

## Effect Use of Two Chemical Compounds Sodium Nitrate and Sodium Silicate as Corrosion Inhibitor to Steel Reinforcement

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#### Abstract

Corrosion of steel reinforcement is one of the biggest problems facing all countries in the world like bridges in the beach area and marine constructions which lead to study these problems and apply some economical solutions. According to the high cost of repair for these constructions, were studied the effect of using kind of chemical compounds sodium nitrite(NaNO<sub>2</sub>) and sodium silicate(Na<sub>2</sub>SiO<sub>3</sub>) as corrosion inhibitors admixture for steel bars that immersed partially in electrolyte solution (water + sodium chloride in 3% conc.) (Approximately similar to the concentration of salt in sea water). The two inhibitors above added each one to the electrolyte solution at concentrations (0.5%, 1% and 2%) for both of them.

The results were corrosion rate for steel sample that's immersed partially in salt solution was higher than corrosion rate of steel bar that's immersed partially in electrolyte solution with inhibitors also the two corrosion inhibitors (sodium nitrite and sodium silicate) that added to the electrolyte solution were working successfully to prevent and inhibit the corrosion by using weight loss technique with best percent of 0.5% sodium nitrite ( efficiency 94.1\% ) and best percent of 2% sodium silicate ( efficiency 92.5\%).

Keywords: Steel bar, Electrolyte solution, Corrosion, Inhibitors.

#### 1. Introduction

Corrosion is the deterioration of a metal by chemical or electrochemical reaction with the surrounding environment [1]. Steel in concrete is generally in a non-corroding, passive state. But, steel reinforced concrete is used in quick environments such as sea water. When chloride moves through the concrete, it damage the passive layer protecting the steel, causing it to rust and hole[2] as show in Figure (1). The two main reasons of corrosion of the steel in reinforced concrete are chloride attack and carbonation. These mechanisms are uncommon in that they do not attack the safety of the concrete. Instead of aggressive chemical species express into the pores in the concrete and aggression the steel. This is unlike normal deterioration processes cause chemical attack within concrete. Other acids and aggressive ions like sulphate destroy the safety of the concrete prior the steel is affected [3].



Fig. 1. The corrosion damage namely localized corrosion [2].

Corrosion also affects to mechanical properties of the steel such as reduce the steel elongation at maximum load, affecting the structure ductility. The composite of concrete and steel in a concrete structure is depending the bond between them, and this is affected by corrosion into the several mechanisms:

(a) Increasing of stresses due to pressure from rust, occurring concrete cracking,

(b) Change of main properties of the interface reinforced concrete-steel.

(c) The corrosion of stirrups [2].

Among the several methods to corrosion of metal surface, the corrosion inhibitor method is a useful method on the industry because give the best protection from corrosion with low cost [4][5][6].

Inhibitors had one of best method consent in the manufacture because it excellent anticorrosive .However, several showed up as other effects, than this harm the environment. Thus the scientific community began searching for friendly environmentally inhibitors, like the using organic inhibitors [7][8][9].

Corrosion inhibitor is a great effective to reduction the corrosion rate by added small percent of chemical compound (inhibitors) to an aggressive environment [10].

The corrosion inhibitors types can be chemicals, synthetica, natural; the inhibitors classified depended to many inhibitory factors such as:

• The chemical kind of the inhibitors as (organic or inorganic).

• The mechanism of activity such as (anodic, cathodic or anodic-cathodic mix)

• Oxidants or do not oxidants.

Anodic inhibitors (passivation inhibitors) action to decrease anodic reaction, the anode reaction and backing the natural reaction of passivation metal surface, with to the formulation a thin layer adsorbed on the metal surface. Generally, the inhibitors interact with the rust (corrosion product), initially formed, resulting in a consistent and insoluble layer on the metal surface [10].

The anodic inhibitors interact with metallic ions  $Me^{n+}$  produced on the anode, forming generally, insoluble hydroxides film which are deposited on to metal surface as indissoluble thin layer to metallic ion. From the hydrolysis of inhibitors results in  $OH^{-1}$  ions. As shown in Figure (2) the mechanism of the anodic inhibitory effect.



Fig. 2. Figure shows the mechanism of the anodic inhibitor effect.

#### 2. Experimental Part

To study the effect of the use of inhibitors on the corrosion steel reinforcement in the media of an effective corrosion in order to measure the corrosion rate in the steel reinforcement. The media of the concrete replacing the prepared solution consists of (water + NaCl 3%) (Approximately similar to the concentration of salt in sea water) the two materials were used sodium nitrite (NaNO<sub>2</sub>) and sodium silicate (Na<sub>2</sub>SiO<sub>3</sub>) with concentration (0.5%, 1%, 2%) to the electrolytic solution, the iron samples have length (10 cm) and diameter (10 mm) that partially immersion in this solutions following details :

Sample1 (S1): steel sample immersion in prepared solution.

Sample2 (S2): steel sample immersion in (prepared solution +0.5%).

Sample3 (S3): steel sample immersion in (prepared solution) +(1%NaNO<sub>2</sub>)..

Sample 4(S4): steel sample immersion in (prepared solution) +  $(2\%NaNO_2)$ .

Sample 5(S5): steel sample immersion in (prepared solution) +  $(0.5\%Na_2SiO_3)$ .

Sample6 (S6): steel sample immersion in (prepared solution) +  $(1\% Na_2SiO_3)$ .

Sample 7 (S7): steel sample immersion in (prepared solution) +  $(2\% \text{ Na}_2\text{SiO}_3)$ .

#### Samples preparing:

The specimen prepared for corrosion included cutting steel to circular specimens with diameter (10mm) to length (10 cm) cleaned specimens by grinding and polishing. The area of cylinder specimen measured (33 cm<sup>2</sup>) by following law: Cylinder area =  $2\pi r^2 + 2\pi rL$  .... (1) Where

r =radius of specimen

L= length of specimen

Weights of samples of steel accurately and record the date and time of immersion to calculating the amount of weight loss for each samples by recording the weights after immersion every seven days. The samples immersion in electrolytic solutions for 48 days.

#### Measuring of corrosion rate:

Weight loss: In these method specimens were immersion in solutions (S1,S2,S3,S4,S5,S6,S7) for 48days. The corrosion rate CR, was calculated using the following formula:

CR= 
$$\Delta$$
 W/ AT ....(2)  
CR: Corrosion rate in mdd.  
 $\Delta$ W: weight loss in milligrams.  
A: Exposed surface area in dcm<sup>2</sup>.  
T: time exposure in days.  
The conversion of corrosion rate in units' mile  
penetration per years (mpy) by following  
relationship [7]:  
C.R (mpy) =(1.44/S.G)C.R (mdd) ...(3)  
Where:  
mpy: corrosion rate unit (mils penetration per  
year)  
S.G: specific density of metal (for steel =7.9  
mg/cm<sup>3</sup>).

#### **Inhibitors Efficiency**

The efficiency of an inhibitor can be calculated by using this formula  $E(\%)=100\frac{CR_{uninhibited} + CR(inhibited)}{CR_{uninhibited}} \dots (4)$ Where E: Inhibitor efficiency

 $\ensuremath{\mathsf{CR}}\xspace$  uninhibited :Corrosion rate of the uninhibited system.

CR inhibited :Corrosion rate of the inhibited system.

#### 3. Results and Discussion

(Table1) represent the corrosion rate of carbon steel specimens in different solutions (electrolyte) calculated by weight loss specimens immersing in these solutions for 48 days. Note that the corrosion rates in (S1) is the highest corrosion rates occurring because don't add inhibiter and the less the corrosion rate occur in (S2) with higher efficiency (94.1%) with 0.5% NaNO<sub>2</sub>.

#### Table 1,

Corrosion rate and inhibitor efficiency of samples in Electrolyte solutions

sample	Corrosion rate (mdd)	Corrosion rate (mpy)	Inhibitor efficiency (%)
S1	384.7	70.1	
S2	22.62	4.12	94.1%
<b>S</b> 3	28.704	5.52	92.5%
S4	30.296	5.6	92.1%
S5	35.735	6.5	90%
S6	29.857	5.44	92.22%
S7	28.637	5.20	92.5%

(Fig.3) represents the rate of corrosion of carbon steel specimens in different solutions (electrolyte) contain (NaNO<sub>2</sub>) inhibiter calculated by weight loss specimens. Show the best percent to inhibiter add in (S2) Contain (0.5% NaNO<sub>2</sub>) but when increases the NaNO<sub>2</sub> percent the corrosion rate increasing too.

The concentrations of inhibitor percent becomes high suitable, the cathodic current density at the initial passivation potential turn off higher than the critical anodic current density, the metal is becomes passivated [11]. For the anodic inhibitors effect, it is so important that the inhibitor concentrations percent must be high enough in the solution. The wrong amount of the inhibitors affects the consistence of layer protection, because it will not all covered the metal, leaving pits of the metal uncover, so causing a localized corrosion [11].



Fig. 3. Show corrosion rate of steel in solution with different concentrations percentages of (NaNO<sub>2</sub>).

Figure 4 represents the rate of corrosion of carbon steel specimens in different solutions (electrolyte) contain  $(Na_2SiO_3)$ inhibiter calculated by weight loss specimens .Show the best percent to inhibiter add in (S7) Contain $(Na_2SiO_3 2\%)$ 

The corrosion rate happened in (S7, S6) classified to mildly corrosive at percents (1%, 2%) of Na<sub>2</sub>SiO<sub>3</sub>, but the corrosion rate happened in (S5) classified to moderately corrosive at percent (0.5%) Na<sub>2</sub>SiO<sub>3</sub> depended to Table (2). The Concentrations below to the critical value are inappropriate than without use inhibitors at all. generally cause pitting, with reduction at the anodic area relative to cathodic, or can accelerate corrosion process, like generalized corrosion, due to full slump the passivity [12].



Fig. 4. Show corrosion rate of steel in solution with different concentrations percentages of (NaSiO<sub>3</sub>).

Table	2,							
Degre	e of	cor	ros	sively	ra	ting	[12].	
~				1		2		

<b>Corrosion rate (mpy)</b>	Corrosive degree
1>	Essentially noncorrosive
5-1	Mildly corrosive
20-5	Moderately corrosive
50-20	Corrosive
200-50	High corrosive
+200	Extremely corrosive

Figure (5) represents the inhibitors efficiency for samples show the higher in [S2: steel sample immersion in water contain (3%NaCl) + $(0.5\%\text{NaNO}_2)$ ] and the lower in [(S5):steel sample immersion in water contain (3%NaCl) + $+(0.5\%\text{Na}_2\text{SiO}_3)$ ].



Fig. 5 .Inhibitors efficiency.

#### 4. Conclusions

- The corrosion inhibitors method have many advantages as the best method of corrosion protection, easy to use and apply in wide range of sectors.
- Maximum inhibitory activity for was obtained for (0.5% NaNO2).
- Maximum inhibitory activity for was obtained for (2% Na2SiO3).
- Inhibitive action as assumed due to oxidation of Fe+2 ion form Fe2O3 on the surface in near neutral.

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# تأثير استخدام نوعين من المركبات الكيمائية نتريد الصوديوم و سيليكات الصوديوم مثبطات التنفي المركبات التقام التقا

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#### الخلاصة

يعد تأكل حديد تسليح المباني من المشاكلات الكبيرة التي تعاني منها العديد من البلدان العالم كما في جسور المناطق الساحلية والمنشأت البحرية مما يستوجب در اسة هذه المشكلة وتطبيق بعض الحلول المناسبة اقتصاديا. ونظرا للكلفة العالية لترميم هذه المنشأت واصلاحها تناول البحث استخدام مادتي نتريد الصوديوم وسليكات الصوديوم مواد مثبطه لتأكل حديد التسليح المغمور جزئيا في المحلول الالكتروليتي مكون من (ماء+ ملح كلوريد الصوديوم بالتركيز ٣%) (مقارب للنسبة الاملاح في مياه البحر) حيث اضيفت المادتين منفصلتين الى المحلول الالكتروليتي مكون من (ماء+ ملح كلوريد الصوديوم منهما. وقد اظهرت النتائج ما يلي: معدل التأكل حديد التسليح المغمور جزئيا في المحلول الالكتروليتي بالتركيزات (٥,٠ %,١ %,٢ %) لكل منهما. وقد اظهرت النتائج ما يلي: معدل التأكل لنموذج حديد التسليح المغمور جزئيا بالمحلول الملحي كانت اعلى من معدالات التأكل للنماذج الحديدية المغمورة جزيئا في المحالي الالكتروليته الحاوية على المأبط، كما عملت المادتين منفصلتين الى المحلول الملحي كانت اعلى من معدالات التأكل للنماذج الحديدية المغمورة جزيئا في المحاليل الالكتروليته الحاوية على المثبط، كما عملت المادتان اعلاه على تتبيط واضح لتأكل حديد التسليح المغمور معلي اعلاه على تثبيط واضح لتأكل للنماذج الحديدية المغمورة جزيئا في المحاليل الالكتروليته الحاوية على المثبط، كما عملت المادتان اعلاه على تثبيط واضح لتأكل حديد التسليح حيث تم قباس معدل التأكل بطريقة الفقدان بالوزن وكانت افضل نسبة اضافة نترات الصوديوم هي (٥,٠ %) وبكفاءة مقدارها (٩٤, ٣) وافضل نسبة اضافه مادة سليكات الصوديوم (٢ %) وبكفاءة (٥, ٩ %).