Morphologies of rust on mild steel in tropical atmosphere

[1]Khin Khin Thaw, [2]Thinzar Khaing, [3]Nyo Nyo Tun
[1]Ph.D Student, [2]Professor, [3]Lecturer
[1]Department of Civil Engineering, [2]Department of Civil Engineering, [3]Department of Civil Engineering
Yangon Technological University, Yangon, Myanmar
Email - [1]khinkhinthaw87@gmail.com, [2]tzkhaing@gmail.com, [3]nyonyotuncivil@gmail.com

Abstract: *The morphologies of rust on two types of mild steels, most widely used in Myanmar, has been examined at two exposure sites, Yangon and Mawlamyine. The intension is to study the morphologies of corrosion products in tropical environments. Characterizations are based on corrosion products of standard specimens at the end of 1, 2, 3, and 6 month's exposure period. The characterization of rust layer has been done by Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDX). After 1month, 2 months, and 3 months exposure, the corrosion products formed on all of the mild steels on both sites are lepidocrocite (sandy crystals) and lepidocrocite (flowery structures). The formation of akaganeite (cotton balls & rosette) is only in Mawlamyine after 3 months. Goethite (cotton ball structures) and akaganeite (cigar-shaped crystals) are the increased corrosion products after 6 months exposure. Lepidocrocite is commonly found in the early stage weathering of mild steel. If the specimens are in longer TOW, lepidocrocite transforms into goethite in later period. The most common morphologies on both sites are lepidocrocite (sandy crystals and flowery structures), goethite (cotton ball structures), and akaganeite (cotton balls and cigar-shaped crystals).*

Key Words: *Atmospheric corrosion, morphologies, mild steel, rust, tropical*

1. INTRODUCTION:

Mild steel is a versatile structural material in construction of buildings, bridges, flyovers, pipelines, etc. But this is very much prone to corrosion in normal humid atmosphere and these corrosion problems are much severe in Myanmar, one of tropical countries with vast coastline. In Myanmar, tropical monsoon in the lowlands below 2,000 m (6,562 ft); cloudy, rainy, hot, humid summers (southwest monsoon, June to September); less cloudy, scant rainfall, mid temperatures, lower humidity during winter (northeast monsoon, December to April). Climates varies in the highlands depending on elevation; subtropical temperate climate at around 2,500 m (8,202 ft), temperate at 3,000 m (9,843 ft), cool, alpine at 3,500 m (11,483 ft) and above the alpine zone, cold, harsh tundra and Arctic climate. The higher elevations are subject to heavy snowfall and bad weather.

Mild steel corrodes relatively faster and thus leads to colossal loss in every year. Therefore, engineers and scientists all over the world are deeply concerned in research works at surface science and engineering of atmospheric degradation of mild steel. Endeavours have been made in the present investigation for better understanding of the degradation process and surface characterization through electron microscopy and EDX.

Rust layers on mild steel are not protective and are permeable to air and moisture. On mild steel, major rust phase γFeOOH transforms to the more stable αFeOOH with time. Presence of chlorides in the atmosphere aggravates corrosion of steels leading to the formation of basic Fe^{2+}, Fe^{3+} chlorides and βFeOOH on mild steel. In mild steel corrosion products form as two different phases, and there are two layers with a common interface allowing moistures to go in and experiences higher corrosion rate in outdoor exposure. Field exposure test is a very slow oxidation process so several months/years together are required to get measurable rust on surface of steel panels.

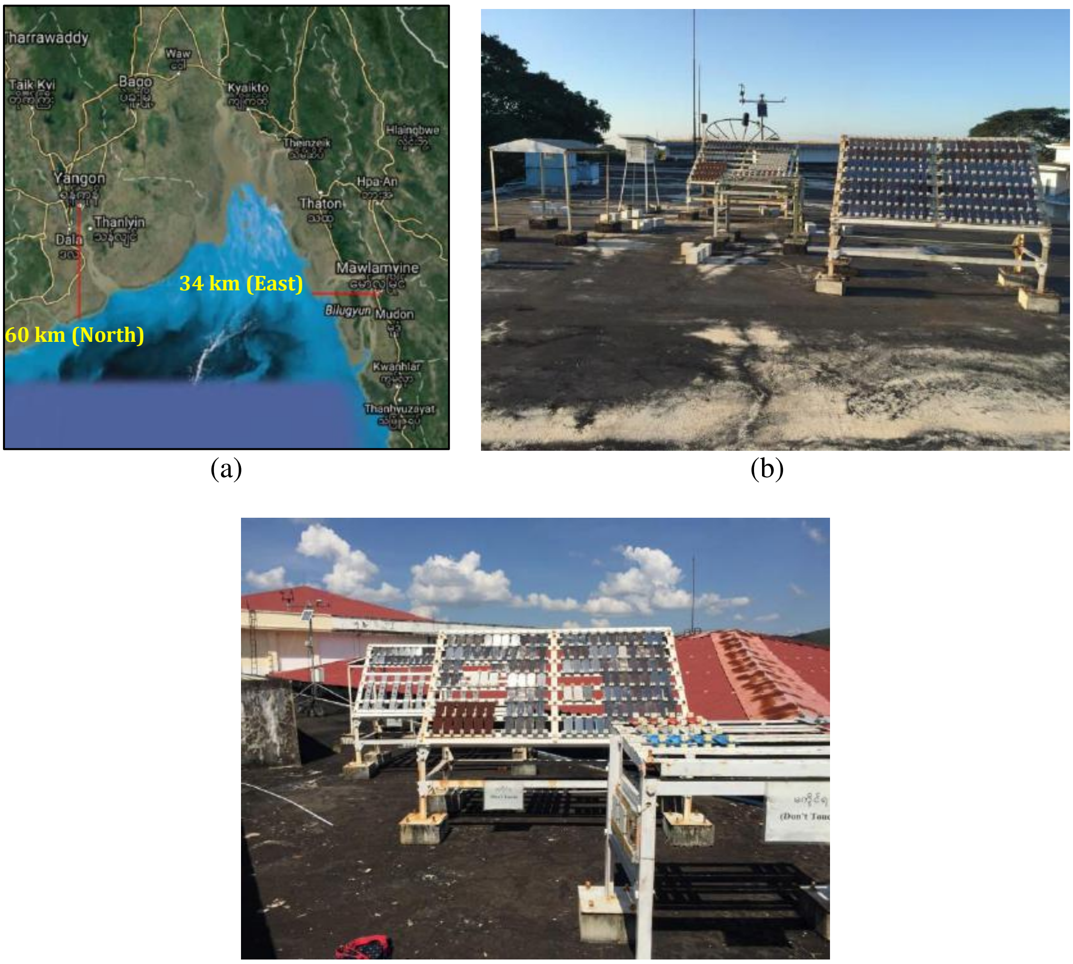
2. MATERIALS AND METHODS:

Exposure test has been carried out in two sites Yangon and Mawlamyine, Myanmar. Under field exposure test Yangon: urban environment and 60 km far from the North of Andaman sea coastline and Mawlamyine: urban environment also and 34 km far from the East of Andaman sea coastline. Bare panels were withdrawn from field exposure sites for characterization after different time intervals. Analytical technique SEM was employed for understanding the morphological state.

A. Exposure Test Sites

The urban atmosphere of the Yangon test site is located between the latitude 16 ° 48′ 19.01″ N and the longitudes 96 ° 9′ 22″ E. The test panels were exposed on the top floor of Yangon Technological University, close to the road with considerable traffic. The test site Mawlmyine is also the urban atmosphere and located between the latitude 16 ° 29′ 25.84″ N and the longitudes 97 ° 37′ 41.7″ E. The test panels were exposed on the top floor of

Technological University (Mawlmyine), slightly far from the road with moderate traffic. The exposure test site locations are shown in Fig. 1.



(a) (b)

(c)

Fig. 1 (a) Exposure Site Locations, (b) Exposure Racks on YTU Top Floor, and (c) Exposure Racks on TU (Mawlamyine) Top Floor

B. Types and Chemical Composition of Steel

The types of mild steel selected for atmospheric corrosion are two SS-400s and one SS-490. The source of one SS-400 and one SS-490 is Mottama Holdings Co.,Ltd, one of steel structure and distribution companies in Myanmar and the certificate has been got for these steel. Another type of SS-400 steel is from Moe Thauk Kyal Trading, which is from local market in South Dagon Industry and the certificate has not had. The chemical compositions of all types of steel are described in TABLE I and the composition of SS-400 (MTK) steel has been done by EDX results.

TABLE I
CHEMICAL COMPOSITION (%) BY WEIGHT OF STEELS

Steel Types	SS-400 (MTK)	SS-400 (MTM)	SS-490 (MTM)
Sources	Moe Thauk Kyal Trading	Mottama Holdings Co.,Ltd.	Mottama Holdings Co.,Ltd.
Fe	99.058	99.16	98.51
C	0.05	0.06	0.16
Si	0.14	0.14	0.13
Mn	0.36	0.26	0.86
P	0.035	0.035	0.013
S	0.007	0.007	0.009
Cr	0.35	0.34	0.32

C. Experimental Procedure for Atmospheric Exposure

Flat sheet specimen size is 150mm x 70mm and the specimen thicknesses are 3mm for SS-400 and 3.2mm for SS-490. A well-defined surface preparation is needed. Surface preparation involves a combination of a degreasing stage using organic solvents and a mechanical descaling treatment for surfaces bearing mill scale, heat treatment scale or rust. The number of test specimens of each type in an evaluation is three for each exposure time interval. The flat coupons are mounted on the metal rack which is designed by ISO 8565 to enable specimens to be exposed at an angle of 45° from horizontal skyward facing. For short term testing, the results might depend on the season when exposure is initiated. Therefore, the exposures are commenced in the period of highest corrosivity (autumn). Coupons of two types of mild steel were exposed at the two sites for one month, two months, three months, and six months interval. One number was dismounted on each interval and this is for scanning electron microscopy (SEM) and EDX. [3]

D. SEM and EDX

The degree of corrosion, surface morphology, particle size and texture can be effectively studied by scanning electron microscope (SEM) and energy dispersive X-ray analysis (EDX). The optical microscope can be used for imaging the surface but it has limitations of resolution and depth of field at higher magnifications. SEM can be used for high- resolution imaging of the surface, with a large depth of focus. [2]

3. CORROSION PRODUCT ANALYSIS AND DISCUSSIONS:

The morphologies of rust on SS-400 (MTK) steel in Yangon and Mawlamyine are characterized by Scanning Electron Microscopy (SEM) at the end of 1, 2, 3 and 6 months corrosion period and described in Fig. 2 and Fig. 3. In Yangon, the corrosion products formed on that are Lepidocrocite (Sandy Crystals) only after one month and two months, Lepidocrocite (Flowery Structure) after 3 months, and Goethite (Cotton Balls) after 6 months exposure. In Mawlamyine, the corrosion products formed on that are Lepidocrocite (Flowery Structure) only after one month and two months, Lepidocrocite (Sandy Crystals) after 3 months, and Goethite (Cotton Balls) after 6 months exposure.

The morphologies of rust on SS-400 (MTM) steel on both sites are also characterized by Scanning Electron Microscopy (SEM) at the end of 1, 2, 3 and 6 months corrosion period and shown in Fig. 4 and Fig. 5. In Yangon, the corrosion products formed on that are Lepidocrocite (Sandy Crystals) after one month, Lepidocrocite (Flowery Structure) only after 2 months and 3 months, and Akaganeite (Cotton Balls and Rosette) after 6 months exposure. In Mawlamyine, the corrosion products formed on that are Lepidocrocite (Sandy Crystals) only after one month, two months and 3 months, and Akaganeite (Cotton Balls and Cigar-Shaped Crystals) after 6 months exposure.

The morphologies of rust on SS-490 (MTM) steel on both sites are also characterized by Scanning Electron Microscopy (SEM) at the end of 1, 2, 3 and 6 months corrosion period and shown in Fig. 6 and Fig. 7. In Yangon, the corrosion products formed on that are Lepidocrocite (Flowery Structure) after one month and 3 months, Lepidocrocite (Sandy Crystals) after 2 months, and Akaganeite (Cigar-Shaped Crystals) after 6 months exposure. In Mawlamyine, the corrosion products formed on that are Lepidocrocite (Sandy Crystals) only after one month and two months, Akaganeite (Cotton Balls and Rosette) after 3 months, and Akaganeite (Cigar-Shaped Crystals) after 6 months exposure.

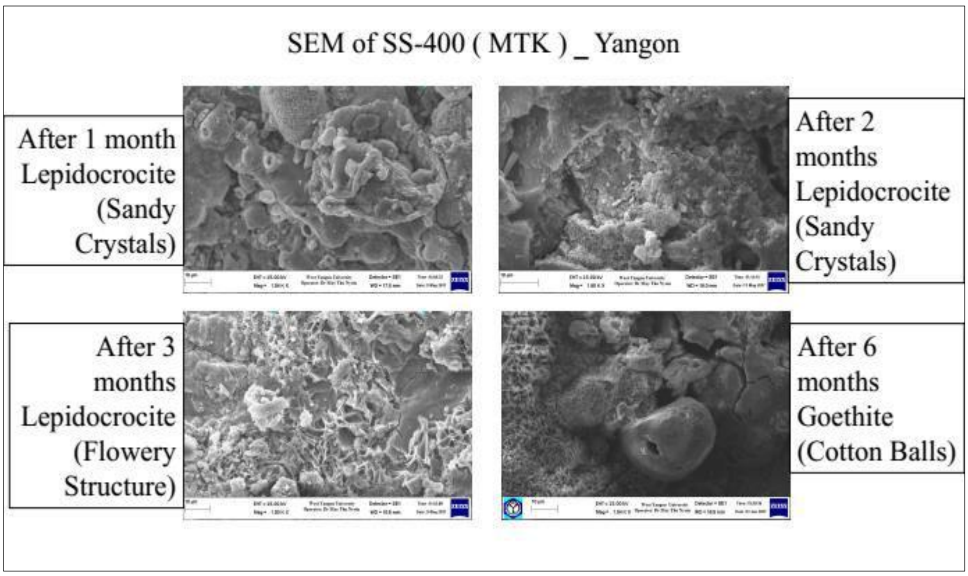


Fig. 2 Morphologies of rust on SS-400 (MTK) steel in Yangon

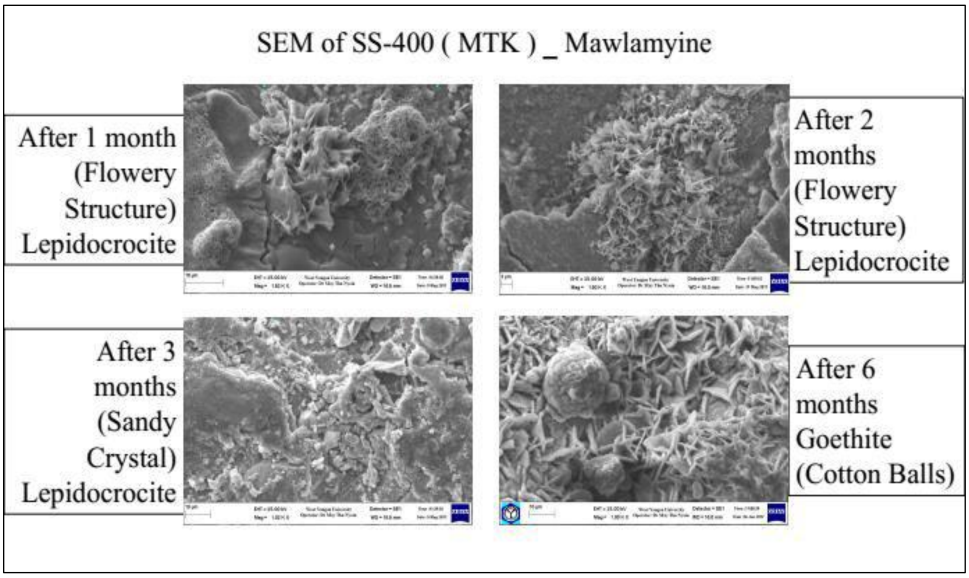


Fig. 3 Morphologies of rust on SS-400 (MTK) steel in Mawlamyine

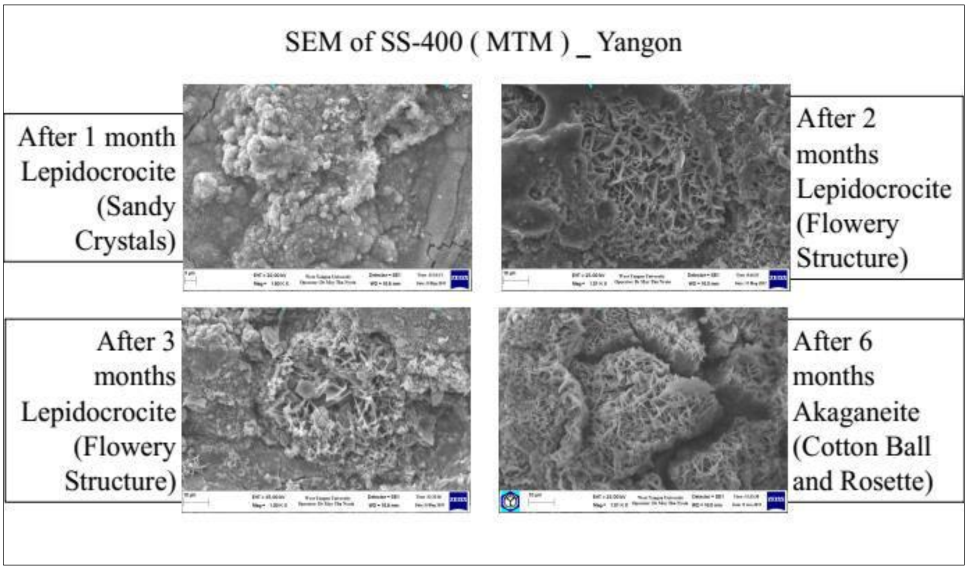


Fig. 4 Morphologies of rust on SS-400 (MTM) steel in Yangon

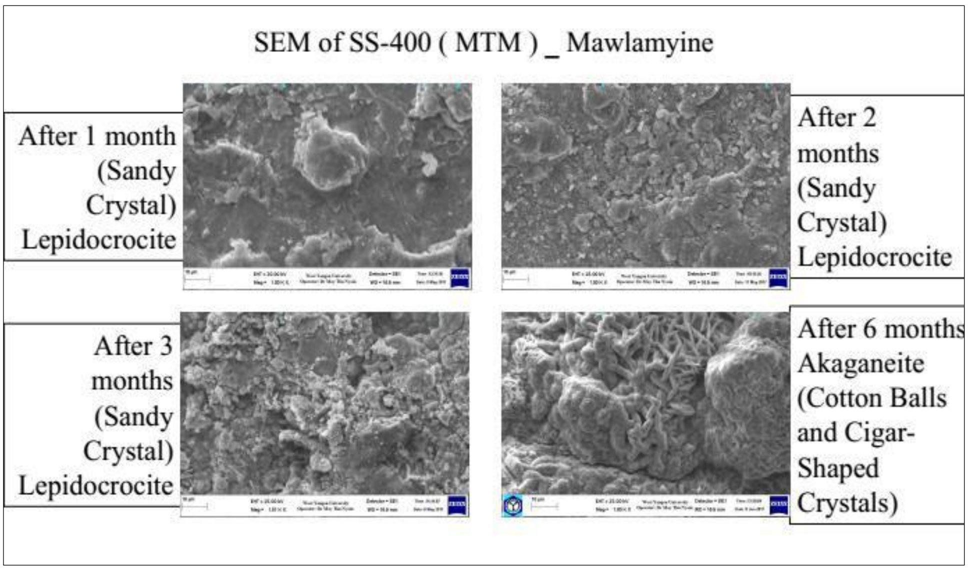


Fig. 5 Morphologies of rust on SS-400 (MTM) steel in Mawlamyine

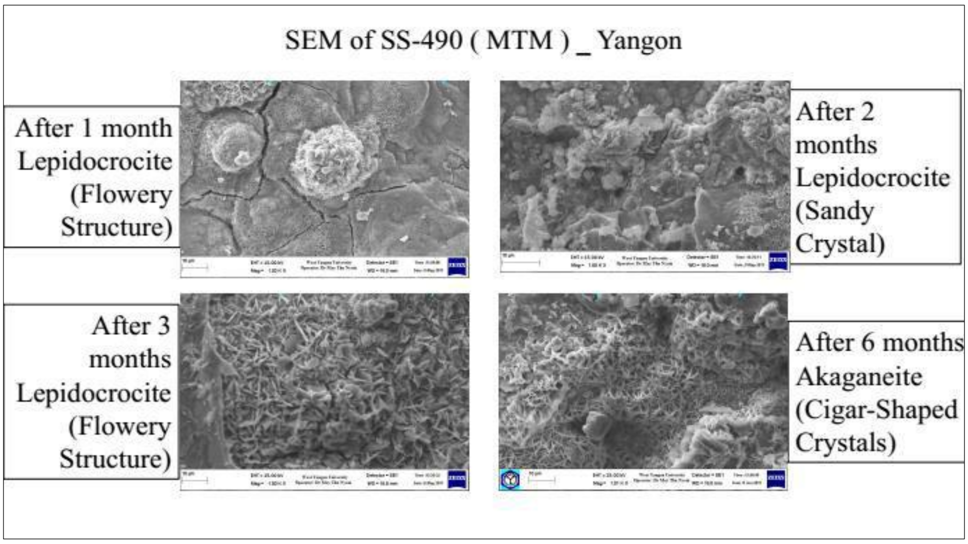


Fig. 6 Morphologies of rust on SS-490 (MTM) steel in Yangon

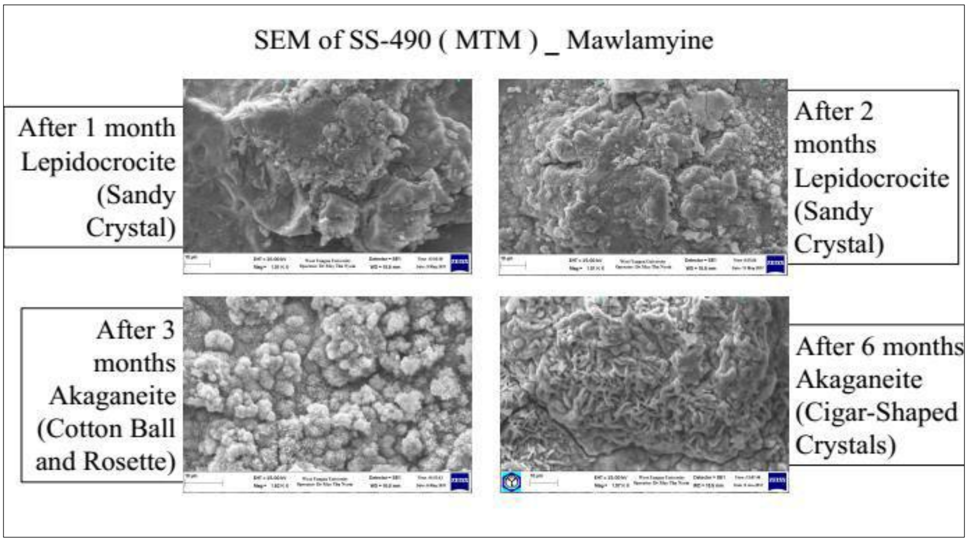


Fig. 7 Morphologies of rust on SS-490 (MTK) steel in Mawlamyine

After 1 month, 2 months, and 3 months exposure, the corrosion products formed on both sites are lepidocrocite (sandy crystals) and lepidocrocite (flowery structures). The formation of akaganeite (cotton balls & rosette) is only in Mawlamyine after 3 months. Goethite (cotton ball structures) and akaganeite (cigar-shaped crystals) are the increased corrosion products after 6 months exposure. Lepidocrocite is commonly found in the early stage weathering of mild steel. If the specimens are in longer TOW, lepidocrocite transforms into goethite in later period.

Rust characterization has also done by energy dispersive X-ray spectroscopy (EDX) at the end of 1, 2, 3 and 6 months corrosion period in Yangon and Mawlamyine. According to EDX results, the significant element is Fe_2O_3 (Hematite_ α-Fe_2O_3 and Maghemite_γ-Fe_2O_3).

5. CONCLUSION:

In general, the morphological structures found for the corrosion products of SS-400 (MTK), SS-400 (MTM), and SS-490 (MTM) have been sandy crystal and flowery structures of Lepidocrocite, cotton ball structure of Goethite; and cotton ball and rosette, and cigar-shaped crystals of Akaganeite in those two tropical regions. Cotton ball structure of Goethite is found on SS-400 (MTK) steel only and cotton ball and rosette, and cigar-shaped crystals of Akaganeite are formed on both SS-400 (MTM) and SS-490 (MTM) steels in these regions.

REFERENCES:

1. Herbet E. Townsend (Editor),(August 2002), *Outdoor Atmospheric Corrosion*, ASTM: STP1412,.
2. Philip A. Schweitzer (1999), *Atmospheric Degradation and Corrosion Control*, ISBN: 0-8247-7709-3.

3. Sheldon W. Dean, Guillermo Hernandez-Duque Delgadillo, James B. Bushman (Editors),(September 2000) *Marine Corrosion in Tropical Environments*, ASTM: STP1399,.
4. Jayanta Kumar Saha, *Corrosion of Constructional Steels in Marine and Industrial Environment*, Frontier Work in Atmospheric Corrosion, Springer.
5. ISO 8565: Metals and Alloys – *Atmospheric corrosion testing – General requirement for field tests*
6. ISO 8407: Corrosion of Metals and Alloys - *Removal of Corrosion Products from Corrosion Test Specimens.*
7. ISO 9223: Corrosion of Metals and Alloys - *Corrosivity of Atmospheres – Determination of corrosion rate of standard specimens for the evaluation of corrosivity.*
8. ISO 9223: Corrosion of Metals and Alloys - *Corrosivity of Atmospheres - Classification.*
9. ASTM G 101 - 04: *Standard Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steel.*
10. ASTM G 16 - 95: *Standard Guide for Applying Statistics to Analysis of Corrosion Data,* (Reapproved 2004).
11. D. de la Fuente, I. Diaz, J. Simancas, B. Chico and M. Morcillo, Long-Term Atmospheric Corrosion of Mild Steel, National Centre of Metallurgical Research (CENIM-CSIC), Avda. Gregorio del Amo, 8, 28040-Madrid, Spain.