Influence of Environmental Variables on Corrosion of Carbon Steel

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The influence of environmental variables on corrosion of carbon steel in the Cochin Harbour waters was investigated. The coefficients of correlation between days of exposure and fouling, corrosion rate were worked out and polynominals for the same were determined. The coefficient of correlation between days of exposure and corrosion rate was significant at 0.1% level.

Marine biofouling and marine corrosion are economically important problems confronting all the maritime nations of the world. Failures of structures in the field have led to great emphasis on extensive studies on corrosion behaviour and the designer's responsibility to ascertain the influence of environmental factors likely to be faced in the operating environments. Because of the versatility, free availability and economy, steel continues to be the basic structural material for ocean engineering structures. The corrosion and fouling behaviour of carbon steel, though studied extensively (De *et al.*, 1968,1977, Forgeson *et al.*, 1958), the environmental variables influencing its service life have not been studied in detail. Pranesh and Sudarson (1981) using a statistical technique, studied the influence of time factor, oxygen, temperature and velocity on the corrosion rate of marine steel and galvanised steel in the marine environment. Microfouling and corrosion are simultaneous processes occurring on the surface of the metal immediately upon immersion in the seawater. The fouling in turn affects the corrosion process, predominently by shielding the metal from the environment and providing a conducive environment for crevice corrosion attack. Predicting the life of carbon steel structures, based on understanding of environmental effect on corrosion, has become an area of considerable importance in recent days. Realising the economic importance of the problem, the environmental factors like fouling intensity, water temperature, salinity, dissolved oxygen and hydrogen ion concentration are investigated in detail.

Materials and Methods

The metals and alloys for use in this work were cut to 10 X 7.5cm from rolled sheets of carbon steel. The metal plates were cleaned and weighed as recommended by Champion (1952) and were fitted on mild steel racks of Carnegie Illinois Steel Corporation design (LaQue., 1948) where the galvanic action between the specimens or

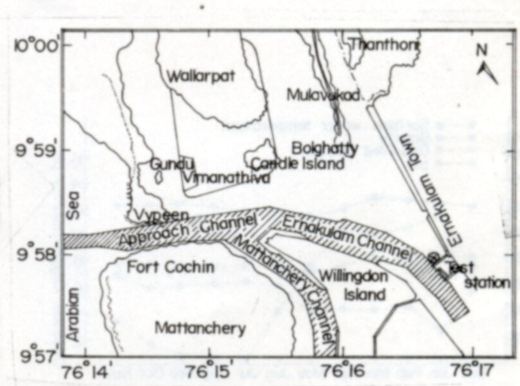

Fig. 1. Cochin harbour showing the test station

between the specimen and the rack was prevented. The panels were kept submerged at one metre level from the low water level at the Oil Tanker Berth in Cochin Harbour (Fig. 1). The Cochin Harbour (Lat 9° 58′ N, Long 76° 16′E), a natural harbour situated at the south-west coast of India, is an important centre of commercial shipping and fishing activities and forms an ideal location for studies on marine corrosion and marine fouling and its control. The panels in triplicate were retrieved at 30 days intervals and quantitative assessment of marine biofouling was made. The plates were cleaned as described in ASTM (1974) and the rate of corrosion was determined. The hydrographic parameters were determined as described in Strickland & Parsons (1968).

Results and Discussion

Data concerning the hydrographical parameters of the test site are given in Fig.2. The corrosion rates and the accumulated wet mass of the fouling complex on carbon steel as a function of the period of exposure are presented in Fig.3. Graph representing the age in days on X -axis, the height in mm on the Y-axis and the number settled per m^2 area on the Z-axis, of the barnacles, the most predominent fouling organism, is given in Fig.4.

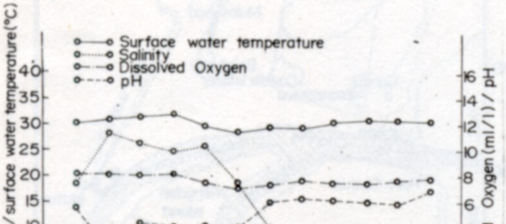

Fig. 2. Hydrographic data

The corrosion rate of carbon steel was high in the initial period of exposure.It gradually declined and attained near constant rate in a period of 270 days as can

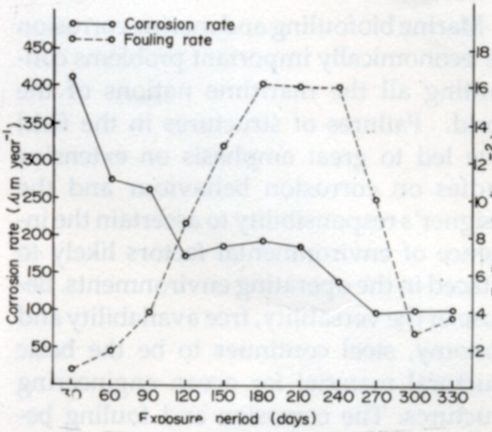

Fig. 3. Corrosion rates of fouled carbon steel

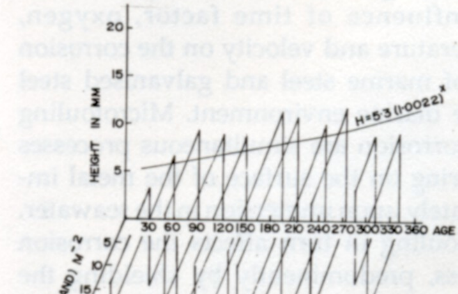

Fig. 4. Growth of barnacles on freely corroding carbon steel

be seen in Fig.3. The near constant rate of corrosion is controlled by factors like salinity, dissolved oxygen, temperature and biofouling. In Cochin Harbour there is progressive dilution of sea water from May to July owing to precipitation and river discharge during south-west monsoon and low saline conditions tend to persist during August to October due to influence of north-east monsoon. The corrosion rate was also seen to depend on the decrease in salinity and increase in dissolved oxygen during monsoon period. Thereafter the corrosion rate decreased and from 270 days onwards uniform rate of corrosion 101 micron year $^{-1}$ was noticed. The corrosion rate of mild steel at Bombay and Cochin (De *et al.*,1968) and Vishakhapatnam (De *et al.*, 1977) are 200, 176 and 165 micron year $^{-1}$ respectively. In Panama canal, a corrosion rate of 150 micron year^{-1} for unalloyed carbon steel was reported by Forgeson *et al.* (1960). Pillai & Ravindran (1983) reported a corrosion rate of 234 micron year^{-1} for carbon steel under fouling free condition in Cochin Harbour.

The effect of fouling on the metallic surface is evident from the slopping trend of the corrosion rate curve. Pitting was absent on the panels during the period under observation. The fouling of carbon steel was seen sloughed off periodically along with corrosion products, exposing fresh surface of the metal for attack. The comparable corrosion rate of carbon steel in tropical and temperate waters is in conformity with the reasoning that in tropical waters fouling is massive and restricts access of oxygen and in temperate waters dissolved oxygen is more and fouling is less. These factors are interrelated (Schumacher,1979).The quantum of fouling on carbon steel in the present study as a function of period of exposure is shown in Fig.3. The fouling complex mainly consisted of barnacles, hydroids, *Modiolus* sp. and tube worms.. The major share of the weight was from barnacles.

The present study showed a period of increased and progressive settlement of fouling organisms on the surface, followed by a period of reduced activity and absence of fresh settlement and further a period of sloughing off of fouling organisms and fresh settlement of larval forms (Fig.3). The maximum fouling loads observed in the study was 16 kg m^{-2} on carbon steel. Periodical sloughing off of solid corrosion products from carbon steel occurred much before attaining the maximum fouling load. The fouling load was mainly related to salinity changes and did not appear to depend upon small changes of temperature of the Cochin Harbour area. The effect of salinity on the rate of settlement of fouling organisms was reported by workers like Nair (1967), Ehrler & Lyke (1980) and Kinne (1963)

The coefficients of correlation between days and fouling and corrosion were worked out and presented in Table 1.

Table 1. *The coefficient of correlation between days and parameters like fouling and corrosion.*

	r	m	c	n
Foulers	0.2955	0.0172	3.9210	11
Corrosion	-0.8990^{d}	-0.8415	346.2480	11

d = significant 0.1% level

The coefficient of correlation between days and corrosion rate was significant at 0.1% level. Polynomials were worked out and shown below:

$$Y_1 = 9.85944 + 8.39650X - 0.62354X^2 - 0.44250X^3 + 0.0249X^4$$

$$Y_2 = 183.24259 - 18.48202X - 3.66146X^2 - 0.76145X^3 + 0.27050X^4$$

where Y_1 represents quantity of fouling, Y_2 rate of corrosion and X the number of days measured from mean values.

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