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Stregthening of precracked high strength concrete beam using fibre reinforced ferrocement laminate

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ABSTRACT

Ferrocement laminates are introduced to enhance the overall performance of pre-cracked high strength concrete beams. Eight beams of size 150mm width, 200mm depth and 1500mm overall length were cast and tested for flexure. Out of eight beams two beams were treated as control beams and the remaining beams are to damaged under overloading by applying 65% ultimate load for two beams and 75% ultimate load for another two beams and 85% ultimate load for remaining two beams and strengthened by fastening ferrocement laminates. Fastening of ferrocement laminates onto the tension surface of the pre-cracked beam was done by using epoxy resin adhesive. The strengthened beams were again tested for ultimate load carrying capacity by conducting flexural test. A comparative study was made between the control beams, the pre-cracked beams strengthened by ferrocement laminates. From the test results it could be seen that ferrocement can be used as an alternative strengthening material for the pre-cracked high strength concrete beams damaged due to overloading.

Introduction

A large number of Civil Engineering structures around the globe are in a state of serious deterioration today due to carbonation, chloride attack, environmental pollution, poor quality of building materials, and lack of involving expertise opinion. Moreover many Civil Engineering structures are no longer considered safe due to increase in load specification in the revision of new codes, due to overloading, due to under design of existing structures. Every structure should have designed to withstand particular intensity of loading. However many structures are often required to be upgraded or strengthened to withstand the increased load requirement. Therefore strengthening of the existing structures becomes inevitable both economically and environmentally compared to replacement. In order to maintain efficient serviceability older structures must be repaired and strengthened so that they can meet the same requirements of structures built today and in future. It is becoming both economically and environmentally preferable to repair or strengthen the structures rather than to replace particularly when rapid, effective, simple, economical strengthening methods are available. Ferrocement strengthening technique over the years have gained respect in terms of its superior performance and versatility not only in housing industry but also in retrofitting and strengthening of damaged structural members. Ferrocement is a thin structural member consisting of closely spaced relatively small diameter wire mesh like weld mesh and woven mesh completely embedded in rich cement mortar mix. These meshes may be in steel or other suitable materials. Ferrocement laminates with skeletal bar can take significant role in strengthening reinforced concrete members. For flexural strengthening ferrocement laminates were cast and bonded onto the tension face of the beams with the laminates having dimensions 150mm width, 25mm thick and 1300mm length. As this technology emerges, the structural behavior of reinforced concrete beam elements strengthened with ferrocement laminates needs to be fully characterized. A strengthening method has been also developed by Lamina et.al (2004), where the strengthening strip is entirely mechanically attached to the concrete surface using multiple small, distributed power activated fasteners without any bonding and showed a greater ductility than the beam strengthened with a bonded strip. Investigations into the methods of anchorage of ferrocement laminates in the strengthened beams, methods of increasing the ultimate load of the original beams using ferrocement laminates and the effect of damage of the Sivagurunathan. B et al (2012) original beams prior to repair are examined. This investigation showed that the strengthened beams have performed better in reducing the deflection and increasing the ultimate load carrying capacity.

Materials Used

For the beam specimens, M30 the concrete was prepared using the locally available coarse aggregate of maximum size 20mm, having fineness modulus 6.97 and specific gravity 2.9, the fine aggregates passing through 4.75mm IS sieve conforming to zone II, having fineness modulus 2.61 and specific gravity 2.65, satisfying the IS specifications were used. Ordinary Portland cement conforming to IS specifications, having specific gravity of 2.92 was used. High yield strength deformed bars of Fe415 steel was used as the reinforcement in beams. For casting the ferrocement laminates, woven and weld mesh tied together having a volume fraction of 2.192% was used. These ferrocement reinforcement was fully embedded in rich cement mortar mix 1:2 made from 1 part of ordinary Portland cement and (1.5 locally available river sand + 0.5 of copper slag)

Details of the casting and testing of specimens

Eight full scale rectangular reinforced concrete beams of dimensions 150mm wide, 200mm depth and 1500mm overall span with 1300 mm effective span were cast and tested. The beams were reinforced with three numbers of 12mm diameter bars at the tension face, two numbers of 12mm diameter bars at the compression face and 8mm diameter bars as stirrups at 125

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mm centre to centre. For casting of beams teak wood moulds and steel moulds satisfying the beam dimensions were prepared. The inner surface of the mould was spread with machine oil. The measured quantity of cement, fine aggregate and coarse aggregate were mixed thoroughly to obtain a uniform color in the laboratory concrete mixer. 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. The concrete was poured into the mould in layers. Each layer of concrete was compacted well. The top surface of the concrete was finished well. The beam specimen was removed from the mould after 24 hours of casting and cured using wet gunny bags for 28 days. The beams CB1 and CB2 were loaded upto failure (ultimate load Pu) by subjecting the beam for two points loading and the general arrangement for testing the control beams and the precracked rehabilitated beams were shown in Figure1. The precracked beams were strengthened using ferrocement laminates. The soffit of the beam was sand blasted to roughen the surface. Then the surface was thoroughly cleaned of debris using an air blower. For casting the ferrocement laminates the wooden moulds of size 150mm width 1300mm length and 25mm thick was used as shown in Figure 2. A thin layer of rich cement mortar 1:2 was laid at the bottom of the wooden mould. Over this two layers of ferrocement reinforcement confirming to volume fraction Vr = 4.384% was placed. Then the top surface was smoothened well. Similarly ferrocement laminate was cast for three layers of ferrocement reinforcement confirming to volume fraction Vr = 6.576 % .The casted ferrocement laminates were cured well. A thin layer of epoxy resin was applied both the surfaces of the cleaned beam surface and the laminates using trowel and the ferrocement laminate was bonded properly without any air gap between the two surfaces on the bottom of the beam as shown in figure 2. From the eight beams two beams (CB1 and CB2) were designated as control beam and were tested for the ultimate load carrying capacity (Pu). The remaining six beams were pre damaged to a load of applying 65% ultimate load for two beams and 75% ultimate load for another two beams and 85% ultimate load for remaining two beams.

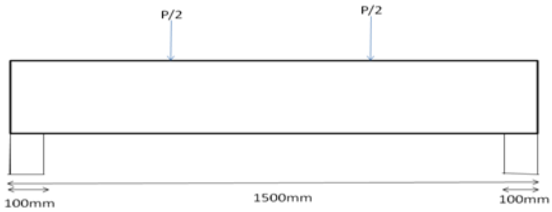


Fig 1. Loading Arrangement

Characteristics of reinforcing MESH

The principal type of wire meshes used in the ferrocement laminates, and their properties are given in table 1.Arrangements of mesh reinforcements with volume fraction (V_r = 2.192%) contributes with one layer of weld mesh and one layer of woven mesh. Arrangements of mesh reinforcements with volume fraction (V_r = 4.384%) contributes two layers of weld mesh and two layer of woven mesh. Arrangements of mesh reinforcements with volume fraction (V_r = 6.576%) contributes three layers of weld mesh and three layer of woven mesh. One layer of weld mesh and one layer of woven layer was tied together to act as one layer of ferrocement reinforcement confirming to volume fraction V_r = 2.192%. Details of Ultimate Load of Beams applied and strengthening details given in table 2.

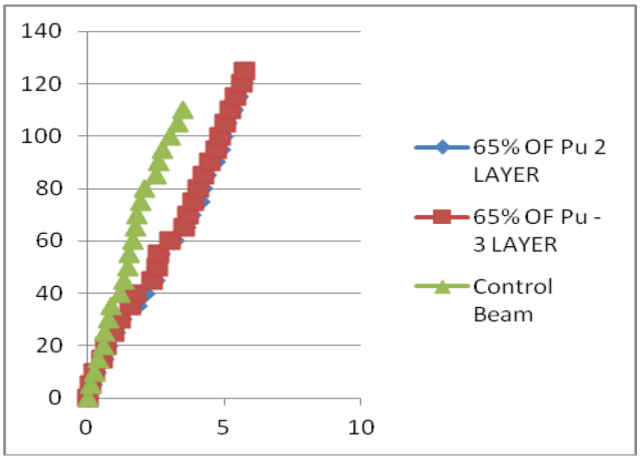
Table 1. Properties of reinforcing mesh

Type	Shape	Gauge	Wire spacing in mm	Wire diameter in mm
Steel mesh	Square weld	20	6.52	0.92
	Hexagonal weld	24	11.24	0.75

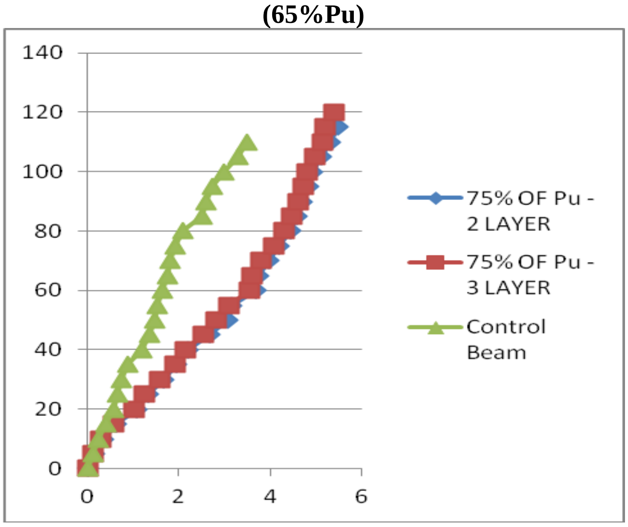

Fig 2. Beam strengthened on loading frame

Beam	% of Pu	No. of layers
B1	65% Pu	2
B2	65% Pu	3
B3	75% Pu	2
B4	75% Pu	3
B5	85% Pu	2
B6	85% Pu	3

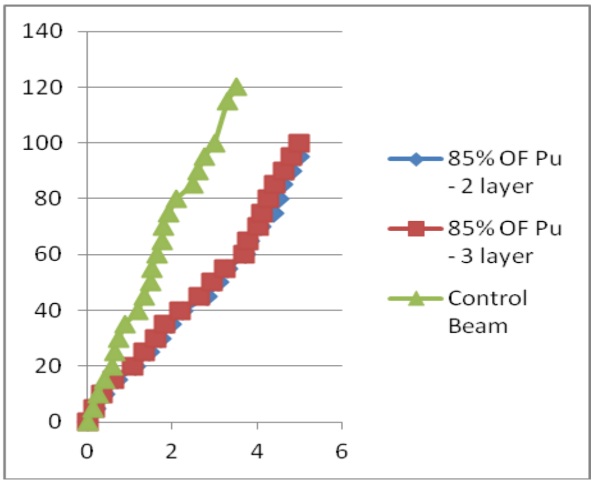
Table 2. Ultimate Load of Beams applied and strengthening details



Graph 1 Comparsion of stregthened beam 2 layer & 3 layer (65%Pu)



Graph 2 Comparison of strengthened beam 2 layer & 3 layer (75%Pu)



Graph 3 Comparison of strengthened beam 2 layer & 3 layer (85%Pu)

Result And Discussion

Graphically represented in Graph 1, 2 and 3 shows the comparative representation of all the eight beams grouped in series distressed 65%Pu, 75%Pu and 85%Pu and rehabilitated by ferrocement laminates having two different volume fractions of ferrocement reinforcement. The ultimate load of control beams is 110 KN and the corresponding 65%, 75% and 85% of stress level are 71KN, 82KN, 93KN respectively. Then the rehabilitation of the beams is done with ferrocement laminate of two layers and three layers of meshes for each loading condition. Afterwards these rehabilitated beams were then loaded to failure and data was recorded in the form of load and deflection. The ultimate load of after strengthening of different stress of beams are 65%, 75%, 85% in two layer mesh of laminate are 124KN, 123KN,and 95KN, and three layer of laminate are 127KN,125KN and 102KN. The results indicate that the beams rehabilitated with three layer laminate at 65%Pu beam is best among all other specimen. Compared to control beams 65%Pu rehabilitated beams with two and three layer meshes carries 11.3% and 11.5% more , 75%Pu rehabilitated beams with two and three layer meshes carries 11.1% and 11.3% more 85%Pu rehabilitated beams with two and three layer meshes carries 10.4% and 10.7% high.

Conclusion

The application of ferrocement layer has given adequate confinement for the reinforced concrete beams. Hence during testing of beams, splitting of concrete did not occur for the beams rehabilitated by plate bonding. The addition of ferrocement laminate in predamaged beams increases the stiffness of the beam and hence increases in load carrying capacity and reduction in deflection. Moreover the bonding of ferrocement laminate by plate bonding technique has less labour involvement and is cheaper compared to other methods of strengthening the distressed beams available.

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