Effect of Soil Parameters on Corrosion of Metals: A Review

Vishal Bansode[1], Aniket Kolekar[2], Sandesh Solepatil[3]
[1, 2, 3] Dept of Mechancal Engineering
[1, 2, 3] DYPIEMR. Ak Pune

Abstract- *Corrosion by soil is a complex phenomenon due to the number of variables involved. In principle, steels should be in the passive state in soils but the presence of water and aggressive chemical species such as chloride ions, sulphates as well as different types of bacteria and stray current can cause localised corrosion. Soils constitute the most complex environment known to metallic corrosion. Corrosion of metals in soil can vary from relatively rapid material loss to negligible effects, depending on soil environment. Soil engineering properties and soil contents are important parameters that influence soil corrosivity and level of corrosion dynamic.*

Keywords- Corrosion, Soil properties, Soil Parameters

I. INTRODUCTION

Corrosion is defined as degradation of material or its properties due to a reaction with environment. Soil corrosion is a complex phenomenon with number of factors involved. Chaker and Palmer defined soil corrosion as deterioration of metal or other material brought about by chemical, mechanical and biological action by the soil environment. [8]

Metals have a natural tendency to revert to their oxidized form given the proper environment and opportunity. The appropriate circumstances necessary for the degradation of metals can vary greatly between environments. Free hydrogen ions found in all waters, soils and some gases can provide a means of removing the excess electrons from metals. In addition, oxygen in the air can accelerate the oxidation of most metals and alloys. The electrical conductivity of water also increases with its dissolved mineral concentration. Therefore highly mineralized waters or soils readily conduct the electrical currents of electrolytic cells and can accelerate the corrosion process. The same can also be said for exposed atmospheric conditions where moisture is present in the form of vapor water or can condense and fall as rain concentrating the collection of salts, chemicals and other pollutants. The environment for many structures provides conditions that favor the formation of natural corrosion cells. The metals of a structure can serve as the anode, cathode and as the necessary conductor between any two metal components of the building. Free water, or as moisture in soil or air, provides the electrolyte required to complete the cell circuit

In case of steel pipeline, corrosion is common form of structure degradation that reduces both static and cyclic strength. Due to degradation of steel pipeline causes serious problem human, environmental and financial losses.

Corrosion of buried steel pipe in soil mainly depends on soil properties such as soil resistivity, soil redox potential, soil pH, soil organic content, and chemical composition also by microbial activity. Fig.1 shows 3 phase boundaries that arise at the soil to pipe interface. [1]

1.1 Basic Mechanism for Corrosion: [1]

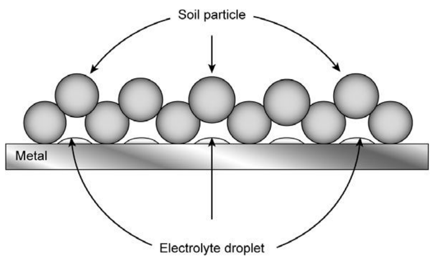

Fig.1. Schematic of three-phase boundaries that arise at the soil to pipe interface. [1]

There are two basic mechanisms responsible for corrosion of buried metals,

Electrolytic corrosion
Galvanic corrosion

Electrolytic corrosion:

Electrolytic corrosion is a result of direct current from outside sources. This direct current is introduced into the soil and is picked up by underground pipeline. The locations where the current is picked up are not affected or are provided some degree of protection. But the locations along the pipe where this current leave the pipe to enter the soil, those locations are driven anodic and corrosion will result. This type of corrosion is often known as stray current corrosion.

Galvanic corrosion:

Galvanic corrosion is self generated corrosion activity, which result when pipe is placed in soil. Therefore if we are to analyse corrosion problem it is essential to know potentials as they apply to underground pipe.

1.2 Conditions for corrosion of steel in soil:

High moisture contains.

A pH value less than 4.5.
A resistivity less than 1000 Ω.cm.
Presence of chloride, sulphides and bacteria.
Presence of stray currents.

2.1 Corrosion electrochemistry of steel pipe in alkaline soil [7]

The cathodic reaction of steel in aerated, alkaline soil is dominated by reduction of oxygen.

$$\frac{3}{2} O_2 + 3 H_2O + 6 e^- = 6 OH^- \qquad (1)$$

The anodic process is complex one including dissolution of steel and formation of iron compounds with different chemical valances.

$$Fe = Fe^{++} + 2 e^- \qquad ..... (2)$$

$$Fe^{++} + 2 OH^- = Fe(OH)_2 = FeO + H_2O \qquad .. (3)$$

$$4 Fe(OH)_2 + O_2 + 2 H_2O = 4 Fe(OH)_3 \qquad ....(4)$$

$$4 Fe(OH)_2 + O_2 = 2 Fe_2O_3 + 4 H_2O \qquad (5)$$

2.2 Relationship between soil properties and corrosion of carbon steel: [12]

M.N. Norhazilan et. al. [8] had studied the relationship between soil properties and corrosion of carbon steel.

The soil engineering properties and soil content are important parameter that influences the soil corrosivity and level of corrosion dynamics that are listed below,

Soil properties responsible for corrosion of metal:

Soil resistivity
Soil pH
Soil redox potential
Soil temperature
Soil content
Liquid limit , Plastic limit
Soil chemical content

Resistivity of soil:

Soil resistivity is a measure of ability of soil to conduct a current. [5] The resistivity of soil is determined by moisture content and concentration of different ions and their mobility. The lower the resistivity of soil betters the soil electrolyte properties and higher is the rate of corrosion. Table (2) shows relation between soil resistivity and corrosivity of soil [5]

Table:2. The relation between resistivity and corrosivity of soils [5]

Soil resistivity (Ω cm)	Corrosivity
< 20000	Essentially non-corrosive
10000 – 20000	Mildly corrosive
5000-10000	Moderately corrosive
3000-5000	Corrosive
1000-3000	Highly corrosive
<1000	Extremely corrosive

Fig: 2. Shows effect of resistivity on soil corrosivity range. [5]

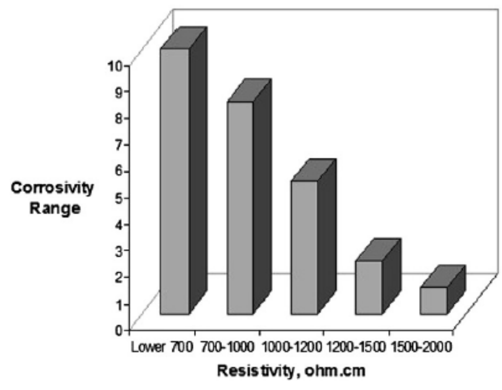

Fig.2. Effect of resistivity on the soil corrosivity range. [9]

Soil pH :

Soil usually has a pH range of 5 – 8. In this range pH is generally not considered to be dominated variable affecting the corrosion rate. Fig.3 shows effect of pH on soil corrosivity range. [9]. More acidic soil obviously represent a serious corrosion risk to common construction material such as steel,

cast iron and zinc coating. Soil acidity is produced by mineral leaching, decomposition of acidic plants, industrial waste, acid rain and certain form of microbiological activities.
However alkaline soil tends to have high Na, K, Mg, Ca contents. The latter two elements tend to form calcareous deposits on buried structure with protective properties against corrosion. The pH can affect the solubility of corrosion product and also the nature of microbiological activity.

The pH value of soil determined by the content of carbonic acid, minerals, organic or inorganic acids. With the exception of the rare highly acid soil , pH is usually between 5 to 8 , in that case corrosivity of soil is mainly determined by other factor than pH . However pH below 5 a protective coating of rust cannot forms on steel and corrosion rate of steel can be relatively high. [5]

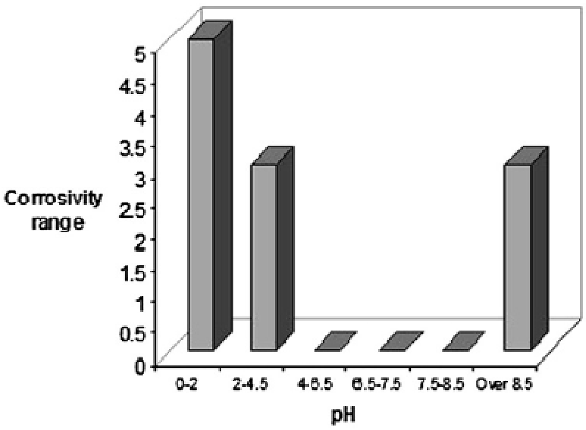

Fig.3. Effect of pH on the soil corrosivity range. [5]

Soil Redox Potential:

Soil redox potential is a measure of degree of aeration in a soil. A high redox potential indicate high oxygen level. Low redox potential provides an indication that conditions are conductive to anaerobic microbiological activity. Fig.4 shows effect of redox potential on soil corrosivity range. [5]

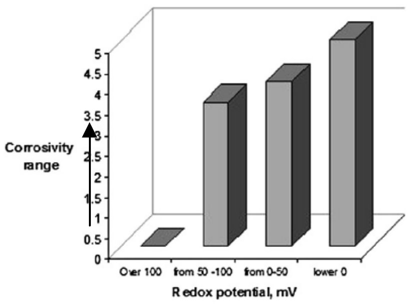

Fig.4. Effect of redox potential on the soil corrosivity rage. [5]

The oxygen concentration of soil moisture generally will determine its redox potential. Thus higher the oxygen content higher is the redox potential. [5]

The soil redox potential value are calculated by following relationship, [11]

$$Eh = Em + 250 + 60 \times (pH - 7)$$

Where,
Eh – is the redox potential at neutral pH
Em – means potential measured with platinum electrode (mV).

Moisture content of soil:

The liquid represent the essential electrolyte required for electrochemical corrosion reaction. A distinction is made between saturated and unsaturated water flow in soil. The unsaturated water flow in soil represents movement of water from wet area towards dry soil area. However, saturated water flow mainly depends on pore size and distribution, texture, structure and organic matter. Fig.5 shows effect of moisture content on corrosivity range of soil, [5]

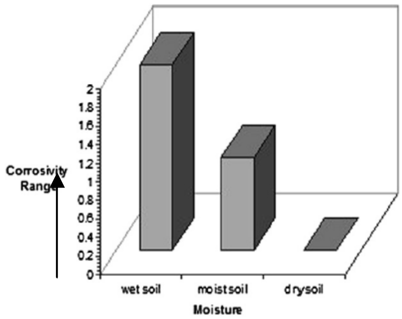

Fig.5. Effect of moisture content on the corrosivity range of the soil. [5]

The moisture content of soil sample can be calculated using weight loss technique as per IS 2720 (Part 2). For this a 30 gm of each soil sample is dried in a drying oven at 110 0C for 24 hrs. The weight difference between sample before and after evaporation is regarded as the moisture content. [2]

Chloride content:

The chloride ions are generally harmful as they directly participate in anodic dissolution reaction of metal and their presence tends to decrease the soil resistivity. They may be found naturally in soil as a result of brackish or from external source such as deicing salt. The chloride ion concentration in the corrosive aqueous soil electrolyte will vary as soil condition alternate between wet and dry. [5]

Sulphate content:

Compared to chloride content, the sulphate content are more benign in their corrosive action toward metallic material. Concrete may be attacked as a result of high sulphate level. The presences of sulphate in soil are considered as major risk for metallic material because sulphate can be converted into high corrosive sulphide, anaerobic sulphate reducing bacteria.

VI. CONCLUSION

Main courses of corrosion towards underground steel pipe is the surrounding environment that is the soil. The main paramaters such are soil PH value, its resistivity, ions contents mainly affecting corrosion of metals .

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