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Yield Strength Capacity of Corrosion Inhibited (Resins / Exudates) Coated Reinforcement Embedded in Reinforced Concrete Beam and Accelerated in Corrosive Medium

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ABSTRACT

An investigative study was carried out to ascertained 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.

Key Words: Corrosion, Corrosion inhibitors, Flexural Strength, Concrete and Steel Reinforcement

1.0 INTRODUCTION

The reduction of designed life span and serviceability of f reinforced concrete structures in many notable ways was caused by corrosion of reinforcing steel. Corrosion generates tensile stresses in steel reinforcement surroundings the in the concrete, resulting to early cracks. In addition, steel reinforcement cross-sectional – area reduction is noticed thereby causing decreased in ductility of the structure, especially during the occurrence of corrosion pitting. Concrete produced with admixtures resulting to high concrete compressive strength and with low water/cement ratio has low permeation which causes reduction to the penetration corrosion inducement resulting from characteristic such as moist, chloride and carbon dioxide to the steel surface (Ahmad, [1].

Otunyo and Kennedy [2] 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.

Cusens and Yu [3] studied the an epoxy coated reinforcing steel bars pull-out tests t in concrete which involved the conduction of single pull-out and double control uncoated bars. The size of the test specimen was 250 × 250 × 410 mm with 25mm bars and 150 × 150 × 200 mm with 12mm bars incompliance with BS 4449. Single pull-out test results suggested loaded end of coated epoxy bars showed more end as compared to non-coated reinforcing steel bars. The reinforcing bars were centrally embedded passing completely longitudinal axis

Kayyali and Yeomans [4] compared galvanized, black and epoxy-coated rebars were embedded in reinforced concrete beams of size 1500 × 160 × 320 mm by evaluating the bond and slip of coated reinforcement in concrete. The test results revealed minimal bond strength loss from galvanized steel bars and as well as minimal reduction in the bond strength of coated epoxy reinforcing steel bars. The formation of surface films covering the metal, while generally protective, can give rise to localized corrosion attack and pitting (Scully, [5], Bertolini *et al,* [6], Lounis *et al*, [7], Elsener [8], 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

Torres-Acosta *et al,* [9] investigated los of capacity of flexural steel cross-sectional loss of reinforcing steel bar to corrosion level of embedded reinforcement steel bar using specimens of concrete beams with 100 mm × 150 mm x 1500 mm cast with chlorides. Sample specimens in flexure tested under three point loading were tested. They concluded that flexural load capacity decreased by 60% with only 10% ratio, in flexural load capacity were affected in reduction, because pitting corrosion greatly decrease the mechanical properties of reinforcing steel at a certain location and change the steel from ductile behavior to brittle behavior.

El-Maaddawy *et al.*, [10] studied the effect of of corrosion in combined actions of flexural loads of reinforced concrete corroded beams. They found that crack width would propagate 22% faster in loaded conditions, observed that with 8.9% and 22.2% mass loss, strength losses of 6.4% and 20.0% respectively.

Huang and Yang [11] investigated the corresponding relationship between the corrosion of reinforced concrete beams and load-carrying capacity. Their results showed that the load carrying capacity reduced significantly reduction due to the increase in corrosion was more in beams with a low w/c or predetermined cracks (mix B or type K). They concluded that this behavior was a result of the chloride ions having easier access to the reinforcing steel in cracked beams than in un-cracked ones.

2.0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Aggregates

Both fine and coarse aggregates for this research work met the requirements of [12]. They are gotten from Etche River sand dumpsites in Rivers state, while coarse aggregate are gotten crushed rock siite at Akamkpa.

2.1.2 Cement

Ordinary Portland cement used for all concrete mixes in this investigation. The cement met the requirements of [13]

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, Rivers State Polytechnic, Bori. The water met the requirements of [14]

2.1.4 Structural Steel Reinforcement

The reinforcements are gotten directly from the market in Port Harcourt. . Met the requirements of [15]

2.1.5 Corrosion Inhibitors (Resins / Exudates)

The study inhibitor (Acardium occidentale l**.**) of natural tree resins/exudates extracts are gotten from bushes and plantations from Odioku communities, Ahoada West Local Government areas, Rivers State, they are sourced from existing and previously formed and by tapping processes for newer ones.

2.2 METHODS

Present study involves direct application of resins / exudates of trees extract known as inorganic inhibitor (Acardium occidentale l**.**), 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 blend ratio was followed, batching by using weighing materials manually. Ratio of 1:2:4 concrete blend with the aid of weight and water-cement ratio of 0.65. guide mixing turned into used on a easy concrete banker, and mixture was monitored and water brought gradually to achieve best blend design concrete. Preferred uniform shade and consistency concrete was received by way of additions of cement, water and aggregates. The beams were cast in steel mold of size 150mm x 150 mm x 650 mm. sparkling concrete blend for each batch became completely compacted by using tamping rods, to dispose of trapped air, which could reduce the power of the concrete and 12 mm and sixteen mm reinforcements of coated and non-coated had been spaced at a hundred and fifty mm with concrete cover of 25 mm were embedded inside the beam and projection of a hundred mm for half of mobile capacity measurement. Demoulded of specimens was executed after 24 hours and curing lasted for 28 in a curing tanks at room temperature, which then gave manner for extended corrosion take a look at process and testing procedure allowed for 39 days first crack noticed and a further 21 days making a complete of 60 days for in addition observations on corrosion acceleration method.

2.2.2 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 56 beam specimens was tested. After curing for 28 days, 6 controlled beam (non-corroded) was kept in a control state, preventing corrosion reinforcement of the, while 48 beam samples of non-coated and resins / exudates coated were partially place in ponding tank for 39 days placed to examine accelerated corrosion process. After 39 days, the accelerated corrosion subjected samples were examined to determine residual flexural strength. Beam specimen 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 12 mm and 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.

3.0 RESULTS AND DISCUSSIONS

Experimental results of flexural strength tests conducted on non-corroded, corroded and acardium occidentale l. steel coated concrete beam members .
Tables 3.1 – 3.3 were used to derive summarized average values obtained in tables 3.4 – 3.6.
Figures 3.1 and 3.4 are the plots of broad test samples and the average obtained values of flexural strength failure load versus deflection for non-corroded, corroded and acardium occidentale l. resins /exudates steel coated concrete beam members.

3.1 Non-corroded Concrete Beam Members

Results of non-corroded concrete beams summarized from tables 3.1, 3.2 and 3.3 to 3.4, 3.5 and 3.6 at average values are failure load 29.09%, midspan deflection 28.30%, tensile strength 12.30% and elongation 31.50%.

3.2 Corroded Concrete Beam members

Results from tables 3.1 -3.3 to 3.4-3.6, the average obtained values for non- corroded beam members on comparison, flexural strength failure load decreases by 22.5 %, midspan deflection increased by 39.30 %, tensile strength decreases by 10.17 % and elongation increased by 46.30 %.

3.3 Acardium occidentale l. resins/exudates steel coated concrete beam members.

In comparison to corroded concrete beam members, flexural strength failure load increased to 29.59%, midspan deflection decreased to 25.69 %, tensile strength increases by 12.14 % and elongation decreased to 32.46 %.

Table 3.1 : Flexural Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated
(specimens)

Flexural Strength of Beam Specimens (Non-Corrode specimens)										
s/no	Samples									
		A	B	C	D	E	F	G	H	I
Beam	**Non-corroded Control beam**									
Bk1-1	Failure load (KN)	78.08	78.08	77.90	77.87	77.87	77.98	78.68	77.65	78.80
Bk1-2	Midspan deflection (mm)	6.27	6.35	6.95	7.06	6.15	7.09	6.18	6.35	6.15
Bk1-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
Bk1-4	Yield Strength, fy (MPa)	460	460	460	460	460	460	460	460	460
Bk1-5	Ultimate Tensile Strength, fu (MPa)	629.3	631.2	629.9	628.7	631.2	629.7	629.5	630.3	628.9
Bk1-6	Strain Ratio	1.35	1.31	1.32	1.35	1.32	1.32	1.32	1.31	1.33
Bk1-7	Elongation (%)	26.05	26.25	26.15	26.22	25.65	25.75	26.25	26.22	26.35

Table 3.2 : Flexural Strength of Beam Specimens (Corrode specimens)

Corroded beam										
Bk2-1	Failure load (KN)	61.55	62.23	59.80	59.28	61.57	59.57	59.34	61.77	59.55
Bk2-2	Midspan deflection (mm)	9.52	9.35	8.98	8.95	8.55	9.45	8.98	8.58	9.25
Bk2-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
Bk2-4	Yield Strength, fy (MPa)	460	460	460	460	460	460	460	460	460
Bk2-5	Ultimate Tensile Strength,fu (MPa)	565.3	561.9	562.5	561.8	561.5	561.8	561.2	562.5	561.8
Bk2-6	Strain Ratio	1.19	1.18	1.18	1.22	1.17	1.19	1.18	1.17	1.17
Bk2-7	Elongation (%)	17.91	18.05	17.72	17.25	18.24	17.53	18.05	17.75	17.76

Table 3.3: Flexural Strength of Beam Specimens (Resin Coated specimens)

3	**Acardium occidentale l. (steel bar coated specimen)**									
Bk3-1	Failure load (KN)	78.35	77.85	77.72	77.15	78.28	77.88	78.15	78.28	78.28
Bk3-2	Midspan deflection (mm)	6.95	7.24	7.36	7.36	7.02	7.32	7.15	7.10	7.08
Bk3-3	Yield Strength, fy (MPa)	460	460	460	460	460	460	460	460	460
Bk3-4	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
Bk3-5	Ultimate Tensile Strength, fu (MPa)	629.4	630.4	630.7	631.4	629.6	629.9	630.0	629.6	629.6
Bk3-6	Strain Ratio	1.31	1.30	1.30	1.30	1.31	1.30	1.30	1.30	1.31
Bk3-7	Elongation (%)	26.38	26.27	26.30	26.25	26.33	26.23	26.35	26.35	26.33

Table 3.4: Average Flexural Strength of Beam Specimens (Non-Corroded Specimens)

1	**Non-Corroded beam**			
Bk1A-1	Failure load (KN)	78.07	78.01	78.37
Bk1A-2	Midspan deflection (mm)	6.52	6.766	6.22
Bk1A-3	Bar diameter (mm)	16	16	16
Bk1A-4	Yield Strength, fy (MPa)	460	460	460
Bk1A-5	Ultimate Tensile Strength, fu (MPa)	630.1	629.8	629.4
Bk1A-6	Strain Ratio	1.32	1.33	1.32
Bk1A-7	Elongation (%)	26.15	25.87	26.27

Table 3.5: Table 4.4: AverageFlexural Strength of Beam Corrode Specimens)				
2	**Corroded beam**			
Bk2A-1	Failure load (KN)	61.19	60.14	60.22
Bk2A-2	Midspan deflection (mm)	9.28	8.98	8.93
Bk2A-3	Bar diameter (mm)	16	16	16
Bk2A-4	Yield Strength, fy (MPa)	460	460	460
Bk2A-5	Ultimate Tensile Strength, fu (MPa)	563.2	561.7	561.8
Bk2A-6	Strain Ratio	1.18	1.19	1.17
Bk2A-7	Elongation (%)	17.89	17.67	17.85
3	**Table 3.6: Average Flexural Strength of Beam Specimens (Resin /Exudates Coated Specimens)**			
	Acardium occidentale l. (steel bar coated specimen) `			
		150µm) coated (A)	**(250µm) coated(B)**	**(350µm) coated (C)**
Bk3A-1	Failure load (KN)	77.97	77.77	78.23
Bk3A-2	Midspan deflection (mm)	7.18	7.23	7.11
Bk3A-3	Bar diameter (mm)	16	16	16
Bk3A-4	Yield Strength, fy (MPa)	460	460	460
Bk3A-5	Ultimate Tensile Strength, fu (MPa)	630.1	630.3	629.7
Bk3A-6	Strain Ratio	1.30	1.30	1.30
Bk3A-7	Elongation (%)	26.31	26.27	26.34

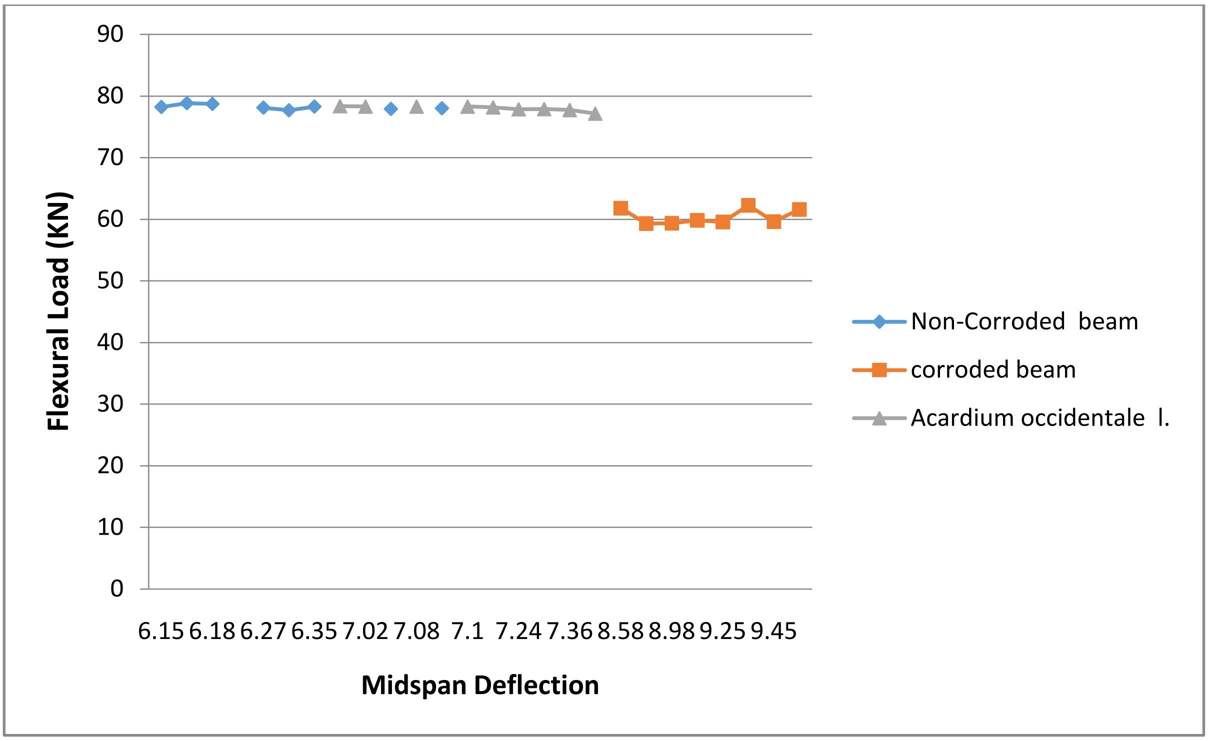

Figure 3.1: Failure Load versus Midspan deflection of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

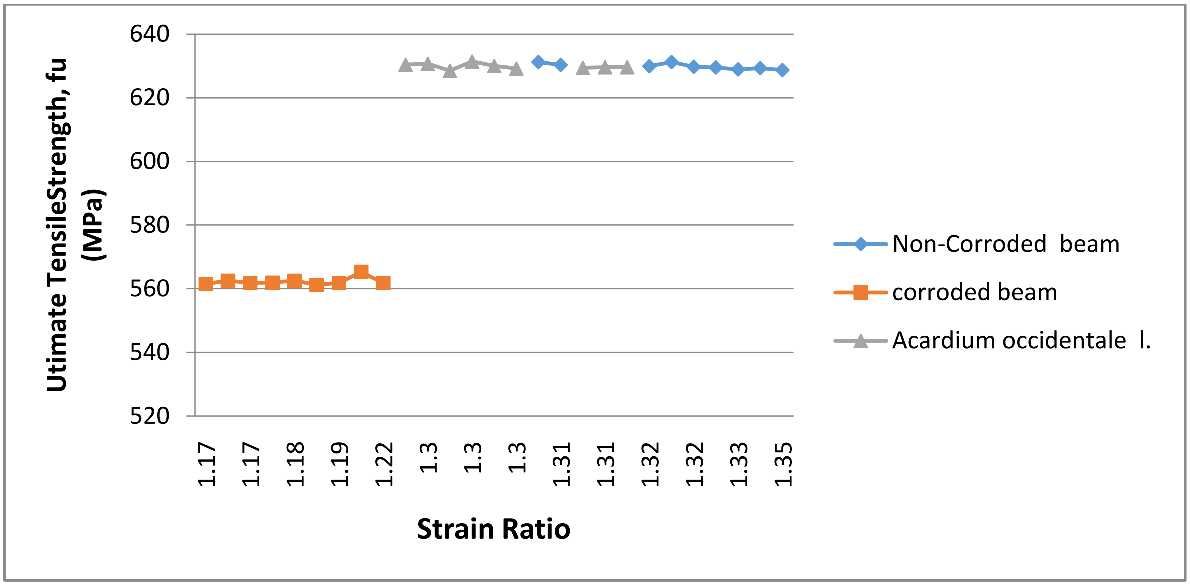

Figure 3.2: Ultimate Tensile Strength versus Elongation of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

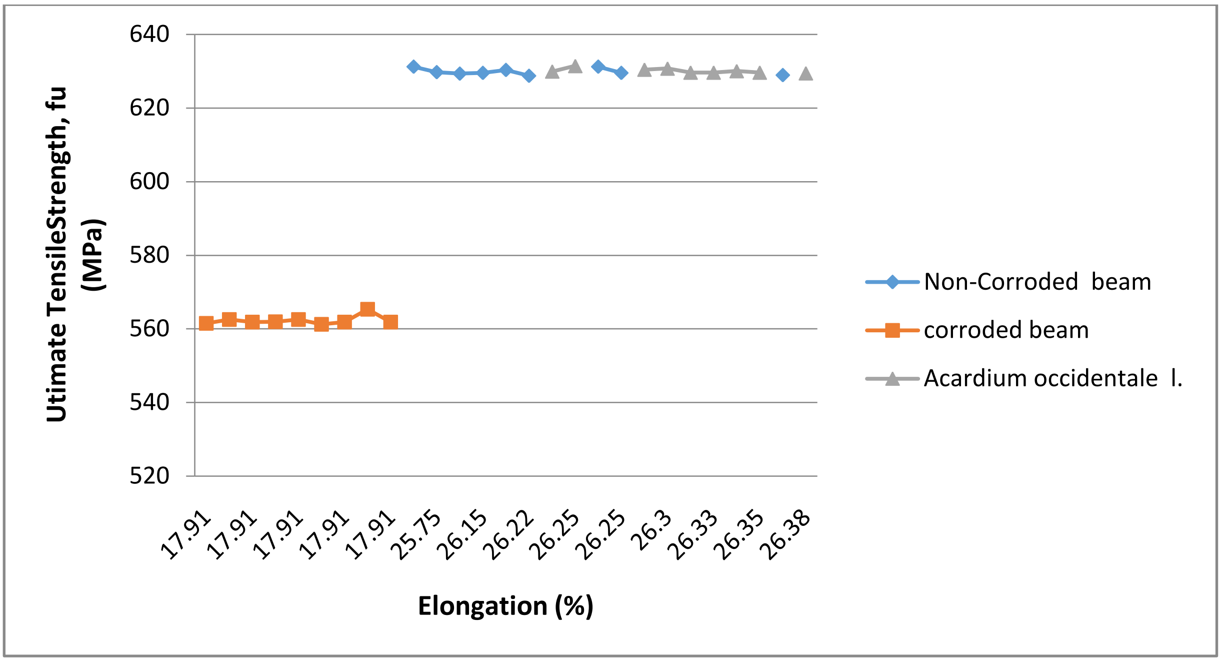

Figure 3.3: Ultimate Tensile Strength versus Strain Ratio of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

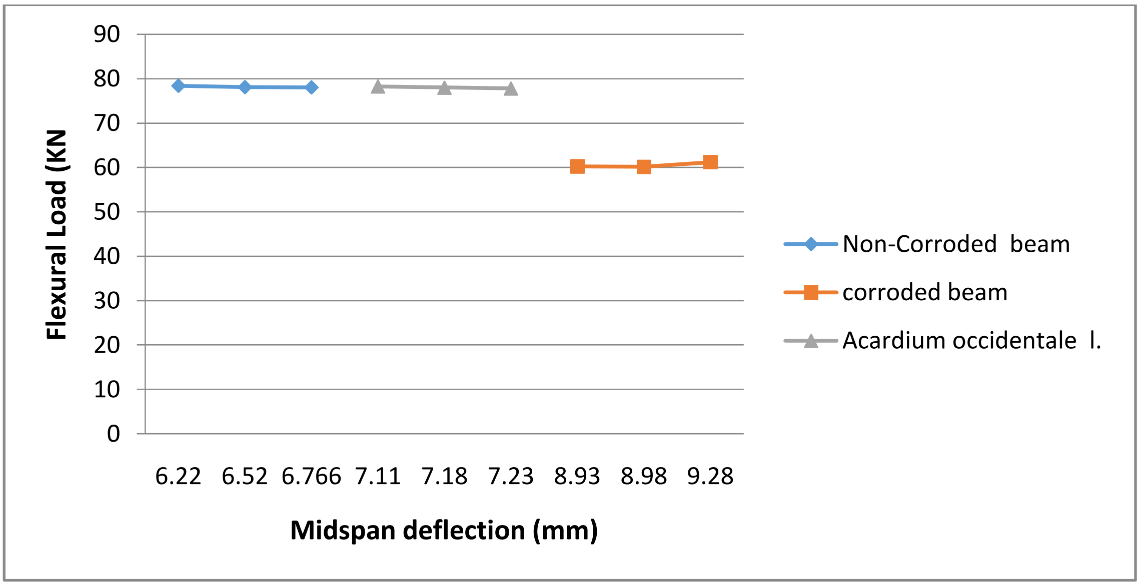

Figure 3.4: Average Failure Load versus Midspan deflection of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

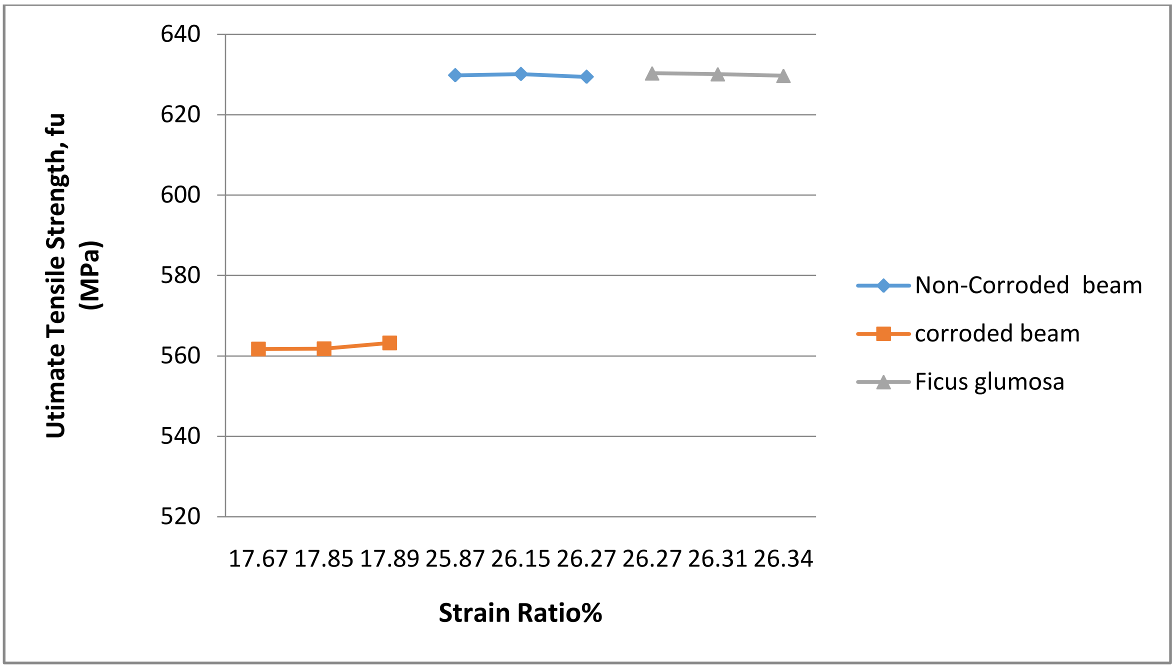

Figure 3.5: Average Ultimate Tensile Strength versus Elongation of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

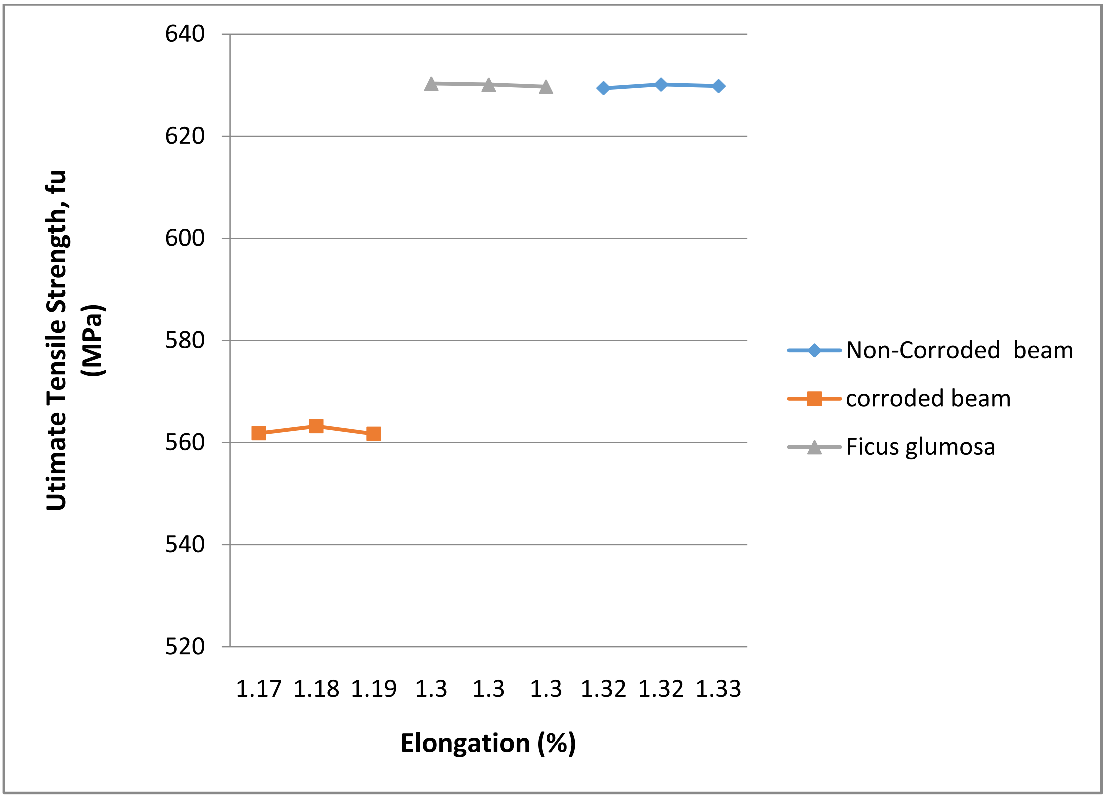

Figure 3.3: Average Ultimate Tensile Strength versus Strain Ratio of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

4.0 Conclusions

Experimental results gotten from tables 3.1 – 3.6 and figures 3.1 – 3.6, the below conclusions were drawn:

i. Cracks, pitting and spallings recorded which is corrosion potential possibility on uncoated concrete beam members
ii. Non-corroded and resin / exudates coated steel bars showed higher floral failure load to uncoated member due to corrosion attack
iii. Residual yield strength capacity was affect due to corrosion attack

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