International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.3, 2015

RESEARCH ARTICLE

ISSN: 2321-7758

EXPERIMENTAL EVALUATION OF CORROSION DAMAGED FLEXURAL MEMBER.

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Article Received: 22/04/2015 | Article Revised on:30/04/2015 | Article Accepted on:02/05/2015

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ABSTRACT

In this paper experimental investigations, GFRP and ferrocement were used to externally strengthen reinforced concrete beam. This work present result of 8 beams strengthened with using ferrocement and GFRP sheet. The result of this experimental work pointed out a general improvement in terms of load carrying capacity for the strengthened beam.

KEYWORDS – GFRP – glass fibre reinforced polymer

CFRP – carbon fibre reinforced polymer

FRP– fibre reinforced polymer, Ferrocement, Reinforcement concrete beam, Flexural test

1. INTRODUCTION

Reinforced concrete structures are important elements of infrastructure and buildings. Now a days buildings are found to be distressed or damaged. Such a building requires immediate attention and need of strengthening, retrofitting to bring them back to their functional use again. Today detritions of RC structures is one of the major problems in civil industry mostly large number of buildings are constructed according to older design course. Since replacement of such deteriorated structure takes plenty of money and tine, strengthening has become an acceptable way of improving the performance of the structures and extending their service. Many modern techniques are involved to proper effective strengthening and retrofitting methods.

In general structures my need retrofitting for one of the following:

1. Normal deterioration due to environmental effect
2. New functional or loading requirements entraining modifications to a structures
3. Damage due to accident

2. LITERATURE REVIEW :

I. Flexural Strengthening of Reinforced Concrete Beam using Ferrocement laminates With Partial Replacement of Fine Aggregate by Steel slag

II. J. Sridhar, R. Malathy[1], R.K. Sangeetha- Department of civil engineering, K.S. Rangasamy, College of technology, Tiruchengode, Namakkal, [1]Sona college of technology , salem, Tamilnadu, India

FINDING:The load is increased by using Volume fraction of mesh reinforcement 2.35% and 30 % replacement of fine aggrement by steel slag on the Strengthened beamand reduced deflection of beam is 46.43% as compared to control specimen.

III. Response of reinforced concrete beam retrofitted by ferrocement, International journal of scientific and Technology research volume 3, ISSUE 9, September 2014, Dr. Ragheed Fatehr Makki

FINDING: To increase the strength of beam in both shear and flexural by applying ferrocement method on reinforced concrete beam

IV. Khalifa , A.,A. Belarbi, and A. Nanni,"Share Performance of RC Members Strengthened with externally bonded FRP Wraps" Proc., 12th World conference of earthquake engineering, January 30- February 04 , 2000, Auckland , New zealand, Paper 305 ,10 PP

FINDING:To increases Share capacity of RC beam with efficiency by externally bonded CFRP on Retrofitted beam

3. Objectives:

A. To find out an effect on strength of the corrosion damaged RC Beam Retrofitted with Ferrocement in single layer at 0 Orientation by comparing the load carrying capacity of the retrofitted beam and control beam .
B. To determine the flexural rigidity of corrosion damaged RC Beam Retrofitted with ferrocement in single layer at 0 orientation by measuring deflection of the retrofitted beam and compare with control beam

4. Ferrocement:

Ferrocement is a type of thin wall reinforced concrete commonly constructed cement mortar with closely space layers of continuous and relatively small size wire mesh. In its role as thin reinforced concrete product and as laminated cement based composite, Ferrocement has found itself in numerous application both in new structure and repair.

4.1 Basic concepts of ferrocement:

i) Increase in bond strength: In reinforced concrete construction, the four ingredients are cement, fine aggregate, coarse aggregate, and steel reinforcement shares the load. The transfer of load from steel to concrete and vice versa takes place through bond between the two materials. The bonds depends on the bond strength of the concrete and the area of concrete between steel and concrete. The bond can be substantially increase if the contact area between steel and mortar is increased. In ferrocement it achieved by small diameter wire in place of steel bar

ii) Crack control: In conventional reinforced concrete the bars are spaced at some distance a part the surface this arrangement acts as crack arrester.

iii) Equal strength in both direction – The continuity and the placement of equal mesh reinforcement on both direction make ferrocement to achieve equal strength in two direction and become strong resisting diagonal tension due to sheer

iv) Its basic row materials are readily available in most countries.

4.2 Constituents materials and properties:

a) Cement- Cement should comply with Indian standard. The cement should be fresh of uniform consistency and free of limps. Cement factors are normally higher than in reinforced concrete.

b) Fine aggregate- The most common aggregate using ferrocement 2.36 mmIS Sieve passing Fine aggregates are used In Ferrocement Jacketing. It should be clean, hard, strong and free organic impurities, slit, and clay.

c) Water- Water use in the mixing is to be fresh and free from organic and harmful solutions which will lead to deterioration in the proportion of the mortar. Portable water is fit for use as mixing water as well as curing for ferrocement structure

d) Reinforcing Mesh- One of the essential components of the ferrocement is wire mesh. The function of the wire mesh and reinforcing rod in the first instance is to act as lath providing the form and to support the mortar.

e) Skeletal Steel- Skeletal steel as the name implies is generally use for making the framework of the structure upon which layers of mesh are laid. The rods are spaced as widely as possible up to 305 mm apart where they are not treated as a structural reinforcement.

f) Resins- A widerange of polymeric resins, including primers, putty fillers, saturates and adhesives are used with FRP system

g) Fiber: The great majority of materials are stringer and stiffer in the fibrous form than as bulk material. Fiber can be manufactured in continuous and discontinuous form. Continuous glass, armed, carbon fibers are common reinforcements use with FRP systems from strengthening of civil engineering structures.

Table 1: Typical types of Fibers

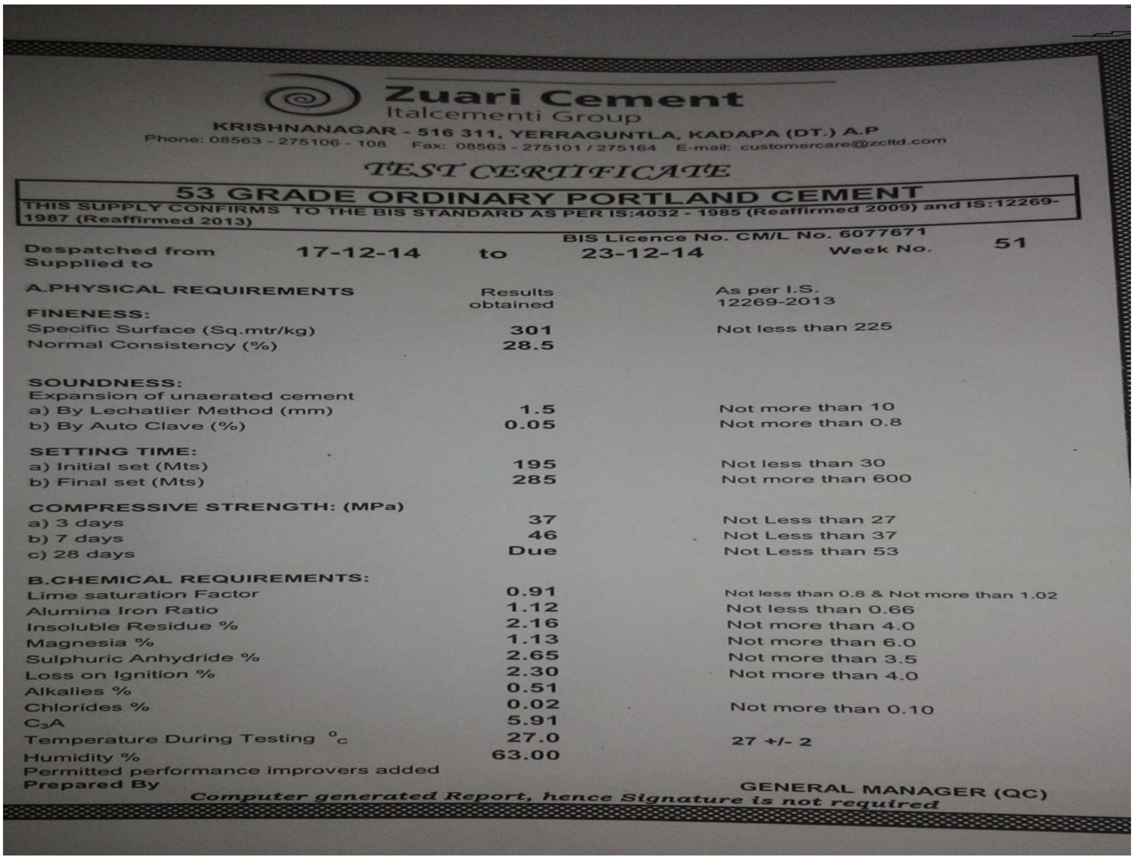
Materials	Elastic modules (GPA)	Tensile strength (MPA)	Ultimate tensile Strain(%)
Carbon			
High strength	215-235	3500-4800	1.4-2.0
Ultra high strength	215-235	3500-6000	1.5-2.3
High modulus	350-500	2500-3100	0.5-0.9
Ultra high modulus	500-700	2100-2400	0.2-0.4
Glass			
E	70	1900-3000	3.0-4.5
S	85-90	3500-4800	4.5-5.5
Aramid			
Low modulus	70-80	3500-4100	4.3-5.0
High modulus	115-130	3500-4000	2.5-3.5

5. EXPERIMENTAL WORK:

The objective of this investigation study the effect of ferrocement retrofitting on corroded beam.To acheievethis objectives a particular size of beams 100 mm × 150 mm × 1500 mm was used. Total 9 Beams were casted by M25 grade concrete out of this 3 beams are act as control beam with regular steel and 3 beams are act as control beam with corroded steel, to find out ultimate load carrying capacity of retrofitted beam and compare with control beam. 3 corroded beams are retrofitted with ferrocement of 0˚ in single layer. All beams were tested under two point loading by using universal testing machine.

5.1 Material used for M25 Grade concrete

5.1.1 Cement- Ordinary Portland cement of 53 Grades is used in this project work



Zuari Cement
Italcementi Group
KRISHNANAGAR - 516 311, YERRAGUNTLA, KADAPA (DT.) A.P
Phone: 08563 - 275106 - 108 Fax: 08563 - 275101 / 275164 E-mail: customercare@zclttd.com

TEST CERTIFICATE

53 GRADE ORDINARY PORTLAND CEMENT

THIS SUPPLY CONFIRMS TO THE BIS STANDARD AS PER IS:4032 - 1985 (Reaffirmed 2009) and IS:12269-1987 (Reaffirmed 2013)

BIS Licence No. CM/L No. 6077671

Despatched from 17-12-14 to 23-12-14 Week No. 51

Supplied to

A.PHYSICAL REQUIREMENTS	Results obtained	As per I.S. 12269-2013
FINENESS:		
Specific Surface (Sq.mtr/kg)	301	Not less than 225
Normal Consistency (%)	28.5	
SOUNDNESS: Expansion of unaerated cement		
a) By Lechatlier Method (mm)	1.5	Not more than 10
b) By Auto Clave (%)	0.05	Not more than 0.8
SETTING TIME:		
a) Initial set (Mts)	195	Not less than 30
b) Final set (Mts)	285	Not more than 600
COMPRESSIVE STRENGTH: (MPa)		
a) 3 days	37	Not Less than 27
b) 7 days	46	Not Less than 37
c) 28 days	Due	Not Less than 53
B.CHEMICAL REQUIREMENTS:		
Lime saturation Factor	0.91	Not less than 0.8 & Not more than 1.02
Alumina Iron Ratio	1.12	Not less than 0.66
Insoluble Residue %	2.16	Not more than 4.0
Magnesia %	1.13	Not more than 6.0
Sulphuric Anhydride %	2.65	Not more than 3.5
Loss on Ignition %	2.30	Not more than 4.0
Alkalies %	0.51	
Chlorides %	0.02	Not more than 0.10
C_3A	5.91	
Temperature During Testing °c	27.0	27 +/- 2
Humidity %	63.00	

Permitted performance improvers added

Prepared By

GENERAL MANAGER (QC)

Computer generated Report, hence Signature is not required

Fig. 1: Test certificate for Zuari cement

5.1.2 Fine Aggregate- Locally available natural river sand is used. The specific gravity is 2.82 and sieve analysis is confirmed to zone-II

5.1.3 Coarse Aggregate- crushed stone aggregate of maximum size 20 mm is used and specific gravity is 3.05

5.2 List of Test-

5.2.1 Test on Cement

a) Fineness Test (IS 12269-1987)

b) Standard Consistency Test

c) Setting Time Test

b) Compressive Strength

5.2.2 Test on coarse Aggregate-

a) Specific Gravity of coarse aggregate (IS 2386- part III 1963)

b) Sieve analysis of coarse aggregate (IS 3386 part I 1963)

c) Water Absorption- 1.24%

Table 2: Sieve Analysis of coarse Aggregate

IS Sieve	Weight Retained (kg)	Cumulative Weight Retained	Cumulative Percentage Retained (%)	Cumulative Percentage Passing
80mm	0.00	0.00	0.00	100
40mm	0.00	0.00	0.00	100
25mm	0.35	3.50	3.50	96.50
20mm	5.49	54.90	58.40	41.60
16mm	3.90	39.00	97.40	2.60
12.5mm	0.21	2.15	99.55	0.45
10mm	0.02	0.25	99.80	0.20
6.3mm	0.01	0.05	99.85	0.15
Pan	0.00	0.00	100	
Total	9.98	99.89	558	

5.2.3 Test on Fine Aggregate

a) Specific Gravity of Fine aggregate(IS.. 2386 part III-1963)

b) Sieve Analysis of Fine Aggregate(IS 2386 part I 1963)

Table 3: Sieve Analysis for Fine aggregates

IS Sieve	Weight Retained(kg)	Cumulative Weight Retained(kg)	Cumulative Percentage Weight Retained(%)	Cumulative percentage passing	Limits as per IS 386-1970
4.75mm	0	0	0	100	90-100
2.36mm	0.205	0.205	10.098	89.902	75-100
1.18mm	0.350	0.555	27.35	72.67	55-90
600 u	0.540	1.095	53.94	46.06	35-59
300 u	0.395	1.490	73.39	26.61	8-30
150 u	0.345	1.835	90.369	9.61	0-10
Pan	0.195	2.030	-	0	
Total	2.030		255.68%		

c) Water Absorption Test(IS 2386 part 1963)

d) Moisture Content of Fine Aggregate (IS 2386 part 3 1963)

5.2.4 Test On Steel:

HYSD steel of grade FE 500 manufactured by “Tata steel” were used in this project . The tensile strength results and testing arrangement are shown in below:

Table 4: Result of Tensile strength of 8 mm Fe 500 TMT Steel bar

Sr. No	Weight/meter(Kg)	Yield load(N)	Yield Stress(N/mm2)	Ultimate load (N)	Ultimate Stress(N/mm2)
1.	0.395	22560.66	448.66	27958.50	556.21

5.2.5 Corrosion of Steel By using Sulphuric Acid(H_2SO_4): The steel got Corroded in the presence of reaction due to water and sulphuric acid. The proportion used for the corrosion of steel as water: Sulphuric Acid is 1:0.001.The concentration of Sulphuric acid used for corrosion was 0.98 normality

After the 21 days the bar gave the following results

1. Weight of bar = 0.191 kg
2. Length of bar = 1m
3. Diameter of bar = 5.56 mm

Table 5: Result of Tensile strength of 8 mm Fe-500 TMT Corroded Steel bar

Sr. No.	Weight/meter (Kg)	Yield load (N)	Yield Stress (N/mm^2)	Ultimate load (N)	Ultimate Stress (N/mm^2)
1	0.191	11650.00	231.76	13150.33	261.61

5.3 Mix Design of M25 Grade Concrete

5.3.1 Design requirements:

1. Characteristics compressive strength at 28 days (fck) = 25 N/mm^2
2. 2. Type of cement = OPC 53-Grade conforming to IS 8112
3. Maximum normal size of the available aggregates = 20mm.
4. Minimum cement content = 300 kg/m^3
5. Shape of coarse aggregate = Angular
6. Workability =100mm Slump
7. Exposure condition = Mild
8. Degree of supervision = Good
9. Maximum Cement content = 450 kg/m^3

5.3.2 Test data of materials:

1. Specific gravity of cement =3.15
2. Specific gravity of coarse aggregate =2.65
3. Specific gravity of fine aggregate =2.82
4. Water absorption of coarse aggregate =1.24%
5. Water absorption of fine aggregate =2.56%
6. Surface moisture in fine aggregate =1.01%
7. Compressive strength of cement = 53 N/mm^2

Table 6: Mix proportion for M25 Grade concrete

Cement	Water	Sand(Fine aggregate)	Coarse aggregate
372.0 kg/m^3	186.0 kg/m^3	676.09 Kg/m^3	1216.71 Kg/m^3
1	0.5	1.81	3.27

5.4 Casting and Testing of Trial Mix:

To check the Compressive strength of calculated mix proportion of M25 Grade concrete casting if concrete cube specimens is done. Three concrete cube specimens were casted of 150 mm ×150mm × 150mm size, to check their 7 days compressive strength.

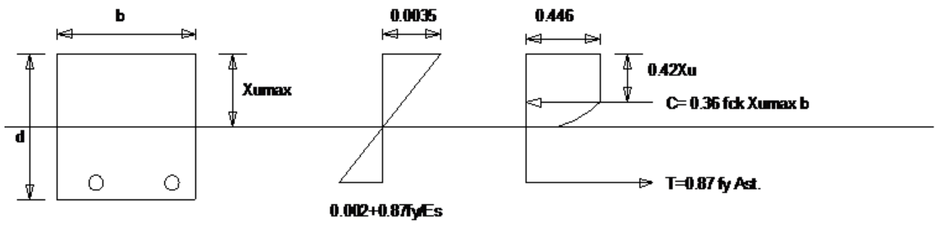
Table 7: Compressive strength result for Trial mix

Specimen Description	Age in Days	Load at failure (KN)	Compressive strength (N/mm^2)	Average Compressive strength(N/mm^2)
A	07	460.0	20.44	21.33
B	07	480.0	21.33	21.33
C	07	500.0	22.22	21.33
A	28	670.0	29.77	30.22
B	28	695.0	30.88	30.22
C	28	685.0	30.44	30.22

Test result of compressive strength of above mix for 7 days is 70.58 % of 28 days compressive strength so trial mix is adapted for further casting of concrete beams.

Fig 2: Testing of Cube on Compression Testing Machine

5.5 Analysis of R.C. Beam:



Equivalent stress diagram

5.6 Design of Reinforced Concrete Beam:

Design of reinforced concrete beam of size 100mm × 150mm × 1500mm.

Material used: Concrete – M25, Steel – Fe415 TMT.

b = 100mm, D = 150mm, effective cover = 25mm, d = 125mm.

For balanced section:-

Xu = Xumax.

Therefore,

Xmax. = 0.48 × d=0.48 × 125=60mm

Ast = [0.36 × fck × b × Xu] / 0.87 ×fy

= [0.36 × 25 × 100 × 60] / 0.87 × 415

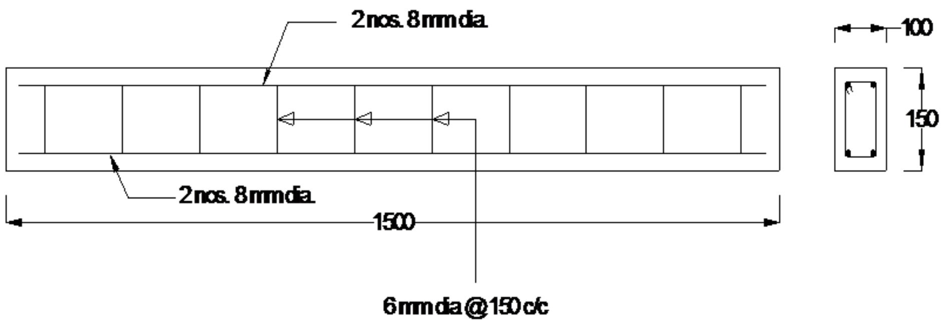
∴ Ast = 149.56 mm²

Use 8mm Φ HYSD bars,

No of bar = 149.56/50.26 = 2.97 = 3.

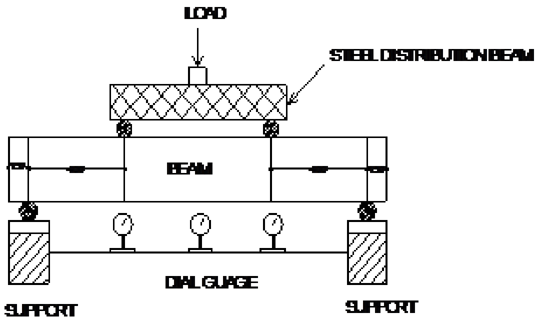
Hence, provide 2 bars of 8mm in dia. Therefore the given section is under reinforced.

Provide HYSD steel of grade Fe415 of 8mm and 6mm diameter bars are used 8mm dia. Bars are used as tension and compression reinforcement steel. 6mm dia. bars are used as shear stirrups and c/c spacing between two stirrups is 150mm. Sketches are shown below: (Photograph in Fig 1.)



5.7 Testing procedure and Instrumentation:

All beam specimens were instrumented and loaded simply supported as shown in fig. The load was applied through UTM machine. All beams were tested under two point loading. They were statically tested to failure at equal 2.45 KN increment of load. During loading the midspan deflection and deflection at 400 mm from two supports was measured by using dial gauge (0.01mm). First crack load and deflection were recorded for each stage.



`6. RESULT AND DISCUSSION

This chapter describes detail discussions of experimental result of control beams and all retro fitted RC beam by using ferrocement. The crack pattern, load vs deflection behaviour, moment of resistant, deflection and comparative study of all types of beams are also described.

6.1 Experimental results:

Table 8: Experimental results of all types of beams specimens

Beam type	Maximum Load (KN)	First crack load (KN)	Avg. Deflection (mm)
Control beam with regular steel	37.52	21.58	7.48
Control beam with corroded steel	23.14	12.75	6.69
Retrofitted beam with ferrocement	35.79	15.94	4.88

6.2.1 Comparison of load vs deflection of beams:

Table 9: Control beam with regular steel

Load (KN)	Deflection(mm)		
	Centre	**Side**	**Average**
2.41	0.02	0.01	0.01
4.90	0.03	0.02	0.02
7.35	0.04	0.03	0.03
9.80	0.45	0.30	0.37
12.25	0.85	0.47	0.66
14.70	1.43	0.96	1.19
17.15	2.10	1.26	1.68
19.60	3.10	1.72	2.41
22.05	3.65	2.10	2.87
24.50	4.07	2.57	3.32
26.95	4.85	2.86	3.84
29.40	5.62	3.12	4.31
31.85	6.04	3.96	5.00
34.30	6.85	4.76	5.80
36.75	7.12	5.22	6.16
37.77	7.71	6.71	7.21

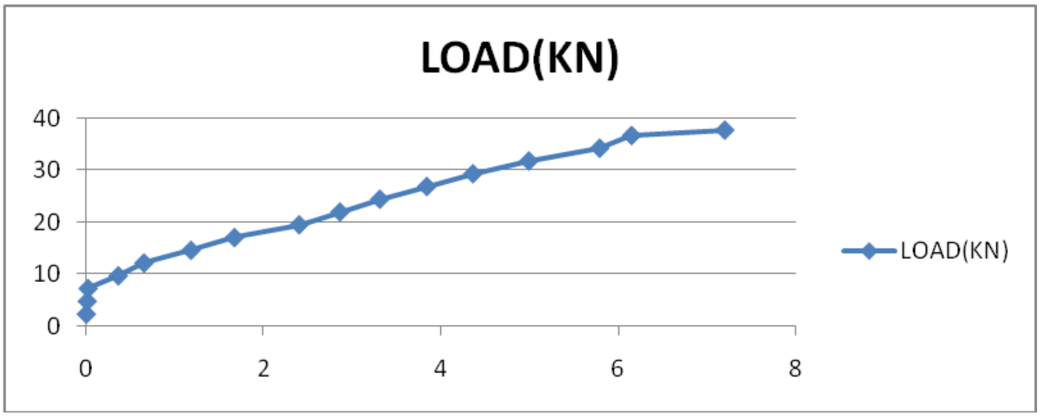


Fig. 3: Load vs Deflection curve for Control beam with regular steel

Table 10: Control beam with corroded steel

Load (KN)	Deflection(mm)		
	Centre	Side	Average
2.45	0.17	0.05	0.11
4.90	0.35	0.10	0.22
7.35	0.62	0.30	0.46
9.80	0.87	0.65	0.76
12.25	1.25	0.94	1.09
14.70	1.96	1.23	1.59
17.15	2.83	1.87	2.35
19.60	3.97	2.26	3.11
22.05	4.64	3.10	3.87
24.75	6.48	4.95	5.72

Table 11: Beam retrofitted with ferrocement

Load(KN)	Deflection(mm)		
	Centre	Side	Average
2.45	0.06	0.02	0.04
4.90	0.15	0.05	0.10
7.35	0.17	0.08	0.12
9.80	0.23	0.09	0.16
12.25	0.36	0.15	0.25
14.70	0.58	0.30	0.44
17.15	1.13	0.65	0.89
19.60	1.63	1.15	1.39
22.05	1.92	1.50	1.71
24.50	2.36	1.92	2.14
26.95	2.80	2.38	2.59
29.40	3.31	2.80	3.05
31.85	3.84	3.20	3.52
34.30	4.56	3.62	4.09

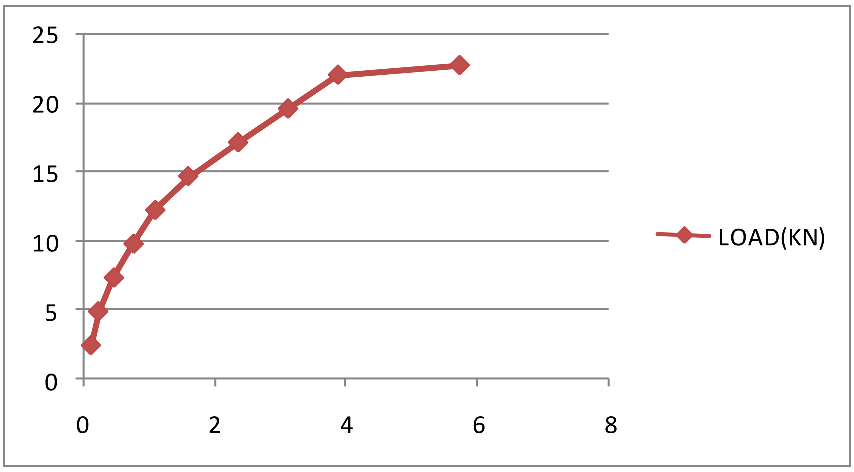


Fig. 4: Load vs Deflection curve for control beam with corroded steel

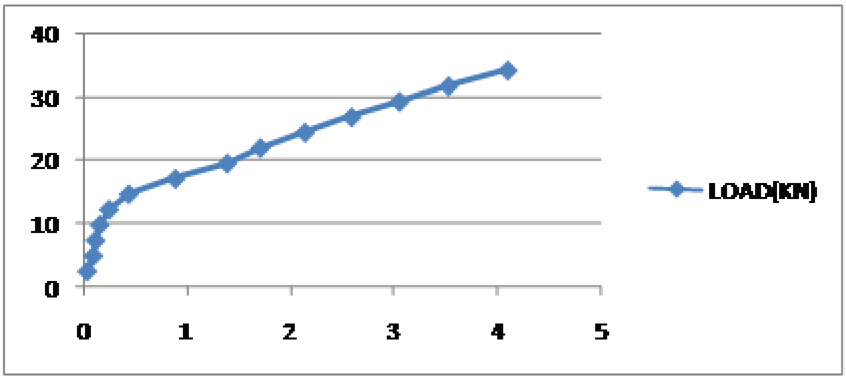


Fig. 5: Load vs deflection curve for retrofitted beam with ferrocement

Conclusion:

In this experimental investigations, Ferrocement were used to externally strengthen reinforcement concrete beams. This work present result of 9 beams strengthened with using ferrocement. The result of this experimental work pointed out a general improvement in terms of load carrying capacity for the strengthened beam.

1. The increase in load carrying capacity and performance of ferrocement beam.
2. Use of ferrocement mesh to reduce the crack width on the beam.
3. To reduce the deflection of beam by applying ferrocement method.
4. The comparison of theoretical moment of resistance and experimental one shows increase in experimental value by 18.78% for ferrocement.
5. The deflection of ferrocement retrofitted beam compared with control beam with regular steel decreases by 34.76%.

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