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Comparative Study on Atmospheric Corrosivity of Under Shelter Exposure in Yangon and Mandalay (Myanmar)

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Abstract

Corrosion is a degrading process and it is the main degradation problem in building industry around the world. This study emphasises on the corrosivity classification of studied areas and discusses long term prediction for thickness loss of carbon steel and weathering steel under shelter condition. Two locations, Yangon and Mandalay, are selected as study areas in Myanmar. Corrosion rates are measured after one year exposure. The pollutant data of sulphur dioxide and chloride deposition rates are measured according to JIS Z 2382 and the meteorological data are collected by Easy USB data logger. The corrosion rate is classified based on ISO 9223 by evaluating the important atmospheric variables, such as time of wetness, CL^- and SO_2. The classes of sulphur dioxide and chloride deposition rate can be seen low level for both areas and Time of Wetness (TOW) can be seen τ_4 for Yangon and τ_3 for Mandalay.

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So, according to ISO 9223, the corrosivity category for Yangon area is C_3 and that for Mandalay area is C_2-C_3. The actual mass loss for weathering steel is a little more than that of carbon steel in Yangon and adverse condition can be seen in Mandalay after one year period. Then the future corrosion rates of studied areas are discussed based on long time test results from JFE Steel Corporation, Japan. From this, weathering steel is suitable when chloride deposition rate is less than or equal to 0.05 mdd because of its protective properties.

Keywords: Carbon steel and weathering steel; under shelter corrosion; ISO 9223 corrosivity classification.

1. Introduction

The great majority of people, corrosion mean rust, an almost universal object of hatred. *Rust* is, of course, the name which has more recently been specifically reserved for the corrosion of iron, while *corrosion* is the destructive phenomenon which affects almost all metals. Although iron was not the first metal used by man, it has certainly been the most used, and must have been one of the first on which serious corrosion problems were encountered [1]. Corrosion is often overlooked, but omnipresent phenomenon. It was estimated by the World Corrosion Organization (WCO) in 2010 that 3% of the world’s GDP, $2.2 trillion was the annual direct cost of corrosion worldwide [2].

The principle factors responsible for atmospheric corrosion of metal are temperature, gaseous pollutants, relative humidity, rainfall, and wind velocity etc. Some of these effects are complicated on corrosion process, for example, the increase of the temperature simulates the corrosion attack by enhancing the rate of electrochemical and chemical reaction as well as diffusion process; moreover, the increase of temperature leads to more rapid evaporation of the surface moisture films created by dew rain. Therefore, time of wetness is decreased by which lower the corrosion rate [3]. Shelter exposure differs from unsheltered exposure in many ways. In the former, the surface is shielded from direct precipitation and solar radiation. The shelter also prevents coarse aerosol particles, such as windblown sea salt or soil dust, from reaching the corroded surface, at that time; it allows interaction with smaller aerosol particles and gases. How these modifications of conditions influence the corrosion process depends on the actual exposure conditions and varies from one case to another. Comparison of long term exposure in the open and shelter conditions in the atmospheres with high air pollution (industrial, marine) showed high corrosion rate of weathering steel in shelter conditions after longer exposures due to the commutation of corrosion simulator on steel surfaces. In shelter conditions, the non-homogenous rust layer formed which obtained higher concentration of corrosion stimulators (sulphates, chlorides) [4]. There is an increasing trend of construction of steel structures in Myanmar because of their shorter construction time and better resistance to earthquake than conventional reinforced concrete structures. However, the main problem of steel structures is corrosion protection. But, there is no readily available record information about corrosion of steel structures in Myanmar.

Therefore, it becomes an important problem to be considered about corrosion of structural steels in Myanmar. This paper intends to classify the atmospheric corrosivity and to predict thickness loss for sheltered exposure of urban area; Yangon and Mandalay in Myanmar.Yangon and Mandalay have high population because these are the main commercial centers in Myanmar.

2. ISO Classification of Corrosivity of Atmosphere

This standard is classified the corrosivity of an atmosphere based on measurement of time the wetness and pollution categories (sulphur dioxide, airborne chloride). Based on these measures, an atmosphere is classified as being one of five categories in terms of its corrosivity as shown in Table 1 [5].

Table 1: ISO 9223 Corrosion rates after one year of exposure predicted for different corrosivity classes

Corrosion Category	Steel ($g/m^2/y$)	Copper ($g/m^2/y$)	Aluminum ($g/m^2/y$)	Zinc ($g/m^2/y$)
C_1	≤10	≤0.9	Negligible	≤0.7
C_2	11-200	0.9-5	≤ 0.6	0.7-5
C_3	201-400	5-12	0.6-2	5-15
C_4	401-650	12-25	2-5	15-30
C_5	651-1500	25-50	5-10	30-60

Sulphur dioxide (SO_2) is a colorless gas, belonging to the family of gases called sulphur oxides (SO_x). It reacts on the surface of a variety of airborne solid particles, is soluble in water and can be oxidized within airborne water droplets. Sulphur dioxide, a product of the combustion of sulphur containing fossil fuels, plays an important role in atmospheric corrosion in urban and industrial type atmospheres. It is adsorbed on metal surfaces, has a high solubility in water and tends to form sulphuric acid (acid rain) in the presence of moisture films. Sulfate ions are formed in the surface moisture layer by the oxidation of sulphur dioxide and their formation is considered to be the main corrosion accelerating effect from sulphur dioxide. Sulphur dioxide may be expressed either in terms of a deposition rate or an airborne concentration. The units used for the sulphur dioxide categories in the ISO 9223 are as sulfate deposition (SD) rate in ***mg m^{-2} day^{-1}*** and it is shown in Table 2 [5].

Table 2: ISO 9223 classification of sulphur dioxide and chloride pollution levels

Sulphur Dioxide Category	Sulphur Dioxide Deposition Rate ($mg/m^2/d$)	Chloride Category	Sulphur Dioxide Deposition Rate ($mg/m^2/d$)
P_0	≤ 10	S_0	≤ 3
P_1	11-35	S_1	4-60
P_2	36-80	S_2	61-300
P_3	81-200	S_3	301-1500

Atmospheric salinity distinctly increases atmospheric corrosion rates. Apart from enhancing surface electrolyte formation by hygroscopic action, direct participation of chloride ions in the electrochemical corrosion reactions is likely. In ferrous alloys, iron chloride complexes tend to be unstable (soluble), resulting in further stimulation of corrosive attack. Metals such as zinc and copper, whose chloride salts tend to be less soluble than those of iron, generally display lower chloride induced corrosion rates. The initiation and propagation of localized corrosion damage under the influence of chloride ions is most important. Pitting and crevice corrosion in passivating alloys such as stainless steel, aluminum alloys or titanium are examples of such damage. The units for the chloride categories (airborne salinity) in ISO 9223 are as chloride deposition (CD) rate in $mg\ m^{-2}\ day^{-1}$ and it is shown in Table 2 [5]. From the fundamental theory, time of wetness (TOW) of a corroding surface is a key parameter, which can directly determine the duration of the electrochemical corrosion process. This is a complex variable, since all the means of formation and evaporation of the surface electrolyte solution must be considered. The TOW refers to the period of time during which the atmospheric conditions are favorable for the formation of a surface layer of moisture on a metal or alloy. For the purpose of the standard, this has been defined as the time period during which the relative humidity is in excess of 80% and the temperature is above 0 degrees Celsius. TOW categories range from "Internal microclimates (τ_1) with climatic control" to "Part of damp climates, unventilated sheds in humid conditions (τ_5) and it is shown in Table 3 [6].

Table 3: ISO 9223 classification of time of wetness

Wetness Category	Time of Wetness (Percent)	Time of Wetness (Hours per Year)	Examples of Environment
τ_1	<0.1	<10	Indoor with climatic control
τ_2	0.1-3	10-250	Indoor without climatic control
τ_3	3-30	250-2500	Outdoor in dry, cold climates
τ_4	30-60	2500-5500	Outdoor in other climates
τ_5	>60	>5500	Damp climates

Table 4: ISO 9223 corrosivity categories of atmosphere [6]

TOW	CL^-	SO_2	Steel	Cu and Zn	Al
τ_1	S_0 or S_1	P_1	1	1	1
		P_2	1	1	1
		P_3	1-2	1	1
	S_2	P_1	1	1	2
		P_2	1	1	2
		P_3	1-2	1-2	2-3
	S_3	P_1	1-2	1	2
		P_2	1-2	1-2	2-3
		P_3	2	2	3
τ_2	S_0 or S_1	P_1	1	1	1
		P_2	1-2	1-2	1-2
		P_3	2	2	3-4

Table 4: ISO 9223 corrosivity categories of atmosphere (Cont;)

TOW	CL^-	SO_2	Steel	Cu and Zn	Al
	S_2	P_1	2	1-2	2-3
		P_2	2-3	2	3-4
		P_3	3	3	4
	S_3	P_1	3-4	3	4
		P_2	3-4	3	4
		P_3	4	3-4	4
τ_3	S_0 or S_1	P_1	2-3	3	3
		P_2	3-4	3	3
		P_3	4	3	3-4
	S_2	P_1	3-4	3	3-4
		P_2	3-4	3-4	4
		P_3	4-5	3-4	4-5
	S_3	P_1	4	3-4	4
		P_2	4-5	4	4-5
		P_3	5	4	5
τ_4	S_0 or S_1	P_1	3	3	3
		P_2	4	3-4	3-4
		P_3	5	4-5	4-5
	S_2	P_1	4	4	3-4
		P_2	4	4	4
		P_3	5	5	5
	S_3	P_1	5	5	5
		P_2	5	5	5
		P_3	5	5	5
τ_5	S_0 or S_1	P_1	3-4	3-4	4
		P_2	4-5	4-5	4-5
		P_3	5	5	5
	S_2	P_1	5	5	5
		P_2	5	5	5
		P_3	5	5	5
	S_3	P_1	5	5	5
		P_2	5	5	5
		P_3	5	5	5

Table 4 shows classification of corrosivity of atmosphere based on ISO 9223.

3. Experiment

The corrosivity categories are defined by the one-year corrosion effects on standard specified in ISO 9223. The corrosivity categories can be assessed in terms of the most significant atmospheric factors influencing the corrosion of metals and alloys.

3.1. Test Sites

For this study, two stations, Yangon and Mandalay, were selected. The details at each site are described in Table 4 and the location of test sites are shown in Figure 1.

Table 4: Location of test sites

Environment	Location	Description
Urban	Yangon	Under the third floor ,Yangon Technological University, Yangon, Myanmar
Urban	Mandalay	Under the third floor , Mandalay Technological University, Mandalay, Myanmar

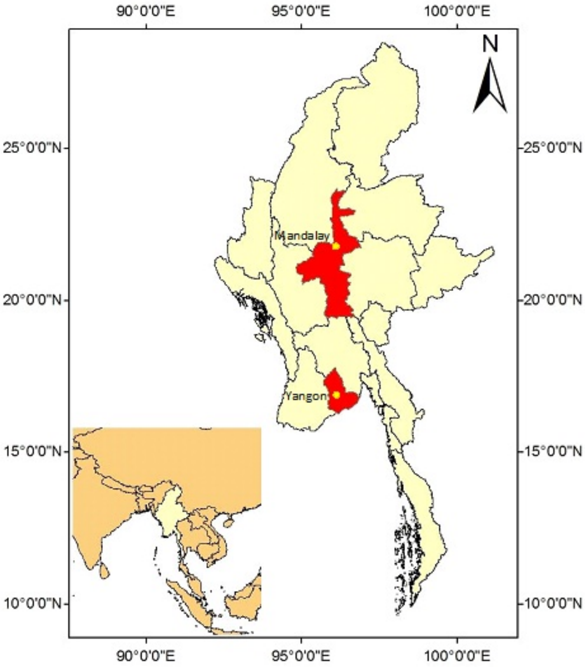


Figure 1: location of test site

Yangon is located in lower Myanmar at the convergence of the Yangon and Bago Rivers about 30 km away from the Gulf of Martaban at 16°48' North, 96°09' East. It is a tropical monsoon climate under KÖppen climate classification system. It is primary due to the heavy precipitation received during the rainy season that Yangon falls under the tropical monsoon climate category [7].

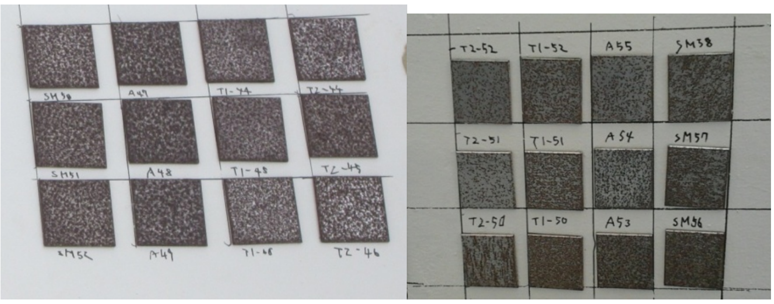
Mandalay is located in upper Myanmar and it is a tropical wet and dry climate under KÖppen climate classification system. Mandalay lies 21°58'30" North and 96°5'0" East [8].

3.2. Test Specimen Installation

Structural steel plates SM (carbon steel) and SMA (weathering steel) with dimension of 50mmx50mmx2mm coupons were installed under the shelter of third floor at Yangon Technological University and Mandalay Technological University. The location that the specimens installed are in open and free for air, facing with wind direction.Exposure test was carried out under the shelter condition for 12 months, and corrosion loss was measured after one year. The chemical compositions of selected structural steels supported by JFE are shown in Table 6. Test specimen installation is shown in Figure 2.

Table 6: Chemical composition of selected structural steels

Material	Chemical Composition (% by weight)								
	C	Si	Mn	P	S	Cu	Cr	Ni	Nb
SM	0.17	0.32	1.39	0.016	0.012	-	-	-	-
SMA	0.12	0.39	0.9	0.008	0.006	0.36	0.61	0.22	0.014



(a) (b)

Figure 2: test specimen installation (a) Yangon (b) Mandalay

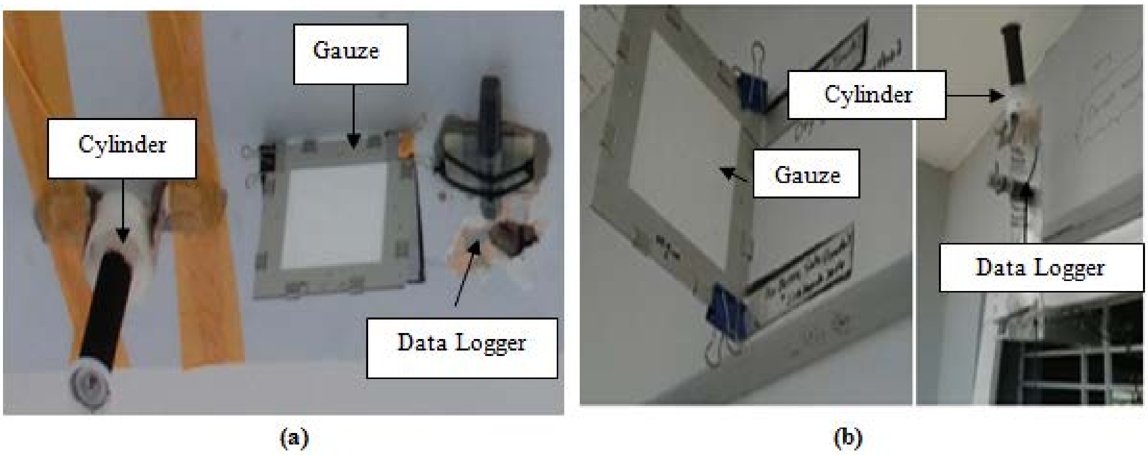
3.3. Collection of Atmospheric Variables

Meteorological data; such as temperature and humidity of locations, was recorded hourly by data logger. Time of wetness (TOW) was calculated from the collected weathering data, based on ISO 9223.

The pollutant data of chloride and sulphur dioxide were obtained by using dry gauze and lead dioxide cylinder methodology, according to JIS Z 2382 [9]. The instruments were placed under the third floor of main building of Yangon Technological University and Mandalay Technological University. They were collected one month interval and determination of chloride and sulphur dioxide deposition rates were done by supporting Kyoto University, Japan. The dry gauze method, JIS Z 2382 [9], was used for measuring the chloride deposition. This method employs a dry gauze screen of 10cmx10cm gauze, which is chipped in hollow acrylic frame. After the exposure, the chloride content was determined by Ion chromatograph method.

The sulphation cylinder method, JIS Z 2382 [9], was used for measuring the SO_2 deposition. This method employs a cylinder with a PbO_2-coated gauze (100 cm^2) wound around it for SO_2 collection. Lead dioxide in paste form was painted as a thin layer on a gauze cylinder and allowed to dry. This PbO_2 reacts with SO_2 of air to form $PbSO_4$. After the exposure, the lead peroxide layer was removed and the sulfate content was determined by Barium sulfate precipitation method.

The collection of these environmental variables is shown in Figure 3.



(a) (b)

Figure 3: collection of environmental variables (a) Yangon (b) Mandalay

3.4. Corrosion Rate Measurement

Corrosion rate may increase, or decrease, or remain constant with time. Quite often the initial attack is high and then decreases.Thus, proper selection of time and number of exposure are important.

The exposure time was started at August, 2014 and after the completion of one year, identical three coupons for each type was removed, cleaned, and weighted, which gives weight loss of that particular time interval.

Constructing an accurate corrosion prediction methodology requires the use of corrosion rate measurements (weight loss per increment of time). Corrosion occurs at a rate determined by equilibrium between opposing electrochemical reactions. Various methods are available for the determination of dissolution of metals in corrosive environments but electrochemical employing polarization techniques are by far most widely used. The corrosion rate (CR) is evaluated by mass loss method considering uniform corrosion after removal of corrosion products. The corrosion rate is determined by the following Equation 1 as per standard, ISO 9226 [10].

$$r_{corr} = \Delta m/At \qquad (1)$$

In which, $r_{corr}$is the corrosion rate, expressed in grams per square meter per year. Δm is the mass loss, expressed in grams. A is the surface area, expressed in square meter and t is the exposure time, expressed in years.

4. Results and Discussion

Corrosivity classification for selected structural steels is determined based on ISO 9223 and then comparison between estimated corrosion rates given by ISO 9223 and actual corrosion rates obtained from under shelter exposures for two selected locations, Yangon and Mandalay.

4.1. Results for Corrosivity Classification Based on ISO 9223

The pollutant data of chloride and sulphur dioxide deposition rates for under shelter exposure for both Yangon and Mandalay from March, 2014 to March, 2015 are shown in Figure 4 and Figure 5, respectively.

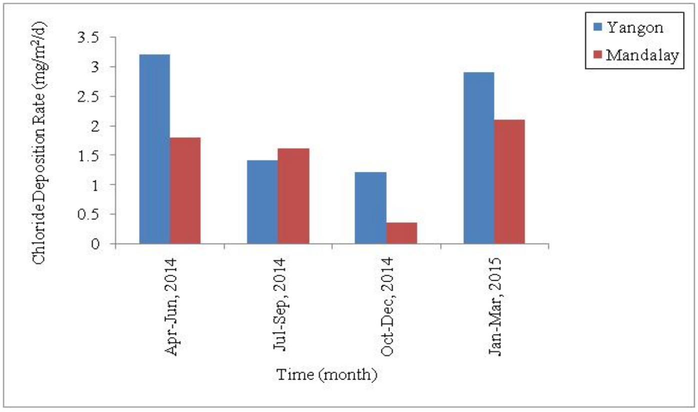


Figure 4: variation of chloride deposition rates for test sites

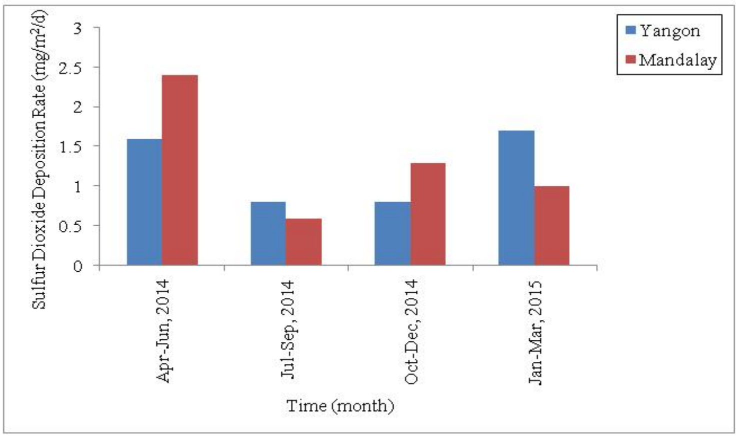


Figure 5: variation of sulphur dioxide deposition rates for test sites

From figures, the chloride deposition rate for Yangon is higher than that for Mandalay. According to theory, the closer the sea, the higher the chloride deposition rates. Yangon is near to the Gulf of Martaban and thus this can cause higher chloride deposition rate than Mandalay.

The average chloride deposition rate for Yangon and Mandalay are 2.196 $mg/m^2/d$ and 1.43 $mg/m^2/d$ respectively. According to ISO 9223, chloride class are S_0 for both sites.

From sulphur dioxide deposition, Yangon is higher than Mandalay, in general. However, higher sulphur dioxide deposition rates can be seen in Mandalay at April and May.

The average sulphur dioxide deposition rates are 1.242 $mg/m^2/d$ and 1.167 $mg/m^2/d$ for Yangon and Mandalay, respectively. Therefore, according to ISO 9223, SO_2 class for both sites is P_0.

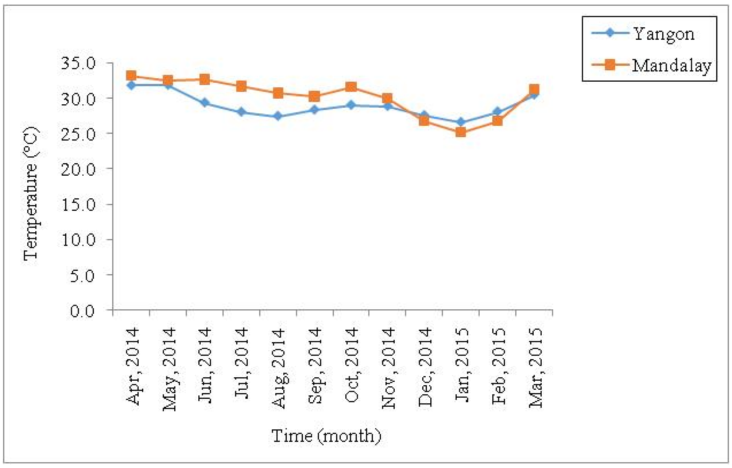


Figure 6: variation of temperature for test sites

The meteorological data, temperature, and relative humidity, for both Yangon and Mandalay from March, 2014 to March, 2015 are shown from Figure 6 and Figure 7, respectively.

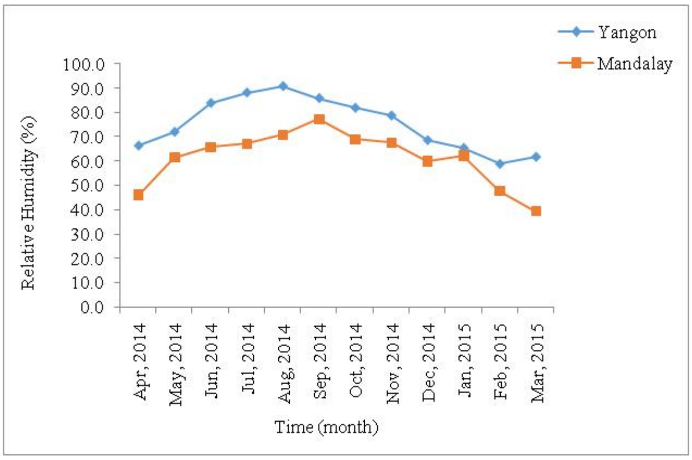


Figure 7: variation of relative humidity for test sites

From these figures, the temperature in Mandalay is relatively higher than that in Yangon although the relative humidity in Mandalay has lower percentage than that in Yangon. The maximum relative humidity is over 90% in Yangon when it is about 80% in Mandalay for the whole year.

Time of wetness is one of the important parameters that affect the corrosion rate. According to ISO 9223, time of wetness can be calculated based on temperature and ralative humidity for each site, and the calculated values are shown in Figure 8. The annual time of wetness in Yangon is much higher than that in Mandalay. In Yangon, the annual time of wetness was 4002 hours and thus its class is $\tau_4$under ISO classification and in Mandalay, the annual time of wetness was 1172 hours and thus its class is τ_3 under ISO classification.

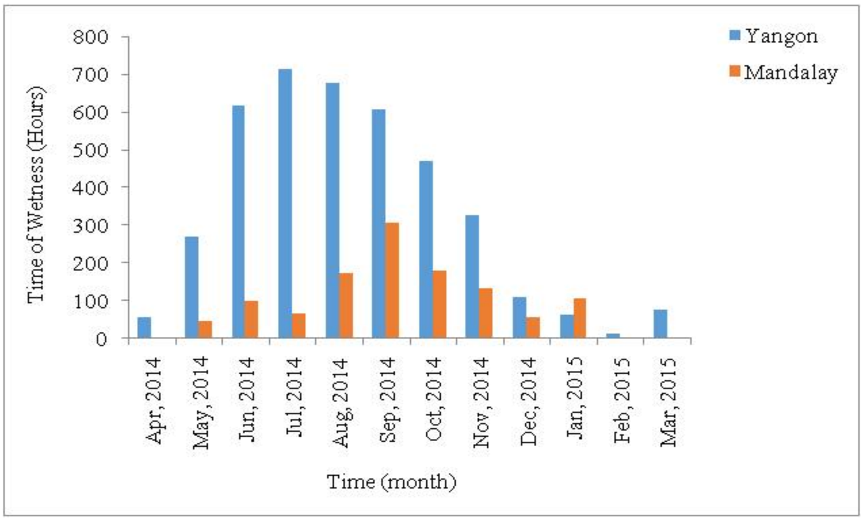


Figure 8: variation of time of wetness for test sites

Table 7: Classification of corrosivity class based on ISO 9223

Site	SO_2			CL^-			TOW		Corrosivity Class
	Deposition (mg/m^2/d)	Rate	Class	Deposition (mg/m^2/d)	Rate	Class	Hours per Year	Class	Steel
Yangon	1.242		P_0	2.196		S_0	4002	τ_4	C_3
Mandalay	1.167		P_0	1.43		S_0	1172	τ_3	C_2-C_3

In Table 7, the classes of sulphur dioxide and chloride deposition rate can be classified as low level and TOW can be classified as τ_4 in Yangon and τ_3 in Mandalay. According to ISO 9223, τ_4 can be found in outdoor atmosphere in all climates (except for dry and cold climates); ventilated sheds in humid conditions; unventilated sheds in temperate climate.

Yangon is the tropical monsoon climate and it has humid condition. Therefore, TOW is also high in Yangon than Mandalay. The corrosivity class of Yangon is C_3 and that of Mandalay is C_2-C_3 and it is mainly due to TOW class.

4.2. Results for Corrosion Rates

Corrosion rates and thickness losses for SM and SMA steel that are considered for under shelter condition after one year exposure are shown in Table 8 and Figure 9.

Table8: Corrosion rates and thickness losses for SM and SMA steel

Site	Corrosion Rate,g/m^2/year (Thickness losses,mm)	
	SM	SMA
Yangon	25.68 (0.0033)	27.58 (0.0035)
Mandalay	10.50 (0.0013)	8.26 (0.0011)

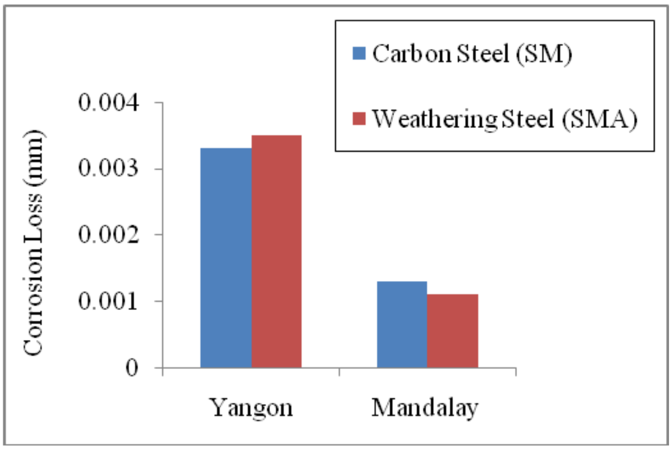


Figure 9: corrosion loss (mm) for carbon and weathering steels

4.2.1. Relation Between Causes and Rate of Corrosion

As described in the previous section, the corrosivity class of Yangon is C_3 and Mandalay is C_2-C_3. So, the estimated corrosion rate for carbon steel in Yangon is 201-400 g/m^2/y and that in Mandalay is 11-400 g/m^2/year according to ISO 9223. However, actual corrosion rate of carbon steel for Yangon is 25.68 g/m^2/year and that for Mandalay is 10.5 g/m^2/year. So, the corrosivity classification of Yangon and Mandalay are both in C_2 from the view point of actual corrosion rate of carbon steels.

By comparing actual corrosion rates and estimated corrosion rates based on ISO 9223, it can be seen that actual corrosion rates for carbon steel are much lower than estimated corrosion rates for under shelter exposure in both sites.

In Yangon, SMA has little higher corrosion rate than SM after one year of exposure because the protective layer for weathering steel can form under the alternating wetting and drying cycle and this cycle cannot be formed easily under shelter condition. According to literature, the longer exposure of sunlight seems to have resulted in a more protective layer. The sunlight is so higher in Mandalay and it can help for formation of protective layer to weathering steel and corrosion rate for SM steel is more than that for SMA steel.

Figure 10, Figure 11, and Figure 12 show the relation between thickness loss (mm) of SM steel and SMA steel and chloride deposition rate (mdd), sulphur dioxide deposition rate (mdd), and distance from the sea (km) respectively.

From these Figures, it can be clearly seen that thickness loss of SM steel is directly correlated with chloride deposition rate and distance from the sea. However, the significant effect of sulfur dioxide deposition rate cannot be seen on thickness loss of SM steel after one year of exposure.

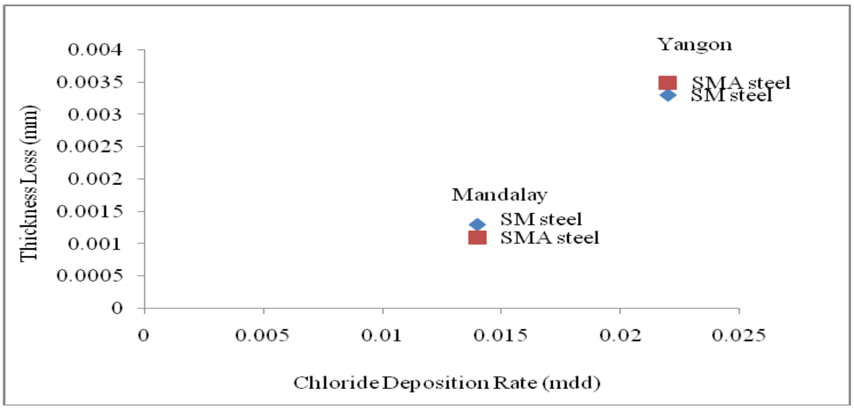


Figure 10: relation between thickness loss of SM and SMA steels and chloride deposition rate

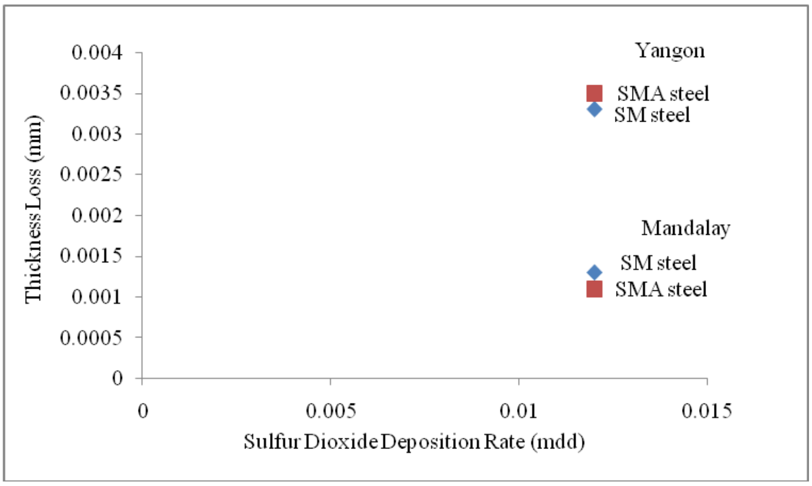


Figure 11: relation between thickness loss of SM and SMA steels and sulphur dioxide deposition rate

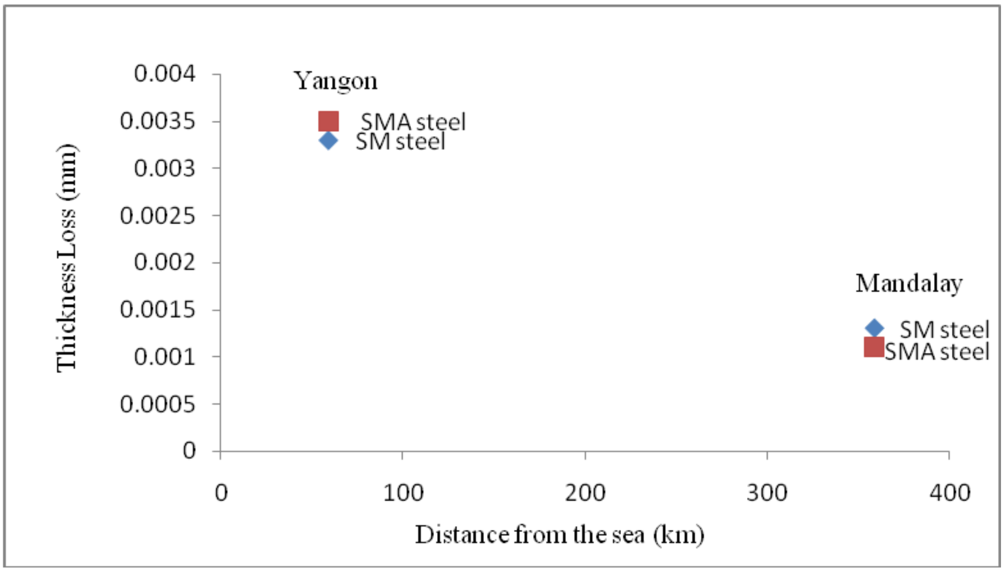


Figure 12: relation between thickness loss of SM and SMA steels and distance from costal

4.2.2. Testing Result for carbon steel and weathering steel in Japan

This article discussed in relation between corrosion loss and chloride deposition rate for 1 year, 3 year, 5 year, 7 year, and 9 year exposure testing data tested in 40 locations, Japan supported by JFE steel cooperation. These are considered as two conditions, chloride deposition rate is greater 0.05 mdd and less than or equal to 0.05 mdd.

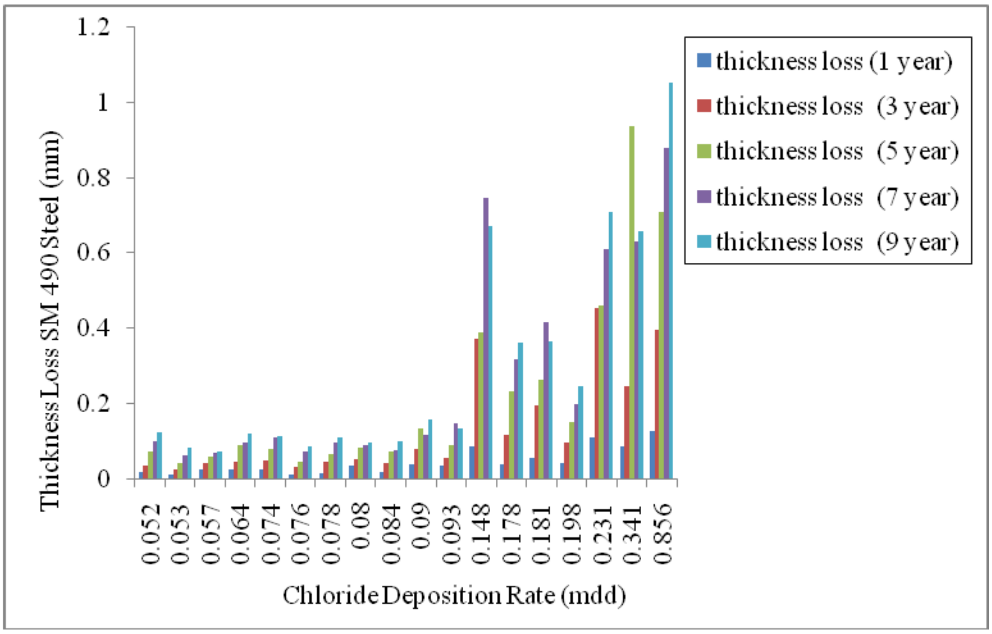


Figure 13: relation between Thickness Loss of SM steel and chloride deposition rate (greater than 0.05mdd)

Figure 13 shows relation between thickness loss of SM steel and Chloride deposition rate and Figure 14 shows relation between thickness loss of SMA steel and Chloride deposition rate (greater than 0.05mdd).

As shown in Table 9, the best correlation is found in 9 year exposure (correlation is 0.859 for SM and 0.882 for SMA). From the correlation result, it is concluded that they have great influence in long duration. In conclusion, it cannot be occurred the protective properties of SMA steel in the case of chloride deposition rate of greater than 0.05 mdd due to higher chloride rate can destroy the protective properties of weathering steels.

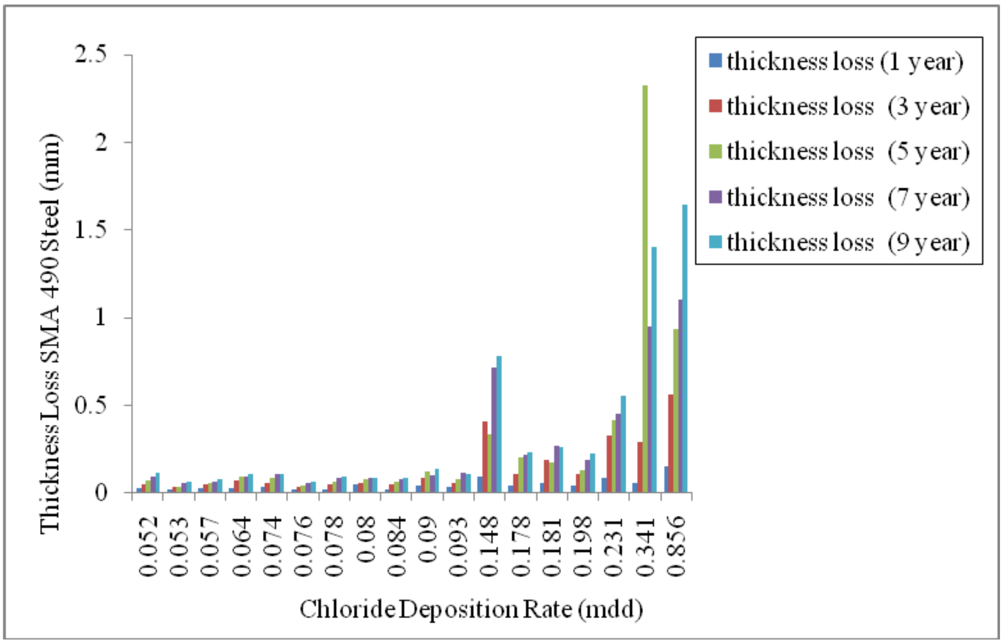


Figure 14: relation between thickness loss of SMA steel and chloride deposition rate (greater than 0.05mdd)

Table 9: Correlation between thickness loss (mm) and chloride deposition rate (greater than 0.05mdd)

Exposure Year	Pearson Correlation	
	SM 490 Steel	SMA 490 Steel
1 year	0.804	0.874
3 year	0.681	0.843
5 year	0.768	0.578
7 year	0.788	0.849
9 year	0.859	0.882

Figure 15 shows relation between thickness loss of SM steel and chloride deposition rate and Figure 16 shows relation between thickness loss of SMA steel and chloride deposition rate (less than or equal to 0.05mdd)

From Table 10, the best correlation can be seen in 3 year exposure (correlation is 0.880) for SM steel. The best correlation can also be seen in 3 year exposure (correlation is 0.814) for SMA steel. The correlation is decreasing after long time duration. In 9 year exposure, the correlation is only 0.561.Therefore, SM steel has more chloride deposition effect than SMA steel for chloride deposition rate of less than or equal 0.05 mdd.

In conclusion, SMA steel is more suitable for the condition of chloride deposition rate of less than or equal 0.05 mdd because of protective properties of SMA steel.

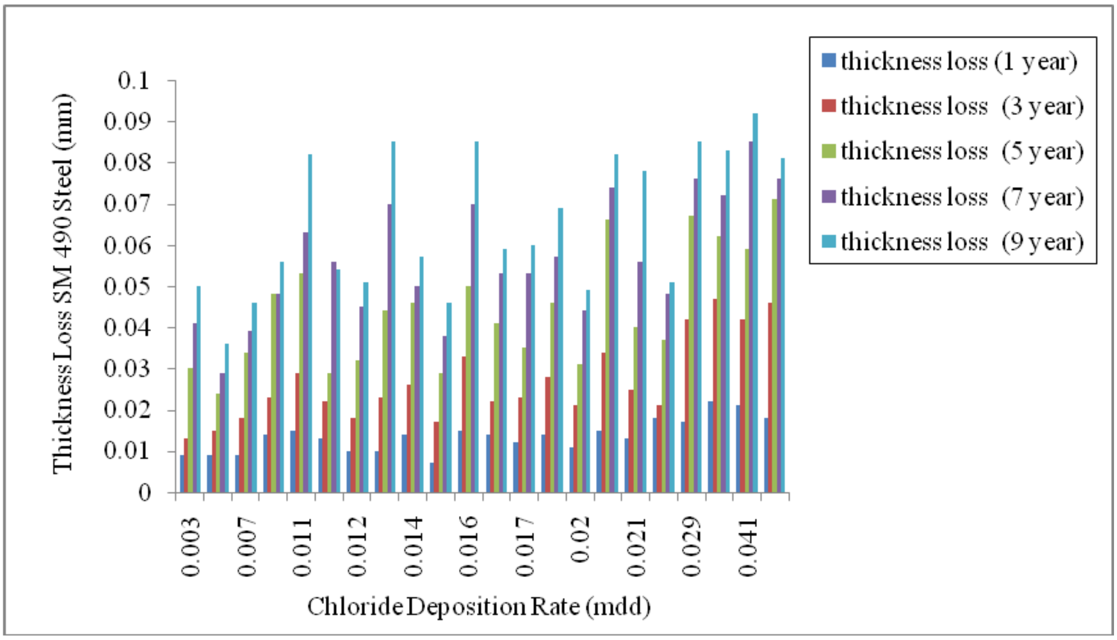


Figure 15: relation between thickness loss of SM steel and chloride deposition rate (less than or equal to 0.05mdd)

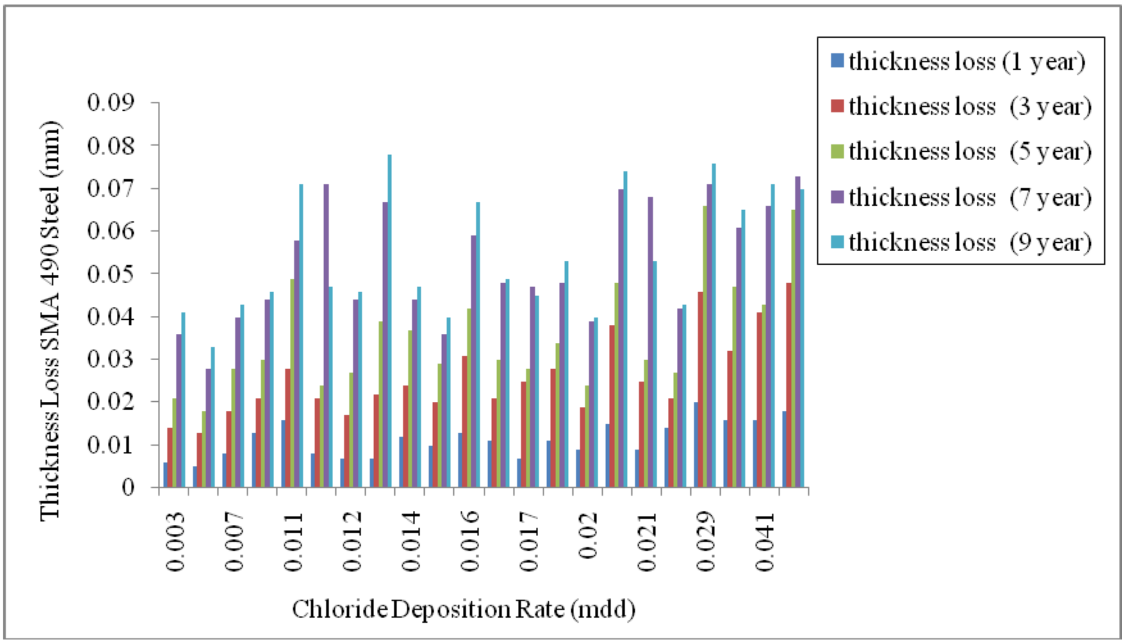


Figure 16: relation between thickness loss of SMA steel and chloride deposition rate (less than or equal to 0.05mdd)

Table 10: Correlation between thickness Loss (mm) and chloride deposition rate for SM and SMA Steels (less than or equal to 0.05mdd)

Exposure Year	Pearson Correlation	
	SM 490 Steel	SMA 490 Steel
1 year	0.815	0.720
3 year	0.880	0.814
5 year	0.727	0.680
7 year	0.744	0.598
9 year	0.643	0.561

4.2.3. Discussion on future corrosion loss in Myanmar

Future corrosion loss for Yangon and Mandalay are predicted based on thelong-term data from JFE steel cooperation tested in Japan and the one year data tested in Myanmar.

As shown in Figure 4, the chloride deposition rate for both Yangon and Mandalay is well under 5 mg/m^2/d (0.05 mdd) and Mandalay area has lower chloride deposition rate than Yangon area. The average chloride deposition rate for Yangon is 0.022 mdd and that for Mandalay is chloride deposition rate 0.014 mdd. Distance from the sea of Yangon is about 59 km and that of Mandalay is 359 km. Therefore, the chloride deposition rate of Mandalay is only about half for that of Yangon because the nearer the sea, the higher the chloride deposition rate.

Thus the corrosion rate in Yangon is more than that in Mandalay. In Mandalay, the corrosion rate of SMA steel is less than that of SM steel after one year of exposure.However the corrosion rate of SMA steel is a little more than that of SM steel after one year exposure in Yangon. The chloride deposition rate in Yangon is only 0.022 mdd and thus it is well below 0.05. So, the protective properties of SMA steel will be occurred in longtime and the corrosion rate will be decreased.

5. Conclusion

This paper emphasis on the corrosivity classification for under shelter corrosion of carbon steel (SM) and weathering steel (SMA) in Myanmar (Yangon and Mandalay). The results are based on atmospheric variables, such as pollutant and meteorological data and actual corrosion rate from one year results and discuss oncorrosion rate for future is based on the results obtained from JFE steel Corporation, Japan.

The main conclusions of this paper are:

1. Average yearly sulphur and chloride deposition rate and time of wetness for Yangon is more than that

for Mandalay.

2. According to ISO 9223, the corrosivity class of Yangon is C_3 and that of Mandalay is C_2-C_3.
3. From specimen exposure test, corrosion rate is lower in Mandalay than Yangon for carbon steel and weathering steel.
4. Corrosion rate of carbon steel is more than that for weathering steel in Mandalay.
5. Converse condition can be seen in Yangon, where corrosion rate for weathering steel is more than that for carbon steel.
6. The protective properties of SMA steel will be occurred in long time and the corrosion rate will be decreased as chloride deposition rateis less than 0.05 mdd.

6. Recommendations

1 Long term test should be done for sheltered atmospheric exposure test to emphasize the influence of atmospheric variables to structural steel

2 Unsheltered atmospheric exposure test should be done and compare with sheltered exposure test

3 Corrosion with laboratory testing should be studied and compare with atmospheric corrosion test result

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