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EVALUATION OF MECHANICAL PROPERTIES OF CORRODED AND COATED REINFORCING STEEL EMBEDDED IN CONCRETE

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ABSTRACT

Chlorides has been known to be introduced in concrete through several sources which in turns result to corrosion that generates tensile stresses in steel reinforcement surroundings concrete thereby resulting to early cracks and poorly on service life of the structure. This study evaluated the utilizations of inorganic eco-friendly exudates / resin extracts of trees original from cola acuminate as preventive measure towards the corrosive actions of salt water attack on embedded reinforcing steel in concrete structures within the marine region using experimental application of half cell potential, concrete resistivity and tensile strength test to examined the change in the surface condition of reinforcements mechanical properties of non-coated and exudates/resin coated specimens embedded in concrete slab in an accelerated corrosive medium of for 150 days immersion in sodium chloride and with applied currents potential of -200 mV through 1200mV, with a scan rate of 1mV/s. Results of potential $E_{corr,}^{mV}$ corroded specimen percentile value is 337.3433% and percentile differences of 237.3433% against -70.3566% and -68.347% of control and coated specimens. Concrete resistivity ρ, kΩcm percentile average value 64.36129% and percentile difference -35.6387% against 55.3729% and 96.06209% of control and coated specimens. Mechanical properties “ultimate strength” of corroded specimen percentile average value of 107.6483% and percentile difference 7.648311% against -7.10491% and -6.67339% of control and coated specimens. Results showed high ultimate yield 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 has percentile average value 180.4375% and percentile difference 80.43747% against -44.5791% and -45.1857% 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 has percentile average value 87.75926% and percentile difference -12.2407% against 13.94809% and 13.94809%. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel. Entire results proved the usefulness of cola acuminate exudates as corrosion inhibitor.

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

1.0 INTRODUCTION

The minimization and curbing the effects of corrosion experienced by embedded reinforcing steel in reinforced concrete structures such as protective coatings, cathodic protection, and corrosion inhibitors has been studied by many researchers. Corrosion generates tensile stresses in steel reinforcement surroundings concrete thereby resulting to early cracks and poorly on service life of the structure. Chlorides have been known to be introduced in concrete through several sources (Morris *et al*. [1], Ann and Song, [2]), stated that concrete cast that contains chloride ions from seawater and aggregates can be used as an accelerative agent. Environmental concerns worldwide are increasing and are likely to influence the choice of corrosion inhibitors in the future. Inorganic inhibitors and Greener approach inhibitors has shown highly and environmentally friendly, toxic free, generally, widely and inexpensive for future use, based on this properties, there is great demand of green inhibitors to organic ones due to their biodegradable properties. (Uhlig [3]). The use of corrosion inhibitors is probably more attractive from economics point of view and ease of application, inhibitors are widely used to delay corrosion of reinforcing steel in concrete. Novokshcheov [4] studied and showed that calcium nitrite is in no way detrimental to concrete properties as seen in the issue of inhibitors based on sodium or potassium. Skotinck [5] and Slater [6] showed that considering long-standing accelerated testing, calcium nitrite was of better quality in terms of strength

Charles et.al [7] 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. Corrosion test was conducted on high tensile reinforcing steel bar of 12mm, specimens rough surface were treated with Symphonia globulifera linn resin extracts with layered thickness of 150µm, 250µm and 350µm polished and embedded into concrete slab. Average results on comparison showed incremental values of 70.1% against 27.2% non-corroded 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. [8] investigated the corrosion potential, concrete resistivity and tensile tests of non-corroded, 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.[9] investigated the effects of chloride attack on reinforcing steel embedded in reinforced concrete structures built in the marine environment. An experimental work simulated the quick process by acceleration process on non-inhibited and inhibited reinforcement of acardium occidentale l. resins extracts with polished thicknesses of 150 m, 250 m and 350 m, embedded in concrete slab and immersed in sodium chloride and accelerated for 119 days using Wenner four probes method, it was done by placing the four probes in contact with the concrete directly above the reinforcing steel bar and assessed the actions of half cell potential, concrete resistivity and tensile strength of reinforcement to corrosion. When compared to corroded samples, corroded has 75.4% increased values potential Ecorr,mV and 33.54% decreased values of concrete resistivity, yield stress against ultimate strength at in comparison to corrode as 100% nominal yield stress decremented from 108.38% to 90.25% respectively, weight loss at 69.3% against 43.98% and 51.45% to 89.25%, cross-sectional diameter reduction, both showed decreased values of corroded compared to coated specimens.

Charles et al. [10] investigated corrosion level probability assessment potential through half cell potential corrosion measurement, concrete resistivity test and tensile strength test mechanical properties of non-corroded, 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. [11] 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 [12] investigated corrosion probability level assessments of three different resins extracts of trees from dacryodes edulis, mangifera indica and moringa oleifera lam using half cell potential corrosion measurement, concrete resistivity measurement and tensile strength test to ascertain the surface condition of the mechanical properties of non-corroded, corroded and inhibited reinforcement coated. Average percentile results of potential Ecorr,mV, and concrete resistivity are dacryodes edulis 29.9% and 63.6% , mangifera indica 26.57% and 61.25%

and moringa oeifera lam 29.9% and 68.74% respectively. 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.

Charles et al. [13] examined the effectiveness in the utilization of three eco-friendly inorganic inhibitors tree extract exudates / resins of Symphonia globulifera linn, Ficus glumosa and Acardium occidentale l. Non-inhibited and inhibited reinforcements with exudates / resins of 150µm, 250µm and 350µm thicknesses were embedded in concrete slab with exposed sections, immersed sodium chloride solution and accelerated using Wenner four probe method. General and compute percentile average values of yield stress against ultimate strength at in comparison to corrode as 100% nominal yield stress decremented ultimate strength from 103.06% to 96.12% , 112.48% to 89.25%, and 108.38% to 90.25% of Symphonia globulifera linn, Ficus glumosa and Acardium occidentale l respectively, weight loss at of corroded against inhibited Symphonia globulifera linn specimens at 67.5% against 48.5% and 47.80% to 94.82%, inhibited Ficus glumosa 69.5% to 47.29%, 48.95% to 77.89% and inhibited acardium occidentale l.

2.0 MATERIALS AND METHODS FOR EXPERINMENT

2.1 Aggregates

The fine aggregate and coarse aggregate were purchased. Both met the requirements of [14].

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 [15].

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 [16]

2.1.4 Structural Steel Reinforcement

The reinforcements are gotten directly from the market in Port Harcourt [17]

2.1.5 Corrosion Inhibitors (Exudates / Resins) Cola acuminata

The study inhibitor is cola acuminata of natural tree resins /exudates substance extracts.

2.2 EXPERIMENTAL PROCEDURES

2.2.1 Experimental method

2.2.2 Sample Preparation For Reinforcement With Coated Exudates /Resins

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, 1985 and Langford and Broomfield ,1987). 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, 1999a). Corrosion rates have been related to electrochemical measurements based on data first reported by Stern and Geary (1957).

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 ?, kΩcm	Probability of corrosion
$\rho < 5$	Very high
$5 < \rho < 10$	High
$10 < \rho < 20$	Low to moderate
$\rho > 20$	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 non-corroded, 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 non-corroded steel bars were subsequently used for mechanical properties of steel.

3.0 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. Randomly cast slab samples results from tables 3.1 into 3.1A of control, corroded and exudates/resin coated specimens are 150μm, 300μm, 450μm and graphically in figures 3.1 and 3.1A of concrete resistivity ρ, kΩcm versus Potential $E_{corr,}{}^{mV}$. Potential E_{corr} control averaged values are -102.725mV, -104.757mV, and 105.365mV summed up to -104.282mV, percentile into 29.6434% and percentile difference -70.3566%. Concrete resistivity ρ, kΩcm averaged values from table 3.2 into 3.2A, presented in figures 3.2 and 3.2A are 12.0722kΩcm, 11.82887kΩcm, 12.1022kΩcm, summed up to 12.00109kΩcm with percentile average value 155.3729% and percentile difference 55.3729%. Mechanical properties "ultimate strength" of control specimens averaged values from tables 3.3 into 3.3A presented in figures 3.3 and 3.3A are 544.8983N/mm^2, 544.5317N/mm^2, 544.0983N/mm^2, fused into 544.5094N/mm^2, with percentile average value 92.89509% and percentile difference -7.10491%. 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 7.218667grams, 7.218667grams, 7.172grams, fused into 7.203111grams with percentile average value 55.42086% and percentile difference -44.5791%. 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 averaged, 12mm, 12mm, 12mm and summed up to 12mm with percentile average value 113.9481% and percentile difference 13.94809%. Control specimens result showed no corrosion potential. They are immersed in free tap water with no contamination.

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3.2 Corroded Concrete Slab Members

Results of control, corroded and exudates/resin coated specimens of 150µm, 300µm, 450µm and represented in figures 3.1 and 3.1A from tables 3.1 into 3.1A of potential $E_{corr,}^{mV}$ are average values potential E_{corr} of corroded are -282.923mV, -362.223mV, -410.223mV fused into -351.789mV, with percentile average value 337.3433% and percentile difference 237.3433% against -70.3566% and -68.347% of control and coated specimens. Potential E_{corr} results showed that the values of non-coated specimens are high with the range of ($-350mV \le E_{corr} \le -200mV$), 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 7.271833kΩcm, 7.681833kΩcm, 8.2185kΩcm, fused into 7.724056kΩcm with percentile average value 64.36129% and percentile difference -35.6387% against 55.3729% and 96.06209% of control and coated specimens. Range of values of non-coated specimens showed indication of likelihood of significant corrosion (⍰ < 5, 5 < ⍰ < 10, 10 < ⍰ < 20, ⍰ > 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 586.7997N/mm^2, 585.1663N/mm^2, 586.4997N/mm^2, fused into 586.1552N/mm^2, with percentile average value 107.6483% and percentile difference 7.648311% against -7.10491% and -6.67339% of control and coated specimens. Results showed high ultimate yield 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 12.98233grams, 12.98233grams, 13.02667grams, fused into 12.99711grams with percentile average value 180.4375% and percentile difference 80.43747% against -44.5791% and -45.1857% 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 10.45333mm, 10.45333mm, 10.68667mm and fused into 10.53111mm with percentile average value 87.75926% and percentile difference -12.2407% against 13.94809% and 13.94809%. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel.

3.3 Cola Acuminata Exudates Steel Bar Coated Concrete Slab Members

Result 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 E_{corr} control values of -111.401mV, -111.231mV, -111.424mV summed up to -111.352mV, with percentile average value 31.65297% and percentile difference -68.347% over 237.3433% 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 14.92283kΩcm, 15.1795kΩcm, 15.3295kΩcm, fused into 15.14394kΩcm with percentile average value 196.0621% and percentile difference 96.06209% over -35.6387% 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 545.811N/mm^2, 547.111N/mm^2, 548.1943N/mm^2, fused into 547.0388N/mm^2, with percentile average value 93.32661% and percentile difference -6.67339% over 7.648311% corroded specimen. 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 7.1165grams, 7.1165grams, 7.139833grams, fused into 7.124278grams with percentilb8e average value 54.81432% and percentile difference -45.1857% over 80.43747% 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 113.9481% and percentile difference 13.94809% over 12.2407% corroded specimen. Control 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	AJ1	AJ2	AJ3	AJ4	AJ5	AJ6	AJ7	AJ8	AJ9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
					Control Concrete slab Specimens				
CSPA1	-103.23	-103.703	-101.24	-106.943	-103.64	-103.687	-106.223	-104.079	-105.792
CSPB1					**Corroded Concrete Slab Specimens**				
	-254.156	-280.356	-314.256	-353.356	-363.156	-370.156	-404.056	-411.256	-415.356
					Cola acuminata exudates (steel bar coated specimen)				
		(150µm) coated			**(300µm) coated**			**(450µm) coated**	
CSPC1	-110.444	-108.114	-115.644	-110.814	-107.754	-115.124	-110.044	-113.814	-110.414

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

S/no	Samples	Average A{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}			Summary Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}	Percentile Average Values Average A{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}	Percentile Difference Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}
				Potential $E_{corr,mV}$			
CSPA1	Control Specimens	-102.725	-104.757	-105.365	-104.282	29.6434	-70.3566
CSPB1	Corroded Specimens	-282.923	-362.223	-410.223	-351.789	337.3433	237.3433
CSPC1	Coated Specimens	-111.401	-111.231	-111.424	-111.352	31.65297	-68.347

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

	Concrete Resistivity ρ, kΩcm								
	Time Intervals after 28 days curing								
Samples	AJ1	AJ2	AJ3	AJ4	AJ5	AJ6	AJ7	AJ8	AJ9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Control Concrete slab Specimens								
CSPA2	11.9922	12.1622	12.0622	12.2922	12.1222	11.0722	12.0922	12.0922	12.1222
CSPB2	**Corroded Concrete Slab Specimens**								
	6.5685	**6.7085**	**8.5385**	**6.8485**	**8.0185**	**8.1785**	**7.9185**	**8.3485**	**8.3885**
CSPC2	**Cola acuminata exudates (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	14.7295	14.8795	15.1595	15.2895	14.9795	15.2695	15.2195	15.3695	15.3995

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{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}			Summary Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}	Percentile Average Values Average A{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}	Percentile Difference Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}
		Concrete Resistivity ρ, kΩcm					
CSPA2	Control Specimens	12.0722	11.82887	12.1022	12.00109	155.3729	55.3729
CSPB2	Corroded Specimens	**7.271833**	7.681833	8.2185	7.724056	64.36129	-35.6387
CSPC2	Coated Specimens	14.92283	15.1795	15.3295	15.14394	196.0621	96.06209

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

	Time Intervals AJter 28 days curing								
Samples	AJ1	AJ2	AJ3	AJ4	AJ5	AJ6	AJ7	AJ8	AJ9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Yield Stress (N/mm^2) for Control, Corroded and Coated Specimens								
CSPA3	410	410	410	410	410	410	410	410	410
	Ultimate strength (N/mm^2)								
	Control Concrete slab Specimens								
CSPB3	545.365	546.265	543.065	543.265	547.465	542.865	545.865	543.365	543.065
CSPC3	**Corroded Concrete Slab Specimens**								
	585.733	586.833	587.833	583.833	587.833	583.833	586.433	583.633	589.433
CSPD3	**Cola acuminata exudates (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	546.711	546.011	544.711	547.111	547.111	547.111	549.811	546.761	548.011

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

S/no	Samples	Average A{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}			Summary Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}	Percentile Average Values Average A{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}	Percentile Difference Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}
				Ultimate strength (N/mm^2)			
CSPB3	Control Specimens	544.8983	544.5317	544.0983	544.5094	92.89509	-7.10491
CSPC3	Corroded Specimens	586.7997	585.1663	586.4997	586.1552	107.6483	7.648311
CSPD3	Coated Specimens	545.811	547.111	548.1943	547.0388	93.32661	-6.67339

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

				Weight Loss of Steel (in grams)					
				Control Concrete slab Specimens					
CSPA4	7.152	7.272	7.232	7.152	7.162	7.352	7.182	7.082	7.252
CSPB4				**Corroded Concrete Slab Specimens**					
	12.856	13.024	13.067	13.104	13.11	13.112	13.063	13.113	12.904
CSPC4				**Cola acuminata exudates (steel bar coated specimen)**					
		(150µm) coated			**(300µm) coated**			**(450µm) coated**	
	7.1065	7.1165	7.1265	7.1165	7.1565	7.1165	7.1565	7.1165	7.1465

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

S/no	Samples	Average A{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}			Summary Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}	Percentile Average Values Average A{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}	Percentile Difference Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}
				Weight Loss of Steel (in grams)			
CSPA4	Control Specimens	7.218667	7.218667	7.172	7.203111	55.42086	-44.5791
CSPB4	Corroded Specimens	12.98233	12.98233	13.02667	12.99711	180.4375	80.43747
CSPC4	Coated Specimens	7.1165	7.1165	7.139833	7.124278	54.81432	-45.1857

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

				Cross- section Area Reduction (Diameter, mm)					
				Control Concrete slab Specimens					
CSPA5	12	12	12	12	12	12	12	12	12
CSPB5				**Corroded Concrete Slab Specimens**					
	10.45	10.45	10.46	10.53	10.56	10.63	10.67	10.68	10.71
				Cola acuminata exudates (steel bar coated specimen)					
		(150µm) coated			**(300µm) coated**			**(450µm) coated**	
CSPC5	12	12	12	12	12	12	12	12	12

Table 35A : Average Mechanical properties of Control, Corroded and Steel Coated Concrete Slab

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S/no	Samples	Average A{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}			Summary Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}	Percentile Average Values Average A{J(1,2,3)},(4,5,6)}, A{J(7,8,9)}	Percentile Difference Average A{J(1,2,3)}, (4,5,6)}, A{J(7,8,9)}
			Cross- section Area Reduction (Diameter, mm)				
CSPA5	Control Specimens	12	12	12	12	113.9481	13.94809
CSPB5	Corroded Specimens	10.45333	10.45333	10.68667	10.53111	87.75926	-12.2407
CSPC5	Coated Specimens	12	12	12	12	113.9481	13.94809

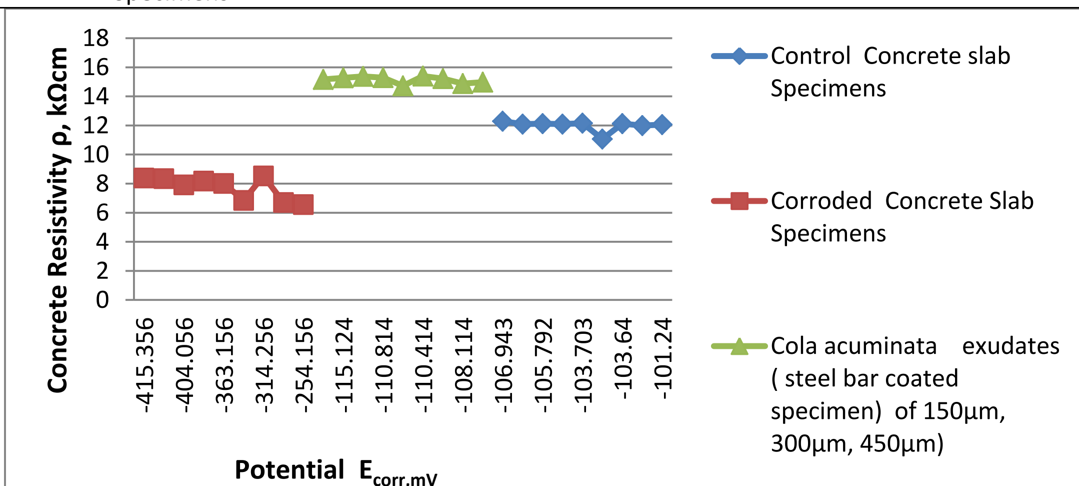

Figure 3.1: Concrete Resistivity ρ, kΩcm versus Potential $E_{corr,}{}^{mV}$ Relationship

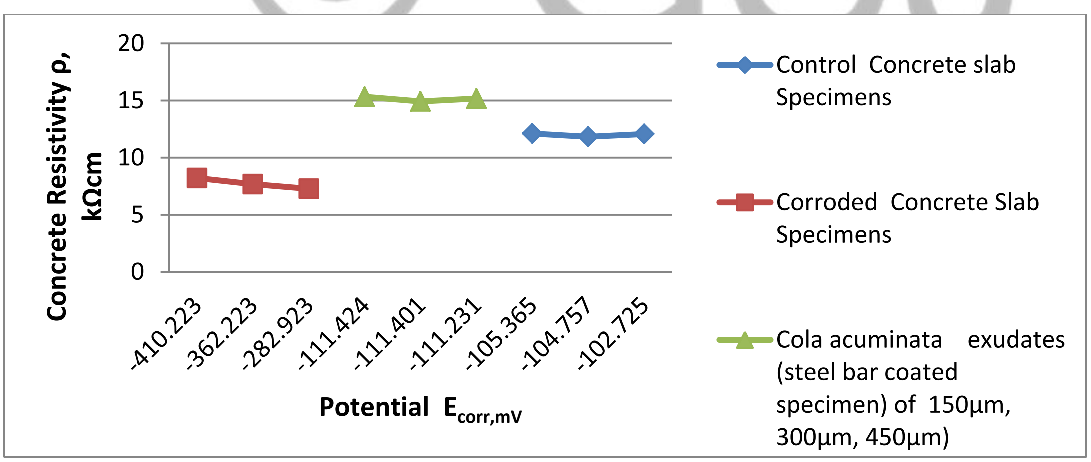

Figure 3.1A: Average Concrete Resistivity versus Potential Relationship

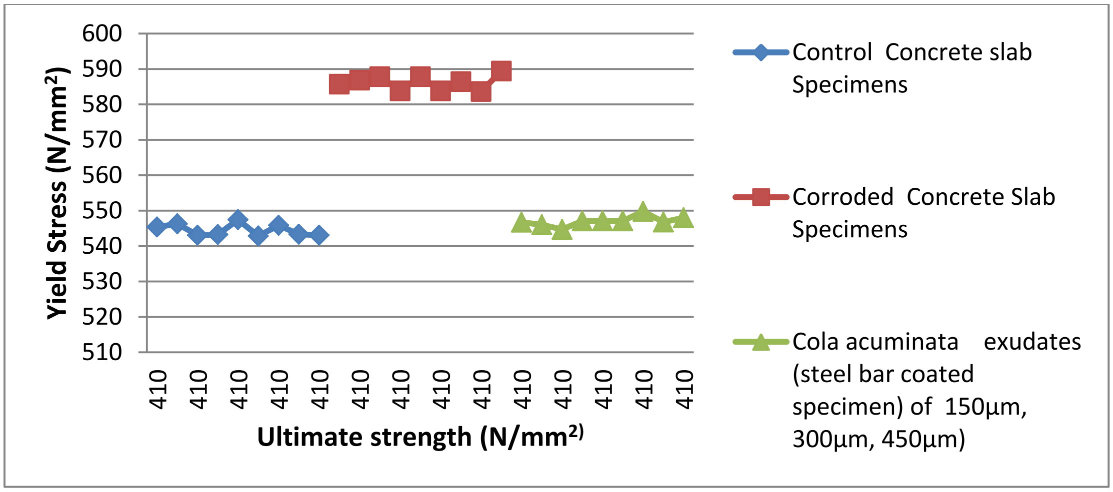

Figure 3.2: Yield Stress versus Ultimate strength

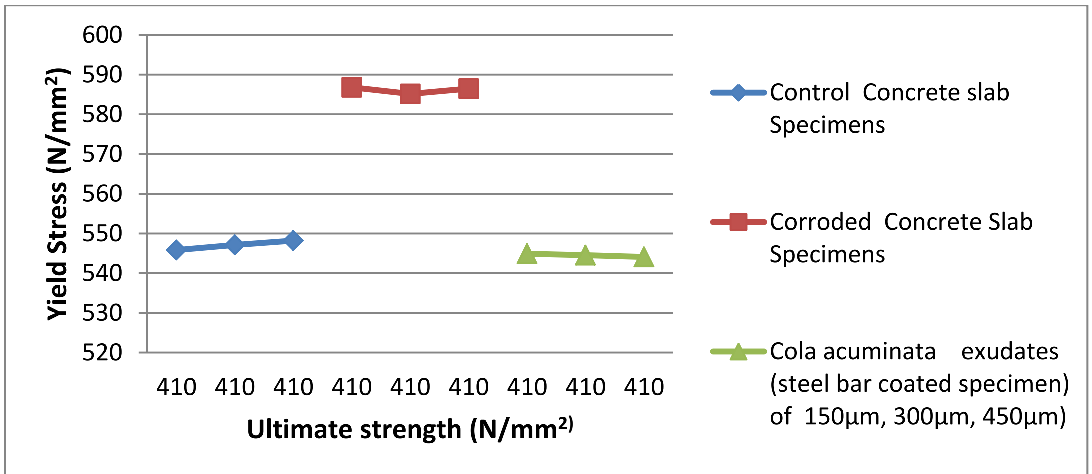

Figure 3.2A: Average Yield Stress versus Ultimate strength

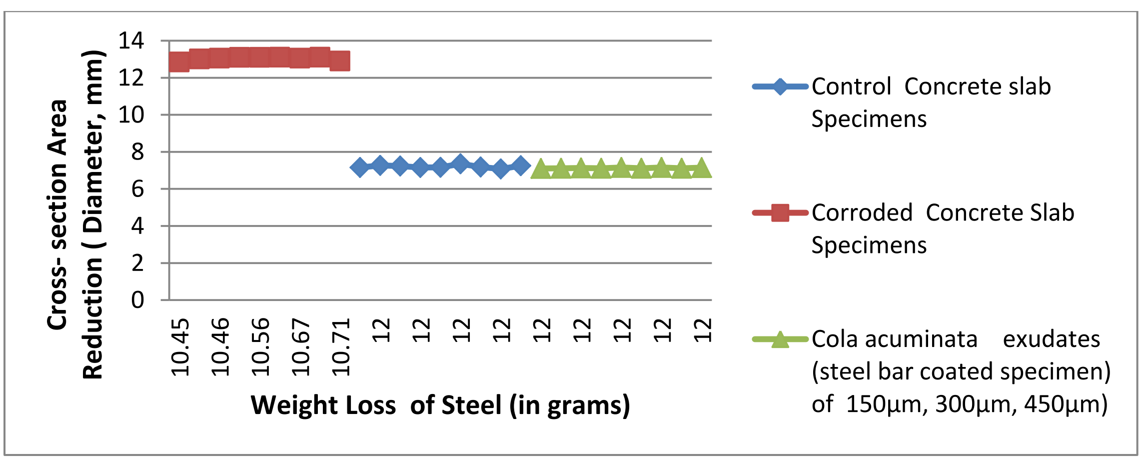

Figure 3.3: Weight Loss of Steel versus Cross- section Area Reduction

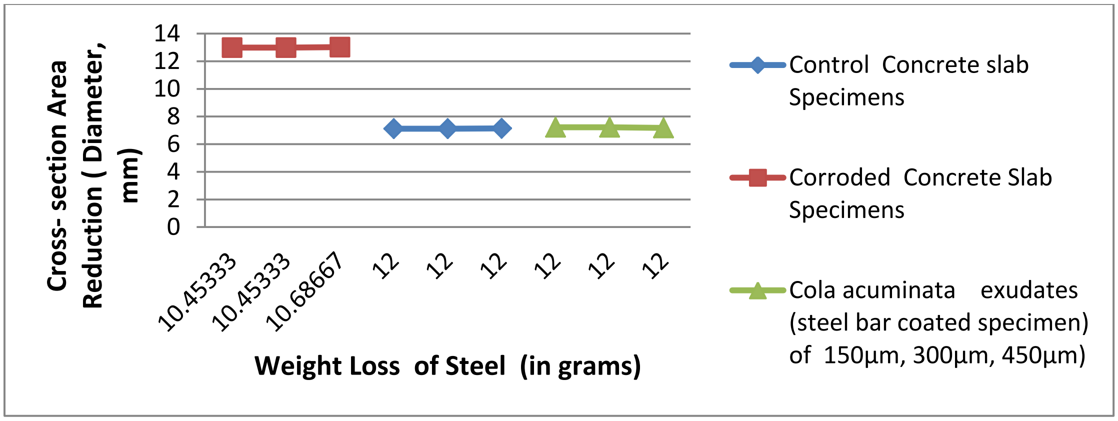

Figure 3.3A: Average Weight of Steel Loss versus Cross- section Area Reduction

4.0 CONCLUSION

Experimental results showed the following conclusions:

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

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