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Shear Behaviour of RC Composite Beams

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Abstract: This paper presents a study of shear behaviour of composite beams. The major parameters used were type of shear reinforcement, namely stirrups alone, wire mesh alone and combination of both wire mesh and stirrups as shear reinforcement. The replacement of wire mesh was done on the basis of weight with stirrups. A high range water reducing admixture (HRWRA) is used in the mix which showed better compressive strength and tensile strength than the mixes without admixture. The experimental program includes four (4) beams. The entire beams prototypes were tested using two point loading system. It is evident from the result that the use of wire mesh enhanced improved shear performance and bearing capacity in the examined beams. Beams with wire mesh as shear reinforcement and combination of both wire mesh and stirrups exhibited some amount of increase in shear capacity with respect to the beams with stirrups alone as shear reinforcement. Furthermore beams with wire mesh and combination of wire mesh and stirrups as reinforcement exhibited less number of crack patterns compared beams with stirrups.
Keywords: Ferrocement,Wire mesh, Shear behaviour and HRWRA.

Introduction

Ferrocement (FC) is defined as welded wire mesh reinforcement impregnated with mortar[1].The main difference between the conventional reinforcement and ferrocement is in scaling of elements. Ferrocement consist of closely spaced steel rods embedded in cement motor. Due to the closely spacing interlocks the reinforced concrete member provides good ductility and bearing capacity. FC element when subjected to upward stress it behaves like linearly elastic material until the first crack pattern appears. The behaviour of FC member under compression mainly depended on mix design properties. Apart from the volume of reinforcement, it is also important the in direction of its use in line with the force direction and tensile stress direction. The use of FC improves properties such as lightness, durability, water-tightness, toughness, strength and environmental stability.

Welded wire mesh is used in shear strengthening techniques to improve the shear capacity of the beam. Increase in diameter of the mesh shows a significant increase in the ultimate strength of reinforced beam. It delay the first crack load and tends to narrow the crack width and causing in large deflection at ultimate load[1].

Wire mesh is used as reinforcement in flanged ferrocement member, such as channel section, box section and sandwich ribbed plates. The ultimate shear strength of thin walled section increases as shear span to depth ratio decreases[2].Ferrocement box beam gives ultimate shear strength and cracking as the mesh reinforcement is increased. As the increase in mesh number the cracks are higher in number and finer in size[3].

Spiral reinforcement in rectangular beam improves the post-peak deformation capacity and exhibits higher shear capacity when compared with the control beam[4].Wire mesh can also be used for strengthening techniques and it proves to have a higher cracking load, ultimate load and also having a lower deflection when compared with control beam specimen[5].

Two types of shear failure were noticed in ferrocement panel, namely flexure shear and web shear. These failure increases with decrease inspan to depth ratio and the volume fraction of mesh is increased. Web shear failure mode occurs higher than the flexure-shear failure[6].

Wire mesh along with epoxy coating, a new composite constituent perform an increase in flexural strength rather than with plain mortar. This type of strengthening also provides a greater first crack load and energy absorption capacity. The optimum layer of wire mesh was found to be four[7].

Experimental Program

The experiment includes testing of 4prototype beamsunder a static loading. The beams were tested under the two point loading system. The strength of M25 concrete was found with and without HRWRA, the better result of strength was used for casting of beam. The major parameters used were type of shear reinforcement, namely steel stirrups, wire mesh and combination of both wire mesh and steel stirrupsas shear reinforcement. These beam are compared with a control beam and with one another. All the beams were rectangular cross section: width, depth and length of the beam were 100mm, 150mm and 1200mm respectively. All the beams were cast and cured for 28 days.

Material properties:

a) Cement: Ordinary Portland cement of 43 gradeconfirming to IS 8112:1989[9]of locally available RAMCO cement which comprises good quality. The chemical configuration of cement was found using X-ray fluorescence analysis and has the following properties

Table 1: Physical and chemical composition of ordinary Portland cement (OPC)

Description	Composition
Physical Properties	
Color	Grey
Specific gravity	3.15
Specific surface area (cm^2/g)	3540
Chemical Composition	
CaO (%)	62.8
SiO_2 (%)	20.3
Al_2O_3 (%)	5.4
Fe_2O_3 (%)	3.9
MgO (%)	2.7
Na_2O (%)	0.14
K_2O (%)	62.8

b) Fine aggregate: For fine aggregates, uncrushed locally available natural river sand of maximum size 2.36 mm with a fineness modulus of 3.35 and specific gravity of 2.65 usingIS 2386(Part III):1963[10] was used.

c) Coarse aggregate: The size of the coarse aggregates used ranges between 12.5 mm to 20 mm of specific gravity 2.74 using IS 2386(Part III):1963. The coarse aggregate properties are given in Table 2.

Table 2. Properties of coarse aggregate

Aggregate properties	Results
Impact value	17.18
Crushing value	21.46
Water absorption	1.56
Abrasion value	24.4

d) Admixtures:Super-plasticizer:CONPLAST SP430 (G) complies with IS: 9103:1999[11] and BS: 5075 (Part 3) and ASTM-C-494[12] type 'F' having a specific gravity of 1.2 was used as a high range water reducing agent.Air entrainment ofApprox. 1% additional (As per Manufacturers manual)

e) Water: Ordinary potable tap water was used for mixing and curing.

f) Reinforcement: Steel bars of Fe 500 grade was used for reinforcement.The welded wire mesh has been used as the shear reinforcement. The replacement of wire mesh was done on the basis of weight with stirrups. The wire were of 2mm diameter and the spacing of interlocking links were of 34 mm × 34mm. The weight of the wire mesh was 2.385kg/m2.

Concrete:

a) Mix proportions: Design of Concrete mix was in accordance with IS 10262:2009[13] and IS 456:2000[14]and was done for M25 grade. The proportions of the materials by weight was 1:1.58:2.9 for M25 mix design. The w/c ratio was maintained as 0.4.The specimens such as cubes and cylinders were cast early with and without chemical admixtures to get the better strength.

b) Casting:Before casting of beam prototype three number of 150mm cube specimens and three number of 150mm diameter and 300mm height cylinder specimens were cast as per IS 516:1959[15] for finding the compressive strength and tensile strength of concrete. The compressive strength and the split tensile strengthwas found out at 7 and 28 days of curingwith and without the use admixture. The averagecompressive strength and tensile strength of concrete is shown inTable 3.

Table 3. Average Compressive strength and Split tensile strength

Description	**Compressive strength(MPa)**		**Split tensile strength(MPa)**	
	7days	**28days**	**7days**	**28days**
Without admixture	19.6	28.4	2.13	3.13
With admixture	19.87	32.7	2.15	3.21

Based on the test results of compressive and tensile strength, 100mm × 150mm × 1200mm size beam specimens were cast for optimum mix proportion obtained for both M25 grade of concrete. Concrete were placed in the well lubricated mould and compacted and the specimens were left at room temperature for 24hrs and after that specimens were placed in curing tank for 28days.The beams were classified based on the details given in the Table 4.The Fig.1, Fig.2 and Fig.3gives reinforcement setup.

Table 4.Beam specimen ID

Specimen ID	Details
B-1	RC beam without shear reinforcement
B-2	RC beam with stirrup as shear reinforcement
B-3	RC beam with wire mesh and stirrup as shear reinforcement
B-4	RC beam with wire mesh as shear reinforcement

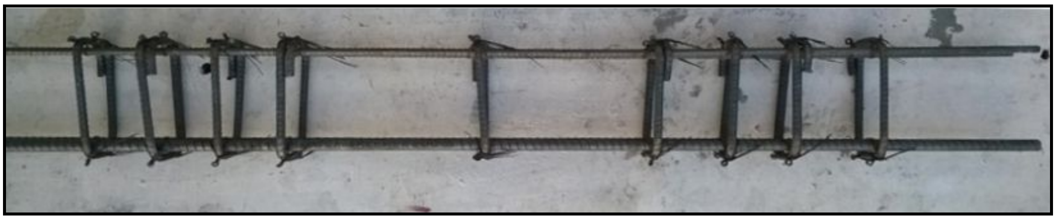

Fig.1 Reinforcement setup of B-2

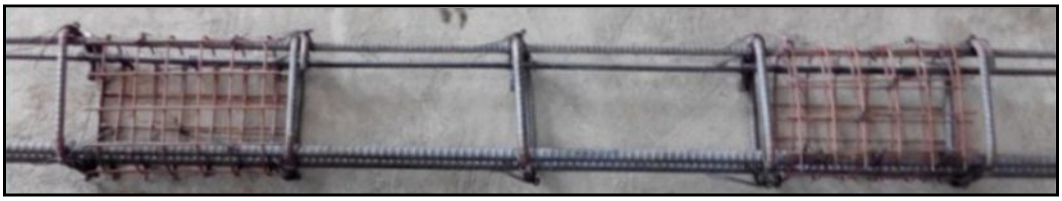

Fig.2 Reinforcement setup of B-3

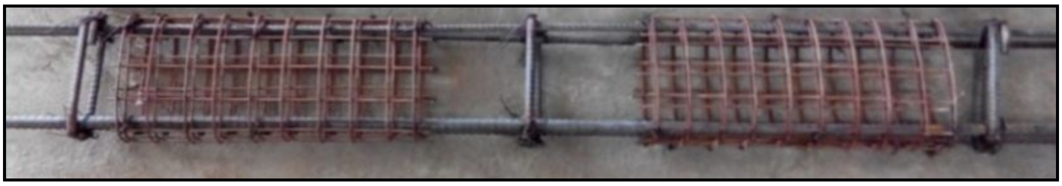

Fig.3 Reinforcement setup of B-3

c) Test setup: The test setup includes two point loading using a single point loading system by which the loads are transferred equally to the two points using a spreader beam and two rollers. Dial gauges are placed in the bottom of the beam at the mid-point to find the deflection. Demecs are placed on the surface of the beam to find the surface strains which are placed at a distance of 100mm from one another. The strains at these points are found using a mechanical strain gauge. The crack patterns are noted on both sides of the beams at particular intervals. The gauge length between the load points is300 mm and 150 mm are left on both sides of the beam at the supports. All the specimens were capped for uniform loading prior testing. The control of load over the test was 10 kN/min. Automatic data acquisition system was used to record the load, strain and axial displacement which in turn connected to the computer. The Fig.4 gives the clear idea about the testing of beam.

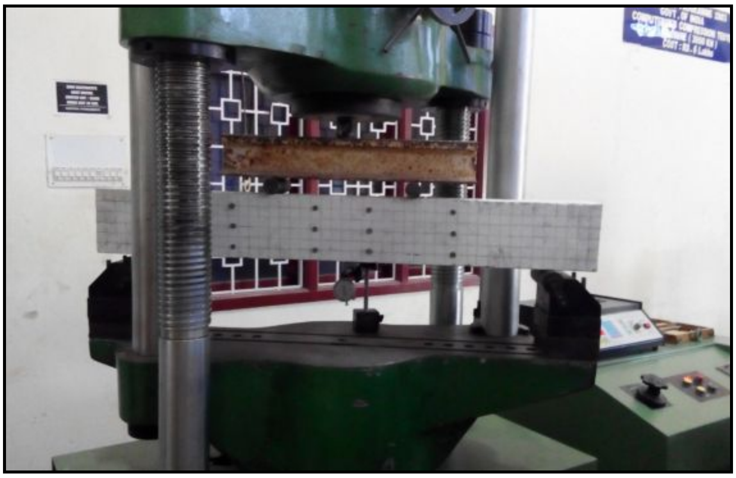

Fig.4. Testing of beam

Experimental Results And Discussions

First crack and peak load

The beam specimen B-1 the peak load is observed at 25 kN and failed at the peak load of 53.35 kN in shear. The peak load of the specimen B-1 can be taken as maximum permissible shear load. The specimen B-2, B-3 and B-4 have shown similar load behaviour. The specimen B-2 with normal steel stirrup, have shown maximum load capacity of 108.42 kN and failed in flexure. The specimen also have cracked at a load of 30 kN. Whereas the specimen B-3 with combination of stirrups and welded wire mesh had a cracking load of 37 kN and a maximum/ peak load of 110.35 kN. The specimen B-4 with wire mesh as shear reinforcement had failed at the maximum load of 114.3kN and the first cracks were observed at a load of 28 kN. The cracking load and peak load of various specimens is given in the Fig.5 below.

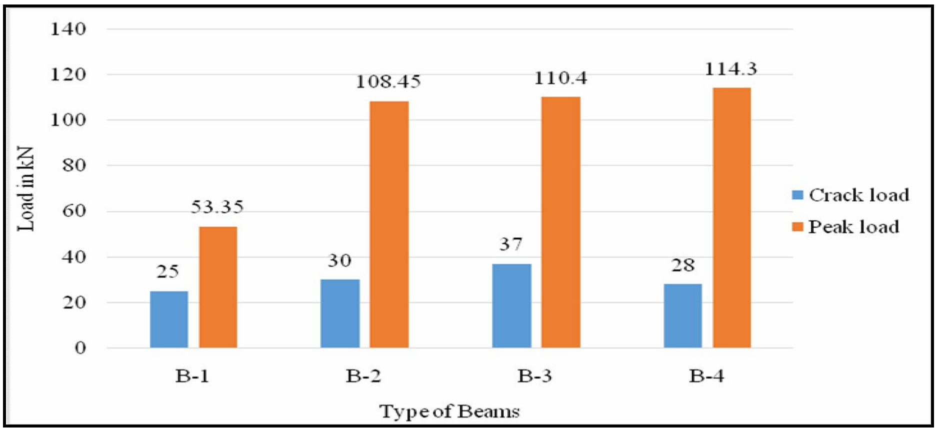

Fig.5 First Crack and Peak load

Crack Pattern and Spacing

All the beam specimens performed well in both shear and flexure. The control specimen provided with only flexure reinforcement failed with a large shear crack having width more than 0.3 mm. For the beam specimen B-2, the beam failed in flexure with number shear cracks than flexural cracks. Specimen B-3 performed similar to that of specimen B-2. The specimen B-4 performed better than other specimens with the cracks distributed all over the surface with the crack width less than 0.1 mm. The crack pattern of the specimens were given in the Fig.6, Fig.7, Fig.8 and the Fig.9 for the beam prototype of B-1, B-2, B-3 and B-4 respectively.

Table 5. Crack numbers along the length of the member

Specimen	Shear zone	Flexure zone
B-1	8	8
B-2	13	11
B-3	13	11
B-4	19	11

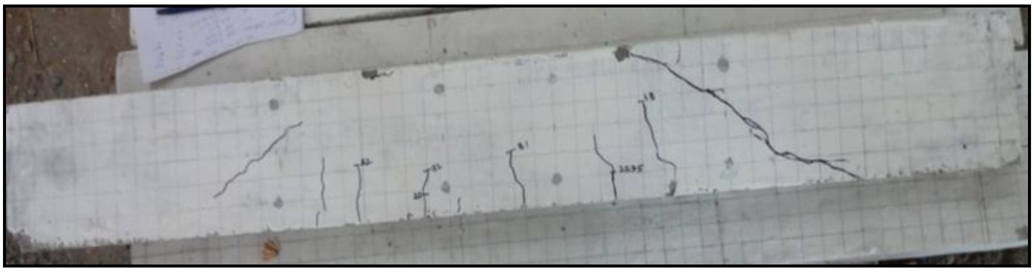

Fig.6 Crack pattern of B-1

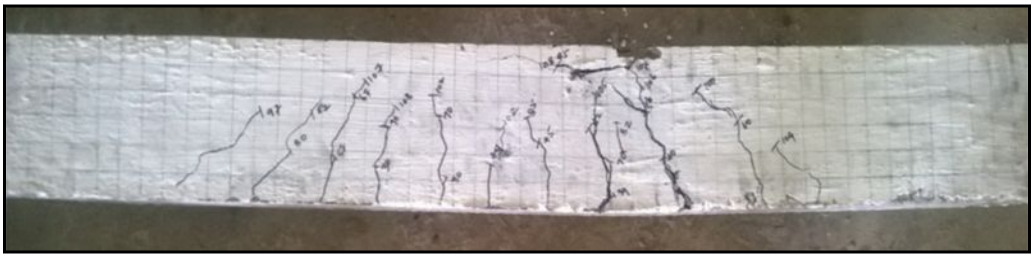

Fig.7 Crack pattern of B-2

Fig.8 Crack pattern of B-3

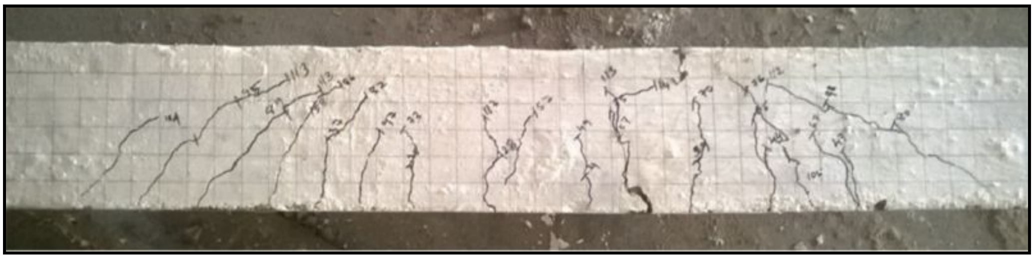

Fig.9 Crack pattern of B-4

Load Deflection Behaviour

The load vs displacement for curve graph was drawn from the readings obtained from the testing of specimens. The beam specimen B-1 failed at the peak load of 53.35 kN in shear with deflection of 7.2mm. The peak load of the specimen B-1 can be taken as maximum permissible shear load. The specimen B-2, B-3 and B-4 have shown similar load-deflection behaviour. The specimen B-2 with normal steel stirrup have shown maximum load capacity of 108.42 kN and failed in flexure with deflection of 8.2mm. Whereas the specimen B-3 with combination of stirrups and welded wire mesh underwent more load-deflection behaviour with deflection of 9.80mm at 110.35 kN. The specimen B-4 with wire mesh as shear reinforcement had failed at the maximum load of 114.3kN with far less deflection of 7.6mm. The load-deflection behaviour is shown in the Fig.4.

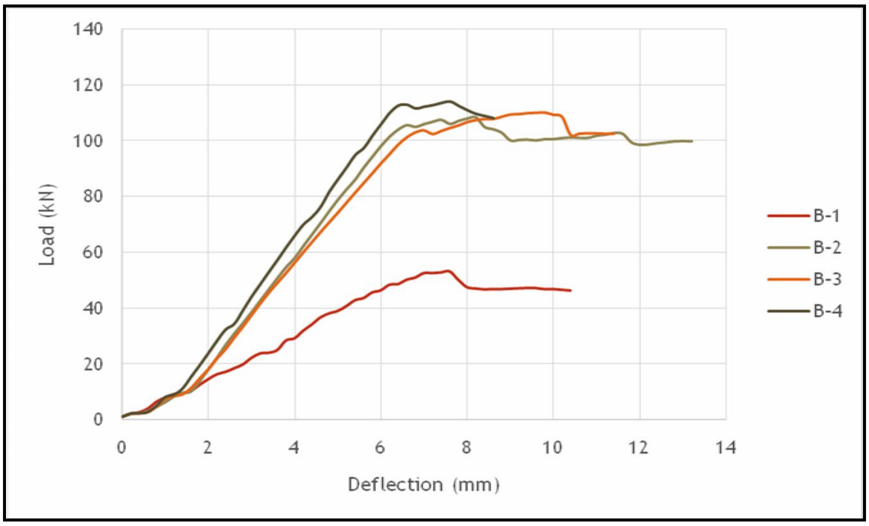

Fig.10: Load vs Displacement for beams

Conclusion

The study on the shear behaviour of the beam specimens, with wire mesh as shear reinforcement have led to the following conclusions.

- Wire mesh when used as shear reinforcement in beam, enhanced the shear behaviour of the beam by distributing the shear forces along the section.
- Beam using only wire mesh as shear reinforcement have performed better than any other specimen by having low deflection at peak load.
- The use of wire mesh have made a significant effect on crack pattern of the reinforced concrete beams by delaying the crack appearance,increasing the number of crack and reducingthe crack width.
- The ultimate moment capacity for the beam specimens have considerably improved if wire mesh alone is used as shear reinforcement.
- The beam specimens with mesh as shear reinforcement and specimen with a combination of wire-mesh and steel stirrup as shear reinforcement have performed similarly and both have failed in flexure. They had more number of cracks all distributed along the direction.

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