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EFFECT OF ORGANIC COATING ON MILD STEEL CORROSION OF REINFORCED CONCERT IN SOME GYPSEOUS IRAQI SOILS

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ABSTRACT:- The present work studies the effect of different types of gypseous Iraqi soils on the corrosion rate of embedded steel in mortar, and studies the effect of coated steel and concrete on the corrosion rate. Three different types of soils were used, which were collected from different locations in Iraq, (Falluja, Kirkuk and Najif) and hydrated gypsum was also used.

Three types of organic coatings were used. Red and black oxides were used for coating the steel and asphalted bitumen for coating the mortar (concrete).

This study shows that the corrosion potential is shifted to more positive direction (more noble) for the coated steel and mortar than the un-coated steel and mortar, whereas the corrosion current for the coated steel and mortar is lower than the un- coated steel and mortar. Kirkuk soil solution is lower corrosive than the Falluja soil solution, the later is lower corrosive than Najaf soil solution and the gypsum is the most corrosive. The expected time to visible deterioration of uncoated structures is more than ten years with Falluja and Kirkuk soils, whereas it is between 3-10 years with Gypsum and Najaf soils.

Keywords:- gypseous Iraqi soils, embedded steel, mortar, organic coating.

INTRODUCTION

Attack and disintegration of concrete structures under the influence of aggressive fluids, , etc, were widely understood as the corrosion of concrete[(1)].The destructive attack by materials which come into external contact with the concrete is the main cause for its corrosion[(2)]. A soil corrosion is complex phenomenon with a multitude of effective variables involved. The chemical reactions involving almost each of the existing elements are known to take place in soils, many of which are not yet full understood[3]

A geological or soil type map can be examined for evidence of the presence of sulfate rocks in the subsoil , and this will suggest a danger of concrete corrosion[4] .

The response of mild steel to soil corrosion depends primarily on the nature of the soil and certain other environmental factors, such as availability of moisture and oxygen. These factors can lead to extreme variations in the rate of attack[4].

The effect of aeration on soils is different from the effect of aeration in water, because poorly aerated conditions in water can lead to accelerated attack by sulfate-reducing anaerobic bacteria[4][5].Corrosion resistance of steel in concrete would remain indefinite in usual atmospheric exposure if the concrete cover could exclude air and water from the embedded reinforcement when the cover is too thin or porous. Corrosive damage to concrete results primarily from access of water solutions containing dissolved oxygen [6]. There are many ways can be used to reduce the corrosion rate of steel in concrete, such as coating steel with different types of pigment and by coating concrete with asphalted film.[7].

MATERIALS

Reinforcement concrete (mortar core mixes) were prepared according to the ratio, cement: sand (1: 3) by weight with 3/8 inch (9.52 mm) diameter of embedded mild steel. After the core was dried well for (48) hr, immersed in tap water for (28) days to reach its 80 percent of its strength according to Iraqi standards.[8] The core was finally immersed in prepared aggressive solutions. The solutions use in this study contained:

A) Hydrate calcium sulfate $CaSO_4.2H_2O$ (gypsum) concentration of 6% (the solubility of gypsum in water 0.2 mg/100 ml water).

B) Different gypseous soils (Kirkuk , Falluja and Najaf) with concentration of 6% (20gm of soil with 100ml distilled water, concentration of soil approximately 26% gypsum).

METHODS

Electrochemical measurements were conducted in these solutions. Anodic and cathodic polarization curves were recorded potentiostatically. Potentiostatic measurement are made using power supply (potentiostate) to supply Current as shown in fig. 1 .The electrical circuit consisted of the following;

a-DC power supply

b-Resistor box is used to get constant current density.

c-Digital multimeter is used to read voltage and current.

For the cathodic polarization the potential was measured by change about 50 mV(maximum) after equilibrium time, the mean of the potential was recorded when it reach the steady state, and also record the current in μA. Then the connection of the power supply was inversed and the polarization points began in anodic direction by changing the potential in the positive direction 50 mV (maximum).

The experiments were done at temperature 28 °C and atmospheric pressure using three electrodes(5) which is the standard laboratory apparatus for the quantitative investigation of corrosion cell, (1) working electrode: is the name given to the electrode being investigated ,we used the term mortar as a "working electrode".(2) auxiliary electrode(c0unter electrode): must be made of materials that are inert to the electrolyte. Platinum is often the choice but we used carbon electrode in this study as an "auxiliary electrode".(3) reference electrode: is placed outside the cell, and the potential of the working electrode is measured through the luggin probe and solution bridge with respect to the reference electrode. We used saturated calomel electrode (SCE) as "reference electrode".

When active corrosion is taking place the log of the applied current density is plotted versus the potential differences of the test electrode a way from a reference electrode; the corrosion current of a metal may be estimated. The corrosion current had been used to calculate the corrosion rate using Faradays law.

RESULTS AND DISCUSSION

Polarization measurements

The type of polarization in our study is activation polarization because we have anodic and cathodic polarization.

Table 1 indicated the E_{corr} (corrosion potential) of the five samples used with and without protection specimens mortar after (120) days of immersion as shown.

This table shows that the Falluja soil solution is less negative potential than the other soil solutions, because of chemical composition for each soil, sulfate content, chloride content and organic material component (appendix 1 and 2) .The extent of concrete corrosion depends primarily on the properties of the external medium, the quality of soils in contact with water, mineralogical composition, temperature, velocity of flowing ground water, and its pressure etc.

Typical polarization curves are presented in Fig. 2 -Fig. 5.

These figures indicate that the value of current for coated steel is lower than the corresponding value of un-coated steel that means the corrosion rate of coated steel is lower than the corrosion rate of un-coated steel .Furthermore, the corrosion potential of coated was shifted to more positive (noble) direction. Best protective result found for steel coated with red oxide and concrete protected with asphalt.

Fig. 6 shows the polarization curves for un–coated specimens in different types of soil solutions , hydrated gypsum , Najaf , Falluja , Kirkuk and tap water .It indicates that tap water is less corrosives than the other solutions with lower value of current this because the sulfate content has great effect on the value of potential and the corrosion rate.

CORROSION CURRENT

Corrosion current data was determined by using Stern and Geary [9,10] equation , this equation has been used successfully for determine the corrosion rates of various metals in several aqueous environments at ordinary or evaluated temperatures,

Current from Stern and Geary equation is given in appendix 3.

The result is shown in table 2**. :**

Table 2. shows that the experimental values of i_{corr} ($\mu A / cm^{2}$) for un-coated and coated specimens, in hydrated gypsum solution have the highest value, and the corrosion rate of un–coated steel embedded in mortar is lower in Kirkuk soil compared to thither tested soils because the Kirkuk soil has higher clay content (appendix 2) which prevents oxygen to reach the steel.

Also it can be seen from table (2) that:

1- Corrosion rate of steel coated with red oxide is less than corrosion rate of steel coated with black oxide.

2- Corrosion rate of steel coated with red oxide and asphalt has the lowest value.

Table 3 indicates the time required to visible deterioration of steel with different corrosion rate[11,12].

When the result given in table 2 is compared with that listed in table 3, the lifes of visible deterioration for structures canbe expected as shown in table 4.

Table 4 indicates that Kirkuk soil and Falluja soil have good resistance against corrosion of embedded steel in mortar than the Najaf and hydrated gypsum solutions for longer time to visible deterioration required for its low corrosion rate after (120) days of exposure time.

This result can be related to difference physical properties (grain size, porosity, permeability, pH) . Chemical analysis of Falluja soil indicated that the calcite content ($CaCO_3$) is more than that in the other soils which increase alkalinity. This is helpful to reduce the attack to the mortar (concrete). Najaf soil has the most chloride content which increases the corrosion rate besides its high sulfate content.

CONCLUSIONS

The following conclusions can be observed from the results obtained in this study

1. The Iraqi gypsies' soils are: The hydrated gypseous solution is the most corrosive than the other soils solutions (Najaf , KirkuK and Falluja) for its lowest corrosion potential and highest corrosion rate. Kirkuk soil solution is lower corrosive than the Falluja soil solution. Falluja soil solution is lower corrosive than the Najaf soil solution**..**
2. The coating of mild steel only with organic pigment shifted the electrochemical potential to more positive direction, and decreases the corrosion currents. The coating of mortar only with asphalt shifted the electrochemical potential to the positive direction, and decreases the corrosion currents .The coating of mild steel with organic pigment and coating the concrete with asphalt gives better results, shifting the electrochemical potential to more positive direction, and decrease the corrosion currents considerably.
3. The expected time to visible deterioration of uncoated structures is more than ten years with Falluja and Kirkuk soils, whereas it is between 3-10 years with Gypsum and Najaf .

REFERENCES

1- Imre Biczok, "Concrete Corrosion, Concrete Protection", Chemical Publishing Co. Inc, 1977 .

2- K . Diertert , "Corrosion of Building Materials" , Van Nostrand Reinhold Company, 1975 .

3- Hubert W. ," Durability of Concrete Construction" , American Concrete Institute Detrot , Michigan, The Iowa State University Press, Ames ,Iowa, 1968 .

4- www . Concorr . corn *1* about CONCORR . htm ,WWW. Corrosion - doctors .0rg/Books/Handbook.htm . "Concrete Corrosion Specialists" 1 Research and Testing, 4/1212003 .

5- Denny A. J., Principles and Prevention of Corrosion. Maxwell Macmillan, New York, 1992, p. 568.

6- Shreier , L.L , " Corrosion Control" , Corrosion Volume2 Newness- Butter Worth, London, Boston ,1976 -

7- Hoar, T.P. and T. W. Farrert , "The anodic Characteristics of mild steel in dilute aqueous soil electrolytes", journal of corrosion Science, vol. 1 pp 49- 61,U.K 1961 .

8- الخلف مؤيد نوري،هناء عبد،" تكنولوجيا الخرسانة" الجامعة التكنولوجية-قسم هندسة البناء والإنشاءات، بغداد- 1984

9- Uhlig, H. H., Corrosion and Corrosion Control, John Wiley & Sons Inc., New York, 1985, p 291

10- Fontana, M. G. and N. D. Green, Corrosion Engineering. 3rd Edition, McGraw-Hill Co., New York, 1985, p. 480

11- www. Construction Chemical. Htd , Degussa , Protectosil® CIT , 2003 .Steel Reinforced concrete - corrosion of the Reinforcing Steel . htm , Paul Lambert , Source : abstracted from Corrosion Protection , Association Monograph , 2003

12- www.Corrosion of metals, The University of Edinburgh.htm, Division of engineering, Material science and engineering, session 2001-2002.

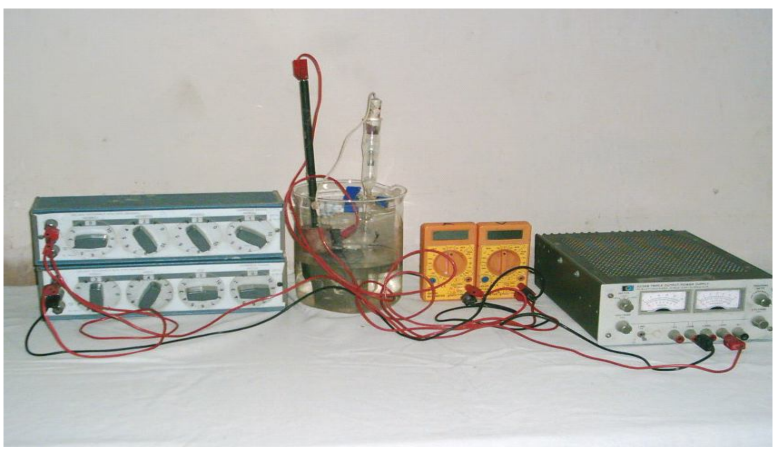

Fig.(1): The polarization- cell potentostatic measurement.

Table (1): The values of corrosion potentials (mV) of embedded steel in mortar at different soil solutions and coatings after 120 day.

	Mortar With un-Coated Steel E_{corr} (mV)	Mortar Coated with Asphalt E_{corr} (mV)	Mortar With steel Coated with Black oxide E_{corr} (mV)	Mortar With steel Coated with Red oxide E_{corr} (mV)	Steel Coated with black oxide and mortar coated with asphalt E_{corr} (mV)	Steel Coated with red oxide and mortar coated with asphalt E_{corr} (mV)
Gypsum	- 607	- 487	- 406	- 578	- 210	- 288
Najaf	-590	-370	-398	-365	-286	-250
Falluja	-500	-221	-276	-309	-111	-120
Kirkuk	-580	-510	-360	-295	-197	-171
Tap wter	-359	-----------	-----------	-----------	-----------	-----------

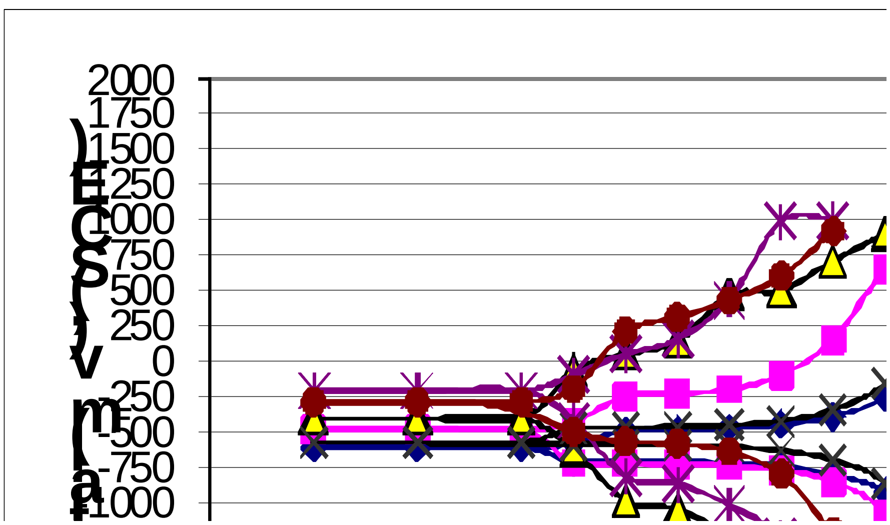

Fig. (2): The anodic and cathodic polarization curves of uncoated and coated embedded steel in mortar immersed into hydrated gypsum solution for (120) days.

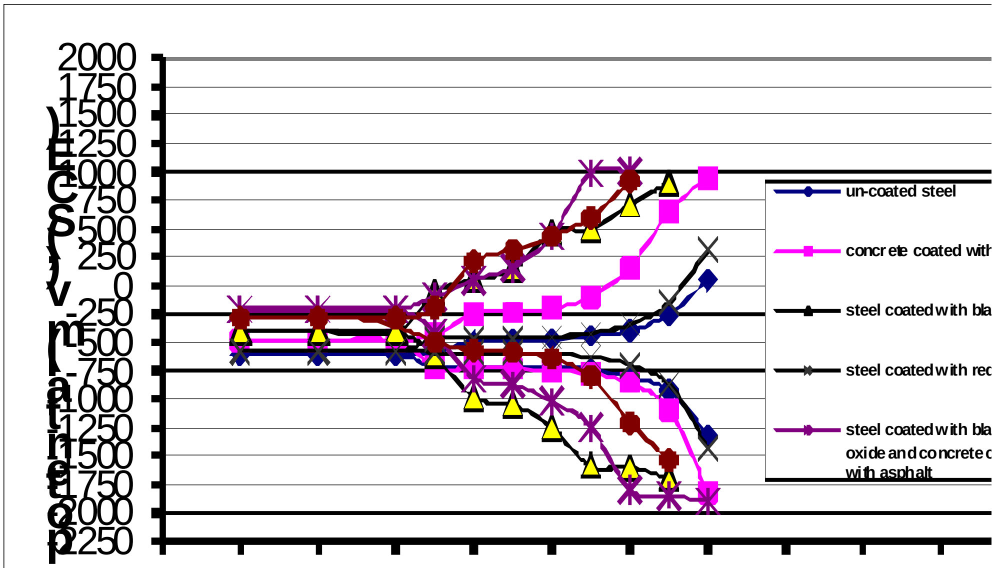

Fig.(3): The anodic and cathodic polarization curves of uncoated and coated embedded steel in mortar immersed into Najaf soil solution for (120) days .

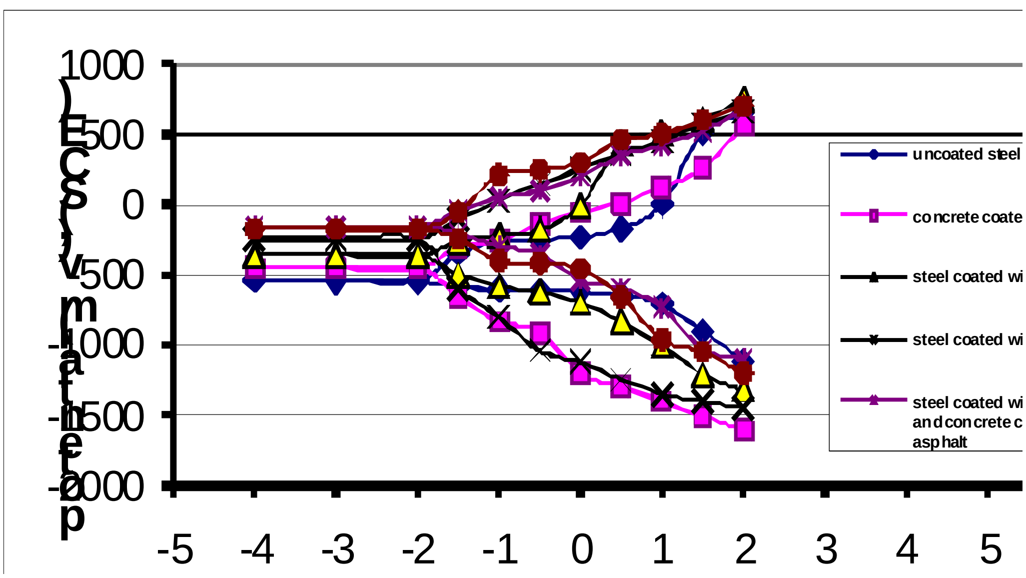

Fig.(4): The anodic and cathodic polarization curves of uncoated and coated embedded steel in mortar immersed into kirkuk soil solution for (120)days.

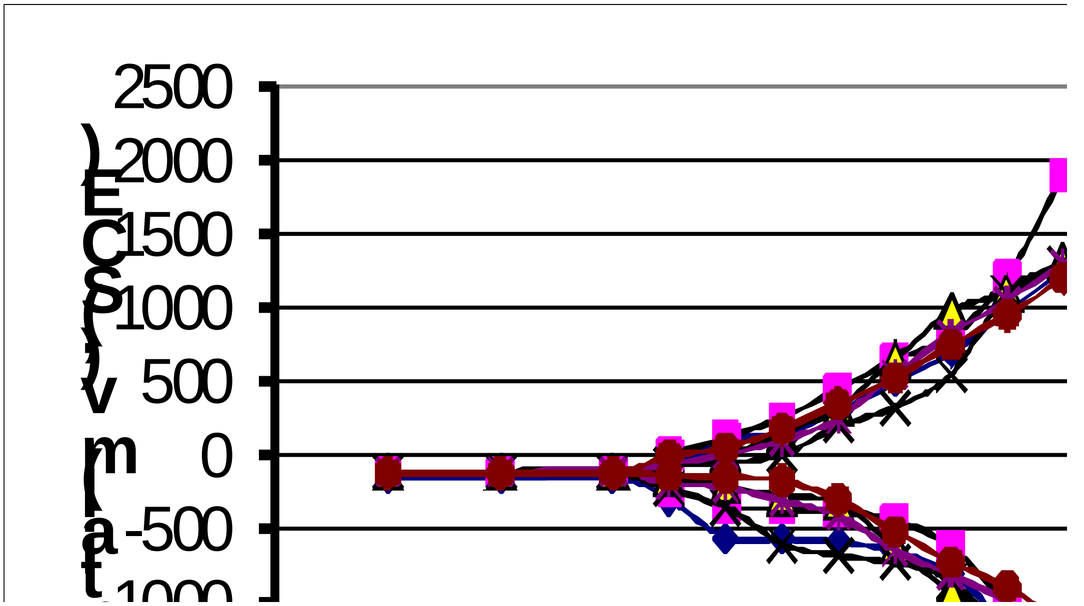

Fig. (5): The anodic and cathodic polarization curves of uncoated and coated embedded steel in mortar immersed into Falluja soil solution for (120)days.

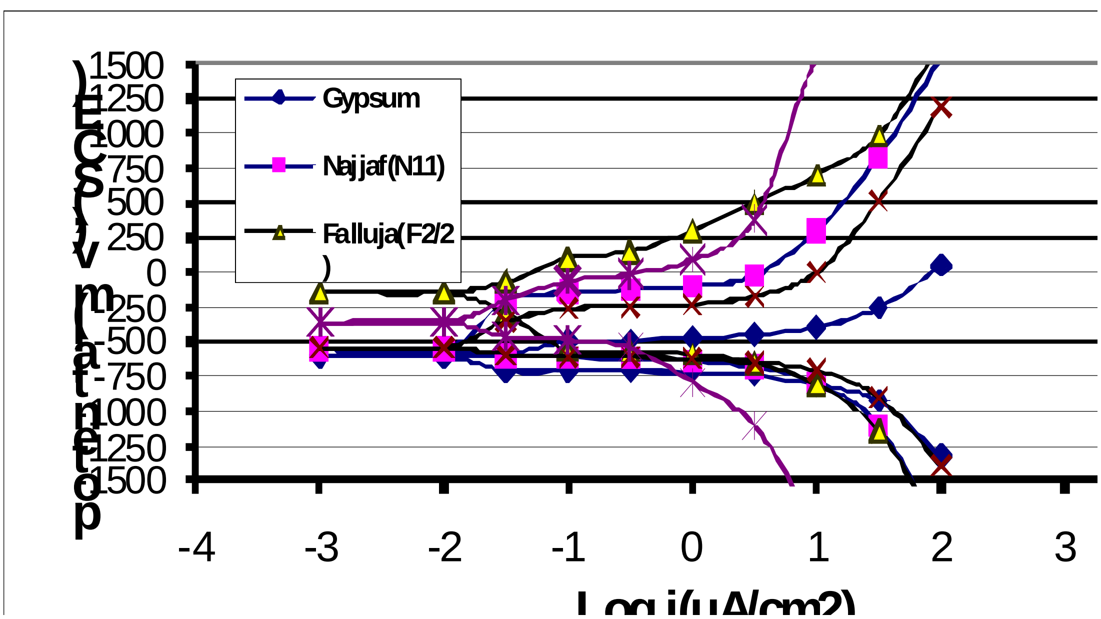

Fig. (6): The anodic and cathodic polarization curves of uncoated embedded steel in mortar immersed in five different solutions for (120) days.

Table (2): The corrosion current for embedded steel in mortar immersed in different soils solutions for (120) days of..

	Mortar with uncoated steel i_{corr} ($\mu A/cm^2$)	Mortar coated with asphalt i_{corr} ($\mu A/cm^2$)	Mortar with steel coated with black oxide i_{corr} ($\mu A/cm^2$)	Mortar with steel coated with red oxide i_{corr} ($\mu A/cm^2$)	Mortar with steel coated with black oxide and with asphalt i_{corr} ($\mu A/cm^2$)	Mortar with steel coated with red oxide and with asphalt i_{corr} ($\mu A/cm^2$)
Gypsum	0.623	0.437	0.380	0.368	0.290	0.137
Najaf	0.535	0.245	0.313	0.224	0.118	0.128
Falluja	0.378	0.222	0.248	0.236	0	0
Kirkuk	0.256	0.157	0.144	0.135	0.035	0.0036

Table (3): The effect of contact time on corrosion rate to visible deterioration as indicated in construction chemicals/degussa[11,12]

Corrosion rate $\mu A/cm^2$	Corrosion level	Time to visible Deterioration
< 0,2	Passive conditions	-
0,2- 0,5	Low corrosion	> 10 years
0,5 – 1,0	Moderate corrosion	3 – 10 years
> 1,0	High corrosion	< 2 years

Table (4): The expected time to visible deterioration of uncoated structures established in different soils.

Soil	Corrosion rate/$\mu A/cm^2$	Time
Gypsum	0.623	3 – 10 years
Najaf	0.535	3 – 10 year
Falluja	0.378	> 10 years
Kirkuk	0.256	> 10 years

Appendix (1)

Chemical analysis of gypsum soils *

Soils	%SO_3	%CaO	%CL	%CO_3	%NO_2	%MgO	pH	%Organic Material
Falluja	11.6	8.2	0.177	0.24	0.06	0.08	6.6	0.11
Kirkuk	22.6	24.36	0.088			1.0	7.5	0.14
Najjaf	23.8	16.68	0.177	0.18	0.18	0.04	6.5	0.122

***** The test had been done in the State Company of Geological Survey and Mining.

Appendix (2)

The grain size of soil used in experimental work*

Soils	Clay %	Silt %	Sand %
Falluja	14	15	61
Kirkuk	29	21	50
Najjaf	-	3.2	84.6

* The test had been done in the State Company of Geological Survey and Mining

For Falluja the samples were taken near the cement factory (500M) far from the street (0.5M) depth.

For Kurkuk the samples were taken from Civil Engineering department of Baghdad-University.

For Najjaf The samples were taken from Mefraq Al-Kafel(depth 0.5M-1M).

Appendix (3)

$\Delta E/\Delta i_{app.} = ba\ bc/2.303\ i_{corr}\,(ba+bc)$ [10,11] (1)

Where ba and bc=anodic and cathodic Tafel slopes.

$\Delta E/\Delta i_{app.}$ =polarization slope in the region near the corrosion potential for which the change of $\Delta E/\Delta i_{app.}$ is essentially linear.[9] .

$ba=RT/\alpha ZF$

$bc=RT/\alpha ZF$

R= Gas constant =8.314 KJ/kmole k

T=Temperature in K =301 K

α = Tafel constant =Symmetry coefficient =0.5 for Fe

Z= Number of electrons =2

F= Faradays constant= 96500 coulombs/mole

ba = bc =2.303×8.314×303/0.5×2×96500

ba = bc =0.06 V

=60 m

$$B = \frac{babc}{2.303(ba + bc)}$$

$$= \frac{60x60}{2.303(60 + 60)}$$

B=13 mV/decade

From equation (1):

$$i_{corr} = \frac{13}{\Delta E l i_{app}} \quad (2)$$

$\Delta E/i_{app}$ can be calculated from anodic and cathodic curves at E_{corr}

Then calculate i_{corr} from equation (2).

تأكل حديد التسليح في الكونكريت المسلح في بعض الترب الجبسية العراقية

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الخلاصة

يهدف البحث إلى دراسة تأثير الترب الجبسية العراقية على تأكل حديد التسليح في الكونكريت ودراسة تأثير تغطية أو طلاء الحديد والكونكريت على سرعة التآكل.استخدمت ثلاث أنواع مختلفة من الترب والتي جمعت من مواقع مختلفة من العراق وهي الفلوجة ، كركوك،والنجف وكذلك الجبس المائي.لقد تم استخدام أنواع مختلفة من نماذج محاليل الترب ولنماذج مختلفة من الكونكريت المسلح.

استخدمت ثلاثة أنواع من الإصباغ العضوية للتغطية وهي الاوكسيد الأحمر والاوكسيد الأسود لتغطية حديد التسليح والإسفلت لتغطية الكونكريت. وتم التوصل إلى النتائج التالية:

زيادة جهد التآكل (corrosion potential) للحديد والكونكريت المغطى إلى الاتجاه الأكثر موجبيه (nobel) قياسا لجهد التآكل للحديد والكونكريت بدون تغطية، ونقصان تيار التآكل (corrosion current) للحديد والكونكريت المغطى بالنسبة لتيار التآكل للحديد والكونكريت بدون تغطية.إضافة إلى إن محلول تربة كركوك أقل تأكليه من محلول تربة الفلوجة والأخير أقل تأكليه من محلول تربة النجف بينما الجبس المائي أكثر تأكليه .كما ان الزمن المتوقع لانهيار الحديد بدون تغطية يكون اكثر من 10 سنوات بالنسبة لترب الفلوجة وكركوك بينما يكون الزمن بين 3-10 سنوات بالنسبة لمحلول الجبس وتربة النجف .