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Corrosion Performance of Rebars Embedded in Concrete and Induced in Chloride Media

Philip Kpae. F. O[1], Letam Leelee Prince[2] and Charles Kennedy[3]

[1]School of Engineering, Department of Electrical Engineering, Kenule Beeson Saro-Wiwa Polytechnic, Bori, Rivers State, Nigeria

[2,3]School of Engineering, Department of Civil Engineering, Kenule Beeson Saro-Wiwa Polytechnic, Bori, Rivers State, Nigeria

Authors E-mail: [1]philipkpae1@gmail.com, [2]leeorices07@yahoo.com, [3]ken_charl@yahoo.co.uk

ABSTRACT

Corrosion products are highly porous, weak, and often form around reinforcing steel, thus decreasing the bond strength between the reinforcement and concrete. This researched work examined the usefulness of acacia senegal exudates / resins of tree extracts as corrosion inhibitors. Concrete slabs were embedded with non-coated and exudates / resin coated paste reinforcing steel and immersed in corrosive media for 150days under accelerated process. Results of average Potential Ecorr corroded value of percentile is -230.4854% against -69.7415% and -67.3178% of control and coated specimens. Potential E_{corr} results showed that the values of corroded specimens are high with the range of ($-350mV \leq E_{corr} \leq -200mV$), which indicates a 10% or uncertain probability of corrosion. Average results of concrete resistivity ρ, kΩcm percentile value is -48.9081% against 95.72572% and 114.8917% of control and coated specimens. Range of values of corroded specimens showed indication of likelihood of significant corrosion ($\rho < 5$, $5 < \rho < 10$, $10 < \rho < 20$, $\rho > 20$) for very high, high, low to moderate and low, for probability of corrosion. Average mechanical properties "ultimate strength" of control specimens is 8.183891% against -7.5648% and -7.60957% of control and coated specimens. Results showed high ultimate yielding of corroded specimens to control and coated specimens due to the effect of corrosion on the mechanical properties of the steel reinforcement. Average mechanical properties "weight loss of steel" of corroded specimen is 84.78709% against -45.8837% and -45.7759% of control and coated specimens. Results of weight loss of steel showed higher percentile values against control and coated specimens due to the effect of corrosion on the mechanical properties of steel. Average mechanical properties "cross- section area reduction" of control is -11.9074% against 13.51692% and 13.51692%. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel. Average mechanical properties "Cross- section area reduction" of control is 13.51692% over -11.9074% corroded specimen. Control specimens result showed no corrosion potential. Entire results showed the potential of acacia Senegal exudates / resins as corrosion inhibitor.

Key words: Corrosion, Corrosion inhibitors, corrosion potential, concrete resistivity and Steel Reinforcement

1. INTRODUCTION

Deterioration of reinforced concrete structures in marine environments is generally associated with external agents such as chlorides that penetrate into concrete causing damage. The severity of marine exposure varies considerably depending on factors such as climate, location relative to the sea and structural considerations. Corrosion products are highly porous, weak, and often form around reinforcing steel, thus decreasing the bond strength between the reinforcement and concrete [1]. In addition, corrosion reduces the cross-sectional area of steel reinforcement, decreasing ductility of the structure, especially when pitting corrosion occurs. It destroys metals due to interaction with its environments. Corrosion inhibitors are widely used to delay corrosion of reinforcing steel in concrete. They are chemical substances added to cement which when properly used, are effective in retarding the corrosion of reinforcing steel in concrete [2-4]. Corrosion inhibitor acts by forming an impervious film on the metal surface or by interfering with either the anodic or cathodic reactions, or both of them. Some inhibitors such as chromates and benzoates have been shown [5-6] to reduce the corrosion rate of steel bar, however, but they also reduce the compressive strength of concrete. Al-Moudi *et al.*, [7] reported that concrete with 2 and 4% CN inhibitor based on weight of cement did not show any corrosion initiation after 122 days when concrete was immersed in 0.8% Cl solution, or exposed to seawater. In another study with reinforced concrete (w/c ratio = 0.50) exposed to 3.5% NaCl wetting/drying cycles for 3 years, 2.5% CN was effective in delaying corrosion initiation. However, in another study CN was only effective in delaying corrosion but not effective after the initiation of corrosion [8].

Charles *et al.,* [9] investigated the electrochemical processed that led to the electron transfer in corrosion process of steel reinforcement in the harsh marine environment with high level of chloride. Average results on comparison showed incremental values of 70.1% against 27.2% Control of potential and 87.8% to 38.8% decremented values in concrete resistivity, yield stress against ultimate strength at summary and average state of corroded slab with nominal values of 100% and decremented in ultimate strength from 100.68% to 96.12%, weight loss versus cross-section diameter reduction decremented due to assail from sodium chloride from 67.1% to 48.5% and 98.2% to 94.82% respectively. When compared to corroded samples, corroded has 70.1% incremented values potential Ecorr, mV and 38.8% decremented values of concrete resistivity, yield stress against ultimate vigor at in comparison to corrode as 100% nominal yield stress decremented from 103.06% to 96.12% and weight loss at 67.5% against 48.5% and 47.80% to 94.82% cross-sectional diameter reduction, both showed decremented values of corroded compared to coated specimens.

Charles *et al.,* [10] investigated the corrosion potential, concrete resistivity and tensile tests of Control, corroded and coated reinforcing steel of concrete slab member Direct application of corrosion inhibitor of dacryodes edulis resins thicknesses 150 m, 250 m, 350 m were coated on 12mm diameter reinforcement, embedded into concrete slab and exposed to severe corrosive environment for 119 days for accelerated corrosion test, half-cell potential measurements, concrete resistivity measurement and tensile tests . When compared to corroded samples, corroded has 70.1% increased values potential and 38.8% decreased values of concrete resistivity, yield stress against ultimate strength at in comparison to corrode as 100% nominal yield stress decreased from 100.95% to 96.12% and figures 3.5 and 3.6 respectively presented weight loss at 67.5% against 48.5% and 98.7% to 94.82%, cross-sectional diameter reduction, both showed decreased values of corroded compared to coated specimens.

Charles *et al.,* [11] investigated the effects of chloride attack on reinforcing steel embedded in reinforced concrete structures built in the marine environment. Results recorded of potential Ecorr, mV, concrete resistivity and tensile strength of Acardium occidentale l. inhibited specimen, indicated a 10% or uncertain probability of corrosion which indicates no corrosion presence or likelihood and concrete resistivity indicated a low probability of corrosion or no corrosion indication.

Charles *et al.,* [13] investigated corrosion level probability assessment potential through half cell potential corrosion measurement, concrete resistivity test and tensile strength test mechanical properties of Control, corroded and inhibited reinforcement with Moringa Oleifera lam resin paste of trees extract. Average percentile results of potential Ecorr, mV, and concrete resistivity are 29.9% and 68.74% respectively. When compared to corroded samples, corroded has 70.1% increased values potential Ecorr, mV and 35.5% decreased values of concrete resistivity. Results of computed percentile average values of yield stress against ultimate strength, when compared to corrode as 100% nominal yield stress decremented from 105.75 % to 96.12% and weight loss at 67.5% against 48.5% and 48.34% to 94.82%, cross-sectional diameter reduction, both showed decreased values of corroded compared to coated specimens.

Charles *et al.,* [14] investigated the use of inorganic inhibitors and Greener approach inhibitors to evaluate the assessment of corrosion potential using Mangifera indica resins paste extracts layered to reinforcing steel with coated thicknesses of 150µm, 250µm and 350µm. Average percentile results of potential Ecorr, mV, and concrete resistivity are 26.57% and 61.25% respectively. When compared to corroded samples, corroded has 70.1% increased values potential Ecorr, mV and 38.8% decreased values of concrete resistivity, yield stress against ultimate strength at summary and average state of corroded slab with nominal values of 100% and decremented in ultimate strength from 105.36% to 96.12%, weight loss versus cross-section diameter reduction decreased due to attack from sodium chloride from 64.8% to 44.45% and 46.76% to 86.43% respectively.

Charles *et al.,* [15] investigated corrosion probability level assessments of three different resins extracts of trees from dacryodes edulis, mangifera indica and moringa oleifera lam. Arbitrarily and computed percentile average values of yield stress against ultimate strength, when compared to corrode as 100% nominal yield stress decreased from100.95% to 96.12% dacryodes edulis inhibited, 105.36% to 96.12% mangifera indica inhibited, and 105.75 % to 96.12% moringa oleifera lam inhibited and weight loss of dacryodes edulis inhibited are 67.5% against 48.5% and 98.7% to 94.82%, cross-sectional diameter reduction, mangifera indica inhibited specimen 64.8% to 44.45% and 46.76% to 86.43% cross-sectional diameter reduction and moringa oleifera lam inhibited specimen 67.5% against 48.5% and 48.34% to 94.82%, cross-sectional diameter reduction, all showed decreased values of corroded compared to coated specimens.

2. MATERIALS AND METHODS FOR EXPERINMENT

2.1 Aggregates

The fine aggregate and coarse aggregate were purchased. Both met the requirements of BS 882 [16]

2.1.2 Cement

Portland limestone cement grade 42.5 is the most and commonly type of cement in Nigerian Market. It was used for all concrete mixes in this investigation. The cement met the requirements of BS EN 196-6 [17]

2.1.3 Water

The water samples were clean and free from impurities. The fresh water used was gotten from the tap at the Civil Engineering Department Laboratory, Kenule Beeson Polytechnic, Bori, Rivers State. The water met the requirements of BS 3148 [18]

2.1.4 Structural Steel Reinforcement

The reinforcements are gotten directly from the market in Port Harcourt. BS 4449:2005+A3 [19]

2.1.5 Corrosion Inhibitors (Resins / Exudates) Acacia senegal Exudates

The study inhibitor (**Acacia senegal exudates**) is of natural tree exudate /resin substance extracts.

2.2 Experimental Procedures

2.2.1 Experimental method

2.2.2 Sample preparation for reinforcement with coated resin/exudates

The corrosion rates were quantified predicated on current density obtained from the polarization curve and the corrosion rate quantification set-up. Fresh concrete mix batch were fully compacted to remove trapped air, with concrete cover of 15mm and projection of 150mm for half cell potential measurement and concrete resistivity tests. The polarization curve was obtained as the relationship between corrosion potential and current density. The samples were designed with sets of reinforced concrete slab of 150mm thick x 350mm width x 900mm long, uncoated and coated specimens of above thicknesses were embedded into the concrete, spaced at 150mm apart. The corrosion cell consisted of a saturated calomel reference electrode (SCE), counter electrode (graphite rod) and the reinforcing steel embedded in concrete specimen acted as the working electrode. Slabs were demoulded after 72 hours and cured for 28 days with room temperature and corrosion acceleration ponding process with Sodium Chloride lasted for 150days with 14 days checked intervals for readings. Mix ratio of 1:2:3 by weight of concrete, water cement ratio of 0.65, and manual mixing was adopted

2.3 Accelerated Corrosion Test

The accelerated corrosion test allows the acceleration of corrosion to reinforcing steel embedded in concrete and can simulate corrosion growth that would occur over decades. In order to test concrete resistivity and durability against corrosion, it was necessary to design an experiment that would accelerate the corrosion process and maximize the concrete's resistance against corrosion until failure. An accelerated corrosion test is the impressed current technique which is an effective technique to investigate the corrosion process of steel in concrete and to assess the damage on the concrete cover. A laboratory acceleration process helps to distinguish the roles of individual factors that could affect chloride induced corrosion. Therefore, for design of structural members and durability against corrosion as well as selection of suitable material and appropriate protective systems, it is useful to perform accelerated corrosion tests for obtaining quantitative and qualitative information on corrosion.

2.4 Corrosion Current Measurements (Half-cell potential measurements)

Classifications of the severity of rebar corrosion rates are presented in Table 2.1. If the potential measurements indicate that there is a high probability of active corrosion, concrete resistivity measurement can be subsequently used to estimate the rate of corrosion. However, caution needs to be exercised in using data of this nature, since constant corrosion rates with time are assumed. This was also stated from practical experience (Figg and Marsden, [20] and Langford and Broomfield, [21]). Half-cell potential measurements are indirect method of assessing potential bar corrosion, but there has been much recent interest in developing a means of performing perturbative electrochemical measurements on the steel itself to obtain a direct evaluation of the corrosion rate (Gowers and Millard, [22]).

Table -2.1 Dependence between potential and corrosion probability

Potential E_{corr}	Probability of corrosion
Ecorr < −350mV	Greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement
−350mV ≤ Ec_{orr} ≤ −200mV	Corrosion activity of the reinforcing steel in that area is uncertain
E_{corr} > −200mV	90% probability that no reinforcing steel corrosion is occurring in that area at the time of measurement (10% risk of corrosion

2.5 Concrete Resistivity Measurement Test

Different readings were taken at different locations at the surface of the concrete. After applying water on the surface of the slabs, the concrete resistivity was measured daily at the reference locations, looking for the saturation condition. These locations were chosen at the side of the slabs, since concrete electrical resistivity measurements could be taken when water was on the top surface of the slab. The mean values of the readings were recorded as the final readings of the resistivity in the study. The saturation level of the slabs was monitored through concrete electrical resistivity measurements, which are directly related to the moisture content of concrete. Once one slab would reach the saturated condition, the water could be drained from that slab, while the other slabs remained ponded. Time limitation was the main challenge to perform all the experimental measurements, as the concrete saturation condition changes with time. In the study, the Wenner four probes method was used; it was done by placing the four probes in contact with the concrete directly above the reinforcing steel bar. Henceforth, these measurements will be referred to as the measurements in «dry» conditions. Since each of the slabs had a different w/c, the time needed to saturate each of the slabs was not the same. Before applying water on the slabs, the concrete electrical resistivity was measured in the dry condition at the specified locations. The electrical resistivity becomes constant once the concrete has reached saturation.

Table -2.2 Dependence between concrete resistivity and corrosion probability

Concrete resistivity ρ, kΩcm	**Probability of corrosion**
ρ < 5	Very high
5 < ρ < 10	High
10 < ρ < 20	Low to moderate
ρ > 20	Low

2.6 Tensile Strength of Reinforcing Bars

To ascertain the yield and tensile strength of tension bars, bar specimens of 12 mm diameter of Control, corroded and coated were tested in tension in a Universal Testing Machine and were subjected to direct tension until failure; the yield, maximum and failure loads being recorded. To ensure consistency, the remaining cut pieces from the standard length of corroded and Control steel bars were subsequently used for mechanical properties of steel.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The results of the half-cell potential measurements in table 3.1 were plotted against concrete resistivity of table 3.2 for easy interpretation. It is evident that potential E_{corr} if low (< −350mV) in an area measuring indicates a 95% probability of corrosion. In the other measuring points, potential E_{corr} is high (−350mV ≤ E_{corr} ≤ −200mV), which indicates a 10% or uncertain probability of corrosion.

Results of the concrete resistivity measurements are shown in Table 3.2. It used as indication of likelihood of significant corrosion (ρ < 5, 5 < ρ < 10, 10 < ρ < 20, ρ > 20) for Very high, High, Low to moderate and Low, for Probability of corrosion. Resistivity survey data gives an indication of whether the concrete condition is favorable for the easy movements of ions leading to more corrosion. Concrete resistivity is commonly measured by four-electrode method.

3.1 Control Concrete Slab Members

Results obtained from table 3.1 of half-cell potential measurements for and concrete resistivity for 7days to 178 days respectively indicated a 10% or uncertain probability of corrosion which indicates no corrosion presence or likelihood and concrete resistivity which indicated a low probability of corrosion or no corrosion indication. Results from tables 3.1 into 3.1A showed the average values derived from randomly slab samples of control, corroded and exudates/resin coated specimens of 150µm, 300µm, 450µm and represented in figures 3.1 and 3.1A of concrete resistivity ρ, kΩcm versus Potential $E_{corr,}{}^{mV}$. Average potential E_{corr} control values of -104.005 mV, -105.865 mV, -103.522mV fused into -104.464 mV, with percentile average value 30.25852% and percentile difference -69.7415%. Average results of concrete Resistivity ρ, kΩcm from table 3.2 into 3.2A and plotted in figures 3.2 and 3.2A are 13.6722 kΩcm, 13.42887kΩcm, 13.7022kΩcm, fused into

13.60109kΩcm with percentile average value 195.7257% and percentile difference 95.72572%. Average mechanical properties “ultimate strength” of control specimens from table 3.3 into 3.3A and plotted in figures 3.3 and 3.3A are 548.8783N/mm^2, 548.51173N/mm^2, 548.0783N/mm^2, fused into 548.4894N/mm^2, with percentile average value 92.4352% and percentile difference -7.5648%. Average mechanical properties “weight loss of steel” of control from table 3.4 into 3.4A and plotted in figures 3.4 and 3.4A are 7.128667 grams, 7.128667 grams, 7.082grams, fused into 7.113111grams with percentile average value 54.11633% and percentile difference -45.8837%. Average mechanical properties “cross- section area reduction” of control from table 3.5 into 3.5A and plotted in figures 3.5 and 3.5A are 12mm, 12mm, 12mm and fused into 12mm with percentile average value 113.5169% and percentile difference 13.51692%. Control specimens result showed no corrosion potential.

3.2 Corroded Concrete Slab Members

Results from tables 3.1 into 3.1A showed the average values derived from randomly slab samples of control, corroded and exudates/resin coated specimens of 150µm, 300µm, 450µm and represented in figures 3.1 and 3.1A of potential $E_{corr,}{}^{mV}$ Average potential E_{corr} corroded values of -276.373 mV , -355.673mV, -403.673mV fused into -345.239mV, with percentile average value 330.4854% and percentile difference -230.4854% against -69.7415% and -67.3178% of control and coated specimens. Potential E_{corr} results showed that the values of non-coated specimens are high with the range of $(-350\text{mV} \leq E_{corr} \leq -200\text{mV})$, which indicates a 10% or uncertain probability of corrosion. Average results of concrete resistivity ρ, kΩcm from table 3.2 into 3.2A and plotted in figures 3.2 and 3.2A are 6.496833kΩcm, 6.906833kΩcm, 7.4435kΩcm, fused into 6.949056kΩcm with percentile average value 51.09191% and percentile difference -48.9081% against 95.72572% and 114.8917% of control and coated specimens. Range of values of corroded specimens showed indication of likelihood of significant corrosion ($\rho < 5$, $5 < \rho < 10$, $10 < \rho < 20$, $\rho > 20$) for very high, high, low to moderate and low, for Probability of corrosion. Average mechanical properties “ultimate strength” of corroded specimens from table 3.3 into 3.3A and plotted in figures 3.3 and 3.3A are 594.0217N/mm^2, 592.3883N/mm^2, 593.7217N/mm^2, fused into 593.3772N/mm^2, with percentile average value 108.1839% and percentile difference 8.183891% against -7.5648% and -7.60957% of control and coated specimens. Results showed high ultimate yielding of corroded specimens to control and coated specimens due to the effect of corrosion on the mechanical properties of the steel reinforcement. Average mechanical properties “weight loss of steel” of corroded specimens from table 3.4 into 3.4A and plotted in figures 3.4 and 3.4A are 13.12933grams, 13.12933grams, 13.17367grams, fused into 13.14411grams with percentile average value 184.7871% and percentile difference 84.78709% against -45.8837% and -45.7759% of control and coated specimens. Results of weight loss of steel showed higher percentile values against control and coated specimens due to the effect of corrosion on the mechanical properties of steel. Average mechanical properties “cross- section area reduction” of control from table 3.5 into 3.5A and plotted in figures 3.5 and 3.5A are 10.49333mm, 10.49333mm, 10.72667mm and fused into 10.57111mm with percentile average value 88.09259% and percentile difference -11.9074% against 13.51692% and 13.51692%. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel.

3.3 Acacia Senegal Exudates Steel Bar Coated Concrete Slab Members

Results from tables 3.1 into 3.1A is the average values derived from randomly slab samples of control, corroded and exudates/resin coated specimens of 150µm, 300µm, 450µm and represented in figures 3.1 and 3.1A of concrete resistivity ρ, kΩcm versus potential $E_{corr,}{}^{mV}$. Relationship which showed average potential Ecorr control values of -112.881mV, -112.711mV, -112.904mV fused into -112.832mV, with percentile average value 32.68219% and percentile difference -67.3178% over 230.4854% corroded specimen. Average results of concrete resistivity ρ, kΩcm from table 3.2 into 3.2A and plotted in figures 3.2 and 3.2A are 14.71183kΩcm, 14.9685kΩcm, 15.1185kΩcm, fused into 14.93294kΩcm with percentile average value 214.8917% and percentile difference 114.8917% over -48.9081% corroded specimen. Average mechanical properties “ultimate strength” of control specimens from table 3.3 into 3.3A and plotted in figures 3.3 and 3.3A are 546.996N/mm^2, 548.296N/mm^2, 549.3793N/mm^2, fused into 548.2238N/mm^2, with percentile average value 92.39043% and percentile difference -7.60957% over 8.183891% corroded specimen. Average mechanical properties “weight loss of steel” of coated from table 3.4 into 3.4A and plotted in figures 3.4 and 3.4A are 7.1195grams, 7.1195grams, 7.142833grams, fused into 7.127278grams with percentile average value 54.22411% and percentile difference -45.7759% over 84.78709% corroded. Average mechanical properties “cross- section area reduction” of control from table 3.5 into 3.5A and plotted in figures 3.5 and 3.5A are 12mm, 12mm, 12mm and fused into 12mm with percentile average value 113.5169% and percentile difference 13.51692% over -11.9074% corroded specimen. Coated specimens result showed no corrosion potential.

Table 3.1 : Potential Ecorr, after 28 days curing and 150 days Accelerated Periods

	Potential $E_{corr,mV}$								
	Time Intervals after 28 days curing								
Samples	AG1	AG2	AG3	AG4	AG5	AG6	AG7	AG8	AG9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Control Concrete slab Specimens								
CSMA1	-106.875	-103.845	-101.295	-107.975	-103.785	-105.835	-100.365	-104.735	-105.465
CSMB1	**Corroded Concrete Slab Specimens**								
	-247.606	-273.806	-307.706	-346.806	-356.606	-363.606	-397.506	-404.706	-408.806
	Acacia senegal exudates (steel bar coated specimen)								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
CSMC1	-111.924	-109.594	-117.124	-112.294	-109.234	-116.604	-111.524	-115.294	-111.894

Table 3.1A : Average Potential Ecorr, after 28 days curing and 150 days Accelerated Periods

S/no	Samples	Average A{G(1,2,3)},(4,5,6)}, A{G(7,8,9)}			Summary Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Average Values Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Difference Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}
CSMA1	Control Specimens	-104.005	-105.865	-103.522	-104.464	30.25852	-69.7415
CSMB1	Corroded Specimens	-276.373	-355.673	-403.673	-345.239	330.4854	230.4854
CSMC1	Coated Specimens	-112.881	-112.711	-112.904	-112.832	32.68219	-67.3178

Table 3.2 : Results of Concrete Resistivity ρ, kΩcm Time Intervals after 28 days curing curing and 150 days Accelerated Periods

	Concrete Resistivity ρ, kΩcm								
	Time Intervals after 28 days curing								
Samples	AG1	AG2	AG3	AG4	AG5	AG6	AG7	AG8	AG9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Control Concrete slab Specimens								
CSMA2	13.5922	13.7622	13.6622	13.8922	13.7222	12.6722	13.6922	13.6922	13.7222
CSMB2	**Corroded Concrete Slab Specimens**								
	5.7935	**5.9335**	**7.7635**	**6.0735**	**7.2435**	**7.4035**	**7.1435**	**7.5735**	**7.6135**
CSMC2	**Acacia senegal exudates (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	14.5185	14.6685	14.9485	15.0785	14.7685	15.0585	15.0085	15.1585	15.1885

Table 3.2B : Average Results of Concrete Resistivity ρ, kΩcm Time Intervals after 28 days curing and 150 days Accelerated Periods

S/no	Samples	Average A{G(1,2,3)},(4,5,6)}, A{G(7,8,9)}			Summary Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Average Values Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Difference Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}
CSMA2	Control Specimens	13.6722	13.42887	13.7022	13.60109	195.7257	95.72572
CSMB2	Corroded Specimens	**6.496833**	6.906833	7.4435	6.949056	51.09191	-48.9081
CSMC2	Coated Specimens	14.71183	14.9685	15.1185	14.93294	214.8917	114.8917

Table 3.3 : Mechanical properties of Control, Corroded and Steel Coated Concrete Slab

	Time Intervals AGter 28 days curing								
Samples	AG1	AG2	AG3	AG4	AG5	AG6	AG7	AG8	AG9

Durations	(7days)	(21day)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Yield Stress (N/mm2) for Control, Corroded and Coated Specimens								
CSMA3	410	410	410	410	410	410	410	410	410
	Ultimate strength (N/mm2)								
	Control Concrete slab Specimens								
CSMB3	549.345	550.245	547.045	547.245	551.445	546.845	549.845	547.345	547.045
CSMC3	**Corroded Concrete Slab Specimens**								
	592.955	594.055	595.055	591.055	595.055	591.055	593.655	590.855	596.655
CSMD3	**Acacia senegal exudates (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	547.896	547.196	545.896	548.296	548.296	548.296	550.996	547.946	549.196

Table 3.3A : Average Mechanical properties of Control, Corroded and Steel Coated Concrete Slab

S/no	Samples	Average A{G(1,2,3)},(4,5,6)}, A{G(7,8,9)}			Summary Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Average Values Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Difference Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}
		Ultimate strength (N/mm2)					
CSMB3	Control Specimens	548.8783	548.5117	548.0783	548.4894	92.4352	-7.5648
CSMC3	Corroded Specimens	594.0217	592.3883	593.7217	593.3772	108.1839	8.183891
CSMD3	Coated Specimens	546.996	548.296	549.3793	548.2238	92.39043	-7.60957

Table 3.4 : Mechanical properties of Control, Corroded and Steel Coated Concrete Slab

	Weight Loss of Steel (in grams)								
	Control Concrete slab Specimens								
CSMA4	7.062	7.182	7.142	7.062	7.072	7.262	7.092	6.992	7.162
CSMB4	**Corroded Concrete Slab Specimens**								
	13.003	13.171	13.214	13.251	13.257	13.259	13.21	13.26	13.051
CSMC4	**Acacia senegal exudates (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	7.1095	7.1195	7.1295	7.1195	7.1595	7.1195	7.1595	7.1195	7.1495

Table 3.4A : Average Mechanical properties of Control, Corroded and Steel Coated Concrete Slab

S/no	Samples	Average A{G(1,2,3)},(4,5,6)}, A{G(7,8,9)}			Summary Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Average Values Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Difference Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}
		Weight Loss of Steel (in grams)					
CSMA4	Control Specimens	7.128667	7.128667	7.082	7.113111	54.11633	-45.8837
CSMB4	Corroded Specimens	13.12933	13.12933	13.17367	13.14411	184.7871	84.78709
CSMC4	Coated Specimens	7.1195	7.1195	7.142833	7.127278	54.22411	-45.7759

Table 3.5 : Mechanical properties of Control, Corroded and Steel Coated Concrete Slab

	Cross- section Area Reduction (Diameter, mm)								
	Control Concrete slab Specimens								
CSMA5	12	12	12	12	12	12	12	12	12
CSMB5	**Corroded Concrete Slab Specimens**								
	10.49	10.49	10.5	10.57	10.6	10.67	10.71	10.72	10.75
	Acacia senegal exudates (steel bar coated specimen)								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
CSMC5	12	12	12	12	12	12	12	12	12

Table 3.5A : Average Mechanical properties of Control, Corroded and Steel Coated Concrete Slab

S/no	Samples	Average A{G(1,2,3)},(4,5,6)}, A{G(7,8,9)}			Summary Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Average Values Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}	Percentile Difference Average A{G(1,2,3)}, (4,5,6)}, A{G(7,8,9)}
		Cross- section Area Reduction (Diameter, mm)					
CSMA5	Control Specimens	12	12	12	12	113.5169	13.51692
CSMB5	Corroded Specimens	10.49333	10.49333	10.72667	10.57111	88.09259	-11.9074
CSMC5	Coated Specimens	12	12	12	12	113.5169	13.51692

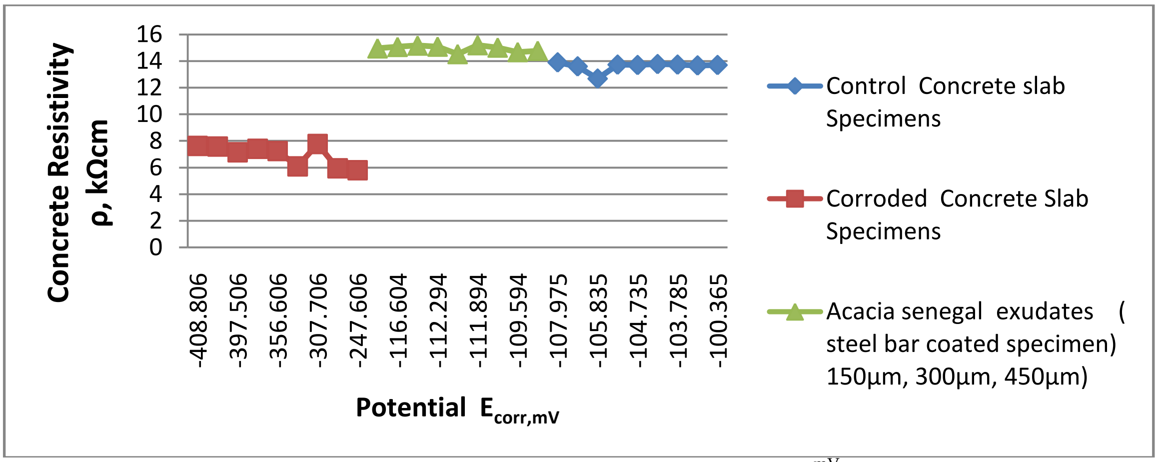

Fig. 3.1 Concrete Resistivity ρ, kΩcm versus Potential $E_{corr,}^{mV}$ Relationship

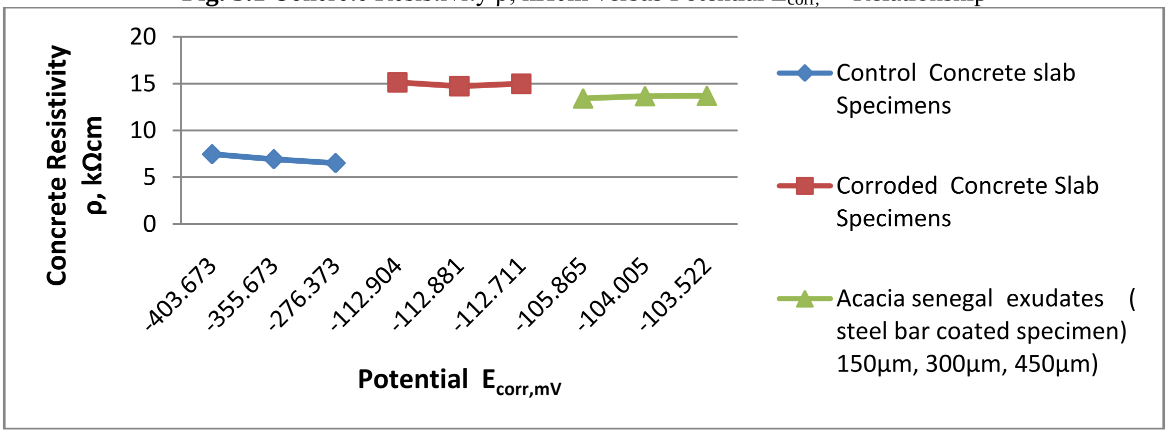

Fig. 3.1A Average Concrete Resistivity versus Potential Relationship

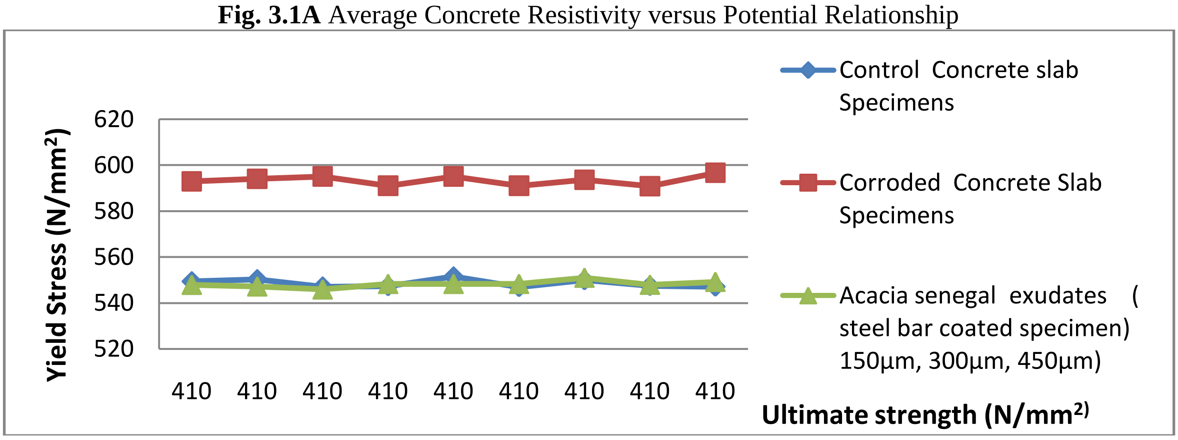

Fig. 3.2 Yield Stress versus Ultimate strength

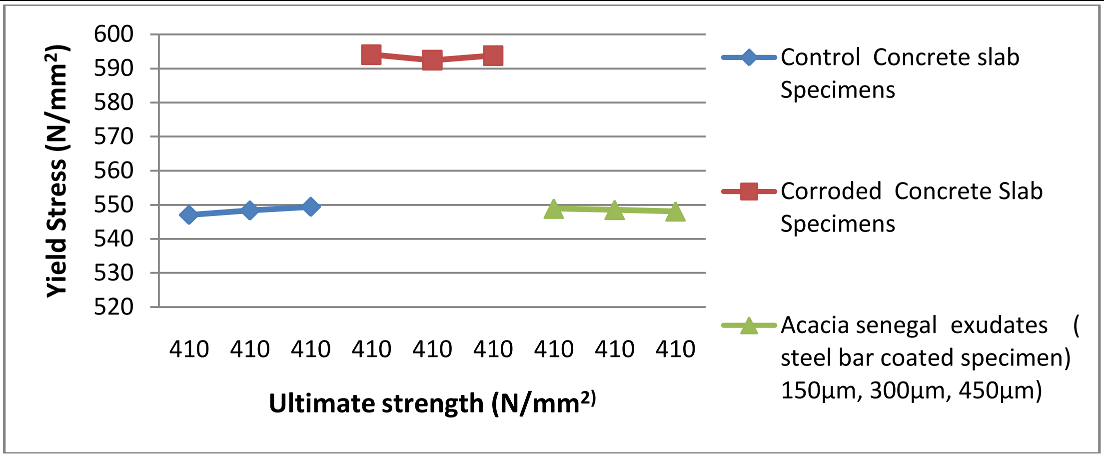

Fig. 3.2A Average Yield Stress versus Ultimate strength

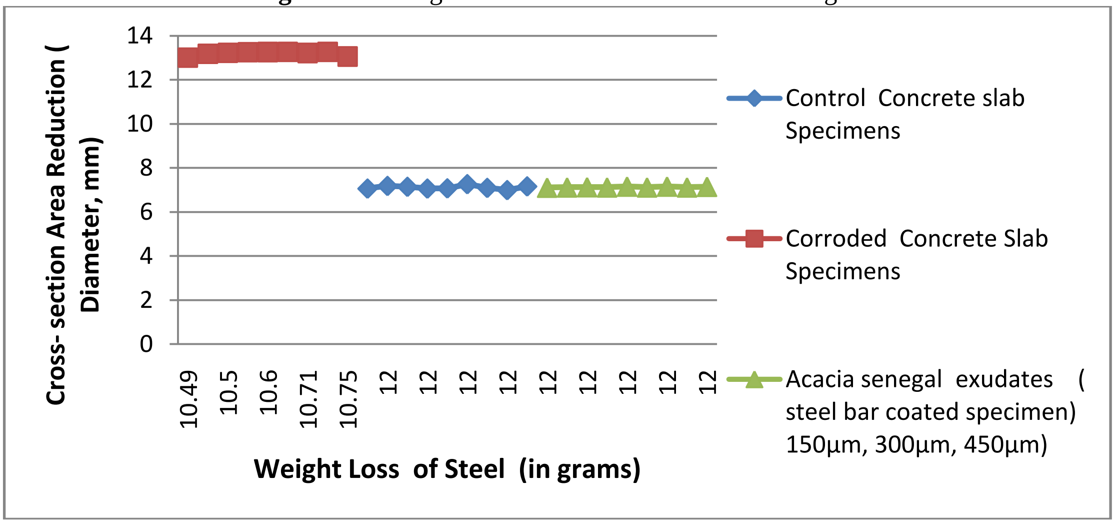

Fig. 3.3 Weight Loss of Steel versus Cross- section Area Reduction

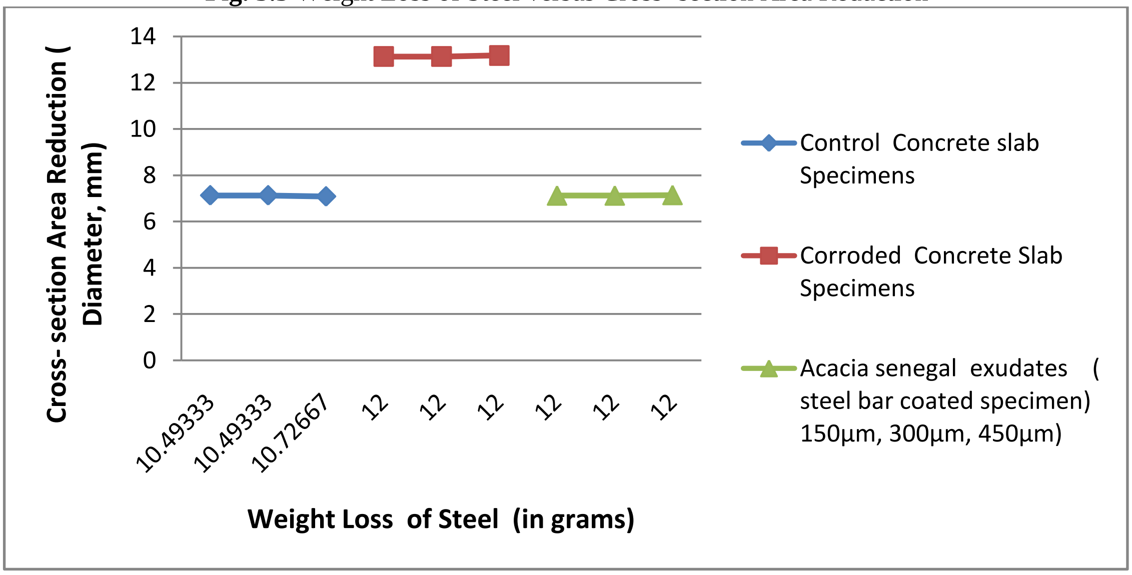

Fig. 3.3A Average Weight Loss of Steel versus Cross- section Area Reduction

4. CONCLUSION

Experimental results showed the following conclusions:

i. Control specimens result showed no corrosion potential

ii. Potential E_{corr} results showed that the values of corroded specimens are high with the range of ($-350mV \leq$ □$_{corr} \leq -200mV$), which indicates a 10% or uncertain probability of corrosion

iii. Results showed high ultimate yielding of corroded specimens to control and coated specimens due to the effect of corrosion on the mechanical properties of the steel reinforcement
iv. Results of Weight Loss of Steel showed higher percentile values against control and coated specimens due to the effect of corrosion on the mechanical properties of steel.
v. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel.
vi. Potential of corrosion probability was notice on mapping areas
vii. Resin extracts of inorganic origins were discovered to curb and prevent corrosion attack on steel reinforcement
viii. Higher tensile values were obtained from Control and coated compared to corroded specimens

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