THE STUDY OF CORROSION RATE FOR CARBON STEEL PIPE IN ALKALINE CONCRETE SOLUTION

MOHD FAIZ MUAZ BIN AHMAD ZAMRI

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I declared that this thesis entitled

'The study of corrosion rate for carbon steel pipe in alkaline concrete solution'

is the result of my own research except as cited in the references.

The thesis has not been accepted for any degree is not

concurrently submitted candidature of any degree.

Signiture   :…………………………..

Name of Candidates   :MOHD FAIZ MUAZ BIN AHMAD ZAMRI

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Special dedicated to my beloved mother and father

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ABSTRACT

Although preservative treatments prolong the life of carbon steel pipeline, they can also accelerate the corrosion of fasteners. This is an issue that needs to be studied because corrosion of building materials and fasteners can negatively affect system performance. In this study, the test methods examine the corrosion of metals in contact with aqueous are summarized and reviewed so that a comparison of their effectiveness can be made. Comparable results are obtained using the same method of study that is following the standard of ASTM Standard G31, "Standard Practice for Laboratory Immersion Corrosion Testing of Metals" principally to steel-water systems (SOLTEQ, Corrosion study kits. Model BP 01), the apparatus is also suitable as a test bench for other chemical systems. Based on the results from the experiment it is stated that NaOH solution recorded the highest weight reduction that is 0.005 mg/cm^2.day at pH 8 with the concentration of 0.000375 mole/L. In the temperature test at the same concentration and pH, corrosion rate of weight loss are very high that is 0.007 mg/cm^2.day. The highest corrosion rate from overall experiment is when the dissolved oxygen concentration is 4.93 mg/L in the temperature range from 55°C. When concentration of solution is decrease the weight reduction is increased The alkaline pH value is proportional to the value of concentration. At low pH the dissolved oxygen is reduced at the metal surface. Increasing the temperature will increase the ionic mobility and thus will increase the rate of oxygen diffusion to the metal surface and more oxygen is available to for cathodic reduction process. Plus increase viscosity and conductivity. When the DO is reduced oxygen reduction and hydrogen evolution become the prevalent to cathodic reaction and the corrosion is further accelerated. [Linda Garveric ,1999]

ABSTRAK

Walaupun terdapat langkah mengurangkan kerosakan bagi memanjangkan jangka hayat paip besi karbon, ia juga sebenarnya mempercepatkan proses pengaratan dengan kadar yang lebih segera. Ini adalalah salah satu isu yang perlu di kaji kerana pengaratan dari bahan bangunan boleh memberi kesan negatif kepada kecekapan sistem. Dalam kajian ini kaedah pemeriksaan ujikaji pengaratan bahan dalam keadaan larutan dirumuskan dan diuji supaya perbezaan kadar kecekapan boleh diperolehi. Perbezaan keputusan eksperimen adalah diperolehi melalui piawaian ASTM G31. Piawaian pengaratan logam melalui ujian rendaman secara prinsip sistem pengaratan berair makmal.(SOLTEQ, Corrosion study kits. Model BP 01), alat ini juga sesuai untuk ujikaji pelbagai jenis sistem larutan kimia. Hasil ujikaji ini dibincangkan berdasarkan kesan suhu, kepekatan, nilai pH dan ketelarutan oksigen. Bedasarkan keputusan yang diperolehi daripada eksperimen menunjukan bahawa larutan NaOH merekodkan kadar penurunan berat yang paling tinggi iaitu 0.005 mg/cm2.hari pada pH 8 dengan kepekatan laruratan 0.000375 mole/L. Bagi ujian kesan suhu terhadap pengaratan, pada kepekatan dan pH yang sama, kadar pengaratan bagi penurunan beratadalah paling tinggi iaitu 0.007 mg/cm2.hari. Hasil daripada keseluruhan eksperimen kadar pengaratan tertinggi direkodkan apabila nilai ketelarutan oksigen 4.93 mg/L pada suhu 55OC. Apabila kepekatan larutan berkurang kadar pengurangan berat bertambah. Nilai pH alkali adalah berkadar langsung dengan nilai kepekatan larutan. Apabila nilai pH rendah ketelarutan oksigen pada permukaan bahan berkurangan. Apabila suhu meningkat kadar pegerakan ion juga akan meningkat dan akan juga meningkatkan kadar difusi oksigen pada permukaan bahan dan lebih banyak oksigen hadir untuk membantu proses penurunan katod. Tambahan pula apabila kelikatan dan konduktiviti larutan bertambah kesan dari suhu yang bertambah kadar pengaratan akan semakin bertambah. Ini adalah kerana ketelarutan oksigen yang semakin rendah dan evolusi hydrogen menjadi pemangkin proses penurunan katod.[Linda Garveric ,1999]

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NaOH	Sodium Hydroxide
KOH	Potassium Hydroxide
$Ca(OH)_2$	Calcium Hydroxide
NaSCN	Sodium Thiocynate
Fe_2O_3	Iron Oxide
$Fe(OH)_2$	Ferrous Hydroxide
H_2O	Water
OH^-	Hydroxyl Ions
Cl^-	Chlorine Ions
e^-	Electron
H_2	Hydrogen

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CHAPTER 1

INTRODUCTION

1.1   Background of The Study

The world energy transportation network world consists of over million miles of pipelines. The network includes onshore and offshore hazardous liquid pipeline, gas transmission and distribution pipeline and other possible carrying material such as water and many more. In the natural gas pipeline networking system, beginning with gas transmission line until to distribution line it is consider as external pipelines system, which transports the natural gas for delivering to the customers. For the internal piping system, it is covering from the handover of the natural gas distribution pipelines to service, area and regulating stations until to the equipment appliances of the industrial, residential and the commercial needs. Although pipelines are existed most of us are unaware that these vast networks ever exist. This is due the fact that most of pipelines are located underground and hidden places such as inside wall and buildings basements. Installing pipelines underground protects them from damage and helps protect our communities as well.

Pipelines play a vital role in our daily lives. Cooking and cleaning, the daily commute, air travel and the heating of homes and businesses are all made possible by the readily available fuels delivered through pipelines. Corrosion is natural process that does occur made from metal return to their original state through a chemical reaction known as oxidation. Corrosion of all types is one of the leading causes of pipeline leaks and ruptures.

Corrosion is the deterioration of metal that results from a reaction with the environment which changes the iron contained in pipe to iron oxide (rust). For example, if your car develops a rust spot, that is corrosion of metal. The same process can occur in various forms on pipelines.

It may be defined as the destruction of metal by electrochemical action, and it cannot takes place unless an electrolyte is present. These leakages are caused primarily by corrosion as the result of the exposure of the inner surface of the pipeline to water. However, corrosion of the external surfaces of pipelines also occurs because the exposure to their external environment and may give influence to the corrosion rate of pipelines.

The purpose of this thesis is to study the corrosiveness of aqueous solution in significantly influenced by concentrations of dissolved species, including gases, pH and temperature. The effects of these entities on corrosion are assumed to be independent, although interactions do exist. This is because it is easier to visualize their contribution when they are considered separately.

1.2   Problem Statement

Carbon steel is a common material for many industrial units because of its low cost and excellent mechanical properties. However its suffers severe attack in service particularly in oil and gas production systems. Although corrosion inhibitors are the most effective and flexible mean of corrosion control in oil and gas production systems the selection and application of inhibitors are actually complicated because of variable corrosive environment in these systems Corrosion is occurred widely through all specific types of pipeline. Mitigation of corrosion in onshore transmission pipelines is primarily accomplished by the combination of the cathodic protection (CP) and dielectric coating systems.

The design of such cathodic protection is reasonably straightforward, because the corrosion engineer can often predict the distance at which protective current application from a remote anode bed will affectively protect the pipeline in both directions from a current drain point attached to pipeline steel. The distance of effective full protection can be estimated if the pipeline diameter, steel type, wall thickness, soil characteristic and general coating quality are known.

This is so because a pipeline has an attenuation characteristic to current pickup from the electrolyte and longitudinal flow that is analogous to a leaky electric transmission line. It is interesting to note that it is possible to protect the pipeline to a greater distance from given anode location on a larger diameter pipeline than on a pipeline with a smaller diameter. In establishing anode beds for transmission pipelines, an attempt is usually made to place the anodes at remotes earth relative to the pipeline.

Remote earth in most soils can be minimum distance of 60 to 150 m (200 to 500 ft) from the pipeline [Linda Garveric ,1999]. The higher the resistivity of the indigenous soil, the farther the anode bed must be from the nearest point on the pipeline to at remote earth. A remote earth anode bed replacement is desirable because it is results in the maximum spread of protective current in each direction from an individual anode bed. On larger diameter (75 to 90 cm, or 30 to 36 in.) pipelines, corrosion can be controlled on 33 to 66 km (30 to 40 miles) of pipeline, assuming a reasonable satisfactory dielectric coating is in place. Remote anode beds are established in primarily two types of installations: surface anode beds and deep anode beds. Surface anode beds are typically installations in which a multiple number of cylindrical anodes 7.5 cm (3 in) in diameter 152 cm (60 in.) long are installed vertically to a depth of 4.55 m (15 ft) at 6m (20ft) centres [Linda Garveric ,1999] The individual anodes are connected in parallel to the positive –polarity output terminal of a suitably rated transformer-rectifier unit by an insulated anode head cable.Deep anode beds are often used where right of way, urban build up in the are, or soil resistivity conditions dictate their necessity. A deep anode is a vertical installation in which the individual anodes such as those described above are installed in a vertical array in a 20 cm (8in) hole drilled to a depth of 30 and 90m (100 to 300ft).

The intent with a deep anode is usually to attain a remote earth installation without the necessity of departing a long distance from the pipeline right of way to attaining a lower electrical resistance (greater operating efficiency) anode installation by placing the anodes in lower resistivity, subsurface soil horizons.

Where localized protection of discrete areas on a transmission pipeline is required, either properly sized galvanic anode arrays or distributed impressed-current anode systems are usually used. Distributed impressed current anode system consist of one or more cylindrical anodes installed relatively close to the pipeline (7 to 30m, or 25 to 100ft) such that a modest current discharge from each anode will couple to the exposed pipeline steel in its vicinity.

Cathodic protection distribution pipelines are accomplished with the same techniques and systems as those cited for transmission pipelines, that is galvanic anodes or impressed current system. However, the installation, surveillance, and maintenance of distribution pipelines cathodic protection system can be much more complex than with a transmission pipeline, which is simple buried, coated steel cylinder running between point A and B.

Distribution pipeline systems are often installed in a grid configuration conforming to the roadways fronting the individual structures that the system services. Whether urban or rural, they are usually in place in commercial areas, often under paved roadways and in close proximity to other buried piping and electrical and telephone system.

In addition distribution pipeline systems serve multiple delivery points, all of which require the installation and maintenance of electric isolation devices, which are often not in readily accessible locations, such as building basements. Failure or inadvertent short-circuiting of just one of electric isolation devices, out of total or perhaps hundred can render a well-designed CP system ineffective.

For this reason many distribution pipelines operators sectionalize their distribution pipeline systems into discrete areas of electrically continuous piping. This protect against the possibility of one short-circuited isolation device disabling a large portion of the CP system.

By virtue of the close proximity of a distribution piping system to adjacent buried metallic structures that may not be cathodically protected (for example, cast iron water or sewer systems), inadvertent contact to such systems can also disable an otherwise effectiveness CP system. In heavily trafficked urban areas, such contact can be extremely difficult to locate and clear. In addition, assessment of the continuing effectiveness of a distribution pipeline CP system through electrical test techniques is also difficult because the system is usually located under paved surfaces.

Despite all of difficulties cited above, distribution pipeline systems are protected against corrosion activity. System operators use both galvanic anode and impressed current systems. The most prevalent type of design is distributed anode type, often with galvanic anodes installed at specifics interval that are a function of the diameter of the pipeline. Impressed current system is also used but their typically higher operating voltages and protective current magnitudes; they are more susceptible to interference current effects from adjacent current buried metallic systems

Therefore, it is established that the transportation in transmission and distribution pipelines are fully protected as pipeline are generally designed with an expected minimum service life of 25 years. [Linda Garveric ,1999] However if we go through to he corrosion process that is occur in internal piping systems is insidious and all-embracing.

When the pipelines go to the customers pipelines system, sometimes the situation is not exactly same comparing to external system. The internal piping is exposed to various types of condition that involves with unexpected corrosion potential such as temperatures, pressure, environment humidity(sea area), the effect of pH and so on.

Dangerous things occur when the pipeline is not properly design to meets these type of corrosion potential as well as normally the gas piping for the equipment appliances are protected by simple paint coating. So a detail understanding should be proceed to attract public awareness of the real situation of corrosion that happen around them.

1.3   Objective

The aims of this research are to study the contribution of pH, temperatures, concentrations and dissolve gas in concrete aqueous solution to the corrosion rate of carbon steel pipe.

1.4   Scope

The scope of this research is to study the influence of pH, temperatures, concentrations and dissolve gas to the corrosion rate of carbon steel pipe and to compare the corrosion rate of carbon steel pipe in concrete aqueous solution (NaOH, KOH, $Ca(OH)_2$ and NaSCN)

CHAPTER 2

LITERATURE REVIEW

Corrosion manifests itself in forms that have certain similarities and therefore can be categorized into specific groups. However, many of these forms are not unique but involve mechanisms that have overlapping characteristics that may influence or control initiation or propagation of a specific type of corrosion. The most familiar and often used categorization of corrosion is probably the eight forms uniform attack, crevice corrosion, pitting, intergranular corrosion, selective leaching, erosion corrosion, stress corrosion, and hydrogen damage [M.G Fontana 1967].This classification of corrosion was based on visual characteristics of the morphology of attack. Other prominent corrosion have avoided classification format classical types corrosion (for example, pitting and crevice corrosion) as they relate specific metals and alloy [H.H Uhlig 1963] Substantial advances in the field of corrosion science have began to define the mechanism of many forms of corrosion more clearly. However, rather than placing the mechanisms into distinct categories, to overlap between many of the forms has become greater. For example there is evidence that hydrogen may dominate the crack initiation or crack propagation portion of fracture in some metal solution systems where stress corrosion cracking occurs.

Additionally, in some metal systems where dealloying (selective leaching) occurs, this form of corrosion may be precursor to stress corrosion cracking. In a similar vein, the magnitude of contribution of stress or corrosion to stress-corrosion cracking, hydrogen damage, or liquid metal embrittlement is not currently understood and can affect whether just pitting or crevice attack occurs or environmental cracking results. The transition from uniform corrosion to highly localized attack is not clearly understood, and there are condition where a distinction cannot be drawn. The forms of corrosions presented in this article were categorized to represent the mechanism of attack involve rather than to emphasize visual characteristics. However as with any classification system, these categories are not distinct or all-inclusive and do not necessarily represent the only mode attack that may be observed.

2.1   Corrosion Process

The corrosion of steel pipelines is an electrochemical process that requires a flow of electric current and several chemical reactions. The three essential components of a galvanic corrosion cell are:

    i.   Anode.

    ii.   Cathode.

    iii.   Electrolyte

The general relationship between the components of a corrosion cell is illustrated in figure 2. The anode and cathode can be on the same steel pipelines. Figure 3 illustrates a corrosion cell for a steel pipe embedded in concrete. The anode is the location on a steel pipe where corrosion is taking place and metal is being lost.[Hime, W. and Erlin, B.1987].

At the anode, iron atoms lose electrons to become iron ions (Fe+2). This oxidation reaction is referred to as the anodic reaction. The cathode is the location on a steel pipe where metal is not consumed. At the cathode, oxygen, in the presence of water, accepts electrons to form hydroxyl ions (OH-). This reduction reaction is referred to as the cathodic reaction.

The electrolyte is the medium that facilitates the flow of electrons (electric current) between the anode and the cathode. Concrete, when exposed to wet-dry cycles, has sufficient conductivity to serve as an electrolyte.
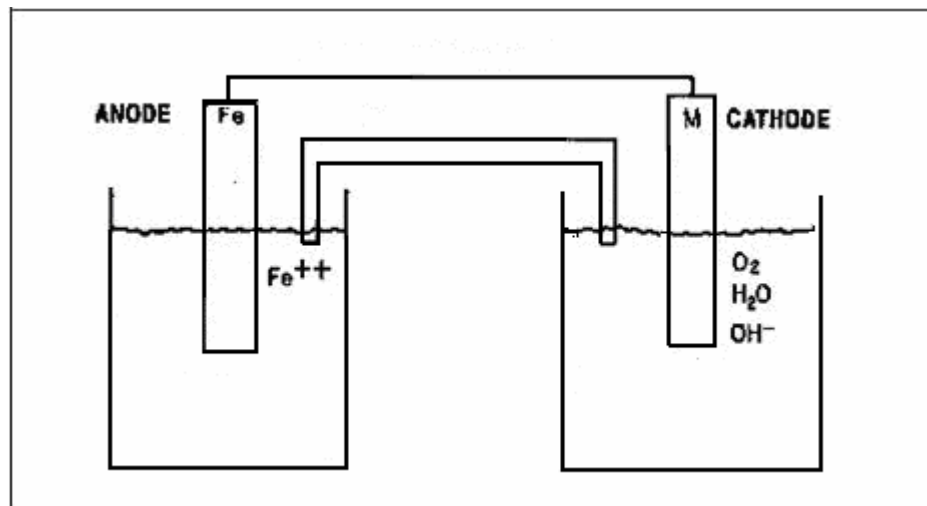

Figure 2. Electrochemical corrosion cell.

Both the anodic and cathodic reactions are necessary for the corrosion process to occur and they need to take place concurrently. The anode and cathode can be located next to each other or can be separated. When they are located immediately next to each other, i.e., on a microscopic scale, the resulting corrosion cell is referred to as a microcell. When they are separated by some finite distance, the resulting corrosion cell is referred to as a macrocell. Figure 4 shows examples of a microcell and a macrocell [Holm, J. 1987]. The corrosion of steel pipe embedded in concrete may be due to a combination of microcells and macrocells.
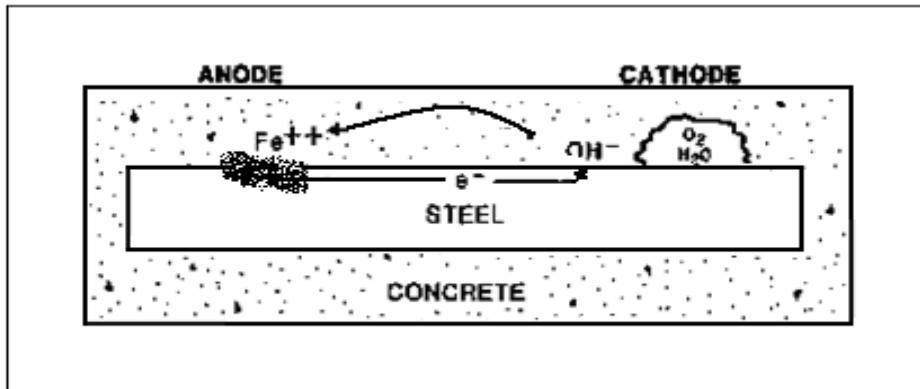
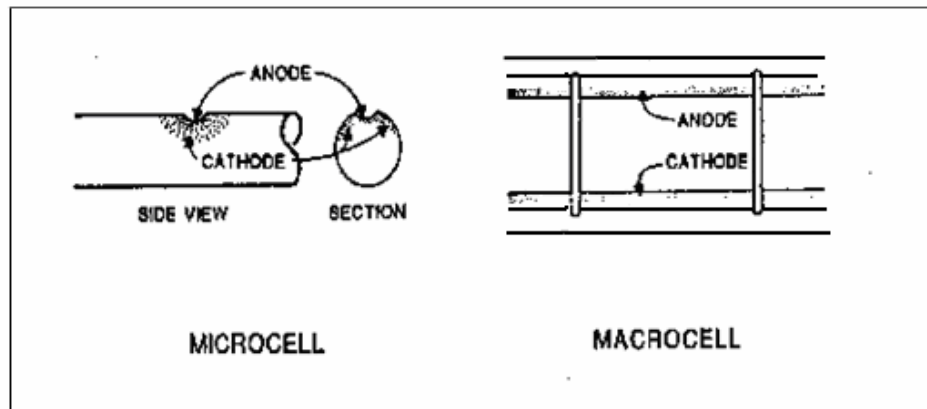Figure 3. Corrosion cell in concrete.

Figure 4. Microcell versus macrocell corrosion

The initiation and continuation of the corrosion process are controlled by the environment in concrete surrounding the steel pipe. The distribution of chlorides in a concrete is not uniform. The chlorides typically enter the concrete from the top surface. The top mat of reinforcing steel is then exposed to higher concentrations of chlorides. The chlorides shift the potential of the top mat to a more negative (anodic) value. Since the potential of the bottom mat has a more positive (cathodic) value, the resulting difference in potentials sets up a galvanic type of corrosion cell called a macrocell. An electric circuit is established. The concrete serves as the electrolyte, and wire ties, metal chair supports, and steel pipe serve as metallic conductors as shown by Figure 5 [Holm, J. 1987]. Likewise, the concentration of chlorides at the top mat is not uniform along the length of the steel pipe due to the heterogeneity of the concrete and uneven de-icer application. These differences in chloride concentrations establish anodes and cathodes on individual steel pipes in the top mat and result in the formation of microcells. Concrete is alkaline due to the presence of $Ca(OH)_2$, KOH, and NaOH and has an alkalinity typically between pH 12 and 13. The concrete pore solution consists primarily of KOH and NaOH. Due to the high alkalinity of the concrete pore water, the steel pipe are passivated by an iron oxide film (Fe_2O_3) that protects the steel (figure 6) [Hime, W. and Erlin, B.1987]. The oxide film itself is a product of the initial corrosion of the steel pipe. In the initial stages of corrosion, a ferrous hydroxide ($Fe(OH)_2$)compound is formed. Ferrous hydroxide has low solubility and, in the presence of oxygen and water, is oxidized to iron oxide (Fe_2O_3) to form the passivation film. As the film is being formed, the oxygen diffusion rate is reduced, which, in turn, reduces the corrosion rate.
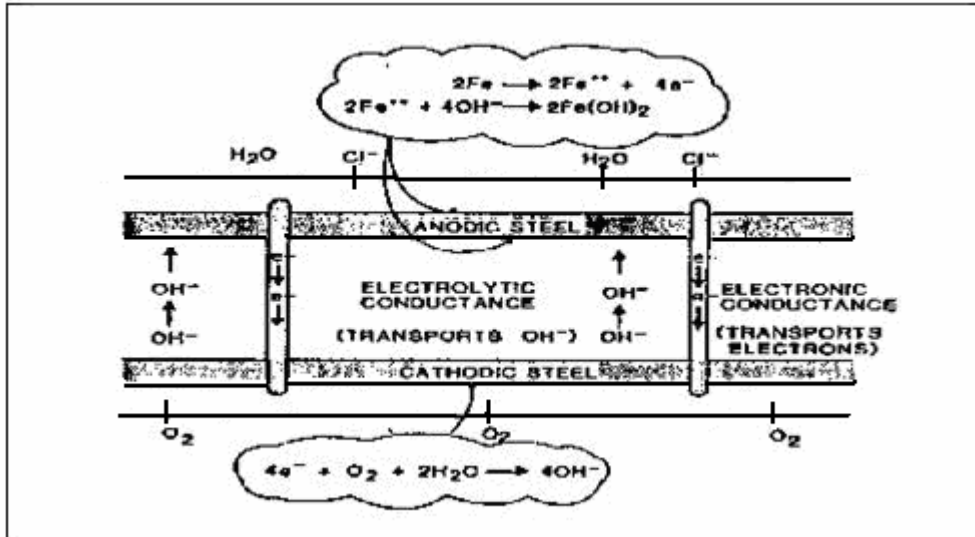
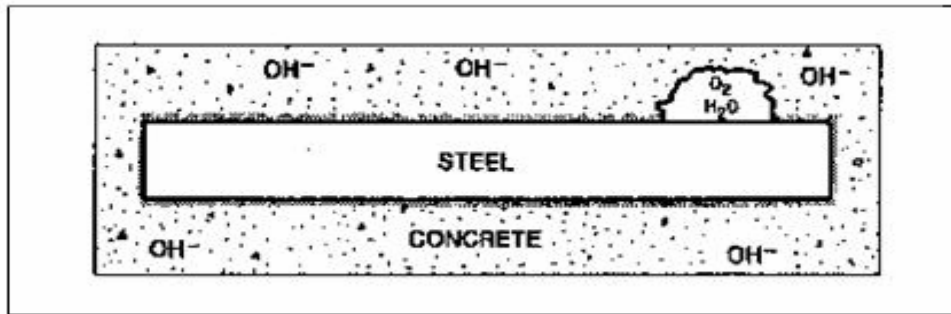Figure 5. Electrolytic corrosion of reinforcement in concrete exposed to chloride and moisture.

Figure 6. Passivated steel in concrete