EXPERIMENTAL STUDY ON FIBER REINFORCED SELF-COMPACTING GEOPOLYMER MORTAR

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ASTRACT

Geopolymer technology is one of the radical technologies. The main problem of global warming is CO_2 emission, during the cement production. This problem can be minimized by replacing the cement with fly ash. When the cement is used as a binder for the construction, it requires more an amount of water for mixing, curing and the period of curing is also very long. Ferrocement construction is a type of thin reinforced concrete laminate commonly constructed with hydraulic cement mortar. In thin densely reinforced elements, it is difficult to apply proper compaction. In ferrocement and densely reinforced thin elements,the failures usually occurs on compression by crushing mortar at ultimate stage and leads to reduce the tensile and flexural strength of the element. To overcome the above problems, fiber is used in self-compacting geopolymer mortar to increase the tensile and flexural strength of the mortar. This study was carried out to evaluate the mix proportions,self-compacting and strength properties of geopolymer mortar for various mix proportions with different fiber. Mortar cubes of size 70.6x70.6x70.6 mm were casted and cured at 70°C for 24 hours in the oven. The workability of fresh mortar was determined using slump flow, V-funnel, U-Box, J-Ring, and V-funnel at T5 minutes as per EFNARC guidelines. The results show better performance in tensile strength and also flexural strength when fiber is introduced.

Keywords: Fiber, Flyash, Self-Compacting Geopolymer Mortar, Sodium Hydroxide, Sodium Silicate.

I. INTRODUCTION

For the production of concrete-the most widely used construction material in the world, Ordinary Portland Cement (OPC) is the main ingredient used which is among the most energy intensive construction material and whose production is for an increase of 3% annually [1]. The production of OPC releases large amount of carbon dioxide (CO_2) to the atmosphere that significantly contributes to greenhouse gas emissions. One ton of CO_2 is released into the atmosphere for every ton of OPC produced [2]. Therefore, there is a need to find an alternative type of binder to produce more environmentally friendly mortar. A promising alternative is the replacement of cement with by product material such as fly ash.

Self-compacting geopolymer mortar is relatively a new concept and can be regarded as the most revolutionary development in the field of mortar technology [3]. Self-compacting geopolymer mortar is an innovative type of mortar that does not require vibration for placing it and can be produced by complete elimination of ordinary

Portland cement. This paper presents the preliminary results of ongoing research study of mechanical behavior of low-calcium flyash were assessed [4]. The test result substantiates the viability to develop self-compacting geopolymer mortar.

Fiber influences the mechanical properties of concrete in all modes of failure, especially those that induce fatigue and tensile stresses [5]. The strengthening mechanism of Fibers involves transfer of stress from the matrix to the fiber by interfacial shear or by interlock between the fiber and matrix [6] . With the increase in the applied load, stress is shared by the fiber and the matrix [7]. With the increase in the applied load, stress is shared by the fiber and the matrix in tension until the matrix cracks then the total stress is progressively transferred to the fibers, till the fibers are pulled out, or break, or break in tension [8]. fiber efficiency and the fiber content are the important variables controlling the performance of fiber reinforced mortar [9]. fiber efficiency is controlled by the resistance to pull out, which depends on the bond at the fiber matrix interface. Pull out resistance increases with fiber length [10]. Since pull out resistance is proportional to the interfacial area, the smaller the diameter, the larger is the interfacial area available for the bond. For a given fiber length, smaller the area, more effective is the bond [11]. The composite effect of these two variables is expressed by the 'aspect ratio' (length/diameter). Fiber efficiency increases with increase in 'aspect ratio'. The contribution of fiber to the composite depends upon the fiber material and type, Length (l), diameter (d), aspect ratio (l/d), and volume concentration of fibers in the matrix.

II. MATERIALS PROPERTIES AND MIX PROPORTIONS

2.1 Materials Properties

2.1.1 Flyash

In this study Low-Calcium Flyash (ASTM Class F), obtained from Thermal Power Plant at Thoothukudi was used as a source material for the synthesis of Self-Compacting Mortar. The specific gravity of flyash is 2.36 and fineness of flyash is 4%. The chemical composition and properties of Flyash as determined as shown in Table1.

S.No	Characteristics	Percentage
1	Silicon dioxide (Sio_2) plus Aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3)	95.95
2	Silica (as Sio_2)	59.71
3	Magnesium oxide (as MgO)	106.0
4	Total Sulphur as Sulphur tri-oxide (So_3)	Nil
5	Loss on ignition	0.71
6	Moisture	0.32
7	Calcium oxide as CaO	0.50
8	Available by alkaline solution oxide (Na_2O)	0.63

Table 1 Chemical Composition of Flyash

2.1.2 Fine Aggregate

Natural River Sand conformation to Zone II of IS383:1997 was used and its properties are found as follows in Table 2.

S.No	Properties	Result
1	Specific Gravity	2.71
2	Fineness Modulus	2.72
3	Bulk Density, Kg/m^3	1709.47
4	Zone Conformation	II

Table 2 Properties of Fine Aggregate

2.1.3 Alkaline Solution

In geopolymerization alkaline solution also plays an important, alkaline solution used in geopolymerization is a combination of sodium hydroxide and sodium silicate. In the present study, a combination of sodium hydroxide and sodium silicate was used as the alkaline solution.

Sodium hydroxide in the form of pellets with 99% purity and Sodium silicate solution (Grade 53A with Sio_2= 29.43%, Na2O= 14.26% and Water = 56.31%) obtained from Deepa Enterprises Madurai was used as the alkaline activator solution. In order to make sodium hydroxide solution the potable water was used for dissolve Sodium hydroxide pellets. Both the liquid solutions were then mixed together and alkaline solution was prepared.

2.1.4 Superplasticizer

To attain higher workability and flowabilty of the fresh mortar, a commercially available Superplasticizer (Conplast SP430 and Glenium SKY 8233 from BASF) supplied by Sivakasi& Coimbatore and specified amount of extra water was also used. The ordinary drinking water available in mortar in concrete laboratory was used for this purpose

2.1.5 Fiber

Name of Fiber	Effective Length in mm	Diameter in µm	Specific Gravity in Kg/cm^3	Aspect Ratio	Company Name
Polypropylene Fiber	12	18	0.91	0.67	Polyfibers Private, Coimbatore
Recron 3s Fiber	12	10	0.91	1.2	Reliance, Tirunelveli.
E-Glass Fiber	11	18	0.91	0.61	GVR Enterprises, Madurai
Steel Fiber	12.5	450	0.91	27.77	Bajaj, Chennai

Table 3 Properties of different fiber

Fig 1: Steel Fiber

Fig 2: E-Glass Fiber

Fig 3: Polypropylene Fiber

Fig 4: Recron 3s Fiber

2.2 Mix Proportions

S.No	Mix ID	Mix Proportion
1	GM	Geopolymer Mortar
2	GM +SF	Geopolymer Mortar with Steel Fiber
3	GM + PPF	Geopolymer Mortar with Polypropylene Fiber
4	GM + RF	Geopolymer Mortar with Recron 3s Fiber
5	GM + GF	Geopolymer Mortar with Glass Fiber
6	SC-GM	Self-Compacting Geopolymer Mortar
7	SC-GM + SF	Self-Compacting Geopolymer Mortar with Steel Fiber
8	SC-GM + PPF	Self-Compacting Geopolymer Mortar with Polypropylene Fiber
9	SC-GM + RF	Self-Compacting Geopolymer Mortar with Recron 3s Fiber
10	SC-GM + GF	Self-Compacting Geopolymer Mortar with Glass Fiber

Table 4 Mix Proportion Detailed

S.No	Mix ID	Flyash / Alkaline Solution	Flyash	SP % of FA	Molarity of NaOH	Na_2Sio_3 / NaOH	Fiber % by Volume Fraction
1	GM	0.45	1	1	10M	1:1	1
2	GM +SF						
3	GM + PPF						
4	GM + RF						
5	GM + GF						
6	SC-GM						
7	SC-GM + SF						
8	SC-GM + PPF						
9	SC-GM + RF						
10	SC-GM + GF						

Table 5 Mix Proportions of Different Mortar

NaOH - Sodium Hydroxide Na_2Sio_3 - Sodium Silicate SP - Superplaticizer

III. MIXING, CASTING AND CURING OF MORTAR

3.1 Geopolymer Mortar

The manufacture of Geopolymer mortar was carried out using the usual concrete technology methods. The Geopolymer mortar Mix design using natural river sand, flyash, sodium hydroxide, and sodium silicate. The flyash and the fiber were first mixed together in the mixer then the fine aggregate were mixed together in the laboratory mortar mixer for about 3Minutes. the liquid component of the mixture, i.e. alkaline liquid prepared 1 day before casting was then added to the dry material and mixing continued for further about 4 minutes to manufacture the fresh mortar. The alkaline solution of flyash ratio was kept at constant as 0.45 whereas the ratio of sodium silicate to sodium hydroxide solution was kept 1:1 and Fly-ash to Sand ratio was 1:1 for mix proportion. Finally the chemical admixture was ConplastSP230 was added in to the mixture the proportion of 1% volume in cementitious mortar the fresh mortar could be handled up to 120 minutes without any sign setting and without any degradation in the compressive strength.

The cubes were cast for mortar. The mortar cube size is 70mm*70mm*70mm. The mortar was placed in the moulds and compacted by manual strokes and together on a vibrating table. All specimens were cured undisturbed for 24 hours at 70 degree Celsius temperature. After that the specimens were removed from the moulds and left open to air up to the testing. The flyash based Geopolymer mortar did not harden immediately at room temperature.

3.2 Self Compacting Geopolymer Mortar

In this study, flyash based Geopolymer was used as the binder instead of ordinary Portland cement based paste to produce mortar. The manufacture of self-compacting Geopolymer mortar was carried out by using the traditional trial and error mortar technology method [12]. A total mixture was made to assess the workability characteristics and the study the influences of various parameters on the compressive strength. The alkaline solution to flyash ratio was kept at constant as 0.45 whereas the ratio of sodium silicate to sodium hydroxide solution was kept 1:1, and Fly-ash to Sand ratio was 1:1 for mix proportion. Finally the chemical admixture was Glenium SKY8233 was added in to the mixture the proportion of 1% volume in cementitious mortar. Then such as V-funnel, L-Box and J-Ring were performed for this purpose all specimens were undisturbed for 24 hours at ambient condition. After that the specimen were removed.

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Fig: 1 Casting of Mortar Specimens

Fig: 2 Specimens under heat curing in oven

IV. TESTING OF SPECIMENS

4.1 Fresh Properties

The functional requirement on a fresh self-compacting mortar is different from those on a vibrated fresh mortar. According to EFNARC [14], a mortar mixture can only be classified as self-compacting mortar, if the requirement for its three key characteristics via: filling ability, passing ability and segregation are fulfilled. In the study the workability related fresh properties of various self-compacting geopolymer mortar were measured using v-funnel, l-box and j-ring test methods. The entire test was performed by following the European guidelines of self-compacting mortar [14].Workability test result for Self-compacting Geopolymer with Fiber Mortar in Table 6.

Mortar Type	V-funnel in Sec (0-10)	V-Funnel At T 5minutes in Sec (0 -10, +3)	J-Ring in mm (6-12)	L-box (H_2/H_1) (0.8 – 1)
SC-GM	6	9	6	0.8
SC-GM + SF	8	10	7.3	0.91
SC-GM + PPF	7	10	6.5	0.85
SC-GM + GF	9	11	7.9	0.88
SC-GM + RF	11	13	9.2	0.98

Table 6 Workability Test Result of Self-compacting Geopolymer Mortar with Fiber

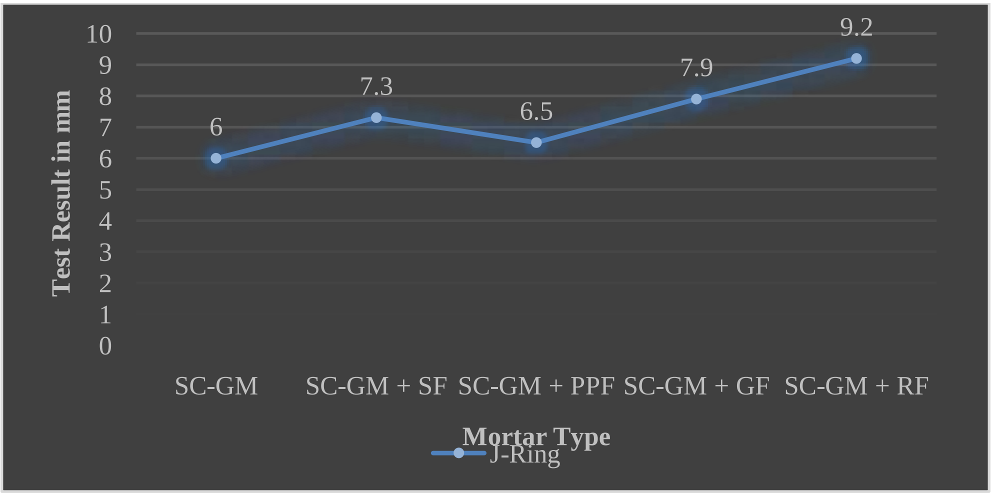

Fig 1: J-Ring Test Results

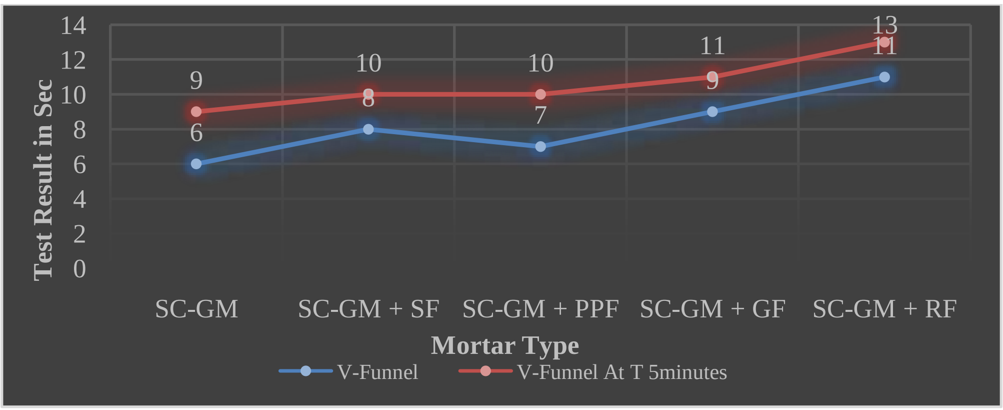

Fig 2: V-Funnel Test and V-Funnel at T5minsTest results

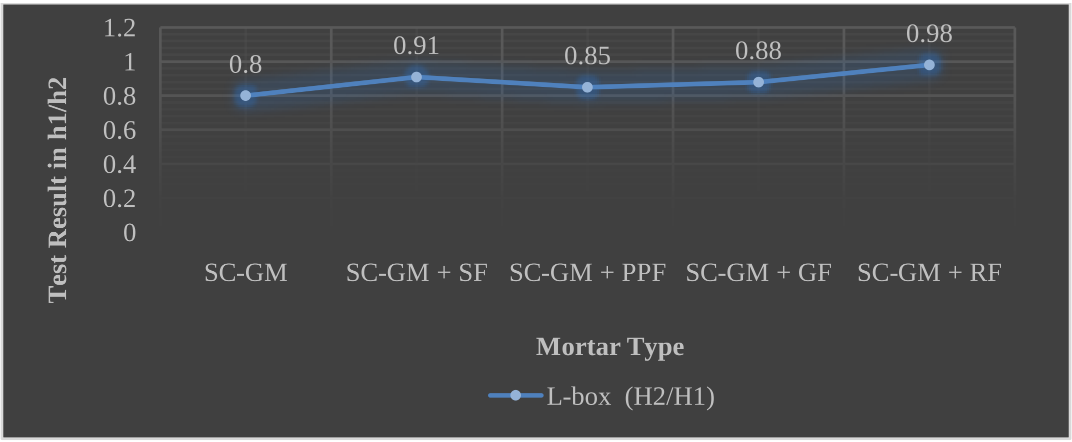

Fig 3: L-Box Test results

4.2 Compressive Strength

Compressive strength is one of the most important parameters of mortar and is considered as the characteristics material value for the classification of mortar. Table 8 shows the Compressive strength for all type of mortar with solution / binder ratio of 0.45 and mix proportion of 1:1

Table 7 Compressive Strength of Mortar Cubes

S.No	Mix ID	Compressive Strength (N/mm2)
1	GM	43.41
2	GM +SF	52.16
3	GM + PPF	54.67
3	GM + RF	52.9
4	GM + GF	52.5
5	SC-GM	52.4
6	SC-GM + SF	54.43
7	SC-GM + PPF	55.7
8	SC-GM + RF	53.53
9	SC-GM + GF	53.13

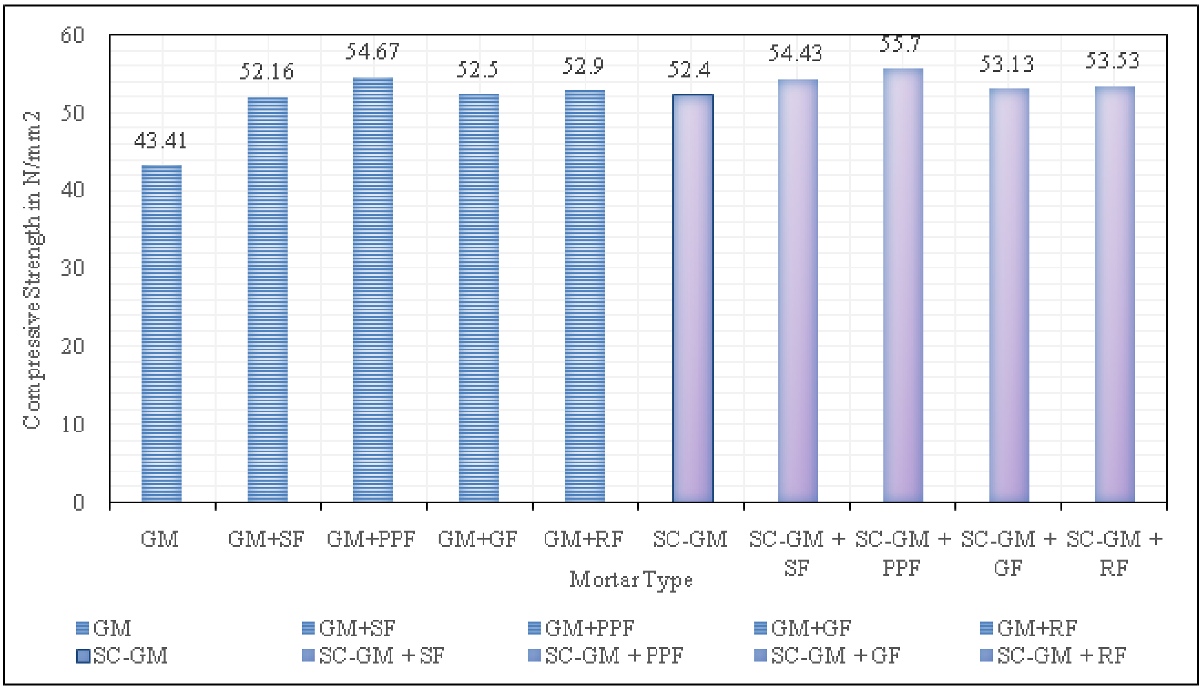

Fig 4: Compressive Strength Test results for various Mix Proportions

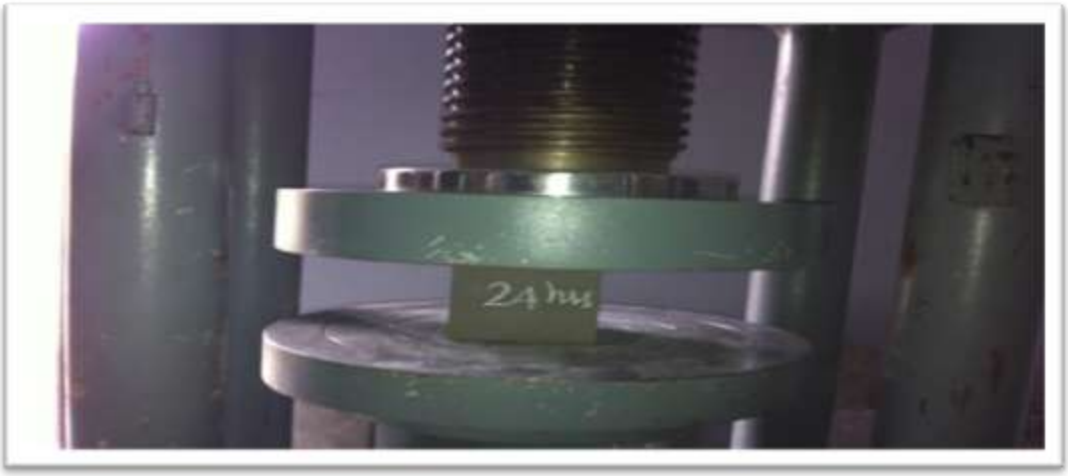

Fig 5: Compressive Strength Test on Mortar Cubes

V. CONCLUSION

Based on the experimental study and analysis of test results obtained, the following conclusions are drawn:

1. Geopolymer Mortar with Polypropylene Fiber gives more compressive strength when compared with Cement Mortar of same mix proportion.
2. Self-Compacting Geopolymer Mortar with Polypropylene Fiber having 0.45 solution/binder ratio shows more compressive strength and also satisfies the workability properties of Self-Compacting Mortar as per EFNARC Guidelines, when compare with Cement Mortar of same mix proportions.

REFERENCES

[1] J. Davidovits, *"Geopolymer: inorganic polymeric new materials", Journal of Thermal Analysis, 37(8), 1991, 1633–1656.*

[2] D. Hardjito and B. V. Rangan, 2005*, "Development and properties of Low-calcium fly ash-based Geopolymer concrete"* Research Report GC 1.

[3] Hajime Okamura[1] and Masahiro Ouchi [2] *"Self Compacting Concrete "Journal of Advanced Concrete Technology Vol 1, No.1, 5-15 2003.*

[4] Mohd Mustafa AI Bakri, H.Mohammed, H.Kamarudin and I.Khairul Niza " *Study on Fly Ash Based Geopolymer Concrete* " , Journal of Engineering and technology research, Jan-2011, vol:3(1).

[5] M. Zeiml, D. Leithner, R. Lackner and H. Mang,*" How do Polypropylene fibers improve the spalling behavior of in situ concrete",* Cem Concr Res, vol 36 , pp. 929–941,2006.

[6] N.Marijanovic, M.Komljenovic, Z.Bascarevic, V.Nikolic **"***Improving Reactivity of Fly Ash and Properties of Ensuring Geopolymer through Mechanical Activation*", Construction and Building Materials 57 (b2014) 151-162.

[7] Sorelli, L. G., ed., "*Some Studies on the Assessment of the Toughness of Steel Fiber Reinforced Concrete with Emphasis on Hybrid Fiber Systems*," Department of Civil Engineering of the University of Brescia, Brescia, Italy, 2000, 370 pp.

[8] Balugaru, P., and Shah, S. P., *Fiber-Reinforced Cement, Composites*, McGraw-Hill, 1992, 530 pp. [10] Mustafa Sahmaran, Heru Ari Christianto "The *Effect of Chemical Admixtures and Mineral Admixture on The Properties of Self-compacting Mortars* ", Cement & Concrete Composites 28 (2006) 432-440.

[9] Plizzari, G. A., "*Experimental Study of Fracture Behavior of Concrete Reinforced with Steel Fibers*," *Research Report* for Officine Maccaferri, Bologna, Italy, 2004. (In Italian).

[10] Ghugal.Y.M, Deshmukh.S.B, *"Performance of alkali resistant glass fiber reinforced concrete*". Journal of reinforced plastics and composites, Vol. 25, No. 6/2006. p. 617-630.

[11] Muthuramu, K.L., Chandran, A., Govindarajan, S., Karu nanidhi, S., *"Strengthening of reinforced concrete elements using glass fiber*". 35th conference on 'Our world in concrete & structures' Singapore Concrete Institute. 2010.

[12] Shetty, M.S., 2012.ConcreteTechnology. (S.chand & company ltd. New Delhi.) 2 I.S. 456, 2000.Indian standard code of practice for plain and reinforced concrete. Bureau of Indian Standards, New Delhi.

[13] Daniel L.Y. Kong, Jay G. Sanjayan, 2008*, "Damage behavior of geopolymer composites exposed to elevated temperature",* Cement & Concrete Composites" 30, 986–991.

[14] EFNARC. Specification and guidelines for self-compacting concrete.