Investigation on Comparative Flexural Residual Yield Strength Capacity of Uncoated and Coated Reinforcement Embedded in Concrete and Exposed to Corrosive Medium

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Abstract

This study 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 examined 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.

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

1.0 Introduction

Corrosion effect on concrete reinforcing steel is the most and severe reasons of premature degradation and failure of structures in environment with chlorides. The effects of the steel corrosion lead to decrease in the bar diameter, deterioration of the mechanical properties of the reinforcing steel (e.g., the change from the normal ductile response of low carbon steel bars to a relatively brittle response in bars damaged by pitting, cracking and spalling of the concrete and noticeable decrease in the bond at the steel-concrete interface. This corrosion deterioration can lead to damage resulting in capacity loss or even failure, this issue creates justified concern in societies with harsh environments as found in Niger Deltaic region of Rivers State. Almusallam [1] concluded that the stress-strain characteristics of corroded reinforcements indicate a decrease in the ductility with an increase in the corrosion level. Other steel parameters, such as yielding and ultimate stresses, are significantly reduced by corrosion (Apostolopoulos *et al*[2]; Du *et al*. [3], [4]; Fernandez *et al*. [5]). Wang and Liu [6] , Azad *et al*. [7] ,and Lundgren [8] reported that the analytical results of predictions for the flexural strength of RC beams agreed well with the experimental results.

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Mangat and Elgarf [9] examined the corrosion effect on the flexural strength of reinforced concrete structures (Beam), an examination was made on 111 simply supported beams. Laboratory Corrosion acceleration potential techniques was implored to all beam samples. In comparison using four-point loading on all the beams. In comparison, the flexural capacity of control samples (0% corrosion) was reduced to about 25% in residual strength and the ultimate flexural strength was reduced to about 75% at 10% of corrosion

Ballim and Reid [10] studied the performance of reinforced concrete due the corrosion effect on continuously load application on varying corrosion condition level. They concluded that 6% of the mass of steel bar was corroded, the deflection of the beams (at SLS) was increased by 40-70% when compared to the deflection of the control specimens.

Chung *et al.* [11] conducted test on 70 slabs of simply supported having 10mm diameter bar on a four– point load. Results showed that corroded slab decreased at higher corrosion level with predictive accuracy of little corrosion increased in the slab flexural capacity with significant loss on the reinforcement area when 2% exceed is recorded.

Chung *et al.* [11] investigated several slabs with 10mm steel reinforcement immersed in 3% salt solution for corrosion accelerated potential with corrosion level variation of 0% control samples and 15% for other .using four-point load. They observed that up to a 2% level of corrosion rapidly reduces the resisting force. It was concluded that influence corrosion level influenced at 2% greater values.

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, University of Uyo, Uyo. Akwa - Ibom State. The water met the requirements of [14]

2.1.4 Structural Steel Reinforcement

The reinforcements are gotten directly from the market in Port Harcourt.

2.1.5 Corrosion Inhibitors (Resins / Exudates) (Dacryodes edulis (African Pear) UBE, Moringa oleifera lam, Mangifera indica

The study inhibitors are of natural tree resins/Exudates substances extracts. They are abundantly found in Rivers State bushes and they are sourced from plantations and bushes of Odioku communities, Ahoada West Local Government areas, Rivers State, from existed and previously formed and by tapping processes for newer ones. They are:

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1. Dacryodes edulis (African Pear) UBE

2. Moringa Oleifera Lam

3. Mangifera indica

2.2 METHODS

Present study involves direct application of resins / exudates of trees extract known as inorganic inhibitor (dacryodes edulis (African Pear) UBE, moringa oleifera lam, mangifera indica), 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,

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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 45 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 18 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.

3.0 RESULTS AND DISCUSSIONS

Results from table 3.1 shows the flexural strength test of 45 concrete beam members of 9 non-corroded (controlled), 9 corroded and 27 samples of resins / exudates coated steel bar paste of (dacryodes edulis (African Pear) UBE, moringa oleifera lam, mangifera indica of thicknesses 150µm, 250µm and 350µm. Tables 3.2 is the computed average values derived from table 3.1 of flexural strength failure load, midspan deflection, tensile strength and elongation for non-corroded , corroded and resins / exudates coated steel bar members. Figures 3.1 and 3.4 are the flexural strength failure load versus midspan deflection for 45 samples randomly tested beams and the average computed values for non-corroded, corroded and resins / exudates coated steel bar, figures 3.2, 3.5, and 3.3, 3.6 are the graphical representations of the ultimate strength versus elongation / strain ratio of the entire samples and the average values obtained from table 3.1.

3.1 Non-corroded Concrete Beam members

Results obtained from table 3.1 and summarized in table 3.2 of non-corroded concrete beams at failure load, midspan deflection, tensile strength, and elongation are 29.09%, 28.30%, 12.30% 31.50% respectively.

3.2 Corroded Concrete Beam members

Results from table 3.1 and 3.2 are the results of flexural strength failure load, midspan deflection, tensile strength and elongation. From results, failure load decreased from 29.09% to 22.50%, midspan deflection increased from 28.30% to 39.30%, tensile strength decreased from 12.30% to 10.17% while elongation increased from 31.50% to 46.30%. Increased and decreased was affected by corrosion attack on uncoated specimens.

3.3 Dacryodes edulis (African Pear) UBE, Moringa oleifera lam, Mangifera indica Coated Steel Bar Concrete Beam Members

Results obtained from dacryodes edulis (African Pear) UBE, moringa oleifera lam and mangifera indica on flexural strength failure load are 35.78%, 29.09%, 29.42% as against 22.30% in corroded members, this shows increased values in coated to decreased in corroded, midspan deflection are 18.57%.,28.30%,27.43% against 39.30% corroded, increased in corroded members and decreased in coated, elongation are 28.75%, 31.50%, 31.60 against 46.30% in corroded, decreased in resins / exudates coated and increased in corroded members, tensile strength are 14.18%, 12.13%, 12.09 against 10.17% in corroded. Overall results indicated that coated steel bar showed higher values increased in failure load and tensile strength while corroded in elongation and midspan deflection.

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

		Beam samples								
s/no		Failure load (KN)								
		A	B	C	D	E	F	G	H	I
BkA1-1	**Non-corroded Control Cube**	78.08	78.25	77.90	77.87	78.18	77.98	78.68	77.65	78.80
BkA1-2	**Corroded**	61.55	62.23	59.80	59.28	61.57	59.57	59.34	61.77	59.55
		Coated Specimens								
		(150μm coated) ABC			**(250μm coated) DEF**			**(350μm coated) GHI**		
BkA1-3	**Dacryodes edulis (steel bar coated specimen)**	78.35	78.40	77.98	78.08	77.65	77.98	78.68	78.15	78.75
BkA1-4	**Moringa Oleifera lam(steel bar coated specimen)**	77.76	78.25	78.00	77.65	78.16	77.75	77.35	78.56	78.55
BkA1-5	**Mangifera indica(steel bar coated specimen)**	62.50	62.25	61.86	61.25	59.95	60.86	62.25	61.15	62.15
2		**Midspan deflection (mm)**								
BkB2-1	**Non-corroded**	6.27	6.35	6.95	7.06	6.15	7.09	6.18	6.35	6.15

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	Control Cube									
Bk B2-3	**Corroded**	9.52	9.35	8.98	8.95	8.55	9.45	8.98	8.58	9.25
	Coated Specimens									
		(150µm) coated			(250µm) coated			(350µm) coated		
BkB2-3	**Dacryodes edulis (steel bar coated specimen)**	6.29	6.38	6.77	7.12	7.19	7.25	6.62	6.79	6.18
BkB2-4	**Moringa Oleifera lam(steel bar coated specimen)**	7.15	6.95	7.08	7.28	7.18	7.21	7.21	7.08	6.90
BkB2-5	**Mangifera indica(steel bar coated specimen)**	8.97	8.95	9.20	9.28	9.48	9.28	8.98	9.22	9.28
3	**Utimate Tensile Strength, fu (MPa)**									
BkC3-1	**Non-corroded Control Cube**	629.3	631.2	629.9	628.7	631.2	629.7	629.5	630.3	628.9
BkC3-2	**Corroded**	565.3	561.9	562.5	561.8	561.5	561.8	561.2	562.5	561.8
	Coated Specimens									
		(150µm) coated			(250µm) coated			(350µm) coated		
BkC3-3	**Dacryodes edulis (steel bar coated specimen)**	630.1	630.7	631.9	630.5	631.1	629.8	629.5	631.6	631.8
BkC3-4	**Moringa Oleifera lam(steel bar coated specimen)**	630.7	629.5	629.9	630.7	629.9	630.7	630.7	630.1	629.7
BkC3-5	**Mangifera indica(steel bar coated specimen)**	560.7	560.5	559.8	559.2	559.0	558.8	560.2	568.5	566.9
	Strain Ratio									
BkD4-1	**Non-corroded Control Cube**	1.35	1.31	1.32	1.35	1.32	1.32	1.32	1.31	1.33

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BkD4-2	**Corroded**	1.19	1.18	1.18	1.22	1.17	1.19	1.18	1.17	1.17
					Coated Specimens					
		(150µm) coated			(250µm) coated			(350µm) coated		
BkD4-3	**Dacryodes edulis (steel bar coated specimen)**	1.32	1.30	1.31	1.33	1.30	1.30	1.31	1.32	1.33
BkD4-4	**Moringa Oleifera lam(steel bar coated specimen)**	1.32	1.31	1.30	1.30	1.30	1.31	1.30	1.32	1.32
BkD4-5	**Mangifera indica(steel bar coated specimen)**	1.20	1.20	1.20	1.20	1.18	1.18	1.19	1.19	1.19
5					**Elongation (%)**					
BkE5-1	**Non-corroded Control Cube**	26.05	26.25	26.15	26.22	25.65	25.75	26.25	26.22	26.35
BkE5-2	**Corroded**	17.91	18.05	17.72	17.25	18.24	17.53	18.05	17.75	17.76
					Coated Specimens					
		(150µm) coated			(250µm) coated			(350µm) coated		
BkE5-3	**Dacryodes edulis (steel bar coated specimen)**	26.59	26.52	26.33	26.35	25.98	26.78	26.35	26.18	26.35
BkE5-4	**Moringa Oleifera lam(steel bar coated specimen)**	26.38	26.54	26.42	26.25	26.45	26.38	26.35	26.45	26.48
BkEE-5	**Mangifera indica(steel bar coated specimen)**	18.83	18.83	18.25	18.60	18.58	18.81	18.8	18.62	18.82

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Table 3.2: Summary Results of Average Flexural Strength of Beam Specimens (Non-Corroded, Corrode and Resins Coated Specimens)

		Beam samples		
1		**Failure load (KN)**		
BkA1-1	**Non-corroded Control Cube**	78.07	78.01	78.37
BkA1-2	**Corroded**	61.19	60.14	60.22
		Coated specimens		
		(150µm) coated (A)	**(250µm) coated(B)**	**(350µm) coated (C)**
BkA1-3	**Dacryodes edulis (steel bar coated specimen)**	78.24	77.90	78.52
BkA1-4	**Moringa Oleifera lam(steel bar coated specimen)**	78.00	77.85	78.15
BkA1-5	**Mangifera indica(steel bar coated specimen)**	62.20	60.68	61.85
		Midspan deflection (mm)		
BkB2-1	**Non-corroded Control Cube**	6.52	6.766	6.22
BkB2-2	**Corroded**	9.28	8.98	8.93
		Coated specimens		
		(150µm) coated (A)	**(250µm) coated(B)**	**(350µm) coated (C)**
BkB2-3	**Dacryodes edulis (steel bar coated specimen)**	6.48	7.18	6.53
BkB2-4	**Moringa Oleifera lam(steel bar coated specimen)**	7.06	7.22	7.06
BkB2-5	**Mangifera indica(steel bar coated specimen)**	9.04	9.34	9.16

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3	**Utimate Tensile Strength, fu (MPa)**			
BkC3-1	**Non-corroded Control Cube**	630.1	629.8	629.4
BkC3-2	**Corroded**	563.2	561.7	561.8
		(150µm) coated (A)	**(250µm) coated(B)**	**(350µm) coated(C)**
BkC3-3	**Dacryodes edulis (steel bar coated specimen)**	631.0	630.4	630.9
BkC3-4	**Moringa Oleifera lam(steel bar coated specimen)**	630.0	630.4	630.1
BkC3-5	**Mangifera indica(steel bar coated specimen)**	560.3	559.7	565.7
4	**Strain Ratio**			
BkD4-1	**Non-corroded Control Cube**	1.32	1.33	1.32
BkD4-2	**Corroded**	1.18	1.19	1.17
	Coated specimens			
		(150µm) coated (A)	**(250µm) coated(B)**	**(350µm) coated (C)**
BkD4-3	**Dacryodes edulis (steel bar coated specimen)**	1.31	1.31	1.32
Bk4-4	**Moringa Oleifera lam(steel bar coated specimen)**	1.31	1.30	1.31
BkD4-5	**Mangifera indica(steel bar coated specimen)**	1.20	1.18	1.19
5	**Elongation (%)**			
BkE5-1	**Non-corroded Control Cube**	26.15	25.87	26.27
BkE5-2	**Corroded**	17.89	17.67	17.85
	Coated specimens			

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		(150µm) coated (A)	(250µm) coated(B)	(350µm) coated (C)
BkE5-3	**Dacryodes edulis (steel bar coated specimen)**	26.48	26.37	26.29
BkE5-4	**Moringa Oleifera lam(steel bar coated specimen)**	26.44	26.36	26.42
BkE5-5	**Mangifera indica(steel bar coated specimen)**	18.63	18.66	18.74

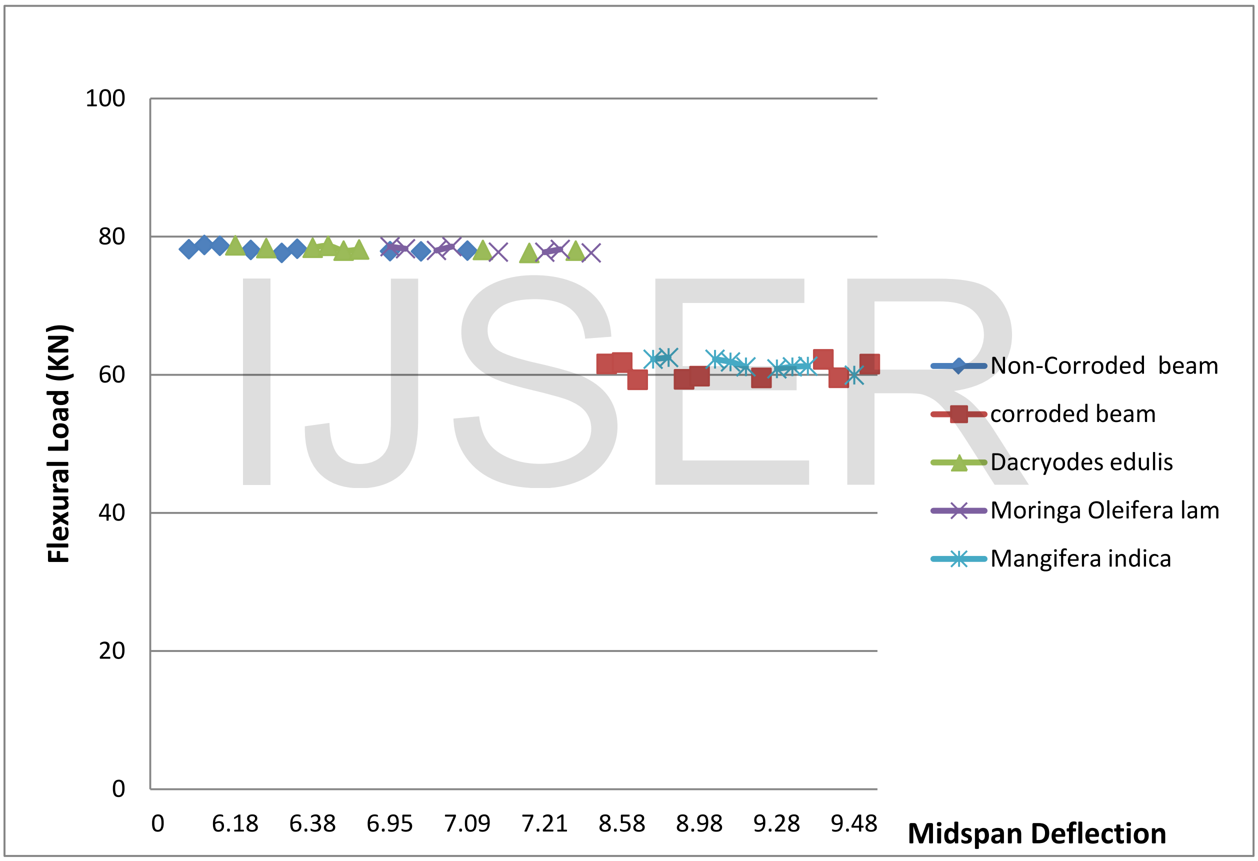

Figure 3.1: Summary Results of Flexural Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens) Flexural Load vs Midspan Deflection

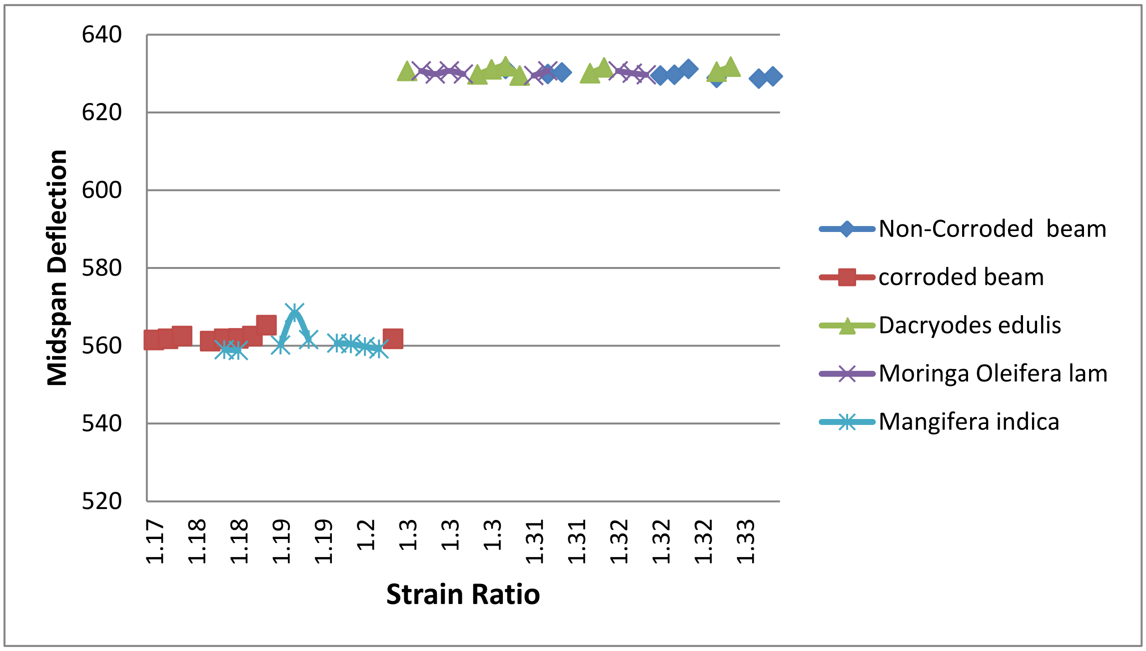

Figure 3.2: Summary Results of Flexural Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens) Midspan Deflection vs Strain Ratio

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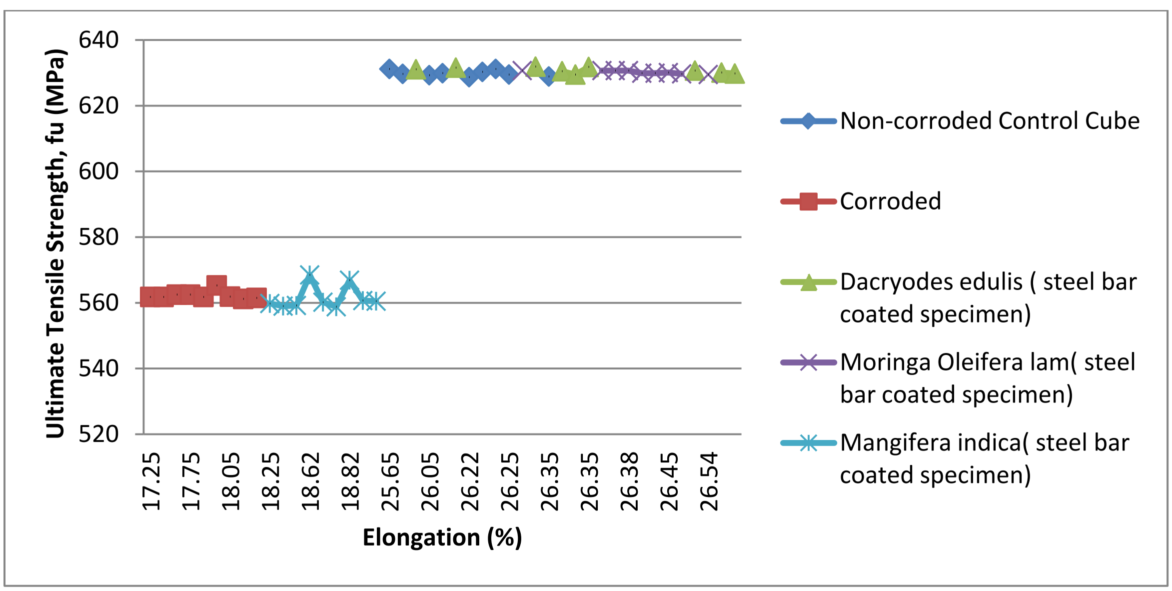

Figure 3.3: Summary Results of Flexural Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens) Ultimate Tensile Strength vs Elongation

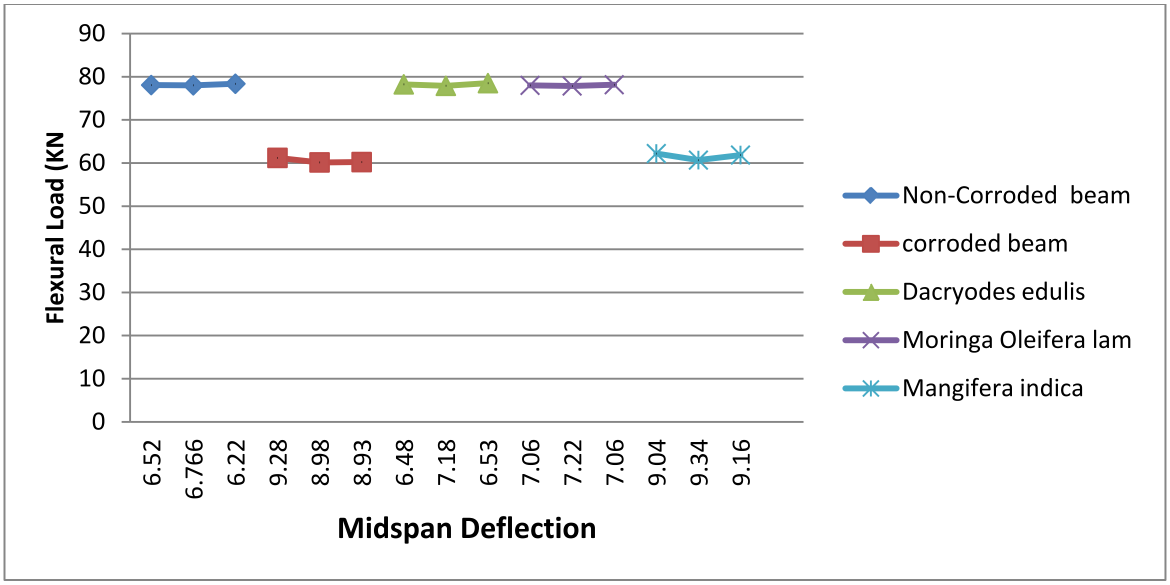

Figure 3.4: Average Results of Flexural Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens) Flexural Load vs Midspan Deflection

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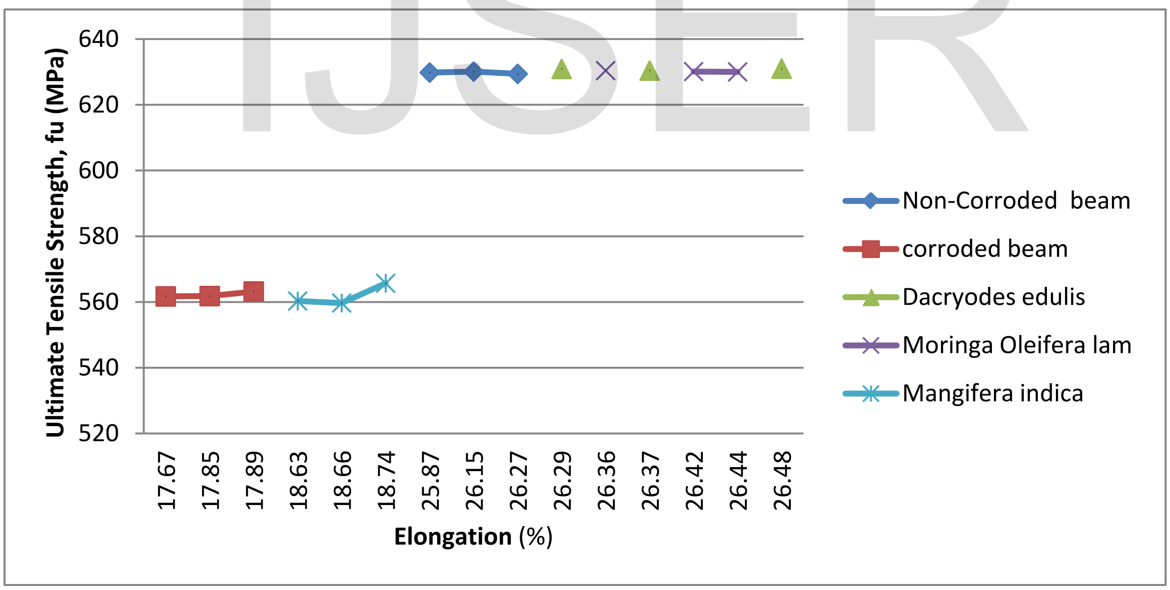

Figure 3.5: Average Results of Flexural Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens) Ultimate Tensile Strength vs Elongation

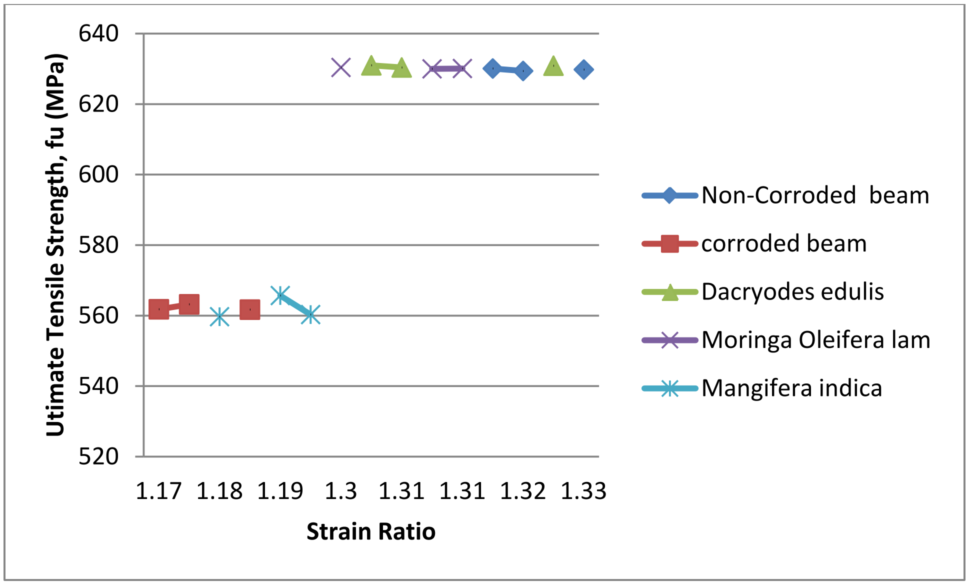

Figure 3.6: Average Results of Flexural Strength of Beam Specimens (Non-Corroded, Corrode and Resin Coated Specimens) Ultimate Tensile Strength vs Strain Ratio

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4.0 Conclusions

The experimental investigations presented in table 3.0 showed that:

i. Higher midspan deflection values recorded in corroded than in non-corroded and coated ones due to corrosion attach on uncoated members

ii. Investigated inhibitors do not add strength to reinforcement in flexural strength test; rather, it sustained the strength reduction by maintaining actual state

iii. Corrosion potential was recorded in uncoated members

iv. Changes in surface condition of reinforcement was noticed in uncoated

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