EXPERIMENTAL STUDY ON FERRO-CEMENT ROOFING UNITS USING GEOPOLYMER COMPOSITE MORTAR

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ABSTRACT

Ferrocement is a composite material generally made up of cement matrix and reinforcement in the form of multiple layers of mesh. Ferro cement structures are flexible and strong, due to the fact that they are thin and the steel reinforcement is distributed widely throughout the mortar. With silicon and alumina as the main constituents, fly ash has great potential to be used as a cement replacing material. Fly ash when in contact with alkaline solutions forms inorganic alumino-silicate polymer product known as geopolymer. Hence in this project we have made an attempt to use geopolymer mortar and geopolymer composite mortar instead of cement matrix in ferrocement flat roofing units. This project aims to study the flexural behaviour of precast Ferrocement roofing units developed using Geopolymer mortar and geopolymer composite mortar.

Keywords: Ferro cement, Geopolymer, Fly ash, composite mortar, Wire mesh, flexural behaviour

1. INTRODUCTION

The project is about replacement of cement mortar with Flyash based geopolymer and geopolymer composite mortars in Ferro cement roofing units. Geopolymers are a new promising binder manufactured by activation of a solid alumino-silicate source material with a highly alkaline activating solution and aided by heat. These binders have been reported to achieve high early strength and better durability as compared to Ordinary Portland cement based counterparts. Demand for concrete as construction material is on the increase so as the production of cement. The production of cement is increasing about 3% annually. Therefore, an attempt has been made in the present investigation to study the strength characteristics of Ferro cement roof slabs prepared using geopolymer mortar considering fly ash as source material and NaOH + Na_2SiO_3 (both in solution form) as alkaline activator.

2. EXPERIMENTAL PROGRAM

2.1 Material Used

In this project, we have used Portland pozzolona Cement, Fine aggregate, Fly ash for manufacturing the precast Ferro cement slabs. The Fly ash is collected from Neyveli Thermal power station.

2.2 Cement

Portland Pozzolona Cement (PPC) having a specific gravity of 3.08 and fineness modulus of 2% was made use of, in the casting of the specimens.

2.3 Fine aggregate

Sand is an important ingredient of mortar. The sand particles consist of small grains of silica. The fine aggregate (sand) used was clean dry sand. The sand was sieved in 4.75mm Sieve to remove all pebbles.

2.4 Fly Ash

Class F dry Fly ash which is shown in Fig 3.2 conforming to IS 3812-2003 obtained from Neyveli Thermal power station of Tamilnadu from southern part of India was made use of in the casting of the specimens.

2.5 Mesh

Mesh consists of semi-permeable barrier made of connected strands of metal, fiber, or other flexible/ductile material. Here we are using three types of meshes for reinforcement, they are Welded wire mesh, Cross linked mesh and Hexagonal mesh. The size and diameter of Grid size: 1cm x 1cm, Diameter of wire: 1mm.

2.6 Sodium hydroxide flakes

Sodium hydroxide was clearly shown in the form of flakes in 97% purity manufactured by Merck Specialties Private Limited; Mumbai supplied by Vijaya Scientific Company, Chennai was used in the preparation of alkaline activator.

2.7 Sodium silicate solution

Sodium silicate in the form of solution supplied by Salfa Industries, Madurai was used in the preparation of alkaline activator. The chemical composition of Sodium silicate solution is as follows: 14.7%, of Na_2O, 29.4% of SiO_2 and 55.9% of water by mass.

2.8 Water

Distilled water was used for the preparation of sodium hydroxide solution and for the extra water to achieve workability

2.9 PARAMETERS USED

The following parameters were adopted in this study,

- Types of meshes used were Welded wire mesh, Cross linked mesh and Hexagonal mesh.
- Numbers of layers used were Single layer and Double layers.
- Mix ratio adopted were 1:2 and 1:1.3
- Quantities of fly ash and cement used in two ratio's were (in GP mortar 100% Fly ash & 0%Cement, and in GP Composite mortar 90% Fly ash & 10% Cement)

3. MIX DESIGN

3.1 Mix design for GP mortar of ratio 1:2 for 1m^3

3.2 Mix design for GP composite mortar of ratio 1:2 for 1m^3

3.1 Details of mix proportions for a 1:2 GP Mortar

Constituents	Composition in kg/m^3
Fly ash	632.35
Cement	0
Fine Aggregate	1264.70
Alkaline activator	252.93

1.2 Details of mix proportions for a 1:2 GP Composite Mortar

Constituents	Composition in kg/m^3
Fly ash	569.12
Cement	63.235
Fine Aggregate	1264.70
Alkaline activator	252.93

2. **DETAILS OF TEST SPECIMENS**

Experimental study on ferrocement slabs with various layers of meshes was carried out to evaluate the flexural strength. Flexure strength of the slabs was found by conducting Flexure test in Universal testing machine of 1000kN capacity.

4. DETAILS OF THE SLAB

The size of the slab is 1m x 0.3m x 0.02m. Mix ratios used were 1:2

4.1 Number of specimens for 1:2 mix ratios

S.No	Type of mesh	No.of.layers	Percentage of cement	Numbers
1	Welded wire mesh	Single	0	1
			10	1
		Double	0	1
			10	1
2	Cross linked mesh	Single	0	1
			10	1
		Double	0	1
			10	1
3	Hexagonal mesh	Single	0	1
			10	1
		Double	0	1
			10	1

5. PREPARATION OF TEST SPECIMENS

5.1 Batching

Here we adopted weigh-batching method, and it is the accurate method too. Use of weigh system in batching, facilitates accuracy, flexibility and simplicity.

5.2 Preparation of the wooden mould

The slab moulds are used of standard size 1000mm x 300mm x 20mm, which is made up of wooden planks. All the faces of the wooden mould are nailed with internal angle of 90°.

5.3 Preparation of alkaline activator solution

Ratio used between Fly ash and alkaline liquid (mixture of NaOH and Na_2Sio_3) is 1:0.4. Ratio used between NaOH and Na_2Sio_3 is 1:2.5. Based on the molarity, 12M NaOH of mass 240gms was taken and it was make-up in 500ml make-up flask. Then weighed in a weighing balance and 2.5 times of NaOH which gives the weight of Na_2SiO_3. Then solution should be shaken well and kept in an ambient temperature for a day before casting.

5.4 Mixing

Through mixing of material is essential for production of uniform course. The mixing should ensure that the mass homogenous, uniform in colour and consistency. As the mixing cannot be thorough, it is desirable to add 5% of water. The mixing was done manually because of using alkaline solution for binding property of fly ash. The usage of alkaline solution makes the mix homogenous, uniform and with little flow ability to get good binding.

5.5 Pouring of geopolymer mortar mix

After mixing, the moulds are filled immediately by pouring the Fly ash paste inside. The Fly ash paste is poured to layers of about 10mm and is smoothened using trowel and then the layers of mesh are laid for single layer. In case of double layers the first layers is kept after 5mm of mix and then 10mm of mortar mix after then second layer of mesh, above second layer 5mm mortar mix should be filled. During pouring it needs less compaction because of the paste nature of mix and usage of the alkaline solution, which reduces entrapped air the mix.

5.6 Curing

The test specimen after demoulding placed in an ambient temperature for a period of 28 days. Here we are using Fly ash so it will end up in polymerization process (i.e.) Absorption of heat, so water curing is not necessary.

6. RESULTS AND DISCUSSION

Compressive strength test

Compressive strength test was the most common test conducted on hardened mortar cubes, partly because it was an easy test to perform, and partly because most of the desirable characteristic properties of concrete were qualitatively related to its compressive strength. The mortar cubes was of size 150x150x150 mm. The compressive strength required was found by testing mortar cubes of curing for 7 days, 28 days and also heat curing. The comparisons of the mortar cubes at various curing periods were tabulated.

6.1 Compressive strength of mortar cubes for mix ratio 1:2 GP Mortar after 7 days

Spec.	Weight (gms)	Load (kN)	Compressive strength (N/mm^2)	Avg. Compressive strength (N/mm^2)
1	725	14	2.6	2.9
2	738	15.5	3.0	
3	698	17	3.1	

6.2 Compressive strength of mortar cubes for mix ratio 1:2 GP Composite Mortar after 7 days

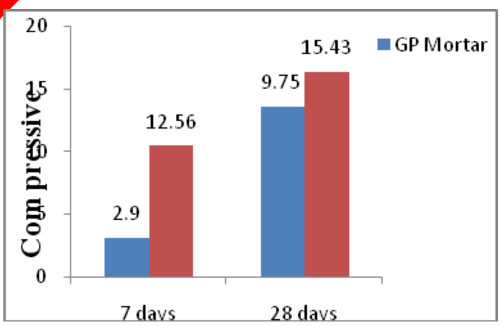
Spec.	Weight (gms)	Load (kN)	Compressive strength (N/mm^2)	Avg. Compressive strength (N/mm^2)
1	707	68.5	12.5	12.56
2	722	69.5	12.9	
3	692	66.5	12.3	

6.3 Compressive strength of mortar cubes of mix ratio 1:2 GP Mortar after 28 days

Spec.	Weight (gms)	Load (kN)	Compressive strength (N/mm^2)	Avg. Compressive strength (N/mm^2)
1	670	115.50	9.76	9.75
2	658	58.5	10.70	
3	666	44.5	8.80	

6.4 Compressive strength of mortar cubes of mix ratio 1:2 GP Composite Mortar after 28 days

Spec.	Weight (gms)	Load (kN)	Compressive strength (N/mm^2)	Avg. Compressive strength (N/mm^2)
1	722	91.50	17.3	15.43
2	700	83	15.60	
3	696	72	13.40	



6.5 7th day & 28th day strength for ratio 1:2

6.6 FLEXURAL STRENGTH OF FERROCEMENT SLABS

Procedure

1. After finishing the slabs, they were prepared for flexural testing which is of size 1000x300mm with thickness of 20mm.
2. The slab was placed in universal Testing Machine (UTM) and then deflectometer was also made to touch in contact with the surface of the slab to get deflection values.
3. Then, the load was applied at a uniform rate until the slab gets failed.
4. The load and corresponding deflection was noted down

Fig 6.7 Flexural test of Ferro cement slabs

7. ULTIMATE LOADS FOR GP AND GPC VARIOUS MESHES

Table 7.1 Ultimate loads of Welded mesh (single layers)

S.No	Type of mix	Mix ratio	Ultimate Load (kN)	First crack load (kN)
1	GP Mortar	1:2	1.250	0.900
2	GPCMortar	1:2	2.050	1.200

Table 7.2 Ultimate loads of Welded mesh (Double layers)

S.No	Type of mix	Mix ratio	Ultimate Load (kN)	First crack load (kN)
1	GP Mortar	1:2	2.400	0.300
2	GPC Mortar	1:2	3.000	1.000

Table 7.3 Ultimate loads of Cross linked mesh (Single layer)

S. No	Type of mix	Mix ratio	Ultimate Load (kN)	First crack load (kN)
1	GP Mortar	1:2	1.40	0.650
2	GPC Mortar	1:2	1.65	0.350

Table 7.4 Ultimate loads of Cross linked mesh (Double layers)

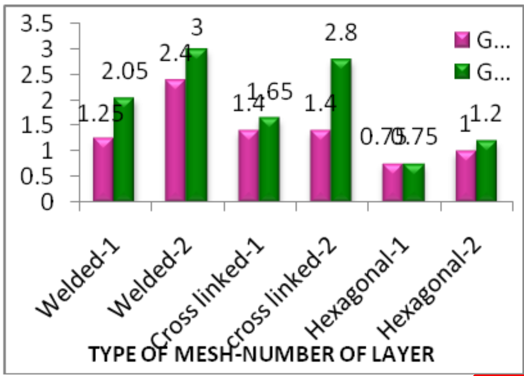
S.No	Type of mix	Mix ratio	Ultimate Load (kN)	First Crack load (kN)
1	GP Mortar	1:2	1.4	0.350
2	GPC Mortar	1:2	2.8	1.8

Table 7.5 Ultimate loads of Hexagonal mesh (Single layer)

S. No	Type of mix	Mix ratio	Ultimate Load (kN)	First crack load (kN)
1	GP Mortar	1:2	0.75	0.300
2	GPC Mortar	1:2	0.75	0.300

Table 7.6 Ultimate loads of Hexagonal mesh (Double layers)

S.No	Type of mix	Mix ratio	Ultimate Load (kN)	First crack load (kN)
1	GP Mortar	1:2	1.0	0.650
2	GPC Mortar	1:2	1.20	0.500



7.1 Ultimate load for ratio 1:2

Slabs after testing

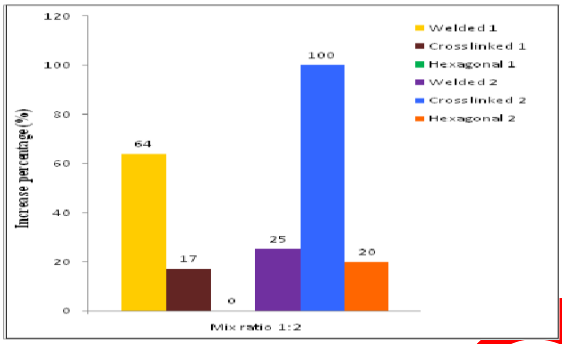
Here by, we are showing the deflected shapes of few slabs with legible marking are arranged one by one.

Fig 7.2 Deflected shapes of Slabs

8. COMPARISION BETWEEN GEOPOLYMER SLAB VS GEOPOLYMER COMPOSITE SLAB

Table 8.1 Percentage increase in Ultimate load

S.No	Mix Ratio	Type of mesh	No. of layers	Percentage increase
1	1:2	Welded	1	64
3	1:2	Welded	2	25
4	1:2	Cross linked	1	17
5	1:2	Cross linked	2	100
6	1:2	Hexagonal	1	0
7	1:2	Hexagonal	2	20

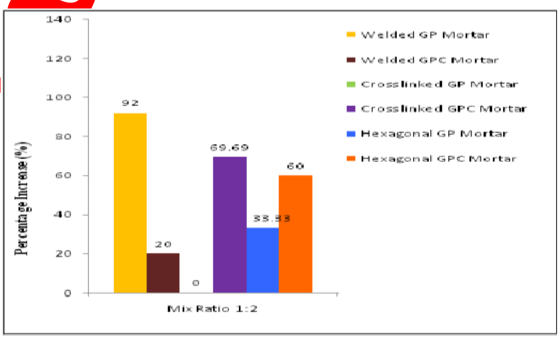


8.1 Percentage increase in ultimate load for GP Composite slabs

COMPARISION BETWEEN SINGLE LAYER AND DOUBLE LAYER MESHES

Table 8.2 Effect of increase in number of mesh layers

S.No	Mix ratio	Type of Mix	Type of Mesh	Percentage increase
1	1:2	GP Mortar	welded	92
2	1:2	GPC Mortar	welded	20
5	1:2	GP Mortar	Cross linked	0
6	1:2	GPC Mortar	Cross linked	69.69
9	1:2	GP Mortar	Hexagonal	33.33
10	1:2	GPC Mortar	Hexagonal	60



8.2 Percentage increase in load for 2 layers slabs with respect to single layer

9. DISCUSSION OF TEST RESULTS

The parameters that had been investigated in this study are the effect of number of mesh layers on the ultimate load. The test results of the samples at the age of 28 days are presented in above results. Different types of meshes for same mix ratio. The Table 8.1 shows the gain in the ultimate Load when the number of layers of mesh is increased from one to two for different types of meshes for same mix ratio.

Results on ultimate load of ferrocement slabs

With respect to GP Mortar, the percentage increase in Ultimate load for GP Composite Mortar for single layer Welded mesh slabs is about 64% for mix ratio of 1:2 and 8.33%. Respect to GP Mortar, the percentage increase in Ultimate load for GP Composite Mortar for single layer Cross linked mesh slabs is about 17% for mix ratio of 1:2 and 40% for Mix Ratio. respect to GP Mortar, the percentage increase in Ultimate load for GP Composite Mortar for single layer Hexagonal mesh slabs are about 0% for mix ratio of 1:2 and 15% for Mix Ratio. When the number of layers of Welded mesh increases from one to two the percentage increase in ultimate Load is about 92% for GP Mortar and 20% for GP Composite mortar for a mix ratio of 1:2. When the number of layers of Welded mesh increases from one to two the percentage increase in ultimate Load is about 95.83% for GP Mortar

10. CONCLUSIONS

GP mortar specimens took a minimum of 5 days for complete setting and hardening and it is considered as a drawback. On the other hand, GP composite mortar specimens harden immediately as that of conventional cement mortar. For all types of meshes when the number of layers of mesh increases the load carrying capacity of the slabs also increases. GP composite mortar slabs is found to be suitable for use in water tank covers, manhole covers and similar roofing works, which has similar properties of cement based ferrocement slabs. Environmental impacts such as emission of CO_2 can be reduced in direct as well as in indirect manner through the efficient use of fly ash and minimum usage of cement.

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