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An Investigative Approach on the Influence of Woven Wire Mesh in Concrete

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ABSTRACT

The traditional concrete cannot be used when it is subjected to cracks, spalling, wear and tear action having low tensile strength, however, it can be substituted by introducing ferrocement. Ferrocement also referred to as ferro concrete or reinforced concrete, a mixture of Portland cement mortar applied over layers of woven or expanded steel mesh and closely spaced small-diameter steel rods rebar. 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. The influence of horizontally orientated woven wire mesh in the mechanical properties of ferrocement concrete cubes were examined with centrally placed single mesh and other being double meshes placed at equal distance perpendicular to the direction of loading. The failure load of the concrete with ferrocement wire mesh has been increased with the increase in layers of wire mesh.

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1. Introduction

A composite material is formed when a closely spaced layers of continuous and relatively small size wire mesh are introduced in the concrete which behaves distinctively from the conventional reinforced concrete. The wire mesh which is soft and malleable, abrasion resistance and high tensile strength strengthens conventional concrete strength, deformation, inter particle adhesion and its potential applications compared with conventional concrete.

B. Kondraivendhan et al. [1] has investigated the effect of ferrocement external confinement on behaviour of concrete specimens and test results showed that confine concrete specimens can enhance the ultimate concrete compressive strengths and failure strains. The ultimate strength of ferro-concrete is identical to that of mesh and modulus of elasticity can be predicted [2]. Prem Pal Bansal et al. has investigated failure characterization of beams under flexure, stressed up to 3/4th of safe load and found that the percent increase in load carrying capacity for beam varies from 45% to 52% retrofitted with ferrocement jackets with wire mesh at 0, 45, 60-degree angle with longitudinal axis of beam [3]. Mitali Patil et al. (2015) [4] investigated the effect of reinforcement orientation on compressive strength of bitumen ferrocement on eleven different combinations of orientations and layers of wire mesh reinforcement with its effect on compressive strength of bitumen ferrocement. As number of layers of wire meshes increases the compressive strength of bitumen ferrocement also increases but wire meshes in vertical orientation in both cases offers more compressive strength than horizontal orientation. Garima Arora et al. [5] found that the flexural strength and ductility of the beams repaired with ferrocement was reported to be greater than the conventional beams. The spacing of cracks characterized by development of flexural cracks over the tension zone are reduced for retrofitted beams. Moreover, the beams retrofitted with wire mesh at different orientations do not de-bond in failure load [3]. Manish Hajare et al. [6] has studied the flexural behavior of ferro cement panels with different types of meshes such as expanded metal mesh, galvanized woven mesh and welded mesh with woven wire diameter of 1.58 mm in panels of a size of 560 × 150 × 35 mm reinforced with three layers of wire mesh. It has been observed that there is a substantial increase in flexural strength ferrocement panels reinforced with weld mesh as compare to expanded metal mesh, galvanized woven mesh and plain cement mortar panels and the panels with weld mesh has greater tendency to take load

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than the other two types of mesh [6]. An experimental study on strengthening and retrofitting of damaged reinforced concrete beams using steel wire mesh and steel angles was investigated by Ezz-Eldeen et al. by testing the beams 100 × 160 mm deep of 1250 mm overall span under two-point loading. This resulted in considerable increase in failure load and decrease in the vertical deformation [7]. Ornela Lalaj et al. [8] has reviewed the application of ferrocement and stated that the properties such as high strength/weight ratio and good resistance to cracking and impact loadings are bringing ferrocement under the spot light. G.M. Naveen et al. [9] employed blast furnace slag as light weight fine aggregate replaced behalf of sand in cement-sand mortar matrix with varied percentages and reinforced with layers of small diameter wire meshes and closely spaced steel bars and tested under monotonic and repeated flexural loading. The results obtained from this study is expected to be useful in determining the first crack strength and ultimate strength of light weight ferrocement beams subjected to similar types of forces and thus will help toward designing ferrocement elements to withstand monotonic and repeated flexural loading. Imrose Bin Muhit et al. [10] has investigated structural shear retrofitting of reinforced concrete beam with multilayer reinforcement for a sustainable and feasible retrofitting technique is necessary to ensure the safety of the infrastructure and its occupants. This study allowed to determine the elastic stiffness by plotting the load versus displacements and hence a plausible technique using ferrocement is suggested [10]. ReXin et al. [11] has studied and compared two scaled unreinforced masonry (URM) walls before and after being repaired by grout-injected ferrocement overlay reinforcement (GFOR), with the aim of investigating the effectiveness of an alternative ferrocement overlay technique. In this experiment, loading was performed on a multistory opening URM wall to induce damages, and the reinforced wall (defined as FRM) was retested using the same procedure resulted in improvement of ultimate resistance, altered diagonal shear failure and ductility. The drawback of ferrocement i.e., corrosion can be avoided by employing stainless steel jacketing for rehabilitation [12].

2. Objectives and methodology

After a detailed study on available literature, the key objectives of this work are to increase in performance of concrete which include:

1. Conducting preliminary tests on the materials and designing M30 grade concrete mix.
2. Study and Evaluation of mechanical properties of ferrocement concrete and comparing with the conventional concrete
3. Influence of horizontally orientated woven wire mesh in the mechanical properties of ferrocement concrete cubes with centrally placed single mesh and other being double meshes placed at equal distance perpendicular to the direction of loading

The methodology of the work is divided into three phases. In Phase 1, after doing the literature study, preliminary tests on materials are conducted and mix design of concrete is prepared confirming to IS 10262:2019. In Phase 2, conventional concrete specimens are casted and mechanical properties are studied and in Phase 3, study on the comparison of the performance of the ferrocement concrete specimens is done.

3. Experimental program

3.1. Ingredients

Cement: Ordinary Portland Cement of grade 53 is used confirming to IS 12269-1987.

Coarse aggregates: Less than 10 mm size aggregates are utilized in this work confirming to IS 383-1970 [13].

Fine aggregates: Fine aggregates of size less than 4.75 mm confirming to grading zone II are used and are confirmed to IS 383-1970. The material properties are tabulated in Table 1 (see Table 2).

Wire Mesh: stainless steel size of 150 × 150 mm which has the opening of size 12 mm and wire diameter 0.1 mm as shown in Fig. 1.

3.2. Mix proportions and cast of specimens

The concrete of grade M30 is prepared confirming to IS 10262:2019 [14] and the same proportions are adopted for casting cubes for Conventional Concrete (CC) as shown in the Fig. 3, Ferrocement Concrete with one layer mesh (FC1) and Ferrocement concrete with two layer mesh (FC2). The mix details are shown in Table 3.

The cubes, cylinders, and beams of standard sizes were casted and tested confirming to Indian Standards code. The cube casting for ferrocement concrete specimens is divided into two types i.e., casting of cubes with one mesh and other being two meshes kept horizontal at equal distance as shown in the Fig. 2.

4. Results and discussions

The cubes specimens are of sizes 150 × 150 × 150 mm, cylinders are of 150 mm diameter and 300 mm height, and beams of sizes 150 × 150 × 700 mm are water cured and tested for mechanical characteristic confirming to Indian Standards code of testing.

4.1. Fresh concrete properties

Workability of fresh concrete is determined using slump cone test confirming to IS. 100 mm slump was observed for CC and FC1 cubes and 98 mm was observed for 98 mm.

4.2. Hardened concrete properties

4.2.1. Compressive strength

The cubes of standard dimensions were tested for compressive strength in compression testing machine with a loading degree of 140 kg/cm^2/minute as per IS 516-1959. Table 4 depicts the average compressive strength test results at the end of 7, 14 and 28 days. Fig. 4.1 shows the cube testing for compression strength.

The conventional concrete of 7, 14, 28 days test results are compared with compressive strength, tensile strength and flexure strength of all the 3 samples i.e., Ferrocement Single layer mesh Concrete, Ferrocement Double layer mesh. It has been noticed that there is an increase in the strength of the concrete of 3.217% and 6.587% when conventional concrete is compared with single layered mesh and double layered mesh ferrocement respectively. Fur-

Table 1
Preliminary tests on cement.

Material	Specific gravity	Consistency
Cement	3.12	28%
Initial setting time	29 min	
Final setting time	9 h 55 min	

Table 2
Physical Properties of Aggregates.

Physical properties	Coarse Aggregate	Physical properties	Fine Aggregate
Fineness Modulus	7.61	Specific Gravity	2.43
Specific gravity	2.62	Fineness Modulus	2.85
Elongation index	11%	Water absorption	1.5%
Flakiness	13.8%	Zone	II
Crushing strength	24%	Bulk Density (kg/m3)	
		Dense rodded	1620
		Loose	1400
Water absorption	0.5%		
Impact value	17%		

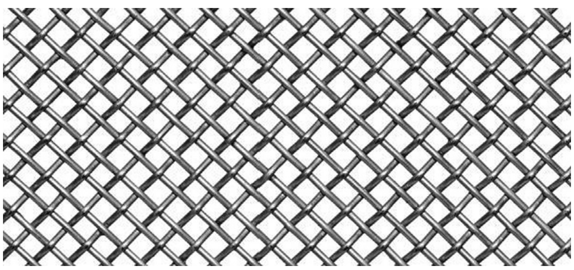

Fig. 1. Stainless steel wire mesh with 12 mm size openings.

Fig. 3. Casting of Conventional Cube.

Table 4
Average compressive strength test results.

Number of days	Compressive Strength (MPa)		
	Conventional Concrete	Ferrocement Concrete with one layer mesh (FC1)	Ferrocement concrete with two-layer mesh (FC2)
7 days	19.50	20.90	21.00
14 days	27.40	28.00	29.00
28 days	30.50	31.00	32.50

Fig. 4.1. Testing the cubes in compression testing machine.

4.2.2. Split tensile strength

This test was performed on cylinders of size 150 mm diameter and 300 mm height and placed longitudinally in compression testing machine. Table 5 depicts the average compressive strength test results at the end of 7, 14 and 28 days. Fig. 4.2 shows the split tensile strength.

The percentage increase of split tensile strength of Conventional concrete to Single layered and double layered mesh ferrocement was increased by 14.45% & 20.136%. Further, it is also noticed that there is an increase of 37.5% when compared single and double layered mesh ferrocement.

4.2.3. Flexural strength

Standard beams of size 150 × 150 × 750 mm are used to determine the flexural strength. Table 6 depicts the average 28 days flexural strength values. Fig. 4.3 shows the flexural testing of beams under two point loading.

The percentage increase of flexural tensile strength of Conventional concrete to Single layered and double layered mesh ferroce-

Table 3
Material proportion for M30 grade concrete (kg/m^3).

Cement	Fine aggregate	Coarse aggregate	Water	Water/cement ratio
383.16	644	1201.6	621.7	0.45

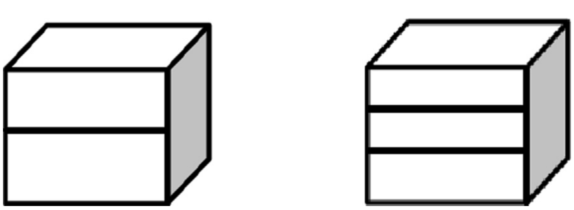

Fig. 2. Cube specimen with one mesh horizontal (ON LEFT) & cube specimen with two meshes at equal distance (ON RIGHT).

ther, it is also noticed that there is an increase of 3.266% when compared single and double layered mesh ferrocement.

Table 5
Average Split tensile strength test results.

Number of days	Split tensile Strength (MPa)		
	Conventional Concrete	Ferrocement Concrete with one layer mesh (FC1)	Ferrocement concrete with two-layer mesh (FC2)
7 days	1.85	2.00	2.97
14 days	2.47	2.97	3.50
28 days	3.43	3.83	4.10

Fig. 4.2. Testing of cylinder moulds.

Table 6
Average Flexural tensile strength test results.

Number of days	Flexural Strength (MPa)		
	Conventional Concrete	Ferrocement Concrete with one layer mesh (FC1)	Ferrocement concrete with two-layer mesh (FC2)
7 days	4.78	5.5	6.32
14 days	5.74	6.5	7.47
28 days	8.33	9.0	10.57

Fig. 4.3. Testing of beams.

ment was increased by 16.32% & 31.09%. Further, it is also noticed that there is an increase of 40% when compared single and double layered mesh ferrocement.

5. Conclusions

Based on the limited study carried out on the behavior of strength in ferrocement concrete, the following conclusions are drawn.

- As number of layers of wire meshes increases, compressive strength of bitumen ferrocement also increases.
- Beams with Ferrocement showed superior performance both at the service and ultimate load.
- The flexural strength and ductility of beams repaired with Ferrocement was reported to be greater than the corresponding original beams
- The ductility and stiffness of the concrete is also observed to increase.

CRediT authorship contribution statement

Karthik Thipparthi: Conceptualization, Methodology, Writing – original draft. **Kastro Kiran:** Project administration, Writing – review & editing. **J. Naresh:** Visualization, Validation, Investigation. **M. Jayaram:** Data curation, Supervision, Resources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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