Studies on The Steel Reinforcement Performance in Presence of NaCl: Effects of Salt Concentration and Temperature

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Sabah hatam obaid[1], JabbarAbbs Jaber[2], Hadi Raheem Ibrahim[3]

[1, 2, 3]Al-Mussaib Technical Institute, Al-Furat Al-Awsat Technical University, 51009 Babylon, Iraq
Email: inm.sbh@atu.edu.iq[1], inm.jbr@atu.edu.iq[2], inm.hadi@atu.edu.iq[3]

Abstract. The present study is to evaluate the performance of steel reinforcement under NaCl concentration chloride exposure. The loss of weight, yield stress and ultimate stress were tested to evaluate the performance of steel reinforcement before and after exposure. The exposure was also repeated under a variable temperature of (50, 60 and 70 C^0). The steel was treated to improve its properties by using hardening in the oxy-acetylene torch, epoxy coating and aluminium spread coating. Results showed that the reduction in reinforcement properties was reduced significantly by using the hardening method and the maximum reduction in the performance of steel reinforcement was in the higher temperature chloride exposure. The increasing of concentration (0.1, 0.2, 0.3 and 0.4 NaCl %) was due to high corrosion in steel wire. The results showed that the treatment of reinforcement was significantly improved.

Keywords: Steel reinforcement, the loss of weight, the treatment of reinforcement

1. Introduction

Most metals are extracted from raw material by applying a specific amount of energy, and according to the second law of thermodynamics, where the last state is returning to lowest probable level of energy i.e. union form that is called corrosion process [1]. The corrosion occurs in the surface metal that is exposed to atmospher. The Process is accompanied by a reduction in the metallic thickness and mechanical properties [2]. The corrosion leads to impair metallic material and neutralize from its function.To eliminator prevent this state and maintain the performance of the materials, two ways can be achieved: Using cheap alloys with corrosion inhibitors using a high coast alloy which did not trend to erode [3].

The corrosion depends on the atmospheric type that surrounds with the metal part and oxygen amount available with the water vapour and amount of salt in the soil in which metal parts are submerged [4]. There are different types of corrosion: corrosion due to dissimilar metal corrosion, corrosion due to differential aeration cells, corrosion due to metal oxide cells corrosion, corrosion due to deferential stresses cells, corrosion due to differential, concentration of salts, and corrosion due to stray current as well as atmospheric corrosion [5]. For all types of corrosion mentioned above Oxygen, Water vapour and salt solution must be present for process occurrence to protect metallic material from corrosion. The first way is by the approach depending on isolation of the metallic part from corrosion of atmosphere by coating it with a temporary layer organically or inorganically sustainable ormetallic. The second way is by electrochemical approach that depends on the application of anodic or cathodic protection or protection by

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sacrifice. The third way is by approach depending on inhibitors of erosion processes by adding materials to erosion surrounding to reduce corrosion rate. These approaches contribute to anodic and cathodic interactions, therefore they are called "anodic and catholic inhibitors, and there are inhibitors of adsorption [6].

2. Methodology

2.1 Preparation of specimens and the procedure of testing

To achieve the aim of this study, Fourteen samples of Ukrainian steel were tested to measure their yield and ultimate stress according to the (ASTM). The samples were in diameter (10mm) and length of (50mm).The tests were carried out in the construction laboratory of civil engineering department of Al – Mussaib technician Institute. The mineral ingredient ratios of steel used from the produced company are listed in table (1).

Table 1: Mineral ingredients and ratio of steel used

%C	%Mn	%Mg	%Cr	%Ni	%Si
0.45	0.75	0.05	0.08	0.07	0.2

The Figure 1 illustrates the samples and tensile tester while the properties of steel tested are listed in Table 2.

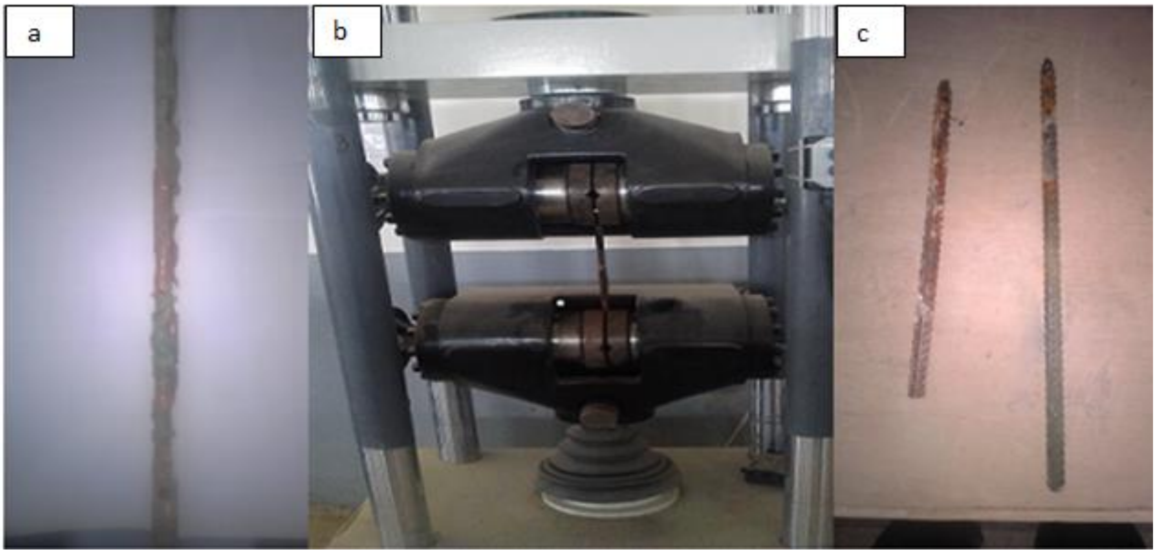

Figure 1: illustrates: (a) Wire steel reinforcement sample epoxy coating, (b) Tensile tester, (c) Wire steel reinforcement after test

Table 2: The results of standard sample test

Dbefore test(mm)	Ls (mm)	Weight(gm)	Yield stress(Mpa)	Ultimate stress(Mpa)	Dafter test(mm)	Actual elongation $(\ell_f-\ell_i)/\ell_{eff}$	Equipment elongation
10	496	294	664.5	729	6	5%	11%

Notes: effective length = 220 mm; D = sample diameter; Ls = sample length

Three samples of steel were immersed in salty soil solution of (3%) concentration of NaCl for (30,60,90) Days to monitor and evaluate the adverse effect of chloride salt according to the influence of chemical corrosion on mechanical properties of reinforcement steel used in construction processes .The corrosion rate depends on the following equation [7,8,9,10]
Corrosion ratio (mmpy) = 534 (w/DAT):
Where: mmpy: mm penetration per year; W = weight loss (mg); D = density of sample (g / cm^3); A = area of sample in (in^2); T = time of exposure of the metal sample in hours.
Also Yield and Ultimate stresses were measured as well as the percentage of elongation .The measured results are listed as in Table 3 also as shown in Figures 2 and 3.

Table 3: The results of three samples in different intervals

Sample no.	**Immersion time (hurs)**	**Yield stress (Mpa)**	**Ultimate stress (Mpa)**	**Actual elongation %**	**Equipment elongation %**	**mmpy (mm/year)**
1	720	574.8	647.3	6.8	12.8	22.50
2	1440	532.7	590.5	8.1	13.8	23.60
3	2160	518.0	565.8	9.2	14.3	23.75

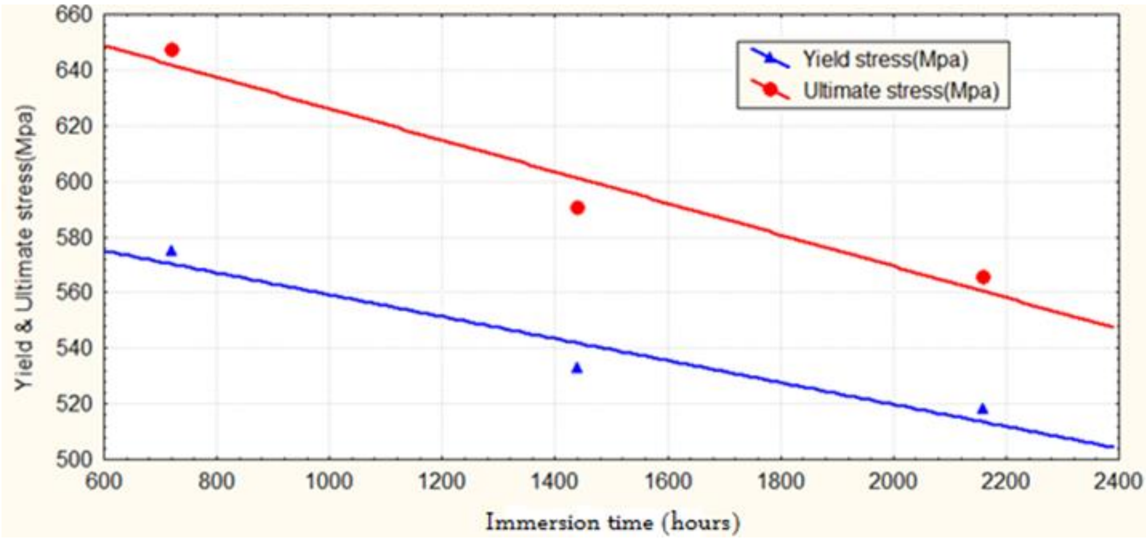

Figure 2: The relationship between the yield and ultimate stress of reinforcement steel Corresponding to Immersion time

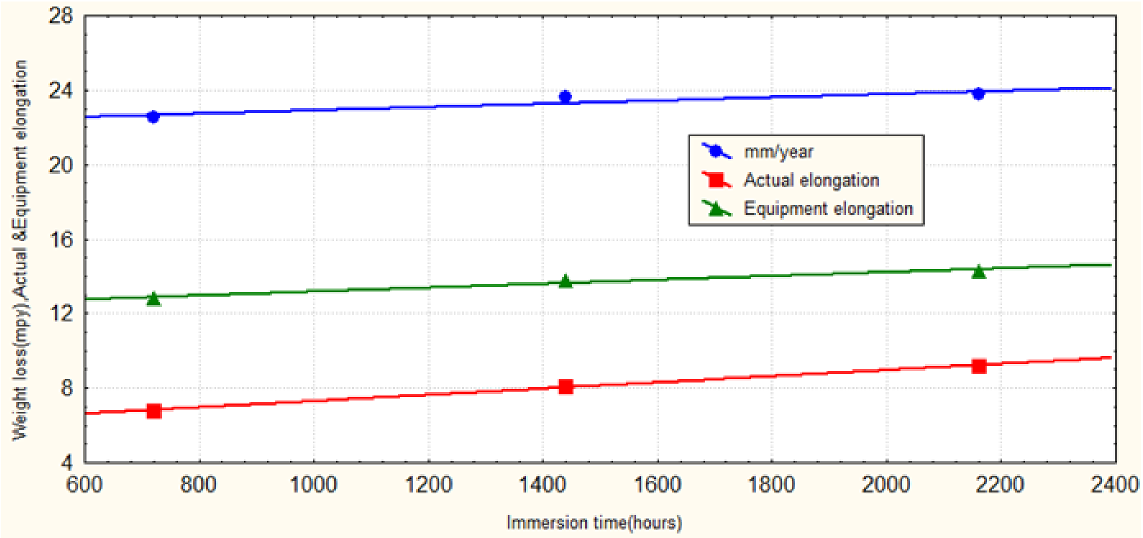

Figure 3: The relationship between the weight loss, actual and equipment elongation Corresponding to Immersion time

2.2 The treatment approaches of wires steel reinforcement

In this research situational treatments were used three reinforced steel samples with the same physical and mechanical properties and then these samples were immersed in salty solution with the same mentioned previous for interval (2160 hours) for all samples, and weighting the samples to know weight loss and after that samples were subjected to tensile test to produce ultimate and yielding stress values and to compare with untreated samples. The treated ways were as follow:

1 Surface hardening process by Oxy-acetylene torch for one sample and then cooling by solution (water and oil with ratio of 50% for each part).
2 Coating process by epoxy material with hardening material .That are used in ceramic works.
3 Aluminum coating by spread way within the electric oven and by recrystallization temperature for aluminum element after the surrounding the sample by element powder.

All the treatments for the samples have done in the laboratory of Almusaib technical institute and after that immersion the samples in salt solution for interval (2160 hours) and the results were listed in table (4) as following:

Table 4: The results of wire steel reinforcement treated

Samples	Immersion time (hrs)	Yield stress (Mpa)	Ultimate stress (Mpa)	Actual elongation %	Equipment elongation %	mmpy (mm/yr)
Hardening with Oxy-acytelineflam	2160	660	709	3	11	10.8
Coating with Epoxy material	2160	662	715	6	11.3	9.6
Coating by aluminum	2160	---	690.7	5	13.4	16.5

2.3 Increasing of temperature and (NaCl) concentration influence

The temperature in Iraq environment is increasing at high rates in summer season may be Reach to (60 ^{0}C) especially in soil which is directly exposed to sun ray and Conceivable for next year's due to thermal retention, there for the temperature is an important variable in this research . (3- samples) was immersed in solution with Concentricity of (3%NaCl) for different temperature (50,60 and 70C^0) and for intervals of (700,800,900 and 1000 hours) and then measuring the loss percent (μg) in sample Weight relative to unit area .The results are illustrate in figure (4).

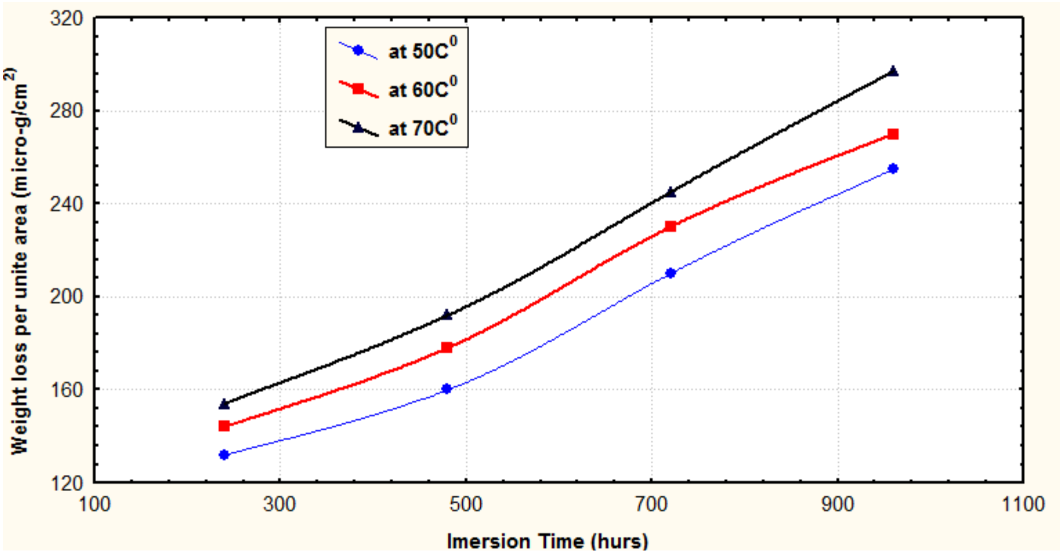

Figure 4: The relationship between weight losses from whole sample area corresponding to different immersion times for different temperatures.

The variation of salt concentration from one soil to another especially relative to soil of Iraq where the soil of southern areas are more saltiness than northern regions and middle , there for the variation of (NaCl) concentration is an important factor that effects on construction steel corrosion which is used in concrete reinforcement works. Four concentration of (0.1, 0.2, 0.3, 0.4 M/NaCl) were used and at high temperature of (70C^0) and was calculated the loss percentage in weight relative to the total area of sample (cm^2) and for different intervals (in hours) for all the samples which are previously mentioned. The results are showed in figure (5).

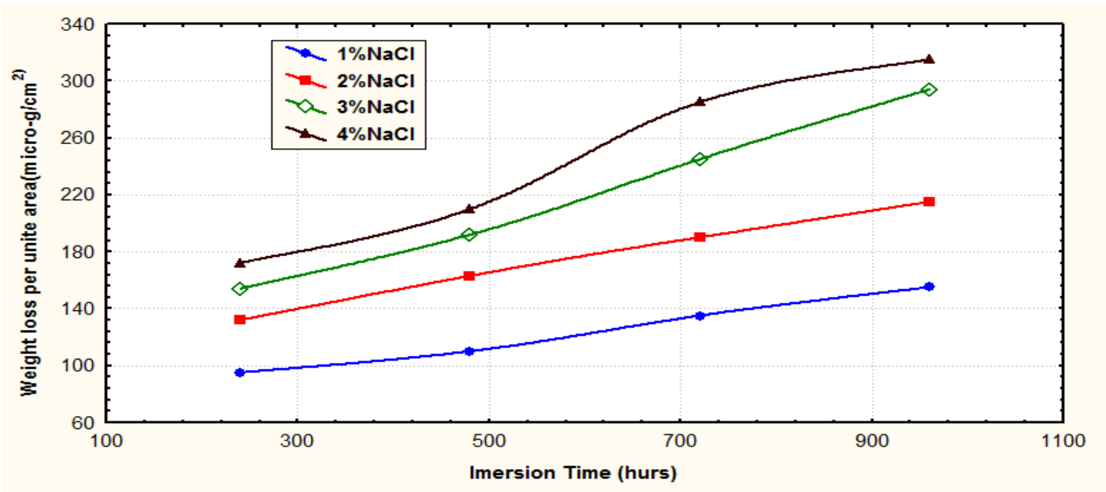

Figure 5: The relationship between weight losses corresponding to different immersion period at different ratios of (NaCl) concentration

The treatment was proceeded for one construction steel sample by heating at steel recrystallization temperature and after that cooling the sample by mixture of (oil and water) in cooling process and immersion the sample in salt solution with concentration (4%NaCl) at temperature of (60 C^0) for interval of (720 hours) . The sample was tested by tensile test to know heat treated construction steel sample ability to resist increase soil temperature with increase percentage of (NaCl) .The results in table 5.

Table 5: The results of tension test for heat treated sample exposure to (60 C & 4 % NaCl)

Immersion period (hours)	σ Yield (Mpa)	σ ultimate (Mpa)	mmpy
720	620	693	11.2

3. Discussion of Results

For Figure 2 which contain different intervals of time in hours for samples immersion process in salt solution .The relationship was inverse between immersion time and yield stress, also the same relationship was with ultimate stress for failure, i .e. the effect of salt solution (3% NaCl) on reinforced steel with over time was high and this effect on resistance of concert blocks in foundation casting and thus on constructions set up on it.
The results are taken from table (3).

For figure 3 shows corrosion rate (mmpy) is directly proportional to immersion interval in salt solution and the range between (23.75 – 22.5) for Different intervals. These values are undesired to avoid steel wires failure within the blocks concrete.

When comparing between standard sample readings immersed samples in salt solution for the yield stress value of drawback difference shall be about (150MPa) also, for the ultimate stress shall be about (163 MPa) . These illustrate negative impact of salt property solution on values of failure steel resistance during time interval.

For table 4 shows that the yield stress for treated sample by epoxy coating, it was observed that tensile equipment didn't give any reading , and this refer to that the ductility has reduced to a level that the material was close to brittleness and it is probably that the reason of chemical interaction between coating material and Hardener with salt had an effect on the increase of carbon ratio in steel making it exceed Eutectic area in (iron-carbon) chart ,there for the ductility is reduced and the brittleness is increased in cementite region .

For figure 4 shows that the relationship between weight loss due to temperature increase of soil with concentration of solution (3%NaCl) and between immersion time in (hours) is directly proportional and it can be represented as a second degree equation with a high inclination, as a result of temperature increase of soil especially in Iraq through the summer season has significant influence on lost ratio in construction steel which is applied in reinforcement.

For figure 5 shows that the relationship between weight loss and immersion time in solutions with different concentrations of (NaCl) was directly proportional and have a slope less inclined than temperature increase effected, but when the Concentration is increases up to (3% NaCl) and when time exceeds (50 hours) , it can be noticed that the inclination has changed with a larger angle and also for the concentration ratio (4% NaCl) . At time (500 hours) where the straight line turning into curve , this refer to that the high concentration and increment of immersion time will inversely effect on construction steel.

In the case of using the sample that has been thermally treated which was tested by tensile equipment, results in table (5) show that the thermal treatment at recrystallization temperature gives good results and approaches to standard sample despite the increase of temperature to (60 C^0) with increase of salt concentration .

4. Conclusions

Based on the experimental works,

1. It has been proved through applications that the effect of salt solution (3%NaCl) on increase of corrosion rate for flooded steel reinforcement in solution in side block of concrete , and this effect is Undesired according to values for long period of time ,where possibly leads to failure in concrete foundations.

2. The treatment was conducted on the samples of reinforcement steel wires and for limited interval of time (2160 hours) which has proved the ability of epoxy coating in keeping steel flooding process in salt solution.

3. The treatment of reinforcement steel wire by surface hardening will be economical approach also, maintains on yield stress and ultimate stress for sample asymptotic well for values of standard sample before flooding process. It is possible to apply this approach in the site for treating steel wires reinforcement process and pour foundations.

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