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Exposure Test of Weathering Steel in Ho Chi Minh City Marine Area

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Abstract: Under appropriate atmospheric environments, weathering steels can be applied to steel structures without painting and can thereby reduce the life cycle cost of those structures. Corrosion factors such as airborne salt, humidity or time of wetness at planning location for construction of bridge can be known by observation of nature. However, amount of airborne salt, humidity or are influenced by location of bridge, clearance under bridge, distance from coastal line and so on. In this study, environmental factors were measured and an exposure tests were conducted in Ho Chi Minh City marine area in order to clarify the influence of environmental factors on the corrosion behaviour and applicability of weathering steels in Ho Chi Minh City marine area.

Keywords: *Weathering Steel, Exposure Test, Air-bone Salt, Corrosion Rate, Distance from Coastline.*

Introduction:
Weathering steel was developed in the United States of America in 1930s. After that, in 1960s, it's applied widely into bridge construction in Japan. Nowadays, weathering steels are used fairly much in many countries that have the advanced steel manufacturing industry. With the self-protecting ability against rust, durability, specific color and safe for environment so weathering steel is the good choice for outdoor structures like sculptures, bridges, buildings, etc. Weathering steel is a high strength, low alloy steel that in suitable environments forms an adherent protective rust 'patina', to inhibit further corrosion. They do not require initial painting or other corrosion protection methods, thereby saving the maintenance cost in the future [1], [2].

Base on the investigation of weathering steel surface showed that the corrosion loss is small with the unpainted structures, even they are in marine environment, areas with extreme climate. The steel can use in long time with very low maintenance cost [3], [4].

Some characteristics of weathering steels:
The specificity of material, as well as the self-protecting ability against rust in the atmosphere, makes this steel having some following characteristics [1], [9]:

1. Very low cost for inspection and maintenance: Weathering steels are ideal for bridge and other structures where access to approach difficultly or dangerously.
2. Initial cost: Typically, the initial cost of weathering steels is 5%~15% higher than conventional painted steel alternatives. However, in the comparison of life cycle cost, cost savings from elimination of the protective paint system in many years so using this steel still have much more economic benefits.
3. Reduce construction time: Overall construction durations are reduced because both shop and site construction times are saved.
4. Changing color of steel surface: the appearance of weathering steel surface often blends attractive with the environment. The color changes with structure age.
5. Environmental benefits: The environmental problems associated with paint VOC emissions and the disposal of blast cleaning debris from future maintenance works is avoided.
6. Safety benefits: Health and safety issues relating to initial painting are avoided, and the risks associated with future maintenance are minimized.

The rust layers formed on most conventional structure steel after operating time. Therefore, the rusting rate progresses as a series of incremental curves approximating to a straight line, the slope of which depends on the aggressiveness of the environment as shown in Figure 1.

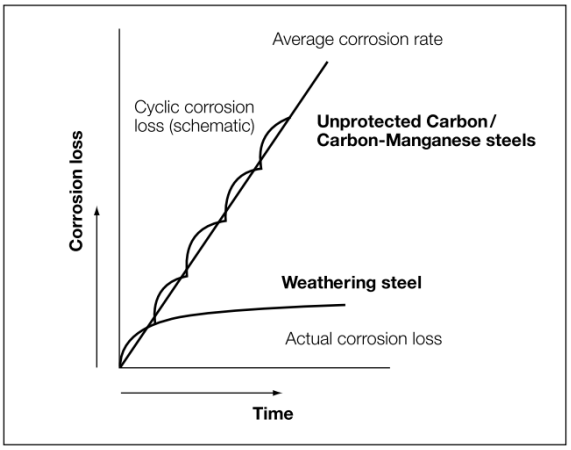


Figure 1: Schematic comparison between the corrosion loss of weathering and carbon steels [1].

With weathering steel, the rusting process is started in the same way, but the specific alloying elements in the steel produce a stable rust layer which protects the base metal. This rust layer develops under alternative wet and dry conditions to produce the protective oxide layer that hinders further access of oxygen and moisture. The resulting reduction in corrosion rates is illustrated in Figure 2.

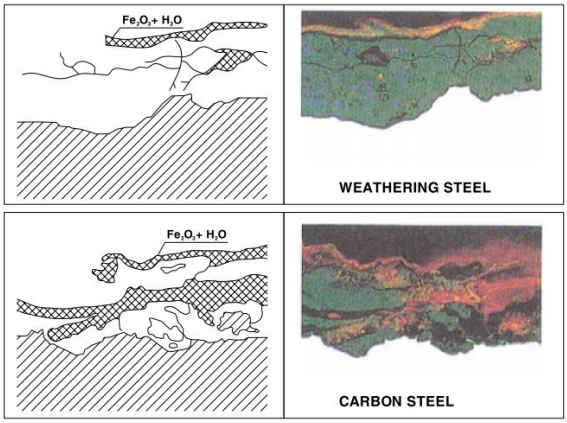


Figure 1: Schematic comparison between the corrosion loss of weathering and carbon steels [1].

Exposure tests of weathering steels in Vietnam:
After over 80 year's development of weathering steel and over 40 years that this steel have been applied into bridge construction. Until now, almost countries recognize the economic and environmental benefits of using weathering steel. The use ratio of weathering steels in steel bridges has increased rapidly, especially in developed countries as shown in Figure 3

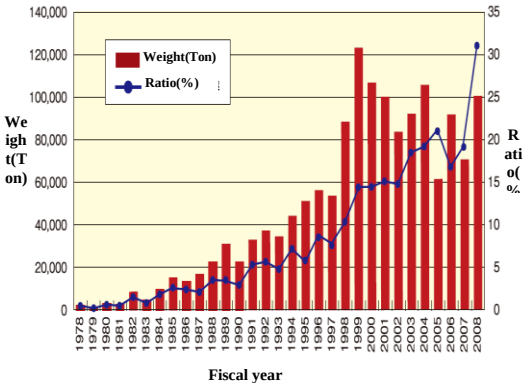


Figure 3: The used ratio of weathering steels in total steel bridges has increased rapidly in Japan

In Southeast Asia, where the development of infrastructure is proceeding, it is important to clarify the applicability of weathering steel in order to reduce the Life Cycle Cost of structures. The corrosion behavior of weathering steel is influenced by environmental factors such as temperature, relative humidity, airborne salt and so on. Many studies on the relationship between the corrosion behavior of weathering steel and environmental factors have been reported in Japan [6] and elsewhere. Recently, it was reported the results of exposure tests of weathering steel in Vietnam [7], [8]. In this study, we investigated the influence of environmental factors on the corrosion behavior of weathering steel in Ho Chi Minh City marine area.

Research objective:
The objective of the research is to propose the guideline in using of weathering steel into bridge construction in coastal areas in Ho Chi Minh City marine area, as follows:

1. Survey the corrosion rate of weathering steel through exposure tests.
2. Collect the environmental data: temperature, relative humidity, air-bone salt, impurities… through exposure tests.
3. Evaluate the influence of environment on corrosion rate of weathering steel.

Research description:
Vietnam climate tends to vary considerably from the north to the south. It can be divided in 3 regions, including humid subtropical climates (CWA) in the north, tropical monsoon climate (AM) in the central and tropical wet and dry climate (AW) in the south [5], as shown in Figure 4.

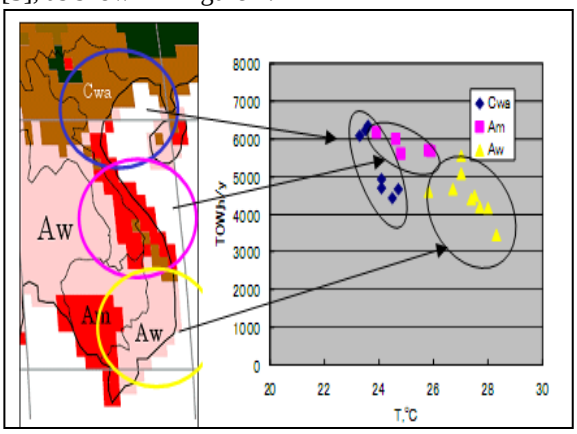


Figure 4: Vietnam climate characteristic [5]

In the first stage, research team chose Ho Chi Minh City marine area as a place to carry out the research as shown in Figure 5. Ho Chi Minh City has a tropical climate, specifically a tropical wet and dry climate; with an average humidity of 75%.The year is divided into two distinct seasons. The rainy season, with an average rainfall of about 1,800 millimetres annually (about 150 rainy days per year), usually begins in May and ends in late November. The dry season lasts from December to April. The average temperature is 28 °C; the highest temperature sometimes reaches 39 °C around noon in late April, while the lowest may fall below 16 °C in the early mornings of late December into early January.

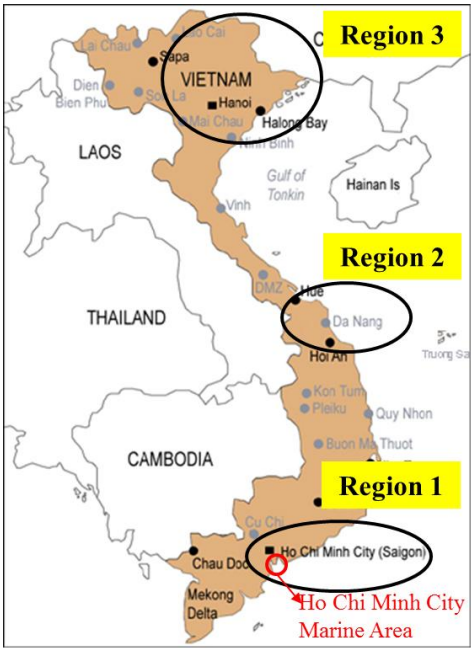


Figure 5: Exposure tests site in whole Vietnam.

Figure 6: Location of selected bridges in Ho Chi Minh City marine area.

The research team has surveyed 11 bridges in the marine area of Ho Chi Minh City. Then, 3 bridges have chosen to carry out the exposure test as shown in Figure 6.

Principle for selecting bridge to survey:

1. Bridge is located in the coastal area with opening structure.
2. The bridge center line is parallel to the coastline.
3. The steel samples are attached far from abutment about 2m to 5m, about 2.5m to 4m above ground level.
4. To install all the steel samples in the same way, choose one type of girder (I-shape girder).
5. The devices collect temperature, relative humidity, air-borne salt and impurities data must be put in the hidden locations aim to prevent stolen.
6. Follow the relationship between air-borne salt concentration and the distance from coastline as shown in Figure 5.

Environmental factors were measured for approximately one year. Temperature and relative humidity were measured with an Ondotori thermo-recorder manufactured by T&D. The amount of airborne salt was measured by the dry gauze method (JIS Z 2382). Specimens were collected after one year and the average of thickness loss of the top and bottom side specimens was evaluated as the annual corrosion loss.

Figure 7: The steel samples in the exposure test.

Results and Discussion:

Table 1: Chemical composition of specimen (mass%)

C	0.08	S	0.003
Si	0.19	Cu	0.32
Mn	0.69	Ni	0.19
P	0.015	Cr	0.53

Table 2: Measurement results of environmental factors

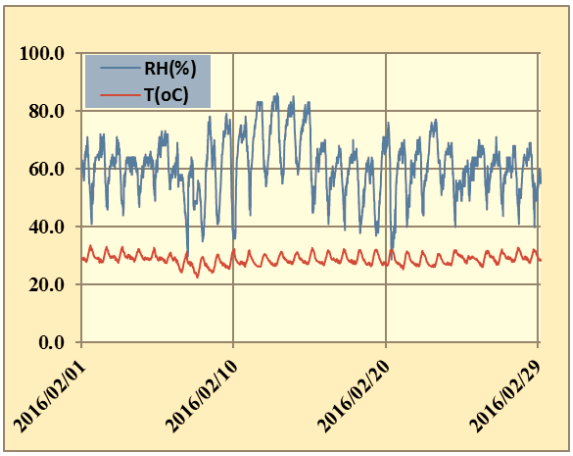
	Bridge name		
	An Nghia	Dan Xay	Ha Thanh
Amount of airborne salt (mdd)	0.027	0.013	0.033
Distance from coastline (km)	18	8	2
Average temperature (^{o}C)	29.5	28.5	29.0
Average relative humidity (%)	69.5	73.4	76.2
Time of wetness (hr)	1404	2171	3260

Table 2 shows the measurement results of the environmental factors at each exposure test site. In this area, the average temperature was relatively high and the average relative humidity was about

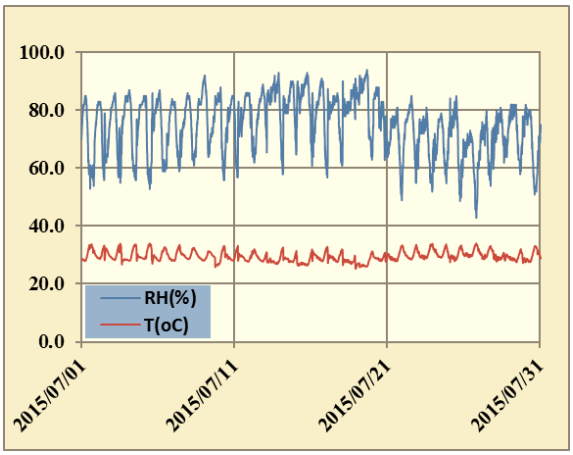
relatively low. At the An Nghia Bridge, wet-dry cycles were seen in the dry and wet seasons. The number of wet-dry cycles in the dry season is larger than that in the wet season.

Figure 9 shows the relationship between the distance from the coastline and the amount of airborne salt. For comparison, the results for Region 1[7] are also shown. In this area, the amount of airborne salt varied depending on the distance from the coastline. This tendency is similar to the results for Region 1.

In Japan, weathering steel can be used without painting when the airborne salt concentration is under 0.05 mdd (mg･NaCl/dm2/day). It is suitable to apply weathering steel in Ho Chi Minh city marine area



a) In dry season



b) In rainy season

Figure 8: Changes of temperature and relative humidity at An Nghia Bridge.

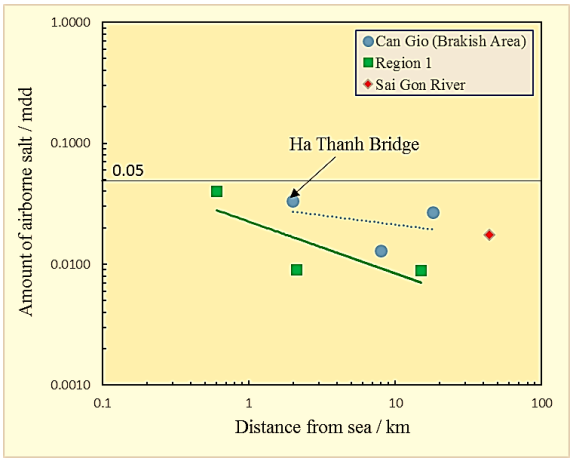


Figure 9: Relationship between amount of airborne salt and distance from the coastline.

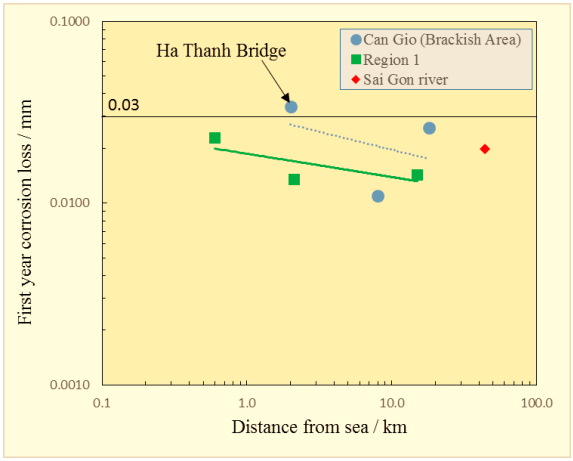


Figure 10: Relationship between corrosion loss and distance from the coastline.

Conclusion:

We carried out the environmental measurements and exposure tests in order to clarify the influence of the environmental factors on the corrosion behavior of weathering steel under atmospheric environment in Ho Chi Minh City marine aria. The results can be summarized as follows:

1. As the result of exposure test, when considering affect of atmospheric environment factors to weathering steel in Ho Chi Minh City marine area, the amount of airborne salt varied depending on the distance from the sea. This result is similar to that in Japan..
2. A strong correlation was observed between the amount of airborne salt and the annual corrosion loss in Ho Chi Minh City marine area. In Vietnam, corrosion loss was less than 0.03mm under an airborne salt 0.05mdd. But further exposure tests are required to evaluate that annual corrosion loss under 0.03mm is to be an index for the applicability such as an experience in Japan.

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