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Research Article

FIBRE REINFORCED METAKAOLIN GEOPOLYMER COMPOSITE

Priyadharshini SP and Kalaiyarrasi ARR*

Department of Civil Engineering, St. Peter's Institute of Higher Education and Research, India

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ABSTRACT

Metakaolin geopolymer concrete is synthesized in ambient curing with flyash and metakaolin in equal proportion and sodium hydroxide and sodium silicate as alkali activator. The compressive strength of metakaolin geopolymer concrete at 28 days is 17.5 MPa. Hooked ended steel fibers were added at the increments of 0.25 % of weight of concrete up to 2%. The compressive strength increased to 29.4 MPa for 2% steel fiber and the flexural strength increased to 12 MPa for 2% of steel fiber. Hooked ended steel fibers are effective in reinforcement of metakaolin geopolymer concrete with 68% increase in compressive strength 50% increase in flexural strength 28 days .

INTRODUCTION

Concrete is a brittle material. When discontinuous fibers are added to the concrete, some of the properties like ductility and energy absorption capacity is improved. Cement used in concrete has larger carbon foot print, almost one tonne of CO_2 is released during production of 1tonne of cement (Davidovits, 1996). Geopolymer concrete uses no cement. Geopolymer comprises of aluminosilicate rich source material and an alkali activator solution. Many materials like Flyash, Kaolinite, Metakaolin, Ground granulated Blast Furnace slag (GGBFS), Rice Husk ash, Biomass ash can be used as source material. Alkaline solutions like Sodium Hydroxide or Potassium Hydroxide are combined with silicate solutions like Sodium silicate or Potassium silicate to form alkali activating solution. Geopolymerization is a polycondensation process in which the aluminate and silicate in the source material are combined with alkali activator solution to form a three-dimensional network of polymeric oxide structures (Rahier, 1997). The typical geopolymer composition is given by

$M_n \{-(SiO_2)_z - AlO_2\}. w H_2O$

where M is an alkali metal, n is the degree of polycondensation and z is 1, 2 or 3. Geopolymers are self- curing at ambient condition though elevated temperature curing results in high early strength. Starting materials and processing conditions affect the physical, chemical and mechanical properties of Geopolymer to a great extent (Granizo, 1997). Metakaolin is different from other pozzolanic aluminosilicate material like flyash, silica fume, slag in that metakaolin is not a by-product of an industrial process. It is manufactured under controlled conditions for the specific purpose.

Meta in Metakaolin indicates the transformation of Kaolinite mineral through loss of hydroxyl ions. This process is known as hydroxylation or calcination. Calcining Kaolinite at the temperature range of 700ºC -800ºC (IS 1344-1981) for 4 hours and grinding to have a specific surface area of $20m^2/g$ makes the clay highly reactive. As concrete is brittle, fibres are used to increase the tensile ductility. Fibres are natural like sisal and jute or manufactured like steel, polypropylene and PVA. Fibres are very effective in controlling the post cracking behavior of concrete and improves the impact resistance and energy absorption capacity

MATERIALS AND METHODS

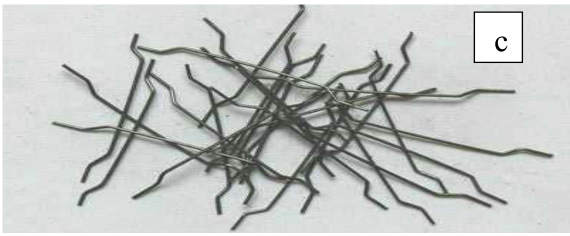
Materials

Flyash and metakaolin are used as cementitious materials in Metakaolin geopolymer composite. Class F flyash used in this investigation is from Ennore Thermal power station, Chennai, India and Metakaolin is procured under the brand name Metacem from 20 Microns, Mumbai. Kaolin is sourced from the mines of Gujarat. The Physical and Chemical properties of

Corresponding author:* **Kalaiyarrasi ARR
Department of Civil Engineering, St. Peter's Institute of Higher Education and Research, India

flyash and metakaolin are given in Table 1. Aggregates used in this investigation are natural sand and crushed granite conforming to IS 383- 1970 Specifications for coarse and fine aggregates from natural sources for concrete. Hook end steel fiber conforming to ASTM-A820 is used. The length and diameter of fibres are 35 mm and 0.55 mm with an aspect ratio of 65. The tensile strength of the steel fibers was >1500 MPa according to the manufacturers specification.

a) Flyash b) Metakaolin



c) Steel fiber

Figure 1 Constituents of Fiber reinforced Geopolymer Concrete

Alkaline activator is a mix of Sodium Hydroxide and Sodium Silicate Solution. Sodium Hydroxide solution is prepared by dissolving 99% pure Sodium Hydroxide flakes in distilled water. Sodium silicate solution is viscid and conforms to IS 381 Indian Standard sodium silicate –Specification with a composition of Na_2O (8.74 %), SiO_2 (27.96 %), H_2O (63.3 %) with the modulus of 3.2 (mass of Na_2O/ SiO_2=3.2). The ratio between two liquids was maintained as 2.5.

Table 1 Physical and Chemical composition of FA and MK

Chemical (%mass)	Metakaolin	Flyash
SiO_2	58.90	48.0
Al_2O_3	37.23	29.0
Fe_2O_3	1.70	12.7
TiO_2	0.42	-
CaO	0.29	1.76
MgO	0.20	0.89
Na_2O	0.23	0.39
K_2O	0.26	0.55
SO_3	-	0.5
Loss on ignition	< 1	1.61
Physical property		
Specific gravity	2.5	2.06
Specific surface area m^2/g	19-20	10.5

METHODS

Ambient curing is adopted in this investigation. FA and MK are the cementitious materials used in equal proportions. 10 Molar NaOH solution is used in this investigation. 400 g of NaOH flakes are added in one litre of distilled water. Ratio of sodium silicate to sodium hydroxide is maintained as 2.5. Water to cementitious material is 0.3.

Table 2 Mix proportions

Mix	Flyash (kg)	Metakaolin (kg)	Sand (kg)	Coarse aggregate (kg)	AA solution (kg)	Steel Fiber (kg)
MKGPC	184	184	612	1346	184	-
MKGPC+0.25%SF	184	184	612	1346	184	6.28
MKGPC+0.5%SF	184	184	612	1346	184	12.55
MKGPC+0.75%SF	184	184	612	1346	184	18.84
MKGPC+1%SF	184	184	612	1346	184	25.1
MKGPC+1.25%SF	184	184	612	1346	184	31.38
MKGPC+1.5%SF	184	184	612	1346	184	37.65
MKGPC+2%SF	184	184	612	1346	184	50.2

NaOH flakes were to be added to distilled water slowly and stirred from a distance, as the release of fumes and heat could cause discomfort. Sodium silicate solution was mixed with NaOH solution after 4-5 hours and stored in a container for its use in GPC. Alkaline activator was prepared 24 hours prior to its use in geopolymer concrete. The mix proportions used in this investigation is given in Table 2. Aggregates, flyash and Metakaolin were mixed thoroughly in a dry state in pan mixer of 40 litre capacity. Alkali activator was added and mixed for 5 minutes. Steel fibers are added at the end and mixed for a minute. The resulting geopolymer mix was cohesive and placed in the cube moulds of side 150 mm in three layers and compacted with tamping rod of 40 cm length. 48 number of Prism specimens of size 100 mm ×100 mm ×500 mm for flexural strength test and 72 number of cubes specimens of 150 mm side for compressive strength. To investigate the effect of steel fibre in metakaolin geopolymer concrete, MK50 mix is chosen. Steel fibres are mixed as a replacement in increments of 0.25 % up to 2 % by weight of concrete material.

Figure 2 Compressive Strength and Flexural Strength Testing

Unlike hydration of cement concrete, which requires water curing for strength gain, geopolymer gains strength by expelling water. In this investigation, ambient curing has been adopted to bring down the energy involved in geopolymer synthesis and for investigation of the suitability for practical in situ applications. Molds containing the specimens are left at room temperature for two days and then demolded. UTM of 1000 KN capacity is used for testing and tests were conducted in accordance with IS 516-1959.

RESULTS

The compressive strength and flexural strength of fiber reinforced concrete depends on various factors like fiber content, type and profile of the fibers used. Super plasticizers were not used in spite of the low workability of the metakaolin geopolymer. Fiber content is limited to 2% by weight of concrete as difficulty was faced in placing the concrete. As most of the alkali activator solution is utilised in geopolymerisation, the steel fibers remain unaffected.

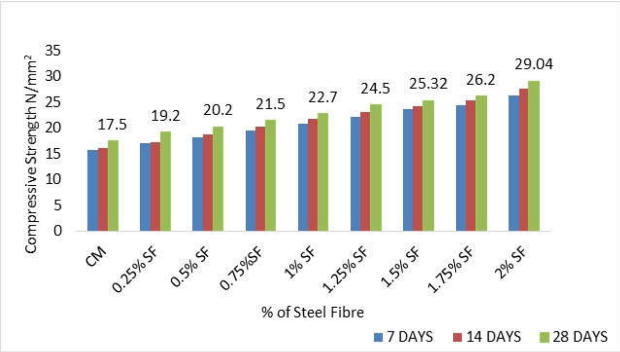


Figure 3 Compressive Strength of FMGPC

The compressive strength continuously increased for all percentage addition of fibers. Variation of compressive strength for different mix proportions is given in Figure 3. The increase incompressive strength is 9.8%, 15%, 23%, 30%, 40%, 45%, 49.7% and 68% for addition of percentages of steel fiber of 0.25%, 0.5%, 0.75%, 1%, 1.25%, 1.5%, 1.75% and 2% respectively. The increase in compressive strength is around 15% for addition of 0.5% of fiber upto 1.5% of addition of fiber and for 2% addition of fiber the compressive strength increases by 18%. The total increase in compressive strength of MK+2% SF is 65% when compared to metakaolin geopolymer concrete. The increase in compressive strength is attributed to resistance offered by the hooked ended fibers to cracking. Only few micro cracks can be seen in MK+2% SF and the cube even after failure looks as if it is not tested at all.

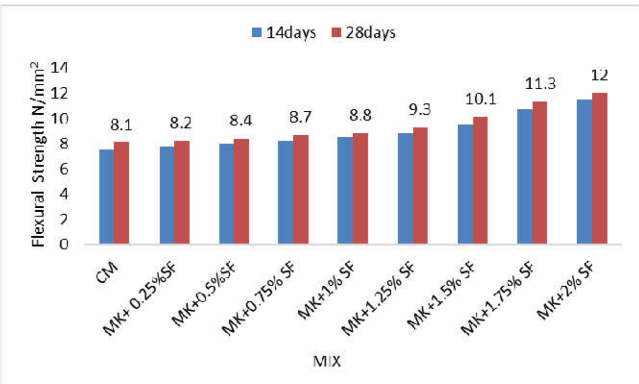


Figure 4 Flexural Strength of FMGPC

Variation of flexural strength for different mix proportions is given in Figure 4.The flexural strength of mix MK+ 0.5% SF increases by 5% and MK+1% SF increases by 10%. The incremental increase in flexural strength varies when the SF are more than 1%. The flexural strength of MK+1.5% SF increases by 26% and flexural strength of MK+1.75% SF mix increases by 41.25%. The flexural strength of MK+2% SF increased by 50% compared to metakaolin geopolymer concrete at the age of 28 days.

CONCLUSION

1. 1.It is possible to synthesis metakaolin geopolymer with reasonable strength in ambient curing.
2. Addition of 2% steel fibre by weight of concrete increases the compressive strength of fiber reinforced metakaolin geopolymer composite by 65%.
3. Flexural strength of fibre reinforced metakaolin geopolymer composite increased by 50% when compared to metakaolin geopolymer concrete.
4. Workability concerns can be addressed using super plasticiser and the % addition of steel fibres can be increased.

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