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Effect of Different grades of River sand Cement and Copper Slag Cement Matrices on Flexural Behaviourof Ferrocement Slabs

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Abstract

Ferrocement is a versatile construction material having light weight, closely spaced small diameter reinforcement covered with cement mortar. Lot of works have been carried out onferrocement by using river sand as fine aggregate in India and other countries. Research also has been carried out on ferrocement with other than cement mortar. Matrices like polymer impregnated cement mortar, resin mortar, latex modified cement mortar and fibre reinforced mortar matrix and studied their structural responses at CSIR-Structural Engineering Research Centre, Chennai and Nihon University, Japan. Research works on ferrocement is under progress by using copper slag as fine aggregate in cement mortar at Easwari Engineering College, Ramapuram, Chennai. Totally six mortar mixtures, three with river sand and three with copper slag as fine aggregate and three different strength in each were used as matrix in preparation of ferrocement slabs. Reinforcement content was same in all specimens. Mechanical properties, Viz., compressive strength, split tensile strength and flexural strength were evaluated for all the mixtures.

To evaluate the effect of different mortar proportions and different types of fine aggregates on flexural behaviour of ferrocement slabs having same size and reinforcement content. The types of fine aggregate used are normal river sand and the same gradation of copper slag. Different mortar mixtures used are 1:1, 1:2 and 1:3 (Cement: Fine Aggregate) and equal volume to river sand of copper slag was used in another three mixtures. Totally 6 mortar mixtures were used and studied their mechanical properties, viz., compressive strength, split tensile strength and flexural strength.

Keywords River sand; Copper slag; Wire mesh; Ferrocement; Flexural strength; Stiffness

1.Introduction

Ferrocement was invented by Joseph Monier and Joseph LouirLambot in the year 1848. In the first half of the twentieth century Italian Pier Luigi Nervi noted for his use of ferrocement. Ferrocement has relatively good strength and resistance to impact. When used in house construction in developing countries, it can be provided better resistance to fire, earthquake and corrosion than traditional materials, such as wood and stone masonry. It has been popular in developing countries for building because the technique can be learned relatively quickly allowing people to cut costs by suppling their own labour. The advantages of a well builtferrocement construction are the labour-intensive nature of it, which makes it expensive for industrial applications in the western world.

Ferrocement is a strong, versatile long lasting building materials made from a wire reinforced mixture of cement, sand and water. Ferrocement is a special material called "thin membrane" that is quite strong despite being thin. It is strong under both stress and strain, because it is both strong and thin in nature, many things can be constructed at low cost. Making of ferrocement products use more man power than machines. This makes it especially suitable for developing country like India where manpower is relatively cheap.

2.Mortar Mixtures

In this investigation six different mixtures were used. Two types of fine aggregate, viz., normal river sand and copper slag were used. Normal river sand and copper slag based mixture details are given in **Table 1.** The density of copper slag is higher than the river sand. Therefore the copper slags in the mixture are taken to the equal volume of normal sand in all the mixtures. Mixture ratio in copper slag mixtures is not same in weight basis as in river sand mixture and higher values. But same water / cement ratio was used to the respective mix both in river sand and copper slag based mortar mixes.

Table 1 Detail of Mortar Mixture Proportions(Weight)

Sl. No.	Mixture Id.	Type of Fine Aggregate	Mixture Ratios			Remarks
			Cement	Fine Aggregate	W/C	
1	RS-1	Normal River Sand	1.00	1.00	0.35	More cohesive and workable
2	RS-2		1.00	2.00	0.42	Cohesive and workable
3	RS-3		1.00	3.00	0.48	Workable
4	CS-1	Copper	1.00	1.26	0.35	More cohesive

		Slag Sand				and workable
5	CS-2		1.00	2.52	0.42	Cohesive and more workable
6	CS-3		1.00	3.78	0.48	More workable

3.Preparation of Test Mortar Specimens

To evaluate the mechanical properties of six mortar mixtures, test specimens of size 40x40x40mm cubes for compression, 40×40×160 mm prisms for flexure and 100 mm dia.×200 mm height cylindrical specimens for split tension were prepared as per the Japanese Industrial Standards JIS A1182. After 28 days of water curing all the specimens were tested under their respective strength. Three identical specimens were tested in each batch of mixture and test.

4.Preparation of Ferrocement Slabs

Ferrocement slab of size 300 × 600 × 20 mm was proposed to prepare for flexural test. 3 mm diameter and 50 × 50mm spacing in both direction welded wire fabric and 1 mm dia. and 10 mm spacing in both direction wire mesh were used as reinforcement. 2 layers of welded wire fabric and two layer of wire mesh one at top and another at bottom to 2 layer welded wire were tied together with binding wires at closer spacing. Wooden moulds of inner dimensions of 300 × 600 × 20 mm with mould releasing agent applied at inside surface were used. The area of reinforcement content to the cross section area of slab along span direction is 2.78 % (welded wire + wire mesh). The same size of specimens and same reinforcement content was used in all slabs. The variation in slabs is types of fine aggregates and strength grade of mortar mixtures.

Moulds inner surface area was applied with mould releasing agents and kept in leveled surface. The prepared mortar mix was poured into the wooden mould to a height of 6 mm and compacted. The reinforcement gauge was placed over the mortar layer in the mould and mortar was placed on the top of the reinforcement and compacted. Care was taken to keep the reinforcement at equal cover at top and bottom of the slabs. Compacted well to all the gaps in between the reinforcement gage fill by mortar and finished the top surface. Slabs were prepared for all the six mixture proportions. After 24 hours of casting, slabs were demoulded and kept in curing tank in fully immersed condition for 28 days.

5.Test Results

5.1 Mechanical properties

Compressive strength test were carried out on 40 × 40 × 40 mm cube specimens (as per JIS A 1182) in a UTM of range 40 kN. Three identical saturated surface dried specimens were tested in all six mixtures. 100 mm dia. × 200 mm height size three identical saturated surface dried specimens were subjected to split tensile test in all the mixtures. Flexural strength test was carried out on 40 × 40 × 160 mm size prisms. Four point load test with span of 120 mm was carried out on three identical saturated surface dried conditions in all six mixtures. **Table 2** presents the test results of mechanical properties of all six types of mortar mixtures.

Table 2 Mechanical Properties of Mortar Mixtures

Mixture Id.	Compression (MPa)		Split Tension (MPa)		Flexure (MPa)	
	Individual	Average	Individual	Average	Individual	Average
RS-1	20.00	20.08	5.18	5.35	5.38	5.48
	20.50		5.68		5.57	
	19.74		5.18		5.49	
RS-2	17.98	18.34	4.21	4.23	4.81	4.56
	18.60		4.33		4.51	
	18.45		4.14		4.36	
RS-3	16.73	16.26	3.03	2.84	3.53	3.43
	17.00		2.75		3.16	
	15.05		2.74		3.61	
CS-1	19.58	19.62	4.07	4.03	5.41	5.64
	19.90		4.08		5.57	

	19.38		3.95		5.94	
CS-2	16.10	16.01	3.45	3.42	4.36	4.24
	16.60		36.31		4.10	
	15.33		3.50		4.25	
CS-3	13.60	12.03	2.83	2.67	2.56	2.52
	12.00		2.43		2.56	
	10.68		2.74		2.44	

5.2 Flexural behavior of Ferrocement Slabs

Ferrocement slab specimens of size 300 × 600 × 20 mm were subjected to four point load flexural test. After 28 days of water curing all the specimens were dried at room temperature and applied white wash for easy observation of cracks occurred during test. Load points and supports were marked on all the slab specimens. Specially fabricated load set up was fixed in the 40kN ranged UTM and placed ferrocement slab on it. A 0.01 mm accuracy dial gauge was fixed at mid span of top surface to measure the deformation at different load level. In this test set up two point load was applied from the bottom and supported at top to bending of slab due to load towards top side. The advantage in this set up is easy to observe cracks formation, crack marking, measuring crack width, measuring crack spacing and counting no of cracks at different load intervals. **Figure1** shows the flexural test under progress.

Slab specimen was placed on the load set up and aligned properly. Dial gauge was adjusted to zero reading and positioned exactly at mid span. Load was applied to the level of 0.4 kN and released to zero for proper settle the slab on the test set up. Initial dial gauge reading was noted down. Load was applied on the slab specimen at bottom. Load was applied in increment of 0.4 kN and every load interval the deflection values, number of cracks developed, the average crack spacing and crack pattern were observed and recorded. Load was applied up to failure of slab specimens. The same method was followed for all the slabs prepared with different mortar mixtures. **Figures**.**2** shows the load Vs central deflection curves for normal river sand based ferrocement and copper slag based ferrocement slabs. The number of cracks and crack spacing at different load intervals are presented in **Figures.3** and **4,** respectively. The failure pattern at ultimate load level of all the ferrocement slabs are shown in **Figure5.** First crack and ultimate load behavior of all the slabs are presented in **Table 3**.

Table 3 First Crack and Ultimate Load Behaviour of Ferrocement Slabs

Sl. No.	Specimen Id.	First Cracking Load Behaviours				Ultimate Load Behaviours			
		Load (kN)	Deflection (mm)	No. of cracks	Crack spacing (mm)	Load (kN)	Deflection (mm)	No. of cracks	Crack spacing (mm)
1	RS-1	1.6	2.72	4	51	5.28	27.54	16	8
2	RS-2	2.4	4.68	8	49	6.48	27.26	17	5
3	RS-3	1.6	2.47	4	46	6.10	29.51	20	9
4	CS-1	1.6	1.35	2	28	5.40	28.49	27	4
5	CS-2	2.4	4.41	5	28	6.35	33.61	21	9
6	CS-3	3.2	4.14	4	29	7.36	25.29	21	18

Figure1 Flexural test setup

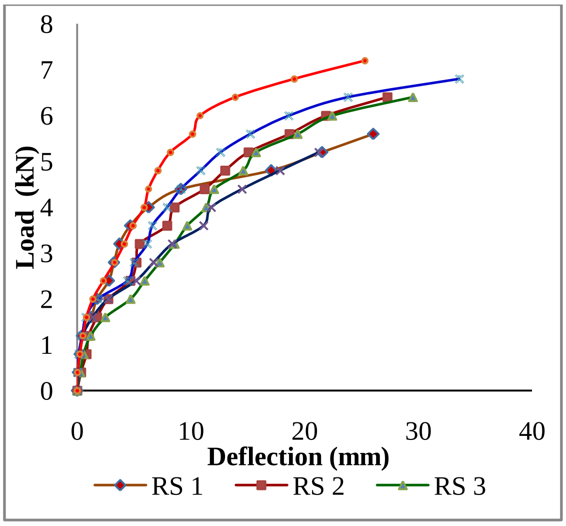


Figure 2 load Vs central deflection curves for normal river sand based ferrocement and copper slag based ferrocement

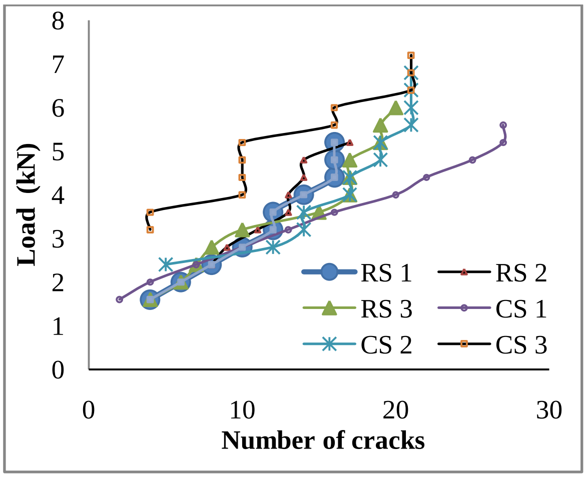


Figure 3 Number of cracks at different load intervals

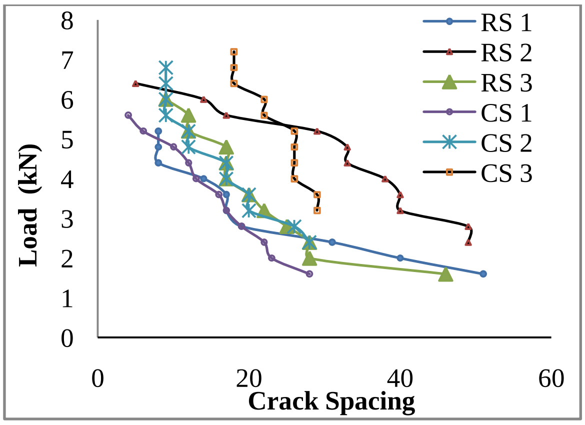


Figure 4 Crack spacing at different load intervals

6.Discussion on Test Results

6.1 Mechanical Properties of Mortar Mixtures

When compared RS - 1 to CS – 1, RS – 2 to CS – 2 and RS – 3 to CS – 3, the compressive strength decreased to 2.29 %, 12.7 % and 26.02 %, respectively. The copper slag based mortar showed reduction in compressive strength and also the reduction increases when the mortar mixtures goes to low strength when compared to river sand based When compared to RS – 1 mix the decrease in RS – 2 and RS – 3 mixtures are 8.67 % and 19.02%, respectively. CS – 2 and CS – 3 registered reduction in compressive strength are 18.40% and 38.69 %, respectively when compared to CS – 1. The same trend occurred in split tensile strength and flexural strength**. Figure 6** shows mechanical properties in between river sand based mortars and copper slag based cement mortars.

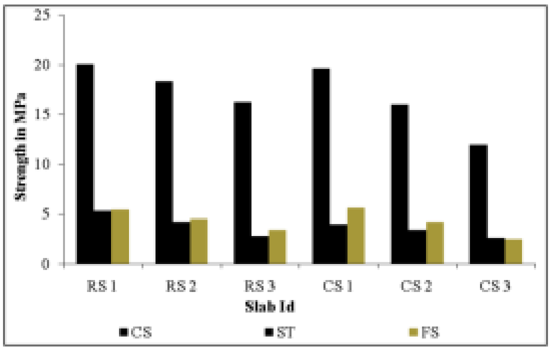


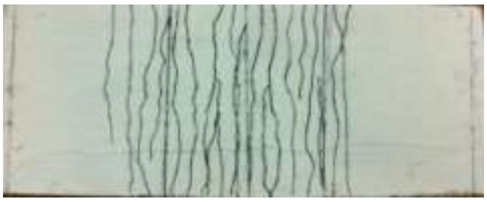
Figure 5 Mechanical properties of river sand and copper slag based cement mortars.

6.2 Flexural Behaviour

The first cracking loads of slab specimens, corresponding deflection, ultimate load and corresponding deflection, number of cracks and crack spacing for slabs RS 1, RS 2, RS 3, CS 1, CS 2 and CS 3 are given in Table 3 . The ultimate load increased for RS – 2 and RS – 3 are 22.73 % and 15.53 % , respectively. When compared top CS -1 slab , slabs CS – 2 and CS – 3 showed 20.66 % and 36.30 % , respectively. When compared to CS -1 slab the ultimate load carrying capacity was increased when the strength of mortar mix decrease. Copper slag based ferrocement registered better flexural performance than river sand based mortar mix slabs. The reason may be reduction in stiffness for lean mix. Stiffness of the ferrocement slabs RS 1, RS 2, RS 3, CS 1, CS 2 and CS 3 are 1.16, 0.73, 0.43, 0.73, 1.09 and 1.45 kN/mm , respectively. In river sand ferrocement slabs the stiffness values are decreased towards lean mix but the opposite trend was observed in copper slag based ferrocement slabs. The deflection energy absorption of RS 1, RS 2, RS 3, CS 1, CS 2 and CS 3 slabs are 1380, 1080, 1490, 1390, 2100 and 1710 kNmm, respectively. Compared to river sand based ferrocement slabs, copper slag based slabs registered high deflection energy compared to the same strength grade of mixtures. **Figure 6** shows the failure pattern of all six type of ferrocement slabs.

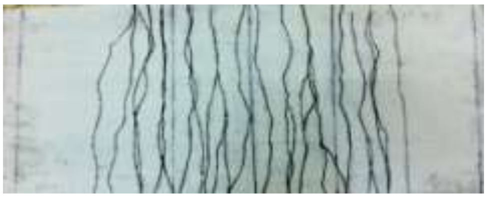
RS 1

RS 2



RS 3

CS 1



CS 2

CS 3

Figure 6 Failure patterns of ferrocement slabs

The first cracks appeared in constant bending moment zone inside the loading points in all the six type slabs. At ultimate load level, cracks are appeared away the load point in both side shear zones in RS-1 and RS-2, but in RS-3 cracks are occurred just away from loading point outsides. Similar crack patterns are noticed in all the copper slag based ferrocement slabs.

7.Conclusions

Based on the above test results, the following conclusions are arrived on mechanical properties mortars mixtures and flexural behaviourferrocement slabs.

1. Compared to copper slag based mortar mixtures RS-1, SS-2 and RS-3, the percentage decrease in compressive strengthfor CS-1,CS-2,CS-3 are 2.29,12.70 and 26.02, respectively, The same trends are noticed in split tensile and flexural strength.
2. First cracks appeared under flexure on slabs RS-1, RS-2, RS-3, CS-1, CS-2 and CS-3 are 1.6, 2.4, 1.6, 1.6, 2.4 and 3.2 kN, number of cracks developed are 4, 8, 4, 2, 5 and 4 and average crack spacing are 51, 49, 46, 28, 28 and 29, respectively.
3. Ultimate load carrying capacity of river sand based ferrocement slabs RS-2 and RS-3 are increased to 22.73% and 15.53%, respectively when compared with slab RS-1. In copper slag based slabs CS-2 and CS3 registered 17.59% and 36.30%, respectively compared to slab CS-1.
4. The change in ultimate load carrying capacity of slabs CS-1, CS-2 and CS-3 are 2.27%, -2.01% and 20.66%, respectively when compared with same grade slabs RS-1, RS-2 and RS-3.
5. Ferrocement slabs with lean grade of mixtures showed increase in ultimate load carrying capacity.
6. The stiffness of ferrocement slabs RS-1, RS-2, RS-3, CS-1, CS-2 and CS-3 are 1.16, 0.73, 0.43, 0.73, 1.09 and 1.45 kN/mm, respectively. Stiffness of river sand based ferrocement slabs showed descending order but copper slag based slabs in accenting order from rich mixture to lean mixture.
7. Number of cracks appeared at failure load are more in constant bending moment zone than outside the zone.
8. Overall, copper slag based ferrocementis better flexural performance than river sand based ferrocement slabs

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