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EFFECTS OF CLAY AND MOISTURE CONTENT ON SOIL-CORROSION DYNAMIC

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Abstract: Soil corrosion is a serious threat to the integrity of buried structures such as underground storage tanks, oil and gas transmission pipelines, and many other structures. This paper investigates the effects of soil engineering properties towards metal loss of buried X70 carbon steel coupons. The study focuses on soil engineering properties which are soil clay and moisture content. A number of 160 pieces of X70 carbon steel coupon were installed underground in five different locations in Peninsular Malaysia for 12 months period to study the influence of the above mentioned parameters towards metal loss caused by soil-corrosion. The samples were retrieved every 3 months to determine its weight loss and corrosion growth rate over time. The result shows that the rapid growth of corrosion is relatively correlated with the high moisture content of soil. Yet, corrosion initiated at a slow rate for clayey soil. Soil moisture content was found more influential towards corrosion dynamic as compared to clay content based on the qualitative evaluation.

Keywords: *Underground Corrosion, Soil, Pipeline, Steel*

1. Introduction

Soil corrosion is the deterioration of metal or other materials brought about by chemical, mechanical, and biological action by soil environment [Chaker and Palmer, 1989]. Buried pipelines (commonly made from carbon steel) are one of the most common mediums used to transport products such as crude oil and gas from one point to another. These underground pipelines are exposed to various environment elements such as seawater (offshore) and soil (onshore) that may lead to experience of corrosion attack. Steel pipelines deterioration due to corrosion attack is well known as a common and serious problem, involving considerable cost and inconvenience to industry and to the public. There is always a chance that pipelines could leak or rupture and a pipeline failure can constitute serious hazards to the environment, assets and even humans due to explosion and leakage [Hopkins, 1995; National Energy Board, 1996; Yahaya *et al.*, 2009]. Although maintenances are done regularly, corrosion attack still remains as a serious risk to structure reliability and integrity. Soil engineering properties and soil contents are two important classes of parameters that influence soil corrosivity and level of corrosion dynamic. Previous researches had successfully prevailed in investigating the soil corrosiveness, but mainly focused on the soil chemical content instead of soil engineering properties. In most cases, study on the influence of soil engineering properties towards corrosion is hardly available due to assumption that these parameters have minor or no effect on corrosion dynamic [Noor *et al*., 2011]. Therefore, this research is carried out to investigate the relationship between soil moisture content and clay content towards material degradation, in the aspect of corrosion dynamic.

2. Materials and Method

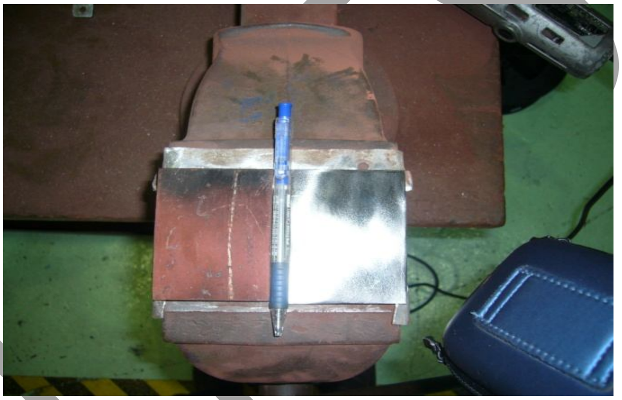
2.1 Soil properties testing

Moisture content, clay content and plasticity index testing were carried out according to BS1377-2:1990 [BS, 1990]. Soil samples from all sites were collected repeatedly during coupon retrieval so that the average value of soil engineering parameters can be properly recorded for correlation and sensitivity analysis purposes.

2.2 Steel samples preparation

Material used for this study is X70 carbon steel pipes from actual pipe segment (as shown in Figure 1). The pipes were cut into smaller size of coupons (80mmx60mm) using hot cut method [Noor *et al.,* 2011]. Cold cut method was then used to remove heat affected zone on the coupon which might cause changes in properties of the material. Coatings of those samples were removed (refer to Figure 2) to avoid inconsistent coating protection that might lead to unfair result as well as to let the coupon to corrode under worst case scenario. The samples were thoroughly cleaned prior to underground installation to avoid any contamination or any possible entity that can affect the corrosion process. The procedures of the preparation and cleaning process are referred to ASTM G01-03 [ASTM, 2003].

Figure 1 : Original X70 pipe segments



. Figure 2: Removal of pipe coating

2.3 Field work

Field works were carried out to measure the metal loss rate due to corrosion when steel coupons are exposed to various soil conditions. There are five major areas selected to install the coupon underground, namely site 1, site 2, site 3, site 4 and site 5. All these sites were selected based on different soil conditions, site workability and safety. The field work set-up requires a hole of about one meter deep to accommodate two specimens of steel coupon placed at 1m and 0.5m from the ground level. Figure 3 shows the digging process which took place on site using mechanical auger machine. A total of 32 steel coupons were installed underground per site. The retrieved samples will not be restored back into the hole for later retrieval because the retrieved sample is regarded as disturbed sample. The cleaning process will mess up the rust layer on the sample (corrosion product), hence causing interruption to the natural dynamic of corrosion mechanism. Every single sample is assumed uniform in terms of strength, dimension and corrosion resistance so as to get a time-function data of metal loss. Hence, metal loss measurements from retrieval at different time within 12 months period are considered correlated with each other. A number of eight coupons were dug-out to measure the average of metal loss rate as shown in Figure 4. The field test was completed in the period of 12 months with a total of 160 coupons retrieved from the above mentioned sites.

Figure 3: Drilling process

Figure 4: Retrieved sample in a sealed plastic bag

2.4 Weight loss measurement

Two cleaning techniques were used to remove the impurities and corrosion product off the coupons, namely mechanical cleaning and chemical cleaning (refer to Figures 5 and 6). The mechanical cleaning was carried out to remove the soil particles on the surface of samples using a soft steel brush. It was then followed by chemical cleaning whereby the samples were immersed in a pre-mixed solution (Hydrochloric acid + Hexamethylene Tetramine + Reagent water), as stated in ASTM G01-03. The weight of the sample prior and after being exposed to soil environment was recorded to determine the corrosion rate. Boisch [1970] mentioned that the difference in weight of the sample is most often used as a measure of corrosion or the basis for calculation of the corrosion rate. The average corrosion rate can be calculated using the following equation:

$$\text{Corrosion Rate} = \frac{K \times W}{A \times T \times D} \qquad (1)$$

Where;

K = a constant,
T = time of exposure in hours to the nearest 0.01 hr,
A = area in cm^2 to the nearest 0.01 cm^2,
W = mass loss in g, to nearest 1 mg (corrected for any loss during cleaning),
D = density in g/cm^3

Figure 5: Mechanical cleaning

Figure 6: Chemical cleaning

3. Result and Discussion

3.1 Moisture content influence

Water is one of the main elements for corrosion to occur. First and foremost, there are three types of sources which provide the soil moisture: free ground water, gravitational water, and capillary water. Certainly, they have significant influence on the determination of corrosion growth. The free ground water is present in the soil below the surface and usually only river crossing pipelines are surrounded by ground water. In such condition, corrosion is regarded to occur in an aqueous environment. The main sources of gravitational water are snow, rainfall, irrigation and flood. This water enters and flows through the soil, governed by soil physical properties, including pore and capillary spaces at various zones in the soil profile. The capillary water represents an important reservoir of water in soil. Moisture/water is an essential element which acts as electrolyte for the corrosion process and therefore, it can affects corrosion growth directly. Generally, corrosion rate increases with the increasing moisture content. Figure 7 shows the relationship between moisture content and corrosion rate for the selected sites. The line and bar graph shared a similar trend that reflects the possible existence of correlation between moisture content and corrosion rate. The metal loss process was accelerated by the high moisture content as exhibited by results from Sites 2 and 3 whereby the highest corrosion growth rate and moisture content were recorded at both sites.

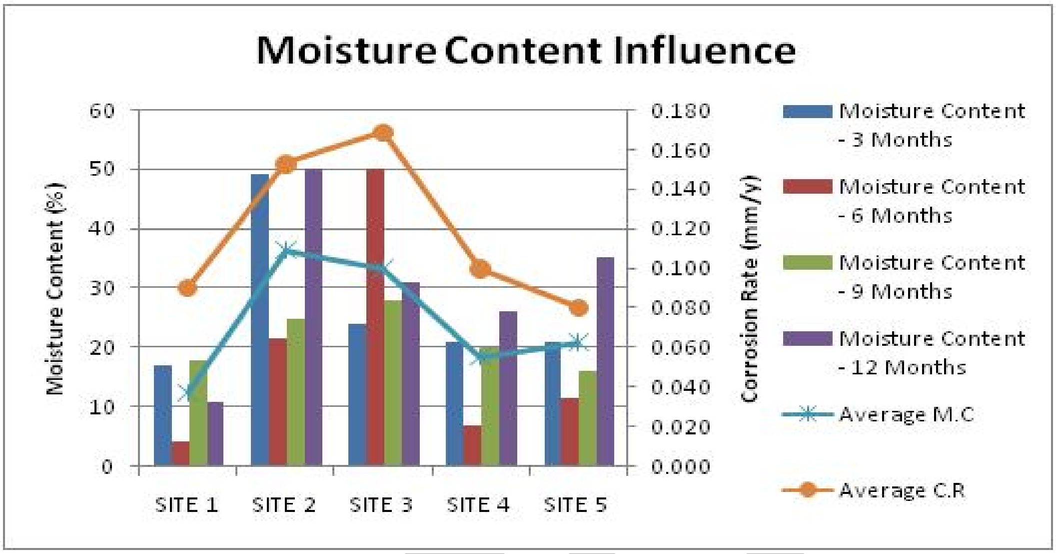


Figure 7: Relationship between corrosion rate and moisture content

3.2 Clay content influence

Soils are usually named and classified according to the size range of their particular size/grain diameter. For example, cobble (> 60mm), gravel (2mm-60mm), sand (2mm-0.063mm), silt (0.063m-0.002mm) and clay (<0.002m). Soil texture is one of the first factors to be considered during corrosion surveys because it determines the degree of aeration and the permeability of the soil [Velázquez *et al.*, 2009]. High clay content soils present more packed particles and have less pore capacity for moisture (water) and gases (oxygen) diffusion than an open-type-soil such as sand/gravel. Therefore, soils with high clay content are less corrosive. Figure 8 displays the relationship between clay content and corrosion rate according to sites and retrieval sequences. Unlike moisture content, clay content was found to have minor influence upon corrosion rate due to the unparallel pattern between averaged corrosion rate and clay content at most of the sites. Sites 1 to 3 have a high variation of clay content, yet the corresponding corrosion growth rates were relatively similar. Furthermore, the coupons installed at clayey site (Site 2 and 3) experienced low rate of metal loss and vice versa. This is in line with the theory of soil corrosivity as a function of clay content.

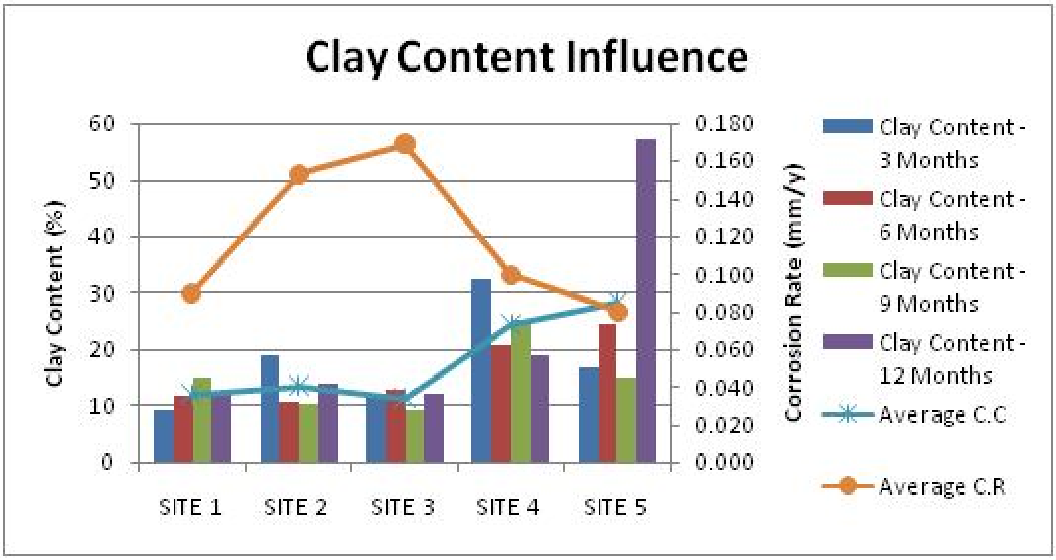


Figure 8: Relationship between corrosion rate and clay content

4. Discussion and Conclusion

The purpose of the study is to determine a qualitative indication of the governance of soil engineering parameters, which are moisture content and clay content upon corrosion growth rate. In fact, this paper has isolated individually the above mentioned soil engineering parameters from all possible factors which may govern metal loss of buried steel coupon and later correlated with corrosion growth rate as measured through field work testing. The measured metal loss from the coupon which buried underground is mathematically caused by so many factors including soil chemical contents and other third party factors such as pollution. If strong relationship can be seen from the result, then it can be deduced that the isolated parameter has dominant influence on corrosion rate. Soil moisture content was found to have greater influence than clay content towards corrosion dynamic at most of the sites, if not all, due to distinct pattern of relationship between variations of averaged corrosion rates and soil properties. The findings do not express empirically and quantitatively the magnitude of the soil properties governance on soil-corrosion dynamic. Further investigation is necessary to prove that the soil engineering properties may pose minor influence on corrosion rates, hence not the most influential factor. The measured corrosion rates from the loss of weight of buried steel coupon may be dominantly caused by other factors such as bacteria, chloride, sulphate, sulphide, organic content and salinity.

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