Experimental Investigation of Ferrocement Deep Beams with Partial Replacement of River Sand by Pond Ash

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Abstract— The recent application of ferrocement includes prefabricated roof elements, load bearing panels, bridge decks and others. This present study deals with the experimental investigation of ferrocement deep beams with partial replacement of river sand by pond ash under two point loads. A total of 18 deep beams have been casted of dimension 120x250mm and the lengths of beams have been varied along with the variation of wire mesh layers and mortar strength kept constant. Before testing the top surface of these beams were white washed, to get a clear picture of crack pattern. Along with these beams 18 cubes have been casted with the dimension 7.06cmx7.06cmx7.06cm.the compressive strength of motor is determined.

Key words: pond ash, Hexagonal wire mesh, deep Beams, Fibrocement, shear span

I. INTRODUCTION

Ferrocement is a composite material consisting of cement-sand mortar (matrix) reinforced with layers of small diameter wire meshes. It consists of closely spaced multiple layers of mesh or fine rods completely embedded in cement mortar. Usually steel bars are used in addition to form a steel skeleton which helps in retaining the required shape of the ferrocement components until the cement mortar hardens. It differs from conventional reinforced concrete primarily by the manner in which the reinforcement is arranged within the brittle matrix. Since, its behavior is quite different from that of conventional reinforced concrete. in performance strength and potential applications it is classed as a separate material.

Usually the wire mesh reinforcement will be uniformly distributed across the thickness of the element. This helps in achieving improved mechanical properties fracture, tensile and flexural strength, and fatigue and impact resistance. Hence 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 mesh may be made of metallic being thin-walled in nature Ferrocement has found to be most suited for structures like shells and folded plates, where the applied load is primarily carried through the action of in-plane shear and axial stress.

Deep beam is a beam having large clear span to depth ratio and shear span depth ratio less than 2.5 for concentrated load and less than 5.0 for distributed load. It is a reinforced concrete member in which the total span or shear span is exceptionally small in relation to its depth. Deep beams play a very significant role in design of mega and as well as small structures. Some times for architectural purposes buildings are designed without using any column for a very large span.

A. Pond Ash

Coal ash has been dumped for many years on free land and has also partially been deposited in landfill sites. The waste has been generated in vastly increasing amounts as the demand for electricity, heat and energy has progressed. Electricity is one of the basic inputs required for the development of any country. In India nearly 73% of installed power generation capacity is thermal, of which about 90% is coal-based generation.

Thermal power is produced from combustion of Pulverized coal in boilers at thermal power plants. During the combustion of the coal three categories of waste products are formed in the form of bottom ash, fly ash and vapour. Fly ash collected from different rows of electro static thermal precipitators in dry form. Its used for manufacture of Portland Pozzolana cement, cement concrete and mortar, lime fly ash bricks, building blocks etc. Bottom ash collected at the bottom of boiler furnace characterized by better geo technical properties. It is good for fill, road and embankment construction.

Here, we are dealing with Pond ash. Fly ash and bottom ash is mixed together with water to form slurry, which is pumped to the ash pond area. In ash pond area, ash gets settled and excess water is decanted. This deposited ash is ‘Pond ash’. It is being used as filling material including embankment and road construction. Selected pond ash can be used for manufacture of building products like lime fly ash bricks/blocks.

II. MATERIALS

A. Cement:

Ordinary Portland cement (OPC-53 grade) of Grasim industries Ltd. from single batch is used throughout the course of the investigation.

Properties	Results
Normal consistency	31%
Initial setting time	44min
Final setting time	209min
Specific gravity	2.954
Soundness	1mm

Table 1: Properties of Cement

B. Fine Aggregate:

Well graded locally available river sand from Shahpur taluka of 2.36mm size is used. Lumps of clay were separated out from the sand. The sand having fineness modulus between 4-4.6 is suitable for ferrocement deep beam construction. The grading of sand for mortar mixes becomes very important to get workable cement mortar with low w/c ratio

Properties	Results
Moisture content	2.0%

Water absorption	1.20%
Specific Gravity	2.56
Sieve analysis	Zone II

Table 2: Properties of fine aggregate

C. Pond ash:

In this study pond ash is used as fine aggregate i.e. sand is partially replaced by pond ash. Pond ash is a mixture of fly ash and bottom ash mixed with water obtained from thermal power plant. The pond ash collect from thermal power plant, Raichur was used for the experiments.

Properties	Results
Specific gravity	1.75
Finess modulus	1.79

Table 3: Properties of pond ash

D. Water:

Water used for both mixing and curing should be free from injurious amounts of deterious materials. Potable water is generally considered satisfactory for mixing and curing of concrete. In the present work potable tap water is used.

E. Wire mesh:

Wire mesh is one of the important constituent of Ferrocement. This generally consists of thin wires. The mechanical properties of ferrocement depend upon the type of quantity and strength properties of mesh reinforcement. The different types of wire mesh are chicken (Hexagonal/aviary) wire mesh, square woven or welded mesh, expanded metal mesh lath etc. Except for expanded metal mesh, generally all the meshes use are galvanized.

Wire mesh type	**Properties**	**Value**
Welded wire mesh	Average diameter	1.2mm
	Opening size of mesh	12.5mmx12.5mm
	Yield strength in tension	410 N/mm^2
	Modules of elasticity	10000 N/mm^2

Table 4: Properties of Wire Mesh

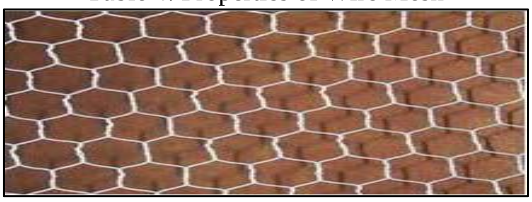


Fig. 1: Hexagonal wire mesh

F. Steel:

Steel consists of 2 main bars of 10mm diameter at the bottom and 2 holding bars of 6mm diameter at the top tied with the vertical stirrups of 6mm diameter at a spacing of 150mm.

III. EXPERIMENTAL PROGRAMME

The experimental investigation includes casting of 18rectangular deep beams with cubes. Two groups of specimens were casted. In Group-A, nine beams of span 800mm with cross section of size 120mm x 250mm were casted. The parameter considered in this group is varying wire mesh layers (N) while the shear span to depth ratio (a/h) and mortar strength (f_{cu}) were kept constant.

In Group –B, again nine beams of same cross section with varying span 800mm, 850mm, 900mm were casted. The parameter considered in this group is varying shear span to depth ratio (a/h) while the mortar strength (fcu) and wire mesh (N) were kept constant. All beams have kept same dimension and are reinforced in a symmetrical manner as show in fig2. The length has been varied i.e. a/h ratio.

The details of test specimen as shown in Table 7 the parameters considered were the shear span-to-depth ratio a/h and the number of mesh layers N. The a/h ratio was varied by changing the span of the beam from 800mm to 900mm. While maintaining the overall depth of the beams at 250mm the variation in the amount of reinforcement was accomplished by varying the number of mesh layers from 2 to 7. The designation has been given for the deep beams as shown in table 7.

A. Mix Proportion

1) Grade of mortar (M30)

Throughout the whole program the cement to sand ratio 1:2 and w/c ratio from 0.3 to 0.6 based upon the mortar strength required and to obtain the desired workability.

2) Fresh state properties of mortar:

Mortar flow table test is carried out in order to fix the w/c ratio for 1:2 mix proportion and the results are presented in table 3.

W/C ratio	Flow%	Remark
0.3	18.6	Dry mix
0.4	21.69	Dry mix
0.5	25.26	Workable mix
0.6	30.92	Bleeding

Table 5: Mortar flow

From table it was observed that mix no.1, 2 & 4 were not workable, workability of mix no.3 was good and it has been finalized for further casting.

3) Trial casting for 1:2 mix proportion

Trial casting of mortar using cement to sand ratio 1:2 with water to cement ratio 0.5 & replacing the sand by pond ash from 0%, 10%,15%,20% & 30%.

4) Size of specimen

The mortar cubes of size 7.06cm x7.06cm x7.06cm were casted using the above mentioned proportional .cubes were cured under accelerated curing .the results are in given table 6.

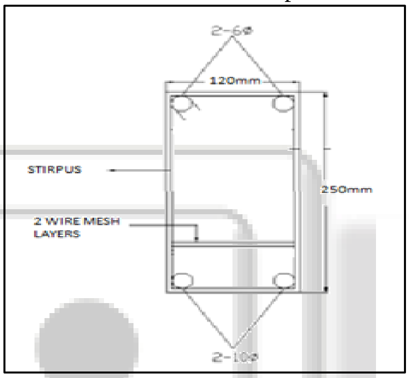
Cube Desiganation	w/c ratio	Cement sand ratio	Replacement of sand by Pond ash in %	Compressive strength N/mm^2	Avgcomp strength N/mm^2
A1	0.5	1:2	0	34.45	33.36
A2	0.5	1:2	0	32.27	
B1	0.5	1:2	10	33.278	33.646
B2	0.5	1:2	10	34.014	
C1	0.5	1:2	15	36.194	35.758
C2	0.5	1:2	15	35.322	
D1	0.5	1:2	20	40.544	40.311
D2	0.5	1:2	20	40.118	
E1	0.5	1:2	30	31.19	30.715
E2	0.5	1:2	30	30.24	

Table 6: Trial mix proporation of motor

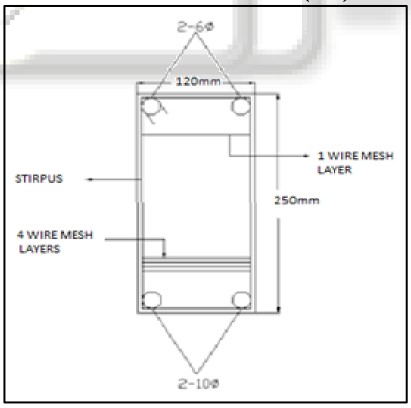
From the above test results, the w/c=0.5, compressive strength 35.758N/mm^2 with 15% replacement of pond ash in sand has been selected for casting of beams.

Beam Designation	Parameters investigated	Span of Beam(mm)	No. of layers of wire mesh	Cube compressive strength of Motor(Fcu)b N/mm2
A11,A12,A13	N	800	2	30
A21,A22,A23		800	5	30
A31,A32,A33		800	7	30
B11,B12,B13	a/h	800	3	30
B21,B22,B23		850	3	30
B31,32,B33		900	3	30

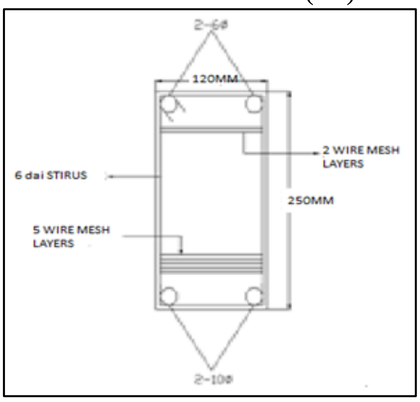
Table 7: Details of test specimens



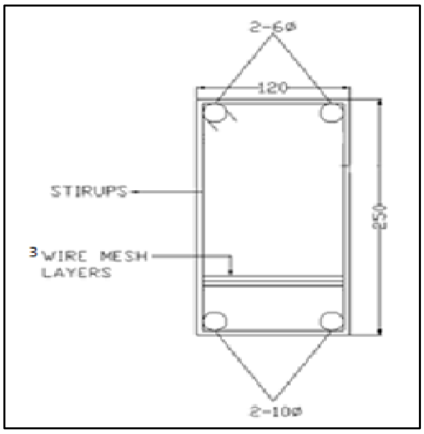
Cross section of beam (A1)



Cross section of beam (A2)



Cross section of beam (A3)



Cross section of beam (B)

Fig. 2: Cross section of beams

IV. PREPARATION OF TEST SPECIMENS AND CURING

The casting process could be summarized as follows. The different ingredients of cement mortar viz. cement, sand and pond ash in dry state and weigh them as per the mix design requirements. The requisite amount of weighed cement, sand and pond ash is initially taken and is mixed in a dry state to get a uniform mix. All the materials are again thoroughly mixed until a uniform colour appeared. Then add water according to mix design The plywood moulds of best quality were made to order. Before pouring the fresh cement mortar in these panels a nominal cover of 5-8mm is provided to the mesh and skeletal steel reinforcement, engine oil is applied in thin layers to the inner surfaces of moulds in order to prevent the sticking of cement mortar to mould. These specimens are allowed to set in the moulds for 24 hours, after 24 hours these specimens are de-moulded and were kept under wet conditions by immersing them in water continuously for 28 days followed by 2 days air dry.

V. TESTING OF SPECIMENS

All beams are simply supported on two edges. The beams were white washed to assist crack detection. All specimens were tested under concentrated two point load.The test setup is shown in the below Figure. Tests were conducted in a Universal Testing Machine with a maximum load capacity of 50 tones. The vertical deflections at mid-span were noted down. The loads were applied gradually with uniform rate of load increments except for the time when the crack width measurements were taken. The deflections and the corresponding applied loads were recorded at the specified displacement intervals. The cracking patterns were traced and the mode of failure identified after final collapse.

Fig. 2: Test Setup for beam

Beam	First crack load Pcr(KN)	Ultimate load Pu(KN)	Deflection in (mm)	Mode of Failure
A_{11}	40.22	120.66	12	Flexural
A_{12}	54.93	117.72	13	Flexural
A_{13}	44.32	110.32	11	Flexural
A_{21}	57.87	132.44	14	Combined flexural & shear
A_{22}	50.03	141.264	12	Flexural
A_{23}	56.898	139.30	13	Shear
A_{31}	62.784	147.15	14	Flexural
A_{32}	63.76	149.30	10	Flexural
A_{33}	65.48	152.45	12	Flexural
B_{11}	48.06	88.29	15	Flexural
B_{12}	35.316	76.12	13	Flexural
B_{13}	38.97	80.78	10	Flexural
B_{21}	43.16	78.48	14	Combined flexure & shear
B_{22}	40.55	80.56	11	Combined flexure & shear
B_{23}	42.56	82.56	15	Combined flexure & shear
B_{31}	46.10	108.89	13	Flexure
B_{33}	42.18	107.91	10	Flexure
B_{33}	39.24	105.94	11	Flexure

Table 8: Results and discussion

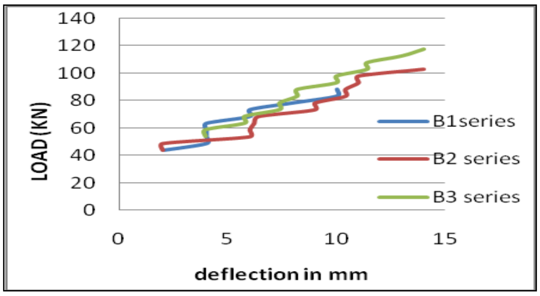


Fig. 3: Load deflection bhevaiour of beams of group A

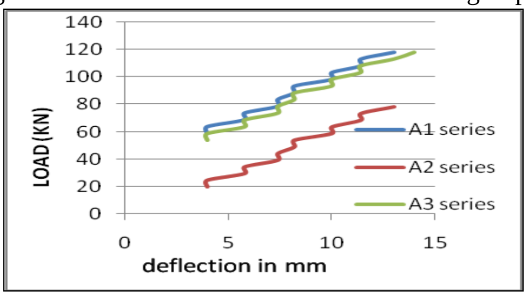


Fig. 4: Load deflection behavior of beams of group B


Fig. 5: Flexural Failure Observed in Beams


Fig. 6: Shear Failure observed in beams


Fig. 7: Beams after failure

A. Cracking Behavior and Modes of Failure

In all specimens, flexural cracks occurred first irrespective of the study parameters of the present study. As the load was increased, additional vertical cracks appeared on beam surface, followed by the formation of diagonal cracks. In the present study, diagonal tension cracks in the specimens with a/h> 0.65 generally originated as vertical flexural cracks that extended from the tensile surface of the beam to slightly above the level of the bottom layer of wire mesh then became inclined and propagated towards the nearer concentrated load. In cases of beams with shorter shear span (a/h<0.65) Diagonal tension cracks originated at about mid-depth of the beam and then progressed towards nearer concentrated load and tensile reinforcement. The other type of failure occurred in beams with a/h=0.7. This was typically shear compression failure characterized by crushing of the mortar near the concentrated load.

The increase in the volume fraction of reinforcement increases the shear strength of ferrocement deep beams when the dimension of the beam and motor are not varied .with decrease in Shear span to depth ratio increases the ultimate shear strength of ferrocement deep beams

VI. CONCLUSION

- The properties of pond ash match with that of the sand so that we can partially replace the river sand by pond ash
- The diagonal cracking strength of fibrocement increases as the a/h ratio is decreased or volume fraction of reinforcement and strength of the mortar are increased.
- Ferrocement deep beams demonstrate excellent crack control characteristics.
- The most effective means of increasing the shear strength of ferrocement deep beams is by increasing the mortar strength.
- Shear behavior of ferrocement element is almost similar to the behavior of reinforcement concrete element

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