International Journal of
Science and Engineering Investigations
vol. 8, issue 92, September 2019
Received on September 21, 2019
ISSN: 2251-8843

Flexural Residual Capacity and Ultimate Yield Strength of Corroded and Inhibitive Reinforced Concrete Beams in Corrosive Environment

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Abstract**-**Corrosion of reinforcing steel in concrete structure assumes many forms and their product results occur when there is chemical reaction between metal and its environment. This research work evaluated the efficiency of olibanum exudates / resins application on reinforcing steel embedded in concrete, immersed in corrosive environment and accelerated for corrosion possibility. Embedded concrete members of non-coated and coated members were monitored to first crack appearance and spalling which are the manifestation stages. Collated averaged obtained results of flexural failure load of corroded member has computed percentile ratio of -22.095% over 28.36144% and 27.25182% against non-corroded and olibanum exudates coated specimens. Midspan deflection average with percentile ratio of 30.17451% against -23.18% and -19.682% non-corroded and coated specimens. Average ultimate tensile strength, with percentile ratio of -11.8236% against 13.40903% and 13.36199% of non-corroded and coated specimens. Average strain ratios with computed percentile ratio of -17.6693% against 21.46142% and 20.74604% of non-corroded and coated specimens. Averaged elongations are 15.94333%, 15.72333%, 15.90333%, summarized to 15.85667% with computed percentile ratio of -22.3431% against 28.77163% and 29.77367% for non-corroded and coated specimens. Corroded members showed little flexural failure loads over non-corroded and coated specimens, midspan deflection rates are higher to non-corroded and coated specimens, ultimate tensile strength of corroded members yield higher with little load to non-corrode and coated specimens. Effect of corrosion on mechanical properties of reinforcing steel resulted to poor state performance of corroded members. Coated members have low; flexural failure load, midspan deflection, strain ratio and ultimate tensile strength over corroded members. Non-corroded members possessed standard mechanical properties of reinforcing steel over corroded members.

Keywords- *Corrosion, Corrosion Inhibitors, Flexural Strength, Concrete and Steel Reinforcement*

I. INTRODUCTION

Corrosion rate of steel reinforcement in concrete is strongly affected by a number of environmental parameters including the presence of oxygen and moisture, concrete permeability and concrete cover, pH of the pore solution and gradients in chloride levels. High compressive strength concrete (low water/cement ratio) allowed permeability which minimizes corrosion of steel by reducing penetration of such corrosion inducing ingredients as CO_2, chlorides and moisture. Principal factors such as concrete pH, chloride ions, oxygen and water needed to be considered in the controlled of corrosion inhibition of reinforcement. Methods adopted to control these factors are the use of epoxy coatings, inhibitors, buffers, electrochemical protection procedures and scavengers. It has been found ([1], [2]) that concrete samples with high water/cement ratios have a higher diffusion rate than samples with lower water/cement ratios. This has been attributed to the higher volume of macrospores and unsegmented capillary pores present in concrete with high water/cement ratios. Low water/cement ratio can resist chlorides penetration into reinforcing steel, also provides a barrier against the entry of oxygen and therefore, provides better concrete corrosion resistance ([3], [4]), [5], [6]). Blend agents (slag, pozzolans and fillers) can influence the permeability and therefore the rate of penetration of chloride ions ([7], [8]). Blending cement with blast furnace slag has been found to reduce the diffusion rate of chloride ions [9]. Also it was reported by ([10], [11]) that the uses of silica fume in concrete reduce concrete permeability, improve durability and lower the penetration rate of chloride.

[12] 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. 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% increase in corroded, elongation are 28.75%, 31.50%, 31.60 against 46.30% increase 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.

[13] 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. 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 hiher 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.

[14] Investigative study was carried out to ascertain 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. 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.

[15] 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.

[16] 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). 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.

[17] 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 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.

[18] Performed and investigated on uncoated and corrosion inhibitors (Symphonia globulifera linn) resins / exudates paste coated steel reforcing bar. Results obtained confirmed corrosion potential with the presence of stress within the steel and concrete surrounding, spalling and cracking. Further 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.

II. MATERIALS AND METHODS

A. *Matterials*

1) *Aggregates*

The fine aggregate and coarse aggregate were purchased. Both met the requirements of [18]

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 [19]

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 [20]

4) *Structural Steel Reinforcement*

The reinforcements are gotten directly from the market in Port Harcourt [21]

5) *Corrosion Inhibitors (Resins / Exudates) Olibanum*

The study inhibitor (olibanum exudates) of natural tree resins/exudates extracts.

B. Methods

Present study involves direct application of resins / exudates of trees extract known as inorganic inhibitor olibanum 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 × 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.

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) *Flexure testing of Beam Specimens*

Universal Testing Machine in accordance with BS EN 12390-2 was used for the flexural test and a total of 27beam specimens were tested. After curing for 28 days, 6 controlled beam (non-corroded) was kept in a control state, preventing corrosion reinforcement of the, while 18 beam samples of non-coated and resins / exudates coated were partially place in ponding tank for 150 days placed to examine 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.

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 were subjected to direct tension until failure; the yield, maximum and failure loads being recorded. To ensure consistency, the remaining cut pieces from the standard length of corroded and non-corroded steel bars were subsequently used in the bond and flexural test.

III. RESULTS AND DISCUSSIONS

Results of 27 samples in table 1, 2 and 3 are derived into averaged values in table 4 and summarized into summary of averages, percentile values and percentile values difference in table 5 of 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 120 days at first crack s observation and 30 days extended period and graphically represented in figures 1-6.

A. Non-corroded Concrete Beam Members

Collated averaged obtained flexural failure load values of non-corroded samples from table 1 into 4 and 5 are 74.34kN, 74.22667kN, 74.69667kN, summarized to 74.42111kN with computed percentile ratio of 28.36144% over -22.095% corroded specimens. Midspan deflection average values are 5.493333mm, 5.736667mm, 5.196667mm, summarized to 5.475556mm with and percentile difference of -23.18% over 30.17451% corroded specimens. Average yield strength, fy 460MPa, summarized to 100% with 0.00% of percentile value and difference, Average ultimate tensile strength, fu, 624.4533MPa, 624.1867MPa, and 623.8867MPa, summarized to 624.1756MPa, percentile difference of 13.409033% over -11.8236% corroded specimens. Average strain ratios are 1.321667, 1.325, and 1.315, summarized to 1.320556 with computed percentile ratio of 21.46142% over -17.6693%. Averaged elongations are 20.47%, 20.19333%, 20.59333%, summarized to 20.41889% with computed percentile ratio of

28.77163% over -22.3431%. Non-corroded members possessed standard mechanical properties of reinforcing steel over corroded members.

B. Corroded Concrete Beam members

Collated averaged obtained flexural failure load values of corroded samples from table 2 into 4 and 5 are 58.65333KN, 57.603kN, 57.68kN, summarized to 57.97778kN with computed percentile ratio of -22.095% over 28.36144% and 27.25182% against non-corroded and olibanum exudates coated specimens. Midspan deflection average values are 7.343333mm, 7.043333mm, 6.996667mm, summarized to 7.127778mm with and percentile difference of 30.17451% against -23.18% and -19.682% non-corroded and coated specimens. Average yield strength, fy 460MPa, summarized to 100% with 0.00% of percentile value and difference. Average ultimate tensile strength, fu, 551.3533MPa, 549.82MPa, 549.9533MPa, summarized to 550.3756MPa, percentile difference of -11.8236% against 13.40903% and 13.36199% of non-corroded and coated specimens. Average strain ratios are 1.088333, 1.095, and 1.078333, summarized to 1.087222 with computed percentile ratio of -17.6693% against 21.46142% and 20.74604% of non-corroded and coated specimens. Averaged elongations are 15.94333%, 15.72333%, 15.90333%, summarized to 15.85667% with computed percentile ratio of -22.3431% against 28.77163% and 29.77367% for non-corroded and coated specimens. Corroded members showed little flexural failure loads over non-corroded and coated specimens, midspan deflection rates are higher to non-corroded and coated specimens, ultimate tensile strength of corroded members yield higher with little load to non-corrode and coated specimens**.** Effect of corrosion on mechanical properties of reinforcing steel resulted to poor state performance of corroded members.

C. Olibanum Resins/Exudates Steel Coated Concrete Beam Members

Collated averaged obtained flexural failure load values of non-corroded samples from table 3 into 4 and 5 are 73.71667kN, 73.82333kN, 73.79333kN, summarized to 78.88178kN with percentile ratio of 47.14752% over -33.1172% over corroded specimens. Midspan deflection average values are 5.692667mm, 5.749333mm, 5.732667mm, summarized to 6.623889mm with and percentile ratio of -52.6715% over 88.73239% corroded specimens. Averaged yield strength, fy 460MPa, summarized to 100% with 0.00% of percentile ratio. Averaged ultimate tensile strength, fu623.9167MPa, 623.95MPa, 623.8833MPa, summarized to 628.9167MPa, percentile ratio of 15.33289% over -13.5952% corroded specimens. Averaged strain ratios are 1.321667, 1.305, and 1.311667, summarized to 1.317678 with computed percentile ratio of 21.19673% over -16.4032% of corroded specimens. Averaged d elongations are 20.56%, 20.61667%, 20.55667%, summarized to 28.43868% with computed percentile ratio of 139.8539% over -59.4698% of corroded specimens. Coated members have low; flexural failure load, midspan deflection, strain ratio and ultimate tensile strength over corroded members.

TABLE I. FLEXURAL STRENGTH OF BEAM SPECIMENS (NON-CORRODED SPECIMENS)

s/no		Non-Corroded Control Beam								
Beam	Samples	KKA	KKB	KKC	KKD	KKE	KKF	KKG	KKH	KKI
BKB1-1	Failure Load (KN)	74.4	74.4	74.22	74.19	74.19	74.3	75	73.97	75.12
BKB1-2	Midspan Deflection (mm)	5.24	5.32	5.92	6.03	5.12	6.06	5.15	5.32	5.12
BKB1-3	Bar Diameter (mm)	16	16	16	16	16	16	16	16	16
BKB1-4	Yield Strength, fy (MPa)	410	410	410	410	410	410	410	410	410
BKB1-5	Ultimate Tensile Strength, fu (MPa)	623.62	625.52	624.22	623.02	625.52	624.02	623.82	624.62	623.22
BKB1-6	Strain Ratio	1.345	1.305	1.315	1.345	1.315	1.315	1.315	1.305	1.325
BKB1-7	Strain (%)	20.37	20.57	20.47	20.54	19.97	20.07	20.57	20.54	20.67

TABLE II. FLEXURAL STRENGTH OF BEAM SPECIMENS (CORRODED SPECIMENS)

s/no		Corroded Beam								
Beam	Samples	KKA	KKB	KKC	KKD	KKE	KKF	KKG	KKH	KKI
BKB2-1	Failure load (KN)	59.01	59.69	57.26	56.74	59.03	57.03	56.8	59.23	57.01
BKB2-2	Midspan Deflection (mm)	7.58	7.41	7.04	7.01	6.61	7.51	7.04	6.64	7.31
BKB2-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
BKB2-4	Yield Strength, fy (MPa)	410	410	410	410	410	410	410	410	410
BKB2-5	Ultimate Tensile Strength, fu (MPa)	553.42	550.02	550.62	549.92	549.62	549.92	549.32	550.62	549.92
BKB2-6	Strain Ratio	1.095	1.085	1.085	1.125	1.075	1.085	1.085	1.075	1.075
BKB2-7	Elongation (%)	15.96	16.1	15.77	15.3	16.29	15.58	16.1	15.8	15.81

TABLE III. FLEXURAL STRENGTH OF BEAM SPECIMENS (EXUDATES/RESINS COATED SPECIMENS)

Olibanum Exudate (steel bar coated specimen)										
		150µm Exudate Coated			300µm Exudate Coated			450µm Exudate Coated		
s/no	Samples	KKA	KKB	KKC	KKD	KKE	KKF	KKG	KKH	KKI
BKB3-1	Failure load (KN)	73.3	74.25	73.6	73.64	74	73.83	73.6	73.64	74.14
BKB3-2	Midspan Deflection (mm)	5.796	5.196	6.086	5.896	5.456	5.896	5.876	5.876	5.446
BKB3-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
BKB3-4	Yield Strength, fy (MPa)	410	410	410	410	410	410	410	410	410
BKB3-5	Ultimate Tensile Strength, fu (MPa)	623.45	624.35	623.95	623.95	623.95	623.95	623.55	624.05	624.05
BKB3-6	Strain Ratio	1.315	1.335	1.315	1.305	1.305	1.305	1.295	1.315	1.325
BKB3-7	Elongation (%)	20.32	20.94	20.42	20.39	20.84	20.62	20.53	20.24	20.9

TABLE IV. 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		
BKB4-1	Failure load (KN)	74.34	74.22667	74.69667	58.65333	57.603	57.68	73.71667	73.82333	73.79333
BKB4-2	Midspan Deflection (mm)	5.493333	5.736667	5.196667	7.343333	7.043333	6.996667	5.692667	5.749333	5.732667
BKB4-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
BKB4-4	Yield Strength, fy (MPa)	410	410	410	410	410	410	410	410	410
BKB4-5	Ultimate Tensile Strength, fu (MPa)	624.4533	624.1867	623.8867	551.3533	549.82	549.9533	623.9167	623.95	623.8833
BKB4-6	Strain Ratio	1.321667	1.325	1.315	1.088333	1.095	1.078333	1.321667	1.305	1.311667
BKB4-7	Elongation (%)	20.47	20.19333	20.59333	15.94333	15.72333	15.90333	20.56	20.61667	20.55667

TABLE V. SUMMARY OF PERCENTILE FLEXURAL STRENGTH OF BEAM SPECIMENS (NON-CORRODED, CORRODED, EXUDATES/RESINS COATED SPECIMENS

s/no	Samples	Summary of Averages			Percentile Values			Percentile Difference		
BKB4-1	Failure load (KN)	74.42111	57.97778	73.77778	128.3614	77.90502	127.2518	28.36144	-22.095	27.25182
BKB4-2	Midspan Deflection (mm)	5.475556	7.127778	5.724889	76.81995	130.1745	80.318	-23.18	30.17451	-19.682
BKB4-3	Bar diameter (mm)	16	16	16	100	100	100	0	0	0
BKB4-4	Yield Strength, fy (MPa)	410	410	410	100	100	100	0	0	0
BKB4-5	Ultimate Tensile Strength, fu (MPa)	624.1756	550.3756	623.9167	113.409	88.1764	113.362	13.40903	-11.8236	13.36199
BKB4-6	Strain Ratio	1.320556	1.087222	1.312778	121.4614	82.33067	120.746	21.46142	-17.6693	20.74604
BKB4-7	Elongation (%)	20.41889	15.85667	20.57778	128.7716	77.65685	129.7737	28.77163	-22.3431	29.77367

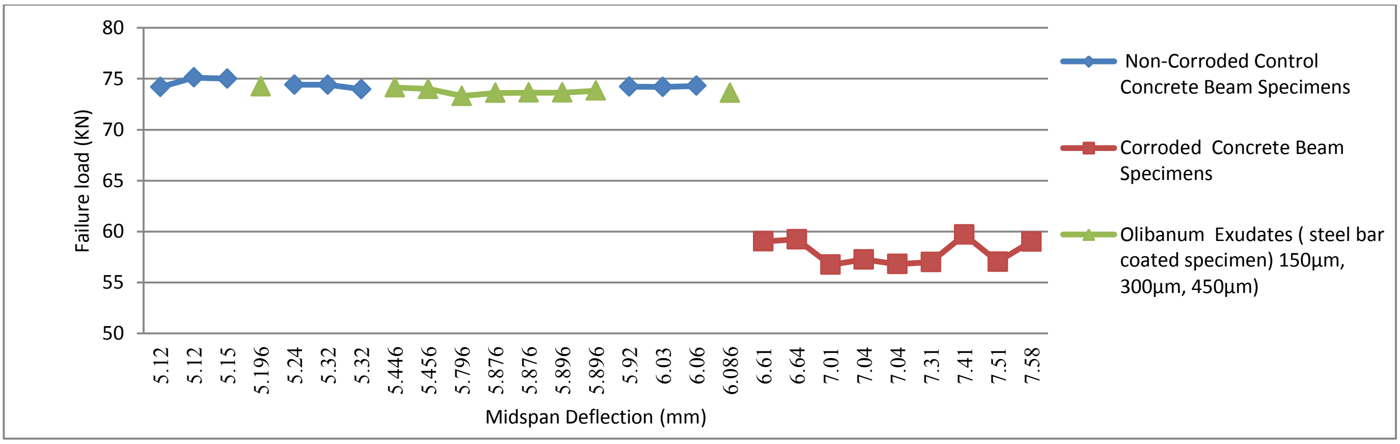

Figure 1. Failure Load versus Midspan Deflection of Beam Specimens (Non-Corroded, Corroded and Resin Coated Specimens)

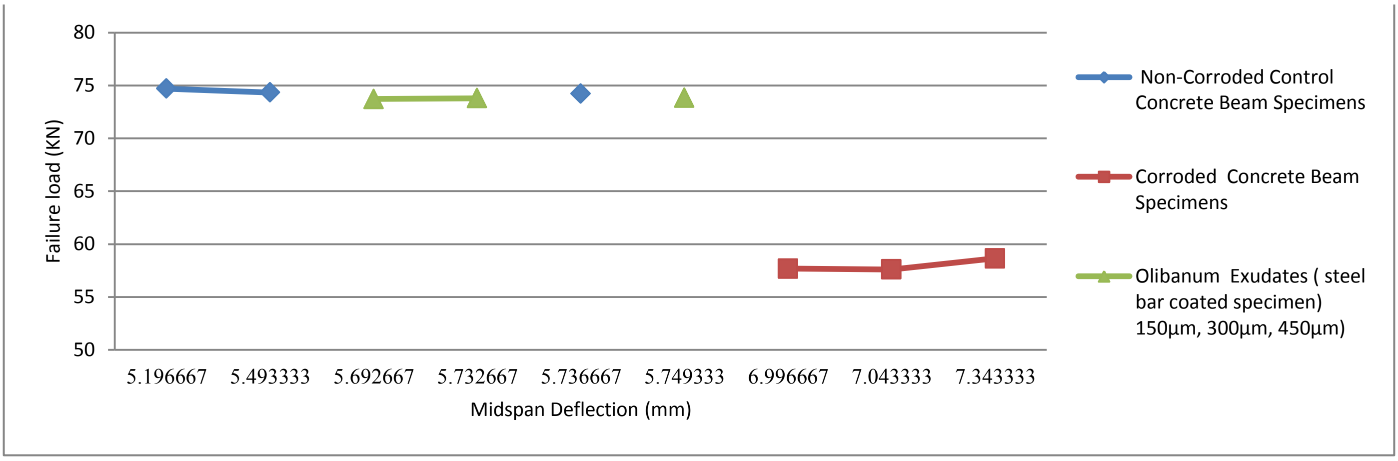

Figure 2. Average Failure Load versus Midspan Deflection of Beam Specimens (Non-Corroded, Corroded and Resin Coated Specimens)

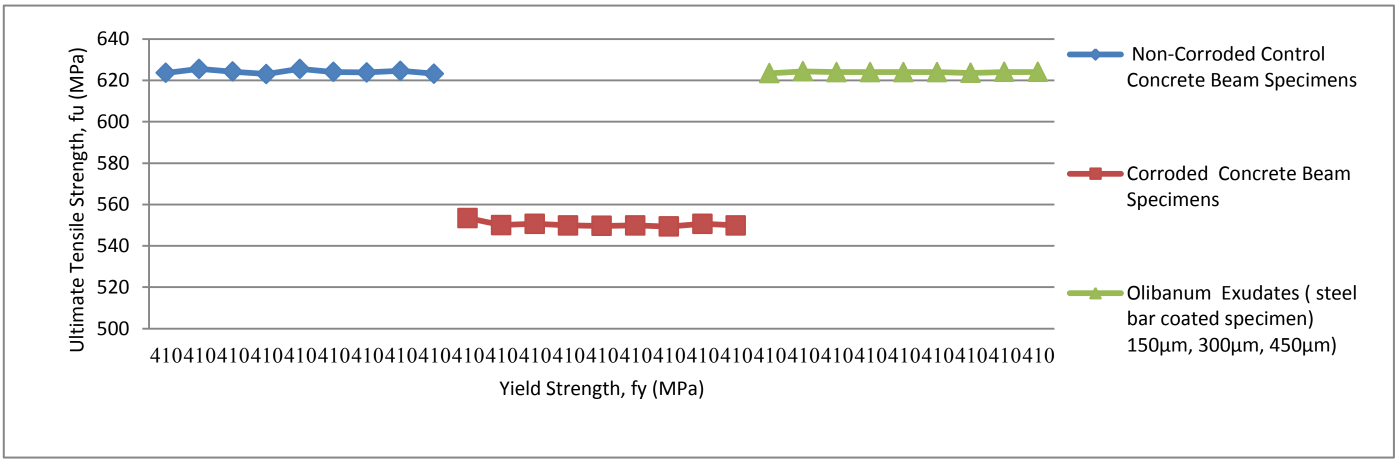

Figure 3. Ultimate Tensile Strength versus Yield Strength of Beam Specimens (Non-Corroded, Corroded and Resin Coated Specimens)

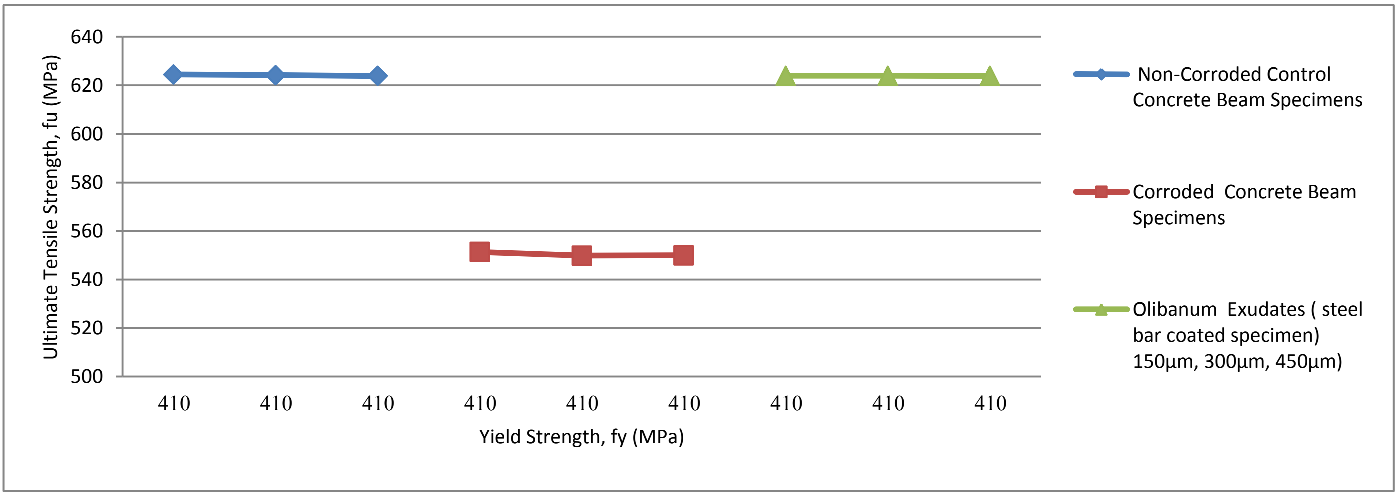

Figure 4. Average Ultimate Tensile Strength versus Yield Strength of Beam Specimens (Non-Corroded, Corroded and Resin Coated Specimens

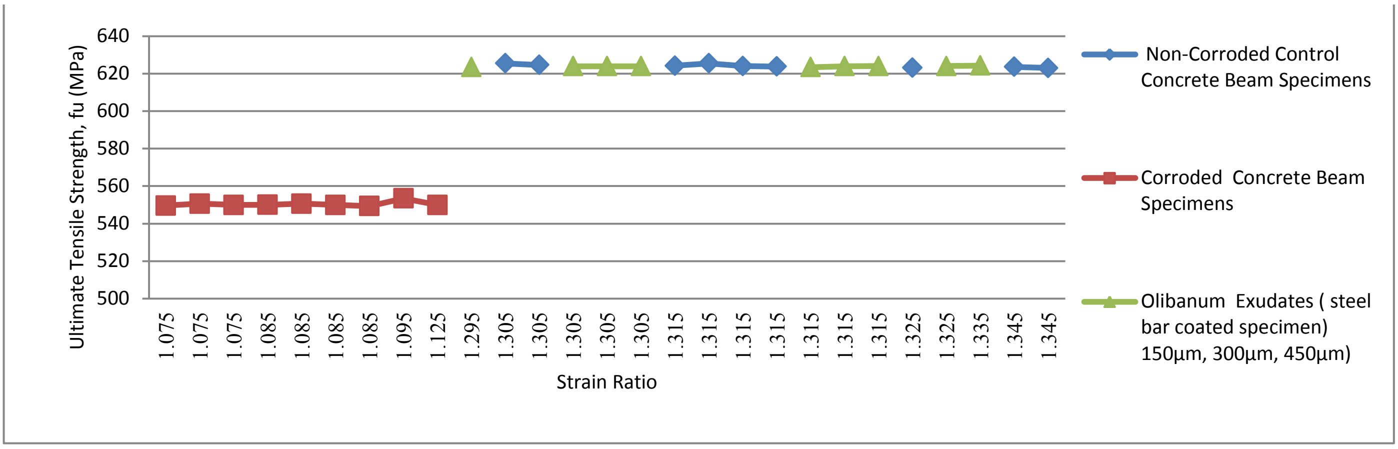

Figure 5. Ultimate Tensile Strength versus Strain Ratio of Beam Specimens (Non-Corroded, Corroded and Resin Coated Specimens)

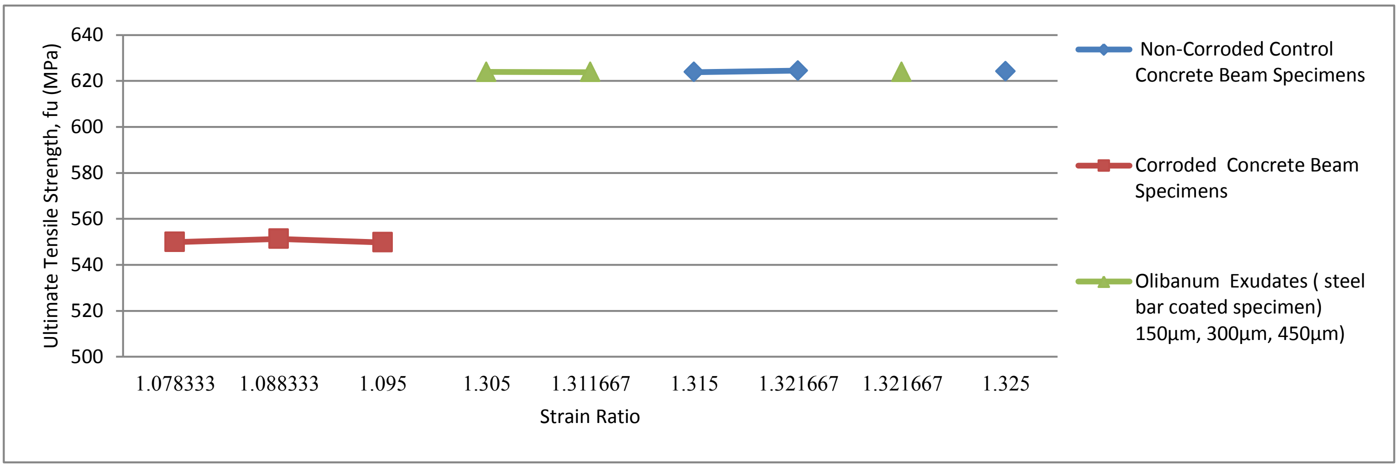

Figure 6. Average Ultimate Tensile Strength versus Strain Ratio of Beam Specimens (Non-Corroded, Corroded and Resin Coated Specimens)

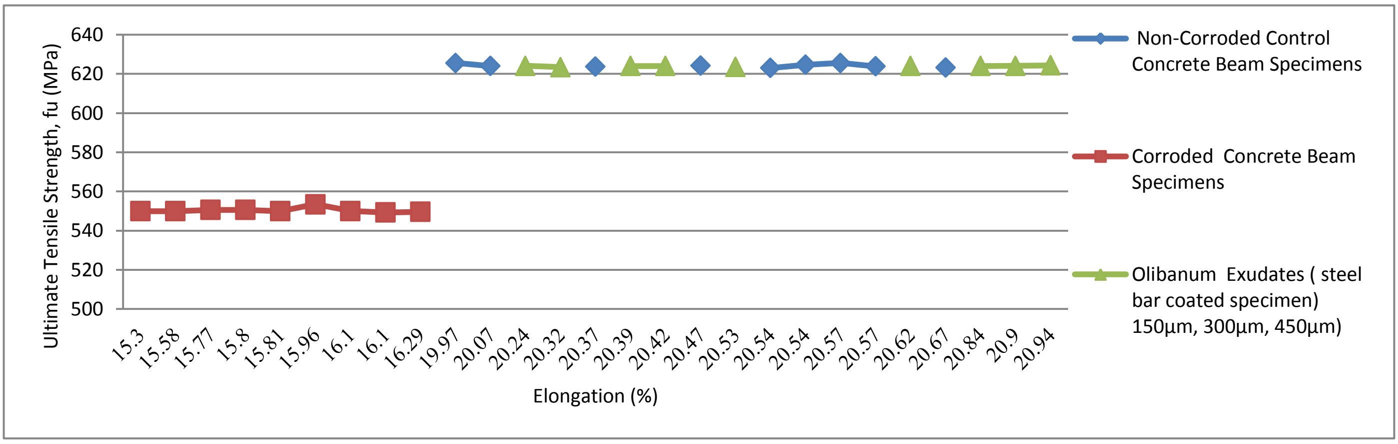

Figure 7. Ultimate Tensile Strength versus Elongation of Beam Specimens (Non-Corroded, Corroded and Resin Coated Specimens)

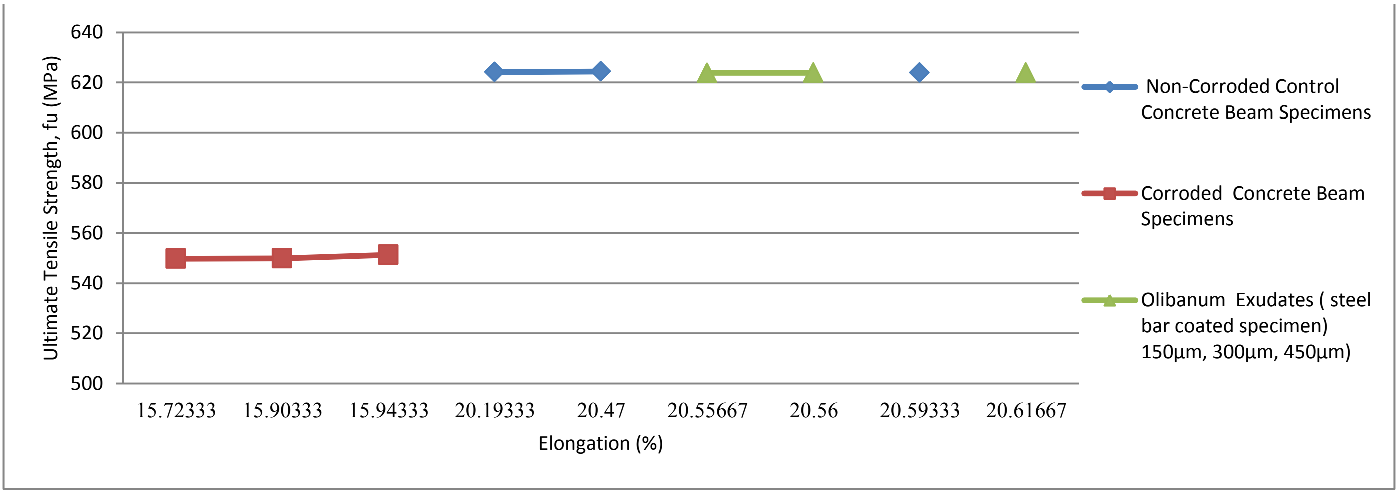

Figure 8. Average Ultimate Tensile Strength versus Elongation of Beam Specimens (Non-Corroded, Corroded and Resin Coated Specimens)

IV. CONCLUSIONS

Experimental results gotten from tables 1–5 and figures 1–8, the below conclusions were drawn:

i. Coated members have high flexural failure load, low; midspan deflection, strain ratio and ultimate tensile strength over corroded members.

ii. Corroded members showed little flexural failure loads over non-corroded and coated specimens with high midspan deflection rates to non-corroded and coated specimens, ultimate tensile strength of corroded members yield higher with little applied load to non-corrode and coated specimens.

iii. Effect of corrosion on mechanical properties of reinforcing steel resulted to poor state performance of corroded members.

iv. Non-corroded members possessed standard mechanical properties of reinforcing steel over corroded members.

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How to Cite this Article:

TrustGod, J. A., Kennedy, C. & Gilbert, D. R. (2019) Flexural Residual Capacity and Ultimate Yield Strength of Corroded and Inhibitive Reinforced Concrete Beams in Corrosive Environment. International Journal of Science and Engineering Investigations (IJSEI), 8(92), 121-129. http://www.ijsei.com/papers/ijsei-89219-16.pdf