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STUDY ON FLEXURAL STRENGTHENING OF RC BEAM USING FERROCEMENT LAMINATES WITH SYNTHETIC FIBRE

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ABSTRACT

It has been understood from the literature review that the load carrying capacity of existing structures can be improved by strengthening it with ferrocement laminates. Also it has been observed from the literature that, properties of ferrocement laminates can be improved by altering the proportion and type of constituent materials. However studies to investigate the effect of fibre in mortar and different volume fraction of mesh reinforcement and utilisation of such material for strengthening of structural elements have not be carried out so far. Hence there exists a technical knowledge gap in its area. A research program to study the effect of fibre in ferrocement laminate as strengthening material for RC beams and their behaviour in terms of strength, ductility, energy absorption capacity would be of much relevance and usefulness. Hence, an attempt is to be made to conduct an experimental and analytical investigation to study the flexural behaviour of RC beams strengthened using ferrocement laminates with fibre. Ferro cement is one of the versatile materials for strengthening of structures and is identified as a novel construction material. For instance, the use of ferrocement in the construction of earthquake resistant structures, precast roof elements and other marine uses will result in the design of smaller sections. This in turn reduces the dead weight and leads to the design of cost effective structures. Ferrocement has been used more widely in recent years for strengthening of existing structural elements like beam, column, slab, beam column joint etc.

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1.INTRODUCTION

1.1 GENERAL

Worldwide a great deal of research is currently being focused on the use of effective material for repair and strengthening of existing reinforced concrete structure and the research is also concern about the effective utilization of fibre in construction industries.

The ageing of the nation's infrastructure in a tight economic environment has necessitated the search for innovative and cost effective solutions. In recent years, the use of ferrocement laminate has become a subject of great interest in structural community. Several studies had been focused on the use of externally bonded ferrocement laminates to reinforce existing structures in need of strengtheningNatural disasters such as earthquakes, tornadoes and tsunami threaten the integrity of civil infrastructures and safety of their uses. A large number of existing reinforced concrete buildings and other structures typically have not sufficient capacity to resist the forces during such catastrophes. In order to guarantee the safety of the people, the older structures need to be repaired and strengthened to prevent their collapse. Efficient methods are needed to be developed for structures repair and strengthening

1.2 STRENTHENING:

1.2.1 Introduction

The explosive growth of repair industry in the past 25 years has resulted in the need for many improvements in areas such as materials, design practices, installation procedure and education. These improvements are needed to increase service life and reduce costs and conflicts. They are of considerable importance when a damaged concrete structure needs to be strengthened to increase its capacity to meet current loading requirements. The concrete repair, protection and strengthening industry is driven by deterioration, damage and defects in concrete structures along with changes in the use of concrete and the development and enhancement of code requirements. Every year larger amount of concrete is laid around the world. Much of the concrete is custom made for each job, using local materials of varying quality. Designs that are not standard and accelerated construction processes sometimes result in quality being sacrificed in the interest of meeting a schedule. Such factors in addition to general causes such as increase in loads and environmental conditions may also increases or accelerate the deterioration if concrete structures.

1.2.2 Strengthening methods

i. Adding reinforcement steel bars to the main steel without increasing the beam's cross sectional area

ii. Section enlargement

iii. Sprayed concrete

iv. Steel plate bonding

v. Ferrocement laminates

vii. Strengthening using Fibre Reinforced Polymer

vi. Span shortening

2. FERROCEMENT

2.1 GENERAL

For achieving higher values of specific surface, number of layers of meshes needs to be increased. Many a time, it becomes difficult to force mortar in this layer. The fine diameter wires, with smaller openings pose more problems. This is over come by using different types of fibres to improve the specific surface of the reinforcement. As the fibre take care of cracking of mortar, bigger diameter wire meshes with larger opening can be used and which simplify the penetration of mortar in the meshes. This results in a high strength material for which flexural properties can be designed and predicted with much accuracy. It also offers higher energy absorption capacity and impact resistance to ferrocrete. Behaviour of such fibre in ferrocement laminates of reinforced beam will be studied in this project which includes flexural test. In general ferrocement is considered as a highly versatile form of composite material made of cement mortar and layers of wire mesh or similar small diameter steel mesh closely bound together to create a stiff structural form. This material, which is a special form of reinforced concrete, exhibits behaviour so different from conventional reinforced concrete in performance, strength and potential application it must be classed as a separate material. In rationally designed ferrocement structures, the reinforcement consists of small diameter wire mesh in which the proportion and distribution of the reinforcement are made uniform by spreading out the wire mesh throughout the thickness of the element. This distribution of achieving improvements in many of the engineering properties of the material such as fracture, tensile and flexural strength, toughness, fatigue resistance and impact resistance but also provide advantages and novelty of the concept have stimulated what is now considered a worldwide interest in the use of ferrocement.

2.2 DEFINITION OF FERROCEMENT (ACI 549)

Ferrocement is a thin walled concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small wire mesh. The mesh may be of metallic or other suitable materials.

2.3 HISTORICAL BACKGROUND

The credit of using ferrocement in the present day goes to Joseph Louis Lambton who In 1848 constructed several rowing boats ,plant pots, seats and other items from a material he called ferciment. Lambot‘s construction consisted of a mesh or a grid reinforcement made of two layers of small diameter on bars at right angle and plastered with cement mortar with a thin cover to reinforcement Lambot’s rowboats were 3.66 m long ,1.22 m wide and 25 mm to 38 mm thick .These were reinforced with grid and wire netting . One of the boat build by him, still in remarkably good condition, is on display in the museum at Brignoles, France .

There was very little application of true ferrocement construction between 1888 and 1942 when Pier Luigi Nervi began a series of experiments on ferrocement. He observed that reinforcing concrete with layers of wire mesh produced a material possessing the mechanical characteristics of an approximately homogenous material capable of resisting high impact. After the second world war Nervi demonstrated the utility of ferrocement as a boat building material. In 1945, Nervi built the 165 ton Motor Yatch “Prune” on a supporting frame of 6.35 mm dia rods spaced 106 mm apart with 4 layers of wire mesh on each side of rods with total thickness of 35 mm. It weighed 5% less than a comparable wooden hull and cost 40% less at that time. In 1947,Nervi built first terrestrial ferrocement structure ,a storage warehouse of about 10.7 m × 21.3 m .size .The strength of the structure was due to the corrugations of the wall and the roof which were 44.45 mm thick. In 1948 Nervi used ferrocement in first public structure, the Tutrin Exhibition building. The central hall of the building which spans 91.4 m, was built of prefabricated elements Connected by reinforced concrete arches at the top and bottom. of the undulations.

In 1958, the first ferrocement structure – a vaulted roof over shopping centre was built in Leningrad in Soviet Union. In 1970,a prototype prefabricated ferrocement home was constructed in U.S.A. The house was found much lighter in weight and higher in resistance to dynamic load than the conventionally built brick or block house.

In 1971 a ferrocement trawler named “Rosy in I” was built in Hong Kong. It had an overall length of 26 m & is claimed to be the worlds most longest ferrocement fishing boat.

In 1972, the US National Academy of sciences through its board on sciences and technology for international development established an ahoy panel on the utilization of ferrocement in developing countries.

In 1974, the American Concrete Institute formed committee 549 on ferrocement.

In 1976,the International Ferrocement Information Centre (IFIC) was founded at Asian institute of Technology ,Bangkok,Thailand). The centre is financed by the United States Agency for International development, the Government of New Zealand and the International Development Research Centre of Canada.

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In 1978 an elevated metro station of 43.5 m × 1.6 m in size with continuous ferrocement roofing was erected in Leningrad..

In 1984,ferrocement was used in the construction of a shaking table of large scale earthquake simulation facility at the state university of New York at Buffalo.

Recently, it has been reported that the Chinese have been building ferrocement boats even before world war second. It is estimated that they have built 2000 boats. Most of these boats are 12 m to 15 m long and are mainly used in carrying goods.

2.3.1 Wire Mesh Reinforcement

1. Hexagonal mesh
2. Woven mesh
3. Welded mesh
4. Expanded metal

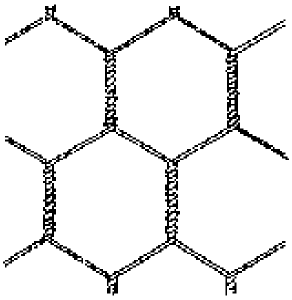

Figure2.1 Hexagonal wire mesh

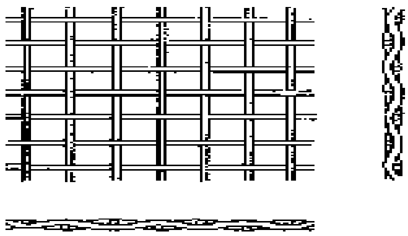

Figure.2.2 Square woven wire mesh

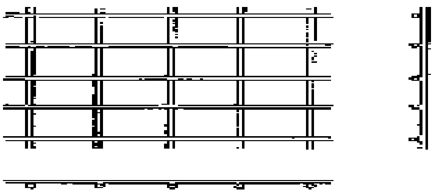

Figure.2.3 Square welded wire mesh

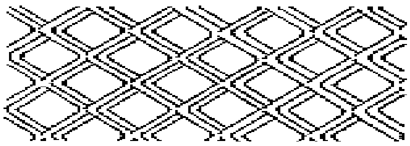

Figure.2.4 Expanded metal mesh

2.4 SPECIFICATIONS FOR FERROCEMENT

Table 2.1 Specifications for Ferrocement

Wire mesh reinforcement	Wire diameter	0.5≤ d_w ≤ 1.5mm
	Type of mesh	Square woven or welded galvanised wire mesh; aviary (chicken) wire mesh; or expanded metal mesh
	Size of mesh openings	6 ≤ D ≤ 25mm
	Number of mesh layer	Upto 6 layers per cm thickness
	Volume fraction of reinforcement	Upto 8% in both directions corresponding to upto 630kg/m^3 of steel mesh reinforcement
	Specific surface of reinforcement	Upto 4 cm^2/cm^3 in both direction
Skeletal reinforcement	Type	Wires; wire fabric, rods, strands
	Diameter	3 ≤ d_b ≤ 10mm
	Grid size	5 ≤ G ≤ 15cm
Typical mortar composition	Portland cement	Any type depending on application
	Sand to cement ratio	1 ≤ S/C ≤ 2.5 by weight
	Water to cement ratio	0.35 ≤ W/C ≤ 0.6 by weight
	Recommendations	Fine sand passing through 2.36 mm sieve is used
	Additives : air entraining agents, corrosion inhibitor, water reducing agent and super plasticizers as needed	
Composition properties	Thickness	< 30 mm
	Steel cover	1.5 to 3mm
	Ultimate tensile load	Upto 35 Mpa
	Allowable tensile stress	Upto 14 Mpa
	Modulus of rupture	Upto 70 Mpa
	Compressive strength	21 to 96 Mpa

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2.5 FIBRES

These are strong thread like filaments which when used in the concrete/mortar act as crack arresters. Continuous meshes woven fabrics and long rods do not fall within the category of discrete fibre type reinforcing elements. The main aim of introducing the fibres is to arrest cracks developed due to loading by applying the pinching force on the crack face. It doesn't allow the cracks to widen further and thus create a low crack propagation state.

Depending upon the parent material used for manufacturing fibres can be broadly classified as:

- Metallic fibres (e.g. Low carbon steel, Stainless steel, Galvanized iron, Aluminium)
- Mineral fibres (e.g. Asbestos, Glass, Carbon)
- Organic fibres or Polymeric or Plastic or Synthetic (e.g. Cotton, Resin, Polyester, Nylon, Polypropylene and Polyethylene)
- Inorganic or Natural fibres (e.g. Akwara, Bamboo, Coconut, Jute, Sisal, Sugarcane Bagasse, wood, coir and others).

2.5.1 Recron-3S Fibre:

There are so many type of polymer fibre available as secondary construction materials, The Recron-3S fibre is one of them, and The Reliance Industry Limited (RIL) has launched Recron-3S. Recron-3S polymer fibre for mixing concrete and mortar for improving certain properties of the concrete and mortar. Fibres have special triangular shape for better anchoring with other ingredient of the mix. There are two types of Recron-3S fibre i.e., polyester and polypropylene fibre.

Polyester fibre diameter varies from 20 µm to 40 µm. The fibres are generally sized by cutting. Common length of Polyester fibre is 3, 4.8, 6, 12, 18 and 24 mm. the properties of polyester fibre is given in table 2.2.

Table 2.2 Properties of Recron-3S (Polyester) fibres

Diameter (µm)	Specific gravity	Tensile Strength (GPa)	Elastic Modulus (Mpa)	Softening Point (°C)	Elongation (%)
20 – 40	1.34 – 1.39	4 – 6	>5000	250 – 265	20 – 60

2.5.2 Advantages of Recron-3s Fibre:

1. Addition of Fibres helps improve Concrete's early Resistance to Plastic Shrinkage cracking and thereby protects Concrete from Drying Shrinkage Cracks.
2. Improved Durability and Reduced Surface Water Permeability of Concrete.
3. Fibre Reinforcement in Concrete decreases the risk of Plastic Settlement Cracking over Rebar.
4. Easier and smoother finishing.
5. Reduced Bleeding of Water to surface during concrete placement which inhibits the migration of cement and sand to the surface and the benefits of the above will be Harder, more Durable surface with better abrasion resistance.
6. Uniform Distribution of Fibres throughout the Concrete improves Homogeneity of Concrete Matrix.
7. Enhanced Flexural Strength and Tensile Strength of Concrete.
8. Reduced Water Absorption, Greater Impact Resistance.

3.REVIEW OF LITERATURE

Sridhar et al. (2014)[11] investigated the flexural behaviour of reinforced concrete (RC) beams strengthened with ferrocement laminates using steel slag as a partial replacement material for fine aggregate. The parameter varied in this study includes Volume fraction of mesh reinforcement 1.88% and 2.35% and percentage replacement of steel slag (0% and 30%) to fine aggregate in ferrocement laminate. Galvanized square weld mesh with mortar mix ratio of 1:2 and water-cement ratio of 0.4 was used for ferrocement laminate. Four beams were strengthened with ferrocement laminates using the epoxy resin as a bonding agent. One control specimen and four strengthened beams were subjected to flexural test under two-point loading. The observations were focused on first crack load, ultimate load and mid span deflection. From the investigation result, it was concluded that the beams strengthened with ferrocement having a Volume fraction of 2.35% and 30% replacement of steel slag increases the load carrying capacity significantly under flexural load. Furthermore, other mechanical properties such as ductility and energy absorption capacity were found to be increased for specimens with 2.35% of Volume fraction of mesh reinforcement and 30% of steel slag replacement.

Rahman et al. (2014)[12] studied the effect of wire mesh on the strength of RC beams repaired using ferrocement layers. Three set RC beams of the same dimension (width 4″, thickness 6″ and span 5.5′) are tested up to ultimate load by one point loading system as a simply supported beam. After testing of beams three beams were repaired by 0.5 inch ferrocement layer on three sides. Three Beams were subjected to two layers of ferrocement on the bottom of thickness 1 inch and only one layer in a two sides. And another three beams were surrounded by total 1 inch ferrocement layer on three sides. Then the beams were tested again and comparison was made on cracking load, ultimate load and deflection between the normal beams and repaired beams. The study also represents performance of beam sets according to their different layer by graphical representation. From this paper, we can understand that the beams of bottom two layers ferrocement overlay (repairing) gave comparatively good performance.

4.EXPERIMENTAL INVESTIGATION ON FLEXURAL BEHAVIOUR OF RC BEAMS STRENGTHENED WITH FERROCEMENT LAMINATES

4.1 Cement

Cement is a material, generally in powder form, that can be made into paste usually by addition of water. The cement used for this investigation was OPC 43 grade cement. The specific gravity of the cement was found to be 3.15.

4.2 Fine Aggregate

The locally available river sand was used as fine aggregate in the present investigation. The sand is free from clayey matter, salt and organic impurities. Fine aggregate passing through 4.75 mm sieve was used. The specific gravity of sand was 2.65 and it is tested in accordance with IS 383-1970.

4.3 Coarse Aggregate

Coarse aggregate are the crushed stones, which is used for making concrete. The maximum size of coarse aggregate used for this investigation is 20 mm and its specific gravity was 2.7 which were tested as per IS 383:1970.

4.4 Water

Water should be portable and free from acids, oils, alkalise and other organic impurities

Table 4.1 Concrete compressive strength and split tensile strength

S.NO.	Cube compressive strength (N/mm^2)	Cylinder split tensile strength (N/mm^2)
1	37.7	2.54
2	38.22	2.47
3	37.55	2.75

Table 4.2 Properties of used fibre

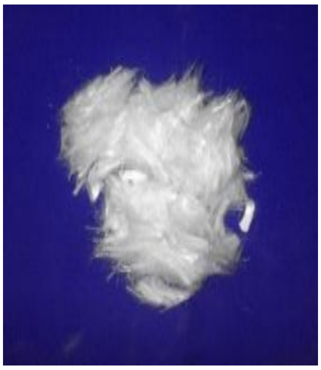
Fibre	**Polyester fibre**	 **Figure 4.1 Recron-3S (polyester fibre)**
Cut length	12mm	
Diameter	0.37mm	
Specific gravity	1.36	
Density	1360 kg/m3	
Aspect ratio	32.43	

Table 4.2Compressive strength of mortar

Cube Specimen	**Compressive Strength in N/mm^2**
CM	45
CM0.5%	32.5
CM1%	30
CM1.5%	23.5

4.5Casting of ferrocement laminate

Figure 4.2 Casting of ferrocement laminate

4.6Application of epoxy resin on RC beams and laminates

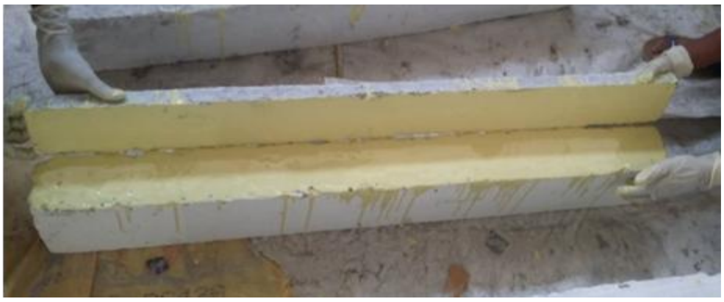


Figure 4.3 Application of epoxy resin on RC beams and laminates

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4.7 Experimental setup for testing of strengthened RC beams

Figure 4.4 Experimental setup for testing of strengthened RC beams

6.RESULTS AND DISCUSSION

6.1 First Crack Load

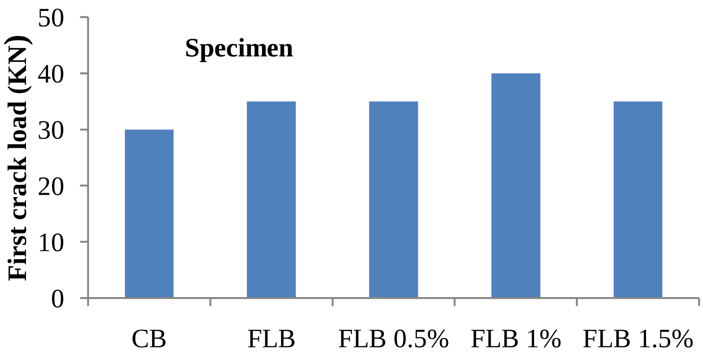

Figure 6.1 First crack load of RC beams

6.2 Ultimate Load

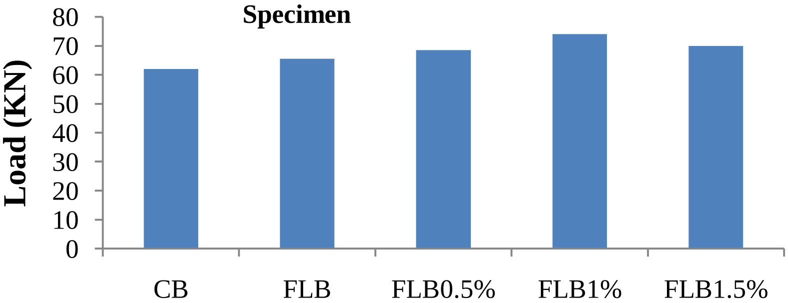

Figure.6.2 Ultimate load of RC beam

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6.3 Ductility Factor

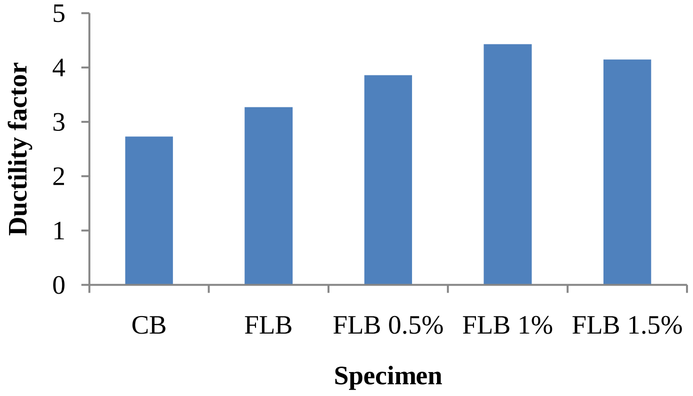

Figure 6.3 Ductility Factor of RC beams

6.4 Energy Absorptin

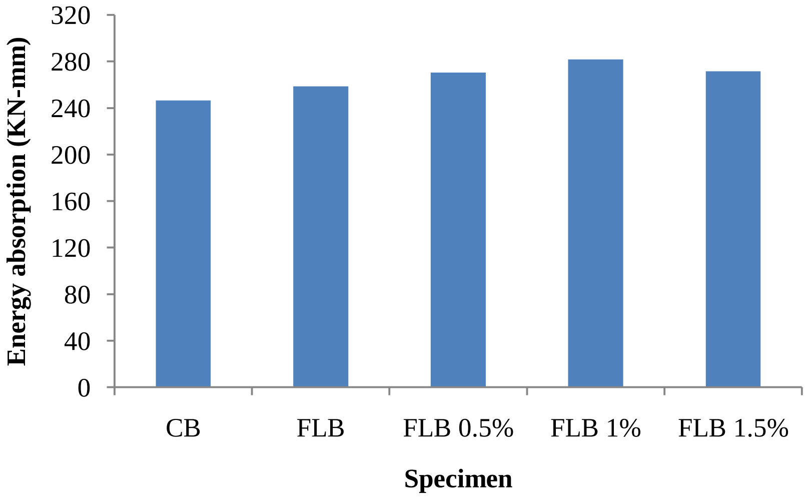

Figure 6.4 Energy absorption of RC beams

6.5 Stiffness Of RC Beams

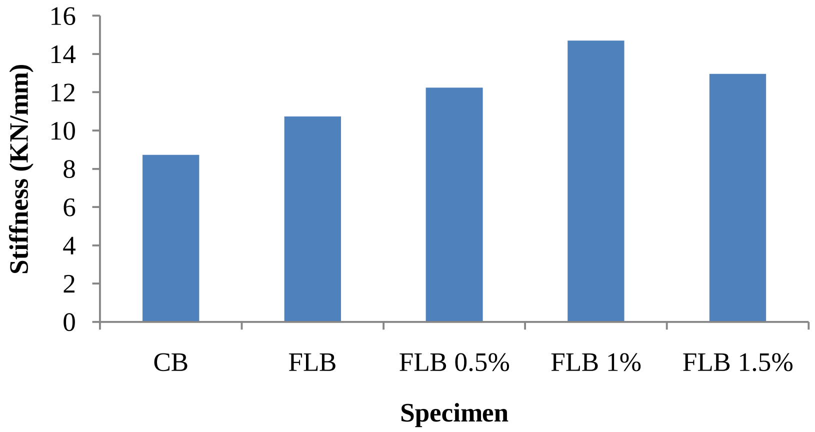

Figure 6.5 Stiffness of RC beams

Table 6.1 Comparison between analytical and experimental mid span deflection of RC beams at ultimate load

Beam designation	Analytical deflection (mm)	Experimental deflection (mm)	Ratio of experimental deflection to analytical deflection
CB	6.7	7.1	1.05
FLB	5.5	6.1	1.10
FLB 0.5%	5.1	5.6	1.09
FLB 1%	4.6	5.1	1.11
FLB 1.5%	4.9	5.4	1.10

Table 6.2 Comparison between analytical and experimental stiffness of RC beams

Beam designation	Analytical stiffness (kN/mm)	Experimental stiffness (kN/mm)
CB	9.25	8.73
FLB	12	10.73
FLB 0.5%	13.52	12.23
FLB 1%	16.3	14.7
FLB 1.5%	14.28	12.96

7. CONCLUSIONS

1. The epoxy resin used for bonding the ferrocement laminates to the tension face of the reinforced concrete beams ensures that the bond line does not break before failure of the beam.
2. The failure of the composite beam is characterised by development of flexural cracks over the tension zone.
3. Similarly The addition of ferrocement laminate to the tension face of the reinforced concrete beams substantially delays the first crack load.
4. Mechanical properties such as load carrying capacity, ductility factor and energy absorption capacity was found to be increased for strengthened beam.
5. The main objective and the background of this research project are outlined in the initial chapters. The experimental program and the analytical study performed during the research project to achieve the objective are explained and discussed in chapters 1 to 6. In general, the main objectives as indicated in chapter 1 have been achieved. This chapter will conclude the research study with the view to design an effective strengthening material for reinforced concrete beams.
6. Finally, it is concluded that use of Recron-3S fibre (polyester fibre) in ferrocement laminate have a considerable impact on its performance as a strengthening material.

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