GSJ: Volume 9, Issue 8, August 2021, Online: ISSN 2320-9186
www.globalscientificjournal.com

Reinforcing Steel Mechanical Properties Surface Modification Effects on Pull-Out Bond Mechanism

Amadise S. Ogboin[1], Charles Kennedy[2], John A.TrustGod [3]
[1,3]Faculty of Engineering, Department of Civil Engineering, Niger Delta University,Wilberforce Island, Bayelsa State
[2]Faculty of Engineering, Department of Civil Engineering, Rivers State University, Port Harcourt - Rivers State, Nigeria
Author's E-mail: [1]amaogboserv@yahoo.com, [2]ken_charl@yahoo.co.uk,
[3]johteskconzults@gmail.com

ABSTRACT

The research involves the direct use of exudates/resins extruded from plants known as inorganic inhibitors, which were coated on reinforcing steel and studied experimentally. Data results of averaged and percentile values, the failure bond loads in controlled and coated samples are higher than uncoated (corroded) cubes, similarly to maximum slip. The obtained values of the measured diameter of reinforcing steel after corrosion test reduced drastically as shown with a negative values indication values reduction awhile coated sample s measured values increased resulting from the exudate/resin weight and resistance/waterproofing nature of the inhibitive materials, same results are obtained from cross-sectional areas, weight after corrosion, weight loss /gain. Corroded samples have reduced (negative) values resulting in the formation of pits and thereby resulting from swollen surface area modification and rib effects that reduced the interactive nature coexistence between concrete and steel while great interactions were seen in coated materials with higher values. Further results of the mechanical characterization properties of corroded, controlled and coated cubes, all corroded cubes showed reductions in cross-sectional areas, reduced weight loss as against controlled and coated members. The effect of corrosion attack has been attributed to the possible reduction in diameter and weight loss, bond interaction between concrete and steel, and the removal of the ribs resulting from surface modifications. The experimental work has revealed that the studied exudate/resin has the potential of inhibiting the effect of corrosion of reinforcing steel, coated with varying thicknesses, embedded in concrete cubes, and exposed to corrosion accelerated media.

KEYWORDS: Corrosion, Corrosion inhibitors, Pull-out Bond Strength, Concrete and Steel Reinforcement

1.0 INTRODUCTION

The corrosion of reinforcement in a concrete structure takes many forms and their product effects occur when there is a chemical reaction between the metal and its environment. The corrosion products build up in the bar, expand their volume and create pressure on the surrounding concrete causing cracks, elevations, and placement of the concrete, and reduce the effective area of the reinforcing section, thus having less bearing capacity. The corrosion of reinforcing steel in concrete is affected by various values such as water-to-concrete ratio, durability, concrete cover, aggregate width and use of cement additives ratio, permeability, concrete cover, crack width, and the use of associated cementitious materials.

Du and Clarkt (2005) Suggested that the strength of the bond is more likely to be affected than the loss of tensile strength of the reinforcement resulting from the general corrosion. The results of the experiment indicated that the reinforcement corrosion level did not affect the tensile strength of the steel bars (calculated on the actual area of the cross-section), but the reinforcement of the steel bars with corrosion of more than 12% indicates brittle failure.

Almusallam (2001) Concluded that the strength ratio and elastic modulus of the reinforcement are not significantly affected by corrosion and consequently the strength and modulus of elastic bars are adopted in practice.

Charles et al. (2019) Investigative work examined the attributes exhibited by non-corroded, corroded, and exudates /resins coated members exposed to corrosive environments using 150 mm x 150 mm x150 mm concrete cubes for 150 days. The combined results have shown that corroded samples are weak during the split test with a large load failure in the low strength bond and with the higher bond strength and low failure load. Exudate/resin members show high protection properties against corrosion effects, which act as a barrier material. The exudate/ resin coated specimens show a higher resistance to bond strength properties, and higher flow failure compared to the coated members.

Toscanini et al. (2019) examined the effect of chloride and carbonation contaminations in the marine zones of the Niger Delta, Nigeria, as the main reasons for the lack of bond between steel reinforcement and concrete, leading to premature deterioration in reinforced concrete structures in rough weather. Steel bars were coated with 150µm, 300µm, and 450µm thicknesses, embedded in concrete cubes, treated in corrosive media, and investigated pull-out bond strength parameters against non-coated. Relatively, the results of corroded specimens decreased whereas control and cola accuminata exudates/resins increased in steel bar coating samples. The overall results show that natural exudates/resins be explored as inhibitors for the corrosion effects of steel reinforcement in concrete construction in the seawater areas.

Gede et al (2019) investigated the strength of the bond between concrete and reinforcement elasticity due to the reduction of steel reinforcement over the presence of saltwater. The introduction of extracts from Artocarpus altilis exudates/resins to boost reinforcing steel with a coating thickness of 150µm, 300µm, and 450µm. An investigative assessment on non-coated and coated reinforcing steel samples were embedded in concrete and saturated with sodium chloride for 150 days. Comparable results showed that the values of the applied load decreased of non-coating (corrosion) and increased in the coating samples. Overall results showed high values of strength from the controlled and the coating samples over the corroded samples due to the reduction of fiber and diameter from the corrosion effect.

Charles et al (2019) studied the use of Acacia Senegal exudates/resins as paste materials in reinforcing steel coating with a thickness of 150µm, 300µm, and 450µm. Experimental studies investigated that coated samples and non-coated samples embedded in concrete cubes and immersed in sodium chloride for 178 days for corrosion assessment effects. In comparison, the values of non-coating samples are reduced due to the corrosion attack on the steel reinforcing mechanical properties, but with the increased strength of the non-corrosive and exudates/resin coated members, which indicates the ability of acacia senegal to be used as exudates/resins reinforcing steel coating operations. Overall results showed high values of pull-out bond strength and low failure load in the control and coated against corroded samples.

Charles et al. (2019) explored the effect of olibanum exudates/resins in reinforcing steel corrosion in coastal zones under the influence of saltwater on concrete structures. To evaluate the effects of corrosion, non-coated and exudates / resin-coated steel were embedded in concrete cubes and pooled in the corrosive medium. The tests showed that the value of the non-coated specimens decreased due to the reduction of corrosion attacks. The average percentage bond strength load was 33.13% and coated members 45.66% and 71.84% compared to the control differential. The mean maximum slip values were 0.083 mm and mean 33.878% and 75.32%, respectively, compared to control and end -25.31%. Experimental results show that reduced samples have lower bond strength and higher failure bond load and lower maximum slip, whereas exudates/resins coated samples have lower test samples and higher percentage values compared to corrosive samples.

Terence et al. (2019) explored the impact of reinforced steel coated inhibitors under a rapid process test of embedded steel failure bond strength for 150 days. Comparable results showed reduced values from corroded samples while coated and controlled samples exhibited increased values. The overall results showed high values of the pull-out bond strength of the exudates/adhesive coating over the corroded samples.
Charles et al. (2019) Evaluated the effect of the bond strength reduction and the interaction between reinforcing steel and reinforced concrete structures in the marine environment of saltwater using non-coated steel and khaya senegalensis exudate / resin-coated steel bar. The results of the failure bond loads showed a difference of -43.62%

and 77.37% and 79.67% for corrosive and coated exudate/resin members. The reduced average percentage bond strength load ranges from 57.06% to 36.33% and 106.57% in stained and coated samples. The obtained results clearly showed that corrosive bond loads are higher for corroded than for exudates / adhesive coating members.

2.0 MATERIALS AND METHODS

The research involves the direct use of exudates/resins extruded from plants known as inorganic inhibitors, which were coated on reinforcing steel and studied experimentally. The test setting mimics and simulates the harsh acidic conditions the marine salt concentration in concrete in the immersed part of the test samples. Samples were designed with 36 numbers of reinforced concrete cubes of 150 mm × 150 mm × 150 mm with a single ribbed bar of 12 mm diameter embedded centrally for pull bond test for controlled, corroded, and inhibited specimens and were all immersed in Sodium chloride (NaCl) solutions for 1 - 360 days after initial 28 days curing period with monthly specimens monitoring and renewal of accelerated media for effective performance.

2.1 Materials and Methods for Experiment

2.1.1 Aggregates

The fine aggregate and coarse aggregate were purchased. Both met the requirements of BS 882;

2.1.2 Cement

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

2.1.3 Water

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

2.1.4 Structural Steel Reinforcement

The reinforcements are gotten directly from the market in Port Harcourt, (BS 4449:2005+A3)

2.1.5 Corrosion Inhibitors (Resins / Exudates) Treculia africana (African breadfruit)

The exuding sticky gummy cream was obtained from the tree bark through tapping process. It was obtained from a plantation farm in Odiokwu Town in Ahoada-West Local Government of Rivers State at *Coordinates*: 5°05′N 6°39′E / 5.083°N 6.650°E / 5.083; 6.650.

2.2 Experimental Procedures

The corrosion accelerated test was performed with a high yield steel (reinforcement) 12 mm diameter and 650 mm long, Specimen surface roughness was treated with wire brush and specimens cleaned with fine water, washed with acetone and dried, and then polished and coated (Treculia africana exudates/resins), pastes with coats of 150µm, 300µm, 450µm, and 600µm before corrosion testing. Test cubes were cast with a metal mold of 150 mm × 150 mm × 150 mm and demolded after 72 hours. Specimens were treated at room temperature in the tanks for 28 days initial curing periods and then proceeded with a rapid acceleration corrosion testing and a test procedure allowed for 360 days on proper monthly monitoring. Cubes were randomly picked on every 3 months interval for 90 days, 180 days, 270 days and 360 days for the corrosion accelerated specimens and were tested to obtain the pullout - bond strength test relationships that included failure bond loads, bond strength, maximum slip, rebar cross-sectional area reduction/increase and weight loss/gain of steel reinforcement.

2.3 Accelerated Corrosion Set-Up and Testing Procedure

In the actual and natural cases, the manifestation of corrosion effects in reinforcement embedded in concrete members are very slow and can take years to achieve; but the laboratory accelerated process takes less and less time to manifest with the introduction of accelerated media representing the saltwater of the marine region. Specimens were immersed in a 5% NaCl solution for 360 days, to test the surface and mechanical properties of the modifications and effects on both uncoated and exudates/resin coated specimens.

2.4 Pull-out Bond Strength Test

The pull-out bond strength test of concrete cubes was performed on 12 samples each of the controlled of distilled water, non-coated and coated members totaling 36 specimens and subjected into a 50KN Universal Testing Machine according to BS EN 12390-2. The 36 cubes' size was 150 mm × 150 mm × 150 mm with a single 12mm diameter embedded in the center of the concrete cube.

2.5 Tensile Strength of Reinforcing Bars

Yield strength and Ultimate tensile strengths of 12 mm diameter reinforcement of control, non-coated and coated were subjected to Universal Testing Machine for direct tension to maximum failure.

3.1 EXPERIMENTAL RESULTS AND DISCUSSIONS

The effect of corrosion in structures built within the coastal region with severe and high acidic consideration poses great danger and thee is the tendency of early collapse and other negative occurrences which in turn renders the unsafe and unfulfilling the designed life. This appalling scourge need to be arrested to allow life span of structures such as bridges, residential, public buildings, social and other infrastructural development serve their purpose.
The data presented in tables 3.1 – 3.5 and represented in figures 1 -6b outline experimental results of controlled, uncoated and coated concrete cubes exposed to the harsh marine environment by artificially introducing 5% sodium chloride aqueous solution and wholly submerged the samples for 360 days and examined their characterized performances. Results of 36 samples were studied, 12 controlled samples were placed in fresh water solutions that met the (BS 3148) requirements. Also, 12 samples each of uncoated and coated samples as described in the tables were wholly submerged in corrosion accelerated media for 360 days with 3 months interval monitored and tested, and samples were examined on the varying surface modifications and other defective properties resulting from the corrosion attacks.

Table 3.1: Results of Pull-out Bond Strength Test (τu) (MPa) Non-corroded Control Cube Specimens

Sample Numbers	TAC	TAC1	TAC2	TAC3	TAC4	TAC5	TAC6	TAC7	TAC8	TAC9	TAC10	TAC11
	Time Interval after 28 days curing											
Samplin g and Durations	Samples 1 (28 days)			Samples 2 (28 Days)			Samples 3 (28 Days)			Samples 4 (28 Days)		
Failure Bond Loads (kN)	29.650	29.173	29.196	30.275	29.001	30.008	29.705	28.822	30.025	29.140	30.183	29.644
Bond strength (MPa)	9.813	10.045	9.345	9.131	9.845	10.162	10.501	10.876	10.053	10.073	10.992	11.143
Max. slip (mm)	0.086	0.106	0.056	0.096	0.116	0.119	0.103	0.104	0.108	0.115	0.119	0.104
Nominal Rebar Diameter	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000
Measured Rebar Diameter Before Test(mm)	11.941	11.932	11.942	11.941	11.932	11.951	11.937	11.926	11.938	11.940	11.928	11.938
Rebar Diamete r- at 28 Days Nominal(mm)	11.941	11.932	11.942	11.941	11.932	11.951	11.937	11.926	11.938	11.940	11.928	11.938
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rebar Weights- Before Test(Kg)	0.561	0.558	0.564	0.558	0.560	0.560	0.559	0.567	0.557	0.558	0.563	0.559
Rebar Weights- at 28 Days Nominal(Kg)	0.558	0.558	0.559	0.558	0.567	0.564	0.560	0.561	0.559	0.557	0.563	0.560
Weight Loss /Gain of Steel (Kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 3.2: Results of Pull-out Bond Strength Test (τu) (MPa) Corroded Concrete CubeSpecimens

Samplin g and Durations	Samples 1 (90 days)			Samples 2 (180 Days)			Samples 3 (270 Days)			Samples 4 (360 Days)		
Failure Bond Loads (kN)	16.877	16.190	16.480	15.922	15.170	16.037	15.617	15.925	15.622	16.858	15.737	16.471
Bond strength (MPa)	6.202	6.212	5.976	6.199	5.965	5.938	5.736	6.425	5.400	5.888	5.735	6.048
Max. slip (mm)	0.079	0.082	0.083	0.092	0.083	0.086	0.085	0.075	0.081	0.082	0.083	0.074
Nominal Rebar Diameter	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000
Measured Rebar Diameter Before Test(mm)	11.933	11.924	11.934	11.933	11.924	11.943	11.934	11.923	11.933	11.930	11.924	11.934
Rebar Diameter- After Corrosion(mm)	11.884	11.875	11.885	11.884	11.875	11.894	11.885	11.874	11.884	11.881	11.875	11.885
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
Rebar Weights- Before Test(Kg)	0.559	0.560	0.560	0.558	0.561	0.561	0.561	0.561	0.560	0.562	0.559	0.559
Rebar Weights- After Corrosion(Kg)	0.513	0.512	0.510	0.512	0.512	0.513	0.514	0.512	0.514	0.512	0.511	0.512
Weight Loss /Gain of Steel (Kg)	0.047	0.048	0.050	0.046	0.048	0.047	0.047	0.049	0.046	0.051	0.048	0.047

Table 3.3: Results of Pull-out Bond Strength Test (τu) (MPa) Treculia africana Exudate / Resin (Steel Bar Coated Specimen)

Samplin g and Durations	Samples 1 (90 days)			Samples 2 (180 Days)			Samples 3 (270 Days)			Samples 4 (360 Days)		
Sample	**150μm (Exudate/Resin) coated**			**300μm (Exudate/Resin) coated**			**450μm (Exudate/Resin) coated**			**600μm (Exudate/Resin) coated**		
Failure Bond Loads (kN)	28.707	26.617	27.181	27.778	28.593	28.294	28.817	28.635	28.699	30.510	29.635	29.836
Bond strength (MPa)	10.752	11.645	10.142	11.073	11.446	12.369	12.462	11.792	11.827	12.532	11.844	12.390
Max. slip (mm)	0.121	0.123	0.113	0.118	0.117	0.116	0.129	0.133	0.141	0.139	0.143	0.141
Nominal Rebar Diameter	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000
Measured Rebar Diameter Before Test(mm)	11.933	11.925	11.934	11.933	11.924	11.943	11.934	11.923	11.933	11.930	11.924	11.934
Rebar Diamete r- After Corrosion(mm)	11.991	11.982	11.992	11.991	11.982	12.001	11.992	11.980	11.990	11.988	11.983	11.992
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.058	0.057	0.058	0.057	0.058	0.057	0.058	0.058	0.057	0.058	0.059	0.057
Rebar Weights- Before Test(Kg)	0.566	0.567	0.567	0.565	0.568	0.568	0.568	0.568	0.567	0.569	0.566	0.566
Rebar Weights- After Corrosion(Kg)	0.628	0.630	0.630	0.627	0.629	0.629	0.630	0.631	0.639	0.639	0.629	0.628
Weight Loss /Gain of Steel (Kg)	0.062	0.064	0.063	0.060	0.063	0.063	0.063	0.063	0.064	0.064	0.063	0.063

Table 3.4: Results of Average Pull-out Bond Strength Test (τu) (MPa) Control, Corroded and Resin Steel Bar Coated

Sample	Non-Corroded Specimens Average Values				Corroded Specimens Average Values				Coated Specimens Average Values of 150µm, 300µm, 450µm, 6000µm)			
Failure load (KN)	29.340	29.548	29.491	29.761	16.515	16.197	15.857	15.710	27.502	27.192	27.851	28.221
Bond strength (MPa)	9.734	9.507	9.441	9.713	6.130	6.129	6.046	6.034	10.846	10.953	10.887	11.629
Max. slip (mm)	0.103	0.103	0.106	0.405	0.081	0.086	0.086	0.087	0.119	0.118	0.116	0.117
Nominal Rebar Diameter	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000	12.000
Measured Rebar Diameter Before Test(mm)	11.938	11.938	11.938	11.941	11.930	11.930	11.930	11.933	11.930	11.931	11.930	11.933
Rebar Diamete r- After Corrosion(mm)	11.938	11.938	11.938	11.941	11.881	11.881	11.881	11.884	11.988	11.988	11.988	11.991
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.000	0.000	0.000	0.000	0.049	0.049	0.047	0.049	0.057	0.057	0.057	0.057
Rebar Weights- Before Test(Kg)	0.561	0.560	0.560	0.559	0.560	0.559	0.560	0.560	0.567	0.566	0.567	0.567
Rebar Weights- After Corrosion(Kg)	0.558	0.558	0.561	0.563	0.512	0.512	0.512	0.513	0.629	0.629	0.629	0.631
Weight Loss /Gain of Steel (Kg)	0.000	0.000	0.000	0.000	0.048	0.048	0.048	0.047	0.063	0.062	0.062	0.062

Table 3.5: Results of Average Percentile Pull-out Bond Strength Test (τu) (MPa)

	Non-corroded Control Cube				**Corroded Cube Specimens**				**Exudate / Resin steel bar coated**			
Failure load (KN)	77.651	82.429	85.977	89.447	-39.948	-40.435	-43.064	-44.334	66.523	67.884	75.635	79.644
Bond strength (MPa)	58.803	55.126	56.134	60.979	-43.485	-44.046	-44.461	-48.115	76.945	78.719	80.053	92.735
Max. slip (mm)	26.024	19.690	23.232	36.738	-31.563	-27.246	-25.938	-25.674	46.120	37.449	35.023	34.542
Nominal Rebar Diameter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Measured Rebar Diameter Before Test(mm)	0.068	0.069	0.070	0.068	0.061	0.068	0.068	0.072	0.051	0.053	0.072	0.082
Rebar Diameter- After Corrosion(mm)	0.482	0.482	0.483	0.482	-0.890	-0.891	-0.890	-0.890	0.898	0.899	0.898	0.898
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.000	0.000	0.000	0.000	-14.549	-14.306	-14.634	-14.494	17.027	16.695	17.143	16.951
Rebar Weights- Before Test(Kg)	1.151	1.026	1.112	1.145	1.226	1.227	1.226	1.226	1.241	1.242	1.241	1.241
Rebar Weights- After Corrosion(Kg)	9.040	9.052	9.647	9.747	-18.665	-18.632	-18.634	-18.467	22.948	22.899	22.902	22.649
Weight Loss /Gain of Steel (Kg)	0.000	0.000	0.000	0.000	-23.669	-23.488	-22.789	-24.096	31.009	30.699	29.515	31.746

3.2 Failure load, Bond Strength, and Maximum slip

Corrosion of steel reinforcement in concrete reduces the bond strength between steel and concrete and thus affects the durability and usability of concrete structures. In recent decades the effect of corroded steel reinforcement on the bond strength of reinforced concrete elements has been investigated by many researchers. Al-Sulaiman et al. (1990), found by investigating the effect of corrosion on reinforcing bars and bond strength up to about 1% of the corrosion rate due to an increase in the surface roughness of the reinforcing bars at an early stage with a strong adhesive layer of rust. This is in line with the experimental results from the RC beam test which increases the bond strength with an increase in the degree of corrosion to 4% due to the increase in radial pressure due to expansion of corrosion products (Mangat and Elgarf, 1999b).

The results of the experimental data shown in tables 3.1 – 3.3 were conducted on 36 samples selected randomly from Samples 1 (90 days), Samples 2 (180 days), Samples 3 (270 days), and Samples 4 (360 days) for controlled, uncoated and coated concrete cubes and averagely summarized into tables 3.4 and 3.5 of the pullout and bond strength characterization performances of tested samples as represented in figures 1-6b. The minimum and maximum range of average values obtained from controlled samples for failure bond load are 29.340KN and 29.761KN representing average percentile values of 77.651% and 89.447%, uncoated values are 16.197kN and 16.515kN (-44.334% and -39.948%) and coated 27.502kN and 28.221kN (66.523% and 79.644%).

For bond strength, the obtained results for controlled are 9.713MPa and 9.734MPa (58.803% and 60.979%), uncoated (corroded) are 6.034MPa and 6.130MPa (-48.115% and -43.485%) and coated samples are 10.846MPa and 11.629MPa (76.945% and 92.735%). Results for maximum slip controlled are 0.103mm and 0.106mm (26.024% and 36.738%) for uncoated (corroded) are 0.081mm and 0.087mm (-25.674% and -31.563%) and coated are 0.119mm and 0.116mm (34.542% and 46.120%) respectively.
From the obtained data of averaged and percentile values, it can be seen that the failure bond loads in controlled and coated samples are higher than uncoated (corroded) cubes -39.948%) against 79.644%) coated, similarly in that of maximum slip corroded value -25.674% against 36.738%) and 46.120% controlled and coated samples. The decreased resulted from the corrosion attack on reinforcing steel that has affected the mechanical properties of surfaced condition. Failure bond loads, bond strength and maximum slip failed at low loads are compared to controlled and coated samples (Charles et al., 2019; Toscanini et al., 2019; Gede et al., 2019; Charles et al., 2019; Terence et al.,2019).

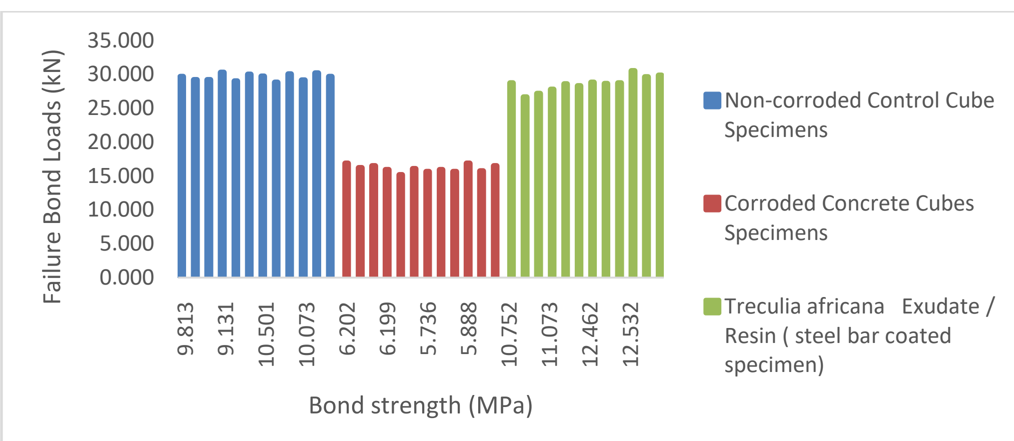

Figure 1: Failure Bond loads versus Bond Strengths

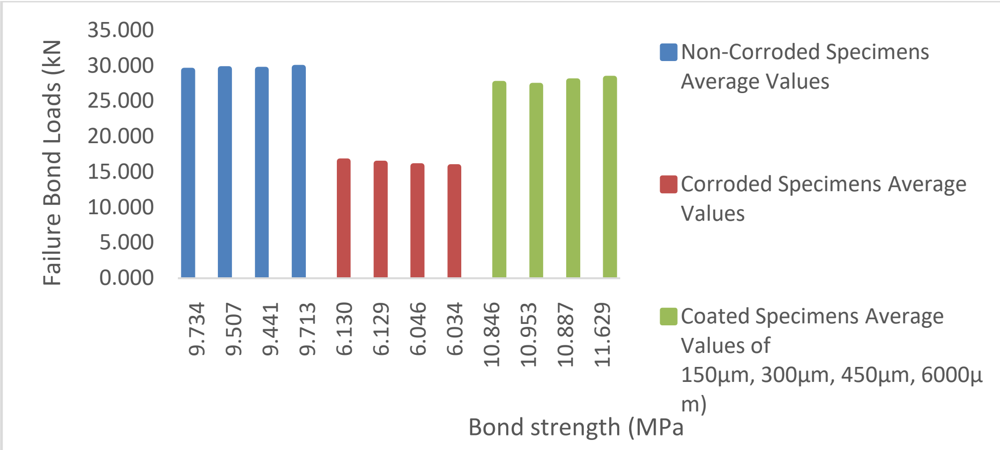

Figure 1a: Average Failure Bond loads versus Bond Strengths

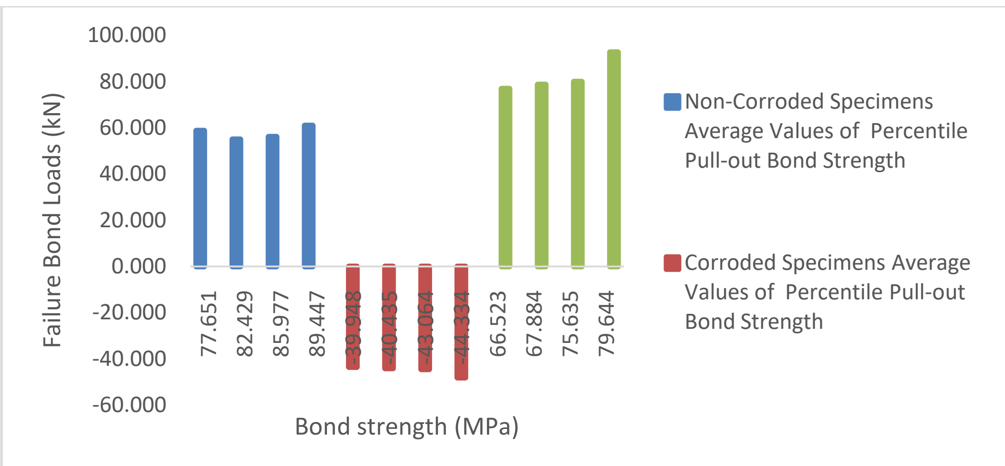

Figure 1b: Average Percentile Failure Bond loads versus Bond Strengths

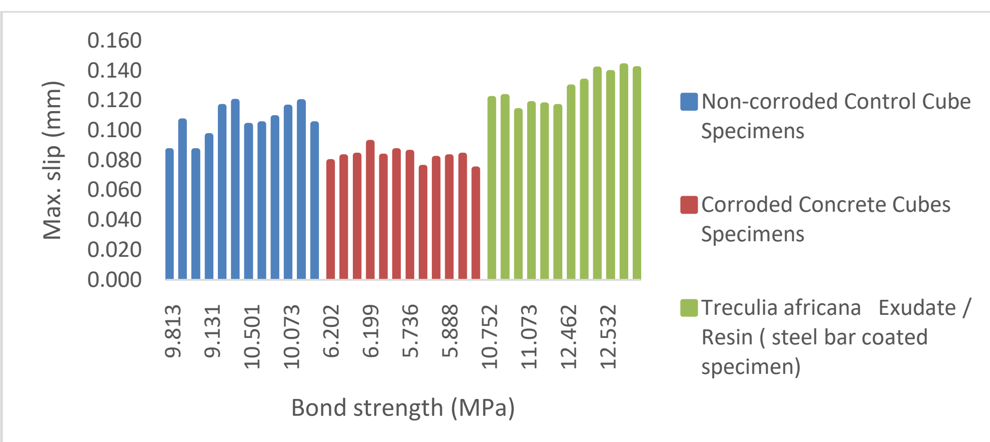

Figure 2: Bond Strengths versus Maximum Slip

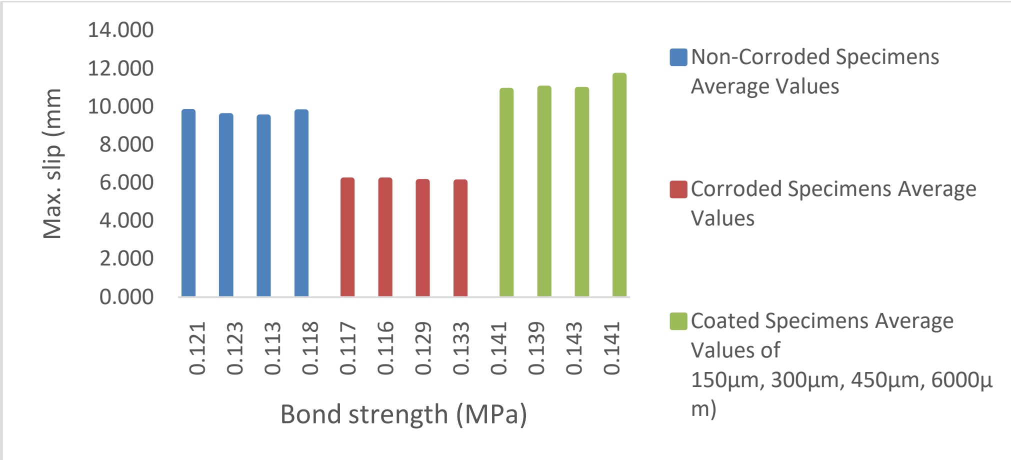

Figure 2a: Average Bond Strengths versus Maximum Slip

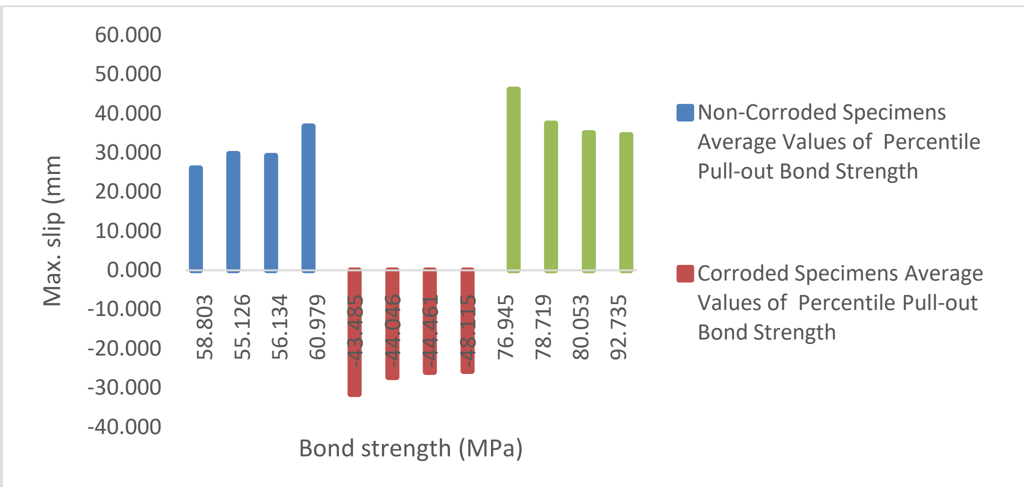

Figure 2b: Average Percentile Bond Strengths versus Maximum Slip

3.3 Mechanical Properties of Reinforcing Bars (Cross-Sectional Reduction and Weight loss / Gain)

The mechanical properties of reinforcing steel embedded in corrosive media are adversely affected by corrosion attack that renders the structure unfit for its intended use. Tables 3.3. 3.2 and 3.3 are the results of pullout bond strength of controlled samples, uncoated (corroded) and coated members for randomly selected results for 360 days sampled test as stated in the tables and tables 3.4and 3.5 are the data derived from tables 3,3. 3.2 and 3.3 and represented graphically in figures 1 – 6b.

The results of reinforcing steel bars nominal diameter, measured diameter of before and after corrosion test, cross-sectional reduction, the weight of rebars (before and after corrosion test), and weight loss/gain) for controlled samples submerged in freshwater that met the requirement of (BS 3148) and of uncoated (corroded) and coated fully immersed in corrosive media for 360 days with routinely checks and tested at 3 months intervals of stated in the tables on duration. Obtained results for all samples nominal diameter reinforcing steel bars are 100%, minimum and maximum rebar measured diameter before test are on the range of 11.930mm and 11.941mm (0.051% and 0.082%).

The results of "Rebar Diameter- After Corrosion" for uncoated (corroded) samples are 11.881mm and 11.884mm (-0.891% and -0.890%) and coated are 11.988mm and 11.991mm (0.898% and 0.899%) , Cross- sectional area reduction/increase values for uncoated (corroded) are 0.049mm and 0.047mm (-14.634% and -14.306%) and coated are 0.057mm (16.951% and 17.143%).

The results of the rebar "Weights- Before" test ranged values are 0.559Kg and 0.567Kg for all samples, rebar weights - after corrosion uncoated are 0.512Kg and 0.513Kg(18.467% and -18.665%) and coated are 0.629Kg and 0.631Kg (22.649% and 22.948%) and weight loss /gain of Steel results of uncoated (corroded) are 0.047Kg and 0.048Kg (18.665% and -18.467%) and coated values are 0.062Kg and 0.063Kg (29.515% and 31.746%).
From the data presented on both averaged values and average percentile values for controlled samples, the values of mechanical properties of reinforcing steel did not change since it was cured in non-corrosive environment and all maintained 100% percentile values with 0.00 changes.

The obtained values of measured diameter of reinforcing steel after corrosion test reduced drastically as shown with a negative values indication values reduction awhile coated sample s measured values increased resulting from the exudate/resin weight and resistance /waterproofing nature of the inhibitive materials, same results are obtained from cross – sectional areas, weight after corrosion, weight loss /gain (Charles et al., 2019; Toscanini et al., 2019; Gede et al., 2019; Charles et al., 2019; Terence et al.,2019). Corroded samples have reduced (negative) values resulting on the formation of pits and there by resulting from swollen surface area modification and rib effects that reduced the interactive nature coexistence between concrete and steel while great interactions were seen in coated materials with higher values.

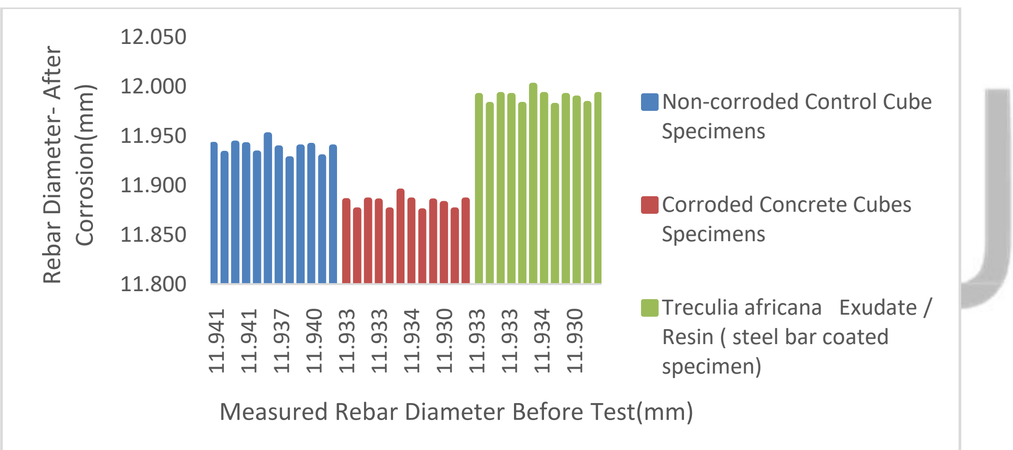

Figure 3: Measured (Rebar Diameter Before Test vs Rebar Diameter- After Corrosion)

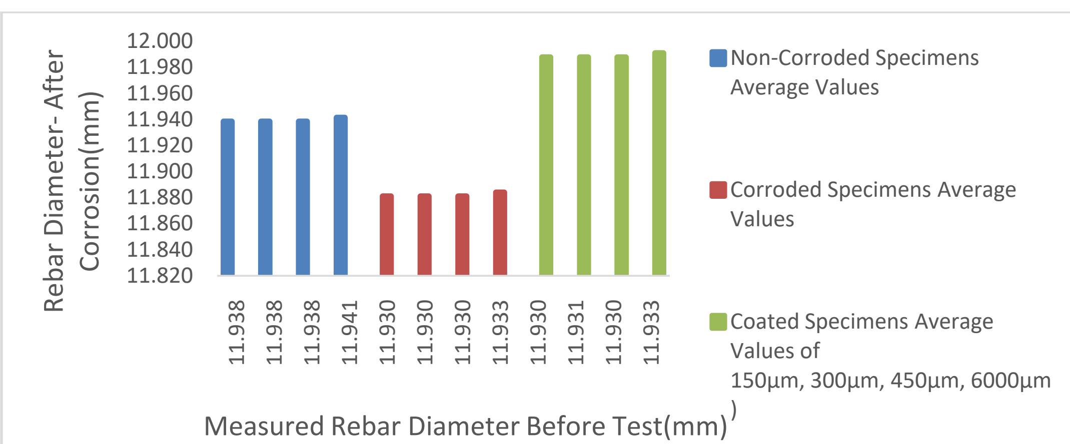

Figure 3a: Average Measured (Rebar Diameter Before Test vs Rebar Diameter- After Corrosion)

GSJ: Volume 9, Issue 8, August 2021
ISSN 2320-9186

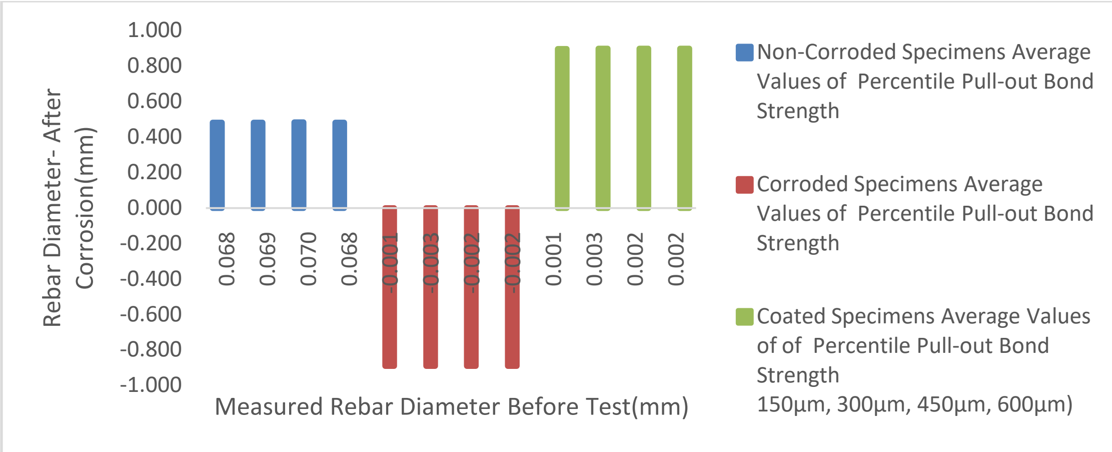

Figure 3b: Average Percentile Measured (Rebar Diameter Before Test vs Rebar Diameter- After Corrosion)

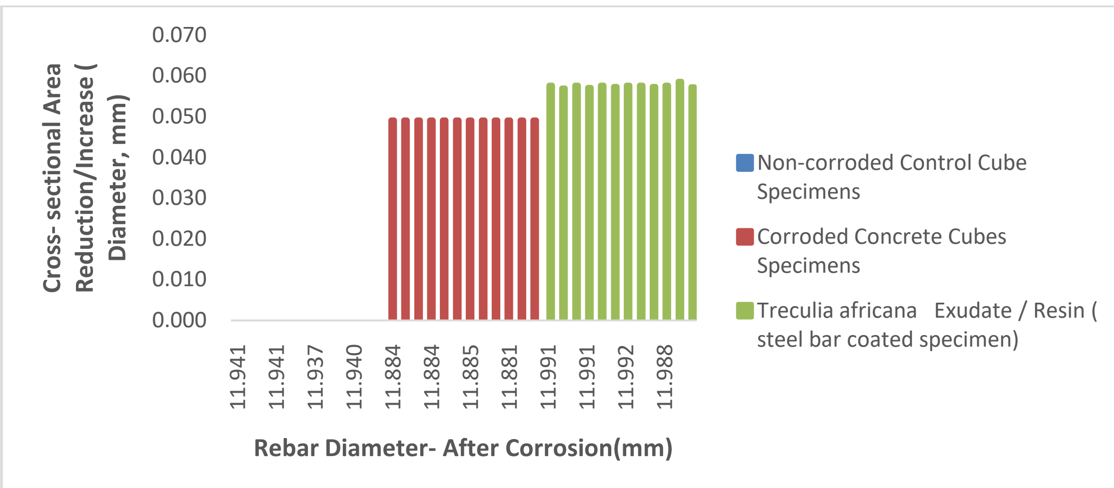

Figure 4: Rebar Diameter- After Corrosion versus Cross - Sectional Area Reduction/Increase

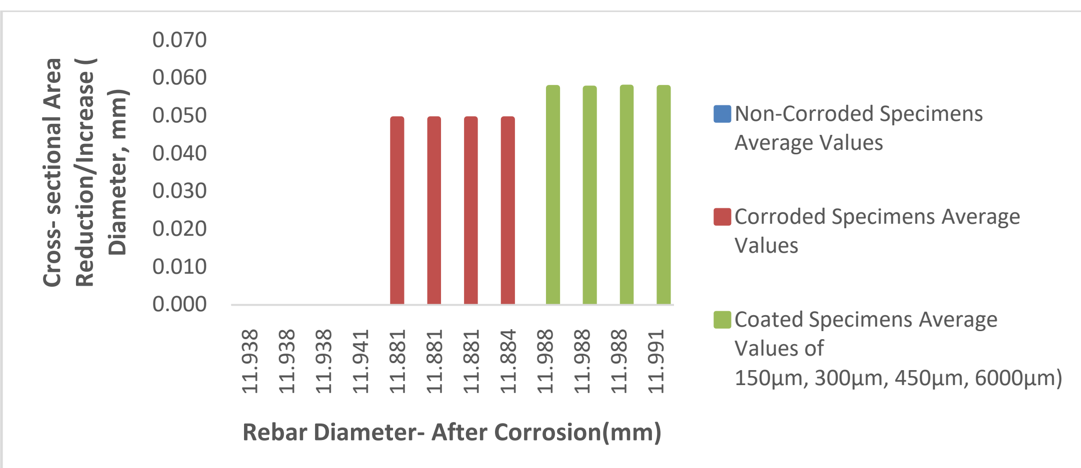

Figure 4: Average Rebar Diameter- After Corrosion versus Cross – Sectional Area Reduction/Increase

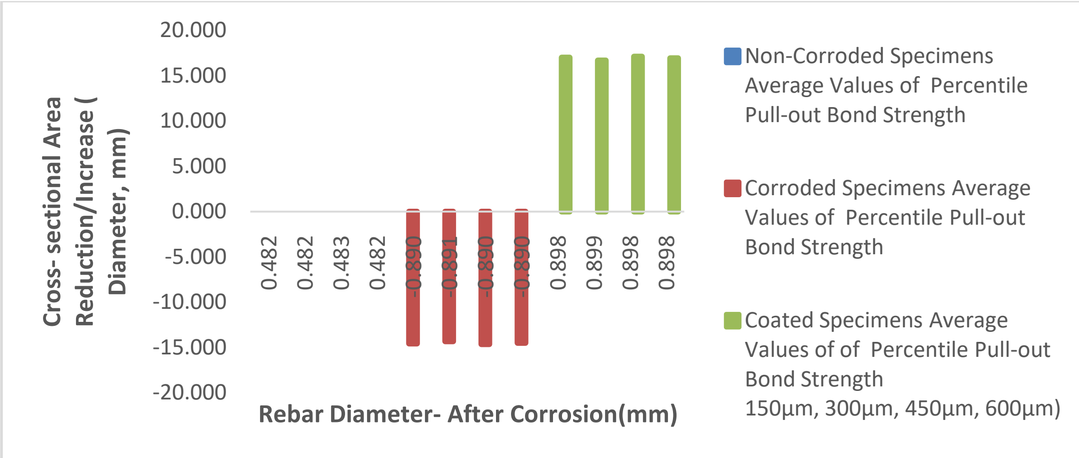

Figure 4b: Average percentile Rebar Diameter- After Corrosion versus Cross - sectional l Area Reduction/Increase

Figure 5: Rebar Weights- Before Test versus Rebar Weights- After Corrosion

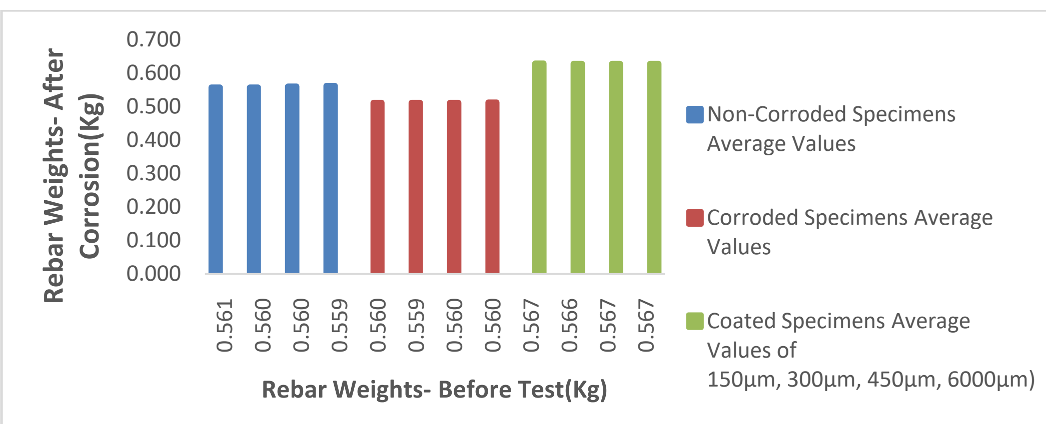

Figure 5a: Average Rebar Weights- Before Test versus Rebar Weights- After Corrosion

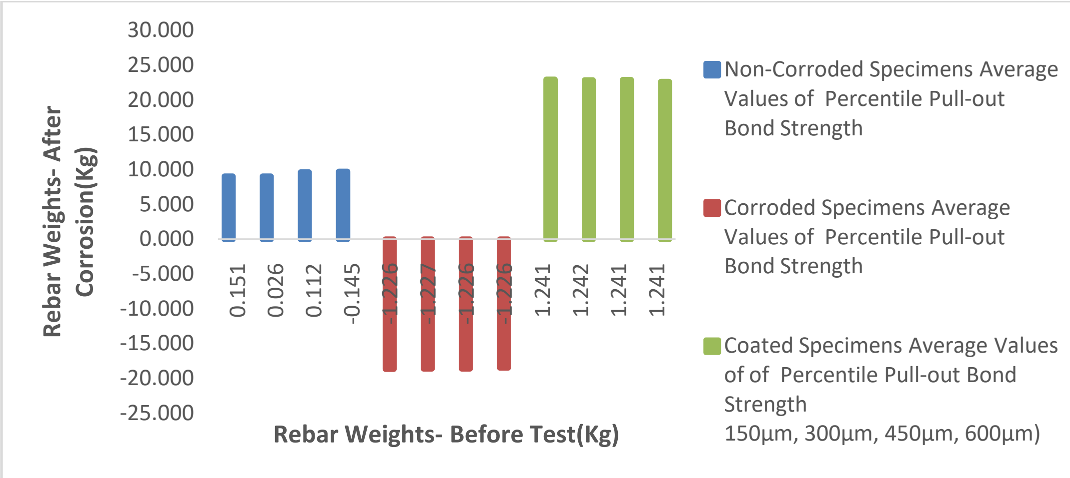

Figure 5b: Average Percentile Rebar Weights- Before Test versus Rebar Weights- After Corrosion

Figure 6: Rebar Weights- After Corrosion versus Weight Loss /Gain of Steel

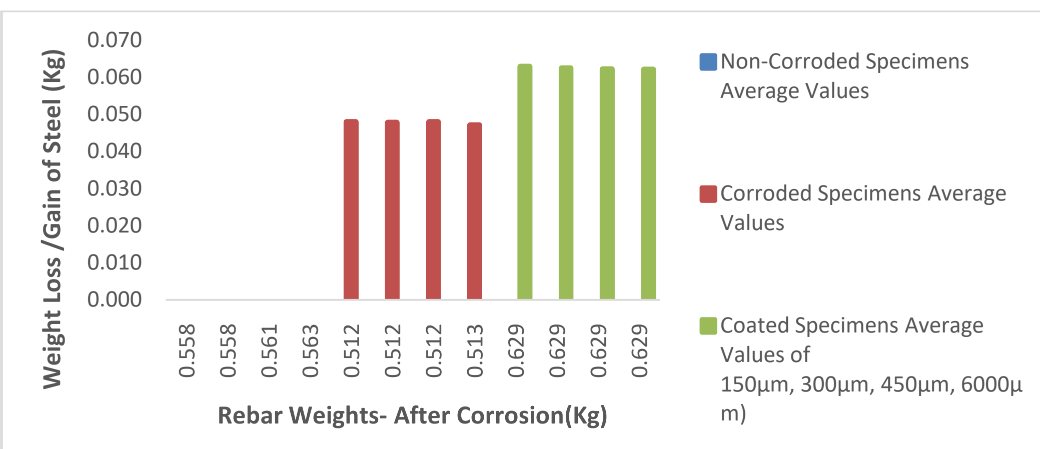

Figure 6a: Average Rebar Weights- After Corrosion versus Weight Loss /Gain of Steel

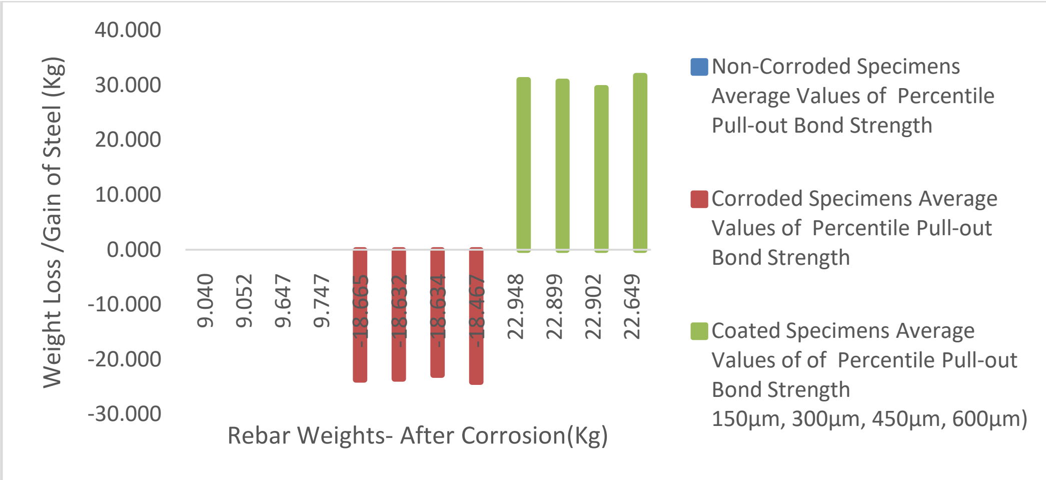

Figure 6b: Average percentile Rebar Weights- After Corrosion versus Weight Loss /Gain of Steel

3.3 Comparison of Control, Corroded, and Coated Concrete Cube Members

Presented data in tables 3.1, 3.2 and 3.3 derived and summarized into 3.4 and 3.5, represented in figures 1-6b for controlled, uncoated (corroded) and Treculia africana exudates/resins) coated concrete cubes. Comparative results of the controlled samples pooled for 360 days in freshwater and of uncoated (corroded) and coated members wholly immersed in 5% sodium chloride (NaCl) aqueous solutions for 360 days as described in tables 3.1 – 3.5 showed that the failure bond loads, bond strength and maximum slip performances of corroded concrete cubes pressured in 50kN Instron Universal Testing Machine (UTM) exhibited failure at low stress as compared to controlled and coated cubes (Charles et al., 2019; Toscanini et al., 2019; Gede et al., 2019; Charles et al., 2019; Terence et al.,2019).

Further results of the mechanical characterization properties of corroded, controlled and coated cubes, all corroded cubes showed reductions in cross-sectional areas, reduced weight loss as against controlled and coated members. The effect of corrosion attack has been attributed to the possible reduction in diameter and weight loss, bond interaction between concrete and steel and the removal of the ribs resulting from surface modifications.

The experimental work has revealed that the studied exudate/resin has the potential of inhibiting the effect of corrosion of reinforcing steel, coated with varying thicknesses, embedded in concrete cubes and exposed to corrosion accelerated media.

4.0 CONCLUSIONS

Experimentally, the results obtained showed the following summary:

i. Treculia africana exudate/resin possess inhibitive characteristics against corrosion attack
ii. Treculia africana has waterproofing and resistance properties to corrosion attacks and penetration
iii. Interaction between concrete and reinforcing steel are higher in coated members to corroded members
iv. The bond nature is higher in coated and controlled than in corroded members
v. Loss of ribs and surface modifications are experienced in corroded.
vi. Lower failure bond load, bond strength and maximum slip are recorded in corroded members
vii. Higher value of failure bond load and bond strength were recorded in coated and controlled samples
viii. Weight loss, and cross -sectional reductions dominantly recorded in corroded over coated and controlled members

REFERENCES

1. Almusallam A. A. (2001). Effect of degree of corrosion on the properties of reinforcing steel bars. Construction and
2. Building Materials, 15(8), 361-368
3. Al-Sulaimani, G.J., Kaleemullah, M., Basunbul, I.A., and Rasheeduzzafar. (1990). Influence of corrosion and
4. cracking on bond behaviour and strength of reinforced concrete members. *ACI Structural Journal*. 87(2), 220– 231.
5. BS. 882; 1992- Specification for Aggregates from natural sources for concrete. British Standards Institute. London, United Kingdom.
6. BS EN 196-6; 2010 - Methods of Testing Cement. Determination of fineness, British Standards Institute. London, United Kingdom.
7. BS 3148; 1980– Methods of test for water for making concrete. British Standards Institute. London, United Kingdom.
8. BS 4449:2005+A3; 2010 – Steel for reinforcement of concrete. British Standards Institute. London, United Kingdom.
9. Charles, K., Ukeamezhim, C. F., Daso, D. (2019). Corrosion Effect on Flexural Mechanical Property of Concrete Reinforcement Steel in Corrosive Environment. International Journal of Advanced Scientific and Technical Research, vol. 5, no 9, pp, 26-37.
10. Charles, K., Ogunjiofor, E. I., Terence, T. T.W. (2019). Pullout Bond Splitting Effects of Corroded And Inhibited Reinforcement In Corrosive Media. Journal of Multidisciplinary Engineering Science and Technology, 6(9), 10747 -10753.
11. Charles, K., Geofrey, B., Gede, T. E. (2019). Corrosion Effect on Reinforcement Pull-Out Bond Strength Characteristics of Corroded and Coated Members in Concrete. American Journal of Sustainable Cities and Society, 1 (8), 61 – 69
12. Charles, E. N., Charles, K., Terence, T. T. W. (2019). Corrosion Degree on the Mechanical Properties of Reinforcing Steel Embedded in Concrete, Global Scientific Journal , Vol. 7, no. 10, pp, 688 -696, 2019.
13. Charles, K., John, A. T., John, C. O. (2019). Reinforcing Steel Mechanical Properties Influence on Bond Strength of Corroded and Coated Members in Concrete Structures, Global Scientific Journal, 7 (9), 1168 – 1178
14. Du Y. G. and Clarkt L. A. (2005). Effect of corrosion on ductility of reinforcing bars. Magazine of Concrete Research, 57(7) 407- 419.
15. Gede, T. E., Charles, K., Geofrey, B. (2019). Reinforcement Bond Strength Interface Behavior of Corroded and Coated in Concrete Members. European Academic Research - 7 (7), 3399 – 3412.
16. Mangat, P. S., and Elgarf, M. S. (1999). Flexural Strength of Concrete Beams with Corroding Reinforcement. ACI Structural Journal, 96 (1), 49-158.
17. Terence, T. T. W., Charles, K., Branly, E. Y. (2019). Bond Strength Characteristics of Reinforcements Embedded in Reinforced Concrete Structures in Corrosive Marine Environment. American Journal of Engineering Research, 8 (10), 128-134,
18. Toscanini, D. S., Gede, T. E., Charles, K. (2019). Pullout Bond Failure Load of Corroded and Coated Members in Corrosive Media, International Journal of Advanced Scientific and Technical Research, 5 (9), 38 – 46.