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Study on strengthening of corroded RC beam using ferro-cement laminates

Dr.P. Subramanian, K.Eswaran, S.Bala Subramanian, N. Prema Nandhini

Department of Civil Engineering, Sengunthar Engineering College, Tiruchengode, Namakkal District, Tamilnadu (India)

ABSTRACT:

Strengthening of reinforced concrete structure improves the load carrying capacity and extends their service life. To extend the life span of RC corroded beam, strengthening is required and this can be effectively achieved using ferro-cement. Ferro-cement is a composite material of weld mesh and woven mesh embedded in mortar with various volume fractions. In this work the ferro-cement laminate with 3 and 4 layer with chicken mesh and square weld mesh is used.

The main objectives of this research work are, to study the flexural behaviour of corroded beam with varies ferro-cement configuration under two point loading, to compare the experimental and analytical results of strengthened corroded RC beam for the parameters likes first crack load, ultimate load carrying capacity, stiffness and energy dissipation.

Keywords: *corroded beam, ferro-cement laminate, 3 and 4 layers, chicken mesh, square weld mesh.*

INTRODUCTION

The initial definition of ferro-cement can be drawn from a patent application submitted by Joseph-Louis Lambot of France, in 1852. Ferro-cement 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 ferro-cement is widely accepted and utilized. Technical information on ferro-cement can be obtained from the International Ferro-cement Centre (IFIC), the American Concrete Institute, RILEM, IASSS and many national centers. The journal of ferro-cement, which is published at the Asian Institute of Technology in Bangkok, presents regular advances in research, applications and standards related to ferro-cement.

American Concrete Institute Committee 549 has defined ferro-cement in broader sense as "a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar, reinforced with closely spaced layers of continuous and relatively small diameter mesh". The mesh may be metallic or may be made of other suitable materials. Ferro-cement possesses a degree of toughness, ductility,

Durability, strength and crack resistance which is considerably greater than that found in other forms of concrete construction these properties are achieved in the structures with a thickness that is generally less than 25 mm, a dimension that is nearly unthinkable in other forms of construction and a clear improvement over conventional reinforced concrete.

The construction of ferro-cement can be divided into four phases:

1. Fabricating the skeletal framing system
2. Placing rods and meshes
3. Plastering
4. Curing

LITERATURE SURVEY

The research works carried out by various researchers related to strengthening of corroded RC beam have been discussed.

Sridhar et al. (2014) probed the flexural behavior of reinforced concrete (RC) beams strengthened with ferro-cement 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 ferro-cement 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 ferro-cement 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 ferro-cement laminates with volume fraction 2.35% and steel slag replacement 30% have highly reduced the deflection when compared to other specimens. The addition of ferro-cement 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 ferro-cement 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 ferro-cement (using bolts) to eliminate the de-bonding of ferro-cement and trying to reach the full maximum tensile strength of ferro-cement. The beams have been tested under two-point loading. From the investigation result, the use of ferro-cement 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.

Bhalsing et al. (2014) investigated the tensile Strength of ferro-cement 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 behavior of other combination has been studied for tensile strength and ultimate load at failure. Author concluded that, the load taken by the ferro-cement depends upon the number of reinforcing mesh layers used in ferro-cement. Increase in number of mesh layers also improves ductility of ferro-cement. As the specific surface increases there is increase in the tensile strength of ferro-cement.

Khan et al. (2013) studied the effectiveness of ferro-cement strengthening techniques i.e., cast in situ Ferro-mesh layers and precast ferro-cement 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 ferro-cement beams reinforced with expanded metal mesh, welded metal mesh and glass fiber 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 ferro-cement strengthening techniques as Cast in situ Wire-mesh layers and precast Ferro-cement 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 Ferro-cement 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.

Naveen et al. (2012) experimentally studied the effect of blast furnace slag on first crack and ultimate strength and the behavior of Light Weight Ferro-cement Beam under Monotonic and Repeated Flexural Loading. In this work foamed blast furnace slag was employed as light weight fine aggregate, as a replacement of sand by 0%, 10%, and 20% and 30%. Galvanized woven square meshes of six layers were used. Based on the experimental investigations it was concluded that the first crack and ultimate strength increases up to 10% replacement of sand, light weight ferro-cement beams had good moment of resistant under both monotonic & repeated loading.

Patil et al. (2012) investigated the performance of chicken mesh in ferro-cement that were retrofitted 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 ferro-cement 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 ferro-cement laminates is significantly increased with chicken mesh used for retrofitting.

Sivagurunathan (2012) studied the behaviour of strengthening the pre damaged reinforced concrete beams by using ferro-cement plates. Ferro-cement laminates are introduced to enhance the overall performance of reinforced concrete beams. The result shows the addition of ferro-cement laminate in pre damaged 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 ferro-cement jacketing while maintaining the original cross sectional dimensions. The preloading levels adopted in this investigation were 70%, 90% and ultimate load. Ferro-cement jacketing with 2,

4, 6 and 8 layers of woven wire mesh. The behaviour of the virgin concrete beams and the rehabilitated concrete beams using Ferro-cement jacketing with various specific surfaces is same up-to about 57 % of the ultimate strength of virgin beam. The mode of failure is transformed from shear to flexure in strengthened beams.

Paramasivam and Ong (2009) reviewed the methods of repair and strengthening of the reinforced concrete beams using ferro-cement 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 ferro-cement is a viable alternative as a strengthening material for the rehabilitation of reinforced concrete structures.

Ganesan et.al (2009) experimentally investigated the suitability of ferro-cement 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 ferro-cement while for the other frame a glass fiber reinforced polymeric (GFRP) laminates were used. The result for the RC frame specimen retrofitted with ferro-cement, there is significant improvement in properties, behavior 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 andVidivelli (2006) presented a method of rehabilitating the overloading damaged reinforced concrete (RC) beams above the original capacity level using ferro-cement 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 ferro-cement 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 ferro-cement 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 behavior for all test specimens could be achieved by strengthening with high performance ferro-cement laminates.

Ganesan andShyju(2005) conducted experimental investigation to study the effect of ferrocement jacketing on strength and behavior 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 fiber and PVA fibers. 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.

Jeyasehar (2001) studied the behaviour of RC beams (125mm x 250mm x 3200mm) rehabilitated with ferrocement laminates .Out of these four beams were damaged under overloading by applying 60%,70%,80% and 90% of ultimate load. The damaged beams were rehabilitated with ferrocement laminates with three different volume fraction of reinforcement (2,3 and 3%).The beam were tested under static monotonic loading .The result shows that ferrocement laminate with 3% volume fraction of reinforcement behaves in a superior way when compared to other percentages (2 and 4).All beams experienced flexural failure. None of the beam exhibit premature failure of laminate.

METHODOLOGY

The objective of the present Study is to strengthen the Corroded RC Beam using Ferrocement Laminates.

The methodology of the project is discussed below.

- Material properties like specific gravity, fineness modulus, setting time will be studied for fine aggregate, coarse aggregate, cement.
- IS method of Mix design will be made for concrete as per IS 10262.
- Six numbers of RC beams will be cast and out of which one is considered as control beam and other five beams as corroded by accelerated corrosion method.
- The corroded RC beams will be strengthened with Ferrocement Laminates of different volume of fractions.
- Experimental and Analytical investigations will be made on strengthened corroded RC beam and results will be compared.

EXPERIMENTAL PROGRAM

Materials

Cement, fine aggregates, coarse aggregates, reinforcing bars are used in designing and casting of beams and MS welded wire mesh, cement slurry are used for strengthening of these beams in the form of ferro-cement. The specifications and properties of these materials are as under:

Cement

Cement used for the specimen were ordinary Portland cement. The cement used was in standard gunny bags and transferred to latter to air tight steel drums to avoid deterioration of the quality. The specific gravity of cement was determined by 576-1964(10) and found to be 3.15.

Fine Aggregates

The fine aggregate used for all specimens in river sand. The fine aggregate used for were sieved through IS 4.75mm sieve. The specific gravity of fine aggregate used for concrete were determined and found to be 2.65.

Coarse Aggregates

The coarse aggregate used in the mixes are hard blue granite stones from quarry around erode. The aggregate should be passed through 20mm sieve were used for concrete. The specific gravity of coarse aggregate were determined and found to be 2.7.

Water

Fresh and clean water is used for casting and curing the specimens. The water is relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per requirements of Indian standard.

Reinforcing Steel

HYSD steel of grade Fe-415 of 10mm diameter bars will be as main reinforcement and 8mm bars will be as shear stirrups.

Steel Mesh

Galvanized square welded steel wire mesh of 2.4mm diameter with square grids was used in ferrocement jacket. The grid size of mesh was 12mmX12 mm.

Concrete Mix

M20 grade concrete mix is designed as per standard design procedure using the properties of materials as discussed and provided. The water-cement ratio which will be used in 0.45. The mix proportion of material comes out to be 1:1.5:3 (cement: sand: aggregate).

Mortar Mix

The range of mix proportion recommended for common ferrocement application are between 1:1.5 to 1:2.5 (cement: sand) by weight, but not greater than 1:3 and water cement ratio by weight, 0.35 to 0.5. The higher the sand content higher is the required water contents to maintain same workability. Fineness modulus of the sand, water cement ratio and sand-cement ratio should be determined from trial batches to ensure a mix that can infiltrate the mesh and develop a strong and dense matrix. In the present study the proportion of cement –sand mortar used for the ferro-cement sheets is 1:2 (cement: sand) and the water-cement ratio for mortar will be taken as 0.40.

Reinforcement details

The size of beam is 1100x100x150mm. The 10mm diameter bar is used in tension and compression zone. The 8mm diameter bar is used to make stirrups. The spacing of stirrups from center to center is 75mm & 25mm cover is provided.

WORK UNDER PROGRESS

Totally 6 beam will be cast. The beams were 150mm deep by 100mm wide and 1100mm span. Ordinary Portland cement 53 grade, sand passing through 4.75mm sieve and crushed stone of maximum size 20mm not exceeding were used for concrete mix.

The cast Corroded RC beam will be strengthened with ferro-cement 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.

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