International Journal of
Advanced Structures and Geotechnical Engineering
ISSN 2319-5347, Vol. 03, No. 01, January 2014

Influence of Fibers in Strength Characteristics of Ferro-Geopolymer Mortar

SABNA J., THANUSH THAMPI, V. SREEVIDYA
Department of Civil Engineering, Sri Krishna College of Technology, Coimbatore, Tamil Nadu, India
Email: sabna08@gmail.com, thanushthampi1988@gmail.com, sreevidya.snkr@gmail.com

Abstract: Cement mortar exhibits brittle behaviour due to its low tensile strength. The addition of fibers, either short or continuous, changes its brittle behaviour to ductile or quasi-ductile with significant improvement in tensile strength, tensile strain, toughness and energy absorption capacities. The binder in the fiber reinforced cement composites (FRCC) is mainly Portland cement. The recent environmental awareness in construction industry promotes the use of alternative binders to partially or fully replace the cement as its production creates environmental pollution due to release of CO2 into atmosphere. Recent years have seen a great development in new types of inorganic cementitious binders called "geopolymeric cement" around the world. This prompted its use in mortar and concrete, which improves the greenness of ordinary concrete. Efforts have been made to replace the current FRCC with "geopolymeric" binder resulting in fiber reinforced geopolymer composites (FRGC), which is greener than the former one. The development of FRGC is relatively new in the field of construction materials. This paper presents the development of FRGC for ferro-geopolymer and investigations on its properties with emphasis on compressive strength and tensile strength by heat and ambient curing. Based on the results obtained, the heat cured FRGC with 0.5% fiber was found to be have superior strength.

Keywords: *Geopolymer, Flyash, Sodium Silicate, Sodium Hydroxide, Curing, Compressive Strength, Split Tensile Strength*

Introduction:

Ordinary Portland Cement (OPC) is widely used material in construction industry. It acts as a binder in concrete and cement mortar. The manufacturing of OPC releases large amount of carbon dioxide (CO_2) which significantly contributes to the green house gas emissions. One ton of carbon dioxide is released for every one ton of cement produced. Currently the world annual OPC production is 1.6 billion tons or about 7% in global loading of CO_2 into the atmosphere. Cement therefore not only contributes towards the global warming but also consumes significant amount of natural resources and energy. It is hence required to find out an alternate source as a substitute for cement. A greener alternative, geopolymer fits into an emerging class of cementitious materials that utilize 'fly ash', one of the most abundant industrial by-products on earth, as a substitute for Portland cement. The development of geopolymer material is an important step towards the production of eco-friendly materials. Geopolymer is an inorganic alumino-silicate compound, synthesized from materials of geological origin or from by-product materials such as fly ash, rice husk ash, etc., that are rich in silicon and aluminium. Fly ash is one of the residues generated from the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants.

Materials used:

A. Flyash

Fly ash is finely divided residue resulting from the combustion of ground or powered coal. The hardened fly ash concrete shows increased strength together with a lower permeability, where the latter leads to a higher resistance towards aggressive admixtures in addition, partial replacement of cement with fly ash reduces the production cost of concrete due to the lower price of fly ash compared to cement . Class F Fly ash(contains less than 20% lime) is collected from Mettur Thermal Power Plant (MTTP), Mettur. Specific gravity of fly ash 2.30 is and fineness modulus is 7.86.

B. Fine aggregate

Clean and dry river sand available locally was used. Sand passing through IS 4.75 mm sieve was used for casting all the specimens. Specific gravity and fineness modulus is 2.64 and 2.85 respectively.

C. Sodium hydroxide

Sodium hydroxides are available in solid state by means of pellets and flakes. It is colourless. Chemical composition consists of Assay, Carbonate(Na2CO3), Chloride (Cl), Sulphate (SO2), Lead (Pb), Iron (Fe) and Zinc. Sodium hydroxide pellets in 16 molar concentrations was used.

D. Sodium silicate

Sodium silicate also known as water glass or liquid glass, available in liquid (gel) form. Sodium silicate 2.0 was used. As per the manufacturer, silicates where supplied to the detergent company and textile industry as bonding agent.

E. Fibers

Present investigations were carried out using synthetic fibers. Polypropylene recron 3S were used. Fibers had a cut length of 12mm and aspect ratio of 334.It has good tensile strength and is resistant to alkali and acid attack.

F. Water

In this project, casting and curing of specimens were done using potable water which shall be free from deleterious materials. Water plays role only to impart workability to the mix.

Mix Design:

Geopolymer mortar is a mixture of flyash, sand and fluid(sodium hydroxide, sodium silicate and water).Flyash in its original form cannot function as binder rather it can be used just as filler material in cement mortar as a replacement of cement. Hence to activate flyash a strong alkali solution of sodium hydroxide and sodium silicate is used. The activated flyash which is rich in silica and aluminium can function as a binder like OPC. In this investigation geopolymer mortar with constant F/B ratio of 0.416 was used and flyash: sand ratio as 1:2. The molar concentration of NaOH is 16M. Ratio of NaOH: Na2SiO3 is taken as 2.5. The mix proportions and details of mix are given in Table I and table II respectively.

Table-1 Mix Design

Flyash	Fine aggregate	NaOH	Na_2SiO_3
1	2	0.096	0.24

Table II - Details of mix proportions

Mix	Flyash Kg/m^3	Fa Kg/m^3	NaOH Kg/m^3	Na_2SiO_3 Kg/m^3	Water L/m^3	PP %
M1	790	1580	75.84	189.6	328.64	0
M2	790	1580	75.84	189.6	328.64	0.5
M3	790	1580	75.84	189.6	328.64	1
M4	790	1580	75.84	189.6	328.64	1.5

II. Method of experiment:

A. Preparation of liquids:

The sodium hydroxide (NaOH) solids were dissolved in water to make the solution. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solution with a concentration of 16M consisted of 16x40 = 640 grams of NaOH solids (in flake or pellet form) per litre of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 444 grams per kg of NaOH solution of 16M concentration. Similarly, the mass of NaOH solids per kg of the solution for 14M concentration was measured as 404 grams. The sodium silicate solution and the sodium hydroxide solution were mixed together at least one day prior to use to prepare the alkaline liquid. On the day of casting of the specimens, the alkaline liquid was mixed together with the super plasticizer and the extra water (if any) to prepare the liquid component of the mixture.

B. Preparation of mortar:

The fly ash and the fine sand were first mixed together in for about 3 minutes. The liquid component of the mixture along with fibers was then added to the dry material sand the mixing continued for further about 4 minutes to manufacture the fresh mortar. The fresh mortar was cast into the moulds immediately after mixing and compacted by vibrating the moulds for 20 seconds on a vibrating table cubes and cylinders were casted for study of compressive strength and split tensile strength respectively. The fiber concentration of mortar is varied from 0 to 1.5%. A total of 72 cubes and 72 cylinders were casted with 36 specimens in each for heat and ambient curing.

III. Results and Discussion:

A. Properties of natural sand

Sand which was available near Coimbatore was used. The test was done to determine physical properties of sand.

Table III Physical Properties of Natural Sand

Property	Natural sand	Test method
Specific gravity	2.64	IS 2386 (Part III) – 1963
Fineness modulus	2.85	IS 2386 (Part I) – 1963
Sieve analysis for grading	II	IS 2386 (Part I) – 1963 & IS 383 – 1970

B. Properties of fly ash

Table IV Physical Properties of fly ash

Property	Value
Fineness modulus	7.86
Specific gravity	2.83

Table V Chemical Properties of Fly Ash

Compound	Percent by weight
$SiO_2+Al_2O_3+Fe_2O_3$	90.5
SiO_2	58
CaO	3.6
SO_3	1.8
Na_2O	2
L.O.I	2
MgO	1.91

C. Compressive strength test

The compressive loading tests on mortar cubes were carried out on a compression testing machine of capacity 2000 kN. The test piece, usually in the form of a cube, prism, or cylinder, is compressed between the platens of a compression-testing machine by a gradually applied load. For the compressive strength test, a loading rate of 2.5 kN/s was applied as per IS: 516-1959. The specimen used was 50 mm cube. The test was performed at 7, 14 & 28 days. The dimensions of the specimens to nearest 0.2 mm and their weight shall be noted before testing. The Table VI and fig 1 and fig 2 shows compressive strength results of the cube.

Table VI Compressive Strength

MIX	Ambient curing			Heat curing		
	7DAYS	14DAYS	28DAYS	7DAYS	14DAYS	28DAYS
M1	20.8	25.2	37	30	35	56
M2	23.2	28	44	34	38	62
M3	18	21.6	34.2	25.6	30	48
M4	16.8	20	31.4	23.2	27.6	44

M = mega, Pa = pascal

Heat cured specimens with 0.5% fiber content had 12% more strength than one without fiber. The compressive strength at 28 days for heat cured specimems was 30% higher than ambient cured specimens. For 1% & 1.5% fiber content strength was reduced. Heat curing proves to be more effective as it gave greater strength than that of ambient cured specimens.

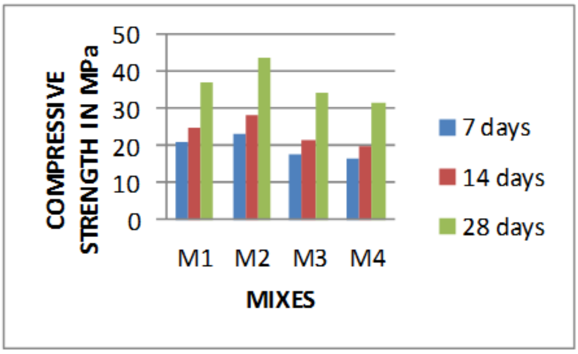

Fig.1 Comparison of compressive strength for different mixes by ambient curing

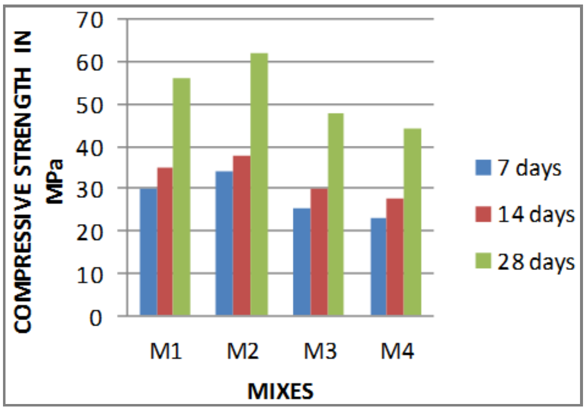

Fig.2 Comparison of compressive strength for different mixes by heat curing

Split tensile strength

The split tension test result is shown in Table VII and Fig 3 and Fig 4.

Table VII Split Tensile Strength

MIX	AMBIENT CURING			HEAT CURING		
	7DAYS	14DAYS	28DAYS	7DAYS	14DAYS	28DAYS
M1	1.7	2.1	3.2	2.4	2.8	4.5
M2	1.92	2.3	3.7	2.6	3.4	5.1
M3	1.53	1.92	3.1	2.3	2.7	4.2
M4	1.3	1.7	2.8	1.9	2.4	3.8

M = mega, Pa = pascal

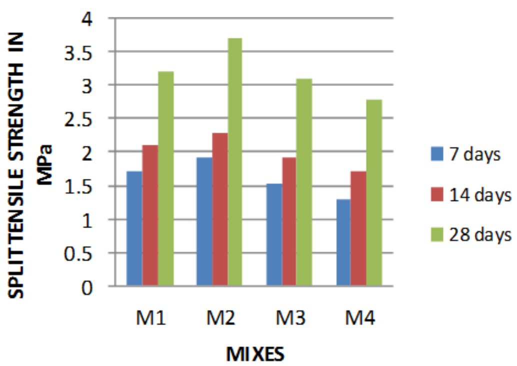

Fig. 3 Comparison of split tensile strength for different mixes by ambient curing

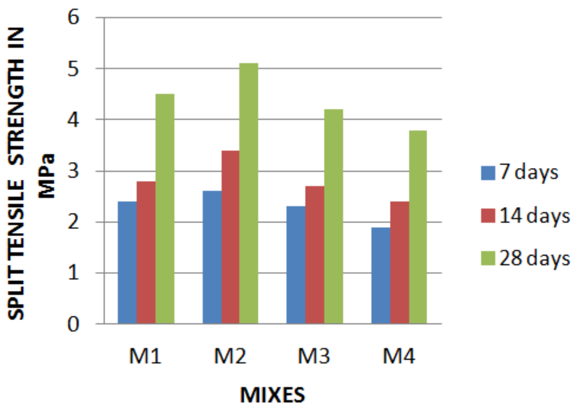

Fig. 4 Comparison of split tensile strength for different mixes by heat curing

It is a method of determining the tensile strength of mortar using a cylinder which splits across the vertical diameter. It is expressed as the minimum tensile stress (force per unit area) needed to split the material apartThe split tensile strength at 7, 14 and 28 days for mortar with and without fibers was investigated and fiber content of 0.5% showed greatest strength. Heat cured specimens with 0.5% fiber content had 12% more strength than one without fiber. The compressive strength at 28 days for heat cured specimens was 28% higher than ambient cured specimens. Beyond 0.5% of fiber the strength of the specimen showed decreasing trend.

Discussion

For a constant F/B ratio of 0.416 the compressive strength and split tensile strength variation of heat and ambient cured specimen for different fiber dosage at 7, 14 and 28 days were arrived. Heat curing was found to be more effective as the 28 days strength developed was 30% more that of ambient cured specimens. The fiber dosage of 0.5% gave higher results for both compressive strength and split tensile strength. This mix also had an increased workability compared to other mixes. Moreover, the addition of fiber helps in bridging the cracks and the failure is ductile in nature.

Conclusion:

The fibrous Ferro-geopolymer mortar is the main strength giving matrix in Ferro-geopolymer. In this investigation on fibrous Ferro-geopolymer mortar following conclusions can be drawn.

- Geo-polymerization is a slow process, so the initial strength gain in ambient condition is very less.
- Increased fiber concentration resulted in less workable mix.
- Out of all the mix the one with 0.5% fiber content gave a greater strength.
- Heat cured specimen showed improved result than ambient cured, the possible reason for this may be that the geo-polymerization process takes place at higher rate in heat cured specimen.
- For the specimen with zero fiber content the fracture was observed to be brittle.
- Ferro-geopolymer mortar with fibers had increased ductility and bonding.
- Beyond certain level, the addition of fibers resulted in decrease of strength of the test specimens.
- Based on the conclusions, the mix with 0.5% fiber content can be considered as optimum fiber dosage.

The fibers in Ferro geopolymer could result in increased strength for the element. Since fibers make the element ductile, sufficient warning is given before complete failure of the structure. The fibers also have the added advantages of reducing self weight of the structure, bridging the cracks, prevention of reinforcement corrosion and spalling. Geopolymers possess mechanical properties which are comparable with materials based on OPC, and they have superior performance regarding heat resistance and acid resistance. Geopolymer will give a promising solution for cement replacement in years to come.

References:

[1] B. V. Rangan, Pan, Zhu and Sanjayan, Jay G (2009), 'An investigation of the mechanisms for strength gain or loss of geopolymer mortar after exposure to elevated temperature', Journal of Material Science. Vol.44, No.7, pp.1873-1880.

[2] Djwantoro Hardjito, Chua Chung Cheak & Carrie Ho Lee Ing (2008), 'Strength and Setting Times of Low Calcium Fly Ash-based Geopolymer Mortar' , Modern Applied Science, Vol.2, No.4, pp 9-18.

[3] Faiz Uddin Ahmed Shaikh (2013), 'Mechanical Properties of Short Fiber Reinforced Geopolymer Composites.', Construction and Building Materials, Vol.43, pp 37-49.

[4] Dr. N. K. Patil & Dr. K B.Prakash (2010), 'Effect of Alternate Wetting and Drying on Impact Strength of Fibrous Ferrocement Using Round Steel Fibers', New Building Materials & construction world.

[5] Maurice Atcheson and Douglas Alexander(1979), 'Fibrous Ferrocement to observe energy absorption and impact loading properties', American Concrete Institute, Vol-61, pp 81-102.

[6] M. Jamal Shannag and Tareq Bin Ziyyad (2007), 'Flexural response of ferrocement with fibrous cementitious matrices', Construction and Building Materials, Vol.21, Issue-6, pp 1198-1205.

[7] M. Komljenovic , Z. Bascarevic, V. Bradic(2010), 'Mechanical and micro structural properties of alkali-activated fly ash

geopolymers' , Journal of Hazardous Material, Vol.181, Issue 1-3, pp 35-42.

[8] P.B. Sakthivel and A. Jagannathan (2012) 'Fibrous Ferrocement Composite with PVC coated weld mesh and Bar-chip polyolefin fibers', Int.J. of GEOMATE, Vol.3, No.2, pp 381-388.

[9] Suresh Thokchom, Dr.ParthaGhosh and Dr.Somnath Ghosh, "Acid Resistance of Flyash based Geopolymer mortars", International Journal of Recent Trends in Engineering Vol. 1 No. 6, May 2009, pp.36-40.

[10] S. Songpiriyakij (2007), 'Effect of Temperature on Compressive Strength of Fly Ash-based Geopolymer Mortar', Silikaty 48(4), 2007, pp.183-197.

[11] V. Sreevidya, R. Anuradha, D. Dinakar, Dr. R. Venkatasubramani (2012)"Acid Resistance Of Flyash Based Geopolymer Mortar Under Ambient Curing And Heat curing" International Journal of Engineering Science and Technology, Vol. 4, No.02 pp 681-684.

[12] Vincent Wen Jun Lin , Ser Tong Quek , Mohamed Maalej (2011), 'Static and dynamic tensile behaviour of PE-fibrous ferrocement', Magazine of concrete research, Vol. 41, pp 138-208.

[13] Vanchai Sata, Apha Sathonsaowaphak, Prinya Chindaprasirt, (2012) 'Resistance of lignite bottom ash geopolymer mortar to sulfate and sulfuric acid attack', Cement & Concrete Composites, Vol-34, pp 700-708.

[14] Shetty M.S., 'Concrete Technology', 15th edition, S.Chand & Company Ltd. , New Delhi, 2005.

[15] A. M. Neville, 'Concrete Technology', 2nd edition, Pearson Education Ltd., England, 2010.

[16] Gambhir M. L., 'Concrete Technology', 5th edition, TataMcGraw-Hill, New Delhi, 2006.