International Journal for Modern Trends in Science and Technology, 6(9): 139-143, 2020

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST060921
Available online at: http://www.ijmtst.com/vol6issue09.html

Effects of Corrosion to the Performance of Steel Reinforcement Embedded in Concrete under Different Aggressive Environments

Bldr. Nagande Umar[1] | Bldr. Marafa Muhammad[1] | Bldr. Tukur Almustafa[1]

Department of Building Technology, Waziri Umaru Federal Polytechnic BirninKebbi, Kebbi State,Nigeria.

To Cite this Article

Bldr. Nagande Umar, Bldr. Marafa Muhammad and Bldr. Tukur Almustafa, "Effects of Corrosion to the Performance of Steel Reinforcement Embedded in Concrete under Different Aggressive Environments", *International Journal for Modern Trends in Science and Technology*, 6(9): 139-143, 2020.

Article Info

Received on 16-August-2020, Revised on 02-September-2020, Accepted on 10-September-2020, Published on 16-September-2020.

ABSTRACT

The corrosion of reinforcement steel bars in concrete has been established as the major factor causing widespread degradation of concrete structures. Corrosion of reinforcement in concrete leads to reduction of good bonding between steel and concrete, decrease of steel cross-sectional area, cracking and loss of serviceability. This paper investigates the behavior and Performance of reinforcement bar embedded in concrete structure under a variety of aggressive environments. The study used 16 mm diameter reinforcement bars embedded in concrete with a uniform cover of 50 mm in 200 mm x 200 mm x 750 mm concrete beam, the curing period of concrete is 28 days. After completion of 28 days' moisture curing period, the beam was loaded in flexure causing cracking of the concrete, thereby exposing the steel reinforcements. The cracked reinforced concrete beams were then immersed in different aggressive solutions of H_2So_4 (Sulfuric Acid), HCl (hydrochloric acid), HNO_3 (hydrogen trioxonitrate), NaOH (sodium hydroxide) and NaCl (Sodium Chloride) for a duration of six months. At the end of this curing period, the embedded steel reinforcement was removed and cleaned off the attached concrete, and then tested for change in strength, diameter, and weight loss. The results obtained shows that corrosion affect steel reinforcement in concrete under HCl, H_2SO_4 and HNO_3 with 15%,13% and 11% very high rate change in strength respectively. Also, the NaCl and HCl, were recorded with 15% and 11% very high rate effects on reduction/ addition in diameter of steel reinforcement respectively. And finally, the HCl, and H_2SO_4 were recorded with 24.1% having the same and very high rate effects on reduction in weight (weight loss).

KEYWORDS: *Reinforced concrete, Corrosion, Aggressive environment, Deterioration*

INTRODUCTION

Concrete is the most widely and available materials used in the production of buildings and other engineering structures [1]. globally, corrosion of reinforcement bars, is the major causes of failure in reinforced concrete (RC) structures, more especially in aggressive environments [2], [3]. Mechanically, reinforced concrete is not only characterized with combination of materials, but also in chemical perspective, why because hydrated cement provides to the reinforcement bar an excellent protection against corrosion [4], [1].

According to [5] Corrosion can be define as "physicochemical interaction between a metal and its environment that results in changes in the properties of metal, and which may lead to significant impairment of the function of the metal, the environment, or the technical system, of which these form a part". Also [6] defined corrosion as

process of declining of metal through an electrochemical reaction with surrounding environment.

The magnitude of corrosion in reinforcement bars, it bonding strength between concrete and reinforcement, was enormously depend on concrete durability and accelerated corrosion period, as strength increased the corrosion rate of embedded steel decreased [7], [8]. Problems of steel reinforcements deterioration in concrete due to corrosion, is a global issue that causing a loss of billions of dollars in replacement and repair, and also leading to structural failures in many countries [9]. Several research was conducted on the effect of corrosion to the mechanical properties of steel reinforcement bars, most of that research focused on accelerated corrosion that are induced by current applied to the surface of the reinforcement bars embedded in the concrete, which is very different from normal corrosion [10], [7].

However, the use of reinforce concrete improves the properties of building structural components physically and mechanically. Because of reinforcements usage, construction of high rise and wide spans of buildings with different shapes, became possible. The initial corrosion time of reinforcement, depends on thickness of the concrete cover, quality and permeability of concrete, so therefore, it's important to know the Chloride content present in mix ingredients from cement, aggregates, and water [11]. The corrosion of reinforcement in concrete is as a result of aggressive agents that break a protective oxide of the environments [1]. Good and very sound cement in concrete production, provide a standard environment against corrosion even with the use of low quality steel reinforcement [12]. The issue of corrosion in steel reinforcement can only be minimized (i.e. protective measures) but can never be control in a natural environment without any protection [12]. The major effect of corrosion to the steel reinforcement is, it causes premature deterioration of concrete structure, especially those located in the costal environment. Previously, there was numerous literatures of the problems of concrete degradation, to minimized the effect of corrosion performance, Proper monitoring of structures should be taken to save time and costs [13].

According to [14] the corrosion of reinforcement bars adversely affects the strength of reinforced concrete and reinforcement inside, by changing it tensile Strength, for that, un-corrodible steel bars should be maintained in the production of reinforced concrete structure.

The size and Area of reinforcement bar is diminishing by the corrosion action, which cause change in diameter, and thereby affecting it load carrying capacity. Corrosion also reduces the malleable and toughness of steel reinforcement [15]. The significant of corrosion in steel bars, include effects on structural serviceability e.g. (cracking, or spalling of the concrete cover) structural safety, e.g. (decreasing the load-bearing capacity of steel reinforcement and weight loss) etc. [16].

Although, different research was carried out on corrosion of steel reinforcement under different aggressive environments, but there is gap of making comparison of this five different chemicals compound HCl (hydrochloric acid), H_2So_4 (Sulfuric Acid), HNO_3 (hydrogen trioxonitrate), NaOH (sodium hydroxide) and NaCl (Sodium Chloride) to ascertain it effect to the performance of reinforcement in concrete structure, This paper investigates the effect of corrosion on the behavior and Performance of reinforcement bars embedded in concrete under the above mention aggressive environments.

MATERIALS AND METHOD

A. MATERIALS/APPARATUS

The four major materials used were, Cement, Fine Aggregates, Coarse Aggregate and Water. For the cement material used was Sokoto Portland cement, with compressive strength of 50.42 N/mm, the cement certified the requirement of Standard Organization of Nigeria (SON). The Sand and aggregates used, was source from river, fine and coarse granite respectively. Size of the coarse aggregate used were 18 mm, and the fineness modulus of sand was 2.80. All the aggregates used complied with the requirement of ASTM C 33-93. All the mixtures consist of 100% cement and water/cement (w/c) ratio of 0.6 were used in casting the concretes beams. The apparatus used includes: concrete mixer, Tamping rods, vibrating machine, weighing balance, Trowel, concrete molds, Crushing Machine

B.Procedure for Concrete Preparation

The concrete mixture was done mechanically with a concrete mixer, firstly a water was added in the drum of concrete mixer, the Coarse aggregates

followed, sand and cement at last. All the materials were Mix continuously by mixing machine for 5 minute. After concrete is fully mixed, the mixed concrete was placed in the molds in one lift, compacted on a vibrating machine and put in curing period for 24 hours in a polythene sheet. The Beam molds of 200 mm x 200 mm x 750 mm in dimension are fitted for 16 mm reinforcing steel bars at a cover of 50 mm. For each mixture 100 mm^2 cubes were cast to test the workability and compressive strength, and also to monitor quality of the mixture. The specimens were demolded after 24 hours, the concrete cubes and beams were moist and cured for 28 days. At the end of the curing periods of 28 days, the cubes were tested for compressive strength while the beams were subjected to a two-point loading in flexure using Flexural Test Machine with the intention of exposing the reinforcing steel. The reinforced concrete beams were immersed in different concentrated solutions (as Aggressive environment), after it was artificially cracked, and put in a plastic container for a duration of six months. The chemical compound used for preparing the aggressive solutions are;(i) Sodium Chloride **(**NaCl**)** (ii) Sulfuric acid (H_2SO_4), (iii) hydrochloric acid (HCl), (iv) sodium hydroxide (NaOH), (v) hydrogen trioxonitrate (HNO_3). After the expiration of the ten months, the concrete Beam were removed from the solution wiped dry and split into pieces, the corroded reinforcement bars were remove out and cleaned up. They were tested to determine change in strength, change in diameter as well as the weight loss.

C. Procedure for Chemical Solution Preparation & Analysis

The three substances Hydrochloric acid HCL hydrogen trioxonitrate HNO_3, and Sulfuric acid H_2SO_4 are strongly acidic because of its complete dissolutions and dissociating of its molecules in water solution, also they attract water molecule from surrounding environment which is called hygroscopic substances. When steel reinforcement gets in contact with these substances, the chemical reaction take place with the formation of hydrogen gas and ferrous ions, and the rate of corrosion in steel reinforcement taking place in dilute acids, will strongly depend on steel chemical composition, especially carbon content [6]

The PH value of these Acidic substances can be seen in table 1

Table 1. PH value of the substances [17]

S/No	Acid	Acid Name	PH Value (mM)
1	H_2SO_4	Sulfuric acid	2.75
2	HCl	hydrochloric acid	3.01
3	HNO_3	hydrogen trioxonitrate (Nitric acid)	3.01

But the substances, sodium hydroxide (NaOH) is a strong base, that 1mM has a P^H value = 13. However, sodium chloride NaCl is common salt that is derived from the reactions of strong Acidic and Base, neutralize to form salt, that has no any properties of acid or base. The PH value of sodium chloride remain always = 7 due to its weak in basicity of cl-ion. An investigation report by [18] reveals that particle of sodium chloride on reinforcement steel get corroded at relative humidity. sodium chloride in water is an electrolyte substance which conduct ions, so it accelerates rusting process by fast movement of electrons easily in salt water than it does in pure water [19]

For this research work, 0.1mM of acidic substances is diluted in 5lit of water, and 2gram of sodium chloride (salt) is also diluted 2litres of water. To determine the rate of corrosion for each specimen of reinforcement equation (1) was used.

$$\frac{MM}{Y} = 87.6\left|\frac{W}{DAT}\right| \quad \mathbf{1}$$

Where $\frac{MM}{Y}$ is rate of corrosion in millimeter per year, W= weight loss in milligrams, D= metal density (g/cm^3), A= Area of sample (cm^2), T= time of exposure of sample in hour.The results are later converted to percentage using Statistical package for Social Sciences (**SPSS).**

RESULTS AND DISCUSSION

Having knowing the effect of corrosion from the literature perspectives, this chapter intended to show the characteristics and behavior of steel reinforcements used for this research work that were found corroded after the completion of ten-month period**.**

At the end of the immersion of the reinforced concrete samples in the various aggressive solutions for a period of ten months, the results obtained from the experiment are plotted in terms of loss of weight, change in reinforcement diameter and change in reinforcement strength for the

different aggressive environments investigated as presented in Fig. 1 to 3.

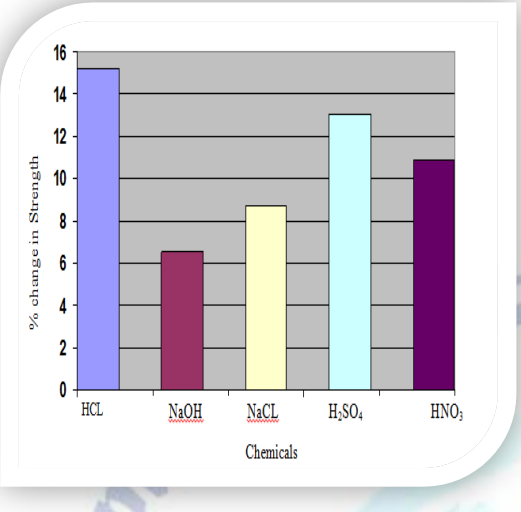

Figure 1: Percentage change in Strength of reinforcement embedded in the concrete.

Figure 1 shows the effects of the corrosion on change in strength of the steel reinforcement embedded in the concrete in different aggressive environment. From the figure, the result shows that, the corrosion in acids HCl, H_2SO_4 and HNO_3 are very prone to attack the steel reinforcement in concrete, with 15%,13% and 11% having a very high rate effects on change in strength respectively. While the NaOH and NaCl have a minimum effect on change in strength of steel reinforcement, with 9% and 7% respectively. So, the corrosion in all the chemicals compound, affect the steels reinforcement under aggressive environment by altering its tensile strength. This testify what (14) said

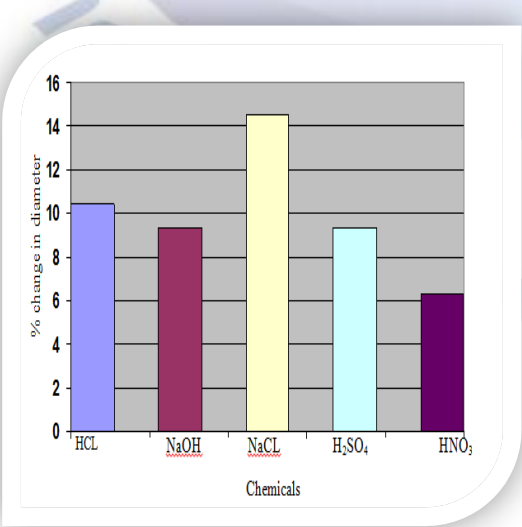

Figure 2: Percentage change in diameter for the different exposures

Figure 2 present the effects of corrosion on the change in diameter of the steel reinforcement embedded in the concrete in different aggressive environment. The reveals that, the corrosion in acids NaCl and HCl, are very prone to attack the steel reinforcement in concrete, with 15% and 11% very high rate effects on reduction/increase in diameter of steel reinforcement respectively. NaOH and H_2SO_4 have the same effect with 9%, While the HNO_3 have a minimum effect on reduction/addition in diameter of steel reinforcement, with 7%. However, the corrosion in all the chemicals also, affect the steels reinforcement under aggressive environment by reduction/increase in diameter of steel reinforcement.

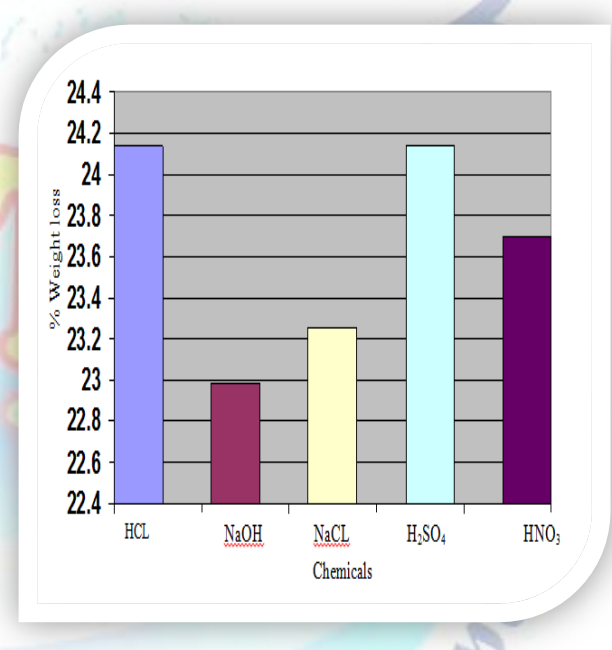

Figure 3: Percentage loss in weight for the different exposures

Figure 3 shows the effects of corrosion on weight loss for the steel reinforcement embedded in the concrete in different aggressive environment. In this figure that, the corrosion in acids HCl, and H_2SO_4 are very prone to attack the steel reinforcement in concrete, with 24.1% having the same and very high rate effects on reduction in weight (weight loss), followed by HNO_3 with 23.7% weight loss, While NaCl and NaOH have a minimum effect on reduction in weight of steel reinforcement, with 23.3% and 23% respectively. therefore, the corrosion in all the chemicals affect the steels reinforcement under aggressive environment by reduction its weight (weight loss).

CONCLUSION AND RECOMMENDATION

Based on this investigation carried out on the effect of corrosion on the performance of steel reinforcement embedded in concrete under different aggressive environments, the study concluded that, the concentrated chemical compound **(**NaCl**),** (H_2SO_4), (HCl), (NaOH), (HNO_3) has strong effect on the performance of steel reinforcement bars in concrete, which is summarized as:

- The corrosion in all the chemicals compound, affect the steels reinforcement under aggressive environment by altering its tensile strength.
- The corrosion in all the chemicals compound also, affect the steels reinforcement by reduction/increase in diameter of steel reinforcement.
- The corrosion in all the chemicals compound affect the steels reinforcement under aggressive environment by reduction its weight (weight loss).

The paper recommended that all corrodible steel bars should be avoided in reinforced concrete construction.

REFERENCES

[1] J. T. Ekere, A. Y Alhassan, E. O. Atama, "The Effect of Aggressive environment on Reinforcing Steel Embedded in Concrete" *Applied Research Conference in Africa*, Ghana, 2016,pp.72-79 [5th Applied research conference in Africa, 25-27 August 2016, pempamsie hotel,cape coarse,Ghana]

[2] R. Patel "Prevention of corrosion of steel reinforcement in concrete"*AIP Conference Proceedings*, vol.2158, Sept. 2019 , pp 1-7[AIP publishing LLC, p 020035-1].

[3] L. Bertolini, M. Carsana, M. Gastaldi, F. Lollini, & E. Redaelli,"Corrosion of steel in concrete and its prevention in aggressive chloride-bearing environments" *Shenzhen University, Shenzhen, Guangdong Province, P.R.China,* 2016,[5th International Conference on Durability of Concrete Structures Jun 30–Jul 1, 2016]

[4]J. L Aquiar, A. Camoes, P. Moreira (2008).Performance of concrete in aggressive environment.*International Journals of Concrete Structure and Materials.2 (1).* pp 21-25.

[5] W.K. Green (2020). Steel reinforcement corrosion in concrete–an overview of some fundamentals.*Journal of Corrosion Engineering, Science and Technology.Vol 55.* pp 289-302.

[6] O.Ofuyekpone, N. Emordi, O. Utu (2015). Effect of sulphuric acid concentration on the inhibiting action of 0.001 M adenine solution during the corrosion of AISI 304L. *Advances in Applied Science. 6 (9)* 7-26.

[7]V. Kothari, & H. Kamplimath, (2020). Effect of Surface Corrosion of Steel Reinforcement on Bond Strength Characteristics of Concrete.*Advances in Structures, Systems and Materials* pp. 153-162.

[8]L. Abosrra, A. Ashour, & M. Youseffi, (2011). Corrosion of steel reinforcement in concrete of different compressive strengths. *Construction and Building Materials, 25* (10), 3915-3925.

[9] E. A. Al Zubaidy, & A. Al Tamimi, A. (2012). Reduction of corrosion process in steel bars using inhibitors. *Int. J. Electrochem. Sci, Vol 7*, pp 6472-648

[10]R.François, I. Khan, & V. H.Dang, (2013). Impact of corrosion on mechanical properties of steel embedded in 27-year-old corroded reinforced concrete beams. *Materials and structures, 46*(6), 899-910.

[11]J. O. Okeniyi, A.P.I. Popoola, C. A. Loto, O. A. Omotosho, S. O.Okpala, & I. J. Ambrose, (2015). Effect of NaNO2 and C6H15NO3 synergistic admixtures on steel-rebar corrosion in concrete immersed in aggressive environments. *Advances in Materials Science and Engineering, 2015*

[12] C. Hansson, A. Poursaee, & S. Jaffer. *Corrosion of reinforcing bars in concrete. R&D Serial. 3013.* Kothari 2012 pp 106 -124

[13]K. Gowers, S. Millard, J. Gill,& R. Gill, (1994). Programmable linear polarisation meter for determination of corrosion rate of reinforcement in concrete structures. *British Corrosion Journal, 29*(1), 25-32.

[14] E. Adukpo, S. Oteng-Seifah, P. Manu, & K. Solomon-Ayeh, (2013). The effect of corrosion on the strength of steel reinforcement and reinforced concrete. *Construction and Building Materials*.Pp 166-175.

[15] D. Ponjayanthi, & K. Vinodh, (2016). Effect of corrosion on the mechanical properties of steel reinforcement. *International Journal of Current Research and Review. 8*(12)pp 14.

[16] N.A.Taha, & M. Morsy, (2016). Study of the behavior of corroded steel bar and convenient method of repairing.*HBRC journal, 12*(2).Pp 107-113.

[17]www.aquion.de<site April2016

[18]Z. Gong, Peng, S. Huang, X. Gao, Lanzhou (2018) nvestigation the corrosion inhibition effect of itraconazole on copper in H2SO4 at different temperatures: Combining experimental and theoretical studies. *Materials* 2018 (11) pp 1-17.

[19]S. K. Dhawan, Bhandari, H. Ruhi, G. Bisht, B. M. S. Sambyal, Pradeep."Corrosion Preventive Materials and Corrosion Testing" Boca Raton: CRC Press. (2020),,https://doi.org/10.1201/9781315101217