INVESTIGATION OF GEOPOLYMER MORTAR IN FERROCEMENT BY VARYING THE COMBINATION, NUMBER AND SIZES OF MESHES

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Abstract
Ferro- geopolymer is Recent trending building material which replace cement for construction. Geopolymer mortar as a matrix and wire mesh as a reinforcement together called as ferro-geopolymer. Geopolymer is a by-product material such as Fly ash, Rice husk ash, GGBS, Blast furnace slag etc., which are rich in silicon and aluminum. Use of geopolymer mortar reduce the pollution due to release of CO2 into the air. Ferrocement is simply a cement mortar reinforced by a steel wire meshes of different shapes. Aim of this project is to Investigation of using geopolymer mortar in ferrocement by varying the combination, number and sizes of meshes. In this paper we are going to use geopolymer mortar, GGBS material is used with sodium silicate and sodium hydroxide. Ferrocement that means wire meshes such as Square woven, Square welded and Expanded metal mesh is used. The number of layers in each mesh was varied from single, double and triple layers. Mortar Mix of 1:3 have to take. Optimum molarity has to find out and then casting of cubes for 150mm *150 mm* 150 mm have to done, to check the desire w/c ration as well as molarity. Specimen have to cure for 28 days with ambient curing. Further casting of slab specimen of 1100mm * 400mm * 150mm have to cast with ferro geopolymer by varying the combination, number and sizes of meshes. Flexural behavior, acid attack, corrosion resistance test and long-term other test etc. preformation provision is done and effectiveness of the Square woven, Square welded and Expanded metal mesh were compared. Total nine rectangular slab have to cast with different meshes such as square woven, square welded and expanded metal mesh.

Keywords: Ferro geopolymer, GGBS, molarity, Sodium hydroxide, sodium silicate, wire meshes

I. 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 chickenmesh, 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.

II. LITERATURE REVIEW

Dr. P. Thamilselvi (2017) Geopolymer concrete offers environmentally friendly and protects the natural resource by utilizing the waste/by-products from the industry which is harmful of the environment converted into value added construction building materials. This paper presents the overview of geopolymer materials, characterizations, different testing, code for testing and economic benefits, instead of the traditional Portland cement to make concrete.

Sandeep L. Hake (2019) When 10% of lime by weight the mixture observed was deficient of the binder i.e. fly ash thereby decreasing the compressive strength of the geopolymer concrete making it necessary to add lime rather than replace lime in the preparation of geopolymer concrete. In this work, we have used fly ash which is a waste product from iron industries and it is very economical. And its structure is near about similar to cement. So we can easily replace the cement in concrete. The compressive strength goes on increasing with the increases in the rest period of geopolymer concrete with addition of 10% of lime when cured at normal room temperature and maximum compressive strength was achieved at the completion of 7 days of rest period thereby giving it a wide scope.

V. Sreevidya (2014) The number of layers in each mesh was varied from single, double and triple layers. The specimens were cured for 28 days by ambient curing. Based on the test results, load vs deflection curves were drawn. The effectiveness of the square woven, square welded and expanded metal mesh was compared. Increasing the number of steel mesh layers from 1 to 3 caused a substantial increase in flexural strength and energy absorption to failure. It was also observed that the flexural strength of the section increasing the number of wire mesh layers. This is because of the increased percentage of steel meshes in the specimens and the increased depth of mesh layers from the neutral axis. For the same number of mesh layers, it was found that the strongest configuration in both elastic and inelastic ranges results from the smallest spacing because of the increase in volume fraction of the mesh in longitudinal and transverse direction of the specimens.

Tupakula Nagendra Kumar (2017) The development and application of high-volume fly ash concrete, which enabled the replacement of OPC up to 60% by mass is a significant development. In 1978, Davidovits proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geopolymer. This project presents the experimental investigation of the resistance of geopolymer mortar slabs to impact loading. The results obtained show that the addition of the above mesh reinforcement has increased the impact residual strength ratio of geopolymer ferrocement by 4-28 that of the reference plain ferrocement mortar slab. The combination of 1 layer of weld mesh and 4 layers of chicken mesh of geopolymer ferrocement specimens show the best performance in the test, i.e. energy absorbed, residual impact strength ratio (I-rs), It was concluded that the increase in Volume fraction of reinforcement V-r, increases the energy absorption and also residual impact strength ratio of geopolymer ferrocement than that of ferrocement specimens

K.T. Vipin (2021) Specimens reinforced with square welded wire mesh exhibited higher flexural strength compared with others, consequent to the additional strength imparted through the rigidity of welded connections. Maximum reduction in flexural strength of 20% and 32%, for specimens reinforced with square woven wire mesh and combination of hexagonal and square welded mesh, with respect to square welded wire mesh was observed for 3.0 m span beam elements. the ferro-geopolymer composite trapezoidal section elements were found to be an ideal choice as roofing elements .The use of geopolymer mortar in place of cement mortar not only reduces the global warming, but also helps in utilising the industrial waste (like fly ash, GGBS etc) into useful products. Hence, from the study it may be concluded that the geopolymer mortar is itself a sustainable cementitious composite and can be employed as a better alternative to the conventional cement mortar.

T. Chaitanya Srikrishna (2020) Compressive strength and Toughness values of geopolymer mortar are about 90% of cement mortar specimens. Flexural strength of geopolymer mortar prisms were about 70% strength of cement mortar prisms. Increase in layers of wire meshes played a crucial role in improving the flexural strength of geopolymer and cement mortar. Stiffness of geopolymer prisms decreased with increase in layers of wire mesh, due to lack of homogeneity between geopolymer mortar and wire mesh. The provision of wire mesh has a constructive effect on peak load, toughness and stiffness irrespective of type of mortar. The increase in layers of wire mesh has a positive effect on the strength properties and also the failure shifts from brittle to ductile. Wire mesh can be used as reinforcement for members with smaller thickness where the provision of reinforcement is difficult. The wire mesh acts of reinforcement distributed over a larger width. Therefore, the effective contact area between the mortar and mesh increases which results in better mechanical strengths

III OBJECTIVES OF INVESTIGATION

- To check the geopolymer mortar in ferrocement by varying no of layers

To study check the mechanical properties of ferrocement mortar i.e. Flexural strength.

IV. MATERIALS

1. GGBS: GGBS is nothing but the Ground Granulated Blast Furnace Slag is procured from local dealers. GGBFS are the precursor material to prepare Geopolymer Concrete (GPC). GGBS is a cementitious material whose main use is in concrete and is a by- product from the blast-furnaces used to make iron.

2. Sodium Hydroxide (NaoH): of 97% purity and sodium silicates with Na2O=14.7%, SiO2=29.412%, water = 59.9% by mass are used to form Alkaline Activator Solution using ratio Na2Sio3/NaoH =2.5. Generally the sodium hydroxides are available in solid state by means of pellets and flakes. In this investigation the sodium hydroxide pellets of 16 molar concentrations have to used.

Fig.1 – Sodium Hydoxide

3. Sodium Silicate: Sodium silicate also known as water glass or liquid glass,available in liquid (gel) form. In present investigation sodium silicate 2.0 with gel form have to used.

Fig. 2- Sodium silicate

4. Wire Mesh Reinforcement: In this project three types of wire meshes have to use with different layers to find the performances and compressive strength of slab. Wire meshes made of steel were used as prime mesh reinforcement. characteristics of the resulting ferrocement component are influenced by the size of the mesh, ductility, fabrication, and treatment of the mesh used in the panel.

Form of mesh is easily available, affordable, and easy to handle. Square woven, Square welded, expanded metal mesh are used in single layer, double layer & triple layer reinforcement provided in slab. The diameter of wire for three types is same (1.5 mm) and mesh opening also same (15 mm). The different wire meshes used are shown in Fig.

5. Flexural Test Mould: Mould has been prepared of size 750mmX 120mmX 30mm; two angles are placed on metal sheet with screw arrangement. Total 12 numbers of moulds are prepared for casting.

Fig. 3 - Flexure Test Mould

V. METHODOLOGY

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 in the pan mixer for about three minutes. Add the liquid component of the mixture at the end of dry mixing, and continue the wet mixing for another four minutes.

- 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 pellets in 13 molar concentrations were used. Binder solution is mixed 24 hours prior to the mixing of mortar.

VI. Testing Program

Flexural Strength (IS 516:1959): We tested our sample for flexure and estimated flexural strength in accordance with IS 516:1959's requirement for flexure member testing.Flexural strength (F_b)

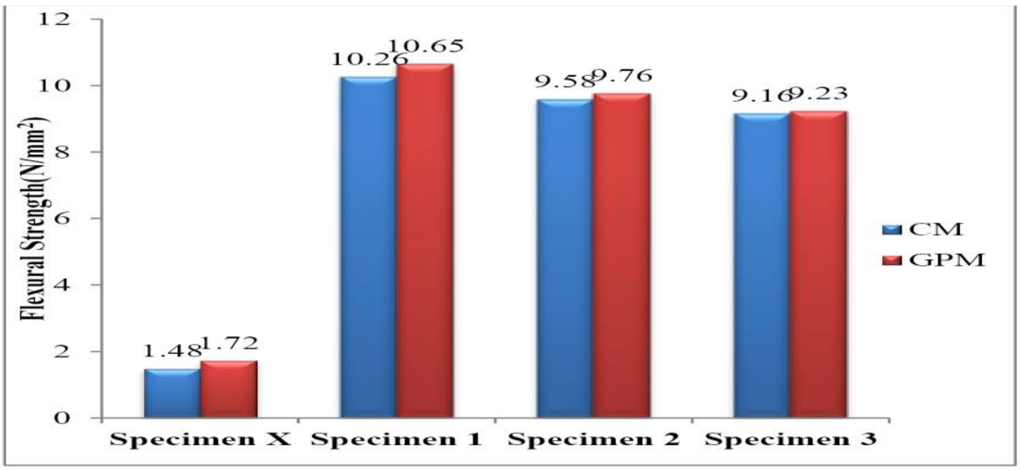
$F_b = \frac{pl}{bd^2}$ (clause no 8.4,page no.17, IS 516:1959)

The specimen's effective length was 600 mm, and the load was raised until it failed, with the greatest load applied to the specimen during the test being recorded.

Fig. 4 - Flexural test on Specimens

Table 1 - Single Mesh Flexure Strength

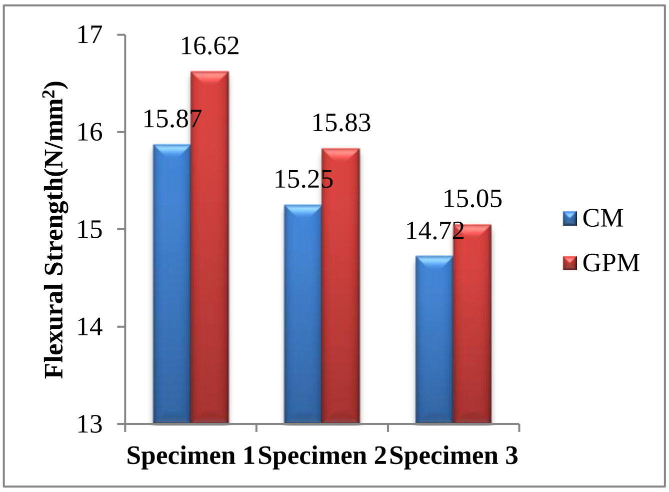
Sr. No	Notation	Opening Size of Mesh (in x in)	Mortar Material	Flexure Load (KN)	Flexure Strength (N/mm2)
1	Specimen X	-	CM	0.38	1.48
2	Specimen 1	0.50” x 0.50”	CM	1.53	10.26
3	Specimen2	0.75” x 0.75”	CM	1.45	9.58
4	Specimen 3	1.0” x 1.0”	CM	1.33	9.16
5	Specimen X	-	GPM	0.44	1.72
6	Specimen 1	0.50” x 0.50”	GPM	2.09	10.65
7	Specimen2	0.75” x 0.75”	GPM	2.10	9.76
8	Specimen 3	1.0” x 1.0”	GPM	1.68	9.23



Graph 1 - Single Mesh Flexure Strength

Table 2 – Double Layer Mesh Flexure Strength

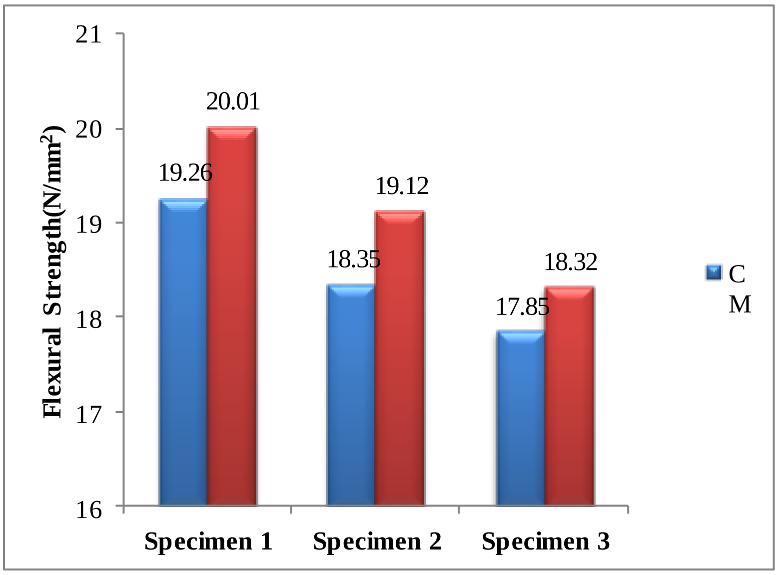
Sr. No	Notation	Opening Size of Mesh (in x in)	Mortar Material	Flexure Load (KN)	Flexure Strength (N/mm2)
1	Specimen 1	0.50” x 0.50”	CM	4.05	15.87
2	Specimen2	0.75” x 0.75”	CM	3.90	15.25
3	Specimen 3	1.0” x 1.0”	CM	3.76	14.72
4	Specimen 1	0.50” x 0.50”	GPM	4.25	16.62
5	Specimen2	0.75” x 0.75”	GPM	4.04	15.83
6	Specimen 3	1.0” x 1.0”	GPM	3.84	15.05



Graph 2 - Double Mesh Flexure Strength

Table 3 –Triple Layer Mesh Flexure Strength

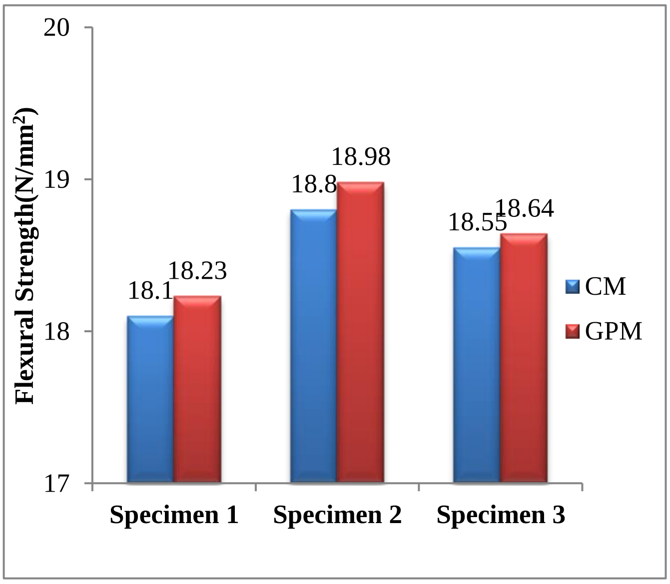
Sr. No	Notation	Opening Size of Mesh (in x in)	Mortar Material	Flexure Load (KN)	Flexure Strength (N/mm2)
1	Specimen 1	0.50” x 0.50”	CM	4.92	19.26
2	Specimen2	0.75” x 0.75”	CM	4.69	18.35
3	Specimen 3	1.0” x 1.0”	CM	4.56	17.85
4	Specimen 1	0.50” x 0.50”	GPM	5.11	20.01
5	Specimen2	0.75” x 0.75”	GPM	4.89	19.12
6	Specimen 3	1.0” x 1.0”	GPM	4.68	18.32



Graph 3 - Triple Mesh Flexure Strength

Table 3 –Combined Mesh Flexure Strength

	Notation	Opening Size of Mesh (in x in)	Mortar Material	Flexure Load (KN)	Flexure Strength (N/mm2)
1	Specimen 1	1.0” x 1.0” + 0.75” x 0.75”	CM	2.59	18.1
2	Specimen2	0.75” x 0.75” + 0.50” x 0.50”	CM	2.42	18.80
3	Specimen 3	1.0” x 1.0” + 0.50” x 0.50”	CM	2.52	18.55
4	Specimen 1	1.0” x 1.0” + 0.75” x 0.75”	GPM	3.19	18.23
5	Specimen2	0.75” x 0.75” + 0.50” x 0.50”	GPM	3.26	18.98
6	Specimen 3	1.0” x 1.0” + 0.50” x 0.50”	GPM	3.12	18.64



Graph 2 - Combined Mesh Flexure Strength

VII. CONCLUSIONS

- It is concluded that Flexural strength of specimen after 28 days of curing with triple layer mesh is increased by around 190% than specimen with single layer mesh & Flexural strength of specimen after 28 days of curing with double layer mesh is increased by around 150% than specimen with single layer mesh
- For various combinations of meshes used, specimen with combination of mesh size 0.75” x 0.75” + 0.50” x 0.50” show better result as compared to other two combinations.
- From test results it was found that due to incorporation of mesh in mortar the flexure strength has increased as compared to specimen without any mesh.

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IX. REFERENCES

1 Sandeep L.Hake , Dr R. M. Damgir , Dr S.V. Patankar “State of Art- Investigation of method of curing on geopolymer concrete”, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 3 Ver. II (May. - Jun. 2015), PP 40-44

2 Rupesh D. Musmade, Sandeep L. Hake, “Compressive and Tensile Behavior of Lime Added Geopolymer Concrete”, Journal of Structural Engineering and Management ISSN: 2393-8773 (Online) Volume 6, Issue 3

3 Tupakula Nagendra Kumar, V Balakrishna, “an experimental investigation on geopolymer concrete with ferro cement” Volume No 6, Issue No 12, December 2017.

4 Sandeep L. Hake, R. M. Damgir,and S. V. Patankar, “Temperature Effect on Lime Powder-Added Geopolymer Concrete” Hindawi Advances in Civil Engineering Volume 2018, Article ID 6519754, 5 pages

5 Nisha N.Jain, Mohan.N.Shirsath , Sandeep L.Hake, “Percentage Replacement of Cement in Geopolymer Concrete” International Journal of New Technologies in Science and Engineering Vol. 3, Issue 8,Aug 2016, ISSN 2349-0780

6 Sandeep L. Hake, Dr. R. M. Damgir, “Evaluation On Types Of Fly Ash And Alkaline Activators Of Gpc” International Journal of Innovations in Engineering, Research and Technology,IJIERT-ICITER-16,ISSN:2394-3696 26th June,2016

7 S. L. Hake, O. D. Waghmare and M. P. Bhorkar, “Evaluate Properties of GPC with the Addition of an Alkaline Solution and Different Types of Fly Ash”

8 Sandip Laxman Hake and Divakar Machhindra Waghmare. "Studies on Characteristics of Geo-Polymer Concrete Mix Design" Techno-Societal 2020, Springer Nature Switzerland AG 2021.
9 Rajesh Suryanarayan1, Dr. S. L. Hake, "EFFECT OF NA2SIO3/NAOH RATIO FOR FLY ASH BASED SELFCOMPACTING GEOPOLYMER CONCRET" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 06 Issue: 12 | Dec 2019
10 Pradeep D. Chimane, Dr. Sandeep L. Hake , Mohan N. Shirsath, "Investigation on Membrane Cured Geopolymer Concrete- Review" International Journal of Engineering Research and General Science Volume 5, Issue 4, July-August, 2017 ISSN 2091-2730
11 K.T. Vipin , N. Ganesan, P.V. Indir, " Ferro-geopolymer composites for roofing – A sustainable approach for infrastructures Structures", 34 (2021) 215-223.
12 T. Chaitanya Srikrishna , T.D. Gunneswara Rao , " A study on flexural behavior of geopolymer mortar based ferrocement." Materials Today: Proceedings, 14 September 2020.
13 V. Sreevidya, R. Anuradha, R.Venkatasubramani and S. Yuvaraj, " Flexural Behavior Of Geopolymer Ferrocement Elements" Asian Journal Of Civil Engineering (Bhrc) Vol. 15, No. 4 (2014) Pages 563-574.
14 K.Ranjitha , S.Sowmya , R.Manojguru, " REVIEW ON FLEXURAL BEHAVIOR OF FERROCEMENT PANELS",2021 IJCRT | Volume 9, Issue 5 May 2021 | ISSN: 2320-2882.