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Experimental Study of Flexure and Impact on Ferrocement Slabs

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Abstract :*Ferrocement has been widely used in construction of various structural elements in the construction industry, apart from being used as hulls of ship in the ship building industry. It is possible to achieve considerable improvements in various properties of this Ferrocement slabs by substituting regular materials. This project aims to study and compare the structural behaviour of Ferrocement slabs of different ratios and its mechanical properties. The Ferrocement slabs are made by using cement and copper slag with constant layers of welded meshes. Copper slag is a waste material that is abundant and which is hard to dispose off. Copper slag provides considerable strength and its mechanical properties are quiet convincing. Performance of the tested slabs are presented and discussed in this project. Normally for a Ferrocement slab, 3mm dia. welded wire fabrics are used for construction, in this study very small dia. wires (1mm) and also closely spaced (10 mm) wires are used in order to increase the ductility properties and also durability related properties of Ferrocement. Very fine powdered form of copper slag has been used in this project. The flexural properties of these Ferrocement slabs are evaluated and compared under four point static loading system using specific test setups and comparative study of the test results confirm that Ferrocement slabs made of copper slag are more effective in flexural strength and other mechanical properties. Impact strength of slab is tested and it is found that as the copper slag content is increased the kinetic energy is increased.*

***Keywords** - Copper Slag. Ferrocement slab, Flexural Strength, Impact Strength, Wire Mesh*

I. INTRODUCTION

Ferrocement is a wire mesh reinforcement embedded with mortar. This is durable and efficient material. Due to their thinness, ferrocement elements can be used as roofing / flooring elements to cover large spans. "Ferrocement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh". The Endeavour looked as a better idea to prevent shrinkage cracking and control of early thermal contraction right after placing the fresh concrete in the formwork. Concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of layers of steel meshes. The main objective of this experimental work is to study the behavior of ferrocement panels under flexural loading in which welded square mesh has been used as a reinforcement and copper slag is also used replacing river sand .The various parameters considered in this study are as follows -:

a) Effect of using copper slag instead of river sand.
b) Effect of using various mix proportions for cement with sand and copper slag.

II. MATERIALS

2.1 Copper Slag:

Copper slag is a by-product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2-3.0 tons of copper slag is generated as by-product material and is used as replacement for sand in the construction industry. The blasting media manufactured from copper slag brings less harm to people and environment than sand. The product meets the most rigid health and ecological standards.Copper slag is used as a building material, formed into blocks.

Table.1 Properties of Copper Slag

S.no	Property	Value
1	Bulk Density	1.7-1.9 g/cc
2	Specific Gravity	3.68
3	Hardness (moh scale)	6-7 pH
4	pH in a aqueous solution	6.6-7.2

2.2 Steel Mesh:

Steel mesh reinforcement is broadly used as the main and characteristic reinforcing for industrial concrete floor slabs, shortcrete. It is also measured for structural purposes in the reinforcement of water tanks, tunnel segments, concrete cellars, meshes help to develop the compressive strength, tensile strength, flexural strength, post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks. The main reason for addition of meshes to mortar is to develop the post cracking response of the concrete, i.e., to improve its energy absorption capacity and apparent flexure.

III. EXPERIMENTAL WORK

The experimental program includes preparing and testing of flat ferrocement slab panels under two-point loading. The primary variables were the two layers of meshes with different mix proportions and the use of copper slag instead of river sand.

3.1 Preparation of Mesh:

1/2 inch and 1 inch mesh was cut according to the required dimensions. The meshes were straightened using wooden hammers. Hooks were used for tying the bending wires. 600*300 mm sizes were sandwiched together using binding wires of 1mm for checking the flexural strength. 300*300 mm sizes were used to calculate the impact strength.

3.2 Preparation of Mortar

Mortar was prepared by calculating the exact amount of cement, sand and water by considering the appropriate mix design and water-cement ratio. At first the cement and sand were mixed dry. Water is gradually added to the dry mix and is mixed by using shovel.

3.3 Casting

Closed mould system: the Ferrocement slabs were cast using the closed mould system. The mortar is applied from one side through several layers of mesh, held in position against the surface of a closed mould. The mould is treated with mould releasing agents. In this method, the mortar is applied from one side.

3.4 Curing

The day old Ferrocement slabs and mortar specimens were cured in a fresh water tank for a period of 28 days. The slabs were laid to rest vertically in the upright position, resting on the longer side. The slabs were laid for curing after the specimens were marked legibly with a permanent marker for identification.

IV. TESTING ON FERROCEMENT SLAB

The panels were removed from curing tank after a period of 28 days. White wash was applied to the panels in order to get clear indication of cracks due to bending under service loads. Panels were tested for flexural strength under universal testing machine and also for impact strength. The panels were placed on support leaving a space of 50 mm from both ends. Dial gauge was placed below the panel to record the deflection in mm each stage of loading. Cracks are then marked during each loading and corresponding central deflection is also noted down. Both continuous and cyclic readings are taken to see the changes.

4.1FLEXURE ON SLAB

Bending bending elements is primarily a function of the tensile strain in the extreme layer of mesh and transverse reflects the combined influence of parameters controlling both tensile and compression properties space such a mortar compressive strength, mesh type, mesh properties and mesh orientation. The ferrocement with the mesh layers even bundled at the centre of cross section behaves similar to that of the plain mortar under bending. The average crack width in ferrocement wire spacing. The size of the mesh openings should be within 6-25mm. meshes to be used as reinforcement in ferrocement should have to be easy to install, light weight, adaptability to the curves and contours of any structural shape. The compressive strength of mortar does not seem to have much influence on the bending resistance of ferrocement beams

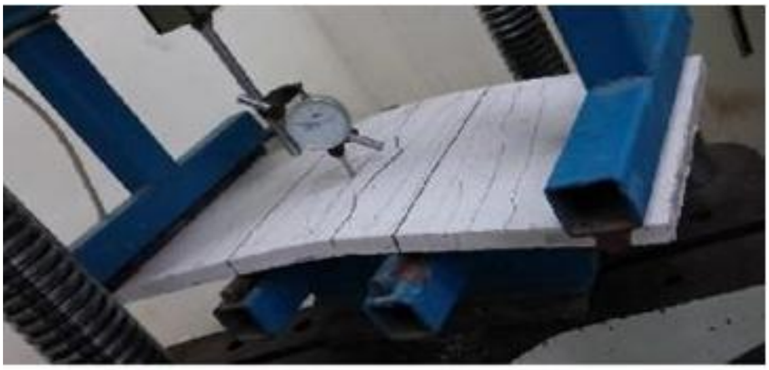

Fig. 1 Flexure and Test on Ferrocement Slab

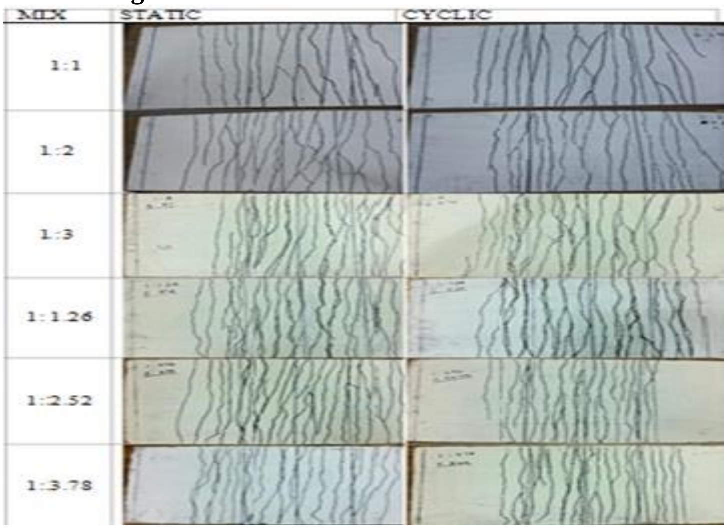

Fig.2 Crack pattern on Ferrocement slabs

4.1 Testing of Companion Specimen

A total number of 12 cylinders of diameter 100mm and 195mm height, 12 beams of size 160 X40 X 40mm and 12 cubes 40mm x 40mm were casting standard steel moulds. These specimens were removed from moulds after 24 hours and cured for twenty eight days in water tank before testing.

Fig .3 Split Tensile Tests on Companion Specimen

Test for compressive strength was carried out on cube, beam and cylinder specimens under saturated surface dry condition in an universal testing machine (UTM).Test arrangements and method used for compression tests were in accordance with IS: 516:1959, "Method of Test for Strength of Concrete". For testing the small mortar cubes Japanese code JISA 1181 is referred.

Table.2 Test results on cement and sand specimen

S.	Mix	Compressiv	Flexural	Split
1	1:1	20	7.2	4.55
2		20.5	8.33	5.63
3		19.7	5.4	5.18
4	1:2	19.85	8.3	4.23
5		18.6	6.75	4.33
6		18.45	6.5	4.15
7	1:3	19.85	5.85	3.03
8		18.25	4.73	2.43
9		18.8	5.4	2.75

Table.3 Test result on cement and copper slag specimen

S.	Mix	Compressive	Flexural	Split
1	1:1.26	20.2	8.1	4.07
2		19.9	8.33	4.08
3		19.38	8.78	3.63
4	1:2.52	16.78	6.53	2.82
5		17.23	5.63	3.31
6		15.33	5.51	4.14
7	1:3.78	19.85	3.83	3.79
8		19.25	3.83	2.43
9		19.8	3.66	2.75

4.2 Cyclic Loading On Slabs

Cyclic loading is applied to the ferrocement slabs A1, A2, A3 and B1, B2, B3 of cement-sand mortar and cement-copper slag mortar respectively for loading upto 3.2 kN for each cycle. From the deflection patter observed at each cycle, the residual deflection of the ferrocement slabs are calculated

Table.4 Residual Deflection for various mixes

Mix ratio	Residual deflection (mm)				
	Cycle1	Cycle2	Cycle3	Cycle4	Cycle5
1:1	0.08	0.23	0.19	0.18	0.26
1:2	1.05	4.15	4.17	4.06	1.13
1:3	1.71	1.38	1.67	1.59	0.44
1:1.26	3.8	3.7	4.1	3.68	3.72
1:2.52	1	0.88	0.95	0.93	0.78
1:3.78	0.55	2.2	2.2	2.22	3.3

4.3 Impact Resistance

Resistance to impact is often measured by the amount of energy absorbed during the impact loading. The results from impact tests indicated that both the duration and amplitude of the square pulse influence the dynamic amplification.. A linear relationship was observed between compressive strain and deflection after localized damage. The experimental results on impact strength indicated that Ferrocement laminate with addition of fly ash and silica fume to the matrix distribute the stresses over large area resulting increase in energy absorption capacity due to impact.

Table.5 Impact Test Results

Mix Ratio	Hegiht (m)	Weight (N)	No. of blows		Energy (joule)	
			First Crack	Failure Crack	First Crack	Failure Crack
1:1	0.3	38.45	2	4	23.07	46.14
1:2	0.3	38.45	2	3	23.07	34.60
1:3	0.3	38.45	1	3	11.53	34.60
1:1.26	0.3	38.45	1	3	11.53	34.60
1:2.52	0.3	38.45	1	4	11.53	46.14
1:3.78	0.3	38.45	2	4	23.07	46.14

V. TEST RESULT AND DISCUSSIONS

- Based on the flexural test and impact test results, the observed behavior of the Ferrocement slabs are as follows.
- The observed ultimate load for cracking of ratios 1:1, 1:2, and 1:3 are 5.4KN, 6.56KN and 7.36KN for Static Loading and 5.36KN, 5.2KN, 5.22KN for Cyclic Loading respectively.
- The observed ultimate load for cracking of ratios 1:1.26, 1:2.52, 1:3.48 are 5.4 KN, 6.56KN, 7.36KN for Static Loading and5.36KN, 5.2KN,5.22KN for Cyclic Loading.
- The crack spacing at first cracking load are 50 mm, 51 mm, 46 mm, 30mm, 28mm and 28mm respectively. The number of cracks developed at first cracking is 6, 7, 8, 2, 4, and 6 for ratios A1, A2, A3, B1, B2 and sB3.
- The crack spacing at ultimate load are 10mm, 23mm, 10mm, 6mm, 12mm and 18mm for A1, A2, A3, B1, B2 and B3 respectively for the Static Loading. The number of cracks developed at ultimate loads is 16, 17, 17, 27, 21 and 21 for A1, A2, A3, B1, B2 and B3.
- Based on the limited experimental investigations the following conclusion was drawn.
- Voided Ferro cement elements possess better ultimate flexural strength almost equal to the solid elements.

VI. CONCLUSION

Thus from the above comparison it is evident that among the cement mortar Ferrocement slabs of 2 layers of different mix proportions, 1:2.52 cement with copper slag mix had provided the best results having a greater flexural strength and impact strength.

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