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Original Research Article

Corrosion Inhibitive Materials Influence on Load Bearing Capacity of Reinforced Concrete Beam

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Abstract

This research studied the negative effects of corrosion attack on steel reinforcement in a marine environment with a high concentration of salt (sodium chloride) by the use of exudate/resins that was applied directly to the steel reinforcement through coatings of different thicknesses and embedded in concrete beams, and checked for suitability as a corrosion protection agent. The maximum value obtained of flexural load tests for controlled is 26.65% as compared to the value of -18.23% and 26.4% for the corroded and coated samples were examined for comparison of the flexural strength test. The results showed lower deformation loads in controlled and coated specimens with reduced values over corroded specimens with higher deformation in comparison with reference ranges (controlled). The calculated mean differential and percentile values were checked (0.03kN and 0.23%), corrosion values (0.030kN and 0.21%) and coating values (0.02kN and 0.21%). The results showed that the effect of corrosion on the mechanical properties of reinforcing steel with a decrease in diameter reduced the average and percentage of samples corroded, while the controlled and coated samples showed a preserved state due to coating due to an increase in diameter different layer thickness with exudates/resin The cross-sectional area of reinforcing steel shows a different mean value and percentile value of the corroded value (0.01 mm and 0.02%) and the coated value (0.05 mm and 2.69%). Differentially, the calculated mean and percentage values of yield strength and tensile strength are (2.13 MPa and 0.97%) and (3.435 MPa and 0.08%) and were examined, the corroded values were (3.44 MPa and 0.86%) and (4.548 MPa and 0.08%), the values of coated are (2.13MPa and 0.97%) and (4.736MPa and 0.09%). From the data obtained and compared, the yield strength and tensile strength values of the corroded samples showed a decrease in the average and percentage values for load failure with lower load applications. Comparison ratios obtained for deformation the maximum values calculated for the mean and percentile values for the controlled were -0.6% against the corroded and closed values of 1.22% and -0.29%. The difference between the mean and percentage values obtained for the control was (0.02 and 0.91%), corroded values (0.02 and 0.93%), and coated values (0.02 and 0.91%). The maximum comparison value for the controlled sample was -31.32% compared to the corroded and coated samples of 63.75% and 31.6%, respectively. The mean differential and percentile values obtained for the controlled samples were (1.69% and 7.34%), corrosion values (1.2% and 17.55%) and coated values were 1.69% and 7.33%). In comparison, the corroded samples showed higher stress values and higher elongation rates, whereas the damaged state of coated samples was lower load and reduced elongation.

Keywords: Corrosion, Corrosion inhibitors, Flexural Strength, Concrete and Steel Reinforcement.

1.0 INTRODUCTION

Corrosion of steel reinforcement embedded in concrete structures often breaks the passive film caused by the high alkaline environment around reinforcing the steel. The end results of steel corrosion are a reduction in strap diameter, wear and tear of mechanical properties of reinforcing steel. Reinforced concrete structures in the marine environment are at risk due to high chloride-induced corrosion, resulting in high chloride concentrations and moisture or saturation conditions. The corrosion of reinforcing steel in concrete is usually associated with cross sectional reduction and the deposition of corrosion products which in turns create expansion on the reinforcement resulting to larger formation than the original steel [1].

Localized corrosion is formed with coverage of reinforcing steel surface with films acting like protective coating [2-5], concluded that steel has an instantaneous kinetics in the oxidative environment, such as air, and that after the formation of the membrane, the metal is "inactive".

Investigated the effect of structural strength on the residual yield strength of a corrugated, corrugated and barred steel bar. Results of a steel bar coated with three different resins / exudates extracts of Symphonia globulifera Linn, Ficus glumosa and Accordium occidental L. Overall results show that coated steel bar failure results in higher values of load and tensile strength, while elongation and midspan deflection are reduced [6].

Torres-Acosta *et al*., (2006) found that maximum pitting depth had the greatest influence on load bearing capacity, and not the average corrosion penetration based on the reinforcing radius. They reported that concrete cracks caused by corrosion are greater in dry environments despite wet hardening and accelerate pit formation on external reinforcement. The experimental results show that the average corrosion is reduced by about 10% penetration of the initial longitudinal radius of reinforcement results in a 60% reduction in reinforced concrete flexural strength the Beam [7].

Du *et al*., (2007) conducted experimental tests on corroded and uncorroded reinforced concrete carriers with reinforcement details in pure flexure. They use an accelerated corrosion process to corrode the samples. Experimental tests include over-reinforced, balanced-reinforced, under-reinforced, and very [8].

Under-reinforced reinforced concrete beam. They reported that corrosion changed the type of damage to over-reinforced beams from brittle fracture to less brittle and even plastic fracture mode, but reduces reinforced plasticity beams fail to be less plastic or even very brittle. They also found that corrosion caused mass loss of more than 10% causes premature damage to the tensile reinforcement in the case of severely inadequately reinforced beams, which can cause severe damage decreased ductility in this beam.

Cairns *et al*., (2008) conducted a series of experimental tests on reinforced concrete girders with highly ductile ordinary round bars, with about 4%-10% loss of cross-sectional area of reinforcement (slightly corroded). You observe this corrosion change the mechanism of RC beam damage from bend to bend, followed by localized slip damage. They found that the flexural strength of the corroded beam was higher than that of the uncorroded sample. This is mainly due to an increase in the strength of the attachment, especially with an increase in radial stress at the reinforcement-concrete boundary near the repository [9].

An exploratory study was conducted to determine the use of natural inorganic materials of tree resin / exudates to assess the yield strength of reinforced concrete beam members. The obtained results showed the presence of corrosion on the uncoated concrete beam members with the presence of pitting and cracking. The non-corroded, tensile strength increased while the decreased in tensile strength was recorded non-corroded and coated members. Overall results indicated that the failure and low failure loads on the tensile strength, the load on the midspan and the elongation, were the result of an attack and decrease in the yield strength potential due to corrosion potential [10].

Investigated corrosion resistant (Symphonia globulifera Linn) resins / paste coated steel exudates on exudates and investigated. The results obtained on the comparison between uncoated and coated are flexural load, midspan deflection, tensile strength and elongation. Obtained results showed that the failure load and the tensile strength of the corroded members decreased, resulting in increased midspan deflection and extension. The strength of these properties was due to the corrosion effect and the decrease in strength from the degradation properties. Resins / Exudates coated members showed high failure load with low deflection [11].

Introduced coated reinforced steel, 150µm, 300µm, and 450µm thick exudates/ resins aimed at reducing the corrosion of steel reinforcement in the saltwater area. Explored the impact of corrosion on concrete beam of coated and non-coated members. Extensive test results have shown potential corrosion resistance with coated members on the mechanical properties with strengthen the effects of diameter reduction, cracking, spalling and weight loss. Experimental results showed signs of corrosion on uncoated reinforcing steel with corrosive properties that reduced the thickness of the reinforcing surface, resulting in weight loss and cracking. These features failed variable load and high retention potential with low average usage, high levels of stress, stretching, and midspan deviation [12].

Studied the reinforcement behavior of coated specimens with different coating thicknesses with Acacia Senegal exudates, embedded in concrete beams and immersed in corrosive and harsh media for 150 days. The results obtained after the fasting period confirm the non-coated shape of the fractures and the corrosion potential of the splinters. High flexibility loads are demonstrated against corroded and specimens; Midspan deflection rates are high for corroded. Overall experimental tests show that the mechanical properties of reinforcing steel were negatively affected by corrosion [13].

Evaluated the effectiveness of olibanum exudates/resins in reinforcing steel embedded in concrete, and uncoated samples, subjected to a corrosive environment in an accelerating corrosion risk. Corroded members showed small flexural loads over the controlled and coated specimens, the midspan deflection rates were higher for the corroded specimen, and the ultimate tensile strength of the corroded members was greater against the coated specimens with lower load. The effect of corrosion on the mechanical properties of steel reinforcement was attributed to the poor state performance of the corrosive members [14].

Investigated naturally available inorganic products of Garcinia cola extracts (exudates/resins) as a protective layer to reinforce the steel embedded in concrete. The corroded member ensemble results showed higher yield with lower applied load, higher midspan deflection, and extension. The results of exudates/resins coated members show less flexibility towards corroded members with lower and less midspan deflection. Non-corroded member outcomes include flexural failure load, low midspan deflection and yield strength, strain ratio and high values of extension over corroded members [15].

Examined the effect of exudates/resins coating members on surface changes, diameter reduction, weight loss, and aggressive weathering of reinforcing steel. Members coated with different thicknesses were embedded in concrete structures, exposed, and monitored within 150 days. Corroded members are found to have a steel reinforcement mechanism due to corrosion, which results in midspan deflection and higher yields, with greater structural integrity for the coated members. The coated members showed high flexibility before failure due to high yields and reduced load to elongation [16].

Kanee *et al*., (2019) investigated the effect of reinforcing steel with the introduction of milicia excelsa exudates/resins for surface modification and the deterioration of the mechanical properties of reinforcing steel in concrete structures. The corrosion acceleration process was 150 days and the corrosion potential was determined. The overall experimental results have shown that the corrosion properties of the spalling and fractures in coated members indicate a lower flexibility failure load; Midspan deflection, extension. Coated members showed less; Midspan deflection, extension, and ultimate yield, high flexibility failure load required, and compared to depleted members [17].

Investigated the comparative effect of reinforcing coated steel with Khaya senegalensis resins and non-coated member on residual flexibility after 150 days of corrosion rapid periods. Flexural fracture loads of midspan deflection and ultimate tensile strength of corroded members are high against controlled and coated members. Mechanical properties of reinforcing steel are adversely affected by corrosion [18].

Studied on the potential application of resin extract of inorganic resistant natural exudates of grewia. The range of values for corrosion models indicates a significant corrosion potential for high, low, moderate, and low. The results showed a high ultimate yield of corroded specimens to control and coating specimens due to the effect of corrosion on the mechanical properties of steel reinforcement. The results of the weight loss of steel showed a high percentage of values against the control and coating models due to the effect of corrosion on the mechanical properties [19].

2.1 MATERIALS AND METHODS

2.1.1 Aggregates

Fines and coarse aggregates were purchased. Both met the requirements of [20]

2.1.2 Cement

Portland lime cement grade 42.5 is the most common type of cement in the Nigerian market. It was used for all concrete mixes in this test. Cement meets the requirements of [21]

2.1.3 Water

The water samples were clean and free from contaminants. Used fresh water was obtained from the Civil Engineering Laboratory, Kenule Beeson Polytechnic, Bori, Rivers State. Water met the requirements of BS 3148

2.1.4 Structural Steel Reinforcement

Reinforcements are obtained directly from the market at Port Harcourt. Confirmed at [22]

2.1.5 Corrosion Inhibitors (Resins / Exudates) Raphia hookeri

The gum exudates / resins were obtained from the cut sections of the raffia palm tree stem inflorescent part from Ubeta forest in Ahoada – West Local Government Area of Rivers State

2.2 METHODS

This study examines the use of exudate/resin from extrusion of plant sap of natural origin with environmental properties of harmless materials from tree trunks. The exudate/resins resin is applied directly to the steel reinforcement through coatings of different thicknesses which are embedded in the concrete beams and checked for suitability as a corrosion protection agent. This study aims to use a locally widely distributed material to limit the negative effects of corrosion attack on steel reinforcement in a marine environment with a high concentration of salt (sodium chloride). Samples of designed beams of 175mm x 175mm 750mm, thickness, width and length were inserted with four (4) figures of 16mm diameter and immersed in sodium chloride (NaCl) for 360 days after the first 28 days of curing. The process of exposure to corrosion is a long-term action that lasts for several years, but the introduction of sodium chloride (NaCl) accelerates and stimulates corrosion rates that are representative of marine coastal areas, and this process can be achieved in a short time. time period. In addition, the role of exudates/resin against harmful attack on reinforcement through waterproofing and resistance as well as in surface modification of reinforcing steel through coating must be determined.

2.2.1 Sample L Preparation and Casting of Concrete Beams

The standard method for mixing ratios of concrete, manual composition by weight of the material is followed. Concrete mix ratio 1:2:4, water-cement ratio 0.65 according to the weight of the concrete. Manual mixing is applied to the clean concrete block and the mixture is checked and water is added slowly to create a complete concrete mix design. A constant uniform color and consistency is achieved by adding concrete cement, water and aggregate. The test beam is poured into a steel mold of 175 mm x 175 mm x 750 mm and is air sealed, reinforced and installed with 16 mm diameter reinforcing steel. The samples were deformed after 72 hours and preserved for 28 days using standard procedures, and the samples were preserved at room temperature in a hardening tank for a rapid corrosion test process of 90 days, 180 days, 270 days and 360 days and the first time the crack appeared.

2.2.2 Flexural Testing of Beam Specimens

According to BS EN 12390-2, a universal testing machine was used for bending testing and a total of 36 carrier models were tested. After 28 pretreated and standardized, 12 rods (uncoated) were controlled to prevent corrosion-related reinforcement, while 24 rod samples from untreated and exudates/resin-coated samples were completely immersed in 5% sodium chloride (NaCl) for 360 days. with regular 3-monthly tests for 90 days, 180 days, 270 days and 360 days, examining changes in surface modification and mechanical properties as well as the effects of uncoated (corroded) and coated samples. The bending test was carried out on an Instron universal testing machine with a capacity of 100KN. The sample is placed in the machine according to specifications and, in the third step; a flexural test is performed on the two supports. Digitally recorded and computer-aided system records cracks and corresponding values of flexural strength loads, average span deformation and all relevant tests of reinforcement diameter measured before testing, diameter of reinforcement - after corrosion, reduction/increase of cross-sectional area, limits tensile strength, maximum tensile strength, deformation ratio, elongation, Weight of reinforcement - before testing, weight of reinforcement - after corrosion and steel loss/weight were observed and recorded.

Table 3.1: Flexural Strength of Beam Specimens (Controlled)

Samples	**Samples A**			**Samples B**			**Samples C**			**Samples D**		
Items	**RH**	**RH1**	**RH2**	**RH3**	**RH4**	**RH5**	**RH6**	**RH7**	**RH8**	**RH9**	**RH10**	**RH11**
Flexural Strength Load (KN)	80.85	80.69	79.55	83.53	79.97	80.48	80.79	80.11	81.04	78.79	80.99	82.77
Midspan Deflection (mm)	8.70	8.78	9.38	9.49	8.58	9.52	8.61	8.78	8.58	8.66	8.66	9.51
Nominal Bar diameter (mm)	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Measured Rebar Diameter Before Test(mm)	16.00	15.99	15.97	16.00	15.99	15.94	16.00	15.98	15.90	15.97	15.96	15.98
Rebar Diamete at 28 days(mm)	16.00	15.99	15.97	16.00	15.99	15.94	16.00	15.98	15.90	15.97	15.96	15.98
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yield Strength, fy (MPa)	410.30	409.81	407.91	411.93	411.55	410.93	410.52	411.04	410.92	411.74	411.33	410.98
Ultimate Tensile Strength, fu (MPa)	591.61	586.56	578.24	584.02	587.55	577.97	577.77	578.57	577.17	589.72	582.22	591.08
Strain Ratio	1.44	1.43	1.42	1.42	1.43	1.41	1.41	1.41	1.40	1.43	1.42	1.44
Elongation (%)	17.66	17.73	17.86	17.06	18.86	19.20	16.66	17.23	16.16	18.76	17.70	16.99
Rebar Weights- Before Test	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.57	1.56	1.56	1.52
Rebar Weights- After at 28 days (Kg)	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.57	1.56	1.56	1.52
Weight Loss /Gain of Steel (Kg) at 28 days	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.2: Flexural Strength of Beam Specimen (Corroded specimens)

	RH1A	RH1B	RH1C	RH1D	RH1E	RH1F	RH1G	RH1H	RH1I	RH1J	RH1K	RH1L
Flexural Strength Load (KN)	64.83	61.98	63.54	64.17	63.96	65.76	64.78	64.10	65.03	64.47	64.48	67.52
Midspan Deflection (mm)	13.01	13.09	13.69	13.80	12.89	13.83	12.92	13.09	12.89	12.97	12.97	13.82
Nominal Rebar Diameter	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Measured Rebar Diameter Before Test(mm)	16.00	15.99	15.97	16.00	15.99	15.94	16.00	15.99	15.90	15.97	15.96	15.98
Rebar Diameter- After Corrosion(mm)	15.93	15.91	15.88	15.85	15.93	15.93	15.93	15.89	15.93	15.93	15.94	15.92
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.07	0.08	0.10	0.15	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06
Yield Strength, fy (MPa)	380.91	393.42	391.52	387.54	386.16	389.24	394.13	387.65	389.53	390.35	391.44	391.46
Ultimate Tensile Strength, fu (MPa)	566.23	561.18	552.86	558.64	562.17	552.59	552.39	553.19	551.79	564.34	556.84	565.70
Strain Ratio	1.49	1.43	1.41	1.44	1.46	1.42	1.40	1.43	1.42	1.45	1.42	1.45
Elongation (%)	25.91	25.98	26.11	25.31	27.11	27.85	24.91	28.28	28.41	27.01	25.95	27.84
Rebar Weights- Before Test(Kg)	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.58	1.57	1.57	1.57
Rebar Weights- After Corrosion(Kg)	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52
Weight Loss /Gain of Steel (Kg)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05

Table 3.3: Flexural Strength of Raphia hookeri Exudate / resin Coated Beam Specimens

	RH1A1	RH1B2	RH1C3	RH1D4	RH1E5	RH1F6	RH1G7	RH1H8	RH1I9	RH1J10	RH1K11	RH1L12
	150µm coated (Exudate/Resin)			300µm coated (Exudate/Resin)			450µm coated (Exudate/Resin)			600µm coated (Exudate/Resin)		
Flexural Strength Load (KN)	80.85	80.19	79.56	83.54	79.98	80.49	80.80	80.12	81.05	78.00	80.50	81.78
Midspan Deflection (mm)	8.76	8.84	9.44	9.55	8.64	9.58	8.67	8.84	8.64	8.72	8.72	9.57
Nominal Rebar Diameter	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Measured Rebar Diameter Before Test(mm)	16.00	15.99	15.97	16.00	15.99	15.94	16.00	15.98	15.90	15.97	15.96	15.98
Rebar Diameter- After Corrosion (mm)	16.06	16.06	16.04	16.07	16.07	16.01	16.07	16.06	15.97	16.04	16.03	16.05
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Yield Strength, fy (MPa)	410.30	409.81	407.91	411.93	411.55	410.93	410.52	411.04	410.92	411.74	411.33	410.98
Ultimate Tensile Strength, fu (MPa)	593.41	588.36	580.04	585.82	589.35	579.77	579.57	580.37	578.97	591.52	584.02	592.88
Strain Ratio	1.45	1.44	1.42	1.42	1.43	1.41	1.41	1.41	1.41	1.44	1.42	1.44
Elongation (%)	17.58	17.65	17.78	16.98	18.78	19.12	16.58	17.15	16.08	18.68	17.62	16.91
Rebar Weights- Before Test(Kg)	1.56	1.57	1.56	1.56	1.56	1.56	1.56	1.56	1.57	1.56	1.56	1.56
Rebar Weights- After Corrosion(Kg)	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
Weight Loss /Gain of Steel (Kg)	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

Table 3.4: Average Flexural Strength of Beam Specimens (Control, Corroded and Exudate/Resin Coated (specimens)

	Average Flexural Strength of Control Beam Specimens				Average Flexural Strength of Corroded Beam Specimens				Average Flexural Strength of Exudate/Resin Coated Beam Specimens			
Flexural Strength Load (KN)	80.36	81.33	80.65	80.85	63.45	64.63	64.64	65.49	80.20	81.34	80.66	80.09
Midspan Deflection (mm)	8.95	9.19	8.65	8.94	13.26	13.51	12.97	13.25	9.02	9.26	8.72	9.01
Nominal Rebar Diameter	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Measured Rebar Diameter Before Test(mm)	15.83	15.88	15.84	15.85	15.99	15.98	15.96	15.97	15.85	15.85	15.84	15.82
Rebar Diameter- After Corrosion(mm)	15.99	15.97	15.96	15.97	15.91	15.90	15.92	15.93	16.05	16.05	16.03	16.04
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.00	0.00	0.00	0.00	-0.08	-0.07	-0.08	-0.07	0.28	0.29	0.24	0.26
Yield Strength, fy (MPa)	409.34	411.47	410.82	411.35	388.61	387.64	390.43	391.08	409.34	411.47	410.83	411.35
Ultimate Tensile Strength, fu (MPa)	585.47	583.18	577.83	587.67	560.09	557.80	552.46	562.30	587.27	584.98	579.64	589.47
Strain Ratio	1.43	1.42	1.41	1.43	1.44	1.44	1.42	1.44	1.43	1.42	1.41	1.43
Elongation (%)	17.75	18.37	16.68	17.82	26.00	26.75	27.20	26.93	17.67	18.30	16.61	17.74
Rebar Weights- Before Test(Kg)	1.56	1.56	1.56	1.55	1.57	1.57	1.57	1.57	1.56	1.56	1.56	1.56
Rebar Weights- After Corrosion(Kg)	1.56	1.56	1.56	1.55	1.52	1.52	1.52	1.52	1.63	1.63	1.63	1.63
Weight Loss /Gain of Steel (Kg)	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.07	0.07	0.07	0.07

Table 3.5: Average Percentile Flexural Strength of Beam Specimens (Control, Corroded and Exudates Coated (specimens)

	Average Percentile Flexural Strength of Control Beam Specimens				Average Percentile Flexural Strength of Corroded Beam Specimens				Average Percentile Flexural Strength of Exudate/Resin Coated Beam Specimens			
Flexural Strength Load (KN)	26.65	25.84	24.77	23.46	-20.88	-20.54	-19.86	-18.23	26.40	25.85	24.78	22.30
Midspan Deflection (mm)	-32.53	-31.94	-33.27	-32.55	47.07	45.83	48.66	47.12	-32.00	-31.43	-32.73	-32.03
Nominal Rebar Diameter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Measured Rebar Diameter Before Test(mm)	0.344	0.357	0.348	0.357	0.335	0.341	0.351	0.348	0.335	0.342	0.352	0.348
Rebar Diameter- After Corrosion(mm)	0.49	0.46	0.27	0.26	-0.92	-0.91	-0.71	-0.71	0.93	0.92	0.72	0.72
Cross- sectional Area Reduction/Increase (Diameter, mm)	0.00	0.00	0.00	0.00	-9.95	-9.95	-9.97	-9.97	20.10	21.41	36.25	37.00
Yield Strength, fy (MPa)	5.33	6.15	5.22	5.18	-5.06	-5.79	-4.96	-4.93	5.33	6.15	5.22	5.18
Ultimate Tensile Strength, fu (MPa)	4.53	4.55	4.59	4.51	-4.63	-4.65	-4.69	-4.61	4.85	4.87	4.92	4.83
Strain Ratio	-0.79	-1.51	-0.60	-0.64	0.49	1.22	0.29	0.33	-0.49	-1.20	-0.29	-0.33
Elongation (%)	-31.72	-31.32	-38.66	-33.84	47.08	46.20	63.75	51.78	-32.01	-31.60	-38.93	-34.12
Rebar Weights- Before Test(Kg)	-0.45	-0.39	-0.51	-1.26	0.47	0.50	0.49	0.41	-0.47	-0.49	-0.49	-0.41
Rebar Weights- After Corrosion(Kg)	2.88	2.89	2.89	2.01	-6.67	-6.61	-6.74	-6.71	7.15	7.08	7.23	7.19
Weight Loss /Gain of Steel (Kg)	0.00	0.00	0.00	0.00	-24.14	-23.65	-20.64	-23.08	31.82	30.98	26.01	30.00

3.1 Results and Discussion of Concrete Beam Members Flexural Strength Load and Midspan Deflection

Corrosion of reinforced concrete or concrete has caused the sudden collapse of many structures in coastal areas by storm. The effect of corrosion on flexural forces has been studied by a large number of researchers and is well understood. Many studies that have been carried out in this area have been characterized by critical tests of their effectiveness in influencing the effect of corrosion on the flexibility of reinforced concrete beams. Because of the corrosive effect on reinforced concrete structures built with the high salinity in the coastal area of the Niger Delta, Nigeria, the application of Raphia hookeri extract exudates/resin from wood sources with environmentally friendly effect was applied directly to the built-in reinforcing beam and assessed its effectiveness as corrosion protection.

If the concrete is aerated to the depth of the steel reinforcement and has little but even moisture, the steel is likely to corrode evenly. This deterioration is often indicated by fine cracks in the hair that are parallel to the direction of reinforcement throughout the length of the component. Fortunately, because the corrosion is relatively uniform, cracks appear in the concrete shell of normally reinforced or prestressed solid structures before the steel becomes too weak to provide early warning of damage visually by many researchers and is well understood.

The experimental data for flexural tests on concrete beam samples are shown in Tables 3.1, 3.2, and 3.3, summarized in 3.4, mean and percentile values in 3.5, and the results are shown graphically in Figures 3.1 - 3.7b. The average value and the minimum and maximum percentage calculated are the flexural strength of the Instron universal testing machine with a pressure of 100kN under pressure to a controlled sample failure state of 80.36kN and 81.33kN (23.46% and 26.65%), corrosion value samples were 63.45kN and 65.49kN (-20.88% and -18.23%) and exudates/resin coated samples were 80.09kN and 81.34kN (22.3% and 26.4 %). The maximum value obtained of flexural load tests for controlled is 26.65% as compared to the value of -18.23% and 26.4% for the corroded and coated samples were examined for comparison of the flexural strength test. Mean differential and percentile range controlled (0.97kN and 3.19%), corroded (2.04kN and 2.65%), coated (1.25kN and 4.1%)

The results showed that the reference percentage of controlled samples according to BS 3148 was placed in fresh water and no corrosion effect was observed and was therefore used as a reference value for uncoated and coated samples immersed in a corrosive environment as described in the test. program. Corroded specimens fail with a lower load, whereas coated specimens have a higher load if the failure occurs. The results further confirm that the flexural rupture load of the controlled and coated specimen maintains a narrow range of values over the corroded specimen at moderate, reduced and lower loads. The minimum and maximum yields and percent midspan deflection values for the uncoated samples were 8.65kN and 9.19kN (-33.27% and -31.94%), the corroded samples were 12.97kN and 13.51kN (45.83% and 48.66). %) and coated samples had 8.72kN and 9.26kN (-32.73% and -31.43%).

The comparison results of midspan deflection showed that the maximum value obtained is controlled to the failure state -33.27% against 48.66% corroded and coated with -31.43%. The difference between the mean and percentage values is recorded (0.54kN and 1.33%), corroded (0.54kN and 2.83%) and coated (0.54kN and 1.3%). The results showed lower deformation loads in controlled and coated specimens with reduced values over corroded specimens with higher deformation on comparison with reference ranges (controlled) and intermediate ranges for the work [12, 15, 17, 16, 18].

From the results obtained, the exudate/resin of ficus plane trees is proven to be a corrosion protective material in reinforced concrete structures exposed to corrosive environments, with high resistance and as membrane sealing against the effects of corrosion.

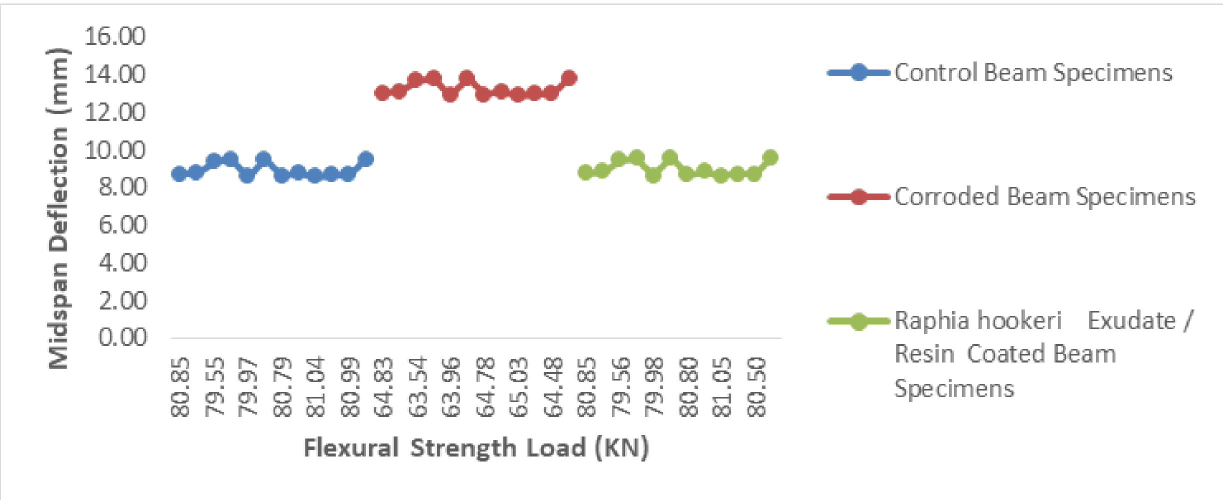

Figure 3.1: Failure Load versus Midspan Deflection of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

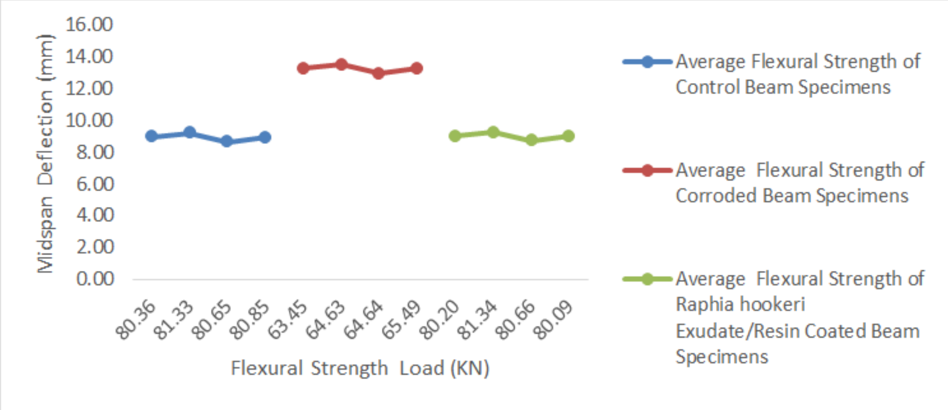

Figure 3.1A: Average Failure Load versus Midspan Deflection of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

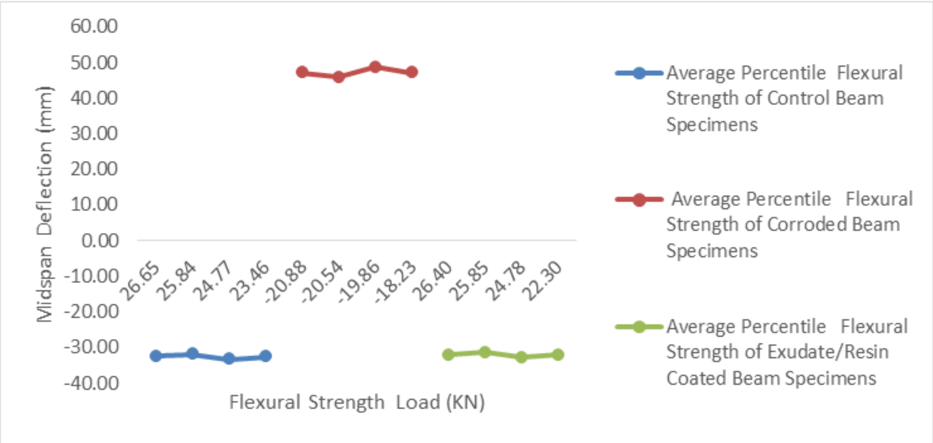

Figure 3.1B: Average Percentile Failure Load versus Midspan Deflection of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

3.2 Results of Measured Rebar Diameter Before and After Corrosion Test

One of the main reasons for premature aging of concrete is corrosion of reinforcing steel and this is caused by the chemical action of external aggressive substances such as carbon dioxide (CO2), oxygen (O2), chloride (Cl-), and sulfate (SO4) [23]). The strength of attack by these external aggressive agents depends on the exposure conditions (temperature, relative humidity (RH), type and concentration of the aggressive substance at the point of exposure) of the RC structure, the quality of the concrete, and the depth of the concrete layer. Coastal RC structures are mostly susceptible to chloride attack. Indoor RC structures (structures more than 50km from the coast) are especially susceptible to CO2 attack (carbonation), whereas buried structures can be exposed to sulfate or chloride attack [24]. The results of the minimum and maximum mean and percentile values for values the nominal diameter of the valve is 16 mm (100%) for all common standards. The fitting diameters measured before testing for the controlled sample were 15.83 mm and 15.88 mm (0.344% and 0.357%), which corroded were 15.96 mm and 15.99 mm (0.335% and 0.351%). and the coatings are 15.82 mm and 15.85 mm (0.335% and 0.352%). The results obtained indicate that the diameter of the reinforcing steel fluctuates within a few minutes due to the manufacture of reinforcement by different companies; the manufacture of the mold used has caused the average value and the percentage difference to be insignificant.

The average values and the minimum and maximum percentages of the rebar diameter - after the corrosion test were controlled 15.96 mm and 15.99 mm (0.26% and 0.49%), the corroded sample values were 15.9 mm and 15 93 mm (-0.92% and -0.71%), coated sample values were 16.03 mm and 16.05 mm (0.72% and 0.93%).

The comparison results obtained during and after the corrosion test the maximum value of the diameter of the anchor checked was 0.49% compared to the corroded one at -0.71% and the sample with a coating of 0.93%. The calculated mean differential and percentile values were checked (0.03kN and 0.23%), corrosion values (0.030kN and 0.21%) and coating values (0.02kN and 0.21%). The results showed that the effect of corrosion on the mechanical properties of reinforcing steel with a decrease in diameter reduced the average and percentage of samples corroded, while the controlled and coated samples showed a preserved state due to coating due to an increase in diameter different layer thickness with exudates/resin. The use of exudates/resin protects the reinforcing steel from severe corrosion damage. The mean and percentile values determined after and before the correction test have a negative effect on the diameter of the reinforcing steel, which leads to a reduction and an increase in the cross-sectional area.

The minimum and maximum obtained "decrease/increase in cross-sectional area (diameter)" of the controlled sample was 0.00 mm, which indicates (100%) for all samples, the corroded samples were -0.08 mm and -0.07 mm (-9.97%) and -9.95%, and coated samples 0.24 mm and 0.29 mm (20.1% and 37.05%).

The cross-sectional area of reinforcing steel shows a different mean value and percentile value of the corroded value (0.01 mm and 0.02%) and the coated value (0.05 mm and 2.69%). The results obtained showed the effect of corrosion on the mechanical properties of reinforcing steel with a decrease in the diameter of the reinforcement in the corroded sample, while the coated sample showed an increase due to the thickness of the exudates paste layer. The reduction in cross-sectional area is due to the corrosive effect on reinforced concrete structures constructed in marine coastal environments and the increased protective layer by work-related exudates/resins [12, 15, 17, 16, 18].

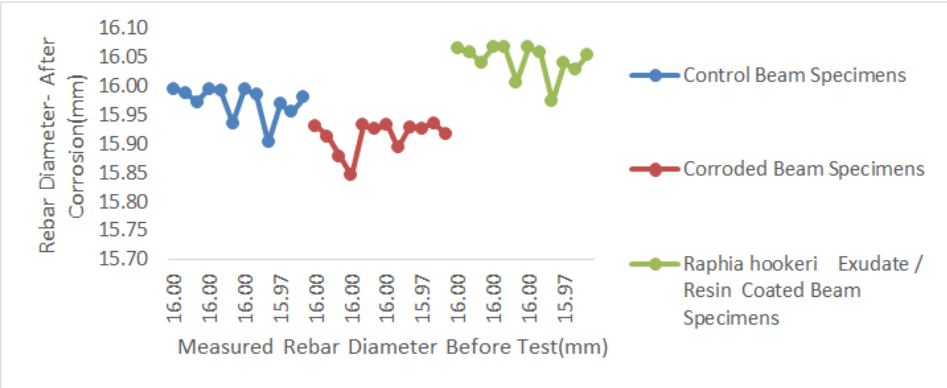

Figure 3.2: Measured Rebar Diameter Before Test versus Rebar Diameter- After Corrosion

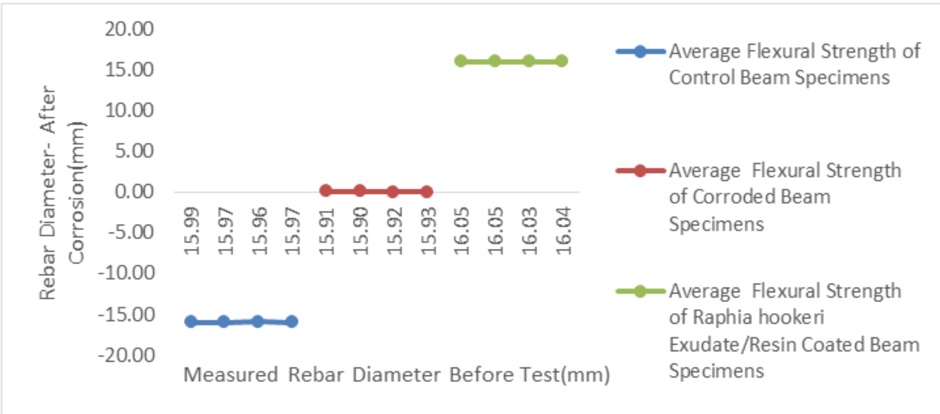

Figure 3.2A: Average Measured Rebar Diameter Before Test versus Rebar Diameter- After Corrosion

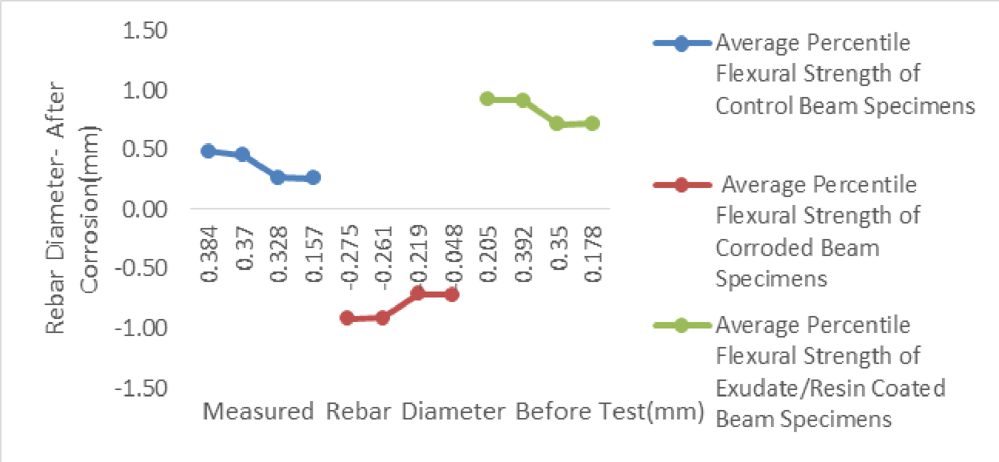

Figure 3.2B: Average Percentile Measured Rebar Diameter Before Test versus Rebar Diameter- After Corrosion

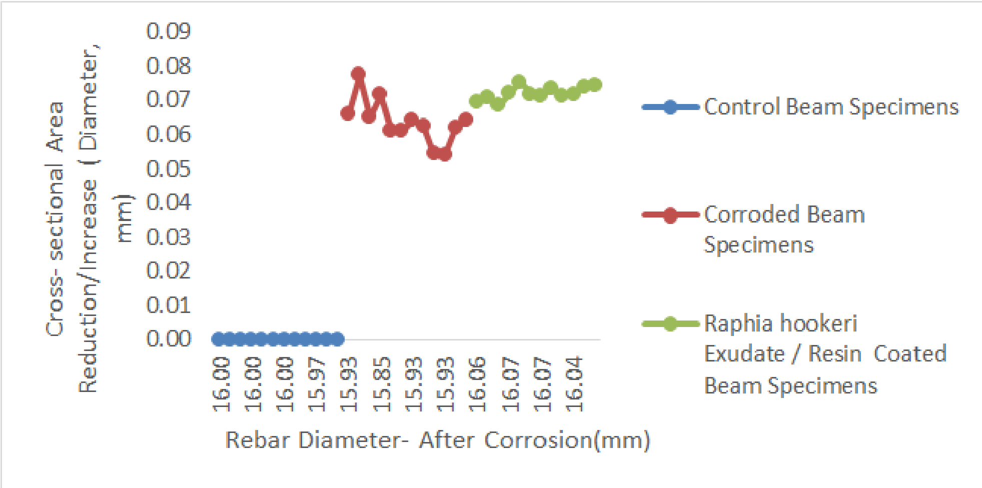

Figure 3.3: Rebar Diameter- After Corrosion versus Cross- sectional Area Reduction/Increase (Diameter)

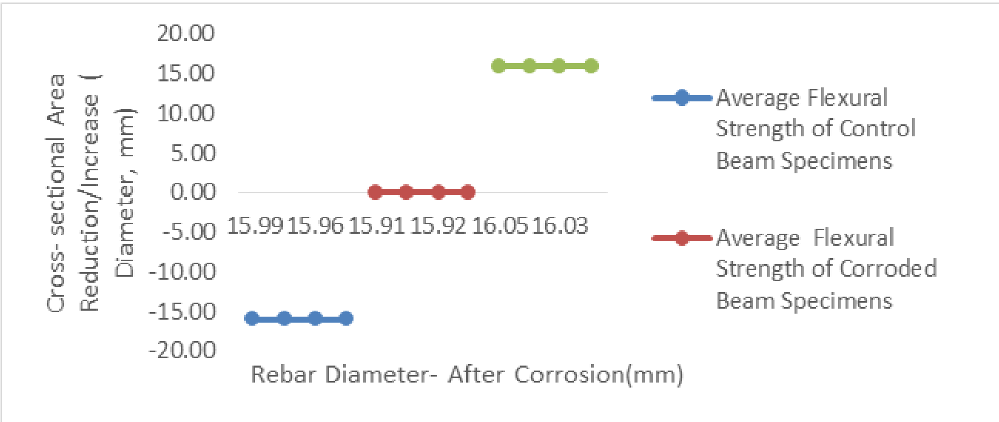

Figure 3.3A: Average Rebar Diameter- After Corrosion versus Cross-sectional Area Reduction/Increase(Diameter)

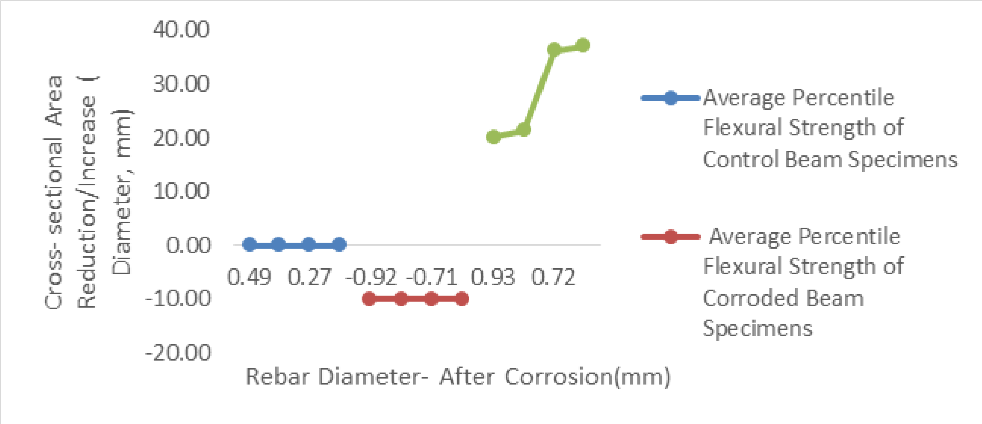

Figure 3.3B: Average Percentile Rebar Diameter- After Corrosion versus Cross-sectional Area Reduction/Increase (Diameter)

3.3 Results of Ultimate Tensile Strength and Yield Strength

Common corrosion processes occur through exposure to chlorides or carbonization of reinforced concrete structures. The effect of reducing the diameter of the rod and decreasing the mechanical properties of the steel bar is a consequence of the corrosion of steel. (e.g., the change from the normal plastic reaction of bars made of low carbon steel to relatively brittle reactions for bars damaged by corrosion ion suppression), cracking and pouring of concrete from expansive iron oxides and hydroxides and a significant reduction at the reinforced concrete interface. Corrosion of reinforcement, immersed or embedded in concrete, has led to the premature collapsed of many structures that have been exposed to marine coastal environments with adverse weather conditions. The effect of corrosion on flexural strength has been studied by many researchers and is well understood. Several studies carried out in this field have been described with a critical assessment of their application to the effects of corrosion on the flexural strength of reinforced concrete beams. [25] Formulated the effect of calculating steel losses due to mechanical damage due to corrosion. Steel losses due to corrosion on the failure capacity of beams are due to corrosion. The results of the calculation of the average and minimum and maximum values in Tables 3.4 and 3.5 obtained from Tables 3.1-3.3 at the point of the sample-controlled value results are 409.34 MPa and 411.47 MPa (5.18% and 6.15) %), the corroded sample had 387.64 MPa and 391.08 MPa (-5.79% and -4.93%) and the coated sample had 409.34 MPa and 411.47 MPa (5.18% and 6.15%) respectively.

The ultimate tensile strength values of the control samples were 577.83 MPa and 587.67 MPa (4.51% and 4.59%), corroded samples were 552.46 MPa and 562.3 MPa (-4.69% and -4.61%), and coated samples of 579.64 MPa and 589.47 MPa (4.83% and 4.92%).

The analyzed results of the maximum comparison value for both yield strength and tensile strength for the controlled sample were 6.15% and 4.59% compared to the corroded and coated values of -4.93% and -4.61%, and 6.15% and 4.92% respectively. Differentially, the calculated mean and percentage values of yield strength and tensile strength are (2.13 MPa and 0.97%) and (3.435 MPa and 0.08%) and were examined, the corroded values were (3.44 MPa and 0.86%) and (4.548 MPa and 0.08%), the values of coated are (2.13MPa and 0.97%) and (4.736MPa and 0.09%). From the data obtained and compared, the yield strength and tensile strength values of the corroded samples showed a decrease in the average and percentage values for load failure with lower load applications. The effect of corrosion on corroded samples caused an effect on the mechanical properties of reinforcing steel through surface modifications affecting the ribs and fibers, whereas the coated samples from the reference area (controlled samples) showed an increase in the mean and percentage values with higher loads carrying capacity associated with the sample, see [12, 15, 15, 17, 16, 18]. From the results obtained, it can be seen that the loss and decrease in the strength of steel reinforcement embedded in reinforced concrete structures is mainly caused by corrosion. The observed corrosion properties generates cracks in the corroded elements which is the manifestation of signs of flexural stresses; deviations and deflection of midspan beyond the average range from reference, elongation, ultimate yield strength, low loads application to high failure criteria in case of corroded samples as compared to controlled and coated samples.

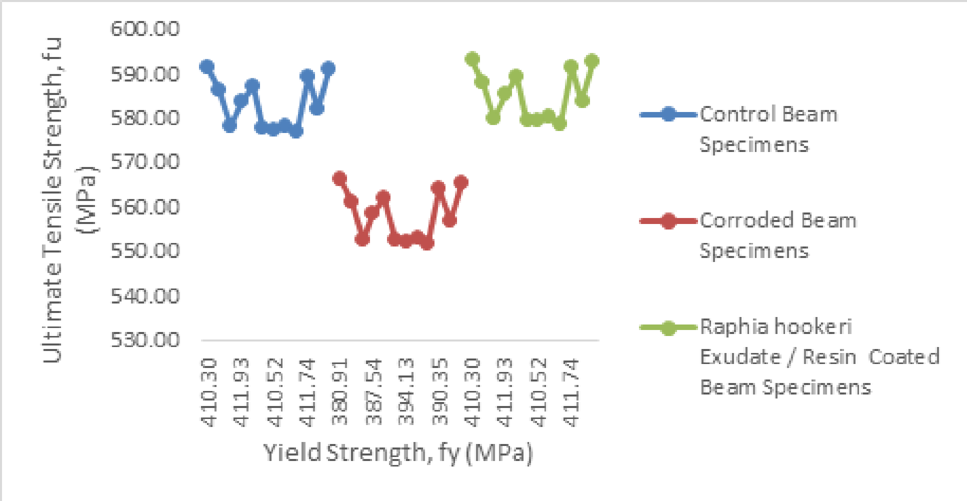

Figure 3.4: Ultimate Tensile Strength versus Yield Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

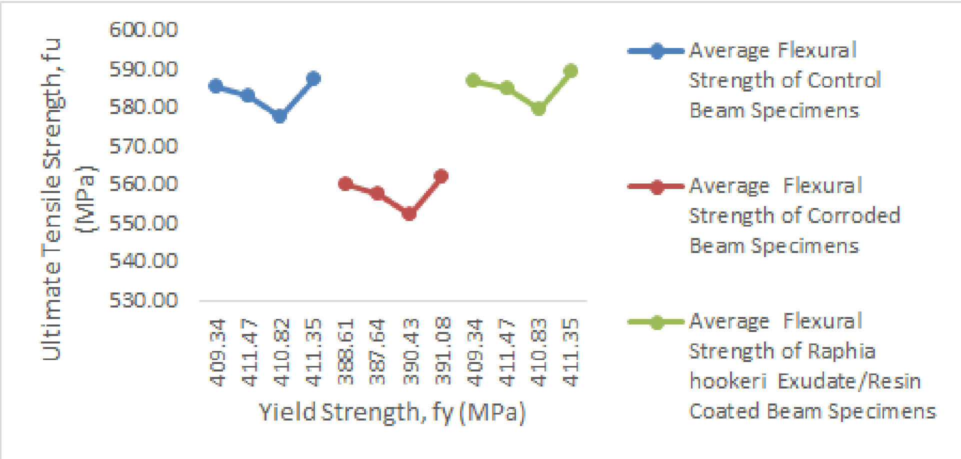

Figure 3.4A: Average Ultimate Tensile Strength versus Yield Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

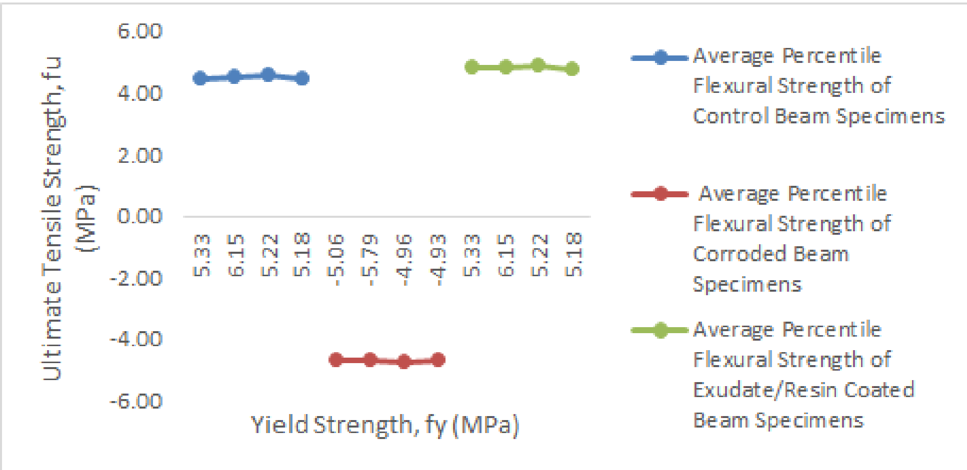

Figure 3.4B: Average percentile Ultimate Tensile Strength versus Yield Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

3.4 Results of Strain Ratio, Elongation, Rebar Weights- Before and After Corrosionn and Weight Loss /Gain of Steel

The load-bearing/ carrying capacity, stiffness, and redistribution of the reinforced concrete structure are affected by the corrosion of cast concrete reinforcement. Reduced shear and torsional resistance, reduced structural rigidity caused by reduction of the cross-sectional area of reinforcing steel, corrosion of steel in concrete in terms of bar diameter and layer thickness, and residual flexural strength of corrosive reinforced concrete structures. The presence of chloride in sufficient concentration at the reinforced concrete boundary causes reinforcement damage by attacking the passive layer. Changes in the ductility of reinforcement have a direct effect on the possible redistribution of forces and moments and limit the load-bearing/ carrying capacity of statically indeterminate structures and can also greatly reduce the load-bearing/ carrying capacity of the structure in the event of earthquake loads.

The results of the calculation of the minimum and maximum mean and percentage values in Tables 3.4 and 3.5 are obtained from Tables 3.1-3.3 the elongation values obtained from the controlled sample are 1.41 and 1.43 (-1.51 and -0.6%), corroded samples reported 1.42 and 1.44 (0.29% and 1.22%), coated sample values were 1.41 and 1.43 (-1.2% and -0.29%).

Comparison ratios obtained for deformation the maximum values calculated for the mean and percentile values for the controlled were -0.6% against the corroded and closed values of 1.22% and -0.29%. The difference between the mean and percentage values obtained for the control was (0.02 and 0.91%), corroded values (0.02 and 0.93%), and coated values (0.02 and 0.91%).

The results showed that the corroded samples had a higher elongation ratio due to lower failure loads and higher yields, whereas coatings had a higher percentage of load application with lower yields. Lower loads and higher yield and deformation strengths are the results of the effect of corrosion on the mechanical properties of reinforcing steel, which affects the interface, surface modification, fiber reduction, and rib removal. The above factors have reduced the load-bearing / carrying capacity of work-related reinforced concrete structures of [12, 14, 18]. The results of the minimum and maximum strain values (%) for the controlled sample were 16.68% and 18.37% (-38.66% and -31.32%), corrosion values were 26.34% and 27.2% (46.2% and 63.75%), the values of the coated samples were 16.61% and 18.3%, -38.93% and -31.6%).

The maximum comparison value for the controlled sample was -31.32% compared to the corroded and coated samples of 63.75% and 31.6%, respectively. The mean differential and percentile values obtained for the controlled samples were (1.69% and 7.34%), corrosion values (1.2% and 17.55%) and coated values were 1.69% and 7.33%). In comparison, the corroded samples showed higher stress values and higher elongation rates, whereas the damaged state of coated samples was lower load and reduced elongation. The effect of corrosion impairs the mechanical properties of reinforcing steel, leading to higher fracture rates at low loads; coated samples show a range of values closer to the reference (controlled sample). The application of exudates materials to rebar has reduced the scourge and tendency of corrosive attack to be exposed to reinforced concrete structures in heavy marine coastal areas in connection with work [15, 17, 16].

The unit Weight of rebar - before the test, the minimum and maximum mean and percentage values are calculated in Tables 3.4 and 3.5 and are obtained from Tables 3.1 - 3.3 of the parameters per unit weight before and after corrosion testing, sample-controlled values are 1.55 kg and 1.56 kg (0.0686% and 0.0675%), the corrosion values were 1.57 kg and 1.57 kg (0.0678% and 0.0685%) and the values coated were 1.56 kg and 1.56 kg (0.0667% and 0.0666%) and anchor weight - after corrosion (Kg) values of the minimum and maximum mean and percentile values, controlled for 1.55 kg and 1.56 kg (2. 01% and 2.89%), the corrosion values are 1.52 Kg and 1.52Kg (-6.74% and -6.61%), the values included are 1.63Kg and 1.63Kg (7.08% and 7.23%. The difference values obtained for the mean and percentile of the controlled sample are (0.01 and 0.88%), corrosion values (0.008 kg and 0.13%), and coated values (0.007 kg and 0.15%).

The results of the unit weight loss/weight gain of the minimum and maximum mean values and percentages of controlled steel for controlled samples (100%), leading to their combination in freshwater without any trace of corrosive attack, those values of corroded samples were 0.05 kg and 0.05 kg (-24.14% and -20.64%), coated samples were 0.07 kg and 0.07 kg (26.01% and 31.82%).

The calculated data for the maximum percentage of reinforcement beam weight before corrosion test for controlled, corroded, and coated values were 0.068%, 0.068%, and 0.065%.

The maximum comparison value recorded of unit weight loss/weight gain after the corrosion test for the controlled sample remained the same, without any trace of corrosive effect, because it was incorporated in freshwater; values of -6.61% and 7.23% were achieved for corrosive and coated samples. The percentage of maximum weight loss/gain for corroded and coated samples was -20.64% and 31.82%, respectively. The calculated data showed a decrease in the value of the corroded sample as a result of the corrosive attack, which led to a decrease in the registered weight, whereas the coated sample showed an increase in weight due to the different coating thickness compared to the reference value of the controlled sample from the works [12, 15, 17, 16, 18].

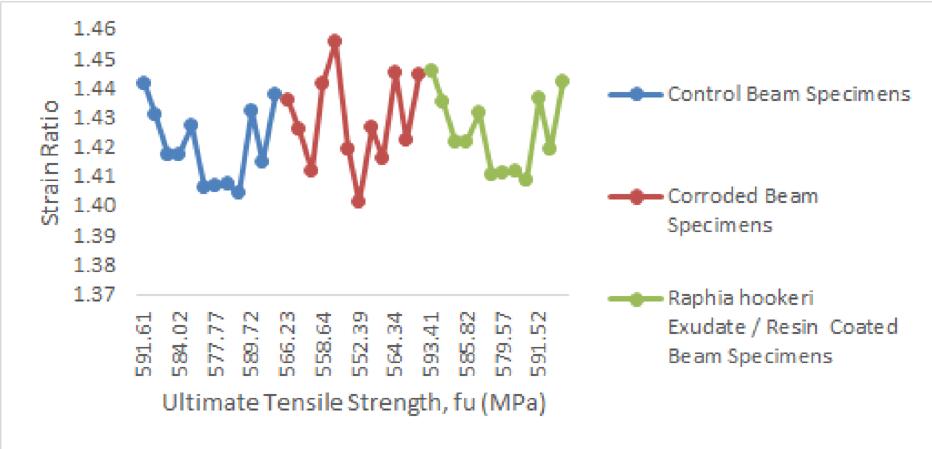

Figure 3.5: Ultimate Tensile Strength versus Strain Ratioof Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

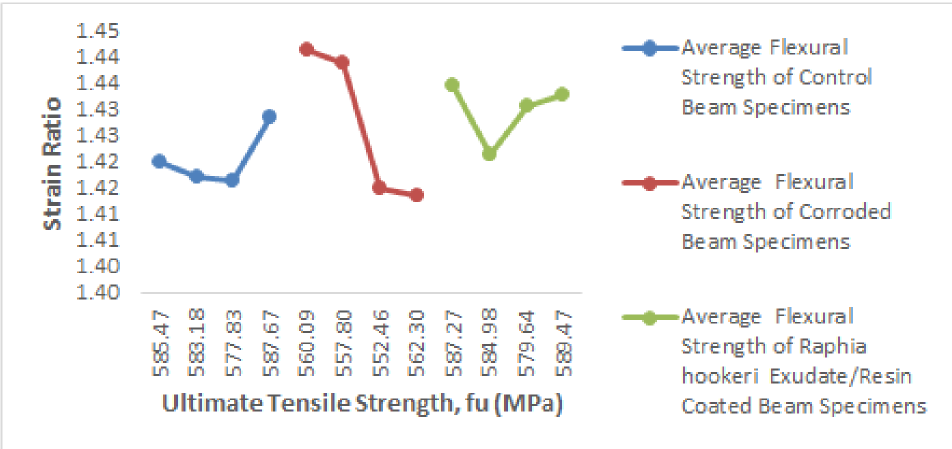

Figure 3.5A: Average Ultimate Tensile Strength versus Strain Ratioof Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

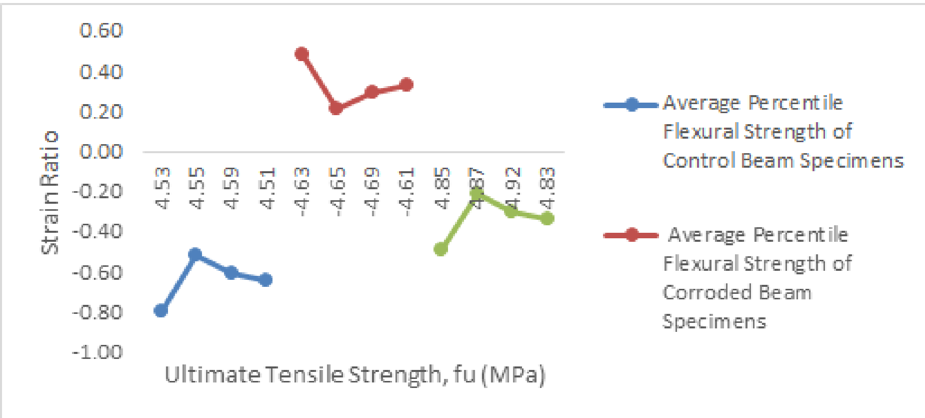

Figure 3.5B:Average Percentile Ultimate Tensile Strength versus Strain Ratioof Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

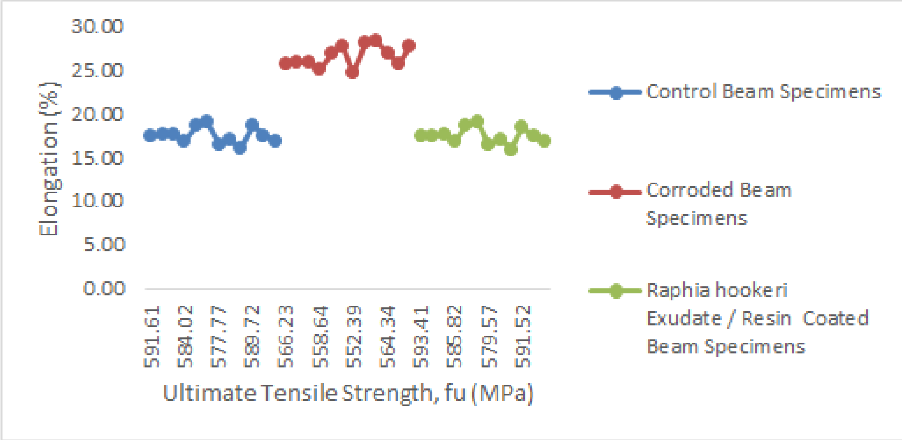

Figure 3.6: Ultimate Tensile Strength versus Strain Ratioof Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

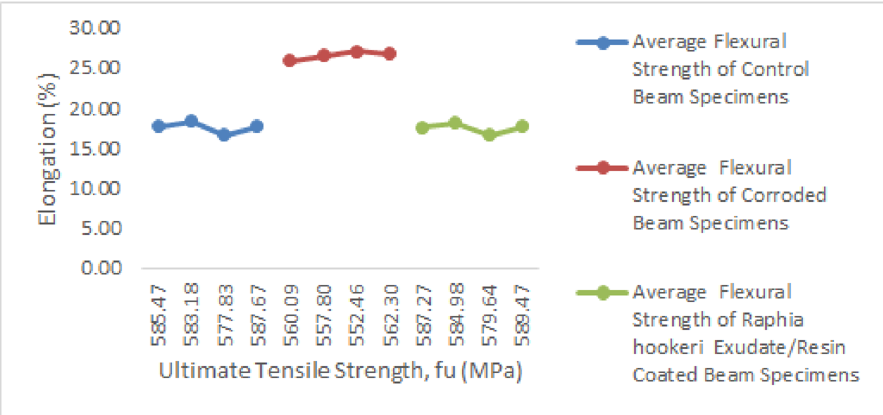

Figure 3.6A: Average Ultimate Tensile Strength versus Strain Ratioof Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

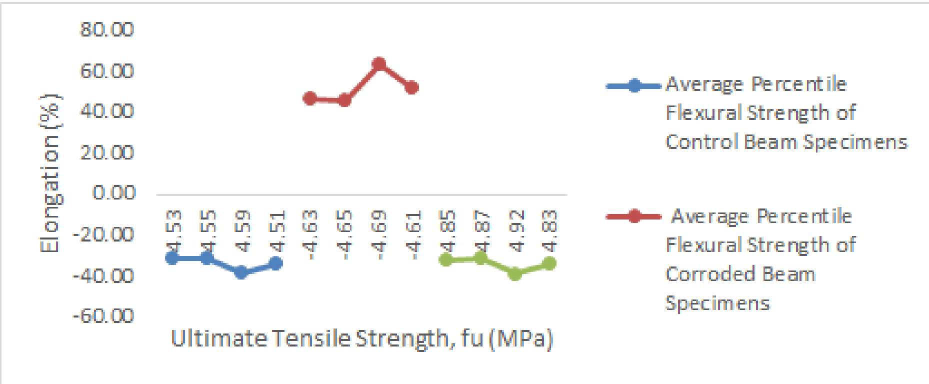

Figure 3.6B:Average Percentile Ultimate Tensile Strength versus Strain Ratioof Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens

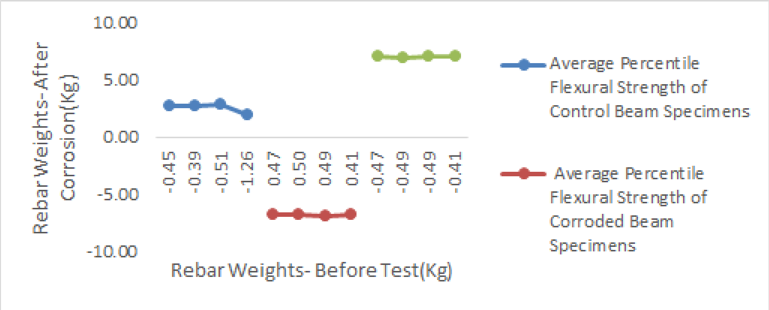

Figure 3.7: Rebar Weights- Before Test versus Rebar Weights- After Corrosion (Non-Corroded, Corrode and Resin Coated Specimens

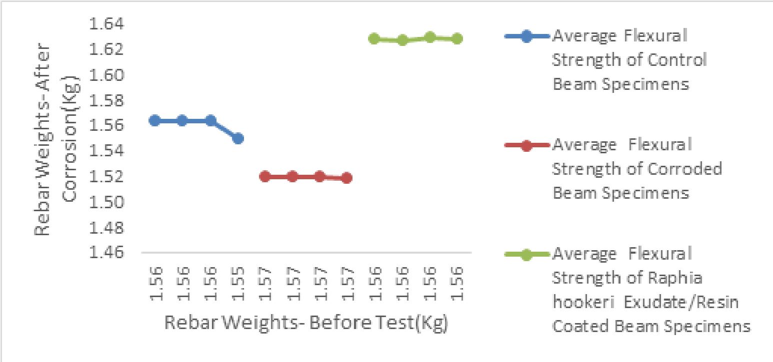

Figure 3.7A: Average Rebar Weights- Before Test versus Rebar Weights- After Corrosion (Non-Corroded, Corrode and Resin Coated Specimens

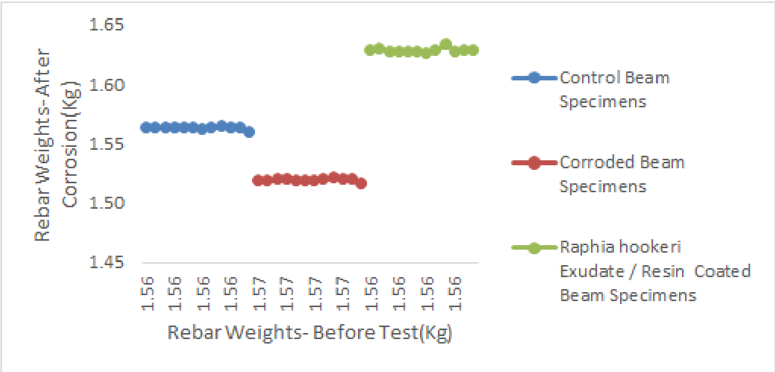

Figure 3.7B: Average Percentile Rebar Weights- Before Test versus Rebar Weights- After Corrosion (Non-Corroded, Corrode and Resin Coated Specimens

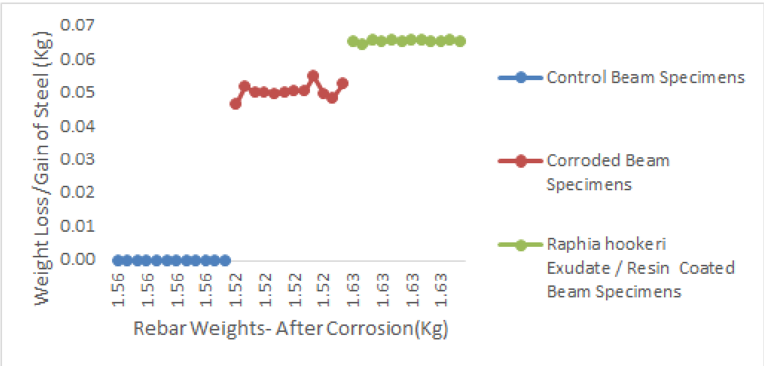

Figure 3.8: Weights- After Corrosion versus Weight Loss /Gain of Steel (Kg) (Non-Corroded, Corrode and Resin Coated Specimen

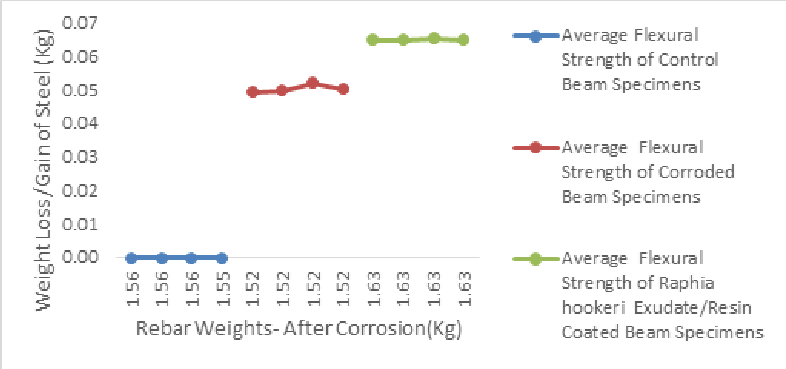

Figure 3.8A: Average Weights- After Corrosion versus Weight Loss /Gain of Steel (Kg) (Non-Corroded, Corrode and Resin Coated Specimens

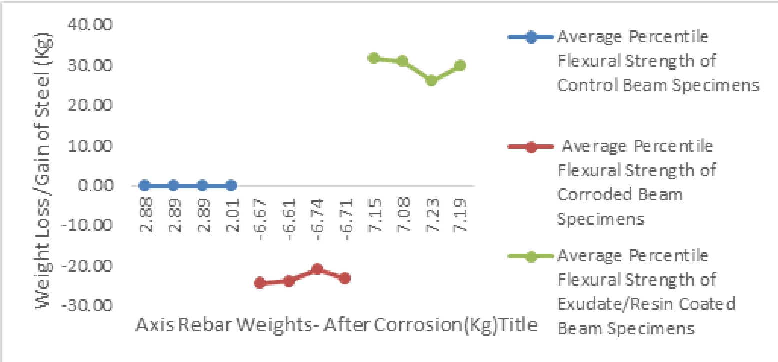

Figure 3.8B: Average Percentile Weights- After Corrosion versus Weight Loss /Gain of Steel (Kg) (Non-Corroded, Corrode and Resin Coated Specimens

4.0 CONCLUSION

The experimental results obtained are summarized with the following conclusions:

1. Results show lower elongation loads for controlled and coated samples with lower values than corroded samples with higher elongation loads and increased values compared to reference ranges (controlled) and coated samples.
2. The results of the comparison of flexural strength and elongation load in the center of the corroded sample indicate the effect of corrosion on the mechanical properties of reinforcing steel with bent reinforcement, high surface modification, low load carrying capacity, breaking strength and high deformation of reinforcing steel
3. The results showed that exudates / resin is a corrosion protection material in reinforced concrete structures exposed to a corrosive environment with high resistance and as a waterproofing membrane against the effects of corrosion.
4. The results obtained showed the effect of corrosion on the mechanical properties of reinforcing steel with a decrease in the diameter of the reinforcement in the corroded sample, while the coated sample showed an increase due to the thickness of the exudates paste layer.
5. Reduced cross-sectional area due to corrosive effects on reinforced concrete structures built in marine coastal environments and increased work-related exudates/resin protective layer
6. Exudates / resins have been proven to be effective and efficient in protecting reinforced concrete structures exposed to corrosive environments.
7. The combined results of the controlled sample on the corroded sample show that the controlled sample replaces the properties of the corroded sample with low flexural deformation, low deviation in the medium deformation range, normal yield strength, high ultimate strength, low deformation / deformation ratio.
8. Corrosion sample results show a high deformation load when bending; the degree of deformation is higher than the average range.

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