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RESIDUAL FLEXURAL STRENGTH OF CORROSION INHIBITED RESIN COATED BEAM IN CORROSION ACCELERATED MEDIA

Charles Kennedy[1], Ogunjiofor Emmanuel Ifeanyi[2], Letam Leelee Prince[3]

[1]Faculty of Engineering, Department of Civil Engineering, Rivers State University, Nkpolu, Port Harcourt, Nigeria.

[2]Department of Civil Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria.

[3,]School of Engineering, Department of Civil Engineering, Kenule Beeson Saro-Wiwa Polytechnic, Bori, Rivers State, Nigeria.

Authors E-mail: [1]ken_charl@yahoo.co.uk, [2]ogunjioforemmanuel@gmail.com, [3]leeorices07@yahoo.com

ABSTRACT

This work 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. Steel reinforcement of umcoated and coated one of various thicknesses of 150µm,(ABC), 250µm (DEF) and 350µm (GHI) steel bars were embedded into concrete and tested for corrosion potential possibility. 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.

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

1.0 INTRODUCTION

Reinforced concrete beam load carry capacity and its moment solely lies or depends on reinforcing steel bar strength. The loss or degradation of steel reinforcement strength is cause by the presence of corrosion. Ting and Nowak [1] formulated the loss calculations aroused from mechanical damages resulting from reinforcing steel resulting from corrosion effect on beam load capacity on corrosion presence.

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 (mdacryodes edulis) added strength to the reinforcement.

Uomoto and Misra [3] established different method in contrast that the cause of structural deterioration resulting from the reinforcement corrosion is indirectly interrelated degradation and failure of reinforcing steel bars resulting from cross-sectional area reduction, caused by factors like crack development in result to loss of strength of the structure.

Huang and Yang [4] experimented on corroded reinforced concrete beams; dimensioning 150 mm × 150 mm × 500 mm, of the 30 beams, 16 had predestined cracks, to enable the study the flexural effect and behavior of the beams due to reinforcing steel bar area loss. Loss of reinforcing load carrying capacity was calculated to ascertain percentage reduction of the steel bar diameter resulting from corrosion. Experinmemetal results showed that loading capacity was reduced by 10%.

AI-Sulaimani *et al*,. [5] investigated the characteristics of beam failure on bond due to corrosion of reinforcement, two series of tests were conducted, one of studies evaluated the behavior of beams designed to fail in flexure. These beam tests were simulated with uniform corrosion, while pullout tests were used to simulate severe local corrosion. In the series aimed at the study of corrosion-bond behavior for beams analyzed to failure in flexure, except that the embedment length was increased to 300mm. They found that the ultimate bond stress in the pullout bonds test of similar level of corrosion was due to failure resulting from yielding of steel bars but not from bond failure.

Minkarah and Ringo [6] investigated the loss of concrete cover of beams to debonding of reinforcing steel nar at tension due to corrosion damage was simulated. Beam section, which contained 0.95% reinforcement, and span were tested with a varying length of bar exposed. Single point load offset from mid-span for all beam specimens were adopted and the load was applied at a section where reinforcement remained bonded to concrete. They noted a marked difference in the pattern of crack formation was noted in specimens with bars disbanded. Exposure of reinforcement results to about 20% of the span of the beam in a slight loss of carrying capacity of load, however, exposure of over 60% of the span of the beam resulted in a strength loss of around 20%.

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 [7]. 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 [8]

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, University of Uyo, Uyo. Akwa - Ibom State. The water met the requirements of [9]

2.1.4 Structural Steel Reinforcement

The reinforcements are gotten directly from the market in Port Harcourt

2.1.5 Corrosion Inhibitors (Resins / Exudates)

The study inhibitor (Ficus glumosa) 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 (Ficus glumosa), 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 29 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 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 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.

Table 3.1 : Flexure Test Results of Non-Corroded (Control) specimens

		Non-corroded Control beam								
s/no		Samples								
		A	B	C	D	E	F	G	H	I
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	Strain (%)	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)

				Ficus glumosa (steel bar coated specimen)						
9										
Bk9-1	Failure load (KN)	77.35	78.30	77.65	77.69	78.05	77.88	77.65	77.69	78.19
Bk9-2	Midspan deflection (mm)	7.25	6.65	7.54	7.35	6.91	7.35	7.33	7.33	6.90
Bk9-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
Bk9-4	Yield Strength, fy (MPa)	460	460	460	460	460	460	460	460	460
Bk9-5	Ultimate Tensile Strength, fu (MPa)	630.0	630.9	630.5	630.5	630.5	630.5	630.1	630.6	630.6
Bk9-6	Strain Ratio	1.31	1.33	1.31	1.30	1.30	1.30	1.29	1.31	1.32
Bk9-7	Elongation (%)	26.23	26.85	26.33	26.30	26.75	26.53	26.44	26.15	26.81

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

1A		**Non-Corroded beam**		
Bk1A-1	Failure load (KN)	78.07	78.01	78.37
BkA1-2	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

2A **Table 3.5: Average Flexural Strength of Beam Specimens (Corrode Specimens)**

		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

3A **Table 3.6: Average Flexural Strength of Beam Specimens (Resin Coated Specimens)**

		Ficus glumosa (steel bar coated specimen)		
		(150μm) coated (A)	**(250μm) coated(B)**	**(350μm) coated (C)**
Bk3A-1	Failure load (KN)	77.76	77.87	77.84
Bk3A-2	Midspan deflection (mm)	7.14	7.20	7.18
Bk3A-3	Bar diameter (mm)	16	16	16
Bk3A-4	Yield Strength, fy (MPa)	460	460	460
Bk3A-5	Ultimate Tensile Strength, fu (MPa)	630.4	630.5	630.43
Bk3A-6	Strain Ratio	1.31	1.3	1.30
Bk3A-7	Elongation (%)	26.47	26.52	26.46

3.0 RESULTS AND DISCUSSIONS

Tables 3.1, 3.2, and 3.3 showed the results of flexural strength test of concrete beam members conducted on 27 samples of non-corroded, corroded and ficus glumosa (corrosion inhibitor) resins/ exudates extract paste, coated specimens of 150µm,(ABC), 250µm (DEF) and 350µm (GHI) thicknesses . Tables 3.4, 3.5 and 3.6, are derived average values obtained from tables 3.1, 3.2, and 3.3 for non- corroded, corroded and coated specimens.

Figures 3.1 and 3.4 are the plots of general test samples and the average obtained values of flexural strength failure load versus deflection for non-corroded, corroded and ficus glumosa lam resins/exudates steel coated concrete beams.

Figures 3.3, 3.5 and 3.3, 3.6 are the plots of ultimate tensile strengths versus elongations / strain ratios of general samples and average values derived from table 3.1-3.3 to 3.4 – 3.6

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 Ficus glumosa Coated Steel Bar Concrete Beam Members

Results from tables 3.3 – 3.6, when compared to corroded concrete beam members, flexural strength failure load increased to 28.59%, midspan deflection decreased to 25.30 %, tensile strength increases by 12.13 % and elongation decreased to 32.12 %.

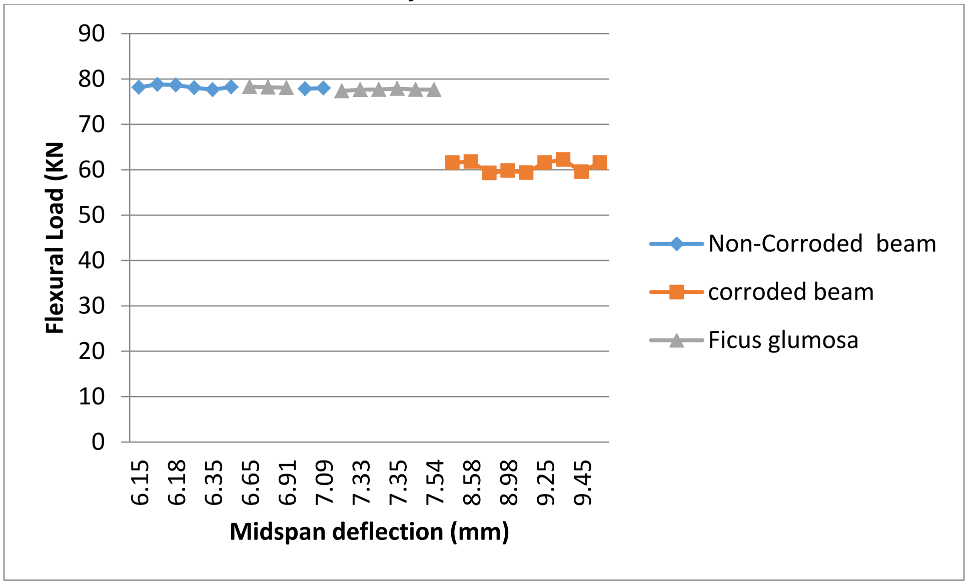

Figure 3.1: Failure Load versus Midspan deflection of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

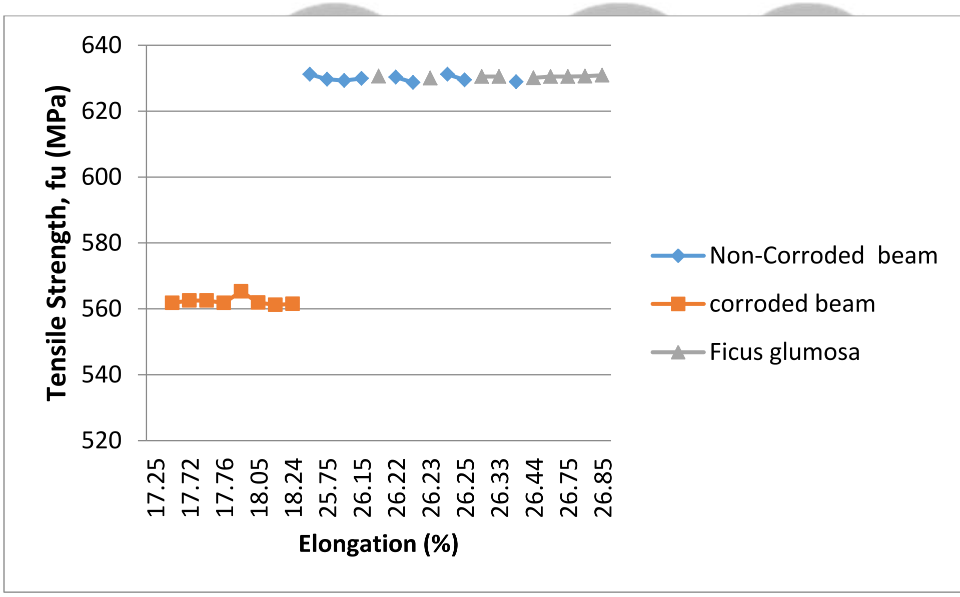

Figure 3.2: Ultimate Tensile Strength versus Elongation of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

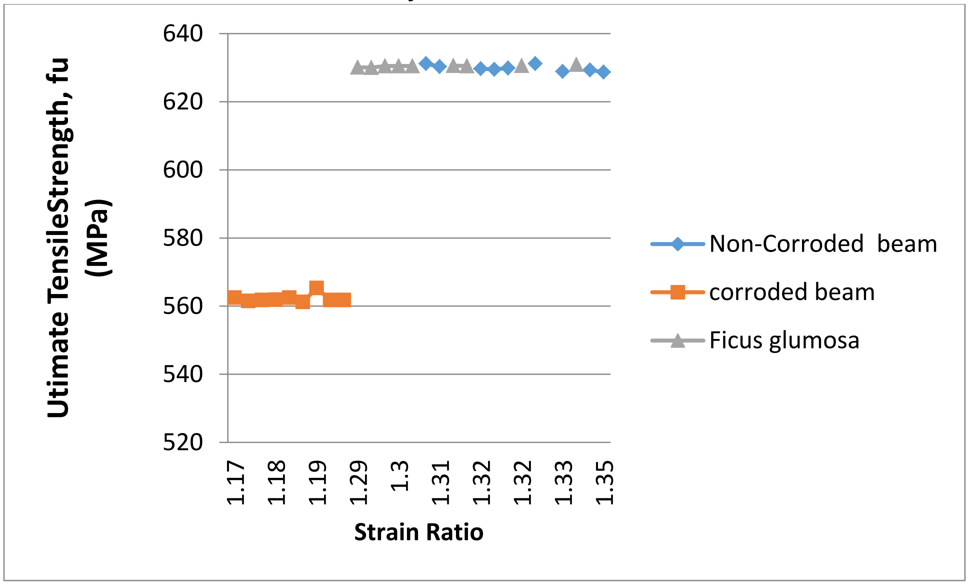

Figure 3.3: Ultimate Tensile Strength versus Strain Ratio of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

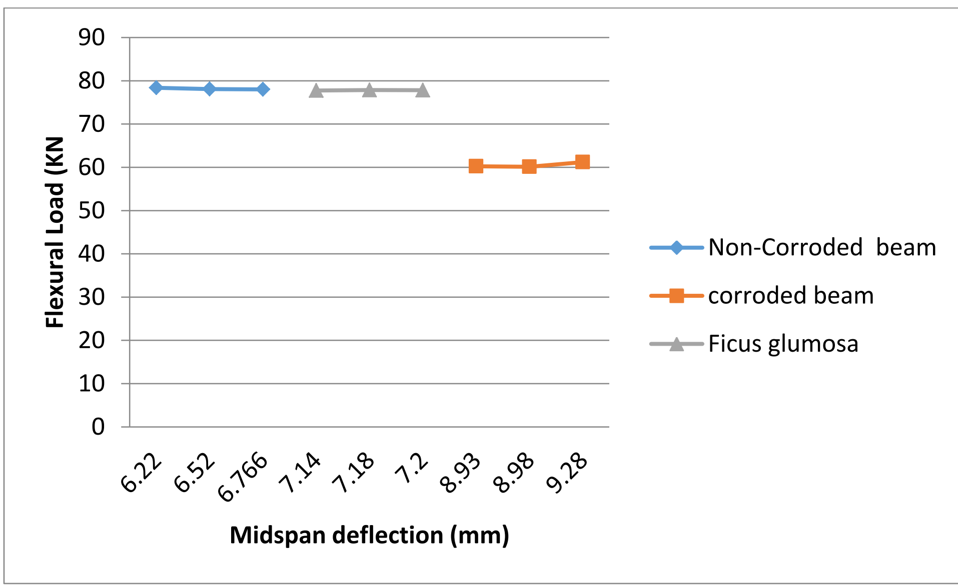

Figure 3.4: Average Failure Load versus Midspan deflection of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

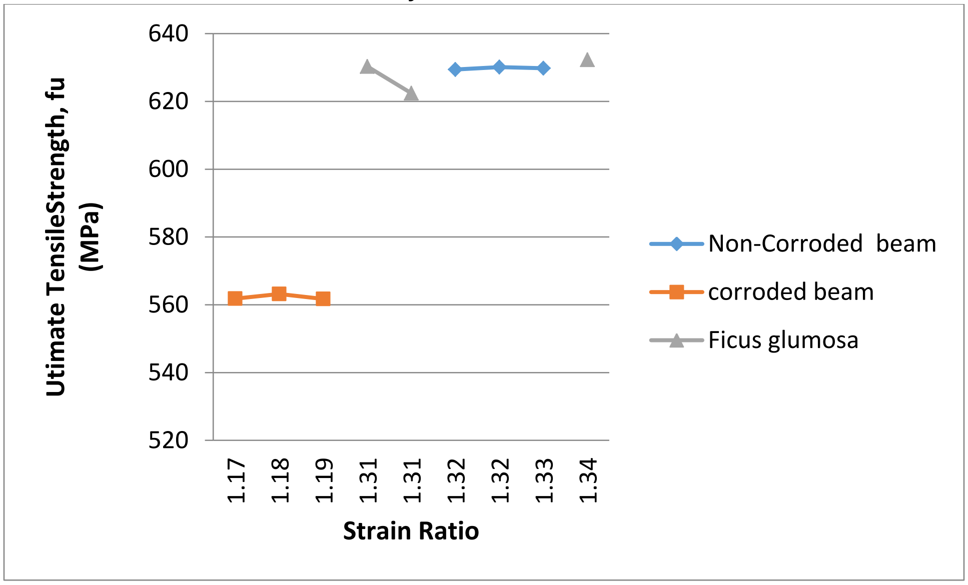

Figure 3.5: Average Ultimate Tensile Strength versus Elongation of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

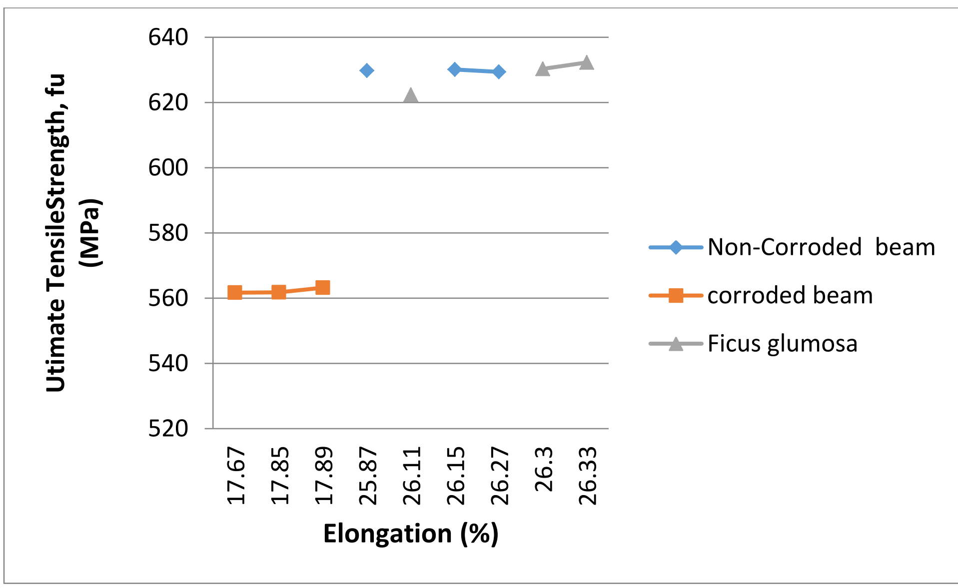

Figure 3.3: Average Ultimate Tensile Strength versus Strain Ratio of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens)

4.0 Conclusions

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

i. Corrosion potential results were recorded from uncoated samples
ii. Residual strength comparison of non-corroded, corroded and resin / exudates coated steel bars showed that flexural failure load was lesser in corroded specimens
iii. Corrosion inhibitors effect on steel reinforcement embedded in concrete exposed to (Nacl) was recorded in terms of protection against Nacl attack
iv. Uncoated member experienced rusty surfaces due to corrosion attack

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