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EFFECT OF REINFORCEMENT ORIENTATION ON COMPRESSIVE STRENGTH OF FERROCEMENT AND BITUMEN FERROCEMENT

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Abstract – *Ferrocement is relatively new material consisting of wire meshes and cement which was developed by P.L. Nervi, an Italian Architect and Engineer in 1940[1]. It is basically considered as a type of thin reinforced concrete construction where cement mortar matrix is reinforced with many layers of continuous and relatively small diameter wire meshes. While mortar provides the mass, the wire mesh imparts the tensile strength and ductility to the material. In terms of structural behavior ferrocement exhibits very high tensile strength to weight ratio and superior cracking performance. [2] Ferrocement is boon for maintain the ecological balance as it does not requires timber formwork. Bitumen ferrocement is new type of ferrocrete in which wire reinforcement replaced by bitumen coated wire mesh. Due to use of bitumen in ferrocement, structure not only carries increased compressive strength but also becomes impervious. Thus this material can be used in construction of swimming pools, retaining walls, small arch dams, water tanks and also in construction of road pavements. The present investigation, highlights on ten different cases of wire mesh combination with one additional case as mortar control specimen which does not contain any type of reinforcement. The concrete cubes were casted with single and double layers of wire mesh placed in horizontal, vertical and diagonal orientations. It reveals from the result of investigation that the vertical orientation offers more compressive strength than horizontal orientation for bitumen ferrocement.*

Key Words: Bitumen, Ferrocement, Compressive strength, square mesh, reinforcement orientation.

1. INTRODUCTION

Ferrocement is highly versatile material containing wire mesh, cement, sand and water. The wire mesh is used as reinforcement, may be woven or welded in different shapes. It is less polluting, inexpensive, generating less wastage with attractive alternative material. This technique was used in Second World War for construction of boats. From 1960s ferrocement can be used successfully for construction of building panels. World famous Sydney Opera House was constructed by ferrocement. In India, ferrocement technique has been also used for rural development with construction of small houses, farm houses etc. [3] [4]

Compressive strength is the capacity of material or structure to withstand loads tending to reduce size. The compressive strength of ferrocement depends on specific surface, volume fraction of reinforcement, orientation of reinforcement. Specific surface is bonded surface area of ferrocement per unit volume of ferrocement. The other factor which is volume fraction of reinforcement is the volume of reinforcement per unit volume of ferrocement. The orientation of reinforcement which is the angle in degree between the reinforcement mesh and direction of applied stress also affects the compressive strength of ferrocement. Also compressive strength of ferrocement depends on the type of wire mesh; welded wire mesh offers more compressive strength than woven type wire meshes.

Bitumen is an oil based substance. It is a semi solid hydrocarbon product produced by removing the lighter fractions from heavy crude oil during the refining process. At ambient temperatures bitumen is a stable, semi-solid substance. The vast majority of refined bitumen is used in paving and roofing application. As bitumen used in ferrocement the compressive strength of ferrocement increases significantly and also material becomes impervious.

2. LITERATURE REVIEW

Ferrocement covers all dimensions of sustainability and also durable material. It has better crack arrest mechanism and efficient autogenesis healing of micro cracks, fire resistant, damage being negligible and easily repairable. Ferrocement can be used in various applications such as housing application rural application such as water tank, grain silos, canal lining, and some special applications as precast sandwich wall, ferrocement water filters, ferrocement segmental shells etc. [5]

Paper state the effect of orientation of wire mesh on ferrocement. The conclusion arises from the study that compressive strength of ferrocement increases with increase in total volume fraction of reinforcement (%) and specific surface of reinforcement (mm^2/mm^3) for horizontal and vertical orientation of hexagonal mesh; the orientation of reinforcement i.e. transverse to axis of loading offers more compressive strength than that of vertical orientation i.e. parallel to axis of loading.[6]

The effect of wire mesh orientation on the strength of stressed beams retrofitted with ferrocement jackets has been studied. The results show that the per cent 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 per cent. Also a considerable increase in energy absorption is observed for all orientations. [7]
The results of testing folded and flat ferrocement panels reinforced with different number of wire mesh layers were presented in this paper. [8]The main objective of these experimental tests is to study the effect of using different numbers of wire mesh layers on the flexural strength of folded and flat ferrocement panels and to compare the effect of varying the number of wire mesh layers on the ductility and the ultimate strength of these types of ferrocement structure. The experimental results show that flexural strength of the folded panels increased by 37% and 90% for panels having 2 and 3 wire mesh layers respectively, compared with that having single layer.

This paper conducted research work is to maintain the eco-balance by preventing the open site dumping of the Blast furnace slag (BFS). This replacement has been found to improve the strength characteristics of ferrocement and also makes it lightweight. Replacement of BFS helps in reducing weight of the structure and thus improving its earthquake resistance. Marginal decrease in ultimate strength with increase in mesh content has been observed and this may be due to bulking of small diameter wires of mesh. [9]
Many researchers were used another materials other than wire mesh or with combination of it such as steel fibers, styrene butadiene rubber latex, scrap tyre, fly ash, BFS, Rise Husk, Coconut fibers etc. for construction of ferrocement structures.
However there is no reported significant work on effect of orientation of reinforcement on compressive strength of bitumen ferrocement. Also there is no significant literature on bitumen ferrocement. Hence the present study attempts to investigate the effect of bitumen content on compressive strength of ferrocement and effect of bitumen-wire mesh reinforcement on compressive strength of ferrocement.

3. EXPERIMENTAL PROGRAM

The present investigation is carried out to study "effect of reinforcement orientation on compressive strength of bitumen ferrocement". The investigation highlights on eleven different combinations of orientations and layers of wire mesh reinforcement with its effect on compressive strength of bitumen ferrocement. The ferrocement cubes casted with single and double layers of wire mesh and also with bitumen coated wire mesh as shown in figure 2.

Fig-1: Reinforcement of bitumen ferrocement

For this investigation main constituents of ferrocement is matrix and reinforcement. The matrix is mixture of sand and cement. These constituents of bitumen ferrocement exhibit the following properties and specification.

- Cement: ordinary Portland cement of grade 53
- Sand: River sand
- Reinforcement: square wire mesh of spacing 5 mm with wire diameter of 0.6096 mm. the weight of mesh 2.29×10^{-3} kg/m^2 as shown in figure 2.
- Water: Potable water used for curing and mixing purpose.

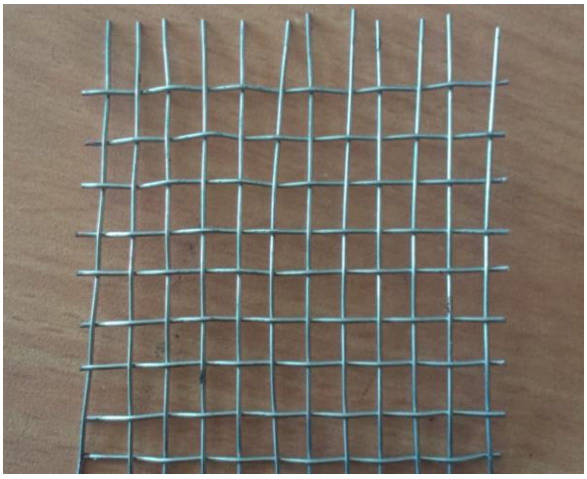


Fig-2: Square wire mesh

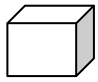
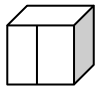
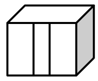
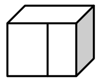
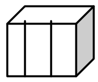
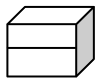
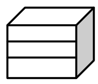
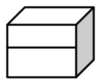
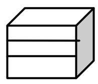
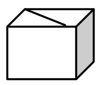
The mesh has been provided in the size of 70 mm x 70 mm in the cube moulds in single and double layer of different orientations. Bitumen used for this investigation is of industrial grade having specific gravity 1.01.

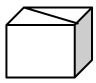
The ferrocement mix was prepared with cement: sand proportion of 1:3 by weight. The water cement ratio adopted was 0.45. For this investigation accelerated curing tank is adopted. In this cubes have been lowered in curing tank with their moulds after an hour of casting and remained totally immersed at 55^0 +- 2^0 for a period not less than 19 hours 50 minutes. The specimen then removed from curing tank, demoulded and immersed in cooling tank at 27 + - 2^0 C before completion of 20 hours from start of immersion in curing tank.

3.1. Specimen and testing details

The table 1 shows the different ten designation of ferrocement with one additional control specimen.

Table-1: Designation of ferrocement cube

Sr. No.	Designation	Orientation of mesh	Particulars
1	M.C.S		Mortar Control Specimen
2	C1V		One mesh, vertical at centre
3	E2V		Two meshes, vertical at equal distance
4	B1V		One bitumen mesh, vertical at centre
5	B2V		Two bitumen mesh at equal distance
6	C1H		One mesh, horizontal at equal distance
7	E2H		Two meshes, horizontal at equal distance
8	B1H		One bitumen mesh, horizontal at centre
9	B2H		Two bitumen mesh horizontal at equal distance
10	D1		One mesh, diagonal

11	BD1		One bitumen mesh, diagonal.

All cured specimens have been tested in compression testing machine. The % volume of mesh reinforcement and specific surface of all the specimens were noted. The % volume of mesh reinforcement and specific surface of all the specimens have been noted.

4. RESULTS AND DISCUSSIONS

In present investigation various test have been planned as discussed in experimental program. The results of various test and discussion based on test results are given in following sections.

4.1 Physical Properties of Cement

The results of tests conducted on cement are presented in table 2.

Table -2: Physical Properties of cement

Sr. No.	Particulars	Requirements as per I.S. 12269:1987	Test Results
1.	Fineness	Min 0.1	0.13
2.	Initial Setting Time	Min 30 minutes	75 minutes
3.	Final Setting Time	Min 60 minutes	380 minutes
4.	Soundness by Le Chatelier	Max 10 mm	8 mm
5.	Specific Gravity	3.15	3.15
6.	Standard Consistency	-	29

4.2 Physical Properties of Sand

The results of tests conducted on sand are presented in table 3.

Table- 3: Physical Properties of fine aggregate

Sr. No.	Particulars	Test Results
1	Specific Gravity	2.80
2	Fineness Modulus	3.03
3	Water Absorption	0.45%

4.3 Compressive Strength of Ferrocement Specimens

The test of compressive strength of ferrocement specimen (Mortar Control Specimen, ferrocement specimen with horizontal, vertical and inclined position and Bitumen ferrocement specimen with horizontal, vertical and inclined position) presented in table 4 and the compressive strength for above position are depicted in chart 1, chart 2, chart 3 and chart 4.

Table – 4: Compressive strength of ferrocement

Sr. No.	Designation	Specific Surface mm^2/mm^3	Volume of mesh reinforcement	Compressive strength
1	M.C.S	-	-	28.97
2	C1V	0.0123	1	32.38
3	E2V	0.0246	2	32.38
4	B1V	0.0123	1	38.16
5	B2V	0.0246	2	38.50
6	C1H	0.0123	1	29.39
7	E2H	0.0246	2	31.02
8	B1H	0.0123	1	28.63
9	B2H	0.0246	2	25.23
10	D1	0.161	1	27.62
11	BD1	0.161	1	34.76

- The compressive strength increases for horizontal orientation in case of both single and double layer reinforcement, for vertical orientation in ferrocement and bitumen ferrocement with both reinforcement.

- In case of diagonal orientation for bitumen ferrocement with respect to mortar control specimen compressive strength increases.
- Compressive strength decreases for horizontal orientation of bitumen ferrocement. The horizontal orientation for bitumen ferrocement does not take much load in both cases
- The compressive strength increased significantly for vertical orientation in case of bitumen ferrocement as compare to mortar specimen control. It increased by 31.68 % and 32.85 % for single layer and double layers of reinforcement respectively.
- For diagonal orientation it increased by 19.94 %.
- In vertical orientation compressive strength increased by 17.58 % for single layer reinforcement as compare to single layer vertical orientated ferrocement and for double layer reinforcement it increased by 17.85 %.
- Compressive strength increased by 25.85 % for bitumen ferrocement of diagonal orientation with respect to diagonal ferrocement.

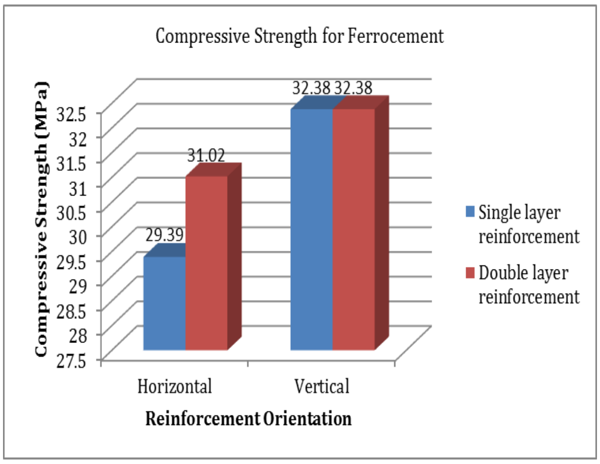


Chart -1: Compressive strength of Ferrocement

As number of layers increases the compressive strength of ferrocement increase is shown in chart 1 whereas chart 2 describes the compressive strength for bitumen ferrocement. It clearly shows that horizontal orientation does not take much compressive strength but vertical orientation gives significantly more compressive strength. Chart 4 and 5 gives the compression of compressive strength for ferrocement with bitumen ferrocement for horizontal and vertical orientation respectively.

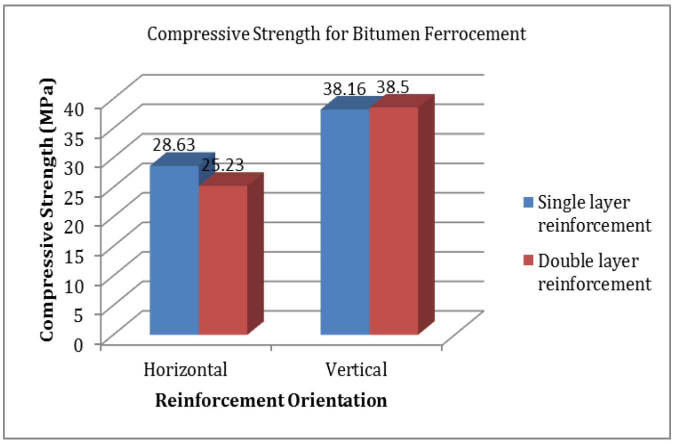


Chart -2: Compressive strength of Bitumen ferrocement

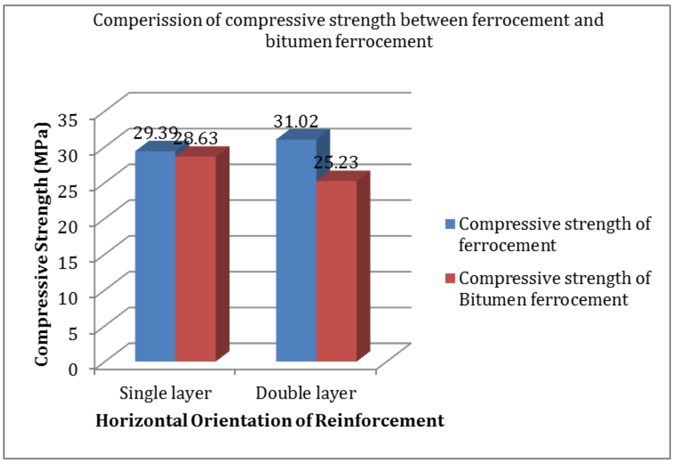


Chart -3: Comperission of Compressive strength between Bitumen ferrocement and ferrocement

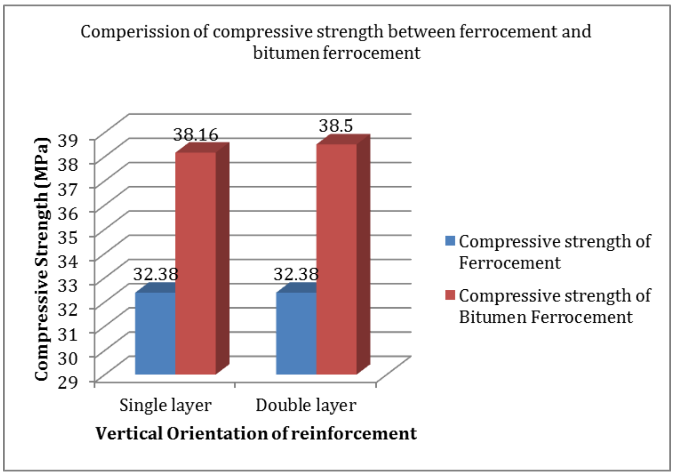


Chart -4: Comperission of Compressive strength between Bitumen ferrocement and ferrocement

5. CONCLUSIONS

Ferrocement is truly the first invasion of reinforced cement concrete, most abundantly used as construction material in the world. Ferrocement reduces construction cost, also it becomes boon for ecological system. Compressive strength of ferrocement depends on the material used, percentage volume of reinforcement, orientation of reinforcement.

From the results of cube testing, the following conclusions are drawn:

- As number of layers of wire meshes increase, compressive strength of bitumen ferrocement also increases.
- Vertical orientation in both cases (ferrocement and bitumen ferrocement) offers more compressive strength than horizontal orientation.
- For vertical and diagonal orientation of bitumen ferrocement offers more compressive strength than same orientation of ferrocement.

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