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Reinforced Concrete Beams Retrofitted USING Ferrocement

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***Abstract* - Various retrofitting techniques are used in field and out of all plate bonding technique is considered as the best. In this technique, the plates of different materials viz CFRP, GFRP, ferrocementetc are bonded to the surface of structural member to increase its strength. Ferrocement sheets are most commonly used as retrofitting material these days due to their easy availability, economy, durability, and their property of being cast to any shape without needing significant formwork. In the present 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 the percent increase in load carrying capacity for beam retrofitted with ferrocement jackets with wire mesh at 0, 45, 60 degree angle with longitudinal axis of beam, varies from 45.87 to 52.29 percent. Also a considerable increase in energy absorption is observed for all orientations. However, orientation at 45 degree shows higher percentage increase in energy absorption followed by 60 and 0 degree respectively.**

***Keywords* - ferrocement, retrofitting, jacket, wire mesh, orientation, beams**

I. INTRODUCTION

Reinforced concrete structural components are found to exhibit distress, even before their service period is over due to several causes. Such unserviceable structures require immediate attention, enquiry into the cause of distress and suitable remedial measures, so as to bring the structures back to their functional use again. This strengthening and enhancement of the performance of such deficient structural elements in a structure or a structure as a whole is referred to as retrofitting [1]. Ferrocement as a retrofitting material can be pretty useful because it can be applied quickly to the surface of the damaged element without the requirement of any special bonding material and also it requires less skilled labour, as compared to other retrofitting solutions presently existing. The ferrocement construction has an edge over the conventional reinforced concrete material because of its lighter weight, ease of construction, low self weight, thinner section and high tensile strength which makes it a favorable material for prefabrication also [1].

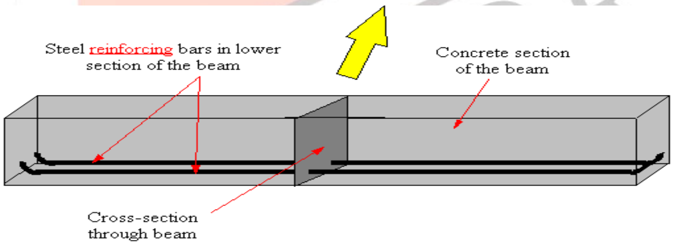

Fig 1: Reinforced concrete beam

II.FERROCEMENT

Ferrocement so often referred as skeletal –shell concrete. Ferrocement is thin walled R.C.C constructed of hydraulic cement mortar with distinctively well placed layers of very thin wire mesh fabric of continuous nature. Ferrocement has found its wide spread use in engineering and industry but its use in retrofitting is quite relevant to present study. It has high reinforcement ratio and is homogenous & isotropic along the both directions of reinforcement laid in it. Ferrocement development took place from the primary conception about R.C.C that pattern of reinforcement distribution ,its spacing and its configuration decides the magnitude of strains which the concrete can resist and these are unique for particular layout of reinforcement pattern.. Composite behaviour of ferrocement is exhibited due to presence of thin layered high tensile wire mesh in brittle mortar of compressive nature. Much better system of arresting of cracks is developed due to closely spaced thin wires laid in ferrocement.

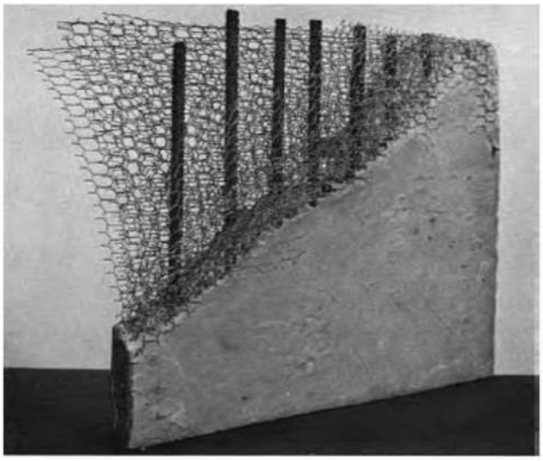

Fig 2: Typical cross section of ferrocement

III. CONSTITUENT MATERIALS OF FERROCEMENT

a) Cement: The cement should comply with Indian Standards. The cement should be fresh, of uniform consistency and free of lumps.
b) Fine aggregate: Normal weight fine aggregate passing IS 2.36 mm sieve used in jacketing. Grading of the sand is to be such that a mortar of specified proportions is produced with a uniform distribution of the aggregate.
c) Water: Water used in the mixing is to be fresh and free from any organic and harmful solution. Portable water is fit for use as mixing water as well as curing for ferrocement structures.
d) Reinforcing Mesh: One of the essential components of the ferrocement is wire mesh. The function of the wire mesh and reinforcing rod in the first instant is to act as lath providing the form and to support the mortar in its green state.

The construction of ferrocement can be divided into four phases:

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

Phase (1) and (3) require special skill while phase (2) is very labour intensive. The development of ferrocement evolved from the fundamental concept behind reinforced concrete i.e. concrete can withstand large strains in the neighbour hood of the reinforcement and magnitude of the strains depends on the distribution and subdivision of the reinforcement throughout the mass of concrete. Ferrocement behaves as a composite because the properties of its brittle mortar matrix are improved due to the presence of ductile wire mesh reinforcement. Its closer spacing of wire meshes (distribution) in the rich cement sand mortar and the smaller spacing of wires in the mesh (subdivision) impart ductility and better crack arrest mechanism to the material. Due to its small thickness, the self weight of ferrocement elements per unit area is quit small as compared to reinforced concrete elements. The thickness of ferrocement elements normally ranges from 10mm to 40mm whereas in reinforced concrete elements the minimum thickness used for shell or plate element is around 75mm. Low self weight and high tensile strength make ferrocement a favourable material for fabrication. With the distribution of small diameter wire mesh reinforcement over the entire surface, a very high resistance to cracking is obtained and other properties such as toughness, fatigue resistance, impermeability also get improved. The major differences between a conventional reinforced concrete structural element and a ferrocement member can be enumerated as follows:

1. Ferrocement structural elements are normally consists of thin sections with thickness rarely exceeding 25mm. On the other hand conventional concrete members consist of relatively thick sections with thickness often exceeding 100 mm.
2. Matrix in ferrocement mainly consists of Portland cement instead regular concrete consist of coarse aggregate.
3. The reinforcement provided in the ferrocement consists of large amount of smaller diameter wire or wire meshes instead of directly-placed reinforcing bars used in reinforced concrete. Moreover, ferrocement normally contains a greater percentage of reinforcement, distributed throughout the section.
4. In terms of structural behaviour, ferrocement exhibits a very high tensile strength and superior cracking performance.
5. In terms of construction, form work is very rarely needed for fabrication.

Metallic meshes are the most common type of reinforcement, Meshes of alkali resistant glass fibres and woven fabric ,of vegetables fibres such as jute burlaps and bamboo have also been tried as reinforcement [3].

IV.LITERATURE REVIEW

Paramasivam et al. (1998) has been carried out to strengthening of reinforced concrete beam with ferrocement laminates. Investigation into the transfer of forces across the concrete/ferrocement interface, the effect of the level of damage sustained by the original beams prior to repair, and the results of repeated loading on the performance of the strengthened beams are discussed. The results show that ferrocement is a viable alternative for strengthening and rehabilitations of reinforced concrete structures[2].
An experimental investigation has been carried out to study the effect of ferrocement jacketing on the strength and behavior of distressed reinforced concrete flexural elements by Ganeshan et al. (2005) The reinforced concrete specimens are subjected to different stages of loading, viz., 0.7, 0.8 and 0.9 times their ultimate load carrying capacity. Such distressed specimens are

retrofitted by ferrocement having different values of volume fraction of mesh reinforcement viz, 0.26, 0.52 and 0.78%. The results indicate that retrofitted beam improves the load carrying capacity, stiffness and energy absorption capacity of the beam[2].
Sheela et al.(2009) made an attempt has been made to determine the effect of number of layers of wire mesh on the performance of the beams retrofitted using ferrocement. Also, the effects of number of layers of GFRP on the performance of retrofitted beams are studied[3]. From the experimental investigation it was found that the ultimate load carrying capacity of beams retrofitted with ferrocement having one, two and three layers of wire mesh increased by 6.25%, 50% and 81.25% and that of GFRP retrofitted beams with 1, 2 and 3 layers increased by 50%, 68.75% and 81.25%, respectively[3]
Andrew and Sharma [4] in an experimental study compared the flexural performance of reinforced concrete beams repaired with conventional method and Ferrocement. They [10] concluded that beams repaired with Ferrocement showed superior performance both at service and ultimate load. The flexural strength and ductility of beams repaired by Ferrocement was reported to be greater than the corresponding original beams and the beams repaired by conventional method[4].
An experimental study in strengthening of reinforced concrete beams using Ferrocement laminates was conducted by Ong et al [5], where eight beams were strengthened with a 20 mm thick laminate attached on the tension face. Three different series with different methods of attachments including Ramset nails, Hilti bolts and epoxy resin adhesive were used. The performance of the strengthened beams were compared to the control beams with respect to cracking, deflection and ultimate strength. All the strengthened beams exhibited higher ultimate flexural capacity and greater stiffness. Use of epoxy resin adhesive and Ramset nails at closer spacing of shear connectors were able to ensure composite action. A decrease in the volume fraction of reinforcement of Ferrocement laminates from 3.25% to 2.36% resulted in a reduction of strength. The presence of the Ferrocement laminates had an inhibiting effect on the tensile crack, and the crack spacing and crack width were reduced after strengthening[5].

V. PROCESS OF RETROFITTING

After first stage of loading, the distressedbeams were retrofitted by using ferrocementjacketing. Ferrocement is another form ofreinforced concrete in which cement sandmortar is reinforced with closely spaced MSwelded wire mesh. In this study, square gridMS welded wire mesh (wire mesh of 16 mm x16 mm x 0.8 mm diameter) was used for allspecimens in single, double layer at 00 and450 orientations. The surfaces of thedistressed beam were roughened by usinghacker and wire mesh was wound over it. The mesh was tightened using binding wires. Athick cement paste was applied as bondingagent before application of mortar in order toget a good bond. Plastering was done withcement mortar having the ratio of 1:3 by weightand water cement ratio was kept as 0.5. The20 mm thickness of mortar was applied on thebeam surface. The retrofitted beams werecured for 28 days in curing tank.

Fig 3:Process of Retrofitting

VI.TESTING PROCEDURE

After completion of curing time, beams were tested using universal testing machine of 600 KN capacity with two point loading. The deflections at three points were recorded by using dial gauge having least count 0.01 mm at every 2.5 KN increment of load. Out of twenty five beams three beams were tested as a control beam to find out ultimate load of the beam. Eight beams were distressed by 60% of ultimate load. Balance eight beams were distressed by 80% of ultimate load.

VII. CONCLUSIONS

In summary, a comprehensive literature review was performed in order to gain a better insight into the key issuesrelevant to retrofit of concrete beam with reinforced walls. In this paper, the specific details of a 4-storey, 3-bay reinforced concrete frame test structure walls were described. The concrete frame was shown to be essentially a “weak-column strong-beam frame”which is likely to exhibit poor post-yield hysteretic behaviour. To make matters worse, there is a decrease instrength and stiffness of the concrete frame of the order of 35-40% at level 2.Hence, three retrofit options were selected for further detailed investigation.The effectiveness of the retrofit schemes eventually selected from among the options discussed here will betested using full-scale pseudo-dynamic tests. The results of the detailed analyses and tests willbe reported in future publications.

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