The Effect of Both Moisture and Clay Content on The Soil Corrosion Process for Different Periods of Time as A Geomorphological Study in Al-Kut City

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Abstract. Soil corrosion is a major hazard to subterranean infrastructure including gas and oil transmission pipes, underground storage tanks and others. The impacts of soil engineering characteristics on buried mild steel coupons' metal loss are investigated in this work. Soil characteristics such as soil clay and moisture content are the focus of the present research in Al-Kut city near Tigris River. For a twelve month period, 100 pieces of mild steel coupons were put underground in five different sites across to look into the effects of the aforementioned variables on loss of metal owing to corrosion of soil. Every three months, the samples were recovered to evaluate the rate of weight loss and corrosion rate development. The data show that the high moisture content of the soil is linked to rapid corrosion development. Corrosion on clay soil, on the other hand, takes longer to start. According to the qualitative assessment, soil moisture content has a greater impact on corrosion dynamics than clay content.

Keywords: soil, weight loss, clay, corrosion, moisture, mild steel, Kut.

1. Introduction

The local cell model and the concept of corrosion potential were the foundations of modern corrosion science in the early twentieth century. Metallic corrosion is described in modern electro-chemical corrosion theory as a mixed electro-chemical process consisting of anodic oxidation and cathodic oxidationization. Iron and steel corrode materials in a variety of gaseous and aqueous environments. The most common corrosion of iron and stain occurs in aqueous solutions and wet ambient air.[1-3]. Soil corrosion is the degradation of metals or other materials caused by the chemical, mechanical, and biological activities of the soil environment. Buried pipelines are one of the most frequent ways to move goods such as crude oil and gas from one location to another (typically made of carbon steel). Corrosion can occur when these underground pipelines are exposed to a number of environmental conditions, including seawater and soil. Corrosion-induced degradation of steel pipes is a well-known and significant problem that costs industry and the public a lot of money and causes a lot of discomfort. Pipelines can burst or leak...
at any time, posing serious dangers to the environment, assets, and even people as a result of explosions and leakage. Despite routine maintenance, corrosion attack continues to pose a severe threat to the structure's dependability and integrity. Two major types of factors that impact soil corrosively and amount of corrosion dynamic are soil engineering features and soil contents. In determining the susceptibility of soil to corrosion, previous studies were effective, and mostly focused on the chemical composition of the soil. Due to the idea that these characteristics have a minimal or no effect on corrosion dynamics, studies on the effects of soil engineering qualities on corrosion are seldom accessible. The purpose of this study is to consider the correlation of contents both clay and moisture through the deterioration of the samples in corrosion processes. [4-7]

2. Experimental Work

According to BS1377-2:1990, of contents both clay and moisture, tests were performed. During coupon recovery, Soil samples were collected from all sites multiple times in order to fully capture the average value of soil characteristics.[4-7]

Mild steel strips (75 mm x 50 mm) were used. The model was then subjected to a cold cutting technique to remove the heat-affected area, which could lead to changes in the material's properties. All coatings on these samples were removed to prepare them for testing. Prior to their underground installation, The samples were properly cleansed to eliminate any potential impurities or entities that may disrupt the corrosion process. ASTM G01-03 specifies methods of preparation and cleaning. [1-7]

Field tests were performed on mild steel coupons exposed to various soil conditions to determine the rate of metal loss due to corrosion. The coupon will be buried in five separate locations: sites 1, 2, 3, 4, and 5. The soil characteristics, site workability, and safety were all taken into consideration while selecting these places. A one-meter-deep hole is required for the field work setup, which includes two steel coupon specimens positioned 1m and 0.5m above ground level. Mechanical auger equipment was used for on-site digging. At each location, a total of 20 steel coupons were buried. Because the retrieved materials are considered disrupted, they will not be returned to the hole for further recovery. The cleaning procedure will disrupt the normal dynamics of the corrosion mechanism by disrupting the rust layer on the sample (corrosion product). In order to get time-function data for metal loss, each sample is assumed to be uniform in terms of strength, size, and corrosion resistance. As a result, metal loss figures gathered at various points during the year are considered linked. [4-7]

2.1. Weight loss method

Mechanical cleaning and chemical cleaning were used to remove contaminants and corrosion products from the coupons. The dirt particles on the surface of the samples were cleaned using a soft steel brush during mechanical cleaning. Following that, the samples were chemically cleaned by immersing them in an ASTM G01-03-compliant pre-mixed solution of HCl, Hexa-methylene Tetra-amine, and Reagent water. To estimate the corrosion rate, the weight of the sample was recorded before and after it was exposed to the soil environment. The difference in sample weight is often employed as a corrosion indicator or to estimate the corrosion rate. The equation below can be used to compute the average corrosion rate. [8-18]

\[
\text{Corrosion rate (C.R) } = \frac{K \times W}{D \times A \times T}
\]
Where; $W$ is denote to mass loss, $K$ is denote to constant, $D$ is denote to density, $T$ is denote to time exposure, $A$ is denote to area.[20-30]

3. Results and Discussions

3.1. Effect of moisture content

One of the most significant components in corrosion is water. To begin, soil moisture is produced by three different sources: There are three types of water: free ground water, gravity water, and capillary water. They undoubtedly have a substantial impact on corrosion development forecast [4-7, 8-18]. Ground water is found beneath the surface of the earth and is usually only surrounded by it around river crossing pipes. In this example, In an aquatic environment, corrosion is thought to occur. Snow, rainfall, irrigation, and flooding are the primary sources of gravitational water. Water enters and flows through the soil, regulated by soil physical characteristics such as pore and capillary gaps located across the soil surface. In the soil, capillary water is a primary water storage mechanism. Moisture/water is an important component that serves as an electrolyte in the corrosion process, and so has the ability to impact the advancement of corrosion [19-25]. In general, when the moisture content rises, the corrosion rate rises [26-37]. Figure 1 depicts the connection between moisture content and corrosion rate for the selected locations. However, it followed a similar pattern, demonstrating a connection between moisture concentration and corrosion rate. As evidenced by data from Sites 2 and 3, where the greatest corrosion development rate and moisture content were recorded at both sites, the high moisture level exacerbated the metal loss process, as shown in Table 1 and Figures 1 and 2. [38-42] as shown in below equation.

Moisture content $\% = \frac{\text{weight of water}}{\text{weight of sample}} \times 100$

Moisture content $\% = \frac{\text{initial weight} - \text{oven dry weight}}{\text{oven dry weight}} \times 100$

| Site | Moisture content, % | Corrosion rate, mm/y |
|------|---------------------|----------------------|
| Site 1 | 3 months 15 | 0.047 |
| | 6 months 5 | 0.018 |
| | 9 months 16 | 0.052 |
| | 12 months 9 | 0.030 |
| Site 2 | 3 months 45 | 0.138 |
| | 6 months 17 | 0.051 |
| | 9 months 20 | 0.060 |
| | 12 months 47 | 0.142 |
| Site 3 | 3 months 20 | 0.060 |
| | 6 months 45 | 0.138 |
| | 9 months 25 | 0.078 |
| Site 4 | 12 months | 27 | 0.085 |
|-------|-----------|----|-------|
|       | 3 months  | 19 | 0.057 |
|       | 6 months  | 6  | 0.021 |
|       | 9 months  | 16 | 0.053 |
|       | 12 months | 22 | 0.071 |
| Site 5|           |    |       |
|       | 3 months  | 18 | 0.054 |
|       | 6 months  | 10 | 0.030 |
|       | 9 months  | 13 | 0.037 |
|       | 12 months | 32 | 0.101 |

**Figure 1:** Corrosion rate vs. moisture content with all sites for (3, 6, 9, 12) months.
Figure 2: Corrosion rate vs. time of moisture content with all sites for (3, 6, 9, 12) months.

The above figure 2 depicts the influence of time on the corrosion rates of the moisture content, with the largest rate of corrosion at site 1 at 9 months, site 2 at 12 months, site 3 at 6 months, site 4 at 12 months, and site 5 at 12 months. The reason for this is the position near or far from the river, as well as the high moisture content, which has an efficient impact on the corrosion process due to the presence of water, oxygen, temperatures, air pressure, and some minerals in the soil.

3.2. Effect content of clay

Soils are commonly referred to and categorized based on the particle diameter range of their particles. Some examples include cobblestones larger than 60mm, gravel ranging from 2mm to 60mm, sand ranging from 2mm to 0.063mm, silt ranging from 0.063mm to 0.002mm, and clay 0.002mm. The degree of aeration and permeability of the soil is determined by its texture, which is one of the first elements evaluated during corrosion inspections. In comparison to sand/gravel-rich soils, clay-rich soils have more compacted particles and a lower pore capacity for moisture (water) and gas (oxygen) diffusion [4-8]. As a result, soils with a high clay concentration are less corrosive. Figure 3 shows the connection between clay content and corrosion rate as a function of location and retrieval sequence. Clay content, unlike moisture content, was shown to have a limited impact on corrosion rate due to the non-parallel connection between mean corrosion rate and clay content at the majority of the sites. Although the clay concentrations at Sites 1–3 vary, the rates of corrosion development are quite comparable. Furthermore, metal loss was minimal for coupons placed at the clayey site (Sites 2 and 3), and vice versa. As demonstrated in Table 2 and Figures 3 and 4, this is consistent with the soil corrosive concept as a function of clay concentration. [8-13] as shown in below equation.

\[
\text{Clay content} \% = \left[\frac{(A_1 X + A_2 (1-X))}{A_1}\right] \times 100
\]

Where; \(A_1\) represents the surface area of the separated clay fraction, \(X\) represents the fractional quantity of clay removed from the soil, and \(A_2\) represents the surface area of the remaining silt plus sand fraction.

Table 2: Effect of corrosion rate on clay content

| Site  | Clay content, % | Corrosion rate, mm/y |
|-------|----------------|---------------------|
| Site 1 |                |                     |
| 3 months | 7               | 0.025               |
| 6 months | 10              | 0.030               |
| 9 months | 13              | 0.039               |
| 12 months | 11              | 0.034               |
| Site 2 |                |                     |
| 3 months | 16              | 0.046               |
| 6 months | 8               | 0.026               |
| 9 months | 7               | 0.025               |
| 12 months | 10              | 0.030               |
| Site 3 |                |                     |
| Site 4     | 3 months | 6 months | 9 months | 12 months |
|-----------|----------|----------|----------|-----------|
|           | 3 months | 6 months | 9 months | 12 months |
| Site 4    | 3 months | 6 months | 9 months | 12 months |
| Site 5    | 3 months | 6 months | 9 months | 12 months |

| Site 5     | 3 months | 6 months | 9 months | 12 months |
|-----------|----------|----------|----------|-----------|
| Site 5    | 3 months | 6 months | 9 months | 12 months |

**Figure 3:** Corrosion rate vs. clay content with all sites for (3,6,9,12) months.
Figure 4: Corrosion rate vs. time of clay content with all sites for (3,6,9,12) months.

The clay consider less corrosion because it electrically imbalanced atomic structure distinguishes it. The surface of its lamellar particles is defined by negative charges linked with the positive earth salt ions, which include sodium, potassium, calcium, and magnesium atoms, in terms of mineral formation. The clay's capacity to participate in ion exchange activities between earth salt ions and other positive ions without altering the fundamental silicate structure distinguishes it. Bonding can take the form of weak physical connections, strong chemical bonds, or what is known as adsorption. [4-7]

The impact of time on the corrosion rates of the clay content is shown in the above figure 4, with the greatest rate of corrosion in site 1 at 9 months, site 2 at 3 months, site 3 at 6 months, site 4 at 3 months, and site 5 at 12 months. The reason for this is the location in near or far of river, as well as the high clay content, which, owing to the presence of silica, alumina, and oxides in the clay, has an efficient influence on the corrosion process.

4. Conclusions

The study's goal is to get a qualitative indication of the influence of soil factors on the rate of corrosion development in Al-Kut, which is located along the Tigris River, namely moisture content and clay content. In actuality, this study used the aforementioned soil properties and connected them to the corrosion growth rate as established by field work testing. Several variables, including soil chemical composition and other external influences like pollution, are theoretically responsible for the observed metal loss from the buried coupon. If the findings indicate a high correlation, it's feasible to draw the conclusion that the isolated parameter has a substantial impact on corrosion rate. Because of the unique pattern of variance in averaged corrosion rates and soil characteristics, it was discovered that soil moisture content has a greater impact on corrosion dynamics than clay content.
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