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Corrosion Potential Assessment of Reinforcement Mechanical Properties Embedded in Concrete in Accelerated Corrosive Medium

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Abstract

Corrosion of reinforcing steel causes damage to concrete structures and it is a very costly problem in terms of its financial implications and also for its structures safety. This experimental work evaluated comparatively the effect of uncoated and exudates / resin coated reinforcement with celtis zenkeri of varying thickness 150μm, 300μm and 450μm, inserted into concrete slab and accelerated in corrosive madia for 150 days to monitored and ascertained corrosion potential rates and mechanical properties effect of reinforcing steel using half cell potential, concrete resistivity measurement, tensile strength tests. Average potential E_{corr} percentile corroded specimen value is 337.1527% and percentile difference 237.1527% against -70.3398% and -67.7193% of control and coated specimens. Averaged percentile results of concrete resistivity ρ, kΩcm value is 45.81129% and percentile difference -54.1887% against 118.2868% and 117.675% of control and coated specimens. Average mechanical properties "ultimate strength" of percentile average value of corroded specimen is 108.7799% and percentile difference 8.779928% against -8.07128% and -7.93467% 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 percentile difference 82.23808% against -45.1267% and -45.4432% 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" percentile average value 86.17593% and percentile difference -13.8241% against 16.04169% and 16.04169%. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel.

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

1.0 INTRODUCTION

Cracks can reduce the overall strength and stiffness of the concrete structure and accelerate the ingress of aggressive ions, leading to other types of concrete deterioration and resulting in further cracking [1]. Cracked concrete surrounding corroded reinforcements and stirrups influences the anchorage and shear capacity of a beam. If the concrete in this region has been cracked by corrosion, it has reached its maximum tensile strength. Cracked concrete not only affects actual shear and anchorage capacities but also reduces the load-carrying capacity of a structure over the longer term by giving less protection to reinforcement and by allowing an aggressive environment direct access to the reinforcement. Corrosion of reinforcing steel causes damage to concrete structures and it is a very costly problem in terms of its financial implications and also for its structures safety ([2], [3]). It is therefore, necessary to develop methods which can increase the surface life of these structures. One method of corrosion prevention is proper concrete design. Corrosion inhibitors are widely used to delay corrosion of reinforcing steel in concrete, it 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 ([4], [5]) to reduce the corrosion rate of steel bar, however, but they also reduce the compressive strength of concrete but inorganic inhibitors are seen to be friendly to the environment and less cost effective.

[6] proposed that for the active state the B value in the Stern-Geary equation be 26mV, and for the passive state 52mV. Using equation (2.21), the value B = 26mV can be obtained if both Tafel slopes are equal to 120mV/decade; and for B = 52mV one of the Tafel slopes could be infinity and the other 120mV/decade.

[7] Suggested that B value for steel in concrete might range from as low as 8mV to approaching infinity under different conditions.

[8] 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. Average percentile results of potential and concrete resistivity are 29.9% and 63.6% 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.

[9] Investigated the corrosion potential, concrete resistivity and tensile tests of Control, corroded and coated reinforcing steel of concrete slab member. Average results on comparison showed an increase of 70.1% against 27.2% Control of Potential Ecorr, mV and 87.8% to 38.8%, decreased values in concrete resistivity.Yield stress against ultimate strength at summary and average state of corroded slab with nominal values of 100% and decreased in ultimate strength from 100.68% to 96.12%, weight loss versus cross-section diameter reduction decreased due to attack 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% 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. The entire results showed effectiveness in the use of dacroyodes edulis as inhitors, it sustained and preserved the reinforcement against environmental.

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[10] Investigated the effects of chloride attack on reinforcing steel embedded in reinforced concrete structures built in the marine environment. Average percentile results of potential Ecorr,mV, and concrete resistivity are 27.45% and 68.45% respectively. 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.

[11] 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.

[12] investigated the use of inorganic inhibitors and Greener approach inhibitors to evaluate the assessment of corrosion potential using Mangifera indica resins paste extracts.. 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.

[13] 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 control, corroded and inhibited reinforcement. When compared to corroded samples, corroded has 70.1% increased values potential Ecorr,mV and 35.5% decreased values of concrete resistivity. 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.

[14] 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. When compared to corroded samples, corroded has 70.1% incremented values potential Ecorr,mV and 38.8% decremented values of concrete resistivity. 69.3% against

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43.98% and 51.45% to 89.25%, cross-sectional diameter reductions, both showed decremented values of corroded compared to coated specimens. 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. Average percentile results of potential Ecorr,mV, and concrete resistivity for Symphonia globulifera linn, Ficus glumosa and acardium occidentale l are 29.9% and 63.6% , 23.75% and 66.48% and 27.45% and 68.45% respectively.

2.0 MATERIALS AND METHODS FOR EXPERINMENT

2.1 Aggregates

The fine aggregate and coarse aggregate were purchased. Both met the requirements of [15].

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 [16]

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 [17]

2.1.4 Structural Steel Reinforcement

The reinforcements are gotten directly from the market in Port Harcourt [18]

2.1.5 Corrosion Inhibitor (Resins / Exudates) Celtis zenkeri

The study inhibitor is Celtis zenkeri 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 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

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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
$E\text{corr} < -350\text{mV}$	Greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement
$-350\text{mV} \le E\text{c}_{orr} \le -200\text{mV}$	Corrosion activity of the reinforcing steel in that area is uncertain
$E_{corr} > -200\text{mV}$	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

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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
$\rho < 5$	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 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

3.0 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 used as 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. In the other measuring points, potential Ecorr is high ($-350\text{mV} \leq E_{\text{corr}} \leq -200\text{mV}$), which indicates a 10% or uncertain probability of corrosion. Results of the concrete resistivity measurements are shown in Table 3.2. It is evident that potential E_{corr} if low ($< -350\text{mV}$) in an area measuring indicates a 95% probability of corrosion. Concrete resistivity is commonly measured by four-electrode method. Resistivity survey data gives an indication of whether the concrete condition is favorable for the easy movements of ions leading to more corrosion.

3.1 Control Concrete Slab Members

Tables 3.1 into 3.1A, are the results of preliminary and average results gotten from control, corroded and exudates/resin coated specimens of 150µm, 300µm, 450µm thicknesses and plotted in figures 3.1 and 3.1A of concrete resistivity ρ, kΩcm versus potential $E_{corr,}{}^{mV}$. Average potential Ecorr control specimens results are -101.81mV,, -101.28mV, -100.76mV, fused into -101.283mV, with percentile average value 29.66015% and percentile difference -70.3398%. Average results of concrete resistivity ρ, kΩcm from table 3.2 into 3.2A and plotted in figures 3.2 and 3.2A are 14.4022kΩcm, 14.4022kΩcm, 14.4022kΩcm, fused into 14.4022kΩcm with percentile average value 218.2868% and percentile difference 118.2868%. 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 547.1783N/mm^2, 545.9783N/mm^2, 546.3783N/mm^2, fused into 546.5117N/mm^2, with percentile average value 91.92872% and percentile difference --8.07128%. 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 7.008667grams, 7.008667grams, 6.962grams, fused into 6.993111grams with percentile average value 54.87327% and percentile difference -45.1267%. 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

116.0417% and percentile difference 16.04169%. Control specimens result showed no corrosion potential.

3.2 Corroded Concrete Slab Members

Unsystematic 27 slab samples of results from tables 3.1 into 3.1A illustrated the average values of control, corroded and exudates/resin coated specimens of 150µm, 300µm, 450µm and shown in figures 3.1 and 3.1A of potential $E_{corr,}^{mV}$. Average potential E_{corr} corroded values are -272.613mV -351.913mV, -399.913mV fused into -341.479mV, with percentile average value 337.1527% and percentile difference 237.1527% against -70.3398% and -67.7193% 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 6.597833kΩcm, 6.597833kΩcm, 6.597833kΩcm, fused into 6.597833kΩcm with percentile average value 45.81129% and percentile difference -54.1887% against 118.2868% and 117.675% of control and coated specimens. Range of values of non-coated 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 595.3617N/mm^2, 593.0617N/mm^2, 595.0617N/mm^2, fused into 594.495N/mm^2, with percentile average value 108.7799% and percentile difference 8.779928% against -8.07128% and -7.93467% 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 12.72933grams, 12.72933grams, 12.77367grams, fused into 12.74411grams with percentile average value 182.2381% and percentile difference 82.23808% against -45.1267% and -45.4432% 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 10.26333mm, 10.26333mm, 10.49667mm and fused into 10.34111mm with percentile average value 86.17593% and percentile difference -13.8241% against 16.04169% and 16.04169%. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel.

3.3 Celtis zenkeri exudates Steel Bar Coated Concrete Slab Members

Results from tables 3.1 into 3.1A, averaged values of control, corroded and exudates/resin coated specimens of 150µm, 300µm, 450µm as presented 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 -110.281mV , -110.111mV, -110.304mV derived into -110.232mV, with percentile average value 32.28066% and percentile difference -67.7193% over 237.1527% corroded specimen. Concrete resistivity ρ, kΩc average results from table 3.2 into 3.2A and plotted in figures 3.2 and 3.2A are 14.36183kΩcm, 14.36183kΩcm, 14.36183kΩcm, fused into 14.36183kΩcm with percentile average value 217.675% and percentile difference 117.675% over -54.1887% 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 546.096N/mm^2, 547.396N/mm^2, 548.4793N/mm^2, derived into 547.3238N/mm^2, with percentile average value 92.06533% and percentile difference -7.93467% over 8.779928% corroded specimen. Average mechanical properties "weight loss

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of steel" of control from table 3.4 into 3.4A and plotted in figures 3.4 and 3.4A are 6.945grams, 6.945grams, 6.968333grams, fused into 6.952778grams with percentile average value 54.55679% and percentile difference -45.4432% over 82.23808% 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 116.0417% and percentile difference 16.04169% over -13.8241% 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	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Control Concrete slab Specimens								
CSLA1	-102.88	-102.25	-100.3	-101.28	-101.72	-100.84	-100.37	-101.44	-100.47
CSLB1	**Corroded Concrete Slab Specimens**								
	-243.846	-270.046	-303.946	-343.046	-352.846	-359.846	-393.746	-400.946	-405.046
	Celtis zenkeri exudates (steel bar coated specimen)								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
CSLC1	-109.324	-106.994	-114.524	-109.694	-106.634	-114.004	-108.924	-112.694	-109.294

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

S/no	Samples	Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}			Summary Average A{F(1,2,3)}, (4,5,6)}, A{F(7,8,9)}	Percentile Average Values Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}	Percentile Difference Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}
	Potential $E_{corr,mV}$						
CSLA1	Control Specimens	-101.81	-101.28	-100.76	-101.283	29.66015	-70.3398
CSLB1	Corroded Specimens	-272.613	-351.913	-399.913	-341.479	337.1527	237.1527
CSLC1	Coated Specimens	-110.281	-110.111	-110.304	-110.232	32.28066	-67.7193

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	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Control Concrete slab Specimens								
CSLA2	14.3222	14.4922	14.3922	14.6222	14.4522	13.4022	14.4222	14.4222	14.4522
CSLB2	**Corroded Concrete Slab Specimens**								
	5.7735	**6.095**	**7.925**	**6.235**	**7.405**	**7.565**	**7.305**	**7.735**	**7.775**
CSLC2	**Celtis zenkeri exudates (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	14.1685	14.3185	14.5985	14.7285	14.4185	14.7085	14.6585	14.8085	14.8385

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{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}			Summary Average A{F(1,2,3)}, (4,5,6)}, A{F(7,8,9)}	Percentile Average Values Average A{F(1,2,3)}, (4,5,6)}, A{F(7,8,9)}	Percentile Difference Average A{F(1,2,3)}, (4,5,6)}, A{F(7,8,9)}
	Concrete Resistivity ρ, kΩcm						
CSLA2	Control Specimens	14.4022	14.4022	14.4022	14.4022	218.2868	118.2868
CSLB2	Corroded Specimens	**6.597833**	6.597833	6.597833	6.597833	45.81129	-54.1887
CSLC2	Coated Specimens	14.36183	14.36183	14.36183	14.36183	217.675	117.675

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

	Time Intervals after 28 days curing								
Samples	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Yield Stress (N/mm2) for Control, Corroded and Coated Specimens								
CSLA3	410	410	410	410	410	410	410	410	410
	Ultimate strength (N/mm2)								
	Control Concrete slab Specimens								
CSLB3	547.645	548.545	545.345	545.545	549.745	545.145	548.145	545.645	545.345
CSLC3	**Corroded Concrete Slab Specimens**								
	594.295	595.395	596.395	592.395	596.395	592.395	594.995	592.195	597.995
CSLD3	**Celtis zenkeri exudates (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	546.996	546.296	544.996	547.396	547.396	547.396	550.096	547.046	548.296

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

S/no	Samples	Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}			Summary Average A{F(1,2,3)}, (4,5,6)}, A{F(7,8,9)}	Percentile Average Values Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}	Percentile Difference Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}
	Ultimate strength (N/mm2)						
CSLB3	Control Specimens	547.1783	545.9783	546.3783	546.5117	91.92872	-8.07128
CSLC3	Corroded Specimens	595.3617	593.0617	595.0617	594.495	108.7799	8.779928
CSLD3	Coated Specimens	546.096	547.396	548.4793	547.3238	92.06533	-7.93467

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

	Weight Loss of Steel (in grams)								
	Control Concrete slab Specimens								
CSLA4	6.942	7.062	7.022	6.942	6.952	7.142	6.972	6.872	7.042
CSLB4	**Corroded Concrete Slab Specimens**								
	12.603	12.771	12.814	12.851	12.857	12.859	12.81	12.86	12.651
CSLC4	**Celtis zenkeri exudates (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	6.935	6.945	6.955	6.945	6.985	6.945	6.985	6.945	6.975

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

S/no	Samples	Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}			Summary Average A{F(1,2,3)}, (4,5,6)}, A{F(7,8,9)}	Percentile Average Values Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}	Percentile Difference Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}
	Weight Loss of Steel (in grams)						
CSLA4	Control Specimens	7.008667	7.008667	6.962	6.993111	54.87327	-45.1267
CSLB4	Corroded Specimens	12.72933	12.72933	12.77367	12.74411	182.2381	82.23808
CSLC4	Coated Specimens	6.945	6.945	6.968333	6.952778	54.55679	-45.4432

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

	Cross- section Area Reduction (Diameter, mm)								
	Control Concrete slab Specimens								
CSLA5	12	12	12	12	12	12	12	12	12
CSLB5	**Corroded Concrete Slab Specimens**								
	10.26	10.26	10.27	10.34	10.37	10.44	10.48	10.49	10.52
	Celtis zenkeri exudates (steel bar coated specimen)								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
CSLC5	12	12	12	12	12	12	12	12	12

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

S/no	Samples	Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}			Summary Average A{F(1,2,3)}, (4,5,6)}, A{F(7,8,9)}	Percentile Average Values Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}	Percentile Difference Average A{F(1,2,3)},(4,5,6)}, A{F(7,8,9)}
	Cross- section Area Reduction (Diameter, mm)						
CSLA5	Control Specimens	12	12	12	12	116.0417	16.04169
CSLB5	Corroded Specimens	10.26333	10.26333	10.49667	10.34111	86.17593	-13.8241
CSLC5	Coated Specimens	12	12	12	12	116.0417	16.04169

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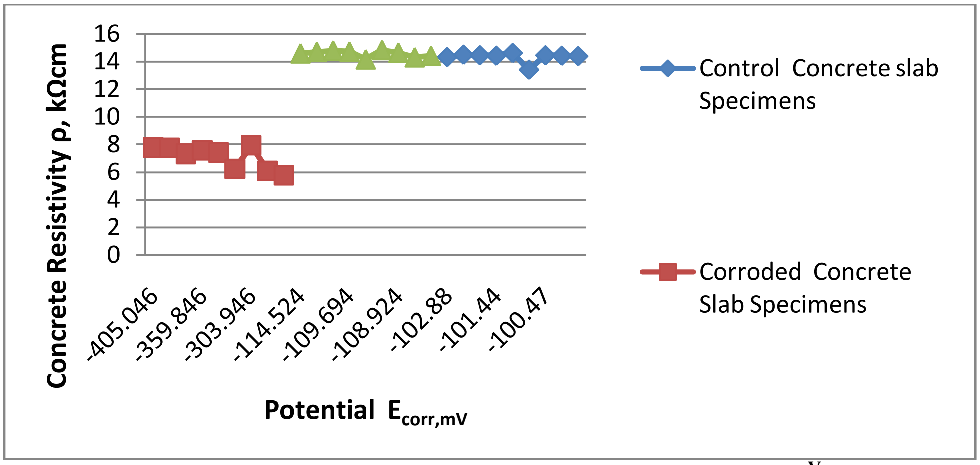

Figure 3.1: Concrete Resistivity ρ, kΩcm versus Potential $E_{corr,}{}^{mV}$ Relationship

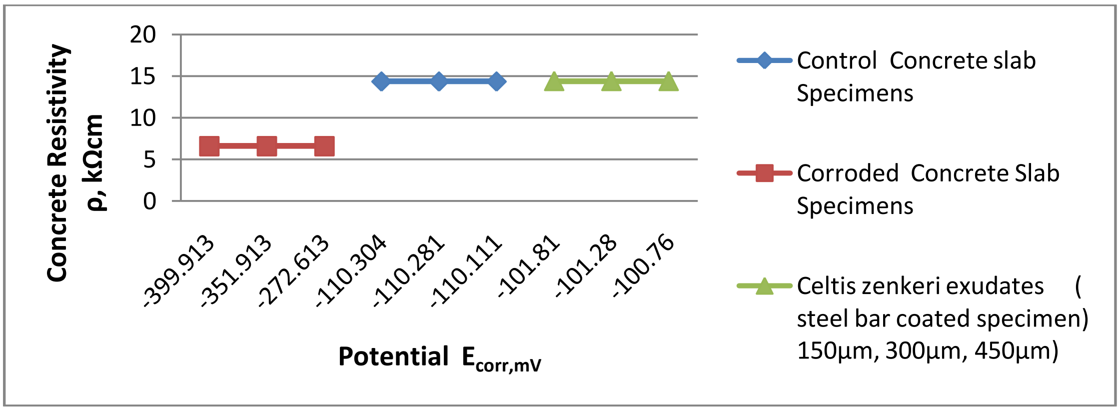

Figure 3.1A: Average Concrete Resistivity versus Potential Relationship

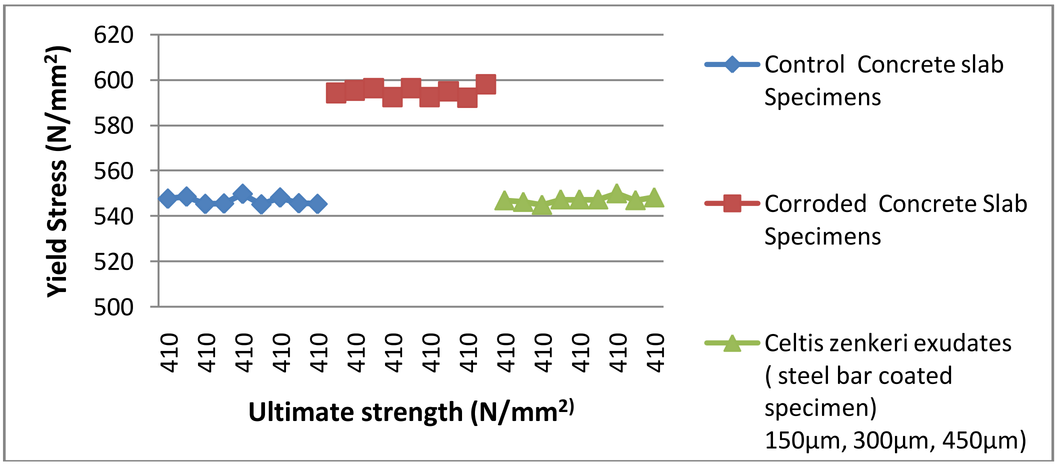

Figure 3.2: Yield Stress versus Ultimate strength

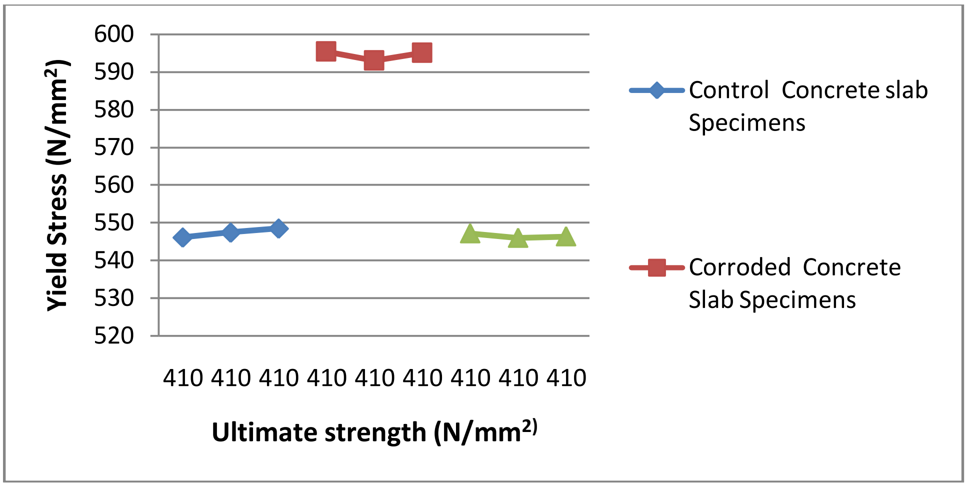

Figure 3.2A: Average Yield Stress versus Ultimate strength.

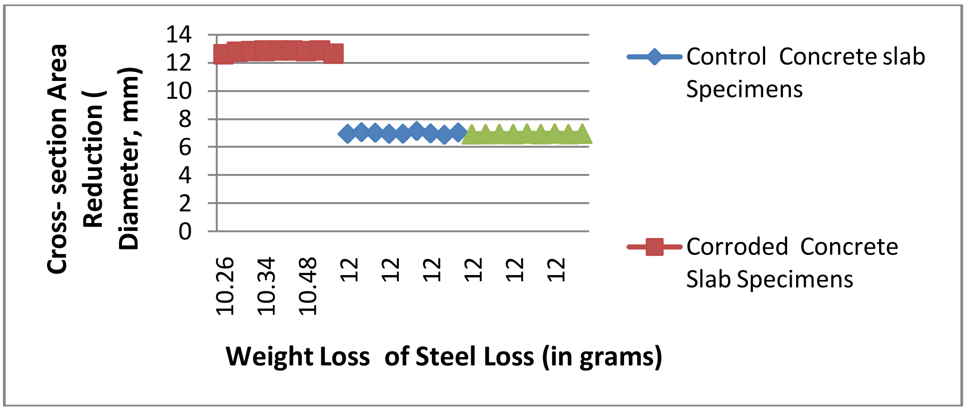

Figure 3.3: Weight Loss of Steel versus Cross- section Area Reduction

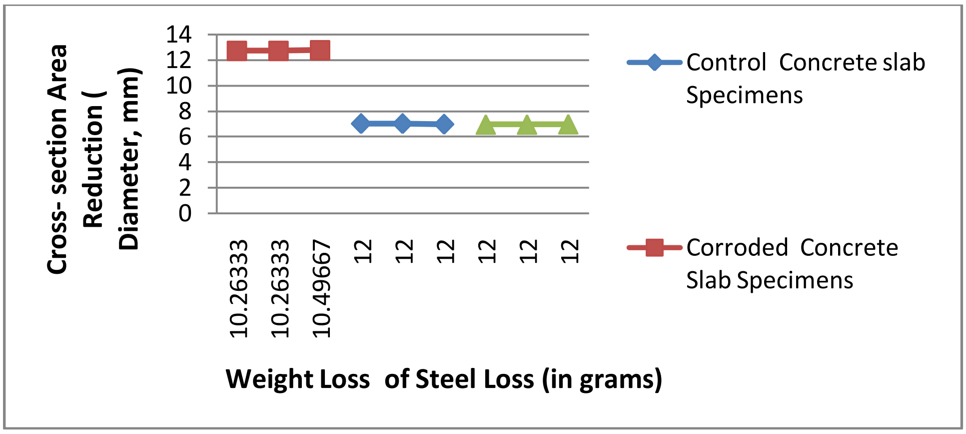

Figure 3.3A: Average Weight Loss of Steel versus Cross- section Area Reduction

4.0 CONCLUSION

Experimental results showed the following conclusions:

i. Results justified the effect of corrosion on the strength capacity of corroded and coated members

ii. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel
iii. 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
iv. 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
v. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel
vi. 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
vii. 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.

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