Al-Khwarizmi Engineering Journal, Vol. 10, No. 2, P.P. 65- 74 (2014)

Al-Khwarizmi Engineering Journal

Corrosion control of Buried Low Carbon Steel Structure by Using Alteration Medias method

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(Received 1 September 2013; accepted 15 April 2014)

Abstract

The aim of the present work is to control of metal buried corrosion by alteration the media method. This method depended on the characteristics of each media. The corrosion rates in different media (soil, sand, porcelanite stone and gravel) for specimens of low carbon steel were measured by two methods weight loss method and polarization method, weight loss measured by buried specimens in these medias separately for 90 days. The polarization method includes preparing of specimen and salt solutions have electrical resistivity equivalent electrical resistivity of these media. The corrosion rate of two method results in (soil > sand> porcelainte stone> gravel). The lower corrosion rate happened in gravel media because of characteristics of high electrical resistivity and lower porosity for gravel while the higher corrosion rate occurred in the soil.

Keywords: *Low carbon steel, corrosion rate, medias, electrical resistivity, soil, sand, porcelanite media, gravel.*

1. Introduction

The study of soil as a corrosive medium is important taking into account the large amount of buried structures .The deterioration of that kind of structures could represent economic, safety, and environmental problems through the years. Soil as defined is an aggregate of minerals, organic matter, water, and gases (mostly air). It is formed by the combined weathering action of wind and water, and also organic decay [1]. Then the corrosion process of buried metal structure is extremely variable and can range from rapid to negligible [2]. The corrosiveness of the soil can be defined as the capacity of producing and developing the corrosion phenomenon. Soil is defined as an electrolyte and can be studied by electrochemical methods [3]. The factors effects of corrosive in soil included:

- Electrical resistivity
- Porosity
- Dissolved salts including depolarizes or inhibitors
- Moisture
- pH.

Each of these variables may affect the anodic and cathodic polarization characteristics of a metal in a soil [4]. Soil electrical resistivity is an important parameter in underground corrosion In general, the lower the resistivity, the higher the corrosion rate as shown in (Table 1).

Table1,
Corrosivity rating based on soil resistivity [1].

Soil resistivity Ω.cm	Corrosion rating
>20,000	Essentially noncorrosive
10,000-20,000	Mildly corrosive
5000-10,000	Moderately corrosive
3000-5000	Corrosive
1000-3000	High corrosive
<1000	Extremely corrosive

Ions from dissolved salts and minerals must migrate through the electrolyte in a soil to supply the metal surface with the electron donors or acceptors necessary for the corrosion reaction to proceed. Soil resistivity is a measure of the concentration of these ions and how easily they move through the soil environment [6]. Metals buried in low resistivity soils will generally be anodic, whereas metals buried in adjacent high resistivity soils will generally be cathode .While the completely free of water has an extremely high resistivity. For example, sandy soils that easily drain water away are typically noncorrosive; clayey soils that hold water have low resistivity and are typically corrosive.

Alteration soil one method of corrosion control soil high in organic acids can be made less corrosive by surrounding the metal structure with limestone chips. A layer of chalk ($CaCO_3$) surrounding buried pipes has been used in some soil formations likely to produce microbiologically influenced corrosion [4]. The resistivity indicates the probable corrosivity of the soil decreases with increasing water contents ions, thus nonporous soils. Exhibit relatively high value of resistance, since the water content is small; these include nearly all of the igneous and metamorphic rocks such as granite, plus much sedimentary rock such as dense limestone or sandstone. The resistivity of bedrock can vary considerably depending upon the type of bedrock and extent of weathering and fracturing .The resistivity of the sand and gravel deposits generally high and uniform, while many bedrock formations have high but erratic resistivity or in the other word Clay soils and shale layers generally have low resistivity values resulting from their inherent moisture and mineral content. Very dry sand, gravel or rock has a very high resistance. As empty pore space fills the water, resistivity decreases. Materials that lack pore space such as massive limestone, granite, and basalt have high resistivity. All other factors being constant, the degree to which crack and fissure are present controls the resistivity of rock [2].In (Table 2) typical resistivity values minerals and soils are given.

2. Experimental Work

Corrosion rate was measured for specimen of low carbon steel in four different media (soil, sand, porcelanite stone and gravel). (Table 3) shows the chemical composition of the low carbon steel. The specimen prepared for corrosion and microstructure test included grinding, polishing, etching and examination processes. (Fig. 1) shows the microstructure of low carbon steel before it was buried in different media.

Methods of measuring the corrosion rate:

1. Weight loss: In these method specimens was buried in (soil, sand, porcelanite stone and gravel) separately for 90days. The corrosion rate (CR), was calculated using the following formula:

$$CR= \Delta W/ AT \qquad \ldots(1)$$

CR: Corrosion rate in mdd.
Δ W: weight loss in milligrams.
A: Exposed surface area in dcm^2.
T: time exposure in days.

The conversion of corrosion rate in units milepenetration per years (mpy) by following relationship [7]:

$$C.R\ (mpy) =(1.44/S.G)C.R\ (mdd) \qquad \ldots(2)$$

Where:
mpy: corrosion rate unit (mils penetration per year)
S.G: specific density of metal (for steel =7. 9 mg/cm^3).

2. Electrochemical techniques called polarization method this method is carried and consisting with an instrument of an electrochemical cell. The electrochemical cell contain three electrodes immersed in the solution ,working electrode (WE) which represents the studied sample ,reference electrode (calomel) and an auxiliary (platinum) electrode, the cell is connected to a device ,which allows the changing in current range and measuring the output potential as a function of current ,at which the input and output data are controlled by computer program .the applied current is a linear function potential.

The corrosion of metal in soil depends upon its resistivity. Electrochemical polarization methods are used for measuring corrosion rate using three solutions of resistivity of **(**20, 10000, 20000) Ω.cm, (20Ω.cm) for soil measurement by use device (soil box resistivity and DET5/4D Megger Digital Earth Tester) shown in (Fig. 2), (10000Ω.cm) for sand and porcelanite, and 20000 for gravel [2],

Table (4) represents the equivalent values of the resistivity of this media depending on the standard value with varying the concentration of NaCl as shown in (Table 4) .The electrical conductivity of the solution was measured using digital electrical conductivity meter model (DDS-307) which is shown in (Fig. 3).

Table 2,
Electrical resistivity of various minerals and soil [2].

Minerals and Soil	Resistivity , Ω.cm
Minerals	
Pyrite	0.1
Magnetite	0.6-1.0
Graphite	0.03
Rock Salt(impure)	3000-500 000
Serpentine	20 000
Igneoue Rock	
Granite	500 000-100 000
Diorite	1 000 000
Gabbro	10 000 000-1 400 000 000
Diabase	310 000
Metamorphic Rocks	
Garnet gneiss	20 000 000
Mica chist	130 000
Biotite gneiss	100 000 000 -600 000 000
Slate	64 000 -6 500 000
Sedimentary Rock	
Chattanooga Shale	2000-130 000
Michingan Shale	200 000
Calumet and hecla conglomerates	200 000-1 300 000
Muschelkalk sandstone	7000
Ferruginous sandstone	18 000
Muschelkalk limestone	18 000
Marl	7000
Glacial till	50 000
Type of Soil	
sand	10 000- 500 000
oil sand	400 – 22 000
Gravel	20 000 – 400 000
Loam	3000- 20 000
Clay	500 -2000
Silt	1000 -2000

Table 3,
The chemical composition of the specimen.

Alloy %	C	Si	Mn	Fe
Component	0.16	0.15	0.7	Reme.

Table 4,
Equivalence of resistivity by NaCl concentration.

NaCl content g\L	Concentration %	Resistivity Ω.cm	Conductivity (μΩ/cm)
.30	3	20	50 000
0.04	0.004	10000	100
0.0187	0.00187	20000	50

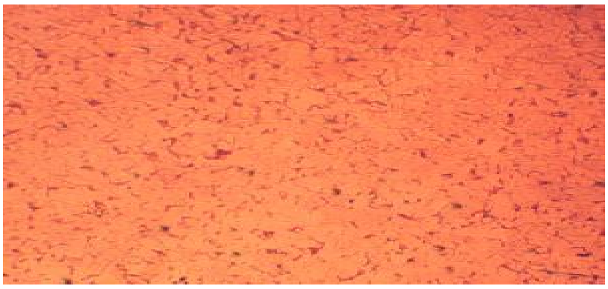

Fig.1. the microstructure of surface of low carbon steel specimen before it was buried in different media (200X).

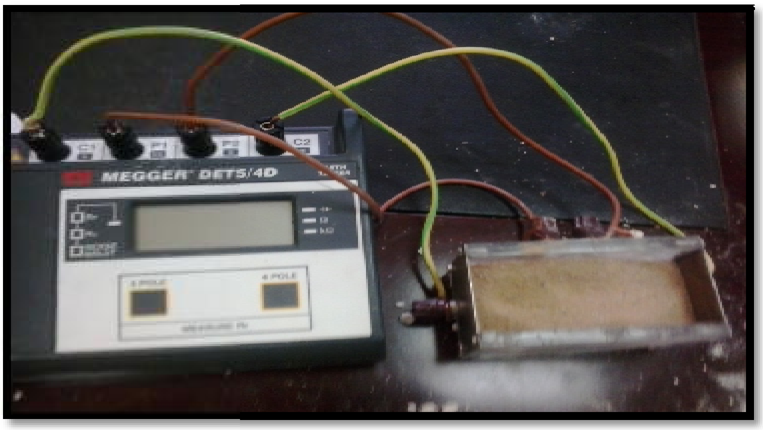

Fig. 2. Devices connected and the experiment of electrical resistivity measurement.

Fig.3. Digital electrical conductivity meter.

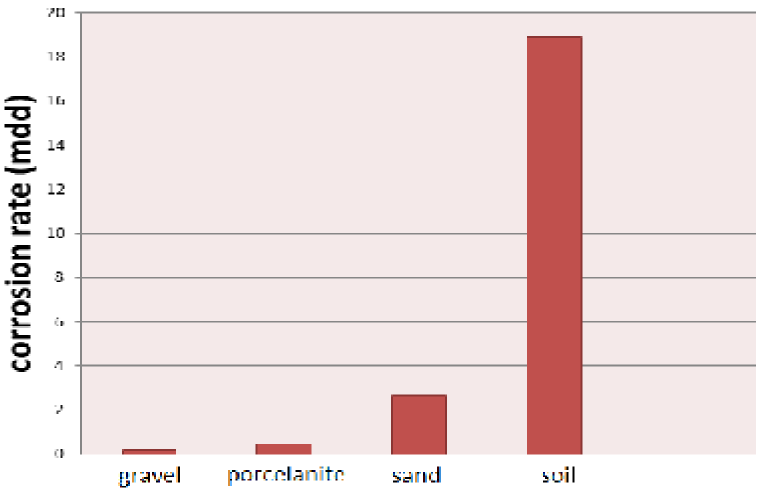

Fig.4. Shows corrosion rates of low carbon steel in different media the buried for 90 days.

Table 5,
Corrosion rates (mdd) and (mpy) for low carbon steel specimen at different medias.

Media	Corrosion rate (mdd)	Corrosion rate (mpy)
Soil	18.93628	3.4516
Sand	2.6717933	0.4870
Porcelanite stone	0.516	0.094055
Gravel	0.2231	0.040666

Table 6,
The corrosion rate of specimen of low carbon steel by polarization method.

Resistivity (Ω. cm)	Corrosion potential E_{corr} (mV)	Corrosion current density i_{corr} (μA/cm^2)	Corrosion rate (mpy)
20	-450.1	199.21	83.592
10000	-330.9	14.38	6.03413
20000	-268	13.16	5.522

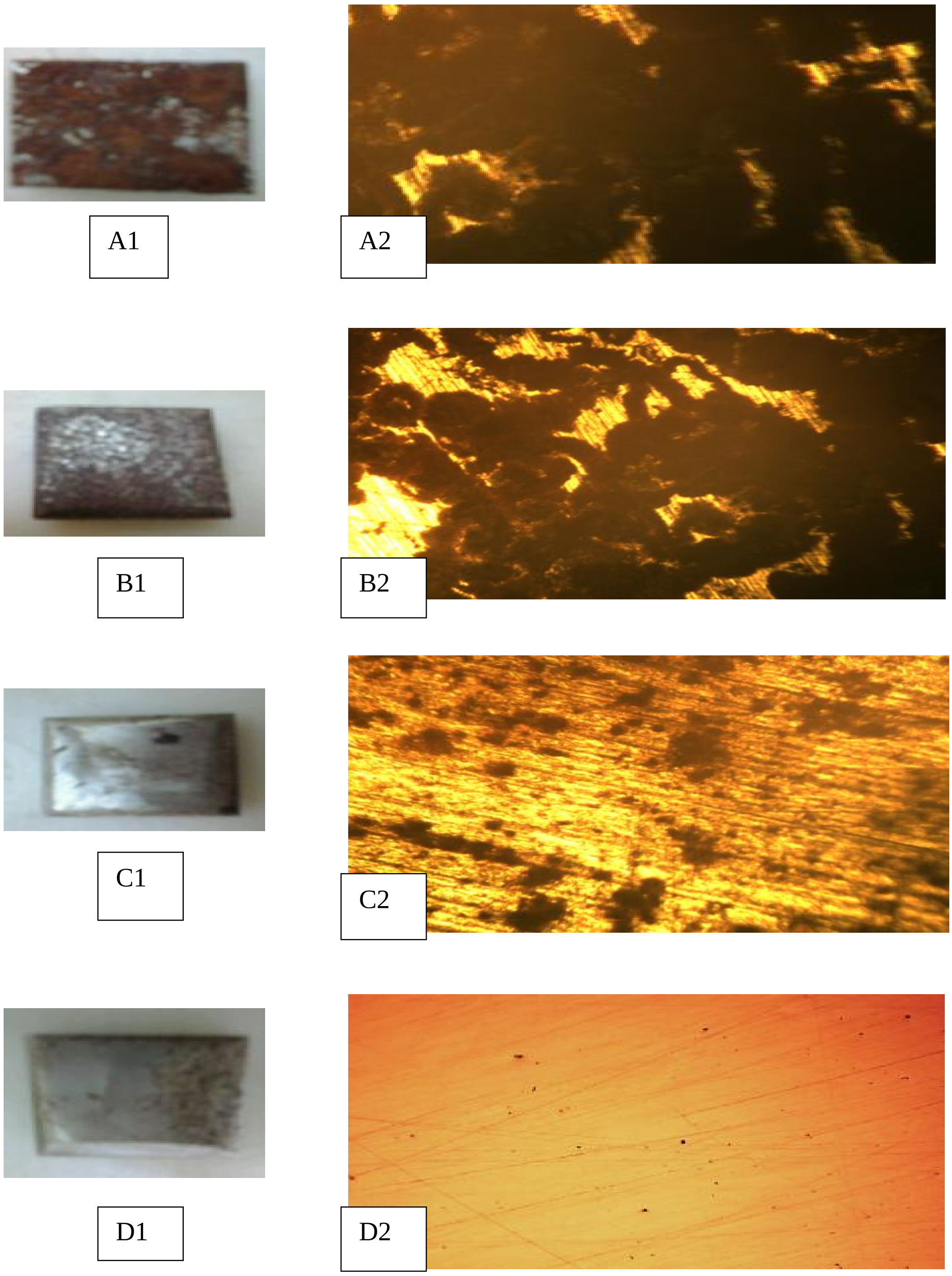

Fig. 5. (A_1, A2), (B1, B2), (C1, C2)and (D1, D2) photographs and the microstructure of the surface specimens buried in soil, sand, porcelanite and gravel respectively (200X).

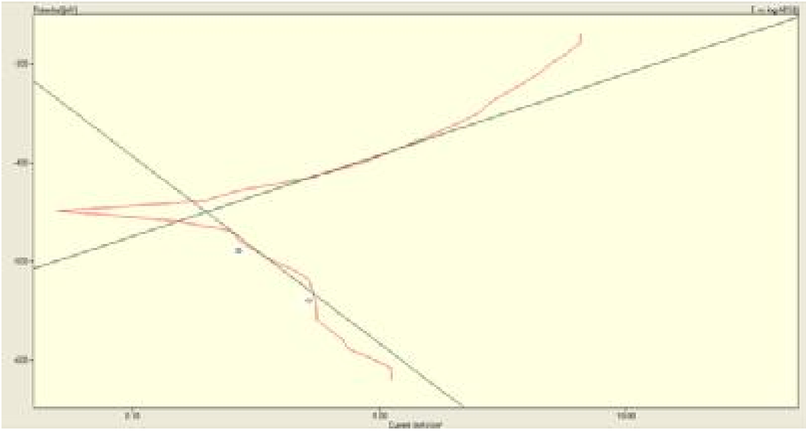

Fig. 6. Polarization curve of specimen of low carbon test in solution with electrical resistivity (20 Ω. cm).

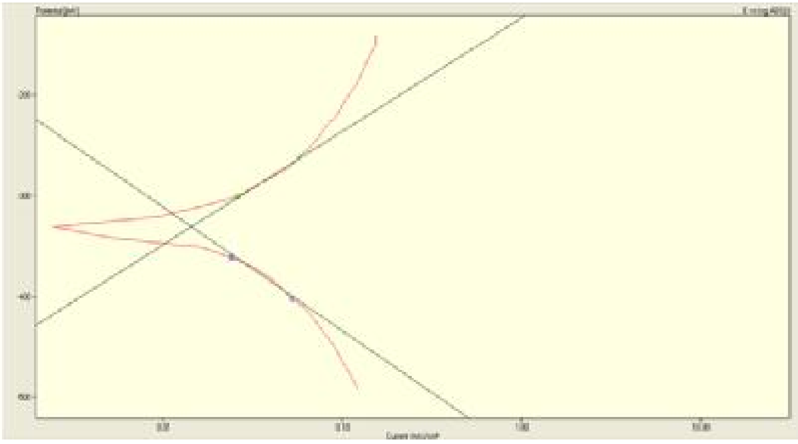

Fig.7. Polarization curve for specimen of low carbon steel in solution with electrical resistivity (10000 Ω. cm).

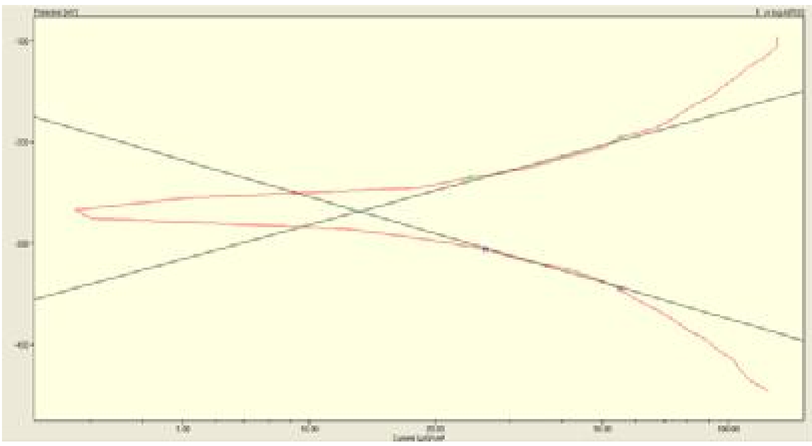

Fig.8. Polarization curve for specimen of low carbon steel in solution with electrical resistivity (20000 Ω. cm).

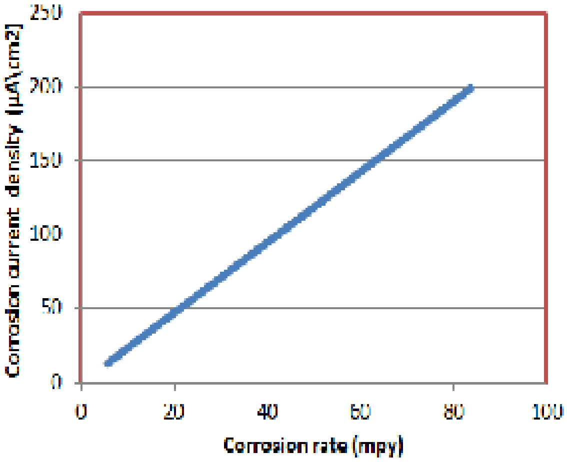

Fig.9. The relationship between corrosion rate and current density.

3. Results and Discussion

(Fig .4) and (Table 5) represents the corrosion rate of low carbon steel specimens in different media (soil ,sand ,porcelanite stone and gravel) calculated by weight loss (first method) , specimens buried in this media for 90 days. Note that the corrosion rates in (soil> sand >porcelanite stone> gravel), are the highest corrosion rates occurring in the soil and the less the corrosion rate occur in gravel because the highest electrical resistivity.

(Fig.5) shows the photographs and the microstructure of the surface of low carbon steel specimens after buried in different media. So the corrosion on surface of specimen buried in soil and sand can be observed, the corrosion product seen here is rust, surface color was dark orange to brown. Those areas that are dark in color contain significant sediment on the surface as shown in (Fig. 5) at (A 1, A2) and (B1, B2).The corrosion product on surface of specimen buried in porcelanite stone and gravel show very low , surface color ranging light orange to dark orange, and the rust is not uniform as shown in Figure (5) at (C1,C2)and (D1,D2).

Calculation of corrosion rates by the second method (polarization method) using three solutions with different electrical resistivity (20,10000,20000) Ω.cm repesenting the electrical resistivity of (soil, sand and porcelanite stone ,gravel) respectively. The solution resistances are very low as would be the case with a specimen having a high corrosion rate ,the effect of the solution resistance may be a significant portion of the corrosion current reading , where corrosion rate can by determined be the following relationship [8]:

Corrosion rate (mpy) = $0.13 * i_{Corr.}\ e/D$ …(3)

Where :
i_{corr}: Corrosion current density µA/cm^2
e :Equivalent weight (for steel= 25.5)
D :Density of metal(for steel = 7.9 gm/cm$^{3)}$

The polarization gave us values corrosion potential (E_{corr}) y-axis and corrosion current density (i_{corr}) x-axis as shows in (Table 6) and (Fig. (6), (7), (8)). The result higher corrosion current density (i_{corr}) at low electrical resistivity values (20Ω.cm) this indicates the high corrosion rate , while lower corrosion current density (i_{corr}) in high electrical resistivity solution (20000Ω.cm) indicates the lower corrosion rate. Results show a propotional relationship of corrosion rate with current density, but inversily proportional with resistivity, this is due to the reduction of water content, the density increases (soil,sand,porcelanite and gravel) which reflects at the values of resistivities.In (Fig. 9) shows relationship between corrosion rate and corrosion current density .

Show presenceis a difference in the rate of corrosion between two methods corrosion rate higher in polarization method than weight loss the reason , The corrosion behavior of iron and steel buried in the soil approximates , in some respects, the behavior of the iron and steel on total immersion in water [4]. When soil resistivity value (> 20,000Ω.cm) essentially noncorrosive [1], This point different corrosion between soil and water, very pure or very soft waters are often excellent solvents for metallic ions. If these waters are very pure or very soft waters are often excellent solvents for metallic ions [9].

Rates corrosion in media depended on the characteristics of the media buried metal structure , Many factors affected of corrosion rate, important factor affected electrical resistivity and porosity . Lower corrosion rate in media with high electrical resistivity and less porosity (more dense) .Than gravel of these four media is best media protect from corrosion .

4. Conclusions

1. Corrosion rates of structure metal buried in media depend on the characteristics of this media (electrical resistivity , porosity, hydraulic permeability which describes how pores are interconnected, etc.).
2. Electrical resistivity of media is important factor effect on corrosion rate for metal buried in it.
3. Select best media for buried metal structure with low corrosion rate. Sand , porcelainte stone and gravel have best corrosion resistance compared to soil.
4. Gravel is the best media with higher corrosion resistance.

5. Reference

[1] Roberge P.R, "Handbook of Corrosion Engineering", McGraw-Hill,USA 2000**.**

[2] Robert Baboian,"Corrosion Test and Standards: Application and Interpretation", Second Edition, ASTM Stock Number: MN120-20nd, 2005.

[3] Córdoba V. C., Mejía M. A., Echeverría F., Morales M. and Calderón J. A. ,"Corrosion mitigation of buried structures by soils modification", Chilean Journal of Engineering, vol. 19,No.3,pp486-497, 2011.

[4] Winston R. R., Herbert U. H., ‘’Corrosion and Corrosion Control’’, Fourth Edition, USA, 2006.

[5] M. Romanoff, “Underground Corrosion,” NBS 579, NTIS PB 168,350, National Bureau of Standards, April 1957.

[6] 6.“Standard Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method,” G 57, Annual Book of ASTM Standards, American Society for Testing and Materials, 1995.

[7] Naser Korde," Cathodic Protection of Steel Pipelines Using Solar Energy", MSc Thesis, Department of Production Engineering and Metallurgy, University of Technology, 2012.

[8] Formerly EFM, Engineering Filed Handbook, Engineering Field Manual Notice NB-21, 1979.

[9] ASM Handbook, “Corrosion Fundamentals, Testing, and Protection”, Vol .13A, ASM,2003.

حمايه التأكل للفولاذ الكاربوني المدفون بوساطة تغير الوسط

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الخلاصة

الهدف من هذا العمل هو السيطرة على تأكل المعدن المدفون بطريقة استبدال أوساط،وهذه الطريقة تعتمدعلى خصائص كل وسط . حيث حسبت معدلات التأكل لعينات من فولاذ منخفض الكاربون في اوساط مختلفة واختيار افضل وسط حامي من التأكل والأوساط تشمل (التربة،الرمل،صخر البورسلينات والحصى) . حسبت معدلات التأكل بطريقتين طريقة فقدان الوزن وطريقة الاستقطاب ،قيس فقدان الوزن بدفن العينات في كل وسط من هذه الاوساط لمده (٩٠يوماً) وطريقة ألاستقطاب تضمنت تحضير محاليل ملحية تملك مقاوميات كهربائية مكافئة للأوساط المستخدمه وحساب معدلات التأكل في هذه المحاليل .اظهرت نتائج معدلات التأكل على نحو التالي(التربة> الرمل > صخر البورسلينات>الحصى).اقل معدلات تأكل حصلت للعينات المدفونة في الحصى بسب خصاص هذا الوسط من مقاومية كهربائية عالية ومسامية قليلة واقل معدلات تأكل حدثت للعينات المدفونة في التربة.