Residual Strength Capacity of Corroded and Coated Reinforcing Bars Corrosion Performance on the Flexural Strength of Reinforced Concrete Members

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Abstract: **Cracks reduced the overall strength and stiffness of concrete structures and accelerate the ingress of aggressive ions, leading to other types of concrete deterioration and resulting in further cracking. Aims: The study investigated the effectiveness of naturally occurring inorganic products of garcinia kola extracts (exudates / resins) as a protective membrane to reinforcing steel embedded in concrete. Members were immersed in severe corrosive environment and accelerated for 150days with examinations on changes of the mechanical properties of steel. Obtained flexural failure load percentile value of -29.0031% against 40.85115% and 39.32435% non-corroded and garcinia kola exudates coated specimens. Midspan deflection percentile value of 57.26586% against -36.4134% and -34.915% non-corroded and coated specimens. Average yield strength, of 460MPa, derived into 100% with 0.00% of percentile value. Average ultimate tensile percentile value of -10.0738% against 11.2023% and 11.58322% of non-corroded and coated specimens. Average strain ratio percentile value of -10.9146% against 12.25184% and 15.75587% of non-corroded and coated specimens. Average elongations percentile value of -41.3245% against 70.42903% and 74.90969% for non-corroded and coated specimens. Collated results of corroded members showed high yield strength with low applied load, high midspan deflection and elongation. Low flexural failure load with high yield. Indications showed that the attributes possessed by corroded members resulted from corrosion attacked on the surface properties of reinforcing steel and reduction in general mechanical properties of steel. Collated results from exudates / resins coated members exhibited low flexural failure load over corroded members with high, low midspan deflection over high in corroded, little elongation over high in corroded. Indications showed that coated members possessed resistance characteristics to corrosion penetration. Results from non-corroded (Controlled) members have high values of flexural failure load, low midspan deflection and yield strength, strain ratio and elongation over all corroded members.**

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

1. INTRODUCTION

The manifestation of corrosion in reinforced concrete structures has resulted to two severe principal forms of spalling and cracking of concrete cover resulting from unrestrained corrosion yield and local pitting of reinforcement at the anode which caused great reduction of the bar cross-sectional area. Reinforced concrete structures built within the coastal marine environment is at most risk of chloride induced corrosion due to the high presence of salt water. The formation of surface films covering the metal, while generally protective, can give rise to localized corrosion attack and pitting (Scully [1], [Bertolini et al.[2], Lounis et al. [3], Elsener [4]), concluded that there is instantaneous film formation in steel in an oxidizing atmosphere such as air, and once the formation of layer is noticed, metal is "passivated" and the oxidation or "rusting" rate will slow down to less than 0.04 mills per year (mpy).

Eyre and Nokhasteh [5] investigated the behavior of reinforcement exposed simply supported beams behavior. In the tests performed, the concrete-steel interface was assumed to have zero bonds over various lengths of the beam and the capacity of the beam was observed to reduce with smaller bond lengths. They concluded that even with the use of a critical un-bonded length, the beams failed by the concrete crushing, regardless of steel ratio. Their results have established that beams may possess considerable strength despite bond being entirely eliminated over part of the span, provided ends of bars remain adequately anchored Eyre and Nokhasteh [6].

Cabrera and Ghoddoussi [7] studied reinforced beams of doubled reinforcement of 10 and 12 mm diameter bars at the top and bottom and 8 mm diameter stirrups corrosion effects. Accelerated corrosion techniques were implored to corrode the tensile reinforcement by applying an unknown current density. Given the importance of confinement from cover and links to bond, it is clear that bond will be severely depleted prior to spalling Cabrera and Ghoddoussi [8]9

Charles et al. [7] investigated the residual yield strength structural capacity effect of non-corroded, corroded and inhibited steel bar. Three trees extract resins / exudates paste of Symphonia globulifera linn, ficus glumosa and acardium occidentale l were directly coated to reinforcement with 150µm, 250µm and 350µm thicknesses, embedded into concrete beam and initially cured for 30days in clean tap water and exposed to corrosive pond for 60 days for corrosion acceleration. Results obtained showed that corrosion potential was recorded on uncoated reinforcement with cracks propagations while resin coated showed resistance. The results of coated steel bar with three different resins / exudates extracts of Symphonia globulifera linn, ficus glumosa and acardium occidentale l.) versus corroded on comparison, the flexural strength failure load are 29.50%, 28.505,29.57% against 22.30% corroded, midspan deflection are 31.14%,25.30%, 22.30% against 39,30% corroded, tensile strength 11.84%, 12.13%, 12.14% against 10.17% and elongation are 32.40%, 32.13%, 32.40% against 46.30% corroded. Overall results indicated that coated steel bar showed higher values increased in failure load and tensile strength while corroded decreased in elongation and midspan deflection.

Charles et al. [10] investigated the effect on flexural residual yield strength capacity of three different resins/exudates extract of trees of dacryodes edulis, moringa oleifera lam, mangifera indica paste coated reinforcement on the concrete beam. Uncoated and coated reinforcing steel bar with thicknesses 150µm, 250µm and 350µm were embedded into concrete beam and exposed to corrosive laboratory medium of sodium chloride for 60 days after 28 days initial curing to examine its effect on uncoated and coated on reinforcement. Results showed corrosion potential on uncoated members. Flexural strength failure loads of coated members with dacryodes edulis, moringa oleifera lam, mangifera indica are 35.78%, 27.09%, 29.42% against 22.30% decreased in corroded, midspan deflection are 18.57%, 28.30%, 27.43% against 39.30% increased in corroded, elongation are 28.75%, 31.50%, 31.60 against 46.30% increased in corroded and tensile strength are 14.18%, 12.29%, 12.08% as against 10.17% decreased in corroded respectively. Entire results showed that low load subjection is recorded in coated members at failure loads as against in corroded with high deflection and elongation. This high yield was attributed to corrosion attack.

Charles et al. [11] examined the effect/impact of corrosion inhibitors on flexural strength of failure load, midspan deflection, tensile strength and elongation of steel reinforcement layered with resins/exudates of magnifera indica extracts as corrosion inhibitors. Steel reinforcement were coated with 150µm, 250µm and 350µm of magnifera indica resins/ exudates paste, embedded in concrete beam members and exposed to harsh and saline environment (Sodium Chloride) Nacl. Corrosion acceleration process was initiated for 90 day to determine corrosion possibility. Results obtained showed corrosion potential on uncoated concrete beam members. More results recorded on experimental work showed flexural strength failure load, midspan deflection, tensile strength and elongation as 29.09%,31.20%, 11.75% and 31.50% for non-corroded, 29.42%, 27.43%, 12.09% and 31.60% for coated concrete beam respectively. For corroded concrete beam members, failure load decreased to 22.505, midspan deflection increased by 39.30%, tensile strength decreased to 10.17% while elongation increased by 46.30%. Entire results showed the effect of corrosion on the flexural strength of reinforcement that led to low load on failure load and higher midspan deflection on corroded beams and load on failure load and low midspan deflection on non-corroded and coated concrete beam members resulting to attack on surface condition of reinforcement from corrosion.

Charles et al. [12] Investigative study was carried out to ascertaine the utilization of natural inorganic extracts of tree resin/exudates to assess the yield strength capacity of reinforced concrete beam members under corrosion accelerated medium. Experimental work were performed on non-corroded, uncoated and acardiun occidentale l. resins/exudates pasted of thickness ranges of 150μm, 250μm and 350μm were directly coated on steel bar, embedded into concrete and performed corrosion acceleration process performed on both uncoated and coated reinforced concrete members. Results obtained showed presence of corrosion on uncoated concrete beam members with the presence of pitting and cracks. Non – corroded and coated members in comparison with corroded recorded increasing values on flexural strength failure load by 23.8% and 29.59% against 22.30% of corroded, tensile strength non – corroded and coated increased by 12.03% , 12.14% over 10.17 % of corroded while decreasing values on midspan deflection of 28.30% and 22.30%, elongation 31.5% and 32.46% recorded on non-corroded and coated concrete beam members as against 39.30% and 46.30% of corroded respectively. Overall results indicated lower failure loads on corroded and tensile strength on corroded members, higher load on midspan and elongation, resulted from an attack and degradation on the yield strength capacity due to corrosion potentials.

Charles et al. [13] investigated the effects of corrosion on the residual structural steel bar capacity of resins/exudates inhibited and non-inhibited reinforced concrete beam members. Results obtained showed corrosion potential presence on uncoated members with cracks and spalling. Further recorded results on non-corroded flexural strength test of failure load 29.09%, midspan deflection 28.30%, tensile strength 12.03% and elongation 31.50%, for coated beam members, failure load 29.42%, midspan deflection 27.42%, tensile strength 12.09% and elongation 31.80%, for corroded beam members, failure load decreased by 22.50%, midspan deflection increased by 39.30%, tensile strength decreased to 10.17% and elongation by increased 46.30%. The entire experimental results showed that corroded specimens has lower flexural load, higher midspan deflection, lower tensile strength and higher elongation due to loss of steel bar fibre from degradation effect from corrosion, inhibitors served as protective coating against corrosion, but no strength was added to steel members.

Otunyo and Kennedy [14] investigated the effect of corrosion on the flexural strength and mid-span deflection of steel reinforcements coated with resins / exudates of trees extract known as inorganic inhibitors (dacryodes edulis-African Pear). The steel reinforcement members were embedded in concrete and exposed to harsh and saline environments (NaCl solution). Corrosion accelerated test were conducted on uncoated and dacryodes edulis resin pastes coated thicknesses of 150μm, 250μm and 300μm on steel reinforcement before corrosion test for 60 days to simulated corrosion process. Results obtained indicated that the flexural failure strength, and elongation increased by (29%) and (48%) respectively for the dacryodes edulis coated steel members, the mid-span deflection decreased by 26%, elongation increased by 23% and 32% respectively, while the mid-span deflection decreased by 40%.. The resin (dacryodes edulis) added strength to the reinforcement.

Charles et al. [15] experimented on the effects of corrosion and inhibitors (Inorganic origin) extracts known as resins/exudates from trees barks on the residual flexural strength of concrete beam members immersed in corrosion accelerated medium for 90 days to ascertain possible changes on surface conditions of investigated samples. Results from this experimental test recorded corrosion potential with visible signs of cracks, color change and spalling. Further results obtained of corroded concrete beam members were 22,50%, 39.30%, 10.19% and 46.30 of failure load, midspan deflection, ultimate tensile strength and elongation, for non- 29.09%, 28.30%, 12.03% and 31.50%, for coated beam members , 28.5%, 25.30%, 12.13% and 32.12% respectively. These results indicated increased in flexural failure load and ultimate tensile strength and decreased in midspan deflection and elongation respectively in corroded concrete beam members. This showed lower load and higher deflection in corroded members and higher in non-corroded and coated, higher elongation in corroded and lower in non-corroded and coated.

Charles et al. [16] performed and investigated on uncoated and corrosion inhibitors (Symphonia globulifera linn) resins / exudates paste coated steel reinforcing bar. This was to determine the coating effects of corrosion on flexural load and midspan deflection on structural capacity of reinforced concrete beam members under harsh saline marine. Results obtained on comparison between uncoated (corroded) and coated are flexural failure load 22.50% to 29.50%, midspan deflection 39.30% to 31.14%, tensile strength 10.17% to 11.84% and elongation 46.30% to 32.40% respectively. Thus, results showed decreased in failure load and tensile strength of corroded members while increased in midspan deflection and elongation. This attributes was due to effect of corrosion and reduction in strength from degradation properties. Resins / exudates coated members showed higher failure load with low deflection.

2. MATERIALS AND METHODS

2.1 Aggregates

The fine aggregate and coarse aggregate were purchased. Both met the requirements of BS 882 [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 BS EN 196-6 [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, and Rivers State. The water met the requirements of 12390-5 [179.

2.1.4 Structural Steel Reinforcement

The reinforcements are gotten directly from the market in Port Harcourt of BS 4449:2005+A3 [120].

2.1.5 Corrosion Inhibitors (Resins / Exudates) Garcinia kola

The study inhibitor (Garcinia kola Exudates) of natural tree resins/exudates extracts.

2.2 Methods

Present study involves direct application of resins / exudates of trees extract known as inorganic inhibitor Garcinia kola Exudates, layered/coated on reinforcement steel ribbed surface. The objective of this study was to determine the usefulness of locally available surface-applied corrosion inhibitors under severe corrosive environments and with chloride contamination. The test setup simulates a harsh marine environment of saline concentration.

The samples of reinforced concrete beams of 150 mm x 150 mm × 650 mm, thickness, width and length specimens and ribbed bars of 16 mm embedded for corrosion test and flexural test for beam was investigated. This was aimed at achieving the real harsh and corrosive state, concrete specimens were ponded in solutions (NaCl) and the depth of the solution was maintained for the given period of experiment as to observe the significant changes that resulted from the actions of the accelerator (NaCl) and the specimens. The determination of the contribution of the resins will be observed through its adhesive ability with the reinforcement through surface coating application and the bonding relationship between the coated specimens and concrete, its waterproofing and resistive nature (resistance) against accelerator penetration into the bare reinforcement.

2.2.1 Specimen Preparation and Casting of Concrete Beams

Standard method of concrete mix ratio was adopted, batching by weighing materials manually. Concrete mix ratio of 1:2:4 by weight of concrete, water-cement ratio of 0.65. Manual mixing was used on a clean concrete banker, and mixture was monitored and water added gradually to obtain perfect mix design concrete. Standard uniform color and consistency concrete was obtained by additions of cement, water and aggregates. The test beams were cast in steel mould of 150mm x 150 mm x 750 mm. Fresh concrete mix for each batch was fully compacted by tamping rods, to remove trapped air, which can reduce the strength of the concrete and 16 mm reinforcements of coated and non-coated were spaced at 150 mm with concrete cover of 25 mm had been embedded inside the beam and projection of 100 mm for half-cell potential measurement. Specimens were molds are removed from specimen after 24hrs and cured for 28 days. The specimens were cured at room temperature in the curing tanks for accelerated corrosion test process and testing procedure allowed for 120 days first crack noticed and a further 30 days making a total of 150 days for further observations on corrosion acceleration process.

2.2.2 Flexure testing of Beam Specimens

Universal Testing Machine in accordance with [18] was used for the flexural test and a total of 27 beam specimens were tested. After curing for 28 days, 6 controlled beams (non-corroded) was kept in a control state, preventing corrosion of reinforcement, while 18 beam samples of non-coated and exudates /resins coated were partially place in ponding tank for 150 days and examined accelerated corrosion process. After 150 days, the accelerated corrosion subjected samples were examined to determine residual flexural strength. Beam specimens were simply supported on a span of 650mm. An

Instron Universal Testing Machine of 100KN capacity at a slow loading rate of 1 mm/min was used in the flexural test. Beam samples were placed in the machine to specification, flexural test were conducted on a third point at two supports. Load was applied to failure with cracks noticed and corresponding values recorded digitally in a computerized system.

2.2.3 Tensile Strength of Reinforcing Bars

To ascertain the yield and tensile strength of tension bars, bar specimens of 16 mm diameter of non-corroded, corroded and coated were tested in tension in a Universal Testing Machine and subjected to direct tension until failure; the yield, maximum and failure loads being recorded. To ensure consistency, the remaining cut pieces from the standard length of corroded and non-corroded steel bars were subsequently used in the bond and flexural test.

3. RESULTS AND DISCUSSIONS

Results of 27 samples in table 3.1, 3.2 and 3.3 are derived into average values in 3.4 and summarized into summary of averages, percentile values and percentile values difference in 3.5of flexural strength of concrete beam members as sampled, arbitrarily cast, cured for 28 days on normal and standard method, accelerated in corrosion medium environment for 120days at first crack s observation and 30days extended period and graphically represented in figures 3.1 - 3.3A.

3.1 Non-corroded Concrete Beam Members

Flexural failure load average values of non-corroded samples are 81.87kN, 81.756kN and 82.226kN derived into 81.951111kN with percentile of 40.85115% against-29.0031% corroded specimens. Midspan deflection obtained average values are 7.3733mm, 7.6166mm, 7.076mm, derived into 7.3555556mm with and percentile value of -36.4134% against 57.26586% corroded specimens. Average yield strength, fy 460MPa, derived into 100% with 0.00% of percentile value. Average ultimate tensile strength is 628.243MPa, 627.977MPa, and 627.676MPa, derived into 627.96556MPa, percentile value of 11.2023% against -10.0738% corroded specimens. Average strain ratios are 1.321, 1.325, and 1.315, derived into 1.3205556 with percentile value of 12.25184% against -10.9146%. Average elongations are 27.205%, 26.928%, 27.328%, derived into 27.153889% with percentile value of 70.42903% against -41.3245%. Results from non-corroded (Controlled) members have high values of flexural failure load, low midspan deflection and yield strength, strain ratio and elongation over all corroded members.

3.2 Corroded Concrete Beam members

Obtained flexural failure load values at averages of corroded samples are 58.858kN, 57.805kN, 57.885kN, derived into 58.18278kN and percentile value of -29.0031% against 40.85115% and 39.32435% non-corroded and Garcinia kola exudates coated specimens. Midspan deflection average values are 11.783mm, 11.483mm, 11.436mm, derived into 11.56778mm and percentile value of 57.26586% against -36.4134% and -34.915% non-corroded and coated specimens. Average yield strength, 460MPa, derived into 100% with 0.00% of percentile value. Average ultimate tensile strength are 565.683MPa, 564.15MPa, 564.283MPa, derived into 564.7056MPa and percentile value of -10.0738% against 11.2023% and 11.58322% of non-corroded and coated specimens. Average strain ratios are 1.177, 1.1842, and 1.167, derived into 1.176422 and percentile value of -10.9146% against 12.25184% and 15.75587% of non-corroded and coated specimens. Average elongations are 16.019%, 15.799%,15.979%, derived into 15.93267% and percentile value of -41.3245% against 70.42903% and 74.90969% for non-corroded and coated specimens. Collated results of corroded members showed high yield strength with low applied load, high midspan deflection and elongation. Low flexural failure load with high yield. Indications showed that the attributes possessed by corroded members resulted from corrosion attacked on the surface properties of reinforcing steel and reduction in general mechanical properties of steel.

3.3 Garcinia kola Resins/Exudates Steel Coated Concrete Beam Members.

Computed flexural failure load average values of corroded samples are 81.001kN, 81.108kN, 81.078kN, derived into 81.06278kN and percentile value of 39.32435% against -29.0031% corroded specimens. Midspan deflection average values are 7.496mm, 7.553mm, 7.536mm, derived into 7.528889mm and percentile value of -34.915% against 57.26586% corroded specimens. Average yield strength, 460MPa, derived into 100% with 0.00% of percentile value. Average ultimate tensile strength, fu, 630.116MPa, 630.15MPa, 630.083MPa, derived into 630.1167MPa, percentile value of 11.58322% against -10.0738% corroded specimens. Average strain ratios are 1.370, 1.354, and 1.360, derived into 1.361778 and percentile value of 15.75587% against -10.9146% of corroded specimens. Average elongations are 27.85%, 27.906%, 27.846%, derived into 15.93267% and percentile value of 74.90969% against -41.3245% of corroded specimens. Collated results from exudates / resins coated members exhibited low flexural failure load over corroded members with high, low midspan deflection over high in corroded, little elongation over high in corroded. Indications showed that coated members possessed resistance characteristics to corrosion penetration.

Table 3.1: Flexural Strength of Beam Specimens (Non-Corroded specimens)

s/no		Non-corroded Control Beam								
Beam	Samples	BA	BB	CC	BD	BE	BF	BG	BH	BI
BB1-1	Failure Load (KN)	81.93	81.93	81.75	81.72	81.72	81.83	82.53	81.5	82.65
BB1-2	Midspan Deflection (mm)	7.12	7.2	7.8	7.91	7	7.94	7.03	7.2	7
BB1-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
BB1-4	Yield Strength, fy (MPa)	460	460	460	460	460	460	460	460	460
BB1-5	Ultimate Tensile Strength, fu (MPa)	627.41	629.31	628.01	626.81	629.31	627.81	627.61	628.41	627.01
BB1-6	Strain Ratio	1.345	1.305	1.315	1.345	1.315	1.315	1.315	1.305	1.325
BB1-7	Elongation (%)	27.105	27.305	27.205	27.275	26.705	26.805	27.305	27.275	27.405

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

s/no		Non-corroded Control Beam								
Beam	Samples	BA	BB	CC	BD	BE	BF	BG	BH	BI
BB2-1	Failure load (KN)	59.215	59.895	57.465	56.945	59.235	57.235	57.005	59.435	57.215
BB2-2	Midspan Deflection (mm)	12.02	11.85	11.48	11.45	11.05	11.95	11.48	11.08	11.75
BB2-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
BB2-4	Yield Strength, fy (MPa)	460	460	460	460	460	460	460	460	460
BB2-5	Ultimate Tensile Strength, fu (MPa)	567.75	564.35	564.95	564.25	563.95	564.25	563.65	564.95	564.25
BB2-6	Strain Ratio	1.1842	1.1742	1.1742	1.2142	1.1642	1.1742	1.1742	1.1642	1.1642
BB2-7	Elongation(%)	16.036	16.176	15.846	15.376	16.366	15.656	16.176	15.876	15.886

Table 3.3: Flexural Strength of Beam Specimens (Exudates/Resins Coated specimens)

		Garcinia kola Exudate (steel bar coated specimen)								
s/no		150µm (Exudate/Resin) coated			300µm (Exudate/Resin) coated			450µm (Exudate/Resin) coated		
Beam	Samples	BA	BB	CC	BD	BE	BF	BG	BH	BI
BB3-1	Failure load (KN)	80.585	81.535	80.885	80.925	81.285	81.115	80.885	80.925	81.425
BB3-2	Midspan Deflection (mm)	7.6	7	7.89	7.7	7.26	7.7	7.68	7.68	7.25
BB3-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
BB3-4	Yield Strength, fy (MPa)	460	460	460	460	460	460	460	460	460
BBE-	Ultimate	629.65	630.55	630.15	630.15	630.15	630.15	629.75	630.25	630.25

5	Tensile Strength, fu (MPa)									
BB3-6	Strain Ratio	1.364	1.384	1.364	1.354	1.354	1.354	1.344	1.364	1.374
BB3-7	Elongation(%)	27.61	28.23	27.71	27.68	28.13	27.91	27.82	27.53	28.19

Table 3.4: Average Flexural Strength of Beam Specimens (Non-Corroded, Corroded Exudates/Resins Coated Specimens)

s/no	Samples	**Non-Corroded Specimens Average Values**			**Corroded Specimens Average Values**			**Coated Specimens Average Values**		
BB4-1	Failure load (KN)	81.87	81.756	82.226	58.858	57.805	57.885	81.001	81.108	81.078
BB4-2	Midspan Deflection (mm)	7.3733	7.6166	7.076	11.783	11.483	11.436	7.496	7.553	7.536
BB4-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
BB4-4	Yield Strength, fy (MPa)	460	460	460	460	460	460	460	460	460
BB4-5	Utimate Tensile Strength, fu (MPa)	628.243	627.977	627.676	565.683	564.15	564.283	630.116	630.15	630.083
BB4-6	Strain Ratio	1.321	1.325	1.315	1.177	1.1842	1.167	1.370	1.354	1.360
BB4-7	Elongation(%)	27.205	26.928	27.328	16.019	15.799	15.979	27.85	27.906	27.846

Table 3.5: Summary of Percentile Flexural Strength of Beam Specimens (Non-Corroded, Corroded, Exudates/Resins Coated Specimens)

Beam	Samples	**Summary of Averages for non-Corroded, Corroded and Coated Specimens**			**Percentile Averages Values for non-Corroded, Corroded and Coated Specimens**			**Percentile Values Difference Values for non-Corroded, Corroded and Coated Specimens**		
BB3-1	Failure load (KN)	81.951111	58.18278	81.06278	140.8511	70.99694	139.3244	40.85115	-29.0031	39.32435
BB3-2	Midspan Deflection (mm)	7.3555556	11.56778	7.528889	63.58659	157.2659	65.08501	-36.4134	57.26586	-34.915
BB3-3	Bar diameter (mm)	16	16	16	100	100	100	0	0	0
BB3-4	Yield Strength, fy (MPa)	460	460	460	100	100	100	0	0	0
BBE-5	Ultimate Tensile Strength, fu (MPa)	627.96556	564.7056	630.1167	111.2023	89.9262	111.5832	11.2023	-10.0738	11.58322
BB3-6	Strain Ratio	1.3205556	1.176422	1.361778	112.2518	89.0854	115.7559	12.25184	-10.9146	15.75587
BB3-7	Elongation (%)	27.153889	15.93267	27.86778	170.429	58.67545	174.9097	70.42903	-41.3245	74.90969

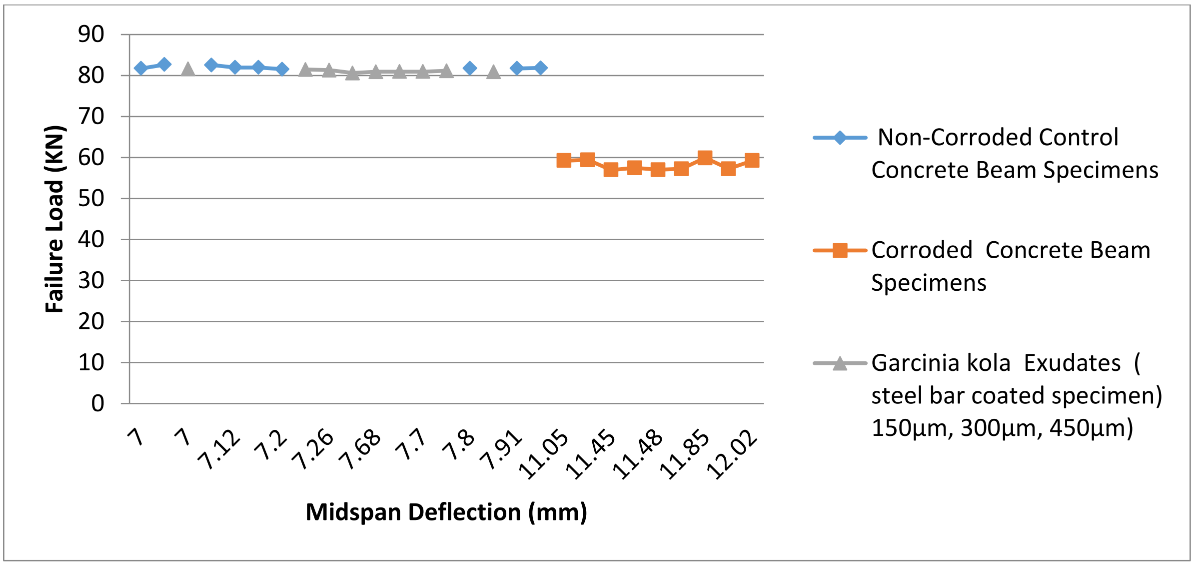

Figure 3.1: Failure Load versus Midspan Deflection of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

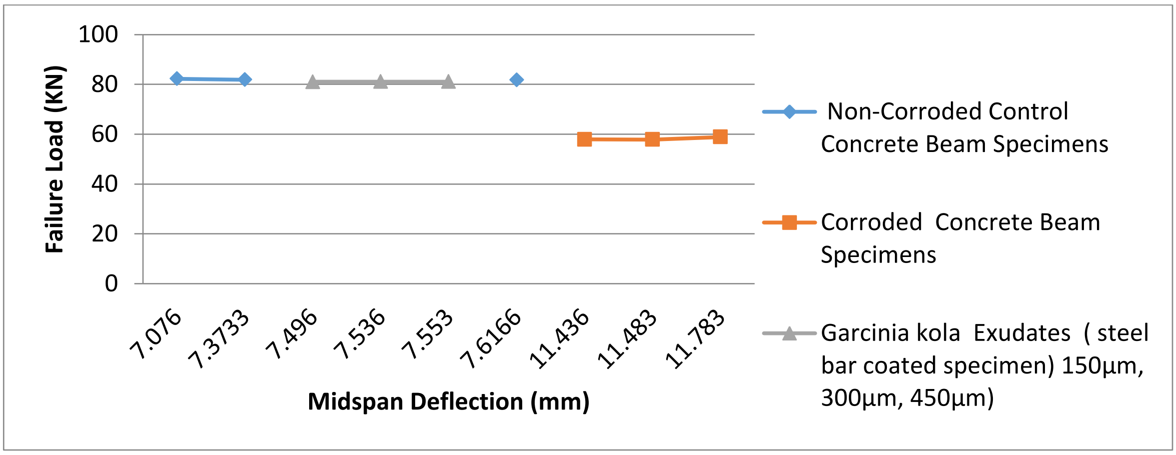

Figure 3.1A: Average Failure Load versus Midspan Deflection of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

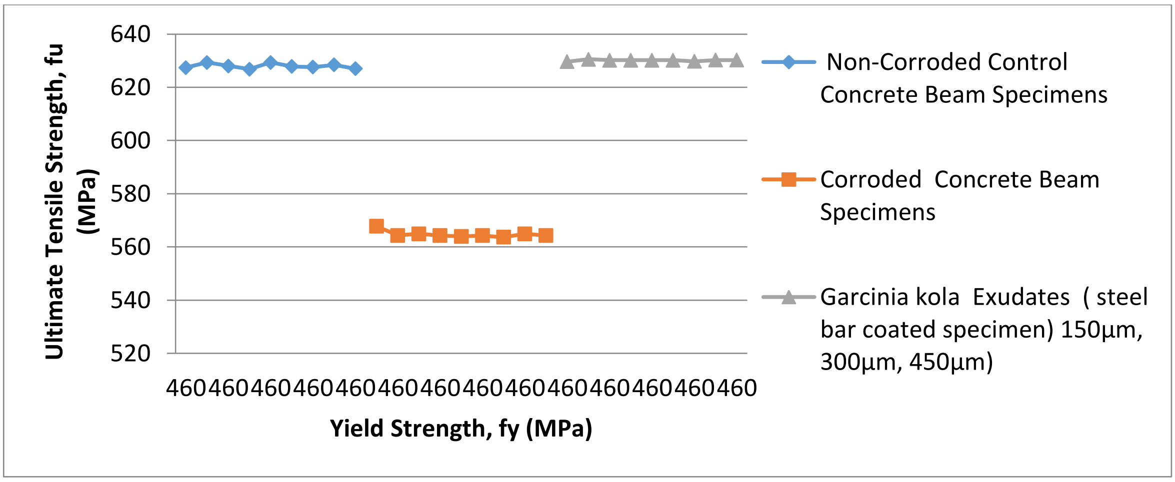

Figure 3.2: Ultimate Tensile Strength versus Yield Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

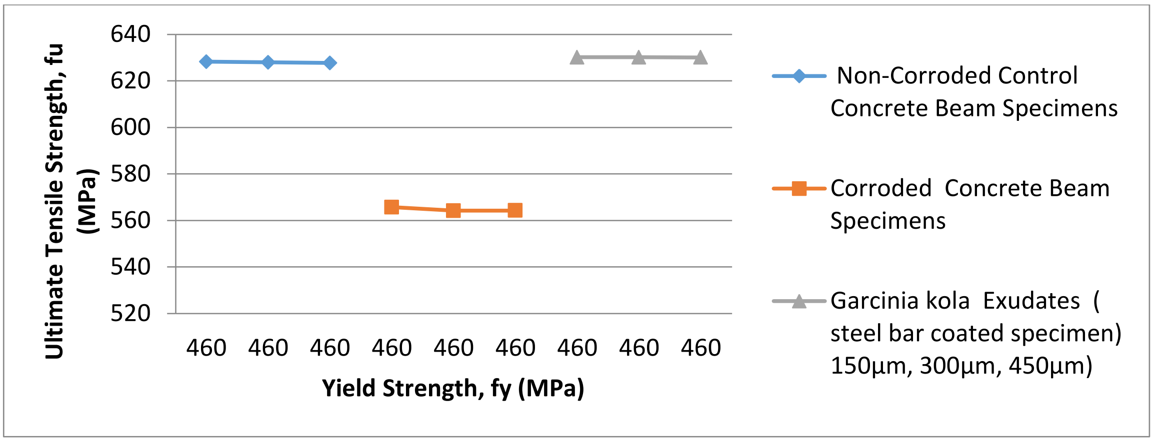

Figure 3.2A: Average Ultimate Tensile Strength versus Yield Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

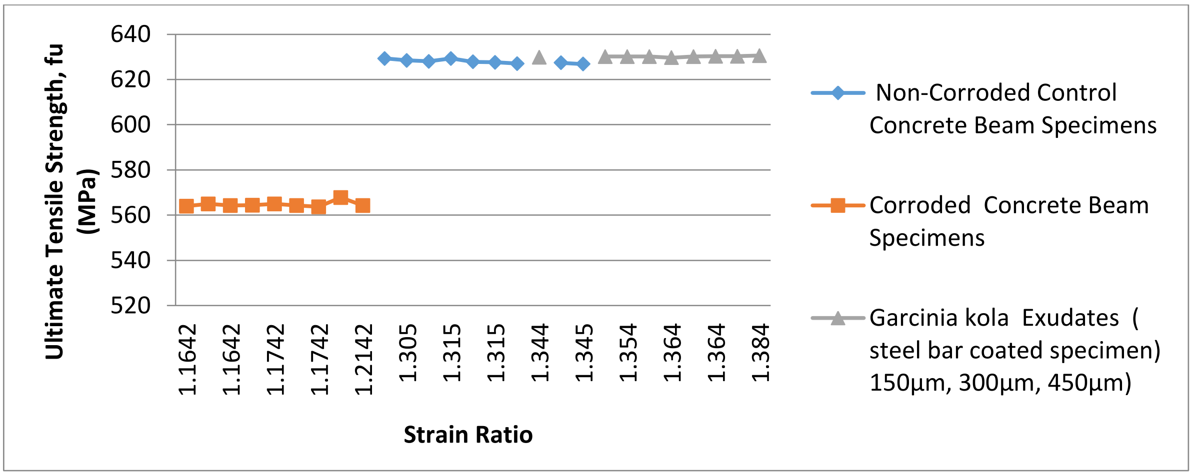

Figure 3.3: Ultimate Tensile Strength versus Strain Ratio of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

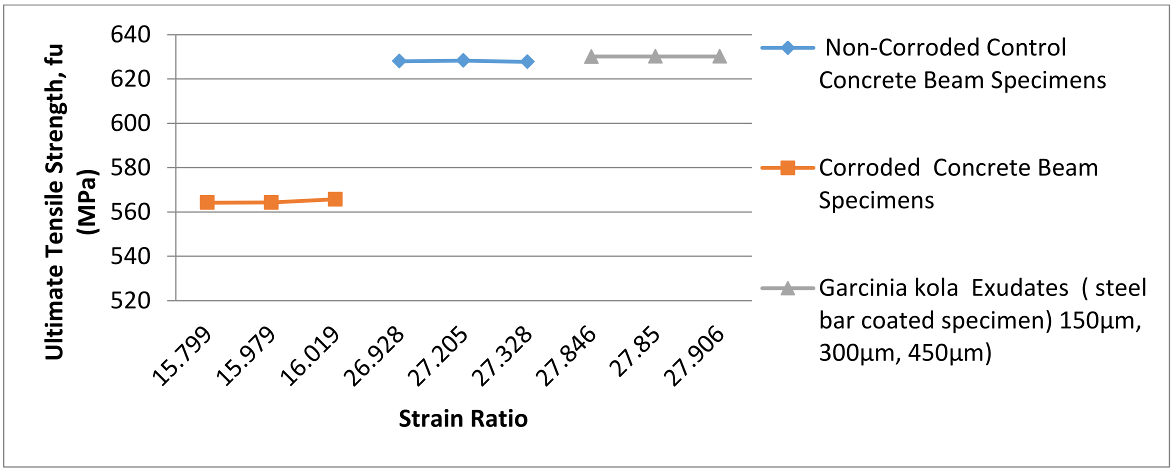

Figure 3.3A: Average Ultimate Tensile Strength versus Strain Ratio of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

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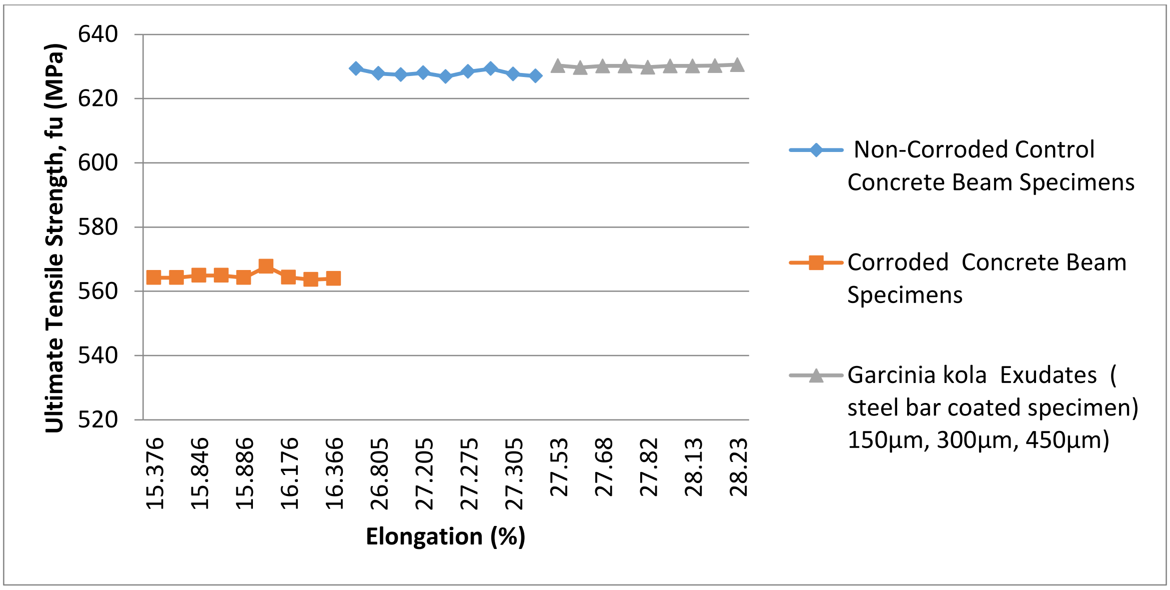

Figure 3.4: Ultimate Tensile Strength versus Elongation of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

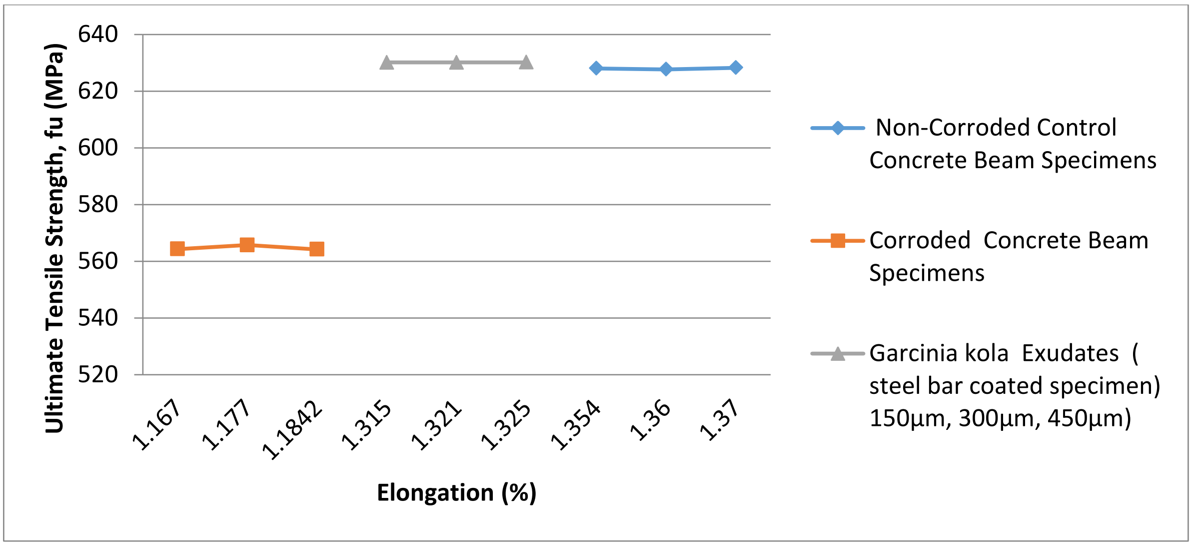

Figure 3.4A: Average Ultimate Tensile Strength versus Elongation of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

4. CONCLUSIONS

Experimental results gotten from tables 3.1 – 3.5 and figures 3.1 – 3.3A, the below conclusions were drawn:

i. Collated results of corroded members showed high yield strength with low applied load, high midspan deflection and elongation.

ii. Low flexural failure load with high yield. Indications showed that the attributes possessed by corroded members resulted from corrosion attacked on the surface properties of reinforcing steel and reduction in general mechanical properties of steel.

iii. Collated results from exudates / resins coated members exhibited low flexural failure load over corroded members with high, low midspan deflection over high in corroded, little elongation over high in corroded. Indications showed that coated members possessed resistance characteristics to corrosion penetration.

iv. Results from non-corroded (Controlled) members have high values of flexural failure load, low midspan deflection and yield strength, strain ratio and elongation over all corroded members.

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