ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Geo-polymer ferrocement slabs- An Experimental Investiagtion

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ABSTRACT

The large global production of fly ash and rapid advances in geopolymer technology and knowledge mean that a viable alternative to ordinary portland cement concrete is now available, in the form of alkaline-activated class F fly ash geopolymer concrete. The aim of this research is to examine a potential mix design process for this emerging product. A process that can be worked through in a calculated way in order to find the full range of mix proportions to meet a particular targeted product has not been investigated or submitted to date. This research seeks to bridge this gap, which is currently preventing the more widespread use of geopolymer concrete (GPC). This work is a largely experimental investigation into mixture proportion and strength relationships, attempting to detail a large amount of data which will be utilised at the core of the process to be investigated. The purpose of this experimental investigation is to study the flexural behaviour of fly-ash based geo-polymer ferro-cement elements. Ferro-cement composite is a rich Geo-polymer mortar mix of 1:1. The effectiveness of the Square woven, Square welded and Expanded metal mesh were compared with different layers such as single layer, double layer and triple layer. Results showed that slabs with square welded mesh triple layer were most suitable and cracked at highest load.

KEY WORDS: Geo-polymer ferro cement slabs, Square oven mesh, Square welded mesh, expanded metal mesh, mesh layers.

1. INTRODUCTION

Efforts are needed to develop innovative and environmentally friendly material in order to reduce the greenhouse gas emissions. Extensive consumption of natural sources, massive amount production of industrial wastes and environmental pollution require new solutions for a more sustainable development. The use of modern day cement contributes to two billion tons of carbon dioxide (CO_2) annually in to the atmosphere, which makes it the third largest man-made source of CO_2. The production of cement is responsible to produce one ton of CO_2 per ton of cement produced, and the cement manufacturing industry is causative to contribution of 7% of global CO_2 emission, which is one of the greenhouse gases that cause climate change due to global warming. Besides, production of cement is energy intensive and is only succeeding to steel and aluminium production. Meanwhile, the growth of the coal fired power plant industry produces flue gases from hydrocarbon combustion that generates extensive particulate emissions such as fly ash, bottom ash as waste products.

These solid waste ashes from coal fired boilers have previously been dumped into the landfill that contributes to the subsequent environmental contamination. Hence, green demands are raised for alternative ways to utilize the ashes to mitigate further environmental pollution by copious uncontrolled disposal of the coal ashes in the landfills. The term geo-polymer was first applied by Davidovits to alkali alumino-silicate binders formed by the alkali silicate activation of alumino-silicate materials. Geo-polymer is amorphous to semi-crystalline equivalent of certain zeolitic materials with excellent properties such as high fire and erosion resistances and high strength materials. The most used alkaline activators are a mixture of sodium hydroxide or potassium hydroxide (NaOH or KOH) with sodium water glass or potassium water glass. The activator solution used in this work is NaOH and sodium water glass. The concentration of NaOH solution can be used is 16M. Prefabricated floor is used in the construction industry as an alternative system to overcome the formwork problems (cost and delay in construction) in addition to getting better quality control.

The prefabricated elements made of reinforced concrete are extremely heavy and difficult to transport, placing in position and to construct. Alternatively, thin ferro-cement panels are being used in floor construction for low cost housing due to its low cost and good structural performance. Ferro-cement is suitable for low-cost roofing, pre-cast units and man-hole covers. It is used for the construction of domes, vaults, grid surfaces and folded plates. It can be used for making water tanks, boats, and silos. Ferro-cement is the best alternative to concrete and steel. Generally, ferro-cement shells range from 10 mm to 30 mm in thickness and the reinforcement consists Ferro-cement 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 which may be made of metallic or other suitable materials. Since ferro-cement possess certain unique properties, such as high tensile strength-to-weight ratio; superior cracking behavior; lightweight; moldability to any shape and certain advantages, such as utilization of only locally available materials and semi-skilled labor/workmanship, it has been considered to an attractive material and a material of good promise and potential by the construction industry, especially in developing countries. It has wide-ranging applications, such as in the manufacture of boats/barges; prefabricated housing units; biogas structures; silos, tanks, and recently in the repair and strengthening of structures. Ferro-cement is a highly versatile construction material and possess high performance characteristic, especially in cracking, strength, ductility, and impact resistance. As its reinforcement is uniformly distributed in the longitudinal and transverse directions and closely spaced through the thickness of the section. Since ferro-cement bends itself to pre-casting and hence, precast ferro-cement elements can be prepared to meet the strength and serviceability conditions. There is an ample scope for mass production and standardization together with the economy in construction.

The main objective of the present investigation is to study the behaviour of Geo-polymer ferro-cement slabs (replacement of cement with 100% activated fly-ash). Geo polymer mortar is prepared by sand:flyash plus activator solution in 1:1 ratio .Slabs are casted using different meshes and tested under the UTM. The primary objective of this study was development of viable housing components which could be used as multipurpose structural elements.

2. EXPERIMENTAL PROGRAMME

2.1. Fine aggregate: The specific gravity of fine aggregate was found to be 2.60 and its water absorption was found to be 1.02%.

2.2. Fly ash: Fly ash was collected from Mettur-Thermal power station. Specific gravity of fly ash was found to be 2.12.

2.3. Geopolymers (NaOH + sodium silicate): The alkaline liquid is prepared at least one day prior to cast. Firstly, the NaOH solution is prepared for the required molarity and then it is mixed with Na2SiO3 in 1:1. Finding optimum Water-Binder ratio of the mix and also the molarity of the binder. Molarity on Compressive Strength of Geopolymer Mortar proportion. The samples were prepared for 8M, 10M and 16M. (Where, M–molarity). For e.g. 8M means, concentration of NaOH in one litre of water is 8 × 40 = 320gm (where 40 is the molecular weight of NaOH). Mix proportions for various samples are illustrated in Table 1.

Table.1.Mix proportions of materials used in experiment

Specimen	Molarity	Water binder ratio	Activator-Fly Ash ratio	Sand–Fly Ash ratio
Sample 1	8	0.30	0.50	1.0
Sample 2	10	0.30	0.50	1.0
Sample 4	16	0.30	0.50	1.0

2.4. Steel Meshes: Three different types of meshes were used. Square woven mesh, Square welded mesh and Expanded metal mesh. The meshes were arranged in three layers as single layer, double layer and triple layer.

2.5. Experimental procedure for Geo-Polymer slabs: The fly ash and the alkaline solution are first mixed together in specified proportion for 5 minutes. Sand is then added and mixed for another 5 minutes. The mortar samples have been casted in moulds of size 400mm x150mm x 30mm size. The mortar is then filled in mould in two layers and hand compacted using cylindrical plunger. After casting, geopolymer mortar samples are left to room temperature for one hour under atmospheric pressure and uncontrolled humidity conditions and are cured in an oven at 85°C for 48 hours. At the end of curing period the oven is turned off and the materials is allowed to cool down inside the oven to room temperature. The samples are then removed from the mould and they are left to air curing (drying) at room temperature before being used in tests. Weld mesh were cut to appropriate dimensions to suit the configuration of square elements. The weld meshes were placed at the appropriate position to make the slab. The elements were cast using the plastering techniques on the level floor of casting yard using very simple wooden formwork. The mould was placed on the level platform of casting yard after applying a thin coat of oil. The mortar mix is put inside the mould and made level while keeping the meshes at particular intervals. The rectangular ferro cement elements were tested to study their flexural behaviour. The general testing arrangement, test set up, instrumentation and testing procedure are explained in the following section. The element was made ready for necessary instrumentation and observation of readings. After arranging the necessary arrangement to measure the strain at middle span, dial gauge were mounted below at middle of the span. The deflection measurements were taken from the middle points.

The slab is fixed in UTM under single point loading system. The slab is kept on the frame and UTM is set. The load is applied gradually on the slab, for every 0.20kN of load application the corresponding deflection reading should be taken. The load should be gradually increased and loading is done till the failure. The first crack load corresponding to that was noticed as the first crack load. The failure load is noted and corresponding deflection is also noted the slab failed due to flexure. The load and deflection reading is taken and the graph is drawn against load vs deflection.

3. RESULTS AND DISCUSSION

Figure.1.Square woven mesh with single layer (UTM)

Figure.2.Crack pattern

Figure.3.Deflectometer placed over the slab

Figure.4.Crack in progress in slab

Table.2.Load deflection (Expanded metal mesh single layer)

Divisions	Deflection (mm)	Load (KN)
0	0	0
8	0.08	0.2
14	0.14	0.4
24	0.24	0.6
28	0.28	0.8
41	0.41	1
55	0.55	1.2
118	1.18	1.4
382	3.82	1.6
402	4.02	1.8

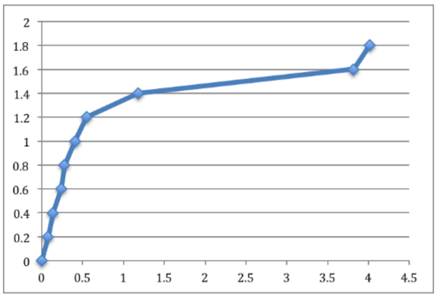

Figure.5.a.Load vs Deflection curve -Expanded metal single layer

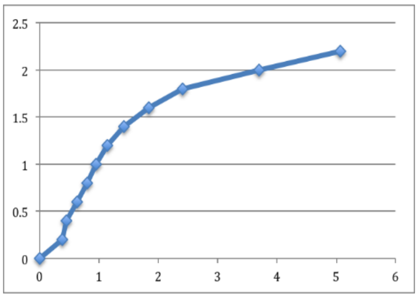

Figure.5.b.Expanded metal double layer

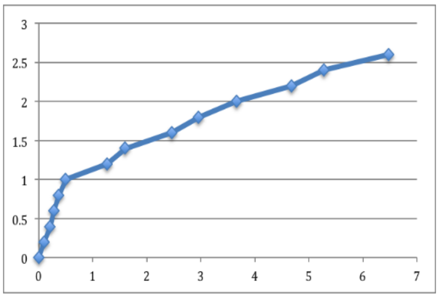

Figure.5.c.Expanded metal triple layer

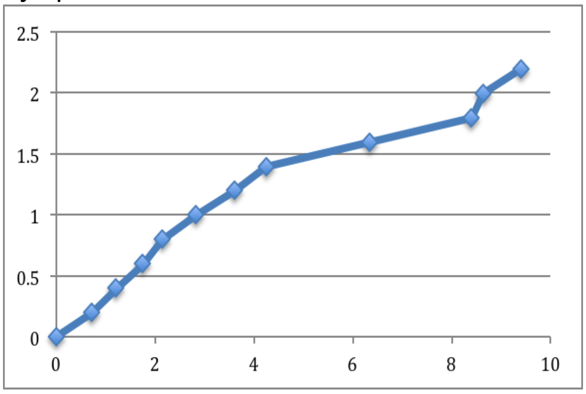

Figure.6.Square oven mesh triple layer

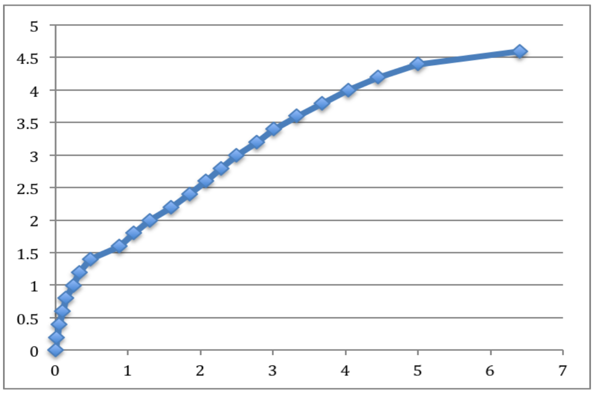

Figure.7.Square welded mesh triple layer

For Expanded Metal mesh slab with single layer, Initial crack for the Triple layer occurred at 2.6kN, for Double layer occurred at 2.2kN and for Single layer occurred at 1.8 kN. For Square Woven mesh slab with single layer, Initial crack for the Triple layer occurred at 2.2kN, for Double layer occurred at 2kN and for Single layer occurred at 1.8kN. For Square Welded mesh slab with single layer, Initial crack for the Triple layer occurred at 4.6kN, for Double layer occurred at 2.8kN and for Single layer occurred at 2.2kN. Hence, it can be seen through the results above that the best-suited mesh for slabs is square welded and the number of mesh layers should be three (3) in number. As it cracks at highest load and bears it as well i.e. 4.6 kN. The ferro cement structural elements involved in this study are having a simple cross-section and it can be fabricated easily with the help of simple formwork. 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 observed that the linear first stage ceases with the initiation of cracking in mortar on the tension force. The load carrying capacity of the specimens, however, continues to increase because the meshes start carrying additional load. with further increase in load, the tension face of the specimen starts cracking following by cracking of the compression face and finally forming a major failure of the compression face and finally forming a major failure crack at the middle of the specimen.

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. From this study it can be considered the Weld mesh is resulted in significant improvement in their flexural behaviour compare to woven and expanded mesh. The use of weld mesh in the ferro-cement structure gives more strength and significant improvement to the ferro-cement.

4. CONCLUSIONS

a) Flexural strength of the section increases with increasing number of wire mesh.
b) Based on the experimental test results it can be concluded that square woven triple layer mesh showed best results.
c) The use of weld mesh in the ferro cement structures gives more strength and significant improvement to the ferro cement.
d) Also utilization of fly ash in geo-polymer slabs leads to reduce environmental pollution.

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