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# FLEXURAL STRENGTHENING OF REINFORCED CONCRETE BEAMS USING FERROCEMENT BY BASALT REINFORCING MESH

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**ABSTRACT**

This paper reveals about work associated with the behaviour of strengthening the pre damaged reinforced concrete beams using ferrocement plates. The experimental study explains the mechanical properties of ferrocement with three different volume fractions of reinforcements. Eight beams of 100mm width, 150mm depth and 1600mm overall lengths were casted and tested for flexure. Out of eight beams two beams were considered as conventional and the remaining six beams were loaded up to 75% of ultimate load $P_u$ and strengthening was done by fastening ferrocement laminates. A Ferrocement plate was provided under the size of 100mm width, 25mm thickness and 1500mm length. For ferrocement laminates, Basalt FRP mesh was provided as reinforcement for three different volume fractions. Bonding between ferrocement and pre damaged beams are done by using epoxy resin adhesive. After strengthening were made to beams, flexural test were conducted for ultimate load carrying capacity. A comparative study was made between the control beams and strengthened beams. From the result it has been seen that the ferrocement laminates of Basalt FRP mesh can be used as a strengthening material for damaged beams.



## 1. Introduction

On day to day civil engineering works damage occurs in structures leads to major problems. That which occurs due to carbonation, chloride attack, environmental pollution, poor quality of building materials. Moreover many civil structures are no longer considered safe due to increase load specifications in the design codes or due to overloading or due to under design of existing structures or due to lack of quality control. On that case to maintain serviceability, retrofitting works has to be done on old structures or to damaged structures so that the structure maintain same requirements built today and in future. The repair and retrofitting work should be economical and environmental. On that case ferrocement has received attention as a potential building material and also as retrofitting material and strengthening on damaged structural members. Ferrocement is a type of reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of relatively small wire diameter mesh. The mesh may be made of metallic or other suitable materials. These meshes may be in steel or other suitable materials. Shuxin wang et.al [10] have used hybrid ferrocement with meshes and fibers such as kelvar mesh and expanded steel mesh. One of the main advantages of ferrocement is that it can be constructed with a wide spectrum of qualities, properties, and cost. In this study Basalt FRP mesh were used as reinforcement for ferrocement. Basalt is a natural, hard, dense, dark brown to black volcanic igneous rock originating at a depth of hundreds of kilometres beneath the earth and the surface as molten magma. Its gray dark in colour, formed from the molten lava after solidification. For flexural strengthening ferrocement laminates of 100mm width, 25mm thick and 1500mm length were casted and bonded on the tension face and compression face of the beams. This investigation showed that the strengthened beam reducing the deflection and increasing the ultimate load carrying capacity.

### 2. Materials used

For the beam specimens, the concrete attaining the design compressive strength of 20 N/mm2 was prepared using the locally available coarse aggregate of maximum size 20mm, having fineness modulus 6.15 and specific gravity 2.62, the fine aggregates passing through 4.75mm IS sieve conforming to zone II, having fineness modulus 2.72 and specific gravity 2.61, satisfying the IS specifications were used. Ordinary Portland cement conforming to IS specifications, having specific gravity of 3.01 was used. High yield strength deformed bars of Fe500 steel was used as the reinforcement in beams. For casting the ferrocement laminates, Basalt FRP mesh of 3mmx3mm spacing and 5mmx5mm spacing are tied together having volume fraction of 0.125% were used. Ferrocement were embedded in mortar mix of 1:2 made of Ordinary Portland cement and locally available river sand. Properties of Basalt FRP mesh are given in table 1.

**Table1: Properties of Basalt FRP mesh**

| Property | Unit | Value |
|---|---|---|
| Mesh window size | mm | 3,5*3,5 |
| Tensile strength | MPa | 3000-4800 |
| Modulus of elasticity | GPa | 110 |
| Density | $g/cm^3$ | 1700 |

## 3. Details of experimental program

The main objectives of the experimental program were to investigate the effect of Basalt FRP mesh on ferrocement as a strengthening material.

### 3.1 Details of beam specimen

Rectangular cross section reinforced concrete beams of eight numbers were casted at size of 100mm width, 150mm depth, 1600mm overall length. M20 grade concrete satisfies mix proportion of 0.5:1:1.57:2.92. Fe500 grade steel bars of 2 nos of 10mm diameter are provided in both compression and tension face of beams and 8mm diameter bar of 150 mm centre to centre are provided as stirrups for shear reinforcement based on design. Inner surface of steel mould were applied with machine oil. The measured quantity of cement, fine aggregate and coarse aggregate were mixed thoroughly, the measured quantity of water was added to the dry mix and mixing was done properly. The steel reinforcement was placed inside the mould with proper cover. Concrete was poured layer by layer and compacted and finished well. The beam specimens were removed from the mould after 24 hours of casting and concrete beams were placed in curing tank for curing for 28 days. Out of eight beams two beams (CB1, CB2) were considered as a control beams were loaded up to failure for ultimate load carrying capacity ($P_u$). Remaining six beams was loaded up to 75% of ultimate load carrying capacity $P_u$. Then the damaged beams were strengthened ferrocement laminates having the volume fractions of 0.126%, 0.252% and 0.378%.

### 3.2 Details of ferrocement laminates

Silver oak wooden moulds were used for ferrocement at size 100mm width, 25mm thickness, 1500mm length provided. Mix provided for ferrocement is 1:2. For reinforcement Basalt FRP mesh of three different volume fractions are used $V_r$ = 0.125%, 0.252%, 0.378%. On a wooden mould cement mortar were poured at bottom surface and first layer conforming the volume fraction of 0.125% (SB1, SB2) swere placed and top surface were smoothened well similarly two layers conforming the volume fraction of Vr = 0.252% (SB3, SB4) were casted and for three layers conforming volume fraction of Vr = 0.378% (SB5, SB6).

### 3.3 Test beam preparation

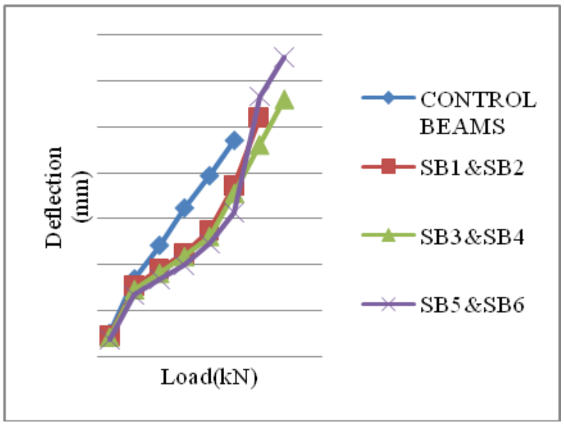
The description of the test beams is summarized in table 2. The soffit of the pre damaged beam was chiselled to rough the surface and cleaned using brush to clear the debris. A thin layer of epoxy resin was applied on both cleaned surface of the beam and ferrocement laminates was bonded properly without any air gap between the two surfaces.

**Table 2 Details of test beams**

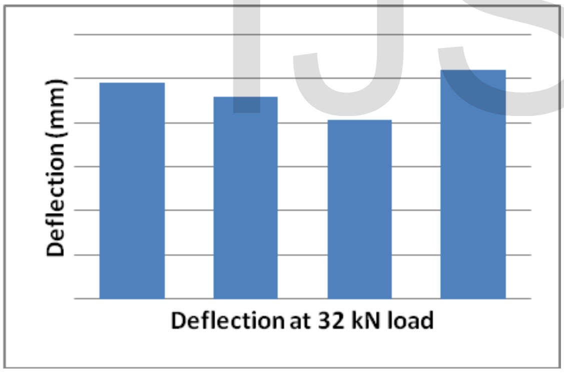
| Series number | Beam code | Damage level | Volume fraction $V_r$ |
|---|---|---|---|
| 1 | CB1&CB2 | - | - |
| 2 | SB1&SB2 | 75% $P_u$ | 0.126% |
| 3 | SB3&SB4 | 75% $P_u$ | 0.252% |
| 4 | SB5&SB6 | 75% $P_u$ | 0.378% |

### 3.4 Test procedure and instrumentation

Beam specimens are instrumented and simply supported and loaded. All beam specimens were tested under two point loading. The load was applied through loading frame machine capacity of 25 tonne. Proving ring with load capacity 50kN is provided for calculating applied load. Mid-span deflections are noted using deflectometer. Load was applied by increment of 2kN, mid span deflections was observed carefully. And the deflection was note for 5kN, 10kN, 15kN, 20kN, 25kN, 30kN and for ultimate load $P_u$. Deflections were noted for control beams and strengthened beams which are predamaged and laminate plates were bonded. Graph1 shows deflection of strengthened beams and control beams at different stages of loading respectively. Ultimate loading and deflections were given in table 3. Graph 2 shows deflection at ultimate load.




**Graph 1 Load Vs Deflection curve**




**Graph 2 Deflection at ultimate load**

**Table 3 ultimate loading and deflections**

| S. No | Beam code | Volume fraction $V_f$% | First crack load kN | Ultimate deflection mm | Ultimate loading kN |
|---|---|---|---|---|---|
| 1 | CB1 & CB2 | - | 13 | 24.62 | 32 |
| 2 | SB1 & SB2 | 0.126 | 15.5 | 27.04 | 38 |
| 3 | SB3 & SB4 | 0.252 | 17 | 31.7 | 43 |
| 4 | SB5 & SB6 | 0.378 | 19 | 35 | 44 |

**Table 4 Deflection at different loadings**

| S. No | Beam code | Deflection in mm at different stages of loading (kN) | | | | |
|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 32 | Ultimate load |
| 1 | CB1 & CB2 | 8.52 | 16.19 | 23.5 | 24.62 | - |
| 2 | SB1 & SB2 | 7.8 | 11.23 | 18.68 | 23.08 | 27.04 |
| 3 | SB3 & SB4 | 7.3 | 10.9 | 17.8 | 20.32 | 31.7 |
| 4 | SB5 & SB6 | 6.7 | 9.98 | 15.72 | 26.03 | 35 |

## 4 Results and Discussion

The test results are given in table 3, table 4 and then graphically represented in graph 1 and graph 2. It shows that all distressed beams of 75% $P_u$ and strengthened by ferrocement using Basalt FRP mesh act as a good strengthening material. A comparison between control beam and strengthening beams shows that initial stage of crack and ultimate loading are get to increased by -----%. Particularly ferrocement having the volume fraction of 0.378% performed well than 0.126% and 0.252%. the ferrocement having volume fraction of 0.252 subjected to reduction in deflection at ultimate load. This increase in load carrying capacity and reduction in deflection is due to the addition of ferrocement laminate which increases the cross sectional area, therefore increasing the moment of inertia and stiffness of the beam sections. Epoxy bonding gets to break after the ferrocement is fully cracked.

**Conclusion**

From the experimental study that adding ferrocement plate on beam surface for strengthening provides good effect on stiffness, reduction in deflection and increases load carrying capacity. Using three layer of Basalt FRP mesh provides better stiffness on rehabilitated beams.