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Corrosion Probability of Reinforcing Steel in Concrete in Accelerated Corrosion Environment of Applied Currents Potential

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***Abstract*—The decreased in the diameter of steel rebar which reduces the mechanical properties such as yield strength, tensile strength and ductility is caused by corrosion of embedded steel in concrete structures. An investigative study on the potential application utility of inorganic inhibitory natural exudates / resin extract of grewia. Direct application of grewia exudates / resin paste on reinforcing steel reinforcement with coated thicknesses 150µm, 300µm, 450µm, embedded in concrete slab structures, immersed in corrosive environment and accelerated for 150 days after initial cured with comparative investigation with non-coated specimens. Results of potential E_{corr} corroded percentile value of 209.8322% against -67.7245% and -64.5944% of control and coated specimens. Average results of concrete resistivity ρ, kΩcm percentile value is -45.4631% against 83.36214% and 107.2234% of control and coated specimens. Mechanical properties “ultimate strength” of control specimen is 9.65248% against -8.80279% and -7.77478% of control and coated specimens. Mechanical properties “weight loss of steel” of corroded percentile of 97.6231% against -49.3986% and -45.2742% of control and coated specimens. Mechanical properties “cross-section area reduction” percentile vale of 19.3241% against 23.95271% and 23.95271%. Potential E_{corr} results showed that the values of corroded specimens are high with the range of (−350mV ≤ $□_{corr}$ ≤ -200mV), which indicates a 10% or uncertain probability of corrosion. Range of values of corroded 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. 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. 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. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel.**

Keywords—Corrosion, Corrosion inhibitors, corrosion potential, concrete resistivity and Steel Reinforcement.

1. Introduction

Corrosion of reinforcing steel embedded in reinforced concrete structure causes a decrease in the diameter of steel rebar which reduces the mechanical properties such as yield strength, tensile strength and ductility. The corrosion products so occupy a much larger volume than the original steel, and will eventually exert a large tensile force on the surrounding concrete which causes cracking and spalling of the concrete coverand loss in adhesion between steel and concrete interface. Half-cell potential measurements are an 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 [1]. Corrosion rates have been related to electrochemical measurements based on data first reported by [2]. 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. This was also stated from practical experience ([3] and [4]). The effect and the destructions caused from corrosion to reinforcing steel has been curbed by the development of corrosion inhibitors based on organic compounds containing nitrogen, oxygen, sulfur atoms and multiple bonds in the molecules that facilitate adsorption on the metal surface [5].

Reference [6] carried out the investigation of inhibitors in solutions of alkaline and extracts from cement. The extracts from cement experiment revealed corrosion was inhibited using sodium nitrite in the presence of chlorides while sodium benzoate did not. Furthermore, the initiation of corrosion was delayed with sodium nitrite, with the delay increasing with inhibitor content.

Novokshcheov [7] 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. Latter study by Skotinck [8] and Slater [9] showed that considering long-standing accelerated testing, calcium nitrite was of better quality in terms of strength.

Reference [10] 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.

Reference [11] 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.

Reference [12] 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 150µm, 250µm and 350µm, embedded in concrete slab and immersed in sodium chloride (NaCl) and accelerated for 119 days using Wenner four probes method. 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.

Reference [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.

Reference [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.

Reference [15] 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 coated specimen. 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..

Reference [16] 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. Results recorded of half cell potential, concrete resistivity and tensile strength properties for non- inhibited concrete specimens on the mapping areas for the expedited periods designated 95% probability of corrosion and betokening a high or moderate probability of corrosion. 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. MATERIALS AND METHODS FOR EXPERINMENT

2.1 Aggregates

The fine aggregate and coarse aggregate were purchased. Both met the requirements of [17]

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 [18]

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 [19]

2.1.4 Structural Steel Reinforcement

The reinforcements are gotten directly from the market in Port Harcourt. [20]

2.1.5 Corrosion Inhibitors (Resins/ Exudates) Grewia Exudate

The study inhibitor is grewia exudates 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 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. 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 .

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
$\rho < 5$	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. 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 (ρ < 5, 5 < ρ < 10, 10 < ρ < 20, ρ > 20) for Very high, High, Low to moderate and Low, for Probability of corrosion. In the other measuring points, potential Ecorr 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 is evident that potential E_{corr} if low (< −350mV) 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

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. Tables 3.1 into 3.1A, are the results of preface and typical 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 $E_{corr,}{}^{mV}$. Typical potential Ecorr control specimens' results are -101.499mV, -101.232mV, -101.365mV, fused into -101.365mV, with percentile average value 32.27554% and percentile variation -67.7245%. Typical outcomes of concrete resistivity ρ, kΩcm from table 3.2 into 3.2A and plotted in figures 3.2 and 3.2A are 13.0722kΩcm, 12.82887kΩcm, 13.1022kΩcm, fused into 13.00109kΩcm with percentile typical value 183.3621% and percentile variation

83.36214%. Typical Mechanical properties “ultimate strength” of control specimens from table 3.3 into 3.3A and plotted in figures 3.3 and 3.3A are 544.5783N/mm^2, 544.2117N/mm^2, 543.7783N/mm^2, merged into 544.1894N/mm^2, with percentile typical value 91.19721% and percentile variation -8.80279%. Typical 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 6.418667grams, 6.422grams, 6.372grams, fused into 6.404222grams with percentile average value 50.60137% and percentile variation -49.3986%. Typical 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 typical value 123.9527% and percentile variation 23.95271%. Control specimens result showed no corrosion potential.

3.2 Corroded Concrete Slab Members

Results from tables 3.1 into 3.1A showed the typical values obtained from arbitrary 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 $E_{corr,}{}^{mV}$. Typical Potential Ecorr corroded values of -274.413mV, -353.713mV, -314.063mV fused into -314.063mV, with percentile typical value 309.8322% and percentile difference 209.8322% against -67.7245% and -64.5944% of control and coated specimens. Potential Ecorr 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 from table 3.2 into 3.2A and plotted in figures 3.2 and 3.2A are **6.597833**kΩcm, **7.06833**kΩcm, 7.605kΩcm, fused into 7.090389kΩcm with percentile typical value 54.53688% and percentile variation -45.4631% against 83.36214% and 107.2234% 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. Typical Mechanical properties “ultimate strength” of control specimens from table 3.3 into 3.3A and plotted in figures 3.3 and 3.3A are 597.36171N/mm^2, 595.7283N/mm^2, 597.0617N/mm^2, fused into 596.7172N/mm^2, with percentile average value 109.6525% and percentile variation 9.65248% against -8.80279% and ---7.77478% 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. Typical 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 12.59933grams, 12.725677grams, 12.64367grams, fused into 12.65622grams with percentile average value 197.6231% and percentile variation 97.6231% against -49.3986% and -45.2742% 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. Typical 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 9.563333mm, 9.683333mm, 9.796667mm and fused into 9.681111mm with percentile average value 80.67593% and percentile variation 19.3241% against 23.95271% and 23.95271%. Cross- section area reduction results showed higher percentile reduction values due to effect of corrosion on the mechanical properties of steel.

3.3 Grewia Exudate Steel Bar Coated Concrete Slab Members

Results from tables 3.1 into 3.1A is the typical 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 typical potential Ecorr control values of -111.281mV , -111.111mV, -111.196mV fused into -111.196mV, with percentile average value 35.40557% and percentile variation -64.5944% over 209.8322% corroded specimen. Typical results of concrete resistivity ρ, kΩcm from table 3.2 into 3.2A and plotted in figures 3.2 and 3.2A are 14.47183kΩcm, 14.7285kΩcm, 14.8785kΩcm, fused into 14.69294kΩcm with percentile average value 207.2234% and percentile variation 107.2234% over -45.4631% corroded specimen. Typical mechanical properties “ultimate strength” of control specimens from table 3.3 into 3.3A and plotted in figures 3.3 and 3.3A are 549.096N/mm^2, 550.396N/mm^2, 551.4793N/mm^2, fused into 550.3238N/mm^2, with percentile typical value 92.22522% and percentile variation -7.77478% over 9.65248% corroded specimen. Typical 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 6.914grams, 6.927333grams, 6.937333grams, fused into 6.926222grams with percentile average value 54.72583% and percentile variation -45.2742% over 97.6231% 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 123.9527% and percentile variation 23.95271% over -19.3241% corroded specimen. Control specimens result showed no corrosion potential

Table 3.1 : Potential E_{corr}, after 28 days curing and 150 days Accelerated Periods

	Potential $E_{corr,mV}$								
	Time Intervals after 28 days curing								
Samples	AE1	AE2	AE3	AE4	AE5	AE6	AE7	AE8	AE9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Control Concrete slab Specimens								
CSGA1	-101.999	-102.199	-100.299	-101.199	-101.699	-100.799	-100.299	-101.399	-100.399
CSGB1	**Corroded Concrete Slab Specimens**								
	-245.646	-271.846	-305.746	-344.846	-354.646	-361.646	-395.546	-402.746	-406.846
	Grewia Exudate (steel bar coated specimen)								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
CSGC1	-110.324	-107.994	-115.524	-110.694	-107.634	-115.004	-109.924	-113.694	-110.294

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

S/no	Samples	Average A{E(1,2,3)},(4,5,6)}, A{E(7,8,9)}			Summary Average A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Average Values A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Difference Average A{E(1,2,3)},(4,5,6)}, A{E(7,8,9)}
CSHA1	Control Specimens	-101.499	-101.232	-101.365	-101.365	32.27554	-67.7245
CSHB1	Corroded Specimens	-274.413	-353.713	-314.063	-314.063	309.8322	209.8322
CSHC1	Coated Specimens	-111.281	-111.111	-111.196	-111.196	35.40557	-64.5944

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	AE1	AE2	AE3	AE4	AE5	AE6	AE7	AE8	AE9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118days)	(148days)	(163days)	(178days)
	Control Concrete slab Specimens								
CSGA2	12.9922	13.1622	13.0622	13.2922	13.1222	12.0722	13.0922	13.0922	13.1222
CSGB2	**Corroded Concrete Slab Specimens**								
	5.7735	**6.095**	**7.925**	**6.235**	**7.405**	**7.565**	**7.305**	**7.735**	**7.775**
CSGC2	**Grewia Exudate (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	14.2785	14.4285	14.7085	14.8385	14.5285	14.8185	14.7685	14.9185	14.9485

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

S/no	Samples	Average A{E(1,2,3)},(4,5,6)}, A{E(7,8,9)}			Summary Average A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Average Values A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Difference Average A{E(1,2,3)},(4,5,6)}, A{E(7,8,9)}
	Concrete Resistivity ρ, kΩcm						
CSGA2	Control Specimens	13.0722	12.82887	13.1022	13.00109	183.3621	83.36214
CSGB2	Corroded Specimens	**6.597833**	**7.06833**	7.605	7.090389	54.53688	-45.4631
CSGC2	Coated Specimens	14.47183	14.7285	14.8785	14.69294	207.2234	107.2234

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

	Time Intervals after 28 days curing								
Samples	AE1	AE2	AE3	AE4	AE5	AE6	AE7	AE8	AE9
Durations	(7days)	(21days)	(28days)	(58days)	(88days)	(118day)	(148day)	(163days)	(178das)
	Yield Stress (N/mm2) for Contro, Corroded and Coated Specimens								
CSGA3	410	410	410	410	410	410	410	410	410
	Ultimate strength (N/mm2)								
	Control Concrete slab Specimens								
CSGB3	545.045	545.945	542.745	542.945	547.145	542.545	545.545	543.045	542.745
CSGC3	**Corroded Concrete Slab Specimens**								
	596.295	597.395	598.395	594.395	598.395	594.395	596.995	594.195	599.995
CSGD3	**Grewia Exudate (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	549.996	549.296	547.996	550.396	550.396	550.396	553.096	550.046	551.296

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

S/no	Samples	Average A{E(1,2,3)},(4,5,6)}, A{E(7,8,9)}			Summary Average A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Average Values A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Difference Average A{E(1,2,3)},(4,5,6)}, A{E(7,8,9)}
	Ultimate strength (N/mm2)						
CSGB3	Control Specimens	544.578 3	544.211 7	543.778 3	544.1894	91.19721	-8.80279
CSGC3	Corroded Specimens	597.361 7	595.728 3	597.061 7	596.7172	109.6525	9.65248
CSGD3	Coated Specimens	549.096	550.396	551.479 3	550.3238	92.22522	-7.77478

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

	Weight Loss of Steel (in grams								
	Control Concrete slab Specimens								
CSGA4	6.352	6.472	6.432	6.352	6.362	6.552	6.382	6.282	6.452
CSGB4	**Corroded Concrete Slab Specimens**								
	12.473	12.641	12.684	12.721	12.727	12.729	12.68	12.73	12.52 1
CSGC4	**Grewia Exudate (steel bar coated specimen)**								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
	6.904	6.914	6.924	6.914	6.954	6.914	6.954	6.914	6.944

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

S/no	Samples	Average A{E(1,2,3)},(4,5,6)}, A{E(7,8,9)}			Summary Average A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Average Values A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Difference Average A{E(1,2,3)},(4,5,6) }, A{E(7,8,9)}
	Weight Loss of Steel (in grams)						
CSGA 4	Control Specimens	6.418667	6.422	6.372	6.404222	50.60137	-49.3986
CSGB 4	Corroded Specimens	12.59933	12.72567	12.64367	12.65622	197.6231	97.6231
CSGC 4	Coated Specimens	6.914	6.927333	6.937333	6.926222	54.72583	-45.2742

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

	Cross- section Area Reduction (Diameter, mm)								
	Control Concrete slab Specimens								
CSGA5	12	12	12	12	12	12	12	12	12
CSGB5	**Corroded Concrete Slab Specimens**								
	9.56	9.56	9.57	9.64	9.67	9.74	9.78	9.79	9.82
	Grewia Exudate (steel bar coated specimen)								
	(150µm) coated			**(300µm) coated**			**(450µm) coated**		
CSGC5	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{E(1,2,3)},(4,5,6)}, A{E(7,8,9)}			Summary Average A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Average Values A{E(1,2,3)}, (4,5,6)}, A{E(7,8,9)}	Percentile Difference Average A{E(1,2,3)},(4,5,6)}, A{E(7,8,9)}
	Cross- section Area Reduction (Diameter, mm)						
CSGA5	Control Specimens	12	12	12	12	123.9527	23.95271
CSGB5	Corroded Specimens	9.563333	9.683333	9.796667	9.681111	80.67593	-19.3241
CSGC5	Coated Specimens	12	12	12	12	123.9527	23.95271

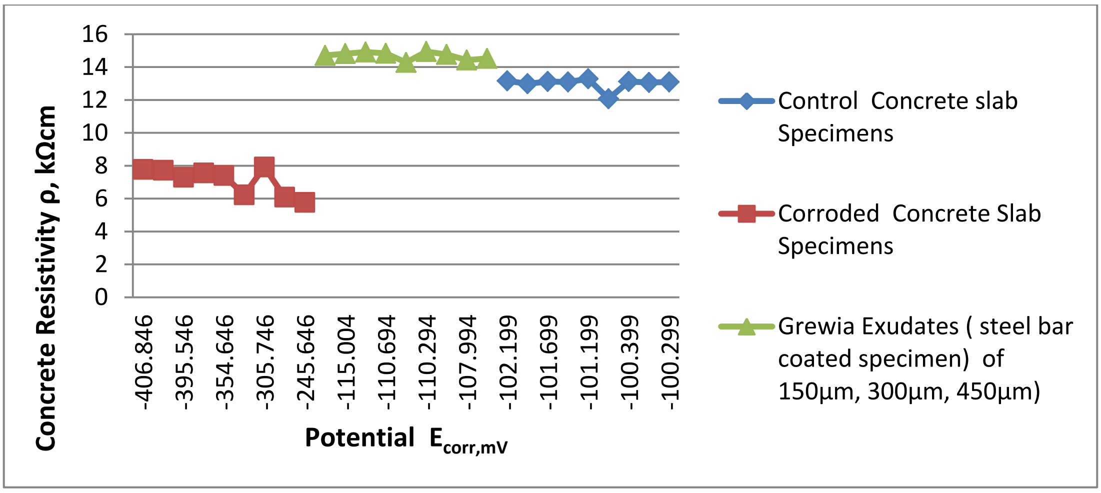

Figure 3.1: Concrete Resistivity ρ, kΩcm versus Potential $E_{corr,}{}^{mV}$ Relationship

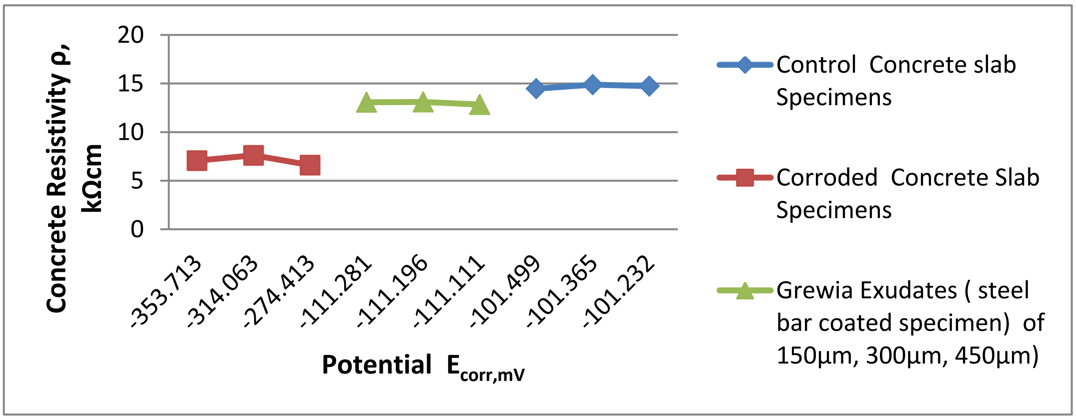

Figure 3.1A: Average Concrete Resistivity versus Potential Relationship

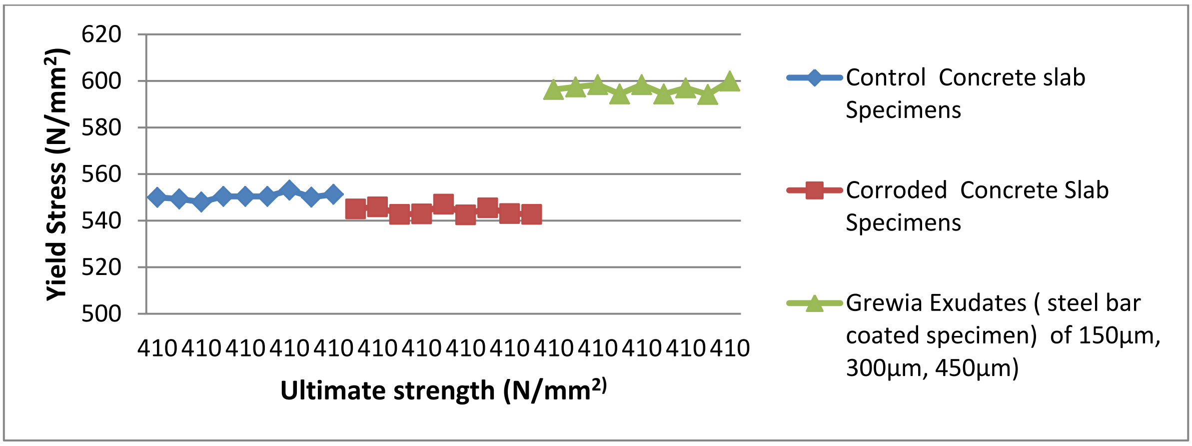

Figure 3.2: Yield Stress versus Ultimate strength

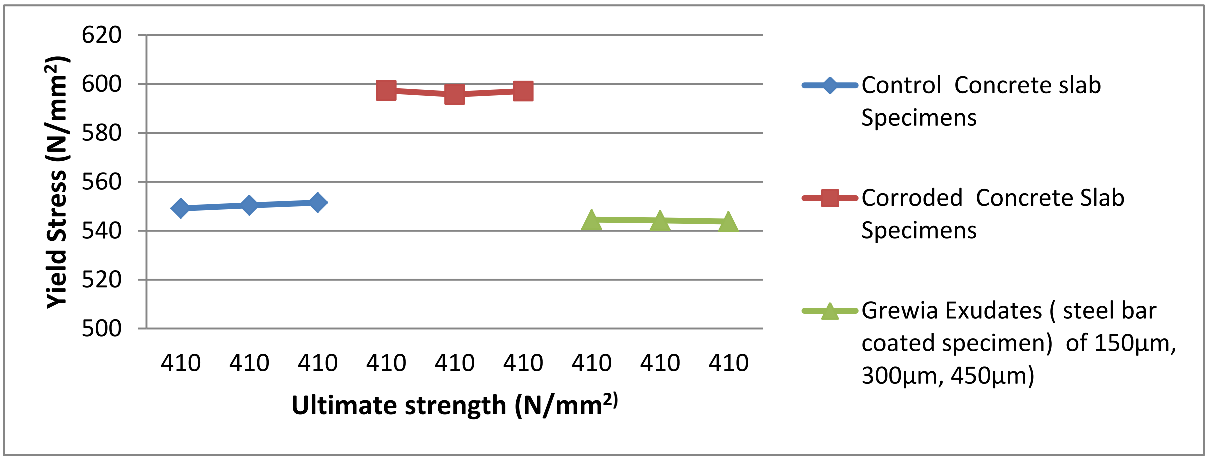

Figure 3.2A: Average Yield Stress versus Ultimate strength

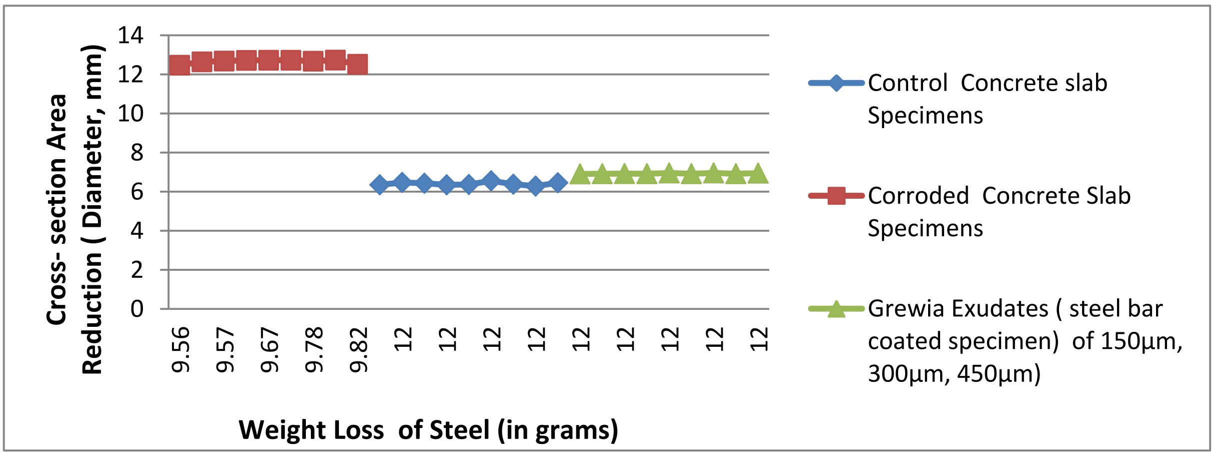

Figure 3.3: Weight Loss of Steel versus Cross- section Area Reduction

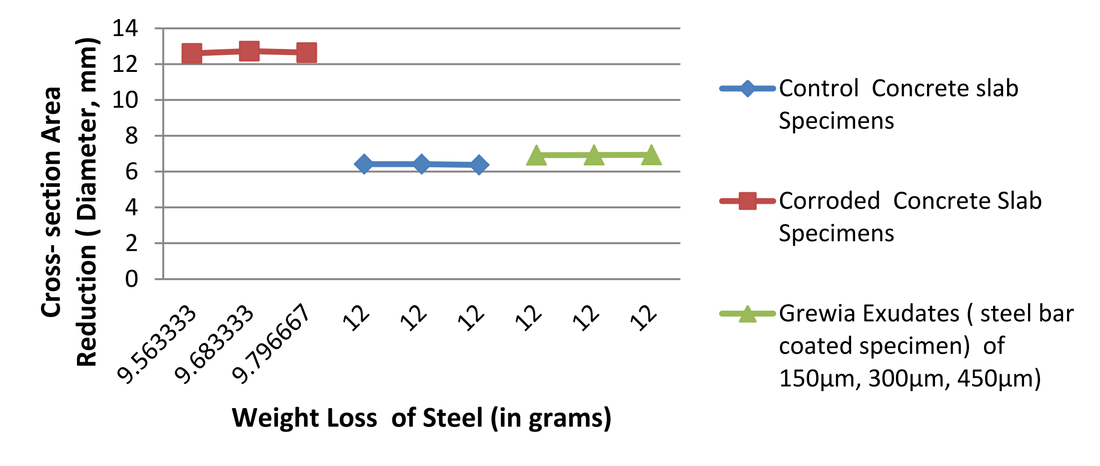

Figure 3.3A: Average Weight Loss of Steel versus Cross- section Area Reduction

4. 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 (−350mV ≤ □$_{corr}$ ≤ -200mV), which indicates a 10% or uncertain probability of corrosion.

ii. Range of values of corroded 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.

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

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