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Experimental Study on Flexural behavior of Metakaolin and Fly ash based Ferrocement panel

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Abstract:	Ferrocement is a form of reinforced concrete differs from conventional reinforced or prestressed concrete primarily by the manner in which the reinforcing elements are dispersed and arranged. It is the composite of ferro(iron) and cement (cement mortar) in which small diameter wire meshes are used uniformly throughout the cross section. This wire meshes are filled in with cement mortar. The mesh made of metallic or other suitable materials. This paper presents an experimental investigation to compare the flexural behavior of partially replaced metakaolin and fly ash based ferrocement panel with control cement mortar panel. The main objective of this study is to investigate different numbers of wire meshes on the flexural strength of the flat ferrocement panels and to compare the effect of varying the number of wire mesh layers in the ferrocement structure under two-point loading. Ferrocement panel of size 940x470mm,40mm thickness has been adopted. panel under two-point loading. In control panel, no meshes have been used. In ferrocement panel, mesh layers of 1,3, and 5 have been tested and their values are compared with control panel. Thus, the flexural strength of varying mesh layers and proportions of material in ferrocement panel has been studied.
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Suggested Reviewers:	VENKATESH A, M.E ASSISTANT PROFESSOR, MEPCO SCHLENK ENGINEERING COLLEGE venkatesha@mepcoeng.ac.in Performs good in felxural aspects when comparing to normal conventional mortars
	HAAMIDH A, M.E ASSISTANT PROFESSOR, MEPCO SCHLENK ENGINEERING COLLEGE haamidh@mepcoeng.ac.in Metakaolin and flyash proportions increases the strength when compared to conventional mixes
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Experimental Study on Flexural behavior of Metakaolin and Fly ash based Ferrocement panel

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Abstract

Ferrocement is a form of reinforced concrete differs from conventional reinforced or prestressed concrete primarily by the manner in which the reinforcing elements are dispersed and arranged. It is the composite of ferro(iron) and cement (cement mortar) in which small diameter wire meshes are used uniformly throughout the cross section. This wire meshes are filled in with cement mortar. The mesh made of metallic or other suitable materials. This paper presents an experimental investigation to compare the flexural behavior of partially replaced metakaolin and fly ash based ferrocement panel with control cement mortar panel. The main objective of this study is to investigate different numbers of wire meshes on the flexural strength of the flat ferrocement panels and to compare the effect of varying the number of wire mesh layers in the ferrocement structure under two-point loading. Ferrocement panel of size 940x470mm,40mm thickness has been adopted. panel under two-point loading. In control panel, no meshes have been used. In ferrocement panel, mesh layers of 1,3, and 5 have been tested and their values are compared with control panel. Thus, the flexural strength of varying mesh layers and proportions of material in ferrocement panel has been studied.

Keywords — ***wire meshes, metakaolin, fly ash, flexural strength, ferrocement, cement mortar.***

I. INTRODUCTION

A highly versatile form of reinforced concrete is ferrocement which is made up of wire mesh, sand, water and cement, and possesses unique qualities of strength and serviceability. The difference between ferrocement and reinforced concrete is ferrocement is a thin composite made of cement matrix reinforced with closely spaced small diameter wire meshes instead of larger diameter rods and large size aggregates. The thickness of ferrocement generally ranges from 25-50mm.The least ACI code encourages the use of non-metallic reinforcement and fibres.

The inventors of ferrocement are Frenchmen Joseph Monier who dubbed it "ciment arme" (armored cement) and Joseph Louis Lambot who constructed a batteau with the system in 1848.He constructed a ferrocement rowing boat in 1848, in which reinforcement was in the form of flexible woven wire mat and small size bars. Italian person, Pier Luigi Nervi was noted in the first half of the twentieth century for his use of ferro-cement, in Italian called ferro-cemento.

Ferrocement is defined in different ways by different organisations:

1)According to United Nations High Commissioner for refugees (UNHCR),

Ferrocement is defined as 'A thin walled construction, consisting of rich cement mortar with uniformly distributed, closely spaced layers of continuous and relatively small diameter mesh (metallic or other suitable material).

2) ACI committee-549 describes it - "Ferrocement is a form of reinforced concrete using closely spaced multiple layers of mesh and/or small diameter rods completely infiltrated with, or encapsulated, in mortar. The most common reinforcement is steel mesh"

With ferrocement it is possible to fabricate a variety of structural elements, may be used in foundations, walls, floors, roofs, shells, etc which are thin walled light weight, durable with have high degree of impermeability. It combines the properties of thin sections and high strength of steel. In addition, it needs no formwork or shuttering for casting. Ferrocement have applications in all fields of civil construction, including water and soil retaining structures, building components, space structures of large size, bridges, domes, dams, oats, conduits, bunkers, silos, treatment plants for water and sewage.

In recent trends, there has been growing interest in a material produced from kaolinite clay called metakaolin. The usage of metakaolin as a cement substitute can reduce up to 127kg of CO_2 per tonne of cement produced. Therefore, metakaolin as a cement replacement is an environmentally friendly option. Fly ash is one of the residues from thermal power plant, which when partially replaced with cement can be used as a construction material. Cement being a large-scale producer of CO_2 is been partially replaced with fly ash in the proposed system.

II. LITERATURE REVIEW

Ferrocement panels exhibit a high value of elasticity and excellent crack resistance. Rate of flexural tensile strength development in metakaolin ferrocement is higher than the control ferrocement at all reinforcement levels. The ferrocement jacket was found to be a satisfactory solution for fire protection due to its post-fire flexural strength and toughness compared with plain mortar or concrete cover. Increases in the number of mesh layers enhance the flexural strength of the ferrocement for all metakaolin percentages and for all curing ages. The crack width of the lateral face of the ferrocement panels significantly decreased as the number of wire mesh increased.

III.RESEARCH SIGNIFICANCE

Ferrocement technique makes the structure light weight. The aim of this study is to compare the conventional panel with partially replaced metakaolin and fly ash based ferrocement panel by experimental investigation under two-point loading. The conventional panel refers to the ordinary cement mortar panel. The welded steel wire mesh inside the ferrocement panel provides better flexural strength than the conventional one. The properties of metakaolin and fly ash makes the flexural strength greater. Under two-point loading, the panel has been tested experimentally for flexural strength results.

IV.MATERIALS USED

A. Cement

The cement used in all mixture was commercially available Ordinary Portland Cement (OPC) of 53 graded confirmed to IS 12269-1987 [2]. The initial and final setting times were found as 32 & 130 minutes respectively. Specific gravity of cement is 3.164.

B. Fine aggregate

Locally available Natural River sand of size below 4.75 mm conforming to Zone II of IS 383-1970 is used as fine aggregate [4]. Specific gravity of fine aggregate is 2.63.

C. Wire mesh as Reinforcement

Reinforcement for ferrocement is commonly in the form of layers of continuous mesh fabricated from single strand filaments.

D. Metakaolin

Use of ferrocement coupled with metakaolin replacement could be a prudent idea for the benefit of reducing use of cement in ferrocement applications. Inclusion of metakaolin in ferrocement matrix influences properties of the mortar. Since the matrix represents approximately 95% of the ferrocement volume, its properties have a significant influence on the final properties of the product.

Table 1. Metakaolin property

Metakaolin	Property
Specific gravity	260
Bulk density	0.3 to 0.4
Physical form	Powder
Colour	white

E. *Fly ash*

One of the practical solutions to economise cement is to replace cement with supplementary cementitious materials like fly ash (Shetty 2005). Fly ash blended concrete can improve the workability of concrete compared to OPC. Fly ash replacement of cement is effective for improving the resistance of concrete to sulphate attack expansion.

V.MATERIAL PROPERTIES

Table 2. Chemical composition of Metakaolin, Fly ash and Cement

Chemical composition (%)	Cement	Metakaolin	Fly ash
Silica (Sio2)	21.8	50.7	65.43
Alumina (Al203)	6.6	45.8	20.67
Ferric oxide (Fe2O3)	4.1	0.35	NIL
Calcium oxide (CaO)	60.1	0.39	1.26
Magnesium oxide (MgO)	2.1	0.08	NIL
Sodium oxide (Na2O)	0.4	0.58	NIL
Potassium oxide (K2O)	0.4	0.05	NIL
Sulphuric anhydride (SO3)	2.2	NIL	NIL
Titanium oxide (TiO2)	NIL	1.25	NIL
Loss on ignition (LOI)	2.4	0.86	NIL

Table 3. Material description

Material	Properties	Characteristics value
Cement	**Specific gravity**	3.12
	Type	Ordinary Portland cement (OPC)
Fine aggregate	**Specific gravity**	2.56
	Fineness modulus	2.51
	Size	Passing through 4.75mm sieve
Mix proportion for mortar	1:3	

Table 4. Mechanical properties of wire mesh

Material	Properties	Characteristics value
Wire mesh	**Size**	2mm diameter,12.5mm x 12.5mm square opening
	Yield strength	390 N/mm^2
	Youngs modulus	2.1x10^5 N/mm^2
	Poisson's ratio	0.2
	Density	7850 kg/m^3

VI.EXPERIMENTAL WORK

In order to investigate flexural strength properties of metakaolin and fly ash ferrocements, six mixes were employed to study the effect of metakaolin and fly ash replacement: namely, a reference mix:

(i) with no metakaolin and fly ash mixes
(ii) with metakaolin and fly ash as cement replacement of 5%, 10%,15%, 20% and 25%.

To analyse the strength of each mortar mix, specimens like cubes were casted and tested for compression, and flexure respectively after 28 days of curing. The mix satisfying the strength requirement in all the three aspects was used in casting panels.

Mortar mix design

One of the ultimate aims of studying the various properties of the materials of mortar, is to design a mortar mix for a particular strength and durability. The design of mortar mix is not a simple task on account of the widely varying properties of the constituent materials, the conditions that prevail at the site of work, in particular the exposure condition, and the conditions that are demanded for a particular work for which the mix is designed. Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. The purpose of designing as can be seen is to achieve the stipulated strength and durability.

Mortar mix ratio is 1:3

Table 5. Total quantities of ingredients and mix proportion: (for mortar cube and panel)

Grade	Cement (kg/m^3)	Fine aggregate (kg/m^3)
Opc-53	59.37	237.42

Table 6. Panel details

Cement	Fly ash	metakaolin	Mesh layer
100	-	-	1,3,5
Partial replacement	Partial replacement	Partial replacement	1
Partial replacement	Partial replacement	Partial replacement	3
Partial replacement	Partial replacement	Partial replacement	5

Table 7. Mix proportion

Cement	Metakaolin	Fly ash
100	-	-
80	15	5
75	15	10
70	15	15
65	15	20
60	15	25
55	15	30

Fig 1. Cube casting

Fig 2. Square mesh

Casting of panels

Based on the results of compression tests, the best mix proportion is chosen. Then the panels were casted with better proportions for replacement of cement with metakaolin and fly ash using steel square mesh separately. For comparison, a control panel without mesh is casted with which the panel with mesh can be compared.

Fig 3. Casting of Ferrocement panel

The panels have been casted from base 5mm cover with mortar then meshes has been laid and covering them by remaining mortar mix.

Panel specifications

Wooden panel moulds of sizes 940mm×470mm and 40mm thick were used for casting panels. A clear cover of 5mm was maintained at the bottom(tension) and top (compression) sides. This panel size was recommended after a thorough study of ferrocement documents. From the compressive results of cube, the appropriate mix proportions were taken into consideration for casting the panels.

Fig 4. Ferrocement panel

VII. TESTS AND RESULTS

A. *Compression test*

The compression test on cubes was conducted on specimen of each of size 70mm×70mm×70 mm was casted and cured. The test was done on 7th, 14th, 28th day in the compression testing machine. Compressive strength is measured in N/mm2.

Fig 5. Compression testing

Fig 6. Cube after failure

B. Two-point loading test

The panels are tested under two-point loading testing machine with two dial gauges at L/3 distance. The specimens were tested up to failure. Ultimate flexural strength was obtained using the following equation based on theory of simple bending.

$$f_{cu}=\frac{wl}{\mathbf{bd^2}}$$

where f_{cu} is ultimate flexural moment, w is load at failure in N, l is effective span in mm**,** b is the width of the specimen in mm, d is effective depth of the specimen in mm.

Fig 7. Demoulded Ferrocement panel

Fig 8. Ferrocement Panel setup

VII. RESULTS AND DISCUSSIONS

The best proportion for mortar mix is taken by testing the cubes under compression testing machine. Compression test machines are specially designed to evaluate static compressive strength characteristics of materials, products and components. The aim of compression test is to determine the behaviour or response of a material by experiencing a compressive load by measuring strain, stress, and deformation.

The compression testing machine weighing upto 1000 KN. For mortar cubes the loads are given at 94.7 KN, 120.3 KN, 125.10KN, 76.26 KN, 65.79KN respectively. The mix proportion which resists maximum load is taken for casting panel. With replacement of cement with 15% metakaolin and 10% fly ash, various panels have been casted.

The ferrocement panels are used as a precast element or cast in site depending on the need.

The handling of the ferrocement panels are simple and don't require heavy machineries for erection

Effect of metakaolin and fly ash percentage

The effect of varying metakaolin and fly ash percentages on flexural strength of ferrocement at ultimate load is studied for different curing periods. It can be observed that, for all curing ages, the strength was either equal to or higher than the control ferrocement up to 15% replacement. The highest strength was observed in 15% replacement of metakaolin and 10% replacement of fly ash which is higher than control ferrocement at 7,14 and 28 days of curing. Metakaolin percentage of 20 and 25 resulted in lower strengths than the control mortar at all curing ages. From this observation, it can be stated that it is possible to obtain higher flexural strength than control mortar for up to 15% replacement of metakaolin, 10% replacement of fly ash and further increase causes decrease in the strength. It can also be observed that for 0.5 water to cementitious ratio, 15% replacement results in the highest strength and can be noted as the optimum metakaolin percentage. The influence of metakaolin and fly ash percentage on flexural strength of ferrocement panel is higher than control mortar up to 15% and 10% replacements.

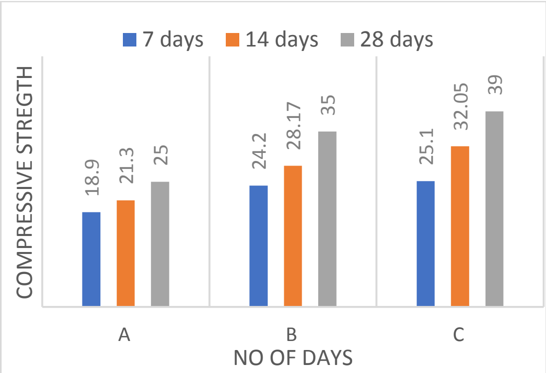

Fig 9. Compressive strength

Table 8. Flexural strength test data for different metakaolin percentages, different curing ages and different mesh layers

No. of mesh layers	Curing days	Ultimate flexural strength, MPa
0	28	2.5
1	28	9.1
3	28	17.6
5	28	25.2

VIII.CONCLUSION

From the results it is concluded that, the flexural results show better result in 5mesh panel with replacement of 10% fly ash and 15% metakaolin than the conventional one**.** The flexural strength of the ferrocement panel has been studied by casting mortar cubes followed by panel casting. The casted panels are tested under two-point loading by increasing the mesh layers and varying the percentage of metakaolin and fly ash. The results obtained from the above has been compared with 1,3 and 5 layers of meshes.Ferrocement uses layers of continuous/small diameter steel wire/weld mesh netting (metallic or non-metallic) as reinforcement with high volume fraction of reinforcement (2 to 8%) with specific surface of reinforcement is higher for ferrocement than for RCC.

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