Corrosion study of metals in an urban atmosphere

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ABSTRACT

Corrosion rate of mild-steel (MS), zinc and aluminium as well as the sulphonation rate was determined during 2005-2007 under outdoor exposure in an Urban atmosphere at Valsad (Dist. Valsad) situated in South Gujarat, India. Monthly corrosion rate vary from 77 to 824, 19 to 109 and 1.5 to 17.8 mg/sq.dm correspond to MS, zinc and aluminium respectively, whereas the yearly corrosion rate vary from 2575 to 3667, 181 to 459 and 8.3 to 37.2 mg/sq.dm for mild-steel, zinc and aluminium respectively. Corrosion rate of these three metals was found more in rainy seasons than the rate of winter and summer season. There is a considerable loss of corrosion rate during exposure for one year of mild steel. Monthly corrosion rate of mild steel indicate a close correlation with rainfall (r = 0.65) and positive correlation with sulphation rate (r = 0.54). No correlation appeared to exist between temperature and corrosion rate of mild steel, zinc and aluminium.

Key words: Corrosion, urban atmosphere, mild-steel, zinc and aluminium.

INTRODUCTION

Urban atmosphere is similar to rural atmosphere where there is little industrial activity, characterized by pollution composed mainly of SO₅ and NO₅ variety, from motor vehicles and domestic fuel emissions which, with the addition of dew or fog. Generate a highly corrosive wet acid film on exposed surfaces (deposition rate of SO₂ higher than 15 mg m⁻² day⁻¹) and that of NaCl lower than this value. In developed countries, the national annual cost of corrosion varies 1% to 3.5% of the Gross National Product (GNP) ¹.

MATERIAL AND METHODS

Test plates of mild steel, zinc and aluminium have the following chemical composition:

**Mild-steel**

- C (0.038%), Mn (0.265%),
- S (0.015%), Cr (0.021%), Mn (0.006%), Al (0.033%), Ni (0.0115%), Fe-rest.

**Zinc**

- 99.39% purity, Pb (0.03% Max), Cd (0.02% Max.), Fe (0.01% Max.)

**Aluminum**

- 99.09 % purity and Si (0.53%).

Panels of test are individually mounted on a wooden rack. Special care should be taken that they were electrically insulated from surrounding metallic stand. The frame was placed in parallel outdoor fully exposed condition on the ground level making an angle of 45° towards the horizontal plane. Two types of time duration viz., monthly and yearly were considered for calculation of corrosion rate with time. All tests were carried out 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. Different cleaning solutions are to clean different metals. Hudson used Clark’s solution²-³ to remove rust from mild-steel made by 2% Sb₂O₃ (antimony Oxide),
5% \( \text{SnCl}_2 \) (stannous chloride) in concentrated HCl (100 ml) at room temperature with constant stirring about 15-20 minutes. zinc plates are derusted by 10% \( \text{CrO}_3 \) and about 0.2 gm \( \text{BaCO}_3 \) in distilled water (100 mL) at 25°C for about 2 minutes. Corrosion products on aluminum plates were removed by using the solution of concentrated \( \text{HNO}_3 \) containing \( \text{CrO}_3 \) (chromic acid, 50 mg/L) at a room temperature for about 10 minutes.

Sulphur dioxide is considered as a major air pollutant causing the corrosion of most metals. The lead peroxide method used for monitoring \( \text{SO}_2 \) content in air\(^6\). Essentially, the technique depends upon the measurement of sulphation caused by gaseous \( \text{SO}_2 \) on an exposed lead peroxide (\( \text{PbO}_2 \)) paste. Lead dioxide in paste form was painted as a thin layer on a gauze cylinder (candle method) and allowed to dry. This \( \text{PbO}_2 \) reacts with \( \text{SO}_2 \) of air to form \( \text{PbSO}_4 \). After exposure, the lead peroxide layer was removed and the sulphate content was determined by a gravimetric method. These candles were exposed at the ground level on a rack with the panels.

RESULTS AND DISCUSSION

Meteorological and pollution data

The average maximum and minimum temperature was noted as 310 K and 291 K corresponds to the year 2005-2007 respectively. There is a considerable variation in temperature during all months. The data of rainfall (in mm) and number of rainy days of the year 2006 are mentioned in Fig.1. Relative humidity (minimum and maximum) in percentage is shown in Fig.2. The relative humidity at urban station was found to be higher than the critical relative humidity value (70%).
Sulphation rate (in mg SO$_2$/sq.dm/month) of the study area is shown in Fig. 3. The prominent direction of wind is South-West (SW) during summer and monsoon season, with comparatively higher speed (9.0 km/hr). A sulphation rate was measured at Valsad urban atmosphere, shows an appreciable value ranging from 10.2 to 20.2 mg SO$_2$/sq.dm/month Fig. 3. A mean sulphation rate was measured 34.6 mg/m$^2$.d SO$_2$ (average 6 months) at Cuba$^9$, 0.3 to 9.0 mg/SO$_2$/m$^2$.d$^{-1}$ of 22 urban atmospheric in the Ibero-American region$^9$. In Urban atmosphere, however the SO$_2$ deposition rate was measured between 10 to 100 mg m$^{-2}$d$^{-1}$.$^{10}$

Mild-Steel (MS)

The corrosion suffered by MS was mainly of a general type. Approximately 1.5 mm thick corrosion product was found deposited on a panel of a twelve months exposure period. Corrosion rate of MS varied from month to month and from season to season.

Monthly corrosion rate of MS was found in the range of 77 to 824 mg/sq.dm/month. These values are higher than that measured 46 to 324 mg/sq.dm at Kanpur$^{11}$, 20 to 286 mg/sq.dm at Jodhpur$^{12}$ and 83 to 635 mg/sq.dm at Tezpur$^{13}$. The yearly corrosion rate was found in the range of 2575 to 3667 mg/sq.dm Fig. 4. These values are higher than the value of 312 to 529 mg/sq.dm at Jodhpur$^{12}$ and 1473 to 3409 mg/sq.dm at Tezpur$^{13}$.

Monthly corrosion rate of MS indicates a close correlation with rainfall ($r = 0.65$), positive correlation with sulphation rate ($r = 0.54$) and weak correlation with minimum relative humidity ($r = 0.19$). No correlation appeared to exist between temperature and corrosion rate of MS.

Corrosion rate of MS in rainy months is six to two times higher compared to the values obtained in winter months and the summer months. Panels exposed in winter months (November to
February) indicate lower initial corrosion loss than the panels exposed to rainy months (June to September). This suggests that a protective film is formed on metal surface which can resist attack during subsequent exposure. Whereas higher corrosion rate in rainy months are attributed to the corrosion product which is washed regularly by rain keeping fresh metal surface exposed to further corrosion. Lower corrosion rate in summer months (March to May) are due to the removal of gaseous and particulate pollutants from the atmosphere by higher wind velocity.

Zinc

The corrosion suffered by a zinc plate is of the general type (uniform attack). Corrosion rate of zinc varied from month to month. Monthly corrosion rate of zinc varied from 19 to 109 mg/sq.dm. This value are higher than the value of 2.1 to 40 mg/sq.dm at Culcatta\textsuperscript{14}, 12 to 40 mg/sq.dm at Bombay\textsuperscript{15}, 10.7 to 42.5 mg/sq.dm at Baroda\textsuperscript{16}, 17 to 59 mg/sq.dm at Surat\textsuperscript{17}. Yearly corrosion rate of zinc at an urban atmosphere was varied from 181 to 459 mg/sq.dm (Fig.5). This value is higher than the value of 41 to 115 mg/sq.dm at Surat\textsuperscript{17}.

Average corrosion rate was obtained in the rainy months (287 mg/sq.dm) is higher compared to the values obtained in summer months (159 mg/sq.dm) and winter months (94 mg/sq.dm)

Monthly corrosion rate of zinc indicates a close correlation with rainfall ($r = 0.69$) and with the number of rainy days ($r = 0.64$). Monthly corrosion rate of MS has a close correlation with minimum relative humidity ($r = 0.64$) and weak correlation with sulphation rate ($r = 0.31$). No correlation appeared to exist between temperature and corrosion rate of Zn.

Aluminum

No significant attack was observed on aluminum panels. The corrosion rate of aluminum was found very low compared to MS and zinc.

Monthly corrosion rate for aluminum was
found in the range of 1.5 to 17.8 mg/sq.dm. This value is higher than the value of 5.0 to 16.0 mg/sq.dm at Surat\textsuperscript{17}. Yearly corrosion rate of aluminum was found in the range of 8.3 to 37.2 mg/sq.dm (Fig. 6). This value is higher than the value of 25 to 37 mg/sq.dm at Baroda\textsuperscript{16}.

Average seasonal corrosion rate of aluminum was obtained in the rainy months (42.8 mg/sq.dm) is higher compared to the values obtained in winter months (9.7 mg/sq.dm) and summer months (12.5 mg/sq.dm). Low corrosion rate of aluminum in outdoor exposure is attributed with the formation of a more protective oxide film on the metal surface which might have offered protection to the metal from reacting with the surrounding environment.

**CONCLUSION**

Monthly corrosion rate of MS was 2 to 27 times higher compared to zinc. Similar results obtained at different cities are as follows: 12 at Bombay\textsuperscript{15} and 6 to 41 at Baroda\textsuperscript{16}. The yearly corrosion rate of MS was 6 to 17 times higher than zinc.

Monthly corrosion rate of MS at an urban atmosphere was 33 to 276 times higher compared to aluminium. Similar results obtained at 27 to 200 times higher at Surat\textsuperscript{17}; whereas Yearly corrosion rate ratio of MS:Al varies from 69 to 398.

Monthly corrosion rate of Zn at an urban atmosphere was 4 to 25 times higher compared to aluminium. Similar results obtained at Surat\textsuperscript{17} (7 to 15 times), whereas yearly corrosion rate of Zn was 11 to 42 times higher compared to aluminium.

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