Material Science Research India Vol. **6**(1), 201-206 (2009)

Progressive corrosion study of mild steel, zinc and aluminium in Vapi industrial environment

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(Received: February 12, 2008; Accepted: April 04, 2008)

ABSTRACT

Corrosion rate (Progressive) of mild-steel (MS), zinc and aluminum have been determined under outdoor conditions of exposure at Vapi (South Gujarat) representing an industrial environment. Mild steel (MS), zinc and aluminium plates exposed during November 2005 indicates corrosion rate of 791, 131 and 2.4 mg/sq.dm for one month exposure period and 12731, 952 and 29.8 mg/sq.dm for mild steel, zinc and aluminium respectively for twelve months exposure period. Mild steel panels exposed vertically suffer less corrosion than those exposed at an angle of 45°. The resistivity towards the environment was in the increasing order of mild steel < zinc < aluminium. Corrosion rate of these three metals was found more in rainy seasons than the rate of winter and summer season.

Keywords: Atmospheric corrosion, Vapi industrial environment, mild-steel, zinc and aluminium.

INTRODUCTION

Atmospheric corrosion is a very important practical process that causes deterioration of structures, machines and materials placed at external environments[1-4]. It constitutes a relatively complicated electrochemical process that consists of a metal and its corrosion products, an electrolyte (a thin wet film on surface) and the atmosphere (more or less polluted). At normal temperature dry air does not have a corroding effect on metals[5-6]. However, in presence of moisture in the atmosphere, corrosion takes places and it is governed by the principle of critical humidity developed as described in[7] and supported in[8-9].

D. D. N. Singh *et al.,* reported[10] corrosion rate of steel exposed for two years at different locations of India found that, Chennai (industrial) 19.0 µm/y, Jamshedpur (industrial) 12.9 µm/y. Larrabee and Ellis[11] reported the yearly corrosion rate of steel plate (4×6 inch) exposed in various atmospheres at different places of North America as follows: 6.52 mil/yr at New York (industrial atmosphere) and 3.30 mil/yr at Kearny (industrial atmosphere). Schikorr[12] exposed pure zinc plate for one year in various atmospheres and measured a corrosion rate as follows: 0.73 mil/yr at Bitterfeld and 0.19 to 0.24 mil/yr at Hamburg. Mattson[13] reported the corrosion rate of aluminium in the range of 1 to 3 $g.m^{-2}y^{-1}$ in industrial atmosphere. In India, data regarding the relative corrosivity of atmospheres at Baroda[14] (industrial), Calcutta[15] (industrial), Jodhpur[16], Kanpur[17] (semi-industrial), Surat[18] (industrial) and Ankleshwar[19] (industrial) are available.

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%), P (0.011%), Si (0.012%), Cr (0.021%), Mn (0.006%), Al (0.033%), Cu (0.011%), Sn (0.002%), Ni (0.0115%) and Fe-rest.

Zinc

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

Aluminum

99.09 % purity and Si (0.53%).

Test plates 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. Another set of mild steel (MS) panels were fully exposed vertically.

Twenty four specimens of each metal (mild steel, zinc and aluminium) were exposed at the same time (i.e. during November 2005). After completion of exposed period, the progressive weight loss of metal was determined. So, we get successive corrosion rates for one month, two months, three months upto twelve months. Similarly, another set was exposed during March 2006.

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 solution[20-21] to remove rust from mild-steel made by 2% Sb_2O_3 (antimony Oxide), 5% $SnCl_2$ (stannous chloride) in concentrated HCl (100 ml) at room temperature with constant stirring about 15-20 minutes. Zinc plates are derusted by 10% CrO_3 and about 0.2 gm $BaCO_3$ in distilled water (100 ml) at 25°C for about 2 minutes[22]**.**Corrosion products on aluminium plates were removed by using the solution of concentrated HNO_3 containing CrO_3 (chromic acid, 50 mg/lit) at a room temperature for about 10 minutes[23]**.**

RESULTS AND DISCUSSION

Meteorological and pollution data

Generally, the rain starts in June and continuous up to September. Total annual rainfall was found 1965 mm in 2006 and 2198 mm in 2007. March, April, May and June are the hot months of the year, whereas December, January and February are considered as cold months. Average maximum and minimum temperatures are about 307 K and 290 K respectively.

Relative humidity is higher than the critical humidity value (70%) for corrosion of iron[24] for six months in a year 2006 and in 2007 (Fig.1). The level of Sulphur dioxide (SO_2), oxides of nitrogen (NO_x) varied from month to month. The concentration of SO_2 was found to be in the range of 19 to 30 µg/m^{3}and NO_x was found in the range of 26 to 40 µg/m^3 in the year 2006 and 2007 (Fig.2) (pollution data supplied by GPCB). Federal primary annual average standards for SO_2 is 80 µg/m^3 (0.03 ppm) for NO_x is 100 µg/m^3 (0.05 ppm)[25].

Mild Steel (MS)

MS plates exposed in winter months indicates that the corrosion rate increases up to

Table 1: Positional effect on corrosion rate of mild-steel at Industrial station

Month	Corrosion rate (mg/sq.dm)	
2006	Vertical	At 45°
January	678	716
February	688	646
March	846	1007
April	810	819
May	924	1249
June	1174	1371
July	1605	1692
August	2199	2010
September	1707	1524
October	1072	1108
November	690	767
December	792	809

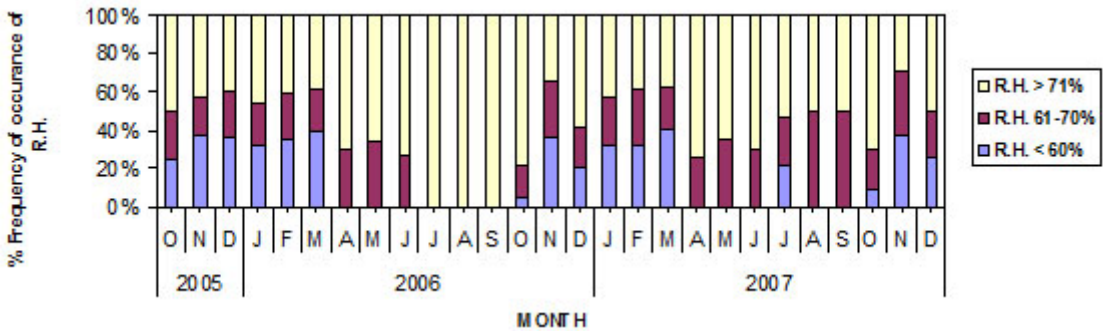

Fig. 1: Percentage of occurrence of relative humidity (R.H.) at Industrial environment

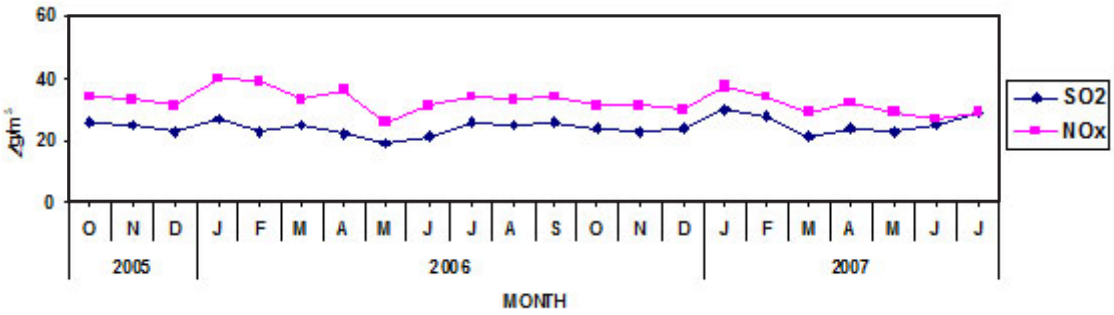

Fig. 2: Sulphur dioxide (SO_2) and oxide of nitrogen (NO_x) content at Industrial environment

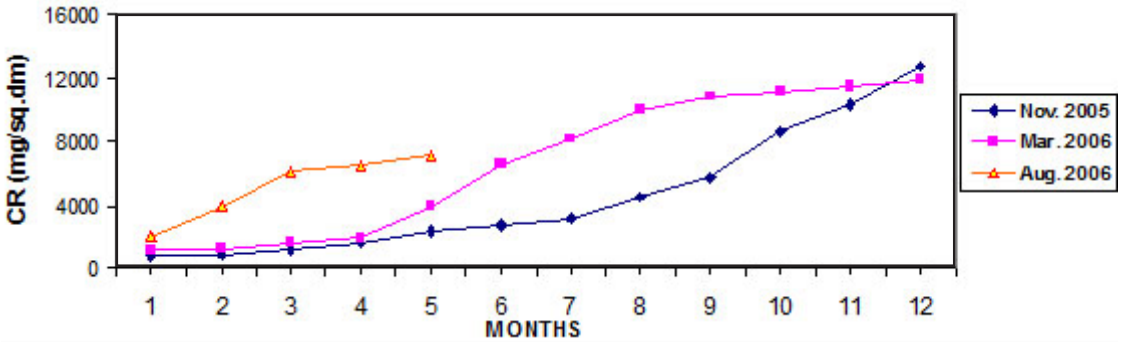

Fig. 3: Progressive corrosion rate (CR) of mild steel under outdoor exposure at Industrial environment

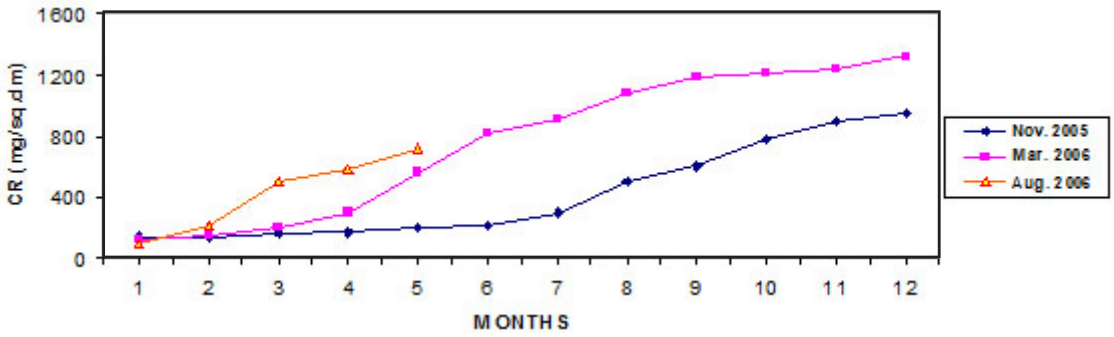

Fig. 4: Progressive corrosion rate (CR) of zinc under outdoor exposure at Industrial environment

seven months (i.e. up to may-2006) and then it increased rapidly for another five months (i.e. from June-2006 to October-2006).The corrosion rate of mild steel indicates 791 mg/sq.dm for one month and 12731 mg/sq.dm for Twelve months exposure period.

Similarly, plates exposed in summer months (i.e. from March-2006) shows corrosion rate increase slowly for eight months (i.e. from March-2006 to October-2006), then it again increase rapidly for further four months (i.e. from November-2006 to Febuary-2007). The plates exposed in rainy season (i.e. August-2006) indicates initially higher corrosion rate than the plates exposed in winter season which is attributed to the corrosion product which is washed regularly by rain keeping fresh metal surface exposed to further corrosion (Fig.-3).

Positional effect

The results indicate that the panels exposed vertically suffer less corrosion than those exposed at an angle of 45° (Table-1).

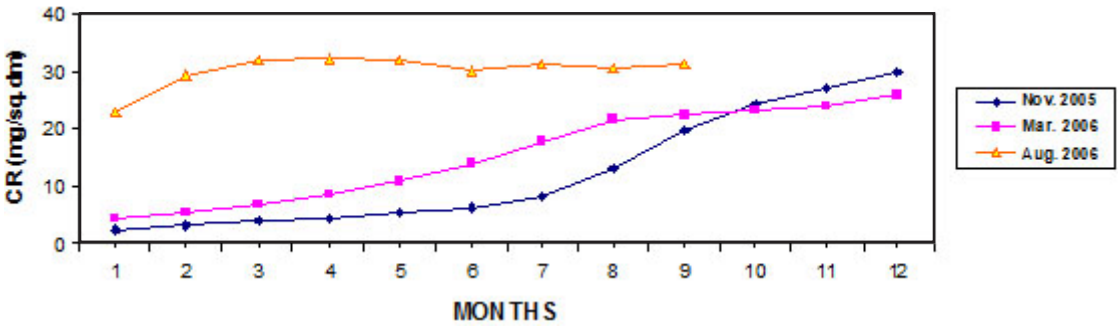

Fig. 5: Progressive corrosion rate (CR) of aluminium under outdoor exposure at Industrial environment

Zinc

The observation of first set of zinc metals exposed in winter month (November-2005) indicates that the corrosion rate increases up to seven months (i.e. up to May-2006) and then it increased rapidly for another five months (i.e. from June-2006 to October-2006). The corrosion rate of zinc indicates 137 mg/sq.dm for one month and 952 mg/sq.dm for Twelve months exposure period. Another set exposed in summer month (March-2006) indicates corrosion rate increases for eight months (i.e. from March-2006 to October-2006), then it steadily increase for further four months (i.e. from November-2006 to Febuary-2007). The plates exposed in rainy season (i.e. August-2006) indicates initially higher corrosion rate than the plates exposed in winter season which is attributed to the corrosion product which is washed regularly by rain keeping fresh metal surface exposed to further corrosion (Fig.-4).

Aluminium

Aluminum plates exposed in winter months (i.e. November-2005) indicates that the slow increases in corrosion rate up to six months (i.e. from November-2005 to April-2006) then it rapidly increases for another six months. The corrosion rate of aluminium indicates 2.4 mg/sq.dm for one month and 29.8 mg/sq.dm for Twelve months exposure period.

Another set of plates were exposed in summer months (i.e. from March-2006). The corrosion rate increases for eight months (i.e. from March-2006 to October-2006), then it steadily increase for further four months (i.e. from November-2006 to Febuary-2007). The plates exposed in rainy season (i.e. August-2006) indicates initially higher corrosion rate than the plates exposed in winter season which is attributed to the corrosion product which is washed regularly by rain keeping fresh metal surface exposed to further corrosion (Fig.-5).

CONCLUSION

The resistivity towards the environment was in the increasing order of mild steel < zinc < aluminium. So, we can say that aluminium or aluminium coated sheets would give better performance compared to mild steel or zinc.

ACKNOWLEDGEMENTS

The authors are thankful to Department of Chemistry, Navyug Science College, Surat and C. U. Shah Science College, Ahmedabad for providing laboratory facilities.

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