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AN EXPERIMENTAL STUDY ON GEOPOLYMER MORTAR PLATE ELEMENTS

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ABSTRACT

This paper presents the results of a study on fly ash-based geopolymer mortar plate elements .The test parameters covered certain aspects of manufacture of geopolymer mortar. The aim of the study is to study the effect of alkaline to fly ash on compressive strength of hardened low-calcium fly ash-based geopolymer mortar and also to study the flexural strength of geopolymer plate elements for shear span to depth ratio,(i.e. a/d=6,5,4).In this project low-calcium (ASTM Class F) fly ash is utilized as the base material for making geopolymer mortar.

Keywords: Geopolymer mortar, plate elements, flexural strength

1.0 Introduction

Now a day's mortar plays a major role in the human life. It has become in such a Way that the usage of mortar became second only to water around the world. In the last two decades environmental issues in the mortar industry have been paid a lot of attention, aiming at reducing the total environmental impact of mortar structures to a minimum, without compromising on their performance. A lot of different tools have been developed in order to reduce the environmental impact of mortar.

Ordinary Portland cement (OPC) is the primary binding material used in the preparation of concrete. It was estimated that 7% of the world's carbon dioxide is attributable to Portland cement industry. Because of the significant contribution to the environmental pollution & to the high consumption of natural resources like limestone etc., we can't go producing more and more cement. So there is a need to economise the use of cement. One of the practical solutions to economise cement is to replace with supplementary cementations materials like fly ash, slag and metakaolin.

1.1 Geopolymer and Geopolymer Concrete

Geopolymer is an inorganic alumino-silicate polymer synthesized from predominantly silicon (Si) and aluminum (Al) materials of geological origin or by-product materials such as fly ash. The term geopolymer was introduced by Davidovits [1] to represent the mineral polymers resulting from geochemistry. The process involves a chemical reaction under highly alkaline conditions on Si-Al minerals, yielding polymeric Si-O-Al-O bonds in amorphous form. It has been reported that geopolymer material does not suffer from alkali-aggregate reaction even in the presence of high alkalinity and possesses excellent fire resistant.

In the experimental work, geopolymer is used as the binder, instead of cement paste, to produce mortar.

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2.0 Literature Review

Davidovits, J. (1999) [1] introduced the term geopolymer to represent the mineral polymers resulting from geochemistry. The process involves a chemical reaction under highly alkaline conditions on Si-Al minerals, yielding polymeric Si-O-Al-O bonds in amorphous form. It has been reported that geopolymer material does not suffer from alkali-aggregate reaction even in the presence of high alkalinity and possesses excellent fire resistant.

Mansur and Paramasivam [2] conducted studies on the cracking behaviour of Ferro cement elements and predicted the ultimate strength of Ferro cement in flexure using plastic analysis.

Trian Onet, et.,al.,[3], have studied on the behavioural aspects of Ferro cement in flexure and reported that Ferro cement elements have better performance under working loads owing to their very small crack widths and improved ductility at post cracking range.

Prakash Desayi et.,al [4]studied on the deflection and Cracking of light weight fibre reinforced Ferro cement rectangular specimens in bending and they proposed a bilinear model to represent the rising portion of the load deflection diagram and equations to predict the same have been obtained. They are also used bond-slip hypothesis with modifications to predict crack spacing for the different specimens.

Kalyan Kr. Mandal, Suresh Thokchom and Mithun Roy[5], presented the engineering properties of geopolymer mortar manufactured from class F (low calcium) fly ash from Kuching, Sarawak, Malaysia, with potassium-based alkaline reactor. Tests were carried out on 50x50x50 mm cube geopolymer mortar specimens. The results revealed that as the concentration of KOH increased, the compressive strength of geopolymer mortar increases. The range of potassium silicate to KOH solution ratio by mass to produce high strength geopolymer mortar is in between 0.8 – 1.5. This study also found that geopolymer posses superior thermal stability at least up to 800°C. The setting time of geopolymer was found dependent on the alkaline concentration.

Djwantoro Hardjito , Shaw Shen[6] presented the results of study on effect of various parameters on mechanical properties of fly ash-based geopolymer mortar with bottom ash as partial or full replacement for sand. Compressive strength of samples with 10% bottom ash (BA) was comparable to those with only sand. Further increase in bottom ash content decreased the compressive strength. However, the reverse tendency occurred after exposing the samples to 1000oC for 24 hours.

T. Chandra Sekhar Rao[7] et al, studied the shear strength of simply supported ferrocement rectangular plates subjected to four point loading. Limited literature is available on the shear behavior of ferrocement elements, as the span to depth ratio of these elements is very high. However, studies on the shear response of ferrocement assume importance to understand the material behavior In their study, tests on Ferro cement elements varying the shear span to depth ratio (a/d) and different layers of mesh are conducted. It is observed that increase in the volume

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fraction of the mesh reinforcement (number of layers of mesh) increased the shear capacity of the member. It is also found that up to shear span to depth ratio 3, shear behavior is predominant. Beyond shear span to depth ratio 3, the flexural behavior is predominant and design of the elements based on flexure is sufficient.

3.0 Experimental Investigation

3.1.1 Preparation of Geopolymer Mortar Cubes, Cylinders & Plate Elements

Low calcium (class F) dry fly ash obtained from a local power station was used as the source material. For the alkaline activator, a combination of sodium hydroxide solution and sodium silicate solution was used. The mix proportion adopted was 1:1 (fine aggregate: fly ash). Alkaline liquid was taken as Ratio of activator solution-to-fly ash, by mass, in the range of 0.33 to 0.4, Sodium Hydroxide (NaOH) solution of molarity 10M, ratio of Sodium Silicate solution-to-Sodium Hydroxide solution, by mass is 2.5. This ratio was fixed at 2.5 for the mixtures.

The sodium hydroxide solution was prepared by dissolving the sodium hydroxide solids, either in the form of pellets or flakes, in water. The Geopolymer motar samples were prepared using equal proportions of Fly ash and Sand. Fly ash was first mixed with the activator solution for 5minutes.Sand was then gradually introduced and further mixed for 5minutes.For workability, if we required additional water, extra water is added. It is better to add NaOH solution as extra water to improves geopolymerisation process.

After 1 day of casting the specimens, the specimens were demoulded and the specimens were cured in ambient condition (30^0C-32^0C) and Oven (60^0C).In the present study , the alkaline liquid to fly ash ratio adopted is 0.33 and 0.4.

The experimental investigation consists of casting and testing of plates. The plates were tested for shear span to depth ratios 6. In each plate number of mesh layers are (unreinforced), 3. For shear span–depth ratio (a/d ratio) plates were tested. The Dimension of each plate is 800mmx150mmx50mm. The dimensions and details of plates were shown in Fig 1.

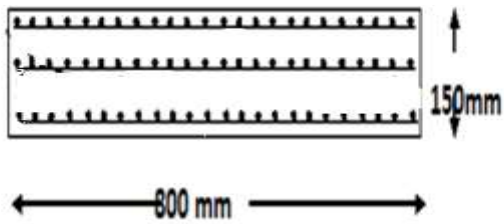

Fig.1 Details & Dimensions of the plate element

Galvanized woven mesh was used as reinforcement to the Geopolymer mortar elements. The wire diameter was found to be 0.55mm. The openings in the mesh measures 2mm x 2mm. The moulds were removed 1 day after casting. The Geopolymer mortar plate's specimens were named and placed in oven curing. After that they were kept in a dry place until they were tested.

3.1.2 Testing of Specimens

The plates were tested on spring testing machine. The Load was applied by means of a proving ring. The load was transferred as a two point symmetrical load by means of a steel rods as shown in Fig 8. The test plates were launched on to the cross head of the machine, and were cantered over the supports. The load points were marked as per requirement of a/d ratios.

The plates were subjected to two symmetrical point loads. The deflection gauges of 0.01mm least count. The crosshead of the machine was raised until the fixed head of the machine just touches the roller placed at the centre of loading beam. Experimental setup is shown Fig.2

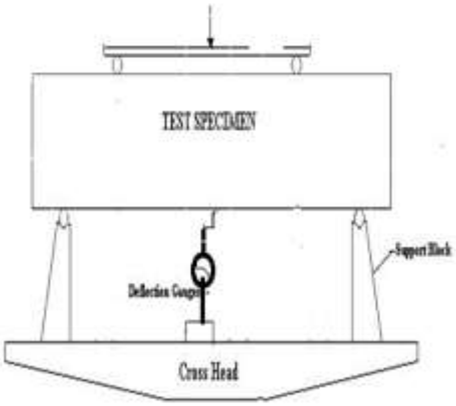

Fig.2 Test Setup

The loads that produced the initial diagonal crack and the ultimate load were recorded. All the specimens were tested on universal testing machine of 40T capacity. The load was transferred as a two point symmetrical load by means of steel rods as shown in Fig 8. The test specimens were launched on the cross head of the machine and were cantered over the supports and All the Plates were tested under load rate control. The deflection gauges reading were noted at each interval. The crack patterns were drawn directly on the plate; the test was continued up to the stage, when the needle of proving ring started returning. Every care has been exercised to obtain the drooping portion of the load- response of the testing then tested under different flexural spans.

The deflection gauges of 0.01mm least count and 50mm range were fixed under load points to facilitate to take the deflections during loading the specimens. The test is continued up to the stage, when the needle of the machine starts returning. Both first crack and ultimate load were noted. All the plates were tested under load rate control the deflection gauge readings were noted at each interval. The crack patterns were drawn directly on the beam and test was continued until the ultimate load is reached.

3.1.3 Empirical Equation to predict Ultimate shear strength of GP plate Elements

$$\frac{Vu}{bd} = k_1\left(\frac{\sqrt{fcm}}{\frac{a}{d}}\right) + k_2 V_f\left(\frac{fy}{\frac{a}{d}}\right)$$

Where, K_1 and K_2 are constants depends on the compressive strength of geo polymer mortar matrix and type of reinforcing material (i.e wire mesh) respectively. From the test data a regression analysis between Experimental shear strength and [$\sqrt{f_{cm}}$/(a/d)] the K_1 value is found as below.

K_1=0.168 & K_2=0.0055

4.0 Test Results & Discussions

Table 1 Theoretical and experimental results of GPC plate elements

S.No	Designation	a/d	V_u Exp (N)	$V_{u,}$ Theory (N)	$V_{u\text{-Th}}$/ $V_{u\text{-exp}}$	V_f (%)	f_y (MPa)
1	P-1(3L)	6	1200	1243	1.035	1.425	380
2	P-2(3L)	5	1390	1492	1.073	1.425	380
3	P-3(3L)	4	1504	1865	1.24	1.425	380

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Fig.3 Load-Deflection curve of plate element (a/d=6)

Above graph represents the Load vs Deflection curve for the geopolymer plate element provide with 3 layers of mesh reinforcement with a/d ratio 6. As the load applied on plate element increases simultaneously the deflection gets increases. The load deflection response is linear up to first cracking load and after cracking it is non linear.

Table 2 Load-Deflection results of GPC plate element with 3 L and a/d ratio 5.

DEFLECTION (mm)	LOAD (N)
0	0
0.57	100
1.13	200
1.7	300
2.1	400
2.6	500
3.4	600
4.3	700
5.2	800
6.3	900
7.2	1000
8.1	1100
8.7	1200

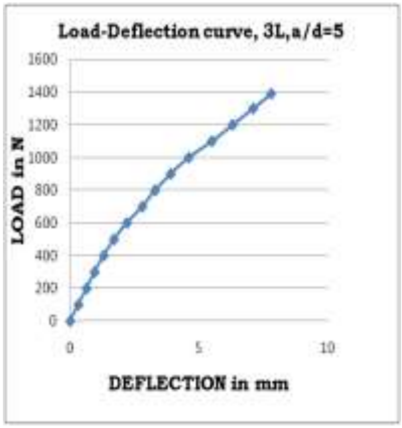

Fig.4 Load-Deflection curve of plate element (a/d=5)

Above graph represents the Load vs Deflection curve for the geopolymer plate element provide with 3 layers of mesh reinforcement with a/d ratio 5. As the load applied on plate element increases simultaneously the deflection gets increases. The load deflection response is linear up to first cracking load and after cracking it is non linear.

Table 3 Load-Deflection results of GPC plate element with 3 L and a/d ratio 4.

DEFLECTION (mm)	LOAD (N)
0	0
0.32	100
0.64	200
0.95	300
1.3	400
1.7	500
2.2	600
2.8	700
3.3	800
3.9	900
4.6	1000
5.5	1100
6.3	1200
7.1	1300

7.8	1390

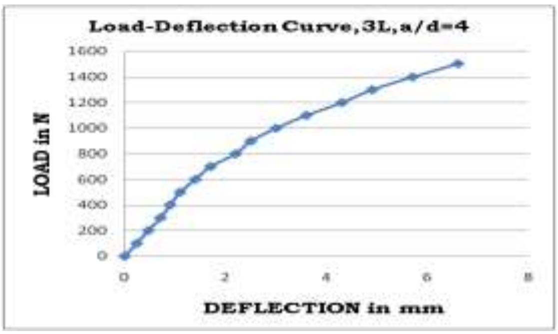

Fig.5 Load-Deflection curve of plate element (a/d=4)

DEFLECTION (mm)	LOAD (N)
0	0
0.24	100
0.47	200
0.7	300
0.9	400
1.1	500
1.4	600
1.7	700
2.2	800
2.5	900
3	1000
3.6	1100
4.3	1200
4.9	1300
5.7	1400
6.6	1504

Above graph represents the Load vs Deflection curve for the geopolymer plate element provide with 3 layers of mesh reinforcement with a/d ratio 4.As the load applied on plate element increases simultaneously the deflection gets increases. The load deflection response is linear up to first cracking load and after cracking it is non linear.

4.1 Load-Deflection Response

Geopolymer mortar elements with a/d ratio decreases shear carrying capacity increases .Crack load of the members was taken as the load corresponding to the point on the load-deflection curve where it changes from linear to non- linear visible crack formed in the member.

5.0 Conclusions

1. Strength of the geopolymer mortar increases with increase in curing temperature for a constant curing period.
2. Geopolymer mortar with silica fume gives better compressive strength.
3. Curing of specimens without moulds gives better compressive strength.
4. Specimens with higher alkaline solution give higher compressive strength
5. As a/d ratio decreases shear strength of geo polymer plate elements increases.
6. For a/d ratio 5 and 6 plates were fail in flexure mode where as plates tested for a/d=4 failed in flexure shear mode

6.0 Photographs

Fig.6 Placing of Reinforcement in Plate Element

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Fig.7 Plates Under Curing

Fig.8 Plate Element Under Flexure Testing For A/D=6 With 3layers

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