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Studies on Corrosion of Metals in Surat Urban Environment

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Corrosion rate of mild-steel, zinc and aluminium as well as the sulphation rate and atmospheric salinity rate have been determined in 1999-2000 under outdoor exposure at Surat representing urban atmosphere. Monthly corrosion rate of mild-steel, zinc and aluminium vary from 270 to 1050 (47 to 182 µm/y), 17 to 59 (3 to 10 µm/y) and 5 to 16 (2 to 7 µm/y) mg/dm^2 respectively; whereas yearly corrosion rate being 1196 to 3205 (17 to 46 µm/y), 41 to 115 (0.6 to 1.6 µm/y) and 27 to 52 (1 to 2 µm/y) mg/dm^2 for mild-steel, zinc and aluminium, respectively. A sulphation rate was measured and was found in the range of 13 to 29 mg.SO_3/dm^2/month. Atmospheric corrosion rate of mild-steel indicates a close correlation with rainfall (r = 0.86) and number of rainy days (r = 0.88).

Key Words: Atmospheric corrosion, Surat urban area, Mild-steel, Zinc, Aluminium.

INTRODUCTION

Atmospheric corrosion is the most wide-spread form of metal deterioration which affects man-made metallic structure, from the most basic community to the most sophisticated one. Atmospheric corrosion has the ability to influence a nation's economic health. The atmospheric corrosion processes have been studied in many places around the world[1].

Urban atmosphere having pollution from domestic fuel consumption, exhaust of motor vehicles, *etc.*, resulting mainly in an increase in sulphur dioxide and/or sulphuric acid. Atmospheric corrosion of metals occurs through electrochemical mechanism. Combined effect of film formation and film-breakdown is responsible for accelerated atmospheric corrosion of metals in polluted atmosphere. Protective film formation occurs mainly due to oxidation rate laws for interpreting corrosion data and the contribution of film growth and dissolution to corrosion loss has also been reported[2].

The most important climatic factors on the corrosion process are the relative humidity, sunshine hours, temperature of the air and the metal surface, wind velocity, duration and frequency of the rain, dew and fog. The latter is related to the layer formation, which is influenced by the relative humidity[3,4]. Sulphur compounds and chlorides ions are the most common and important atmospheric corrosion agents, as has been reported by different authors all over the world[5-8].

In UK, USA and other European countries, the corrosivity of various sites has been systematically studied[9]. In India, data regarding the corrosivity of atmosphere at Patan[10], Ahmedabad[11], Baroda[12], Surat[13], Mumbai[14] and Kolkata[15] are available. The present study was undertaken at Surat city, an urban area of South Gujarat.

EXPERIMENTAL

The chemical composition of the metals are given below: (a) Mild steel: C (0.5 % max), Mn (0.5 % max), S and P (0.05 % max), Fe - rest. (b) Zinc: 98.5 % purity, Pb (0.03 % max), Cd (0.02 % max) and Fe (0.01% max). (c) Aluminium: commercial, soft temper.

Specimen size of all metals were kept 12.5 cm × 7.5 cm × 0.16 cm. Special care should be taken that plates were electrically insulated from surrounding metallic stand. The frame was placed in parallel in fully exposed condition on the ground level making an angle of 45° towards the horizontal plane. Two types of time duration monthly and yearly are considered for the determination of corrosion rate. All tests were carried in duplicate and mean of the two values were taken. After exposure period, test plates were wrapped in plastic bags and brought to the laboratory for cleaning. Hudson used Clark's solution[16,17] to remove the rust from mild steel which is prepared by dissolving 2 % Sb_2O_3 (antimony oxide) and 5 % $SnCl_2$ (stannous chloride) in concentration HCl (100 mL) at room temperature with constant stirring for about 15-20 min. Zinc plates were derusted by solution made by dissolving 10 % CrO_3 and about 0.2 g of $BaCO_3$ in distilled water[18] at 298 K for *ca.* 2 min. Corrosion product on aluminium plates were removed by using a solution of conc. HNO_3 containing CrO_3 (chromic acid 50 g/L) at room temperature[19] for about 10 min.

Measurement of sulphation rate was done by candle method. The salinity content (mg NaCl/dm^2/month) in the air was assessed by adopting the principle as that of the wet-candle method described by Ambler and Bain[20].

RESULTS AND DISCUSSION

Meteorological parameters: Monthly variation in temperature was observed. The average maximum and minimum temperature was noted as 307 and 296 K, respectively (Fig. 2). The data of rainfall (mm) and number of rainfall of the year 1999 and 2000 was mentioned in Fig. 1. Total annual rainfall was measured as 954.2 mm in 1999 and 785.8 mm in the year 2000. The minimum and maximum relative humidity (R.H.) were mentioned in Fig. 2. A sulphation rate measured was ranging from 13 to 29 mg SO_3/dm^2/month (Fig. 3). Atmospheric salinity rate measured was ranging from 14.4 to 35.0 mg NaCl/dm^2/month.

The relative humidity of the area was found to be higher than the critical relative humidity value (70 %), whereas sulphation rate measured was ranging from 13 to 29 mg SO_3/dm^2/month (Fig. 3). A sulphation rate of 0.9 mg SO_3/dm^2/month is usually accepted as representative of clean air[21]. Sulphation rate of different locations

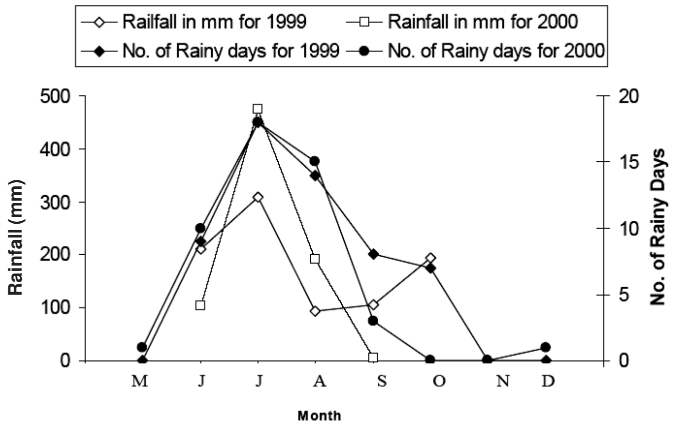

Fig. 1. Rainfall (mm) and number of rainy days

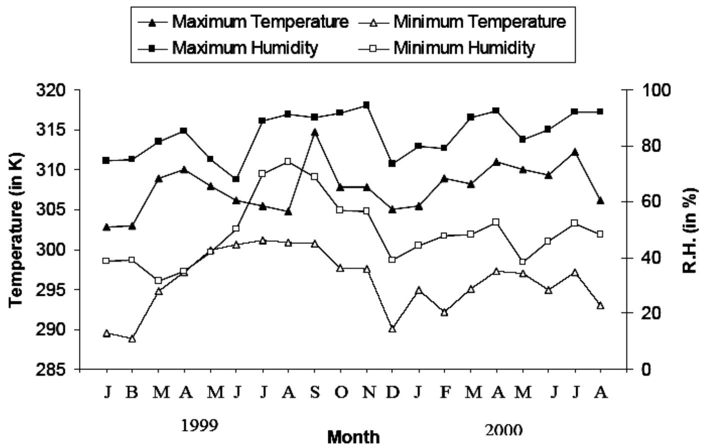

Fig. 2. Temperature (K) and relative humidity (%)

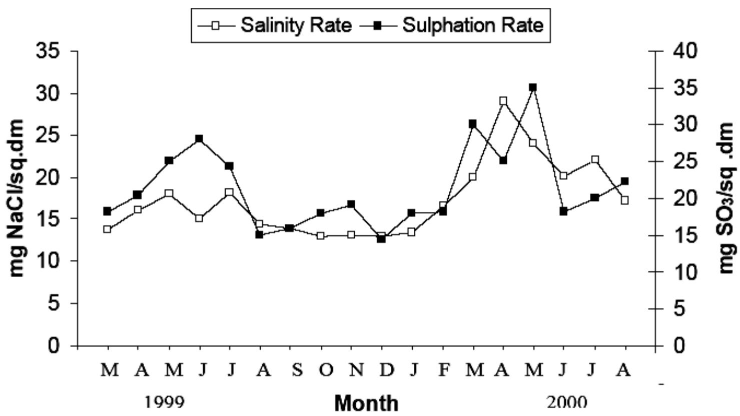

Fig. 3. Sulphation rate (mg SO_3/dm^2/month) and atmospheric salinity rate

are also available. A mean sulphation rate was measured 12.6 mg SO_3/dm^2/month at Delhi (urban)[22]. 4.0 to 10.5 mg SO_3/dm^2/month at Kolkata[15]. 2.0 mg SO_3/dm^2/month at Patan[10]. 3.0 to 40.0 mg SO_3/dm^2/month at Mumbai[14]. 7.5 to 82.2 mg SO_3/dm^2/month at Durban[23].

Atmospheric sanility rate was found to be in the range of 14.4 to 35.0 mg NaCl/dm^2/month (Fig. 3). Atmospheric salinity rate of different locations are also available. 5.0 to 32.0 mg NaCl/dm^2/month at Patan[10] and average 5.4 mg NaCl/dm^2/month at Mumbai[14].

Mild steel: Approximately 1.5 mm thick corrosion product was found deposited on a panel of 12 months exposure period. Corrosion rate of mild-steel varied from month to month and form season to season. The corrosion suffered by a mild-steel was mainly of a general type. Monthly corrosion rate of mild-steel was found in the average of 270 to 1050 mg/dm^2, whereas yearly corrosion rate was found in the range of 1196 to 3205 mg/dm^2 (Fig. 4). Average seasonal corrosion rate of mild-steel in rainy months (748 mg/dm^2) is *ca.* 1.5 times higher compared to the values obtained in hot months (469 mg/dm^2) (Fig. 7).

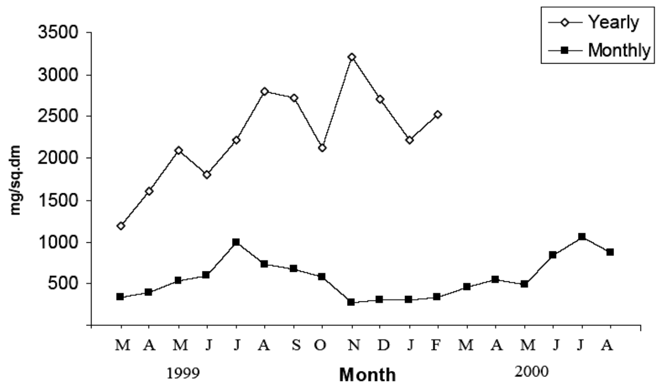

Fig. 4. Monthly and yearly corrosion rate of mild steel corrosion under outdoor exposure during different months

Higher corrosion rate in rainy months attributed to the corrosion product which is washed regularly by keeping fresh metal surface exposed to further corrosion. In rainy months, the metal surface is covered by a film of water and such films are capable of supporting electro-chemical corrosion process[24]. Lower corrosion in summer months (March to June) may be due to absence of such film formation. Panels exposed in winter months indicates (November to February) lower initial corrosion rate than the panels exposed in rainy months (July to October). This suggests that if protective film is formed on metal surface which can resist attack during subsequent exposure.

Monthly corrosion rate of mild-steel indicates a close correlation (a) (i) railfall (r = 0.86) and (ii) number of rainy days (r = 0.88), (b) a weak correlation with sulphation rate (r = 0.32), (c) positive correlation with minimum relative humidity (r = 0.52). These results are in agreement with those of Ahmedabad[11], Baroda[12], Surat[13] and Mumbai[14]. Monthly corrosion rate of mild-steel indicates a weak correlation with atmosphere sanility rate (r = 0.16). As in urban area the salinity was less.

X-Ray diffraction study of MS scrap material (12 month exposure period) in Fig. 5 indicates 10 peaks. Main phases are Lepidocrocipe (Y-FeOOH) and Y-Fe_2O_3.

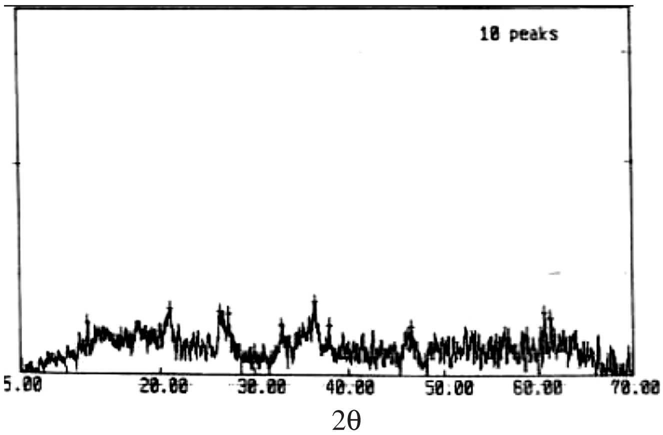

Fig. 5. XRD curve for mild steel scraped materials (exposure period of 12 months)

Zinc: Monthly corrosion rate of zinc was found in the range of 17 to 59 mg/dm^2, whereas yearly corrosion rate was found in the range of 41 to 115 mg/dm^2 (Fig. 6). Average seasonal corrosion rate was obtained in the rainy months (46 mg/dm^2) is higher compared to the values obtained in summer months (33 mg/dm^2) and in winter months (29.5 mg/dm^2) respectively (Fig. 7).

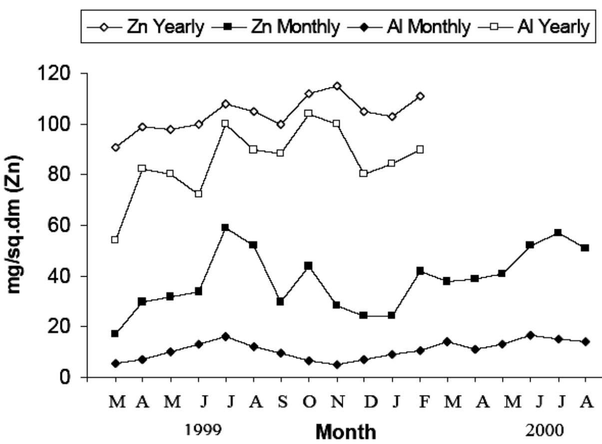

Fig. 6. Monthly and yearly corrosion rate of zinc and aluminum under outdoor exposures during various months

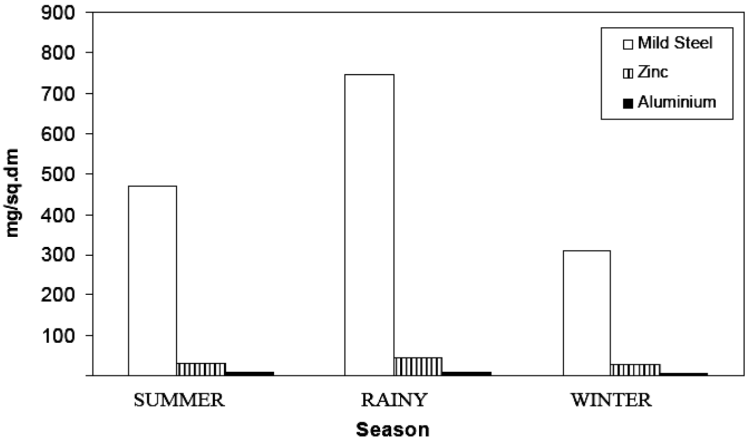

Fig. 7. Average Seasonal corrosion rate (in mg/dm^2) of different metals

Higher corrosion rate of zinc in rainy months may be due to the effect of rain. Monthly corrosion rate of zinc indicates a close correlation with (a) (i) rainfall (r = 0.79) and (ii) with number of rainy day (r = 0.84), (b) positive correction with minimum relative humidity (r = 0.51), (c) weak correlation with sulphation rate (r = 0.35) and (ii) atmospheric salinity rate (r = 0.32).

Aluminium: Monthly corrosion rate of aluminium was found in the range of 5 to 16 mg/dm^2, whereas yearly corrosion rate was found in the range of 27 to 52 mg/dm^2 (Fig. 5). Average seasonal corrosion rate was obtained in the months (11.0 mg/dm^2) is higher compared to the values obtained in summer months (8.9 mg/dm^2) and winter months (7.9 mg/dm^2), respectively (Fig. 6).

Monthly corrosion rate of aluminium indicates a close correlation with (a) (i) rainfall (r = 0.57) and with (ii) a number of rainy days (r = 0.63), (b) a weak correlation with minimum relative humidity (r = 0.28) and (c) (i) positive correlation with sulphation rate (r = 0.50) and (ii) salinity rate (r = 0.48).

No significant attack was observed on aluminium plates. Low corrosion rate of aluminium in outdoor exposure is attributed with the formation of a protective oxide film on the metal surface which might have offered protective to the metal from reaching with the surrounding environment.

Conclusion

(a) Monthly corrosion rate ratio of Mn:Zn is not constant and varies from a low of 8 to a high of 22, whereas yearly corrosion rate ratio of Mn:Zn varies from a low of 13 to a high of 28. (b) Monthly corrosion rate ratio of mild-steel:Al is not constant and varies from a low of 33 to a high of 90, whereas yearly corrosion rate ratio of mild-steel:Al varies from 39 to 68. (c) Zn:Al corrosion rate ratio (monthly) varies from a low of 3 to a high 7, whereas yearly corrosion rate ratio from a low of 2 to a high of 3.

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