior was checked and recorded yearly by corrosion damage, using optical microscope. Depth of cut-edge corrosion was measured in millimeters (mm) from the sample edge.

2.3. In situ observation of cut-edge samples

Zamak hot dipped galvanized coated steel was obtained from Arcelor Mittal. The coating thickness is about 10 - 17 µm for 1 mm of steel substrate. The electrochemical behavior of a Zamak coated steel during galvanic coupling between the steel substrate and the coating in chloride solution was inspected. SEM-EDX analysis, open circuit potential (OCP), pH distribution observation experiments and sample preparation were realized with the same conditions as described in the reference [5].

3. RESULTS AND DISCUSSION

3.1. Features of environmental factors and atmospheric corrosivity

The sampling of air pollutants and the exposure of samples were conducted on the grounds of two test sites with insignificant differences in climatic characteristics. The test sites were chosen to represent different levels of airborne salinity. Nha Trang test site is close to the coastline and open for the seaward wind direction; meanwhile, My Tho is located in Mekong delta with low and flat topography, seasonally influenced by prevailing winds from East Sea or Gulf of Thailand. These geographic and topographic features anticipate distinctive corrosion behavior of materials under different environmental impacts at each site.

The climatic and environmental parameters determining metallic corrosion for the sites during five-year period of testing are presented in Table 1 and Table 2. These values are calculated from monthly collected data at aforementioned Nha Trang and My Tho sites.

| Test duration (year) | Temperature (°C) | Relative humidity (%) | TOW (hour) | Rainfall (mm) | pH of rain water | Airborne salinity (mg/m².d) | Sulfur dioxide (µg/m³) |
|----------------------|------------------|-----------------------|------------|---------------|----------------|-----------------------------|----------------------|
| 0.5                  | 26.2             | 79.9                  | 4851       | 186.4         | 5.9            | 58.0                        | <1.0                 |
| 1.0                  | 27.0             | 79.6                  | 4768       | 819.4         | 5.9            | 79.3                        | <1.0                 |
| 2.0                  | 26.5             | 80.3                  | 4935       | 1902          | 6.1            | 56.2                        | <1.0                 |
| 3.0                  | 24.9             | 82.3                  | 5415       | 2073          | 6.3            | 41.9                        | <1.0                 |
| 4.0                  | 27.3             | 81.1                  | 5107       | 940.7         | 5.9            | 39.5                        | <1.0                 |
| 5.0                  | 27.2             | 78.8                  | 4585       | 1031          | 5.8            | 68.4                        | <1.0                 |

At first glance, we can see the average yearly temperature is relatively stable during exposure testing at both sites with fluctuations in a range of ± 3 degrees and the five-year average values equal to 26.5 °C at Nha Trang and 26.8 °C at My Tho respectively. The similar behavior is observed for the relative humidity change, where the average yearly values are distributed from 78.8 to 81.1 % for Nha Trang and from 80.8 to 83.3 % for My Tho. The higher
average humidity values are recorded in My Tho may arise from specific geographical location of the site in an area with dense river and canal network.

Table 2. Environmental Characteristics at My Tho Rural Test Site

| Test duration (year) | Temperature (°C) | Relative humidity (%) | TOW (hour) | Rainfall (mm) | pH of rain water | Airborne salinity (mg/m².d) | Sulfur dioxide (µg/m³) |
|----------------------|------------------|------------------------|------------|---------------|-----------------|-----------------------------|------------------------|
| 0.5                  | 26.5             | 81.6                   | 5233       | 350.5         | 5.1             | 12.0                        | 5.4                    |
| 1.0                  | 26.9             | 82.6                   | 5455       | 1510          | 5.6             | 17.4                        | 5.2                    |
| 2.0                  | 26.8             | 81.7                   | 5251       | 1522          | 5.5             | 12.0                        | 5.2                    |
| 3.0                  | 26.9             | 80.8                   | 5044       | 1572          | 5.7             | 10.1                        | 5.3                    |
| 4.0                  | 27.2             | 81.1                   | 5108       | 1654          | 5.9             | 11.8                        | 4.3                    |
| 5.0                  | 26.6             | 83.3                   | 5620       | 1616          | 5.6             | 13.2                        | 4.2                    |

According to ISO 9223:2012, both climatic areas can be classified as τ₄ categories based on TOW criteria, recorded predominantly in a range of 2500 ÷ 5500 h. These values range from 4768 h to 5415 h for Nha Trang site and from 5044 h to 5620 h for My Tho site (an exception is the value 5620 h at My Tho, was insignificantly higher than τ₄ top limit 5500 h). The obtained climatic parameters and classified categories are fully consistent with previously reported results of Lien L. T. H. for Nha Trang in [8] and Lan T. T. N. for My Tho in [12].

Rainfall and pH of rain water are considered as ones of the most important factors affecting zinc and alloy corrosion under outdoor exposure testing. Figure 1 shows average values of monthly rainfall for the whole testing period. Like other humid tropical areas, the rainfall amounts in Nha Trang and My Tho are large but distributed unevenly with high values falling mainly in rainy season, usually lasting from May to November. However, in Nha Trang site with higher latitude, the rainfall profile is more complicated with two clear maximums.

From corrosion point of view, the rainfall amount and rain water nature have influence on metal degradation with opposing effects: decrease corrosion due to corrosive agents washing and accelerate corrosion through aggressive electrolyte formation onto metal surface. Various hazardous pollutants from industry and/or chloride aerosols from sea can accumulate in rain water to turn solution into corrosive environment.

Figure 1. Average monthly rainfall at test sites.
Monthly distribution of rain water presented in Figure 2 shows slightly acid range with pH < 5.6 observed only in short period for My Tho site. That means, the sites appear to be low polluted areas with weak to neutral pH values of rain water and very low sulfur dioxide concentrations (P₀ class with <1.0 µg/m³, according to ISO 9223:2012).

Finally, analyzing the environmental data summarized in Table 1 and Table 2, we can see that Nha Trang site is characterized by high airborne salinity ranging from 39.45 to 79.31 mg/m².d (S₂ class by ISO 9223:2012) due to its proximity to the coastline; meanwhile, the airborne salinity in My Tho site is relatively lower with 10.1 – 17.4 mg/m².d (S₁ class by ISO 9223:2012), slightly influenced by salt intrusion into freshwater aquifers of Mekong delta region. In summary, the Nha Trang and My Tho sites should be classified as P₀S₂ and P₀S₁ areas respectively and the airborne salinity can be a determining factor for corrosive damage of zinc and its alloys.

3.2. Corrosion behavior of zinc and zinc alloy in outdoor conditions

Time dependence of corrosion rate and mass loss for the coatings are presented in Figure 3 and Figure 4. It is clear, that corrosion loss values of zinc are very high for the samples exposed in Nha Trang coastal conditions. After the first year of exposure, the mass loss reached a significant value of 21.65 g/m² and continued to grow rapidly through all period of testing. The mass loss reached 45.77 g/m² after third year of exposure which was roughly equal to the whole coating mass (50 g/m²) and instead of white rust, the red rust appeared. For this reason, the mass loss values for the fourth and fifth year were underrepresented due to steel substrate corrosion and were not included in further time dependence diagrams interpretation in Figure 3.

Another situation has been revealed for zinc corrosion in My Tho rural conditions. After first year of exposure testing, this value was about six times lower in comparison to those exposed in Nha Trang site (3.668 to 21.65 g/m²) and steadily increased from year to year. The predominant cause can be attributed to small chlorides deposition on the samples surface from airborne salinity, because other characteristics such as average air temperature, relative humidity, TOW, rainfall amount, pH of rain water and sulfur dioxide content, were approximately similar to Nha Trang coastal conditions.

From the Figure 3 we can see that the dependence of mass loss on exposure time shows the corrosion process of zinc coatings mostly obeys the law of power model \( M = At^n \) with the values of \( A, t \) and \( n \) given in Table 3.
The values $n < 0.5$ for Zn at Nha Trang exposure site indicate that the diffusion process of the aggressive agents from environment decreases with time due to some protective abilities of the corrosion products. Meanwhile, the values $n > 0.5$ at Nha Trang and My Tho exposure site indicate that due to the porous corrosion product layers, the environmental agents easily penetrate into the substrate. Similar findings have been revealed by Benarie M. [14] and Feliu S. [15].

**Table 3.** The fitted $A, n$ values of model $M = A t^n$ for Zn and Zn-55Al coatings.

| Site     | Type    | $A$  | $n$  | $R^2$ |
|----------|---------|------|------|-------|
| Nha Trang| Zn      | 27.41| 0.46 | 0.83  |
|          | Zn-55Al | 2.55 | 0.53 | 0.97  |
| My Tho   | Zn      | 4.23 | 0.81 | 0.97  |
|          | Zn-55Al | 1.95 | 0.55 | 0.99  |

Surface appearance of the samples after five years of testing are presented in Figure 5 showing severe damage of the zinc coatings at Nha Trang coastline, compared to the remaining samples. Corrosion damages on this sample surface are observed not only from edge lines, but are also noticed in other locations. Furthermore, a slight deterioration is revealed for the Zn-
55Al alloy coating samples exposed in Nhatrang, which can be explained by the pronounced role of airborne salinity in corrosion attack. Relatively benign environmental conditions at My Tho site is once again confirmed by surface appearance for both types of coatings, followed by quantitative results presented in Figure 3 and Figure 4.

While a general corrosion loss data and surface examination show significantly lower corrosion resistance of zinc coatings compared to Zn-55Al alloy replacement, the recorded results for cut-edge corrosion of these materials give another picture of the process. Data summarized in Table 4 points out the level of cut-edge corrosion for samples coated with organic painting. The cut-edge corrosion has been estimated to be more severe for alloy coatings and at higher level in coastline conditions.

![Sample surface](image)

*Figure 5. Surface appearance of the tested samples after five year of exposure.*

Other authors [16, 17] have also conducted in laboratory and field test of cut-edge corrosion; however, more understanding is required for the materials exposed in humid tropical region, especially in the area strongly influenced by chloride attack originated from high airborne salinity.

*Table 4. Cut-edge corrosion (mm) of Zn and Zn-55Al samples during testing.*

| Test site | Test sample       | Corrosion depth from the sample edge (mm) after tested duration (year) |
|----------|-------------------|---------------------------------------------------------------------|
|          |                   | 1         | 2                   | 3         | 4         | 5         |
| Nha Trang| Zn sample         | 0         | 0 ± 1               | 0 ± 1     | 1 ± 2     | 2 ± 3     |
|          | Zn-55Al sample    | 2 ± 5     | 2 ± 5               | 2 ± 5     | 3 ± 8     | 7 ± 16    |
| My Tho   | Zn sample         | 0         | 0 ± 1               | 0 ± 1     | 0 ± 2     | 0 ± 2     |
|          | Zn-55Al sample    | 2 ± 3     | 2 ± 5               | 2 ± 5     | 2 ± 7     | 3 ± 12    |

According to our previous work [5], in the case of a Zn-55Al coated steel cut-edge, the coating gave a better protection of steel in chloride medium. In this work, it can be seen that this coating is attacked more in chloride medium than in sulfate medium, which could be because of the high airborne salinity. Chloride ions can form a complex with aluminium oxide and keeps the coating active during galvanic coupling with steel substrate. In order to more thoroughly understand the role of chloride ions, in this work, a laboratory investigation was conducted on Zamak coated steel cut-edge. This Zn-Al alloy, aluminium partly replaced by magnesium.
3.3. Laboratory cut-edge investigation

3.3.1. Microstructure

Figure 6 shows a SEM image of the cut-edge of Zamak (ZnAl₃Mg₃) coated steel. EDX analysis indicates that the coating is mainly composed of: i) zinc-rich dendritic phases, ii) interdendritic aluminium-rich and magnesium-rich area. These interdendritic area can be distinguished easily because of the difference in their forms and colors. There is no intermetallic layer at the steel–coating interface. This observation is different with Galvalume coating and so will help us explain how the steel substrate protection seems to be more efficient with Zamak coating.

![SEM image of cut-edge](image)

*Figure 6. SEM photograph and EDX analysis of the Zamak/steel cut-edge.*

This sample is then immersed in the chloride medium by observing the open circuit potential (OCP) in short time (40 min) and long time (24 h).

3.3.2. Electrochemical measurements on the cut-edge

**OCP measurements and SEM-EDX analysis:**

The results of OCP measurements are shown in Figure 7. In order to remove continuously the corrosion products that precipitate over the cut-edge in static conditions (see further in the pH distribution experiment), these measurements are conducted under low flow rate conditions. It must be emphasized that the potential evolution is very similar in static and flowing conditions. For short times of immersion (about 40 min), it can be seen that the OCP of the cut-edge is about –1.025 V (SCE), indicating that the steel surface is cathodically protected by the coating. At longer time, only a slight increase of the OCP is observed (~0.985 V (SCE)). Thus, it
can be seen that this coating is sacrificial in the chloride medium over the time. Therefore, it can be concluded that steel is cathodically protected in chloride solution.

After the immersion experiments, these samples were examined in SEM and chemical analysis were carried out by EDX. At short times, the Mg-rich phases were firstly attacked, the Zn and Al rich phases remain unattacked. On the steel surface, a layer of zinc hydroxide was detected near the coating as shown in Figure 8.

![Figure 7. OCP evolution of the Zamak/steel cut-edge in chloride medium](image)

![Figure 8. SEM photographs of the Zamak/steel cut-edge after 40 min immersion in 0.1 M NaCl.](image)

Figure 9 shows the SEM images of the cut-edge after 24 h immersion in chloride solution. For the relatively long immersion time, a general dissolution of the coating was observed by SEM. The presence of Zn(OH)$_2$, also identified on the steel, appeared to depend on the distribution of the Zn-rich phases in the coating. Further on the steel, there was a layer of zinc oxide serving as a cathodic inhibition layer protecting steel substrate against the corrosion.


**Figure 9.** SEM photographs of the Zamak/steel cut-edge after 24 h immersion in 0.1 M NaCl.

**pH distribution**

The pH distribution profiles on the Zamak coated steel cut-edge in the chloride medium are shown in Figure 10. They show a strong cathodic inhibition at short times (3 h of immersion) which can be attributed to the formation of a ZnO layer on the steel. This layer transforms into Zn(OH)$_2$ over time and finally leads, in the long term, to a behavior: a nearly stationary regime after 20 h of immersion and no red rust on the steel. It can be concluded that the steel is well protected by this coating in the chloride medium with strong cathodic inhibition at short times and by the long-term barrier effect associated with the presence of a thick layer of the white corrosion products (based on Zn).
Figure 10. pH distribution across the Zamak/steel cut-edge during a 24 h immersion in 0.1 M NaCl.

The pH measurement profiles were in agreement with the open-circuit potential (OCP) measurements on the steel coated with ZnAlMg alloys. After 24 hours of immersion, no red rust was detected on the steel surface. These results show that this coating is sacrificial and protects the steel well. Once again, the role of chloride ion is verified and so it can be concluded that the airborne salinity keeps ZnAl alloys active to protect the steel substrate during galvanic coupling. Other measurements such as current distribution will be necessary to demonstrate the mechanism of this protection.

4. CONCLUSIONS

Corrosion rates of hot dip zinc coatings at Nha Trang coastal site exceed the values obtained for My Tho rural atmosphere by several times. Meanwhile, hot dip Zn-Al coatings express higher corrosion resistance at both atmospheres. The corrosion process obeys an equation of the form $M = A t^n$, where $M$ is the loss of metal and $t$ is the time of exposure. $A$ and $n$ are constants which values depend on the environmental characteristics and the physicochemical behavior of the corrosion products respectively. Corrosion is strongly influenced by atmospheric time of wetness (TOW) and airborne salinity. A laboratory investigation was conducted on Zamak coated steel cut-edge. This coating shows a good cathodic protection due to its sacrificial behavior in chloride medium during galvanic coupling with steel substrate. Once again, the role of chloride ion or airborne salinity is clarified. So it can be concluded that airborne salinity is a main factor accelerating corrosion for zinc and Zn-Al coatings in Nha Trang conditions.
REFERENCES

1. Almeida E., Morcillo M., Rosales B. - Atmospheric corrosion of zinc. Part 1: Rural and urban atmospheres, Br. Corros. J. 35 (4) (2000) 284-288.
2. Almeida E., Morcillo M., Rosales B., - Atmospheric corrosion of zinc. Part 2: Marine atmospheres, Br. Corros. J. 35 (4) (2000) p. 289-296.
3. Qiu P., Leygraf C., Odnevall Wallinder I. - Evolution of corrosion products and metal release from Galvalume coatings on steel during short and long-term atmospheric exposures, Mater. Chem. Phys. 133 (2012) 419-428.
4. Zhang X., Vu T.N., Volovitch P., Leygraf C., Ogle K., Odnevall Wallinder I. - The initial release of zinc and aluminum from non-treated Galvalume and the formation of corrosion products in chloride containing media, Appl. Surf. Sci. 258 (2012) 4351-4359.
5. Vu A. Q., Vuillemin B., Oltra R., Allély C. - Cut-edge corrosion of a Zn–55Al coated steel: A comparison between sulphate and chloride solutions, Corros. Sci. 53 (2011) 3016-3025.
6. Pritzel dos Santos A., Manhabosco S.M., Rodrigues J. S., Dick L. F. P. - Comparative study of the corrosion behavior of galvanized, galvannealed and Zn55Al coated interstitial free steels, Surf. Coat. Technol. 279 (2015) 150-160.
7. Katayama H., Kuroda S. - Long-term atmospheric corrosion properties of thermally sprayed Zn, Al and Zn–Al coatings exposed in a coastal area, Corros. Sci. 76 (2013) 35-41.
8. Le Thi Hong Lien, Pham Thy San, Hoang Lam Hong. - Results of studying atmospheric corrosion in Vietnam 1995–2005, Sci. Technol. Adv. Mater. 8 (7-8) (2007) 552-558.
9. Dang Vu Ngoan, Bui Ba Xuan, Nguyen Nhi Tru. - Corrosion behavior of some alloys in tropical urban and marine atmospheres, Corros. Sci. Technol. 7 (2) (2008) 125-129.
10. Nguyen Nhi Tru, Tran Mai Han. - Comparative performance of zinc passivated coatings in tropical atmosphere, J. Sci. Technol. 48 (5A) (2010) 204-211.
11. ISO 9225:2012: Corrosion of metals and alloys - Corrosivity of atmospheres - Measurement of environmental parameters affecting corrosivity of atmospheres.
12. Lan T.T.N., Nishimura R., Tsujino Y., Satoh Y., Thoa N. T. P., Yokoi M., Maeda Y. - The effects of air pollution and climatic factors on atmospheric corrosion of marble under field exposure, Corros. Sci. 47 (2005) 1023-1038.
13. ISO 9223:2012: Corrosion of metals and alloys - Corrosivity of atmospheres - Classification, determination and estimation.
14. Benarie M., Lifert F.L. - A general corrosion function in term of atmospheric pollutant concentration and rain pH, Atmos. Environ. 20 (10) (1986) 1947-1958.
15. Feliu S., Morcillo M. - The prediction of atmospheric corrosion from meteorological and pollution parameters, II- Long-term forecast, Corros. Sci. 34 (3) (1993) 415-422.
16. Prozek T., Nazarov A., Xue H. B., Lamaka S., Thierry D. - Role of steel and zinc coating thickness in cut edge corrosion of coil coated materials in atmospheric weathering conditions; Part 1: Laboratory study, Prog. Org. Coat. 99 (2016) 356-364.
17. Yildiz R., Dehri I. - Investigation of the cut-edge corrosion of organically-coated galvanized steel after accelerated atmospheric corrosion test, Arab. J. Chem. 8 (2015) 821-827.