International Journal of Advanced Technology in Engineering and Science
Vol. No.7, Issue No. 03, March 2019
www.ijates.com
ijates
ISSN 2348 - 7550

Experimental investigation on strengthening of predamaged Reinforced concrete beam using ferrocement laminates

Dr.P.Subramanian, K.Eswaran , S.Thaththathirian , S.Yogaraj , K.Logesh

Professor and Assistant Professor, Department of Civil Engineering Sengunthar Engineering College, Tiruchengode, TamilNadu, India

Student , Department of Civil Engineering, Sengunthar Engineering College, Tiruchengode, TamilNadu, India

Abstract

Ferrocement are most commonly used as retrofitting material due to their easy availability, durability, and their property of being cast to any shape without needing significant formwork .In this investigation we have studied the flexural failure of flanged beam under various ranges (60% & 70%)of preloading for ultimate strength of control beam..The performance of specimens subjected to cyclic loading was evaluated after being subjected to a predetermined number of cycles at various stress ranges. The results of experimental tests show that ferrocement is a viable alternative strengthening component for the rehabilitation of reinforced concrete structures.

Key Words: *Preloading, Ferrocement Laminates, Flexural, Strengthening*

1. INTRODUCTION

The initial definition of ferrocement can be drawn from a patent application submitted by joseph-louis lambot of France, in 1852. Ferrocement can be considered the first application and the very origin of reinforced concrete. During the First World War, ships and barges were built with reinforced concrete, and this was again attempted during the Second World War due to shortages of materials, particularly steel.

Today ferrocement is widely accepted and utilized. Technical information on ferrocement can be obtained from the International Ferrocement Centre (IFIC), the American Concrete Institute, RILEM, IASSS and many national centres.

2. PREVIOUS RESEARCH WORK

Several research work strengthening of preloading RC beam using different ferrocement laminates flexural strength have been studied in this paper.

Ganapathy and Sakthieswaran (2015) studied the behaviour of Reinforced Concrete Beams Strengthening by using fibrous Ferrocement Laminates composites which were directly glued into the cracked tension face of the beam by epoxy adhesives. Beams were cast and tested under two points loads. Five beams were kept as perfect beam and the remaining beams are cracked under overloading by applying 70% ultimate load. The cracked beams were strengthened by polymer modified fibrous ferrocement composites with two different volume fractions (4.94%, 7.41%).

Eldeen (2015) studied this paper concerned with strengthening and retrofitting of reinforced concrete beams completely damaged due to flexural failure. The strengthening technique consists of steel wire mesh with and without additional longitudinal steel angles, cast and tested less than two points loading. All beams were tested and loaded monotonically to failure, and then cracks were filled with grout mortar. The beams were strengthened and retrofitted under the existing deformation using two and three external plies of expanded galvanized steel wire mesh with square grids in the form of U-jacket. The investigated parameters were the size of longitudinal steel angles, which were added at the bottom corners of beams inside the steel wire mesh. In addition, numbers of vertical steel clamps (2, 4 and 6) were used to fix the jacket to eliminate the de-bonding. The strengthened and retrofitted beams were again tested under two points loading. The results shows the increasing numbers of steel wire mesh plies fixed with 2, 4 and 6 vertical clamps without external steel angles increase the beam carrying capacity from 26.59% to 49.55%.

Sridhar et al. (2014) probed the flexural behavior of reinforced concrete (RC) beams strengthened with ferrocement laminates using steel slag from the steel industry 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. 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

ijates
ISSN 2348 - 7550

ferrocement having a volume fraction of 2.35% and 30% replacement of steel slag increases the load carrying capacity significantly under flexural load. Incorporation of steel slag in ferrocement laminates with volume fraction 2.35% and steel slag replacement 30% have highly reduced the deflection when compared to other specimens. The addition of ferrocement laminate to the tension face of the RC beams substantially delays the first crack load.

Ragheed (2014) conducted experimental works is presented to investigate the behavior of reinforced concrete beams retrofitted by ferrocement to increase the strength of beams in both shear and flexure. Ten reinforced concrete beams are cast in order to study different parameters such as shear reinforcement (stirrups), different diameters of wire mesh used in rehabilitation, two types of rehabilitation are used first (strengthening) and second (repairing) the beams are initially stressed to a different prefixed percentage of the ultimate load and finally mechanical method is used to fixed the wire mesh of ferrocement (using bolts) to eliminate the debonding of ferrocement and trying to reach the full maximum tensile strength of ferrocement. The beams have been tested under two-point loading. From the investigation result, the use of ferrocement meshes as external strengthening or repairing have a significant effect on crack pattern of the reinforced concrete beams by delaying the crack appearance and reducing the crack width, also causing in large deflection at the ultimate load.

Rahman et al. (2014) made a comparison on strengthening of reinforcement concrete beam using ferrocement overlay. Three set beams were subjected to approximately ultimate load. After damaging these beams were repaired by ferrocement layer in three different thicknesses. 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 results of tests performed in this study indicated that significant change has occurred at ultimate load, cracking load and deflection.

Bhalsing et al. (2014) investigated the tensile Strength of Ferrocement with respect to Specific Surface. Single layer and double layer weld mesh was used in this study. Loading was applied gradually through a hydraulic system and mid span displacements were recorded. The loading was continued till the failure of specimen occurred. The initial and final crack width is recorded. The behaviour of other combination has been studied for tensile strength and ultimate load at failure. Author concluded that, the load taken by the ferrocement depends upon the number of reinforcing mesh layers used in ferrocement. Increase in number of mesh layers also improves ductility of ferrocement. As the specific surface increases there is increase in the tensile strength of ferrocement.

Bashandy (2013) studied the efficiency of strengthened reinforced concrete beams using some valid strengthening materials and techniques. Using concrete layer, reinforced concrete layer and steel plates are investigated and Beams have been tested under two-point loading. The experimental results show that the use of steel mesh increases the ultimate load by about 11-25%. It also enhanced the stiffness and the crack pattern compared to plastic meshes used.

Khan et al. (2013) studied the effectiveness of ferrocement strengthening techniques i.e., cast in situ Ferro-mesh layers and precast ferrocement Laminate. Beams have been tested under two-point loading till service limit. Beams have been strengthened in the flexural dominant region only and tested to failure under the same loading arrangement. It has been concluded that strengthening through cast in situ Ferro-mesh layer is the most efficient technique. Cast in situ Ferro-mesh layer has been found to be the most suitable strengthening technique among all strengthening techniques investigated.

Shaheen et al. (2013) determined the mechanical properties of the steel and wire meshes, ultimate load, flexural behaviour, ductility ratio, energy absorption and mode of failure at collapse of the control beams, which were reinforced with steel and compared their behaviour with conventional reinforced ferrocement beams reinforced with expanded metal mesh, welded metal mesh and glass fibre mesh. Use of welded steel mesh gave the highest results compared to all tested beams. Results show a decrease in the ductility ratio, less deflection at the corresponding load levels.

Khan et al. (2013) studied the serviceability performance of RC beams strengthened through two Ferrocement strengthening techniques as Cast in situ Wire-mesh layers and precast Ferrocement Laminates. The beams were cast and tested under two-point loading up to service load of 40 kN. Then, beams were strengthened by Cast in situ Wire-mesh layers and by precast Ferrocement Laminates. Performance of RC beams strengthened by three layers of Wire-mesh using both techniques has been found better in terms of maximum increase in stiffness.

Patil et al. (2012) investigated the performance of chicken mesh in ferrocement that were retrofited to strengthen the RC beams which was initially stressed to a prefixed percentage of the safe load to increase the strength of beam in both shear and flexure, the chicken mesh is placed along the longitudinal axis of the beam. To carry out the investigation, six prototype beams of size 140mm x 220mm x 1550mm reinforced with three bars of 8 mm diameter in tension and two bars of 8mm diameter in compression were cast. Out of these six beams, two were used as control beams and were tested to failure to find out the safe load carrying capacity corresponding to the allowable deflection. The other four beams were stressed to 60 & 80 percent of the safe load obtained from the testing of the control beams and were then retrofitted with 15 mm thick ferrocement jackets made with 1:2 cement sand mortar and w/c ratio 0.40. The jacket was reinforced with doubled layer of 10mm x 10mm Hexagonal chicken mesh. From the study it is seen that the safe load carrying capacity of rectangular RC elements retrofitted by ferrocement laminates is significantly increased with chicken mesh used for retrofitting.

Sivagurunathan (2012) studied the behaviour of strengthening the predamaged reinforced concrete beams by using ferrocement plates. Ferrocement laminates are introduced to enhance the overall performance of reinforced concrete beams. The result shows 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.

Veera Reddy and Maheshwar Reddy (2011) studied the rehabilitation of shear deficient of RC beam, strengthened using ferrocement jacketing while maintaining the original cross sectional dimensions. The preloading levels adopted in this investigation were 70%, 90% and ultimate load. Ferrocement jacketing with 2,4,6 and 8 layers of woven wire mesh. The behavior of the virgin concrete beams and the rehabilitated concrete beams using Ferrocement jacketing with various specific surfaces is same upto about 57 % of the ultimate strength of virgin beam. The mode of failure is transformed from shear to flexure in strengthened beams.

Kumar et al. (2010) studied the effect of Acrylic Latex in ferrocement for strengthening the reinforced concrete beams. The mechanical properties of mortar through difference in polymer content with Acrylic Latex by ferrocement among three different volume fractions of mesh reinforcement were studied. Tests were carried out involving the application of the reinforced repair material to the soffit of the reinforced concrete beams of 3 m length. Result from the test program showed that by incorporation of polymers, the mesh reinforcement with volume fraction 5% appropriate for compressive as well as flexural members and 6.43% for tensile members.

Kumar et al. (2010) reported the mechanical properties of mortar through difference in polymer content (SBR Latex) and by ferrocement with three different volume fractions (3.55%, 5% and 6.43%) of mesh reinforcement. The control beams were loaded to failure and the remaining beams were loaded to 70% of ultimate load under two-point loading. Then it was rehabilitated with ferrocement laminates by filling the cracks with a low viscous resin. Better strength can be achieved by adding of 15% of SBR through 5% volume fraction of mesh reinforcement in the polymer ferrocement specimens. The flexural and compressive strength of polymer-modified mortars were generally improved over unmodified mortar.

Paramasivam and Ong (2009) reviewed the methods of repair and strengthening of the reinforced concrete beams using ferrocement laminates attached on to the surface of the beams. The transfer of forces across the ferrocement interface, the effect of level of damage sustained by the original beam prior to repair, and the results of repeated loading on the performance of the strengthened beams were discussed. The results showed that ferrocement is a viable alternative as a strengthening material for the rehabilitation of reinforced concrete structures.

Ganesan et.al (2009) experimentally investigated the suitability of ferrocement as a retrofitting material for RCC frames, which are subjected to distress under lateral cyclic loading. It is consists of casting and testing two identical single span three storey RCC frame under lateral loading until the frames develop distress in the form of cracks at the beam column joints. After unloading retrofitting at beam column joint was adopted for one of the frames using ferrocement while for the other frame a glass fibre reinforced polymeric (GFRP) laminates were used. The result for the RC frame specimen retrofitted with ferrocement, there is significant improvement in properties, behaviour and strength than the specimen retrofitted with GFRP scheme. Both the retrofitted specimens showed a significant percentage reduction in the deflection values then the bare frame.

Jeyasehar and Vidivelli (2006) presented a method of rehabilitating the overloading damaged reinforced concrete (RC) beams above the original capacity level using ferrocement laminates which were directly glued to the cracked tension face of the beam by epoxy adhesives and were tested under a two point loading system up to failure. For this study a total of sixteen beams were cast and tested. Then these beams were repaired and rehabilitated by ferrocement laminates with three different volumes of fractions of reinforcement, one for each category. The beams were tested under static monotonic and repeated loading. The result shown that all beams experienced flexural failure, none of the beams exhibit premature damage.

Palani and Subramanian (2006) studied the effect of high performance ferrocement laminates on the strengthening of reinforced concrete (RC) rectangular beams. Welded and oven, mesh were used for the preparation of ferrocement. Silica fume and slag were used as mineral admixtures for the preparation of high performance cement (HPC) mortar. The beams were tested under two point static monotonic loading. The experimental results of strengthened beams shown that irrespective of the pre cracking level, better cracking behaviour for all test specimens could be achieved by strengthening with high performance ferrocement laminates.

Ganesan and Shyju (2005) conducted experimental investigation to study the effect of ferrocement jacketing on strength and behaviour of distressed RC beams. The reinforced concrete beams were subjected to different types of loading (0.7,0.8&0.9 times the ultimate load)these loaded beams were then strengthened by laminates having different values of volumes fraction of reinforcement (0.26,0.52 &0.78%).The test result shows that the beams strengthened with ferrocement laminates having increased load carrying capacity .It was also noted that there was an increase in the stiffness and energy absorption capacity of distressed beam jacketed with ferrocement.

Bansal (2004) used the plates of different materials viz CFRP, GFRP, ferrocement etc are bonded to the surface of structural member to increase its strength. In his work, effect of wire mesh orientation on the strength of stressed beams retrofitted with ferrocement jackets has been studied. The beams are stressed up to 75 percent of safe load and then retrofitted with ferrocement jackets with wire mesh at different orientations. The results show that Wire mesh orientated at 45 degree for retrofitting the stressed beams has the highest load carrying capacity as compared to control beam as well as the other beams retrofitted using different orientations.

Naaman et al. (2004) studied the bending response of hybrid ferrocement plates with Meshes and Fibers. Three types of meshes including expanded steel mesh, Kevlar FRP mesh combined with two types of synthetic fibers, namely PE Spectra 900 fibre and PVA fibres. The layers of mesh were made constant. The specimen was tested under four point bending. The addition of fibbers to the matrix was very effective in preventing the spalling of mortar cover at ultimate load.

Shang et al. (2003) studied response of ferrocement thin plates reinforced with wire meshes as flexural strengthening material for reinforced concrete beams. Results show that ferrocement has obvious effects on raise of crack-resisting capacity, increase of the number of cracks, and decrease of the crake width. Ferrocement contributes greatly to improvement of the bending stiffness of RC beams. At given loads, the mid-span deflection for strengthened beams was lower than that of the control beams.

Table .1 Experimental results and load carrying capacity of the reference beam

Author/Size of beam(mm)	**Beam ID**	**Material**	**No of Layer's**	**Adhesive**	**% of Pre-damaged beam**	**Failure mode**
Ezz-Eldeen (2015) / 1250x120x100	Group 1,2,3.4.5	Galvanized steel wire mesh	2,3	Steel bolts	60%	Flexure
Ganapathy and Sakthieswaran (2015) / 150X150X1000	CB	Mesh	Multi layers	Epoxy	70%	The flexural strength is increased
Sridhar et al. (20014) / 1220x100x15	CB,FB01,02,03,04	Square weld mesh	1,2,4	Cerabond EP epoxy resin	Replacement of steel slag(0%-30%)	flexural cracks over the tension zone
Rahman et al. (2014) / 100x150x1600	BS 1.1	Wire mesh	1,2	Bonding agent	-	Shear and flexural cracks over the

						tension zone
Ragheed (2014) / 140x240x2000	CB 1,2 BS1,2,3,4 BR1,2,3,4	CFRP,GFRP, Steel mesh	1	U wrap of steel wire	50% to 70%	Shear and flexural cracks over the tension zone
Khan et al. (2013) / 150x200x1800	Group A,B,C	Wovan Ferro-mesh	2,3,4	Resin	45%	3 layer of ferro-mesh performed better in terms of load carrying capacity and stiffness
Bashandy (2013) / 100x150x1100	CB, Group A,B,C	Steel & Plastic mesh	1	Epoxy resin Sikadur-31CF, Kemapoxy-165GT	76%	flexural cracks over the tension zone
Patil et al. (2012) / 140x220x1550	Type-A,B,C	Chicken mesh	2	Retrofitting	60% to 80%	flexural cracks over the tension zone
Sivagurunathan (2012) / 125x250x3200	BP1, BP2	Wovan and weld mesh	1,2,3	COROCRETIN IHL-18	75%	flexural cracks
Kumar et al. (2010) / 125X250X3200	BP1,BP2BOR1 to BOR6	Wovan and weld mesh	1,2,4	EPLV COROCRETIN IHL-18	70%	flexural cracks
Paramasivam and Ong (2009)	RD1,RD2,RD3	Weld mesh	-	Epoxy resin	-	Shear
Jeyasehar and Vidivelli (2006)	BOR1 – BOR12	Woven mesh, Chicken mesh, Weld mesh	1,2	A low viscous resin grout	60%-90%	Flexural failure
Bansal (2004) / 127x227x4100	A,B,C,D	Weld mesh, CFRP, GFRP, wire	1	Retrofitting	75%	Flexure

3. CONCLUSIONS

In our effort to study on strengthening of pre-damaged RC beams using ferrocement laminate. The following conclusions were made

- The specific gravity of cement and fine aggregate obtained was 3.15 and 2.65.
- Base on the properties of materials the concrete mix design is made.
- The sizes of beam were 1100x100x150mm.
- In the next phase of the thesis the fabrication of RC beams will be made and beams will be preloaded with 60% of control beam.
- The pre-damaged beam will be strengthened using ferrocement laminates with different volume fraction.
- The strengthened beam and UN strengthened beams will be tested under two point loading.
- The observations will be made for first crack load, ultimate load and deflection at the midpoint and crack pattern.

Further a 3D finite element analysis will be carried out using ANSYS. More over comparative study between experimental and analytical results will be made for strengthened and un-strengthened specimen.

REFERENCES

[1] Alaa A. Bashandy (2013), "Experiments on Flexural Strengthening of Reinforced Concrete Beams Using Valid Strengthening Techniques", Acta Technica Napocesis: civil Engineering and Architecture, vol.56, No.1, pp.36-50.

[2] Ezz-Eldeen, H. A. (2015), "An Experimental Study on Strengthening and Retrofitting of Damaged Reinforced Concrete Beams using Steel Wire Mesh and Steel Angles", International Journal of Engineering Research & Technology , vol.4, no. 5, pp.164-173.

[3] Ganapathy.L and N.Sakthieswaran (2015), "Strengthening of Reinforced Cement Concrete Beam Using Fibrous Ferrocement Laminates", International Journal of Science and Engineering Research, vol.3, No.5.

[4] Ganesan.N, Indira.P.V and Shyju.Thadathil.P (2009), "Strength and Behaviour of RCC Frames Retrofitting With Ferrocement", Journal of Ferrocement, vol. 2.2, pp.101-111.

[5] Jeyasehar Antony.C & Vidivelli.B (2006), Behaviour of RC Beams Rehabilitated with Ferrocement Laminates", Eight International Symposium and Ferrocement and Thin Reinforced Cement Composites, vol6, pp 485-499.

[6] Khan.S.U, Nuruddin.M.F, Ayub.T and Shafiq.N (2013),"Effects of Ferrocement in strengthening the serviceability properties of Reinforced concrete structures", Advanced Material Research, vol.690,pp 686-690.

[7] Khan.S.U, Rafeeqi S.F.A and Ayub.T (2013), "Strengthening of RC beam In Flexure Using Ferrocement", IJST of Civil Engineering, vol. 37, pp 353-365.

[8] Malathy.R, Sridhar.J and Sangeetha.R.K. (2014), "Flexural Strengthening of Reinforced Concrete Beams Using Ferrocement Laminates with Partial Replacement of Fine Aggregate by Steel Slag", Journal of Engineering and Technology, vol.4, pp.123-126.

[9] Motiur Rahman. Md, Tahmina Tasnim Nahar and Anish kumer saha (2014), "Effect Of Wire Mesh On The Strength Of R.C.C. Beams Repaired Using Ferrocement Layers", International Journal For Research And Development In Technology ,vol.1,no.1,pp.13-18.

[10] Naaman.E Antoine (2006), "Ferrocement and Thin Reinforced Cement Composites: Four Decade of Progress", Eight International Symposium and Ferrocement and Thin Reinforced Cement Composites, vol6, pp.435-445.

[11] Palani.B and Subramanian.R (2006), "Behaviour of RC Beams Strengthened with High Performance Ferrocement, Journal of Ferrocement,vol. 2.2, pp.89-100.

[12] Paramasivam.P and Kcg Ong (2009), "Structural Strengthening Using Ferrocement Laminates", Journal of Ferrocement,vol. 2.2, pp.331-342.

[13] Prem Pal Bansal, Maneek Kumar, S.K.Kaushik (2004), "Effect of Wire Mesh Orientation on Strength of Beams Retrofitted Using Ferrocement Jackets", Journal of Ferrocement, vol. 2.2, pp.101-111.

[14] Ragheed Fatehi Makki.Dr (2014), "Response of Reinforced Concrete Beams Retrofitted by Ferrocement", International Journal of Scientific & Technology Research vol 3, pp.2277-8617.

[15] Raj kumar.D and Vidivelli.B (2010), "Acrylic rubber latex in ferrocement for strengthening reinforced concrete beams", American Journal of Engineering and Applied sciences, vol.3.No.2, pp.277-285.

[16] Raj Kumar.D and Vidivelli.B (2010), "Performance of SBR Latex Modified Ferrocement for Repairing Reinforced Concrete Beams", Australian Journal of Basic and Applied Sciences, vol.4, No.3, pp.520-531.

[17] Sandesh S Patil, R.A.Ogale and Arun Kr. Dwivedi (2012), "Performance of Chicken Mesh on Strength of Beams Retrofitted Using

Ferrocement Jackets", IOSR Journal of Engineering, vol.2, No.7, pp.1-10.

[18] Sivagurunathan.B and Vidivelli.B (2012),"strengthening of predamaged Reinforced Concrete Beams by Ferrocement Plates", International Journal of Current Engineering and Technology,Vol.2,No.4,pp.340-344.

[19] Veera Reddy.M and Maheshwar Reddy.E (2011), "Rehabilitation of Shear Deficient RC Beams", International Journal of Earth Sciences and Engineering, vol.04, No.6, pp. 1125-1128.

[20] Yousry B.I.Shaheen, Noha M.Soliman and Ashwaq M. Hafiz (2013), "Structural Behaviour of Ferrocement Channels Beams", Concrete Research Letters, vol.4, No.3, pp.621-638.

[21] Shang.S.P , Zeng L.O and Peng.H (2003), "Flexural Strengthening Of Reinforced Concrete Beam With Ferrocement, 28th Conference on our world in concrete & structures, vol.6, pp 501-508.

[22] Ganesan and shyju P.Thadathil (2005), "Rehabilitation of reinforced concrete flexural elements using ferrocement jacketing", journal of structural engineering, Vol.31, No.4, pp.275-280.

[23] Swayambhu Bhalsing, Sayyed Shoaib and Pankaj Autade,(2014) "Tensile Strength of Ferrocement with respect to Specific Surface", International Journal of Innovative Research in Science, Engineering and Technology, vol.3,No.4,pp.501-507.