Coal Ash-based Geopolymer Foam Using Silica Fume

서울시립대학교
UNIVERSITY OF SEOUL

X-Urban

지오테크 팀

김효(지도교수), 지윤구(산업체 멘토), 허지회(팀장),
김민성, 이상경, 조항철, 한현규

2020. 10. 31

Contents

Introduction

Current Problems

- ✓ CO_2 emission in cement production
- ✓ Coal ash landfill

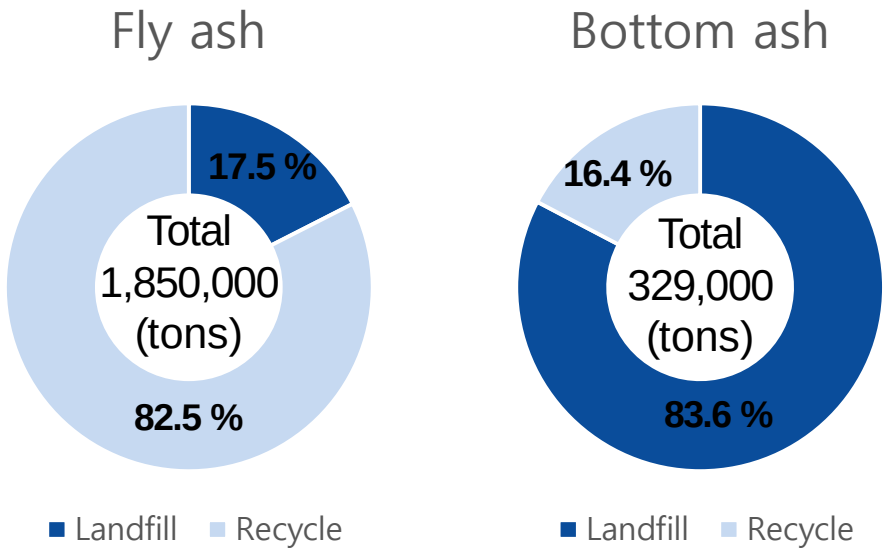

Fig. 1. Status of generation, utilization, and landfill of fly ash(left) and bottom ash(fight) from KOEN(2019).

- ✓ Fire hazards of organic insulation materials

Introduction

Geopolymer?

- ✓ An inorganic binder having aluminosilicate 3-dimensional structure
- ✓ Generally synthesized by alkali activation of aluminosilicate source materials

Geopolymer foam

- ✓ Produced by introducing gas within geopolymer paste
- ✓ Low thermal conductivity, light weight, and fire-resistance

Raw materials

Fly ash
Metakaolin
Blast furnace slag
…

+

Alkali activator

NaOH
KOH
Na_2SiO_3
…

Aluminum powder

Surfactants

- Polysorbate 80
- Cetrimonium bromide
- Sodium dodecyl sulfate

Silica fume

Experiments

Materials

- ✓ Silica fume (SF)
  - An industrial waste from production of silicon and ferrosilicon alloy.
  - Contains free silicon which reacts with water in alkaline medium, producing hydrogen gas.

$$Si^0 + 4H_2O \rightarrow Si(OH)_4 + H_2 \uparrow$$

- ✓ Coal bottom ash (CBA)
- ✓ Coal fly ash (CFA)
- ✓ Sodium silicate solution & sodium hydroxide

Table 1. Chemical compositions of SF, CFA, and CBA.

wt.%	SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	K_2O	MgO	Others	LOI
SF	86.6	0.415	0.896	0.324	0.000	2.71	1.53	4.08	3.40
CBA	52.0	19.1	13.1	6.81	1.16	1.47	1.84	4.40	0.200
CFA	48.4	22.2	6.00	4.03	1.43	1.72	1.11	11.9	3.24

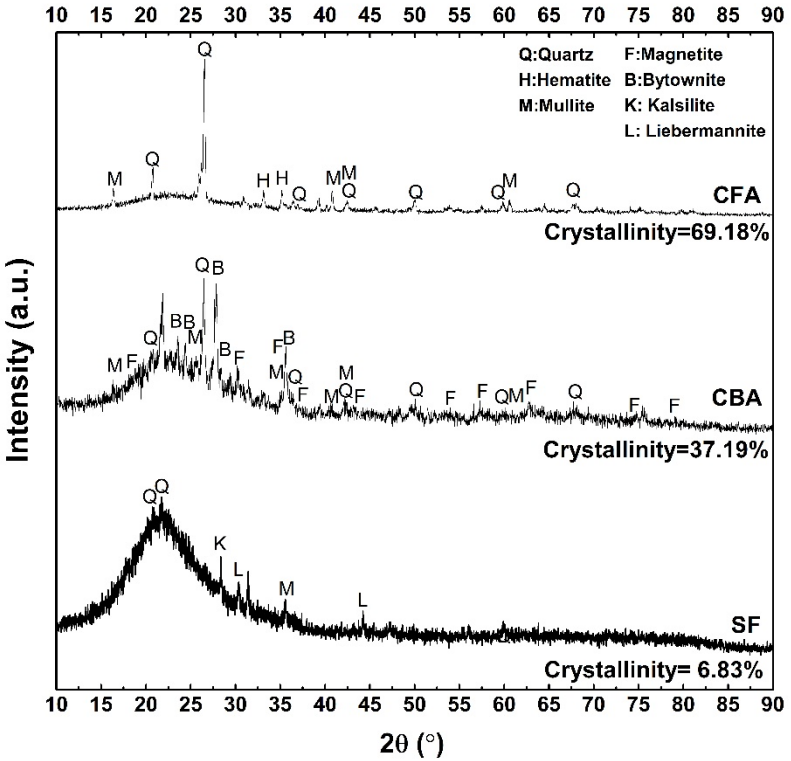

Fig. 2. XRD and crystallinity results of CFA, CBA, and SF.

Experiments

Experimental design

- ✓ CFA content
- ✓ Liquid to solid ratio (L/S ratio)

Table 2. Mix proportions for geopolymer synthesis.

Sample group	Solid materials (wt.% in solid)			Liquid/Solid ratio (L/S ratio)	Note
	Coal ashes		SF		
	CBA	CFA			
FA10	76.50	8.500	15.00	0.38~0.50 with an interval of 0.02	CFA/(CBA+CFA)=0.10
FA30	59.50	25.50	15.00		CFA/(CBA+CFA)=0.30
FA50	42.50	42.50	15.00		CFA/(CBA+CFA)=0.50

➡ Optimum mix proportion with uniform pore structure, low thermal conductivity & enough compressive strength

Results and discussion

Density, thermal conductivity, and compressive strength

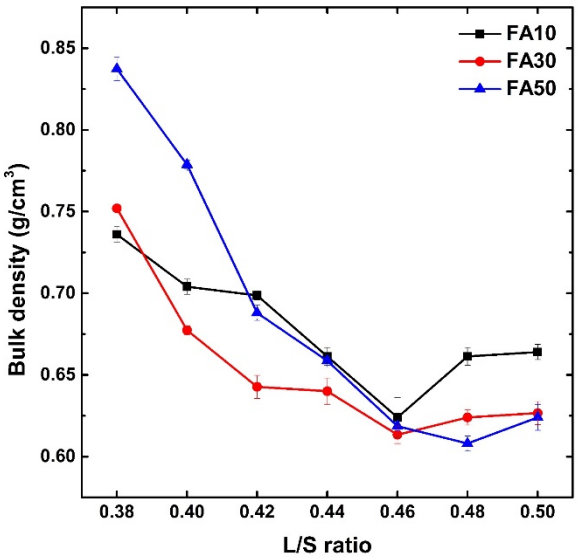

Fig. 3. Bulk density of FA10, FA30, and FA50 with varying L/S ratios.

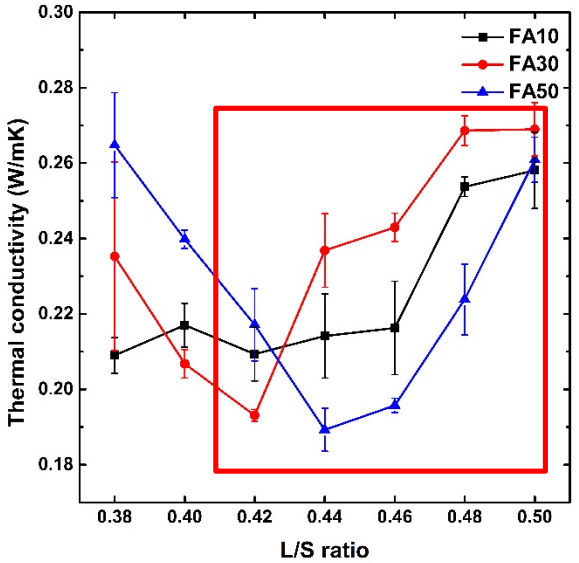

Fig. 4. Thermal conductivity of FA10, FA30, and FA50 with varying L/S ratios.

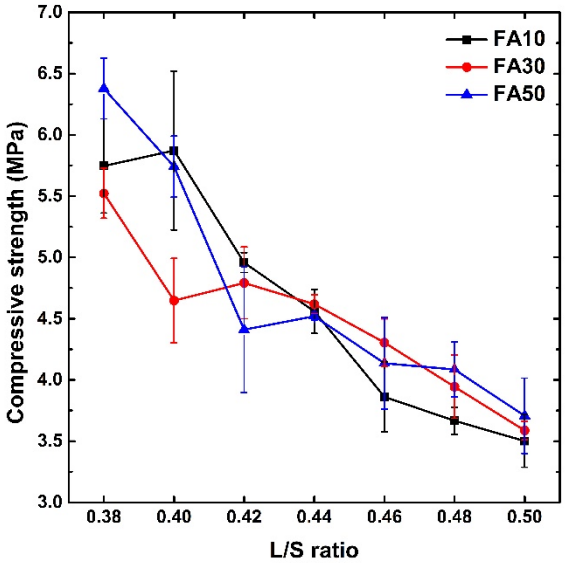

Fig. 5. Compressive strength of FA10, FA30, and FA50 with varying L/S ratios.

Table 3. KS F 2701 standard properties for autoclaved lightweight concrete(ALC) block

	절건 비중	압축강도 (MPa)	열전도도 (W/mK)
0.5품	0.45~0.55	2.9 이상	0.188 이하
0.6품	0.55~0.65	4.9 이상	0.238 이하
0.7품	0.65~0.75	6.9 이상	0.278 이하

Results and discussion

Morphology

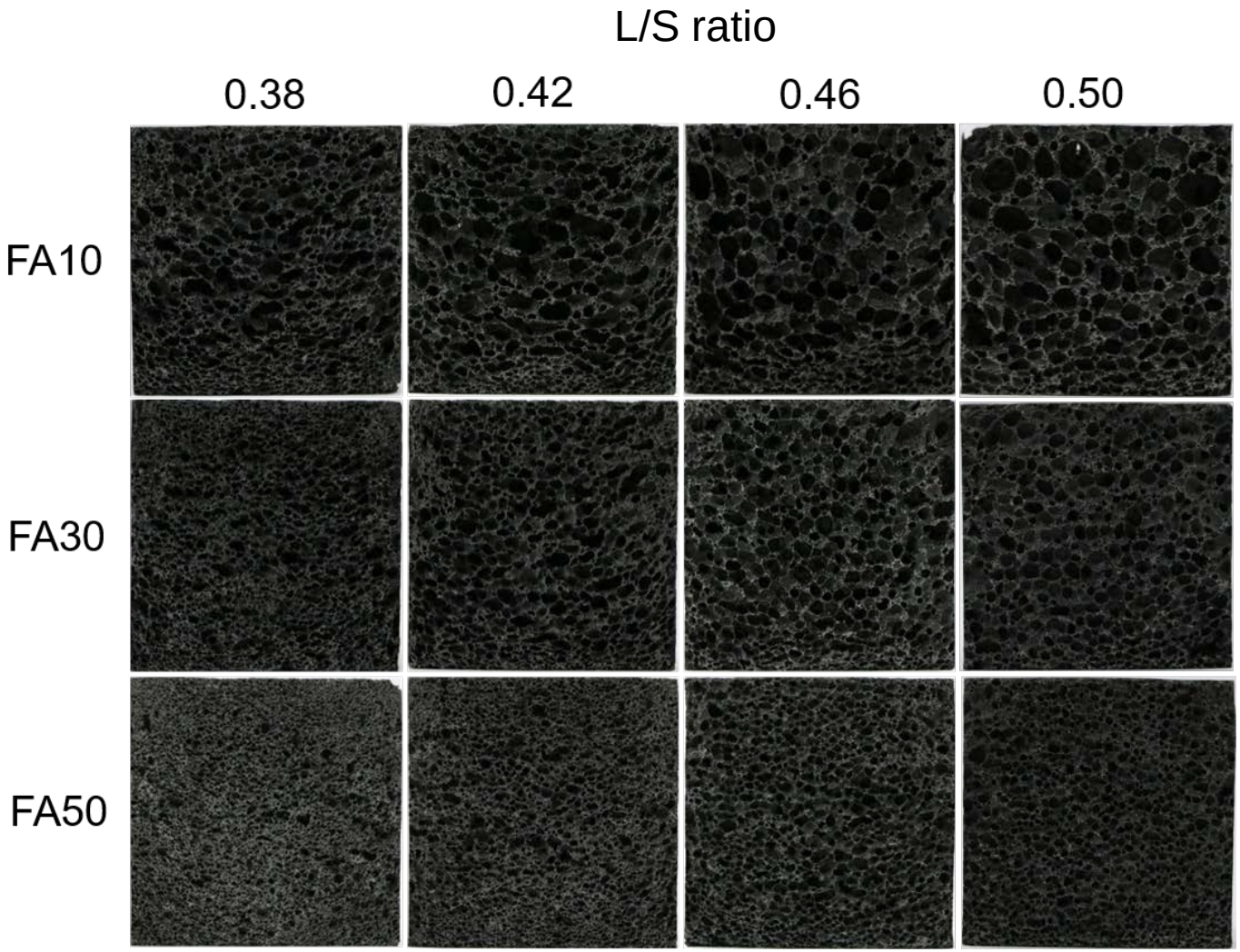

Fig. 6. Cross-sectional photographs of geopolymer foams with various CFA contents and L/S ratios.

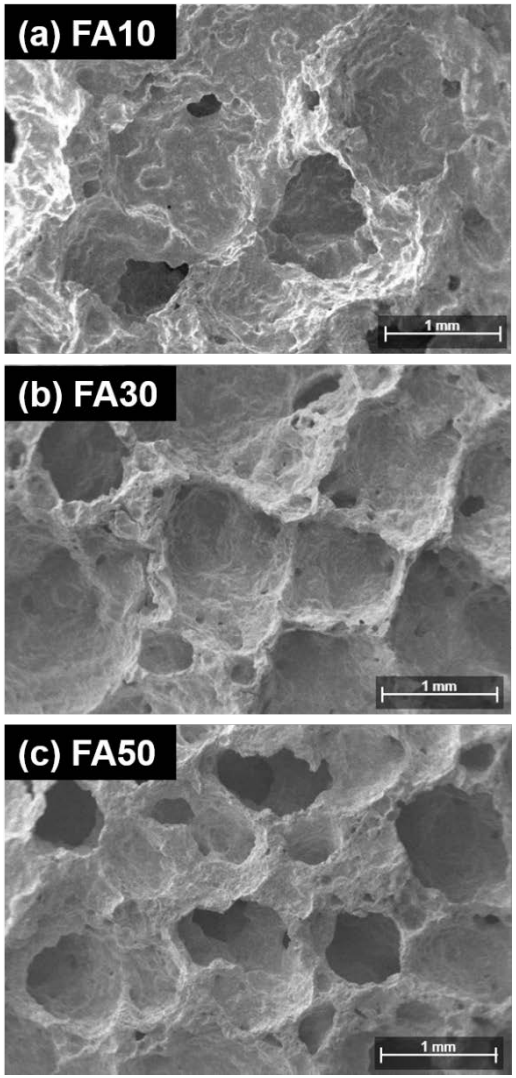

Fig. 7. SEM images of (a) FA10, (b) FA30, and (c) FA50 at L/S ratio of 0.42

Results and discussion

TG/DTG analysis

Silica fume

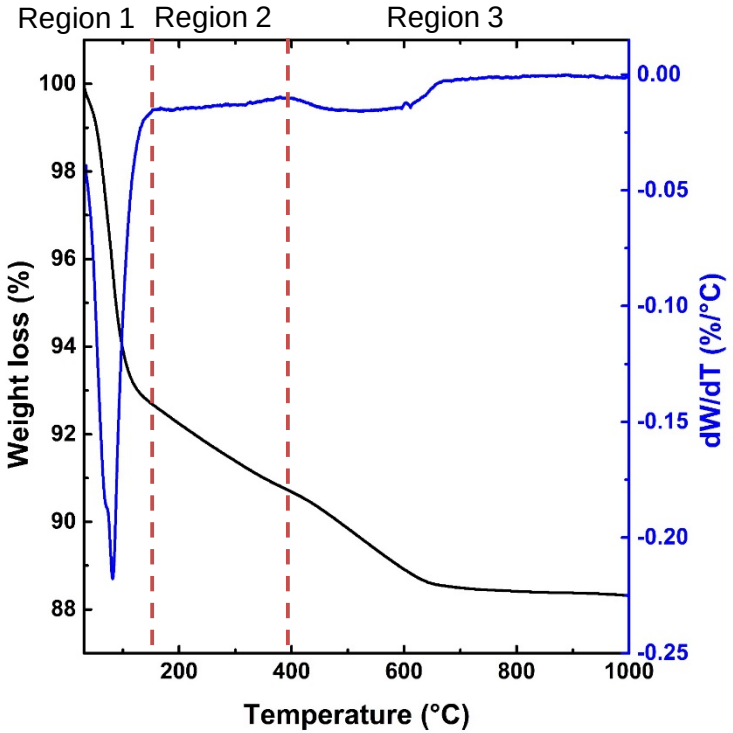

Fig. 8. TG/DTG analysis of FA30 at L/S ratio of 0.42.

Aluminum powder & surfactant

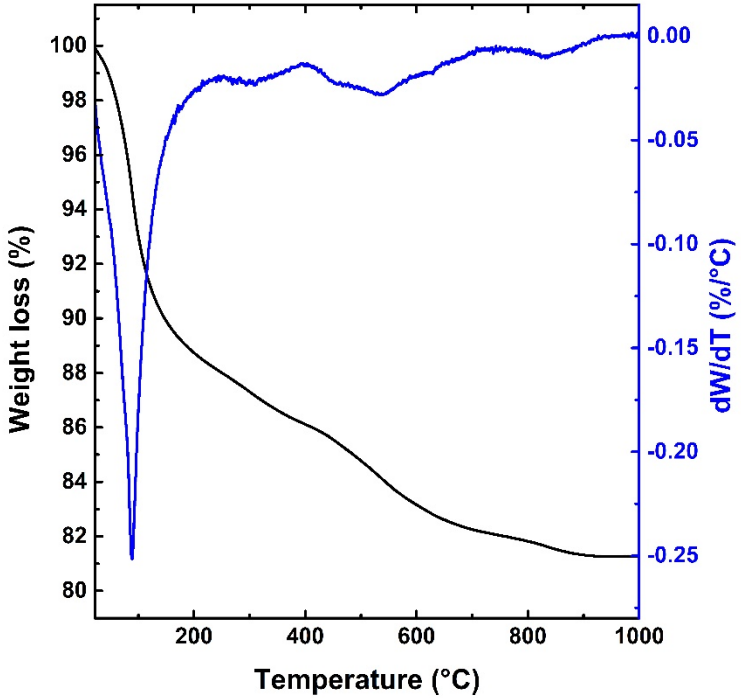

Fig. 9. TG/DTG analysis of geopolymer foam using Al powder and sodium dodecyl sulfate.

- ✓ Region 1: physically bound water
- ✓ Region 2: chemically bound water
- ✓ Region 3: hydroxyl groups

Results and discussion

Additional experiment - Exposure to high temperature

- ✓ Exposed to high temperature of 300℃

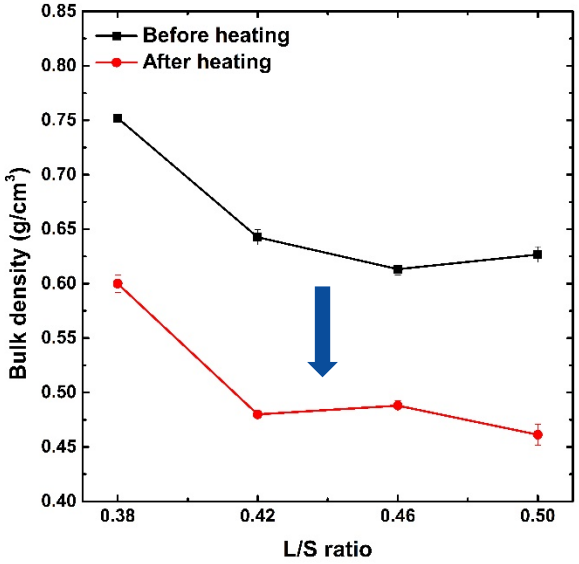

Fig. 10. Bulk density of FA30 with L/S ratios of 0.38, 0.42, 0.46, and 0.50 before and after exposure to 300℃

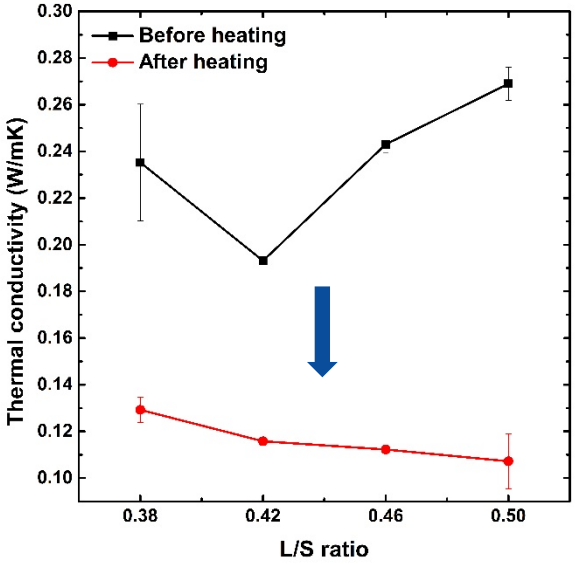

Fig. 11. Thermal conductivity of FA30 with L/S ratios of 0.38, 0.42, 0.46, and 0.50 before and after exposure to 300℃

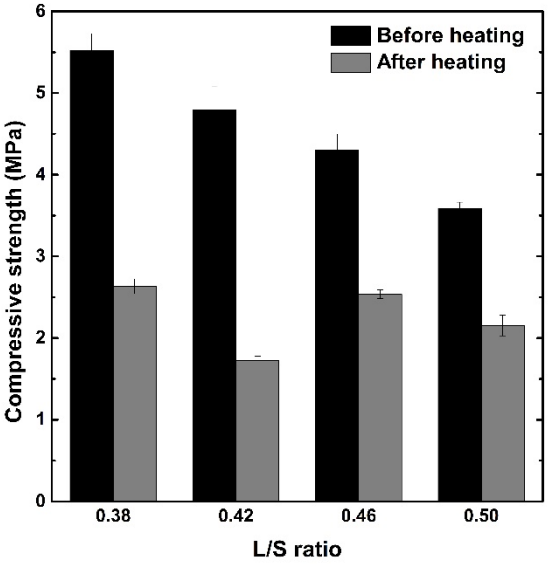

Fig. 12. Compressive strength of FA30 with L/S ratios of 0.38, 0.42, 0.46, and 0.50 before and after exposure to 300℃

Conclusions

Optimum mix proportion

- ✓ CFA content: 30~50% of ash mixture.
- ✓ L/S ratio

Utilization

- ✓ Lightweight construction material, thermal insulation, and fireproofing.

Future work

- ✓ Investigate effects of exposure temperature on properties of geopolymer foam with various mix proportions.
- ✓ Establish drying method of geopolymer foam considering various moisture contents.

Thank you!