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EFFECT OF GEOPOLYMER MORTAR IN FERROCEMENT FOR VARIATION IN MESH SIZE AND NUMBER OF LAYERS

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ABSTRACT:

Globally, the worlds Portland cement production contributes about 1.6 billion tons of CO_2 or about 7% of global loading of CO_2 into the atmosphere. The manufacture of Portland cement releases Carbon dioxide that is significant contributor of Green house gas emissions to the atmosphere. Geopolymer is more eco friendly material and a strong alternative to Portland cement. Geopolymer mortar can be used in Ferro cement instead of other conventional materials like cement mortar. Ferro cement is a composite material formed by closely spaced wire mesh which uses wire meshes as reinforcement. Ferrocement has high tensile strength, minimum thickness, ease of mould ability. Experimental investigation has been carried out to study the Effect of Geopolymer mortar in Ferrocement for variation in mesh size and number of layers. For this, tensile testing was done on Geo-ferrocement specimens of size 750 x 60 x 30 mm reinforced with single, double, triple layer using variation in meshes of different sizes. Similarly, compression testing of cubical specimens of size 70 x 70 x 70 mm reinforced with single, double, triple layer of meshes of different sizes was done. Test results show that tensile and compressive strength of specimen's increases with increase in number of layer of meshes and mesh size also played an important role in strengthening of specimens. Compressive strength of single mesh layer in Geopolymer mortar is greater than single mesh layer in conventional cement mortar by approximately 5 %. For double layer mesh, specimens with Geopolymer mortar show greater strength than specimens with conventional cement mortar by 5-6 %.

KEYWORDS: Ferrocemnt, Flyash, Geopolymer, Tensile strength , Compressive strength.

INTRODUCTION:

The rate of production of carbon dioxide released to the atmosphere during the production of Portland cement and fly ash, a by-product from thermal power stations worldwide is increasing with the increasing demand on infrastructure development, and hence needs proper attention and action to minimize the impact on the sustainability of our living environment. De-carbonation of limestone in the kiln during manufacturing of cement is responsible for the liberation of one ton of carbon dioxide to the atmosphere for each ton of Portland cement, as can be seen from the following reaction equation :

$5CaCO_3 + 2SiO_2\ 3CaO.SiO_2 + 2\ CaO.SiO_2 + 5\ CO_2$ .The current contribution of green house gas emission from the Portland cement production is about 1.35 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere[1]. Furthermore, Portland cement is also among the most energy-intensive construction materials, after aluminum and steel. Geopolymer concrete is a material that does not need the presence of Portland cement as a binder. Instead, the source of materials such as fly ash, that are rich in Silicon (Si) and Aluminium (Al), are activated by alkaline liquids to produce the binder. Hence, concrete with no cement. Geopolymer is produced without the presence of Portland cement as a binder; instead, the base material such as fly ash, that is rich in Silicon (Si) and Aluminium (Al), is activated by alkaline solution to produce the binder. The Geopolymer concrete possesses high strength, undergoes very little drying shrinkage and moderately low creep, and shows excellent resistance to sulphate attack[3][4][5].

Ferrocement is a material of construction having great variety, which possesses unique structural properties. It is a composite formed with closely wire mesh tightly wound round skeletal steel and filled with rich cement mortar. Welded mesh, mild steel angles or bars are used for forming skeleton, while chick enmesh, square mesh or expanded metal are used as mesh reinforcement. Mortar mix may be (1:1.5) to (1:4) by volume[2]. It combines the properties of thin sections and high strength of steel, mouldability of concrete, lightweight and eases of working of timber, high tensile strength capacity of prestressed concrete and crack control of fiber reinforced concrete. Ferrocement can replace all these materials. In addition it needs no formwork or shuttering for casting. Ferrocement has applications in all fields of civil construction, including water and soil retaining structures, building components, space structures of large size, bridges, domes, dams, boats, conduits, bunkers, silos, treatment plants for water and sewage and chimneys partially.

OBJECTIVES OF INVESTIGATION:

- To study Tensile characteristics of Geopolymer based Ferrocement reinforced with wire meshes of different sizes in different layers .
- To compare the behaviour under Compression of cement mortar based Ferrocement and Geopolymer mortar based Ferrocement.

MATERIALS:

The present research work is experimental and requires following materials.

1. Cement: The cement used in this experimental work is "ACC 43 grade Ordinary Portland Cement". All properties of cement are tested by referring IS 8112 - 1989 Specification for 43 Grade Ordinary Portland Cement.
2. Fine aggregate: Locally available river sand conforming to Grading zone II of IS: 383–1970. Fineness modulus was found to be 2.76, Specific gravity was 2.59.
3. Fly ash-Fly Ash is available in dry powder form and is procured from Dirk India Pvt. Ltd., Nashik. It is available in 30Kg bags, color of which is light gray under the product name "**Pozzocrete 63**" Confirming to IS: 3812 Part 1-2003 as mineral admixture in dry powder form.
4. Water: Potable water available in laboratory is used.
5. Sodium hydroxide: Sodium hydroxide available in flakes form is used. In this investigation the sodium hydroxide of 13M concentrations is used.
6. Sodium Silicate (Na_2SiO_3) Sodium silicate also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate in gel form is used.
7. Wire meshes: Weld meshes generally used in ferrocement structures are having opening sizes in mm as 25 X 25,50 X 50, 75 x 75, 100 x 100, and 150 x 150.The wire gauges may vary from 10 to 18.
8. Tension Test Mould: The mould has been prepared by using ISA 30 X 30 x 3 mm, Two angles of 750mm length are placed on metal sheet with screw arrangement so as the spacing between faces of these angles remains equal to the width of specimen i.e. 60mm.The size of mould used in this project is 750 x 60 x 30 mm. Total 6 numbers of Moulds are prepared for casting.

Fig. 1 - Tension Test Mould

9. Compression Test Mould: Cubical moulds of size 70 x 70 x 70 mm were used to conduct compression test. Total 6 numbers of moulds were used for casting of specimens. All the moulds were properly oiled before filling with cement mortar.

METHODOLOGY:

The fresh fly ash-based geopolymer mortar was dark in colour (due to the dark colour of the fly ash), and was cohesive. The amount of water in the mixture played an important role on the behavior of fresh mortar. Davidovits (2002) suggested that it is preferable to mix the sodium silicate solution and the sodium hydroxide solution together at least one day before adding the liquid to the solid constituents.

1. Mix sodium hydroxide with water at least one day prior to adding the liquid to the dry materials.
2. Mix all dry materials for about three minutes by hand mixing. Add the liquid component of the mixture at the end of dry mixing, and continue the wet mixing for another four minutes.

Ratio of sodium silicate solution-to-sodium hydroxide solution, by mass, can be used in the range of 0.4 to 2.5. But this ratio was fixed at 1 for most of the mixtures because the sodium silicate solution is considerably cheaper than the sodium hydroxide solution

- Preparation of Binder Solution

Binder solution plays a vital role in the binding of the fly ash based geopolymer mortar. Binder solution is a mixture of Sodium Hydroxide and Sodium Silicate. In this investigation
the sodium hydroxide flakes in 13 molar concentrations were used. Binder solution is mixed 24 hours prior to the mixing of mortar.

TESTING PROGRAM:

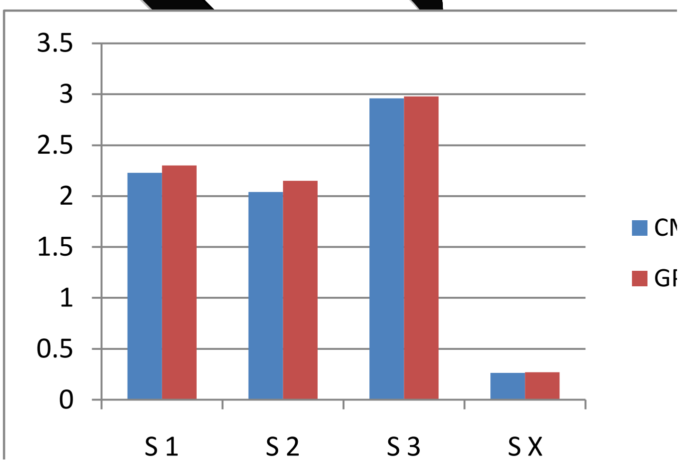
Tensile Strength Test (IS 516-1959): All the specimens were tested on Universal Testing Machine. In order to test the specimen, tensile test setup was prepared. Gauge lengths were marked on the each specimen and for proper arrangement rubber grip were used. Load was applied gradually through a hydraulic system and displacements were recorded.

Fig. 3 - Tension Test Setup

Table 1 - Single Mesh Tensile Strength

Sample	Notation	Opening Size of Mesh (in x in)	Mortar Material	Tensile Strength (N/mm²)
1	S X	-	CM	0.264
2	S 1	0.50 x 0.50	CM	2.23
3	S 2	0.75 x 0.75	CM	2.04
4	S 3	1.0 x 1.0	CM	2.96
5	S X	-	GPM	0.271
6	S 1	0.50 x 0.50	GPM	2.30
7	S 2	0.75 x 0.75	GPM	2.15
8	S 3	1.0 x 1.0	GPM	2.98

Table 1 shows result for single mesh tensile strength of various specimens. It is observed tensile strength of specimen 3 has maximum strength as compared to other specimens.

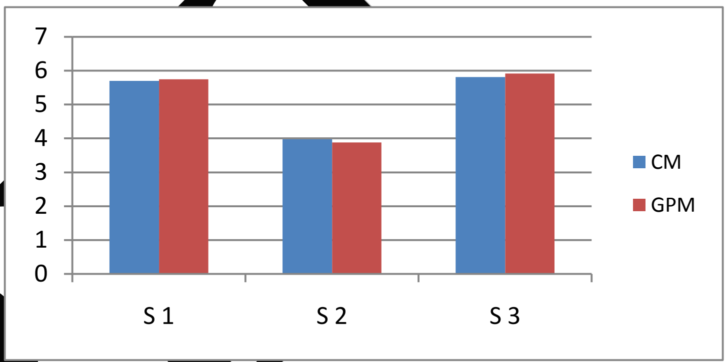


Graph 1 - Single Mesh Tensile Strength

Table 2 – Double Layer Mesh Tensile Strength

Sample	Notation	Opening Size of Mesh (in x in)	Mortar Material	Tensile Strength (N/mm²)
1	S 1	0.50 x 0.50	CM	5.70
2	S 2	0.75 x 0.75	CM	3.98
3	S 3	1.0 x 1.0	CM	5.81
4	S 1	0.50 x 0.50	GPM	5.75
5	S 2	0.75 x 0.75	GPM	3.88
6	S 3	1.0 x 1.0	GPM	5.92

Table 2 shows result for double layer mesh tensile strength of various specimens. It is observed tensile strength of specimens increases with number of layer of meshes.

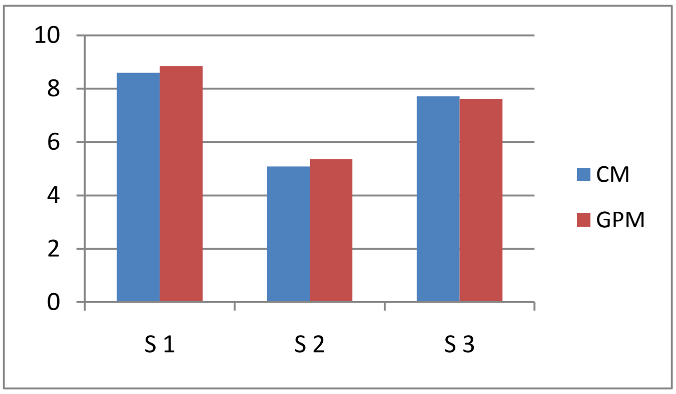


Graph 2 - Double Layer Mesh Tensile Strength

Table 3 – Triple Layer Mesh Tensile Strength

Sample	Notation	Opening Size of Mesh (in x in)	Mortar Material	Tensile Strength (N/mm²)
1	S 1	0.50 x 0.50	CM	8.02
2	S 2	0.75 x 0.75	CM	5.08
3	S 3	1.0 x 1.0	CM	7.71
4	S 1	0.50 x 0.50	GPM	8.26
5	S 2	0.75 x 0.75	GPM	5.36
6	S 3	1.0 x 1.0	GPM	7.62

Table 3 shows result for triple layer mesh tensile strength of various specimens. It is observed triple layer mesh tensile strength of specimens is more as compared to single layer & double layer specimens.

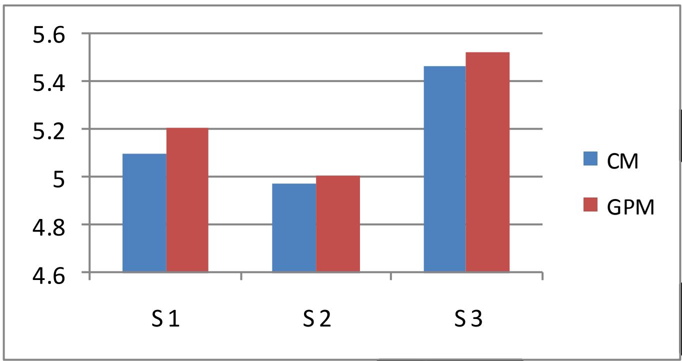


Graph 3 - Triple Layer Mesh Tensile Strength

Table 4 – Combined Mesh Tensile Strength

Sample	Notation	Opening Size of Mesh (in x in)	Mortar Material	Tensile Strength (N/mm²)
1	S 1	1.0 x 1.0 + 0.75 x 0.75	CM	5.102
2	S 2	0.75 x 0.75 +0.50 x 0.50	CM	4.972
3	S 3	1.0 x 1.0 + 0.50 x 0.50	CM	5.463
4	S 1	1.0 x 1.0 + 0.75 x 0.75	GPM	5.211
5	S 2	0.75 x 0.75 +0.50 x 0.50	GPM	5.011
6	S 3	1.0 x 1.0 + 0.50 x 0.50	GPM	5.521

Table 4 shows result for combined mesh tensile strength of various specimens. It is observed of all the various combinations, specimen having combination 1.0 x 1.0 + 0.50 x 0.50 gave more strength.



Graph 4 - Combined Mesh Tensile Strength

Compressive Strength Test (IS 516:1959): For compressive strength test, Cubical specimens of dimensions 70 x 70 x 70 mm were casted . All cured specimens have been tested in compression testing machine as per the guidelines mentioned by **(IS 516:1959)**. The top surface of the specimen was leveled and finished. After 24 hours the specimens were de-moulded and were transferred to curing tank wherein they were allowed to cure for 28 days. After the age 7th,14th & 28th days curing, these cubes were tested on Universal testing machine

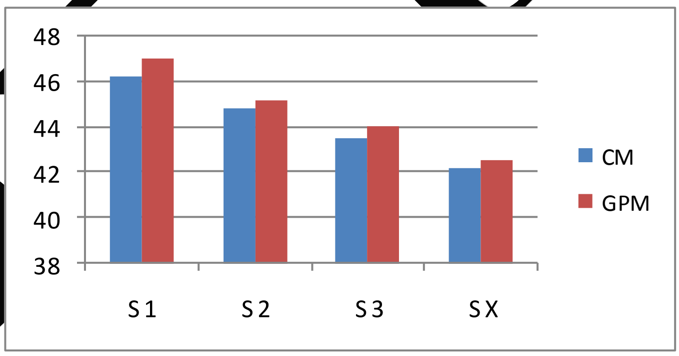
Compressive strength (MPa) = Failure load / cross sectional area.

Fig.4 - Compression Testing

Table 5 - Single Mesh Compressive Strength

Sample	Notation	Opening Size of Mesh (in x in)	Mortar Material	Tensile Strength (N/mm²)
1	S X	-	CM	42.2
2	S 1	0.50 x 0.50	CM	46.23
3	S 2	0.75 x 0.75	CM	44.8
4	S 3	1.0 x 1.0	CM	43.5
5	S X	-	GPM	42.6
6	S 1	0.50 x 0.50	GPM	47.04
7	S 2	0.75 x 0.75	GPM	45.21
8	S 3	1.0 x 1.0	GPM	44.02

Table 5 shows result for compressive strength of specimens with single mesh. It is observed that, specimen 1 has more compressive strength as compared to others.

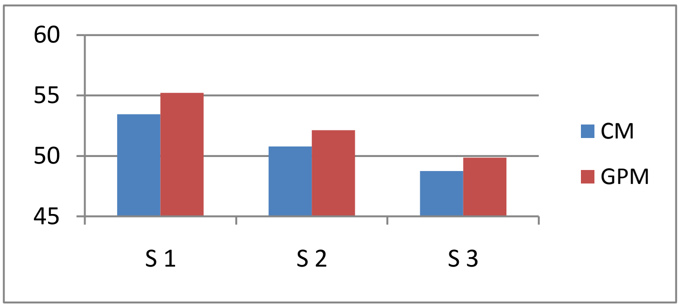


Graph 5 - Single Mesh Compressive Strength

Table 6 – Double Layer Mesh Compressive Strength

Sample	Notation	Opening Size of Mesh (in x in)	Mortar Material	Tensile Strength (N/mm²)
1	S 1	0.50 x 0.50	CM	53.45
2	S 2	0.75 x 0.75	CM	50.78
3	S 3	1.0 x 1.0	CM	48.75
4	S 1	0.50 x 0.50	GPM	55.21
5	S 2	0.75 x 0.75	GPM	52.14
6	S 3	1.0 x 1.0	GPM	49.86

Table 6 shows result for compressive strength of specimens with double layer mesh. It is observed that, compressive strength of specimens increases with increase in number of layer of meshes.



Graph 6 - Double Layer Mesh Compressive Strength

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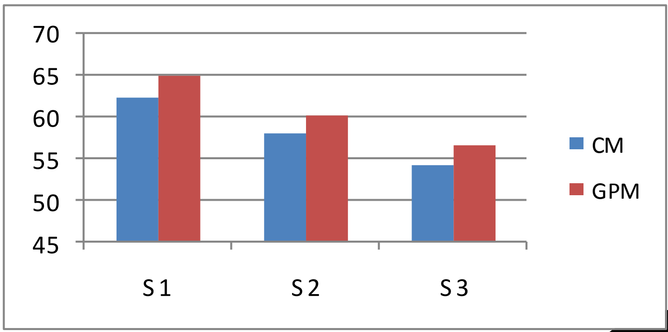
Table 7 – Triple Layer Mesh Compressive Strength

Sample	Notation	Opening Size of Mesh (in x in)	Mortar Material	Tensile Strength (N/mm²)
1	S 1	0.50 x 0.50	CM	62.3
2	S 2	0.75 x 0.75	CM	58.1
3	S 3	1.0 x 1.0	CM	54.4
4	S 1	0.50 x 0.50	GPM	65.1
5	S 2	0.75 x 0.75	GPM	60.3
6	S 3	1.0 x 1.0	GPM	56.6

Table 7 shows triple layer mesh compressive strength of specimens is more as compared to single layer & double layer specimens.

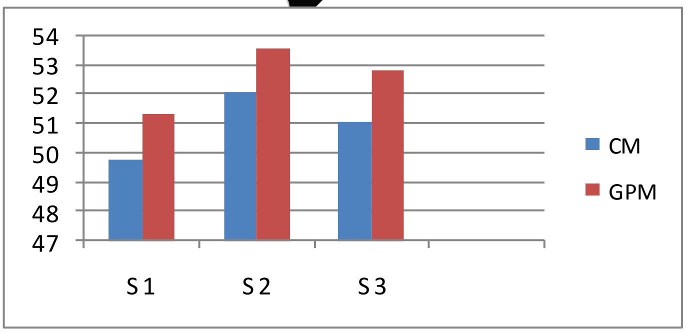


Graph 7 - Triple Layer Mesh Compressive Strength

Table 8 – Combined Mesh Compressive Strength

Sample	Notation	Opening Size of Mesh (in x in)	Mortar Material	Tensile Strength (N/mm²)
1	S 1	1.0 x 1.0 + 0.75 x 0.75	CM	49.76
2	S 2	0.75 x 0.75 +0.50 x 0.50	CM	52.11
3	S 3	1.0 x 1.0 + 0.50 x 0.50	CM	51.10
4	S 1	1.0 x 1.0 + 0.75 x 0.75	GPM	51.35
5	S 2	0.75 x 0.75 +0.50 x 0.50	GPM	53.56
6	S 3	1.0 x 1.0 + 0.50 x 0.50	GPM	52.87

Table 8 shows that of all the various combinations, specimen having combination 0.75 x 0.75 + 0.50 x 0.50 gave more strength.



Graph 8 - Combined Mesh Compressive Strength

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CONCLUSIONS:

- It is concluded that for samples with two layers of mesh the increase in tensile strength is observed to be in the range 96% - 159% as compared to single layer. Further using 3 layers increases tensile strength in the range of 172% - 260% as compared to single layer.
- It is concluded that increase in tensile strength of samples having mesh size 0.5” x 0.5” with 3 layers is 33% - 50% more as compared to samples having mesh sizes 0.75” x 0.75” and 1” x 1” with 3 layers. Similarly, increase in tensile strength of samples having mesh size 0.5” x 0.5” with 2 layers is 66% - 67% more as compared to samples having mesh sizes 0.75” x 0.75” and 1” x 1” with 2 layers.
- Generally, Ferrocement structures are exposed to tension effect but in adverse condition they may be subjected to compression effect too. From above studies it was found that Ferrocement can also be very much effective under compression as result obtained showed increase in compressive strength with increase in number of layers of meshes.
- It is concluded that for various combination of meshes used, combination of mesh 0.75 x 0.75 + 0.50 x 0.50 gives more compressive strength as compared to other two combinations.
- It is also concluded that Compressive strength of single mesh layer in Geopolymer mortar is greater than single mesh layer in conventional cement mortar by approximately 5%. For double layer mesh, specimens with Geopolymer mortar shows greater strength than specimens with conventional cement mortar by 5-6 %.

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