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LOAD CARRYING CAPACITY OF COATED REINFORCEMENT WITH EXUDATES OF CONCRETE BEAM IN CORROSION SOLUTION PONDING

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Abstract: **This study 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 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.**

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

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1. INTRODUCTION

Structures of reincorced concrete built or founded within the harsh marine environment faced great risk due to chloride-induced corrosion of reinforcement which results from the presence of high chloride. Corrosion manifest generally in two principal forms: spalling and cracking of concrete cover resulting from unrestrained corrosion yield and local pitting of reinforcement at the anode which causes great reduction of the bar cross-sectional area. The formation of surface films covering the metal, while generally protective, can give rise to localized corrosion attack and pitting (Scully, 1975). (Bertolini *et al*, 2004, Lounis *et al*, 2004, Elsener 2005), 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)

Considerable factors of concrete pH, chloride ions, oxygen and water are needed to control the corrosion inhibition of reinforcement. Methods adopted to control these factors are the used of epoxy coatings, inhibitors, buffers, electrochemical protection procedures and scavengers. The techniques of the application of corrosion inhibitors and approach is considered to curb corrosion of reinforcing steel bar. Majority of the inhibitors for steel reinforcements are used in conditions of acidic or neutral stages, while very rapid attack is experienced in and uninhibited steel; same way, corrosion of steel under the alkaline conditions in concrete is very slow.

Otunyo and Kennedy (2017) 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.

Rodriguez *et al*., (1997) investigated corrosion levels of different degree of concrete beams. The studies beam specimens were 200mm by 150mm with a clear span of 2000mm. Beams had both tensile, compressive as well as shear reinforcement that was corroded using accelerated corrosion techniques by immersing the specimens in a solution made of 3% calcium chlorides by weight to the mixing water, over a period of 101-190 days. The concluded that cracks resulting from deflection results from increased in the level of corrosion.

Eyre and Nokhasteh (1992) 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.

Cabrera and Ghoddoussi (1992) studied reinforced beams of 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.

2. MATERIALS AND METHODS

2.1 Materials:

2.1.1 Aggregates:

Both fine and coarse aggregates for this research work met the requirements of BS 882. 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 BS EN 196-6

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 BS 3148

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 (Moringa Oleifera Lam) 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 (Moringa Oleifera Lam), 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 garadually 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 27beam 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.

3. RESULTS AND DISCUSSIONS

Results of 27 samples in table 3.1 – 3.3 of flexural strength of concrete beam members of A – I, randomly cast, cured for 30 days on normal and standard method, accelerated in corrosion medium environment for 60 days.

Table 3.4 – 3.4 are the average values of sampled specimens from tables 3.1-3.3 of non-corroded, corroded and magnifera indica (steel bar coated concrete beam members).

Figures 3.1 and 3.4 are the plots of generalized and averaged flexural strength failure load versus deflection for non-corroded, corroded and moringa oleifera lam resins/exudates steel coated beam 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.

3.1 Non-corroded Concrete Beam Members:

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

3.2 Corroded Concrete Beam members:

Results from tables 3.1 and the average obtained values from table 3.2 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 Mangifera indica resins/exudates steel coated concrete beam members:

In comparison to corroded concrete beam members, flexural strength failure load increased to 29.09%, midspan deflection decreased to 31.20 %, tensile strength increases by 11.75 % and elongation decreased to 31.60 %.

Table 3.1: Flexural Strength of Beam Specimens (Non-Corroded 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 (Non-Corroded, Corroded 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	**Mangifera indica (steel bar coated specimen)**									
Bk3-1	Failure load (KN)	77.50	78.25	78.86	77.25	77.95	78.86	78.25	77.15	78.85
Bk3-2	Midspan deflection (mm)	6.52	6.35	6.98	6.95	6.55	6.45	6.98	6.58	6.25
Bk3-3	Bar diameter (mm)	16	16	16	16	16	16	16	16	16
Bk3-4	Yield Strength, fy (MPa)	460	460	460	460	460	460	460	460	460
Bk3-5	Ultimate Tensile Strength, fu (MPa)	630.7	630.5	629.8	629.2	629.0	638.8	630.2	628.5	608.6
Bk3-6	Strain Ratio	1.31	1.31	1.33	1.35	1.34	1.34	1.33	1.31	1.30
Bk3-7	Elongation (%)	25.83	26.83	26.25	25.60	26.58	26.81	26.18	26.02	26.14

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

1A	**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: AverageFlexural Strength of Beam Specimens (Corroded Specimens)			
2A	**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
	Table 3.6: Average Flexural Strength of Beam Specimens (Resin Coated specimens)			
	Mangifera indica (steel bar coated specimen) 150µm) coated (A) (250µm) coated(B) (350µm) coated (C)			
3A				
Bk3A-1	Failure load (KN)	78.20	78.35	78.08
Bk3A-2	Midspan deflection (mm)	6.61	6.65	6.60
Bk3A-3	Bar diameter (mm)	16	16	16
Bk3A-4	Yield Strength, fy (MPa)	460	460	460
Bk3A-5	Ultimate Tensile Strength, fu (MPa)	630.3	632.3	622.4
Bk3A-6	Strain Ratio	1.31	1.34	1.31
Bk3A-7	Elongation (%)	26.30	26.33	26.11

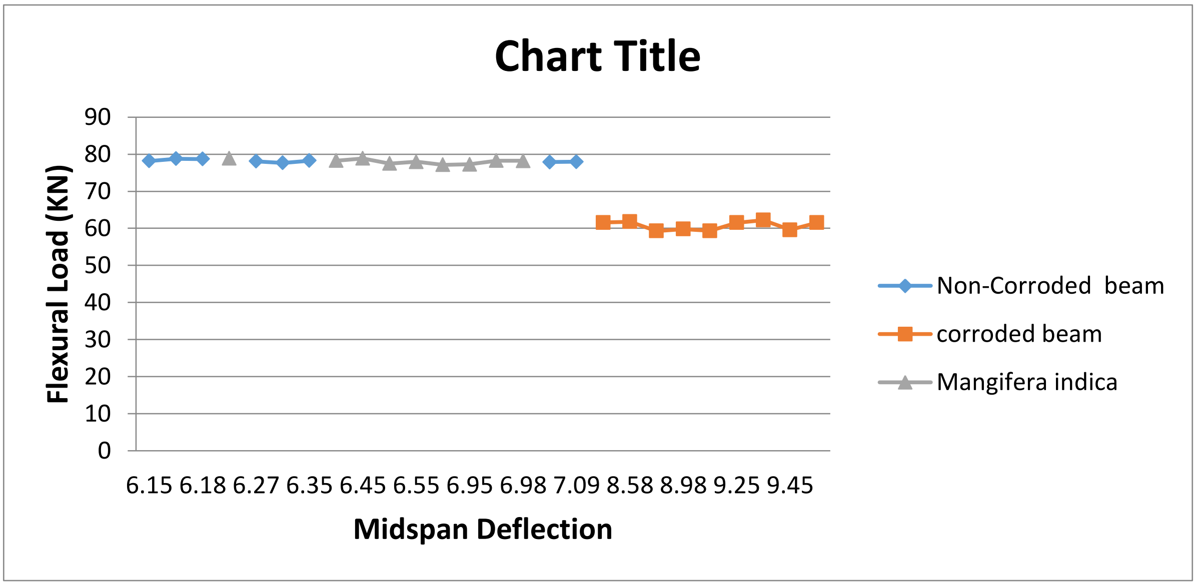

Figure 3.1: Failure Load versus Midspan deflection of Beam Specimens

(Non-Corroded, Corrode and Resin Coated Specimens)

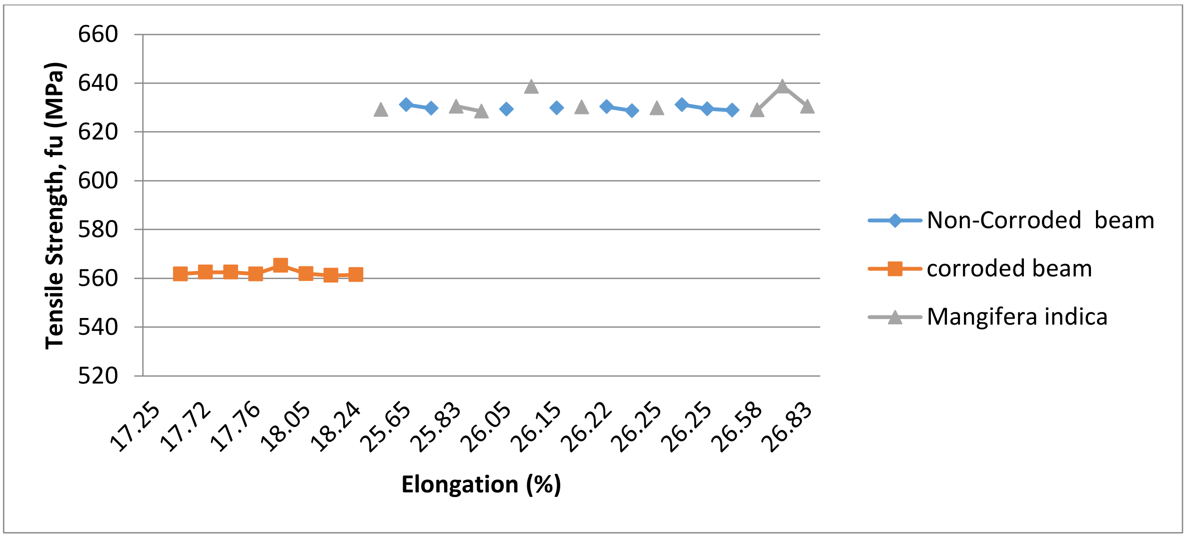

Figure 3.2: Ultimate Tensile Strength versus Elongation of Beam Specimens

(Non-Corroded, Corrode and Resin Coated Specimens)

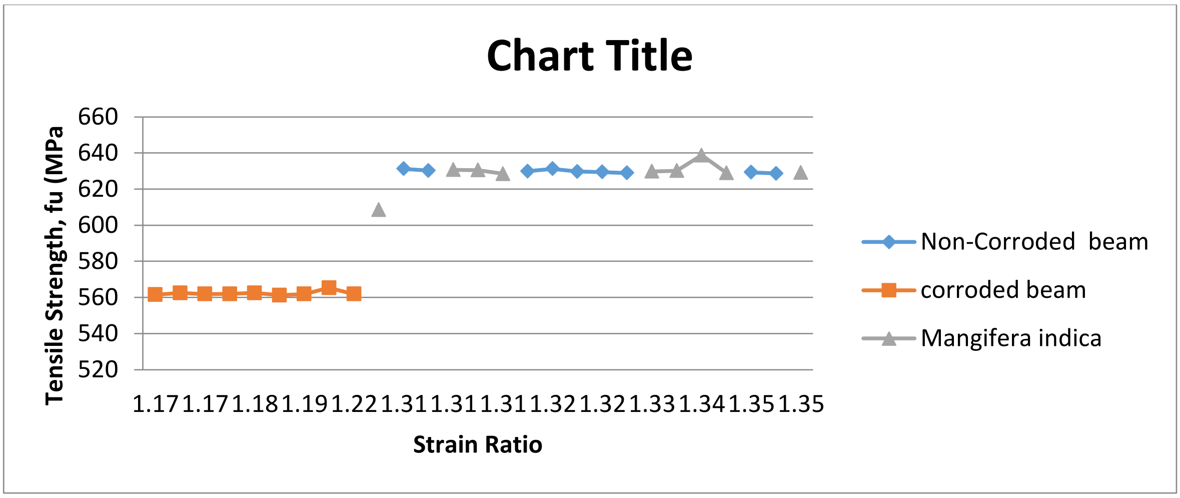

Figure 3.3: Ultimate Tensile Strength versus Strain Ratio of Beam Specimens

(Non-Corroded, Corrode and Resin Coated Specimens)

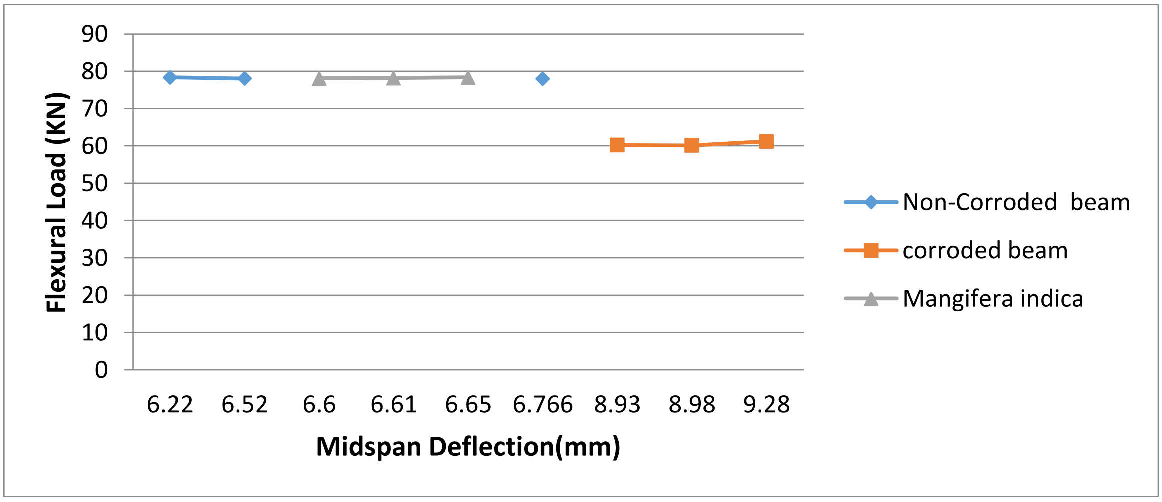

Figure 3.4: Average Failure Load versus Midspan deflection of Beam Specimens

(Non-Corroded, Corrode and Resin Coated Specimens)

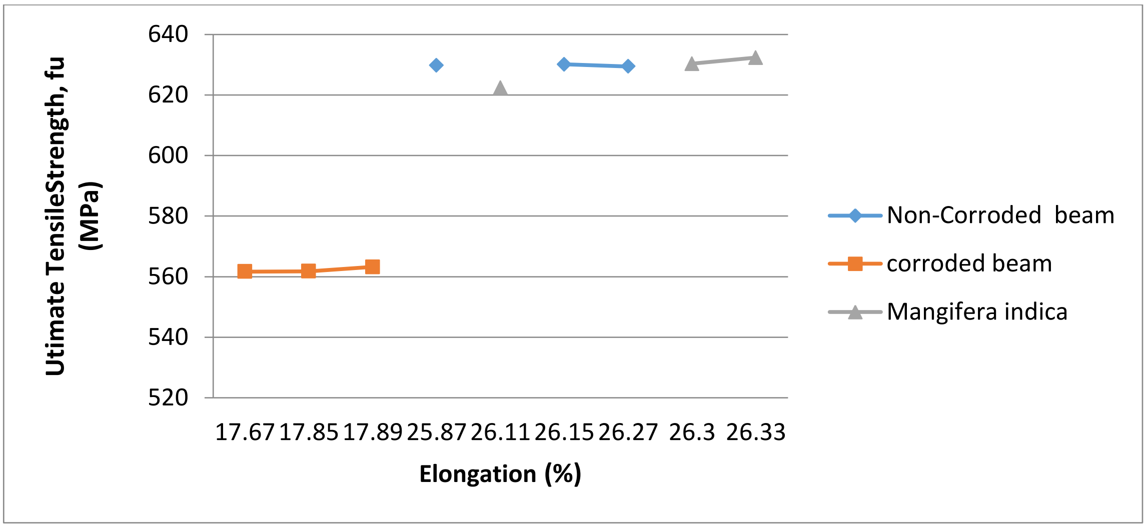

Figure 3.5: Average Ultimate Tensile Strength versus Elongation of Beam Specimens

(Non-Corroded, Corrode and Resin Coated Specimens)

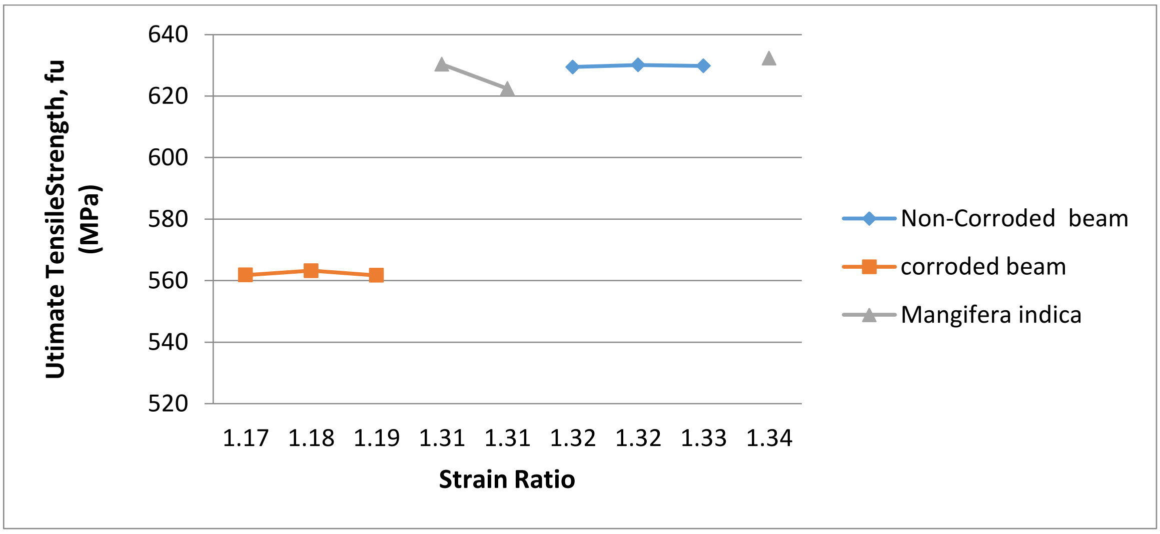

Figure 3.6: Average Ultimate Tensile Strength versus Strain Ratio of Beam Specimens

(Non-Corroded, Corrode and Resin Coated Specimens)

4. CONCLUSIONS

Results from tables 3.1 – 3.6 and figures 3.1 – 3.6, the below conclusions were drawn:

i. Uncoated concrete beam members showed corrosion potential

ii. Corroded concrete beam members yielded higher on flexural failure load as compared to non- corroded and resins/exudates paste coated steel bar

iii. Resins/exudates coated concrete members resisted corrosion attack

iv. Surface condition of steel bar was adversely affected due to effect

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