An Investigation on the Corrosivity Rate of Typical Nigerian made Plain Carbon Steel Reinforcement Rods in a Saline Environment

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Abstract: In this work, an investigation of the corrosivity rate of typical Nigerian made plain carbon steel reinforcement rods was carried out in a saline environment. Four samples of locally manufactured plain carbon steel gotten from four different steel companies located in Asaba and Lagos, Nigeria respectively were used. Each of the samples was cut into four and a total of 16 specimen was used for the experiment. Since the experiment was done in a controlled environment, water from Onne sea-port flt Port-Harcourt, Nigeria was used due to its high salinity. The Plain carbon steel was immersed in the saline water and monitored using the weight loss method at the interval of 10 days, also the electrode potential was monitored at the interval of 5 days using zinc as a reference electrode. This lasted for a period of sixty (60) days for both methods. The results obtained reflects the changes and differences of the samples' corrosion behavior during exposure in the saline water and they respond directly to the influence of saline environmental factors on the corrosion behaviours, especially the influence of temperature.

Keywords: corrosion, plain carbon steel, saline environment, corrosivity.

1 INTRODUCTION

Engineering failure are frequently caused by misuse of materials. When a plastic tea spoon buckles as you stir your tea, when a building collapses or when the fleet of aircraft is grounded because cracks have appeared in the tail plane, it is because the engineer who designed them used the wrong materials or did not understand the properties of those materials used (Ashby et al, 1990). There are more than 50,000 materials available to the engineer. In addition, hundreds of new materials appear on the market each month. Each of these materials has its characteristics, applications, advantages, limitations and cost. Thus, the task of knowing the properties and behavior of all types of available materials becomes enormous and challenging (Vlack, 1982).

This means that adequate knowledge of materials and their properties will no doubt help the Engineers and designers to avoid mistakes that may lead to engineering failure. Admittedly, some are not used widely because of availability, initial properties, cost or service performance. Others like iron and steel, paper, concrete, wood (timber) etc. find extensive uses (Vlack, 1982). Often, materials are reinforced to make them stronger when improved strength is the major goal. The reinforcing components must have a large aspect ratio. This means that its length-diameter ratio must be high so that the load is transferred across potential points of fracture. This is why steel rods are placed in concrete structures as reinforcing components (Vlack, 1982).

Again, Seawater is a complex, delicately balanced solution of many salts containing living matter, suspended silt, dissolved gases, and decaying organic material, the individual effect of each of the factors affecting the corrosion behaviour is not readily separated, as is the case for a simple salt solution. Because of the interrelation between many of the variables in the seawater environment, an alteration in one may affect the relative magnitude of others. These factors which affect the amount and rate of corrosion maybe divided into chemical, physical, and biological. They can be further sub-divided into (oxygen, biological activity, temperature, velocity, salinity, and pH) as the case may be.

However, new types of surface vessels also are rapidly being developed e.g. Hovercraft, hydrofoil ships, nuclear-powered and jet-engine-powered vessels and a great variety of work boats and research vessels. Here in Nigeria, the oil and gas industry has built large numbers of off-shore platforms, pipelines, under water storage and shore facilities. All this increased activity has taxed the ingenuity of the designers of equipment and facilities which must be specially tailored to meet the hostile ocean environments.

Before choosing the materials of construction for an off-shore structure, ship, submersible, ocean-floor installation or instrument package, many factors must be considered. Among these are the initial cost of the materials, their efficiency in the intended design, and the predicted lifetime of the materials as influenced by corrosion processes, function and interaction of stress. Again, many materials when fabricated into a system deteriorate in seawater service in unexpected manners, unlike their predicted behaviour established in laboratory saline solutions.

Therefore, it is the intent of this work to investigate and compare the Corrosivity of typical Nigerian made Plain Carbon Steel Reinforcement Rods in a Saline Environment.

1.1 Research Problem

Corrosion is a widespread problem across many industries like Nigeria National Petroleum Cooperation (NNPC), Dangote Cement Industry, Construction companies Etc. These companies spend a lot of money in failures, capital, operations and maintenance of materials.

Therefore, an attempt to compare the corrosivity of typical Nigerian made plain carbon steel reinforcement rods in a saline atmosphere is proposed as this will contribute greatly to the research against corrosion for a better technology.

1.2 Aim and Objectives of the work

This work is aimed at investigating the Corrosivity of Typical Nigerian made Plain Carbon Steel Reinforcement Rods in a Saline Environment. To achieve this, the study has the following specific objectives;

- To gather samples of locally made plain carbon steel from about 4 different companies in Nigeria.
- To analyze the chemical composition of the plain carbon steel.
- To investigate the corrosion behavior of the samples in a saline environment.
- To compare the data generated from my experiment and make the necessary conclusions.

2.0 MATERIAL AND METHOD

2.1 Material

The materials used for this investigation is a medium carbon steel of 18mm Diameter reinforced steel bars. This samples were obtained from two major sources namely; locally produced steel bars with imported product. This is necessary for comparative investigation and analysis. The locally produced steel bars were obtained from three (3) steel industries in Nigeria which are Eastern Metals (Nig.) Ltd. Asaba (B), PUKKIT (Nig.) Ltd. Lagos (C), and SANKYO (Nig.) Lagos (D). The imported steel, Rathi Steel Mill and Power Ltd, India (A) was purchased from Eastern Metals, Nig. Ltd. Asaba, Delta State. The chemical composition of each of the company steel is shown in Table 1 & 2.

The equipment used are; Table vice, Chemical weighing balance (Metter Toledo), Lathe, Multimeter (DT8300 Digital Multimeter), power saw, iron brush, bench grinder (CBG-150), Tong, Spectrometer, Zinc electrode, Plastic bowl.

2.4 Methods

2.4.1 *Environmental Preparation*

The natural seawater was obtained from Onne River Port-Harcourt, River State. The Composition of the seawater was analyzed at Petroleum Training Institute, Warri – Delta State. The result of the analysis is shown in Table 3.

2.4.2 *Design of the Study*

The setup for the corrosion resistance of the samples in the seawater environment consist of 8 plastic containers. Each company has 2 plastic container with 3 samples each.

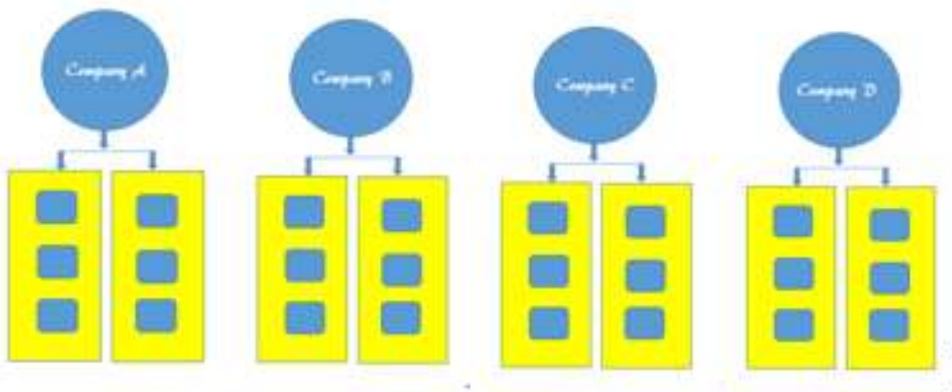

Fig. 1. Design for the corrosion experiment

2.4.2 Determination of Corrosion Penetration Rate from Electrode Potential Measurement

The samples were completely immersed in the seawater for the duration of 60 days. The investigation involved the potential (mV) measurement between the sample surface and the corrosion environment (medium) at regular interval of 5days using DT 8300D digital multimeter, zinc electrode was used as a reference electrode. After the potentials were recorded, conversions was made to have the equivalent values in the Saturated Calomel electrode (SCE) using the relation;

[Ezn – 1.03V] = V (SCE)………..…..….. ………………………………………………………………….. (2.1)

in millivolts (mV) it becomes,

[Ezn (mV) – 1030 (mV)] = mV (SCE)……… …………….……………………………………..…. (2.2)

(Hilbert et. Al, 1984); Afolabi and Fabusa (2006).

Where;

Ezn is the electrode potential obtained using zinc reference electrode.

NB: Data obtained are presented in Table 4.6 for corrosion penetration rate from electrode potential measurement.

2.4.3 Determination of Corrosion Penetration Rate from Weight Loss Measurement

The investigation involves periodic weight loss measurement. The corrosion samples were removed from the corrosion environment (media) with the aid of a tong after which the samples were properly cleaned in distilled water and then dried with a cotton wool. The dried sample were weighed with a chemical weighing balance (Digital) and recorded and this continued at regular intervals of 10days. Data obtained from weight loss are presented in the fig. 3 below.

The corrosion rate of the samples in the corrosive media is given as; ($mg/cm^2/yr$)…………………..……….. (2.3)

(Fontana, 1986); (Oloruntoba, 2002)

Where;

W = Weight Loss (mg), A = Total Surface Area (cm^2) and T/365 = Exposure time in days extrapolated to a year

3.0 RESULTS AND ANALYSIS

3.1 Results

Steel as an engineering material are classified according to their alloying element composition. The normal chemical composition as revealed by spectrometer to know the alloying element present in the steel and their individual composition is tabulated in Table 1 & 2.

Table 1: Chemical Composition (Wt %) of the Medium Carbon Steel Substrates for Company A & B

Alloy Elements	% Composition
C	0.387
Fe	97.760
Si	0.244
Mn	0.827
S	0.040
P	0.041
Cr	0.771
Ni	0.673
Mo	0.077
Cu	0.224
Al	0.008
V	0.009
Sn	0.019

Company A

Alloy Elements	% Composition
C	0.254
Fe	98.000
Si	0.212
Mn	0.555
S	0.020
P	0.015
Cr	0.374
Ni	0.350
Mo	0.026
Cu	0.183
Al	0.014
V	0.090
Sn	0.082
Co	0.012
W	0.016
B	0.008
Nb	0.001

Company B

Table 2: Chemical Composition (Wt %) of the Medium Carbon Steel Substrates for Company C & D

Alloy Elements	% Composition
C	0.275
Fe	98.090
Si	0.252
Mn	0.732
S	0.049
P	0.064
Cr	0.209
Ni	0.102
Mo	0.0001
Cu	0.231
Al	0.031
V	0.0001
Ti	0.005
W	0.0001
B	0.0001
Nb	0.0001

Company C

Alloy Elements	% Composition
C	0.313
Fe	96.754
Si	0.224
Mn	0.991
S	0.038
P	0.036
Cr	0.104
Ni	0.111
Mo	0.0001
Cu	0.311
Al	0.032
V	0.0001
Ti	0.0060
W	0.0001
B	0.0001
Nb	0.0001

Company D

3.1.1 Composition of Sea Water.

Table 3: Composition of the Sea Water used for the Experiment

S/N	Parameters	Results
1.	PH@25^{0}C	7.6
2.	Salinity psu	10.41
3.	Sulphate mg/l	22.10
4.	Sodium mg/l	8.55
5.	Dissolved Oxygen@ 25^{0}C	5.38

3.1.2 Plot from the Data obtained for the Electrode Potentials Method

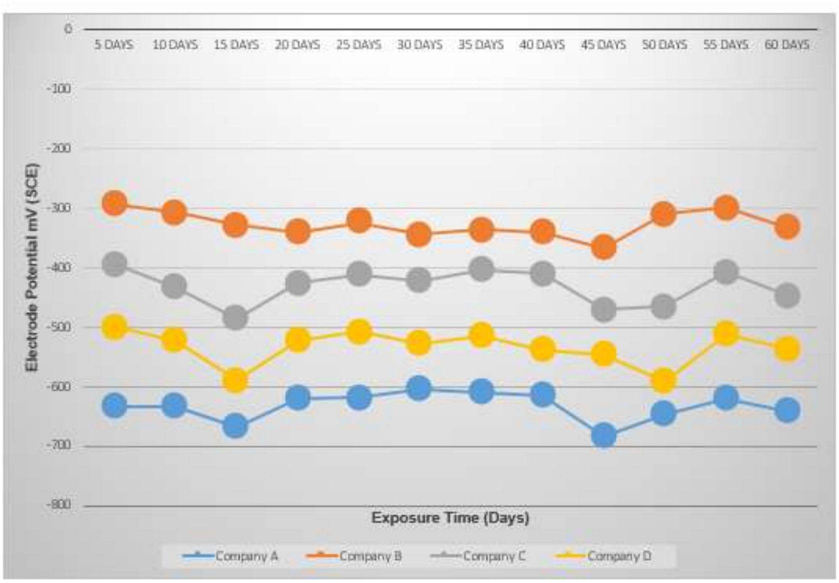

Fig. 2: Plot of electrode potential against exposure time for the various steel samples immersed in saline environment

3.1.3 Plot from the Data obtained for the Weight Loss Method

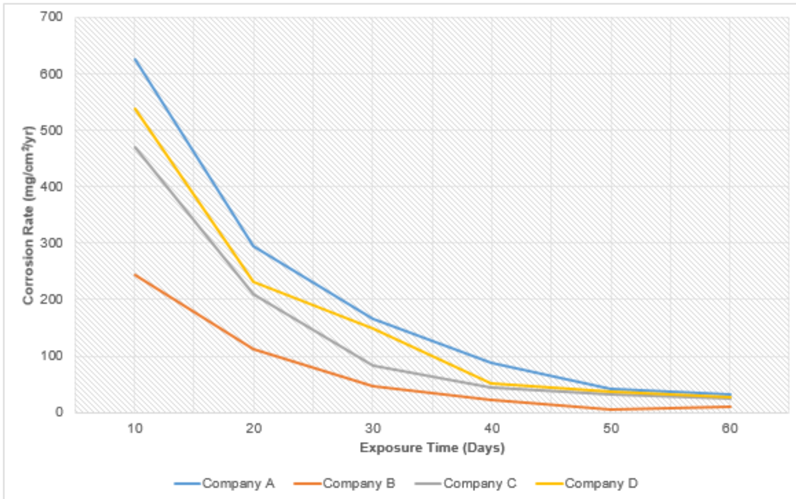

Fig. 3: Plot of corrosion rate against exposure time for the various steel samples Immersed in saline environment.

3.2 Discussion

Figure 2 show the plot of electrode potential against exposure time for the various steel samples immersed in seawater for the period of 60 days. It is observed from the graph that there was a progressive decrease of electrode potential values for all the samples with the imported steel displaying the least electrode potential with exposure period. The company (B) sample indicates the highest electrode potential between the same periods with company (C) and (D) samples displaying the higher electrode potential respectively than the imported sample which displayed the least, and a progressive decrease of electrode potential throughout the remaining exposure period. This progressive decrease of electrode potential for the various samples indicates that at this primary passive potential, the cathodic reduction rate is equal or greater than the anodic dissolution rate for spontaneous passivation to occur. This collaborates also with the finding of Fontana (1974), and Scully (1975) which explain that alloy will be readily passivated if it has a small anodic current density and an active primary passive potential.

At passivity, low corrosion rate occurred to the fact that the potential of the metal is approximately equal to the potential of the solution, as observed by Hilbert and James (1984), no further corrosion occurs. This is evident in the graph between days 25 & 40 for the various steel samples.

The locally produced steel samples show better corrosion resistance tendency than the imported steel sample; However, the steel produced by company (B) show better corrosion resistance tendency throughout the exposure period. This is followed by steel produced by company (C) and (D) respectively. In other words, the corrosion seems to be increasing with increase in carbon content in the steel samples in this medium throughout the exposure period which clearly agrees with the findings of Robert (2003), and it also corresponds with the findings of Khalid (2012).

4.0 CONCLUSION

The comparison of the corrosivity of typical Nigerian made plain carbon steel reinforcement rods in a saline environment was investigated and from the result obtained, within the limit of experimental errors, the following conclusion could be drawn.

- The local steel samples and the imported steel sample experienced corrosion at the initial stage of exposure to the saline environment and later experienced a decrease in corrosion with increase in exposure time.
- The local steel samples showed better corrosion resistance tendency than the imported steel sample throughout the exposure period.
- The steel produced by company (B) showed better corrosion resistance tendency than the steel produced by company (C) and (D) with peak corrosion rate of 243.15mg/cm^2/yr, 469.46mg/cm^2/yr and 538.67mg/cm^2 /yr respectively on the 10th day.
- The steel produced by company (B) appears to be the best steel sample, since they show reasonable corrosion resistance tendency throughout the period of investigations.

RECOMMENDATIONS

From the results obtained from this investigation, the following recommendation are made;

- The steel produced by company [B] is ideal for structural purposes, and it also suitable for saline environment.
- These steel products produced by this various companies should be examined under different environment to see their variations
- More investigations on this work would be necessary from various localities to ascertain the suitability of the materials available in our local markets for use by the construction industries and to assess reproducibility of products.

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