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Near Shore Environment and Its Corrosiveness Towards Steel Pipelines

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***Abstract*— Seabed sediment is an important environment that has significant effect on pipelines buried under it. Hereby, study on corrosion rate of actual steel pipelines has been conducted to highlight the importance of near shore environment as an aggressive environment towards steel structures. Coupons made of X70 steel pipelines have been considered for weight lost determination in order to calculate the corrosion rate at both near shore and offshore areas. The results show that the corrosion rate of coupons buried at near shore area was higher than the coupons at offshore. Conclusively near shore environment has shown a significant influence on corrosion of steel pipelines.**

***Keywords*—Seabed Sediment; Near Shore Environment; X70 Steel Pipelines; Weight Loss; Corrosion**

I. Introduction

Steel corrosion exposed to marine surrounding may results in monetary loss, decrease of productivity and loss of human life if there is an incident due to structure failure. The exposure of pipeline in various type of environment has moved numerous researchers [1, 2, 3, 4] focusing on corrosion study in order to take preventive measure which can prolong the serviceability of the pipeline.

However, little was the studies on the corrosion of pipeline in seabed sediment located near shore in terms of the effects of environmental factors towards corrosion behavior of X70 steel. Success in identifying elements contributing towards the progressing corrosion of pipeline in near shore environment would be helpful for the development of better protection and monitoring system of this steel structure in future. Therefore, the objective of this study is to determine and compare the corrosion rate of steel exposed to near shore environment and offshore area. Weight loss technique has been used in determining the corrosion rate and the behavior of the steel specimens in each environment is also observed.

II. Experimental Programme

On overall the experimental programme comprises of material selection and preparation, site selection and experimental procedures

A. Material Preparation

All the specimens were cut into smaller size coupon from actual X70 steel pipeline. Standard procedures [5] have been followed for preparing bare, solid metal specimens for testing and for removing corrosion products. According to the standard, the size and the shape of specimens will vary with the purpose, nature of the materials and the apparatus used. However a large surface to mass ration and small ration of edge area to total area are desirable. The coupons with dimensions of 60x40x5 mm have undergone process of milling and grinding. The coupons then were washed thoroughly by acetone, hot air dry and stored in desiccator till the time to be used. At one side of each coupon, small holes made to tie the coupons to string in order to keep them at the same position and to ease finding them at retrieval time. All the specimens were weighed accurately prior of bringing them to the site. The nominal composition of the steel that have been analysed by Glow Discharge Spectrometer (GDS) is shown in Table 1.

B. Experimental Site

Two sea sites in state of Johor were chosen for the study that is Danga Bay area and seaside at Permas Jaya. The coupon burial location in Danga Bay sea site is classified as offshore area and location in Permas Jaya site is classified as near shore marine environment. The difference in the geographical location of Permas Jaya area and Danga Bay sea area can be observed in Figure 1 (white flagged location).

The samples of seabed sediment from both locations were analysed and the properties identified were tabulated in Table II.

TABLE I
COMPOSITION OF X70 STEEL COUPON

Chemical Composition	Percentage
Fe	97.7
C	0.0784
Mn	1.67
P	0.0123
Co	0.0222
V	0.0114
Mo	0.0047
Ti	0.11
Al	0.0228
Nb	0.0036
Si	0.318
Cu_2	0.0087
Ni_2	0.0152
Cr_2	0.0275
Pb	0.0023

Fig. 1 Site of experimental

TABLE II
PROPERTIES OF SEABED SEDIMENT AT THE EXPERIMENTAL SITES

Site	Properties			
	Temperature	Salinity	Conductivity	pH
Danga Bay Area	30.3	22.5	35.88	6.5
Permas Jaya Area	31.27	20.3	35.20	6.27

C. Experimental Procedure

In order to ensure that the experimental would represent the actual condition of pipelines the steel coupons were placed at about three feet under sea soil where normally the pipelines are located about that depth. Due to the difference in terms of the depth of water at near shore and offshore area, the method of placing the steel coupons is slight differs. The specimens at Permas Jaya where the near shore environment is presented are pushed into the sediment using manual tools. The tools have been sharpened from one side to be able to make rectangular holes in the sediment in order to place the specimens into the sediment. Whereas, the specimens at Danga Bay been buried using transplanting and burying method as been used in the past study [6]. All specimens were left buried in both locations for 6 months as long period of exposure to insure the corrosion has initiated and progressed, before they were retrieved and determined their weight loss. The size of the specimen is included in the calculation of corrosion rate and done away with its effect on corrosion rate, where the initial total surface area of the coupons and the mass lost during the test are determined. Then the average corrosion rate obtained using the equation provided in the standards as follows:

Corrosion rate = (K * W)/ (A * T * D)

Where:
K = a constant
T = time of exposure
A = area in cm^2
W = mass loss in grams
D = density in g/cm^3

III. Results and Discussion

A. Visual Observation

Specimens retrieved from both sites are covered with black peaty soil adhered to the surfaces of coupons as illustrated in Figure 3. After the debris is removed by washing the specimens with water, it was realized the entire silver shiny coupon before burial has changed its colour to black.

The steel corrosion which takes place in the marine environment consisting water and oxygen has lead to creation of black rust, which also known as Fe_3O_4 giving blackish colour on the surface of both specimen. Identified as insoluble product, black rust or Fe_3O_4 is a result of reaction between ferrous and hydroxide ion leading to creation of Ferrous Hydroxide ($FeOH_2$) which then react further with additional hydroxide ion and sometimes also oxygen [7]. Other than that, it is also noticed that the coupons retrieved from near shore site has more uneven surface as compared to off shore site. The loss of smoothness on the coupon surface is an initial indication of more pitting corrosion points to appear on the surface if the exposure period becomes longer.

Fig. 2 Steel coupons taken at Permas Jaya

Fig. 3 Steel coupons taken at Danga Bay

B. Effect of environmental parameters towards uniform corrosion

The corrosion rate shown in Figure 5 indicates that all specimens in both sites has countered changes in their weight as compared with the original weight. It is also seen that after this period of exposure, specimens buried at Permas Jaya near shore site exhibit slightly higher corrosion rate than the one exposed in Danga Bay offshore site. Although, the corrosion in seabed sediment could be depends on all environmental factors [8], but it is interesting to note that there is difference in the corrosion rate between the coupons retrieved from Permas Jaya and Danga Bay which is located at offshore marine environment. Where the corrosion rate at near shore site were ranged from (0.0652 - 0.0843), while the corrosion rate for off shore coupons were ranged from (0.0711 – 0.0780). The variation between coupons from the two sites is probably because of the difference in the corrosiveness of the environment which could not be observed visually. Measurement of certain parameters such as the pH value, salinity, constituent of seawater and others could help to explain the corrosivity of environment. Among the existing environmental factors, the existence of key factors that essentially influence the corrosiveness of seawater [9] indicates that the distance from shore plays an important role.

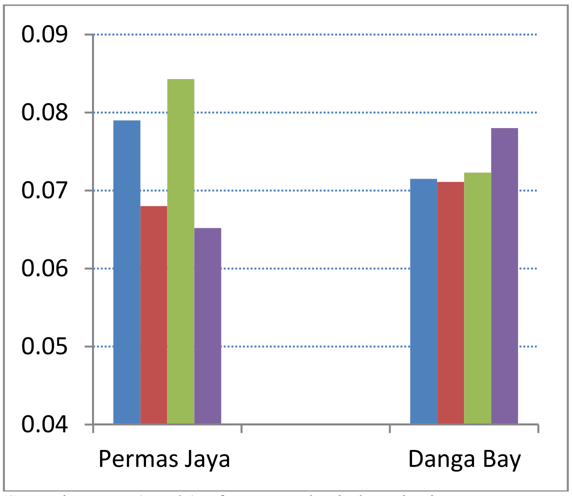

Fig. 4 Corrosion rate (mm/y) of coupons buried at site in Permas Jaya and Danga Bay up to 180 days

Temperature, pH value and salinity were the factors measures at site. Both sites at Permas Jaya and Danga Bay have shown no much difference between each other. In terms of pH which falls in the range of 6 to 8, indicates that in this case the corrosion of steel coupons in both environments is not mainly influenced by pH value. Soil having the pH range 5 – 8 is not considered to be the dominant variable affecting corrosion rates and the corrosivity of soil is mainly determined by other factors than pH [10]. The major reaction governing corrosion in most practical application in the pH range is the reduction of oxygen in the solution [11].

Comparing the average temperature at both locations, there is no much difference in value recorded in Permas Jaya and Danga Bay which is 30.5 and 30.7 respectively. Since both locations are in the tropical region which climate is wet and humid throughout the year, it is expected that corrosion become active due to the moist environment. Although, the severity of corrosion attack increases as the temperature increase [12], but the effect of temperature on the coupons buried could not be observed since the temperature in both site is almost the same. However, it is expected the corrosion rate of all the coupons would be lower if the specimens located in cold climate country. Since the focus of this research is on the corrosion rate of coupons in tropical environment, it can be concluded that the difference in the corrosion rate of coupon of between both locations is not because of the temperature factor.

Salinity is one of the factors playing an important role towards causing the corrosion rate higher. Based on the measurements, salinity at both sites is almost the same. In this study, it can be observed that the higher corrosion rate of the coupons at Permas Jaya site is probably due to the availability of oxygen at near shore area. This influence of distance towards corrosion activity has been mentioned by [13] who stated that the corrosion rate become higher as the distance from the shore become nearer. Therefore it can be deduced that the corrosion rate of steel coupons in seabed sediment at near shore area of tropical environment is more significant as compared to offshore area.

IV. Conclusions

Based on the study, it can be concluded that the corrosion rate of steel in seabed soil located in tropical region is affected due to the difference in the distance from the shore. The corrosion rate of specimen located in near shore area which is higher than offshore area, signifies that corrosivity of near shore area is greater compared to later. The corrosion rate at near shore areas could be up to 10% higher than the corrosion rate at off shore areas.

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