International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)

# Metakaolin Geopolymer Foam Using Aluminium Powder

A. R. R. Kalaiyarrasi[1], P. Partheeban[2]
[1]Research Scholar, Dept. of Civil Engineering, St. Peter's University, Chennai, Tamilnadu, India
[2]Professor, Dept. of Civil Engineering, St. Peter's College of Engineering and Technology, Chennai, Tamilnadu, India

***Abstract*— Metakaolin geopolymer foam is synthesised using Aluminium powder, metakaolin and alkaline activator. The compressive strength of 7.1 MPa is achieved at 28days for the metakaolin geopolymer with 0.2 percent of Al powder. As the quantity of Al powder is increased beyond 0.2 percent, the compressive strength reduces. The metakaolin geopolymer foam is stronger than flyash geopolymer foam**.

***Keywords* — Aluminium Powder, Compressive Strength, Foam, Geopolymer, Metakaolin.**

## I. Introduction

Cement is a widely used construction material. Production of cement depletes the non-renewable natural resources of mineral deposits and also, the high clinkering temperature of cement escalates the embodied energy further [1]. Geopolymer is a promising replacement for cement concrete. Geopolymer uses no cement and water curing is not required. It is a polymerisation process involving an alumino siliceous powder and an activating solution [2]. Industrial wastes such as flyash, GGBFS, Rice husk ash are used as alumino siliceous powder of which flyash is widely used. Metakaolin is derived from Kaolin clay and it is highly reactive compared to flyash. Activator solution is usually a mix of NaOH solution and sodium silicate solution. Energy saving in geopolymer synthesis is 80-85% compared to cement based materials [3]. Using light weight members leads to economy in the design load and resists effectively the seismic forces. Introduction of voids in cement concrete and in geopolymer concrete is done by aerating and autoclaving (AAC), by addition of organic foams or by addition of fine metal powders. In this work, Al powder is used to introduce voids in the geopolymer mix. Geopolymer is synthesised using metakaolin and NaOH and sodium silicate activator solution. The aluminium powder quickly reacts with the activator solution and releases hydrogen gas which is trapped in the metakaolin slurry. Geopolymers are inorganic and hence offers higher thermal resistance.

$$2Al + 2NaOH + 2H_2O = 2NaAlO_2 + 3H_2$$

In this study, attempts were made to design the metakaolin geopolymer foam after many trials and tested for compressive strength.

Peter Hlavacek, 2014 [4] have synthesised geopolymer foams using flyash and Al powder. The dosage of Al is 0.1% and the L/S ratio as 0.38.The compressive strength attained at 28days is 6 Mpa. Pimpawee et al, 2014 [5] have synthesised metakaolin geopolymer foam using Al powder and concluded that the optimum dosage of Al powder is 0.2 percentage of the mass of metakaolin. The compressive strength of MK 0.2Al mix is 11.88MPa. Mohd Mustafa Al Bakri Abdullah et al, 2012 [6] have synthesised flyash based porous geopolymer using preformed foam liquid and achieved a compressive strength of 42.4MPa after exposure to 1000ºC.The properties of geopolymer foam depends on the starting material and the method of curing.

## II. Experimental

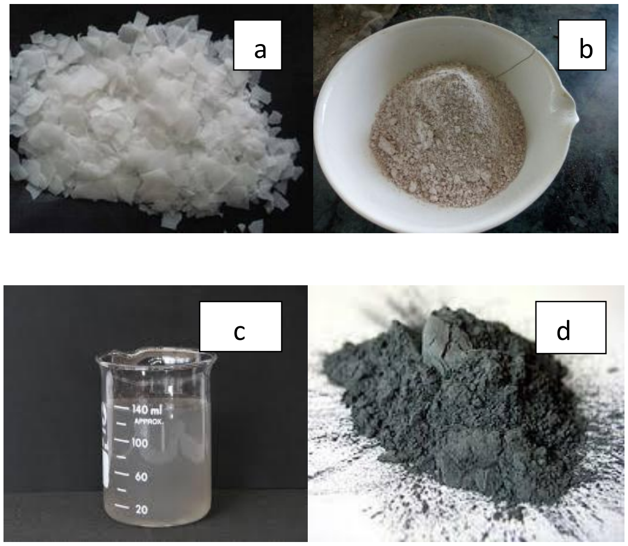
### *A. Material*

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 [7] (IS 1344-1981) for 4 hours and grinding to have a specific surface area of $20m^2/g$ makes the clay highly reactive. Metakaolin is rich in Alumina and Silica and it can be ground to have a particle size as low as 2µm and hence higher specific area of $20m^2/g$.

$$Al_2O_3.\ 2SiO_2.\ 2H_2O \text{ (Kaolin)} \rightarrow Al_2O_3.2SiO_2 \text{(Metakaolin)} + 2H_2O$$

The smaller particle size and the higher specific area is advantageous in producing strong and durable Geopolymer products. The two constituents of alkaline activator are NaOH and Sodium silicate solutions. The common name for NaOH is caustic soda. NaOH flakes of 99% purity are used in this study.8Molar NaOH solution is prepared by using 320g of NaOH flakes in 1 litre of water. Na2SiO3 solution is viscid and translucent with pale white or grey colour. Sodium Silicate having Na2O (8.74 %), $SiO_2$ (27.96%), $H_2O$ (63.3%) with the modulus of 3.2 (mass of $Na_2O/\ SiO_2$=3.2) is used. Aluminium powder used has 89% metallic content with a density of 0.13-0.2g/cc and with the average particle size of 15microns.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)




a) NaOH flakes
b) Metakaolin
c) Sodium Silicate Solution
d) Aluminium powder

**Figure 1 Constituents of Geopolymer Foam**

### *B. Mix design*

Several mixes were tried based on previous research by varying the solid /liquid ratio and the percentage of Al powder. Liquid demand of Metakaolin to form Geopolymer is little high compared to Flyash. For Metakaolin the optimum L/S ratio worked out to be 0.67 from the previous research by the author on metakaolin based geopolymer concrete. Flyash geopolymer can be synthesised using L/S ratio as 0.4. Higher demand is due to the fineness of Metakaolin compared to Flyash. Al powder is used in percentage of mass of metakaolin varying from 0.2 percent to 1 percent as inferred from the previous research [5]. The moulds are only half filled as the slurry expands when hydrogen gas is released.

### *C. Method*

Alkali activator solution is mixed 24 hours prior to the casting of sample. The dry powders of metakaolin and aluminium are mixed thoroughly followed by activator solution. Al powder is added as a percentage of mass of metakaolin starting from 0.2 to 1. The solid to liquid ratio is maintained as 0.67. Dry powders and alkali activating solution should be evenly mixed and quickly transferred to the mould as the hydrogen gas bubbles will start emerging. Improper mixing would result in uneven distribution of pores. The moulds were filled only half of the height and left undisturbed for an hour till all the hydrogen gas gets released. Movement of the mould may puncture the gas bubbles.

Dosage of Al is to be controlled as the higher dosage causes more gas to form at one instant and the size of the bubble is big which will ultimately collapse. The main objective is to entrap the hydrogen gas in the geopolymer slurry in order to have small and evenly distributed pores. The slurry is cured at a temperature of 80ºC for 12 hours. The moulds are covered to avoid evaporation of liquid and left at room temperature till the time of testing.

**Figure 2 Metakaolin Geopolymer Foamed Slurry**

## III. RESULTS AND DISCUSSIONS

The compressive strength of metakaolin geopolymer foam is tested at 7, 14 and 28days using Compression Testing Machine of 400kN capacity. The compressive strength of 0.8Al and 1Al is not determined at 7days and 14 days due to less large pores. When the L/S ratio is increased beyond 0.67, the viscosity of the slurry increases and hence the hydrogen bubbles are not entrapped. Uneven mixing results in the uneven foaming. Delay in mixing and transferring into the moulds collapses some of the bubbles. 5cm×5cm samples are cut from specimens and tested for compressive strength

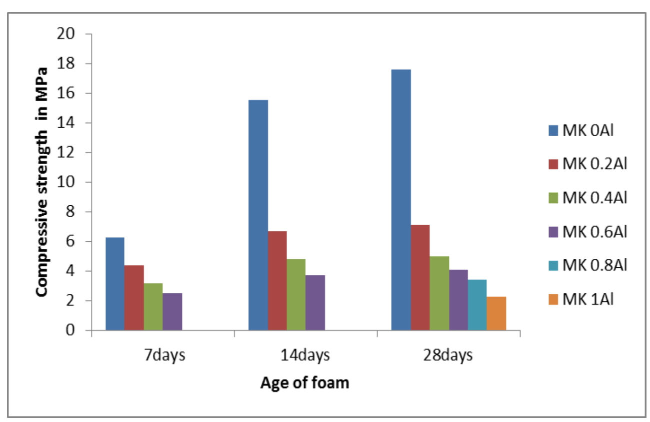



**Figure.3 Compressive Strength of Metakaolin Geopolymer Foam**

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)

The compressive strength of metakaolin slurry (MK0Al) increases from 6.3 MPa in 7days to 15.5MPa in 14days. It increases by 146% in 14days and increases to 17.6 MPa, only 13.5% from 14days to 28days. Most of the strength gained in first 14days is attributed to the elevated curing adopted and the high reactivity of metakaolin. MK 0.2Al at 7days achieved a compressive strength of 4.4 MPa only compared to 6.3 MPa of MK0Al due to the presence of gas bubbles and consequently reduction in the availability of geopolymer matrix. This is the case with the rest of the mixes. The increase in strength from 7days to14days depends on the geopolymer matrix and falls down to 52% for MK0.2Al. From 14days to 28days, MK 0.2 Al gains 5.9% in strength as against 13.5% by MK0Al during the same period. As the percentage of aluminium powder increases the bubbles formed collapsed and hence the strength decreases.

**Fig.4 a) Foamed samples**

**Fig.4 b) Pore distribution**

## IV. Conclusion

Metakaolin geopolymer foam can be synthesised using Al powder. The optimum percentage of Al powder in metakaolin geopolymer is 0.2 of mass of metakaolin. Inclusion of fine sand in the slurry may result in easy handling of the slurry. Skill is required for mixing and casting of the samples. The energy involved in producing geopolymer foam is less compared to the Autoclaved Aerated concrete.

## REFERENCES

[1] Scrivener, KL. and Kirkpatrick, RJ (2007) Innovation in use and research on cementitious material in 12th International congress of chemistry of cement, Montreal, Canada.

[2] Davidovits, J.(1982) Minerals polymers and methods of making them", US Patent 4472199.

[3] Davidovits, J. (1996) Pyramid Illusions, A journey to the truth, Basket Publishing, ISBN 0-9652509-7-0.

[4] P. Hlavacek, V. Smilauer, F. Skvara, L. Kopecky and R. Sulc (2014) Inorganic foams made from alkali-activated fly ash, mechanical, chemical and physical properties, Journal of the European Ceramics Society.

[5] Pimpawee Keawpapasson, Chayanee Tippayasam, Silawat Ruangjan, Pajaree Thavorniti, Thammarat Panyathanmaporn, Alexandre Fontaine, Cristina Leonelli and Duangrudee Chaysuwan (2014). Metakaolin-Based Porous Geopolymer with Aluminium Powder Key Engineering Materials Vol. 608 pp 132-138.

[6] Mohd Mustafa Al Bakri Abdullah, Liyana Jamaludin , Kamarudin Hussin, Mohamed Bnhussain, Che Mohd Ruzaidi Ghazali and Mohd Izzat Ahmad Fly Ash Porous Material using Geopolymerization Process for High Temperature Exposure Int. J. Mol. Sci. 2012, 13, 4388-4395;

[7] Indian standard code for specification of calcined clay pozzolona: IS 1344-1981, Bureau of Indian Standards, New Delhi, India.