An improved study on active conditions of geopolymer reaction and foam formation

Jae Hak Yoo, Ju Yeong Lee, Hwa Jeong Cho, Hyo Kim

Department of Chemical Engineering, University of Seoul, Seoul, 02504

Corresponding author: hkim@uos.ac.kr

Introduction

❑ Coal Combustion Products (CCPs)

- CCPs can be used as a source material of geopolymer because of its high silica and alumina contents.
- Fly ash almost recycled, but bottom ash usually disposed by landfill.

❑ Geopolymer

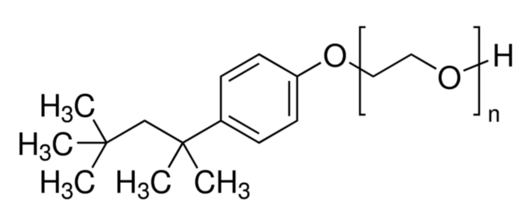
- Geopolymer is a type of alkali-activated materials that can be synthesized by the reaction of aluminosilicate source materials with alkali activator.
- Geopolymer emits less CO_2 than Ordinary Portland Cement (OPC).

❑ Geopolymer foam

- Geopolymer foam has insulation effect and light weight by using foaming agent.

Experimental design

- Geopolymer foam reacts well even under conditions of high concentration of alkali activator. The stability of the bubble is determined by the viscosity of the geopolymer paste by the L/S ratio and the properties of the foaming agent and surfactant.



[Triton X-100]

Name	NaOH	L/S ratio
12-n	12M	From dry pellet to gel (empirical)
14-n	14M	
16-n	16M	
18-n	18M	

Table 1. Mix proportions of coal bottom ash, coal fly ash, and liquid to solid ratio.

Materials

❑ Aluminosilicate source materials

- Coal fly ash (CFA)
  Classified as class F fly ash ($SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70\ wt.\%$)

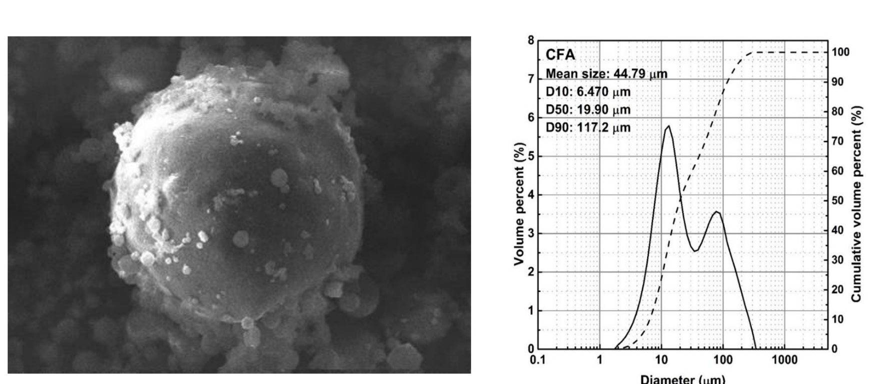


Fig 1. SEM image (left) and particle size distribution (right) of fly ash.

❑ Sulfactant

Ion	Name	
Nonionic	Tween 80	
	Triton CG-110	Poly glucoside, C8~10
	TDS-ELOTANT Milcoside102H	Capryl glucoside, C8~C10
	TDS-ELOTANT Milcoside200	Lauryl glucoside, C12~C14
Cationic	DTAB	C12
	Octylamine	C8
Anionic	SDS	C12
	SDBS	C12

Table 2. Surfactant types and properties.

❑ Foaming agent

Fig 2. Al powder

Fig 3. Al dross

❑ Alkali activator

12~18 M(mole/L) sodium hydroxide aqueous solution

Methods

1. Coal fly ash and coal bottom ash was mixed by hand in dry condition.
2. NaOH solution(12M, 14M, 16M, 18M) and suarfactant(Fig.2) were added into the ash mixture and blended by Hobart mixer for 5 minutes.
3. Foaming agent(Al powder, Al dross) was added into the Geopolymer paste and blended by Hobart mixer for 30 seconds.
4. Mixed geopolymer mortar was casted into triplicate 5 cm cubic mold.
5. The casted mortar was sealed with plastic bag and cured in a 40°C oven for 24 hours and then cured at 75°C dry oven for 24 hours.
6. After curing, specimens were demolded and cooled down naturally.
7. The specimens were further cured for 5 days at room temperature and investigated.

Results & Discussion

❑ L/S ratio

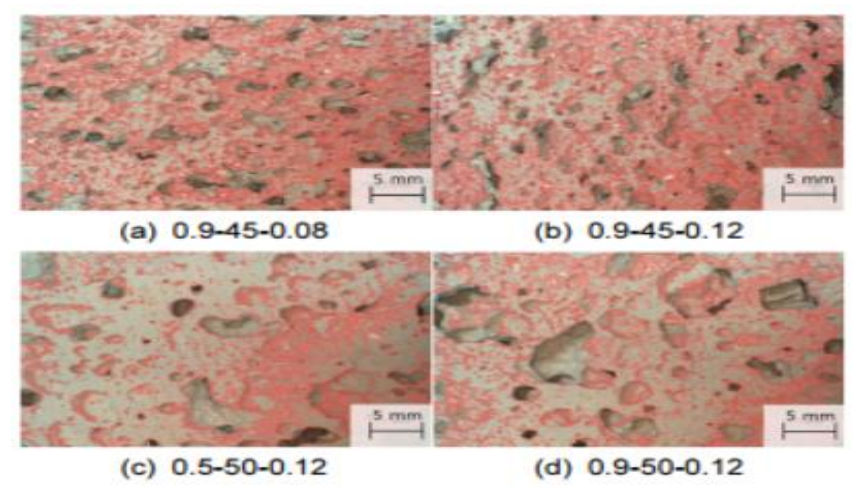


Fig 4. Microscope Photograph by CaO/SiO2 - L/S - Al Powder of ALC

- The value should be determined through the flow test.
  - Autoclaved lightweight concrete(ALC)-related studies have confirmed that the viscosity of the paste greatly affects the form of bubbles forming in the early stages of the reaction and the properties such as compressive strength and thermal conductivity after the completion of the reaction. This will also be applied to geopolymer foam mortar.

❑ Compressive strength

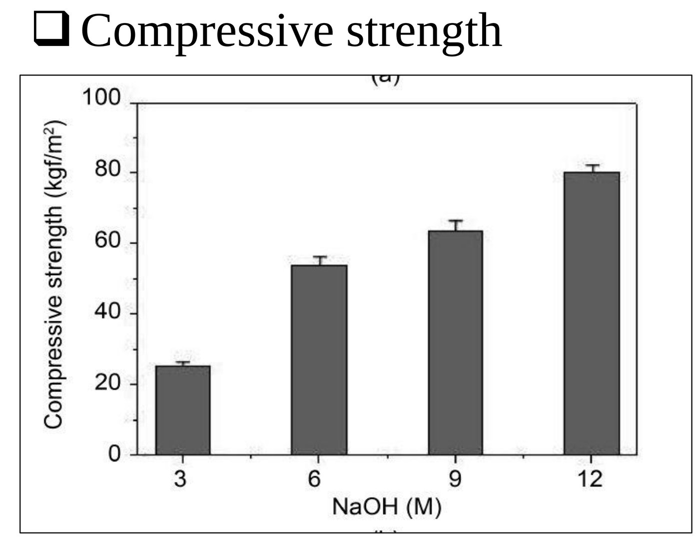


Fig5. Compressive strength of fly-ash based geopolymer cement with the concentration of alkali activator

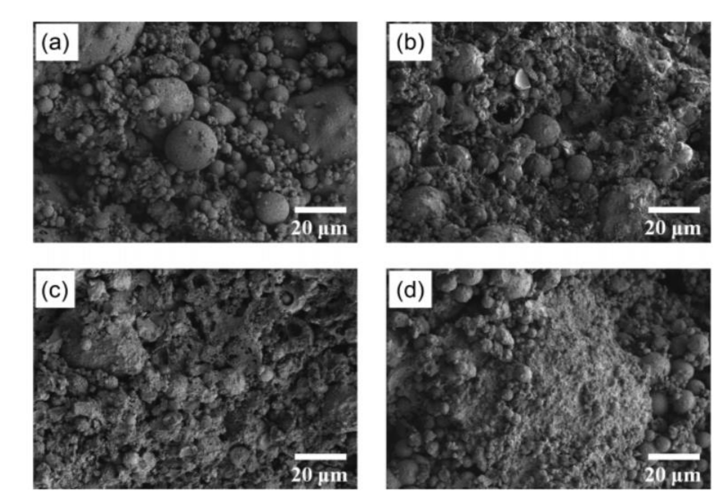


Fig 6. Microstructures of fly-ash based geopolymer cement prepared using (a)3M, (b)6M , (c)9M, and (d)12M NaOH activator

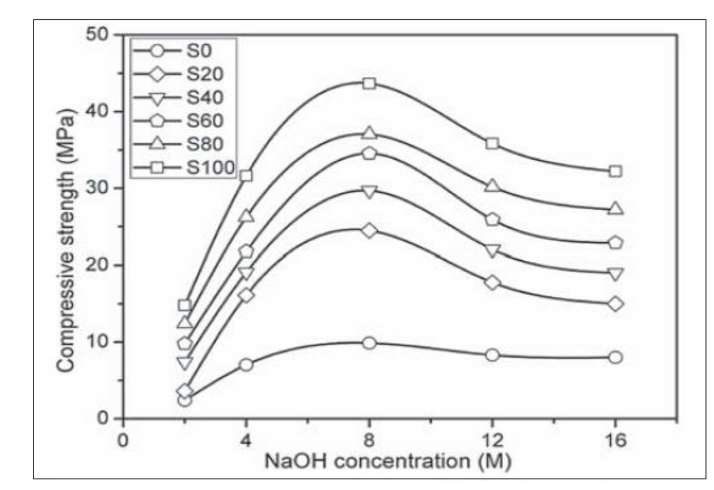


Fig 7. Variation in compressive strength with NaOH concentration.

- Compressive strength is significantly improved by concentration change rather than by type of activator. Because the higher the concentration, the better the polymerization reaction occurs, and the finer the structure becomes.
- Excessive leaching of silica beyond the optimum concentration of alkali slows the geopolymerization process by condensing the particle surface
- This suppresses the further leaching of ions, reducing the strength.

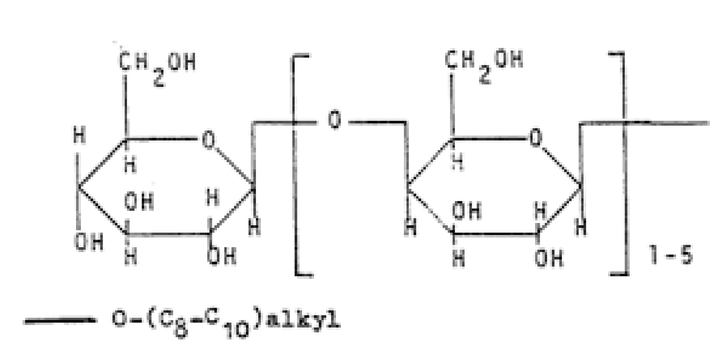
❑ Aluminium Dross

Fig 8. White Dross

Fig 9. Black Dross

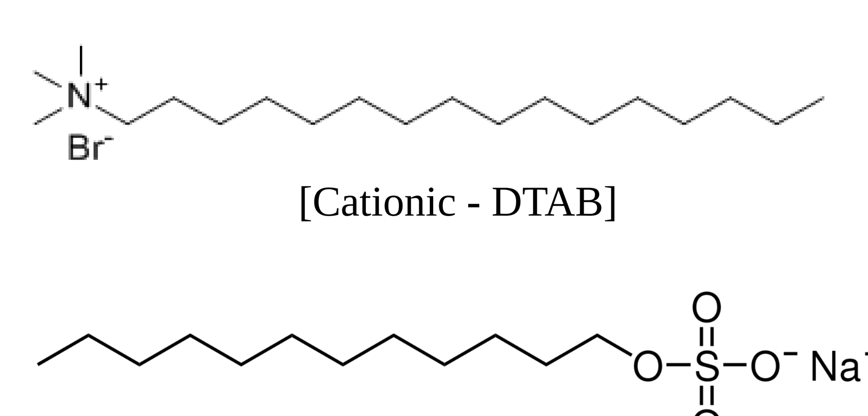
- The white dross has an Al content of up to 70%, which is enough to generate a sufficient amount of air bubbles as a foaming agent. (Black dross : Al 20%)
- As a waste in the aluminum processing industry, it will be able to satisfy the eco-friendliness.

❑ Sulfactant



Triton CG-110

[Nonionic]



[Cationic - DTAB]

[Anionic - SDS]

- Compare according to the structure of the surfactant and the ionic difference of the hydrophilic group.

Conclusions

- The results of experiments conducted in this study could be used as a basis for focusing on creating optimal paste components to improve the performance of geopolymer forms.
- By varying the L/S ratio of the geopolymer foam paste (approximately 0.3 - 0.7) you will be able to analyze changes such as thermal conductivity characteristics of the high viscosity paste.
- By varying the concentration (12M-18M) of the activator, it can be expected that higher compressive strength will be expressed according to the microstructure density of the geopolymer insulation.
- It is expected that it will be easy to control the speed of bubble generation by using aluminum dross (up to 70% of all content) in addition to aluminum powder for the reaction that forms H_2 bubbles.
- Uniform bubble formation in geopolymer insulation can be expected with proper compression strength expression and high insulation effect. In addition, the use of various kinds of surfactants is expected to affect the microstructure of insulation.

References

1. Mohd, M.A.B.A., Kamarudin, H., Mohamed, B., Khairul, N.I., Zarina, Y., & Rafiza, A.R.(2012). International Journal of Molecular Sciences : Fly ash based geopolymer lightweight concrete using foaming agent, 13(6), 7186-7198
2. Marcelo, S.C., Paolo, C., & Marcio, R.M.(2014) Ceramics International : Geopolymer Foams by Gelcasting, 40(4), 5723-5730
3. Rui M. Novais, G. Ascensao, N.Ferreira, M.P. Seabra, & J.A. Labrincha(2018). Ceramics International : Influence of water and aluminium powder content on the properties of waste-containing geopolymer foams, 44(6), 6242-6249
4. Subhashree, S., Suresh, P.S.(2019). Journal of the Korea Concrete Institute : Fresh and Hardened Properties of fly ash-slag blended geo. paste and mortar, 13(6), 769-780
5. Hyun-sub Yoon, Keun-hyeok Yang (2019). Korea Concrete Institute : Optimum Mixture Proportioning of Autoclave Lightweight Aerated Concrete considering Required Foaming Rate and Compressive Strength, 31(2), 2019.4, 123-130