

The Corrosivity of the Mauritian Atmosphere

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Abstract

This study aims to determine the corrosivity of the Mauritian atmosphere through the outdoor exposure of carbon steel samples of commercial quality. They were exposed at three sites, namely Réduit, Vacoas and Palmar, for a total period of about 1 ½ year. The samples were removed at time intervals of approximately 1 ½, 3, 6, 9, 12, 15 and 18 months and their corrosion rates were determined using the weight loss method. These values were then compared according to ISO 9223 to determine the corrosivity of the atmosphere at the three different sites. It was observed that the atmosphere at Réduit, Vacoas, and Palmar falls into category C₂ which refers to environments which have moderate corrosivity.

Keywords: Corrosion rate, corrosivity, atmospheric corrosion, carbon steel samples, weight loss method.

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INTRODUCTION

Carbon steel is being increasingly used in Mauritius. According to the Mauritius Statistical Office (2008), the import of iron and steel has increased from Rs 540 millions in 1990, to Rs 1041 millions in 2000, and Rs 2237 millions in 2005. Being a tropical island, Mauritius has high humidity level and substantial rainfall and is surrounded by sea. These factors are expected to be responsible for the acute problem of atmospheric corrosion (Bhaskar *et al.*, 2004; Graedel & Leygraf, 2000; Rajagopalan *et al.*, 1971) on the island leading to the deterioration of various types of steel structures. However, only very basic studies have been performed on the corrosivity of the Mauritian atmosphere (Seewoodharry, 1993).

Atmospheric corrosion is a serious problem leading to enormous financial losses worldwide. In India, in 2004, corrosion damage was estimated to be responsible for losses to the national economy amounting to around approximately £ 2.5 billion per year (Bhaskar *et.al*, 2004). Studies have shown that the overall cost of corrosion amounts to at least 4-5% of the gross national product, and in that 20-25% of this cost could be avoided by using appropriate corrosion control technology. Atmospheric corrosion is the major contributor to this cost (Natesan *et.al*, 2005). To prevent such losses in Mauritius, it has become important to classify the corrosivity of the Mauritian atmosphere in order to facilitate the task of selecting materials, protection systems, maintenance intervals, e.t.c. Therefore, carbon steel samples were exposed outdoors at three different sites, in order to obtain the corrosivity of the respective atmosphere. The coupons were removed at time intervals of approximately 1 ½, 3, 6, 9, 12, 15, and 18 months and their corrosion rates were determined using the weight loss method. These values were then compared with ISO 9223 to determine the corrosivity of the atmosphere at the three different sites.

MATERIALS AND METHODOLOGY

Exposure of the mild steel coupons

Carbon steel samples, with the composition of the main alloying elements as shown in Table 1, were outdoor exposed according to ISO 8565 (1995), which includes the standards for the proper preparation, handling, storage, and exposure of the test samples. All of them were of 3mm thickness and were cut from the same sheet to the size of 100 mm × 150 mm.

	<i>% composition</i>
<i>Carbon</i>	0.44
<i>Sulphur</i>	0.0244

<i>Manganese</i>	0.549
<i>Phosphorus</i>	0.001
<i>Silicon</i>	0.074
<i>Nickel</i>	0.030
<i>Chromium</i>	0.014
<i>Copper</i>	0.057

Table 1- Composition of the main alloying elements of carbon steel used

The samples were clearly marked using alphabetical stamps. They were then cleaned using acetone. Some of the carbon steel samples which contained stains of rust were cleaned with a rust removing solution (containing buffered acid) and then with acetone. Each of them was subsequently weighed to the nearest 0.001g. Their exact dimensions were recorded and they were kept in sealed plastic bags with silica gel as desiccant. They were then exposed at 3 different sites, namely Reduit, Vacoas and Palmar, as shown in fig. 1.

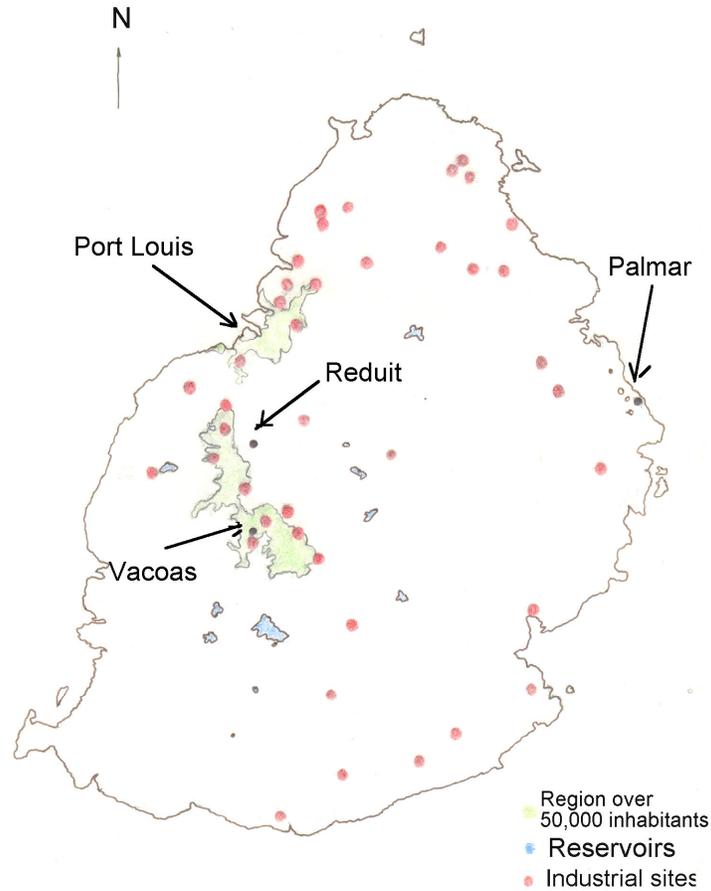


Fig. 1 – Map of Mauritius (Venkatasamy, 1991) showing the selected sites for exposure of coupons

Three sites were chosen, taking into consideration:

- Security at the sites.
- Accessibility.
- Amount of space available at the sites.

The site at Reduit is the University of Mauritius which is situated in a rural region 9 km from the nearest western coast. At Vacoas, the coupons were exposed at the Mauritius Meteorological Services station. It is found in an urban region very near to industrial sites. At Palmar, the coupons were exposed on site of the Ministry of Agriculture. It is found in a rural coastal region (approximately 500 m from the sea shore) very far from industries.

The dates on which the samples were exposed at the three sites are:

- At Vacoas, the samples were exposed on 4/10/02.
- At Palmar, the samples were exposed on 8/10/02.
- At Reduit, the samples were exposed on 6/11/02.



Fig. 2- Exposure frames at Reduit

The weight loss method

After specific intervals of time, the samples were removed from the racks. They were cleaned to determine the mass loss by making use of chemicals according to BS 7545 (1991). Prior to this, a light mechanical cleaning treatment by brushing with a soft bristle brush under running water was first applied to remove lightly adherent corrosion products. Table 2 shows the chemicals that have been used and the procedure adopted for the removal of the corrosion products on the carbon steel samples.

Chemicals	Quantity	Procedure
Sodium hydroxide	200g	The sample is dipped in the mixture of chemicals
Zinc	20g	

Distilled water	Add to 1000 ml	and heated to 80 ⁰ C to 90 ⁰ C for 30 to 40 mins.
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Table 2- Chemicals used for cleaning carbon steel samples

For each removal, the samples were removed in batches of three and the average value for the mass loss was used to determine the average corrosion rate, using equation (1).

$$\text{Corrosion rate} = (87.6W)/(DAT)$$

equation (1)

where,

Corrosion rate is in mm/yr

W= Mass loss, mg

D= density of specimen, g/cm³

A= Area of specimen, cm²

T= exposure time, hr

Results from the weight loss method

Table 3 shows the results obtained based on the weight loss method and fig. 3 shows the average mass loss of the samples plotted against the number of days of exposure

Site	Days after exposure	Corrected Weight loss (g)
Redit	47	2.025
	69.1	3.201
	175	4.364
	271.1	4.602
	408.1	5.465
	506.1	7.846
	624.2	10.369
Vacoas	47	1.746
	102.0	3.699
	194.2	
	304	5.097
	441	6.135
	532.1	7.538
	657.1	9.829
Palmar	44	1.789
	76.1	3.257
	190.0	4.576
	280.1	5.000
	435.1	6.636
	528.0	7.784
	653	9.295

Table 3- Results obtained using the weight loss method

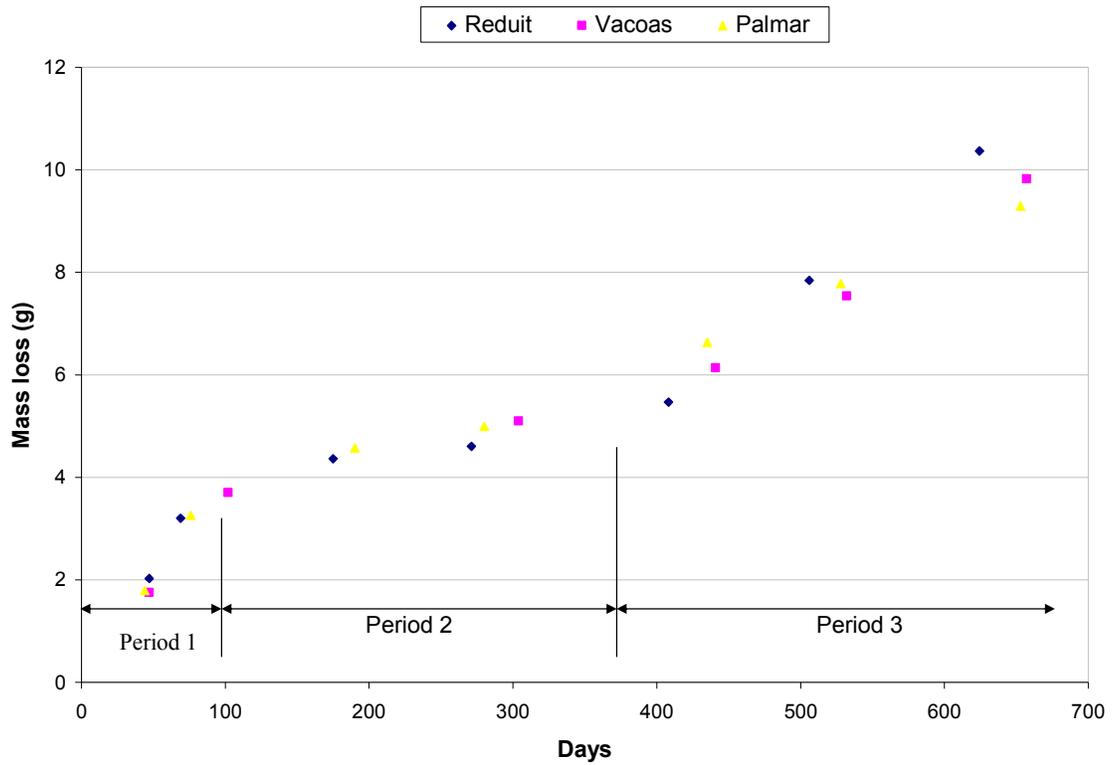


Fig. 3- Results of the weight loss method

DISCUSSION

It can be observed, from fig.3, that there are 3 main periods in the corrosion trend of the carbon steel samples.

In period 1, there is a high corrosion rate for the first 3 months. Moreover, the corrosion rate decreases at a very slow rate and the mass loss of the samples increases sharply. In this period, the rust layer provides very little protection to the metal.

Period 2 corresponds to the period of time during which the corrosion rate has decreased abruptly to a low value. This is characterized by a very low rate of decrease in the mass loss and it can last for about 9 months. In this period the rust layer has become thick enough to inhibit corrosion. The visual appearance of the

samples also confirms that in the 1st and 2nd periods there is the formation of a fairly adherent rust layer.

In period 3, the corrosion increases again, at a near-linear rate. The rust layer has become too much flaky, as observed by the physical appearance of the coupons, such that the rust layer was not adherent and protective and it has become very porous. This leads to shedding of the rust from the metal surface exposing fresh metal for further rusting. It also explains the fact that the corrosion rate increases again in the period 3.

This behaviour of mild steel, however, cannot be attributed to weather parameters, because the specimens were exposed for 600 days and no periodic variation was observed in the 1 year interval.

In order to obtain an insight into the corrosivity of the Mauritian atmosphere, the average corrosion rate over a yearly exposure was determined. The mass loss was obtained from fig. 3 and the corrosion rate was determined from equation (1). The results are shown in Table 4.

Site	Corrosion rate	
	(g m ⁻² /year)	(µm/year)
Palmar	183	24.3
Reduit	151	20.1
Vacoas	170	22.6

Table 4 – Corrosion rate of mild steel coupons after 1 year exposure

It gives very logical results; Palmar being a marine site has the highest corrosion rate. However, when this situation is analysed for the whole period during which the coupons were exposed it is found that in the first and second periods, the corrosion rates of the coupons at the 3 sites is nearly equal, as shown in fig. 3. It is in the third period that a perceivable difference could be observed. It was found that corrosion rate of the coupons exposed at Reduit was the lowest. Corrosion rate was the highest for those exposed at Palmar, while for the ones exposed at Vacoas it was between Reduit and Palmar values.

CONCLUSION

From the results obtained in Table 4, the corrosivity of the atmosphere can be determined by comparing with Table 5, obtained from ISO 9223 (1992).

From the table, it can be concluded that Reduit, Vacoas, and Palmar fall into category C₂. C₂ refers to environments which have moderate corrosivity. Therefore, apart from Port Louis, which consists of a marine industrial region, and regions very near to the shores (less than about 500 m) of the coastal areas, the corrosivity of the atmospheres in Mauritius would most probably fall in category C₂.

Category	Corrosion rate(CR) of mild steel (g m ⁻² /year)
C ₁	CR ≤ 10
C ₂	10 < CR ≤ 200
C ₃	200 < CR ≤ 400
C ₄	400 < CR ≤ 650
C ₅	650 < CR

Table 5 – Corrosivity classification of the atmosphere

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