Journal of Ceramic Processing Research. Vol. 16, Special. 1, pp. 110s~113s (2015)

J O U R N A L O F
Ceramic Processing Research

Introduction to mineral hydrate insulation

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AAC (Autoclaved Aerated Concrete) has relatively high thermal conductivity. In order to im-prove this property, mineral hydrate insulation has been developed. This material holds fine and uniform pores and is much more lightweight in comparison to AAC. It has the same workability, flame retardancy with AAC and improved thermal performance (0.040 ~ 0.050 W/mK). The fabrication method of mineral hy-drate is similar to that of AAC, however making normal slurry with a considerable amount of foaming agent is difficult due to material segregation and collapse of slurry. In this study, the mixing ratio of raw materials meeting the required insulation performance has been investigated. Physical characteristics of mineral hydrate insulation were analyzed.

Key words: Autoclaved aerated concrete, High thermal conductivity, Mineral hydrate insulation, Lightweight.

Introduction

The building sector takes 25% of green-house gas emissions in Korea. Due to the buildings expanding and developing, the emissions will increase gradually. It is predicted that the percentage of emissions will increase up to 40%. For the purpose of low energy consumption and green-house gas reduction from buildings, new insulation materials with improved thermal performance have been developed and are currently being used [1, 2]. Among new insulation materials, mineral hydrate which compensates for the defects of existing materials is used as a prominent insulation material. The fabrication method of mineral hydrate is similar to that of AAC [3]. After mixing cement, gypsum, lime, quartzite and foaming agent with water, this mixture is autoclaved. However, this contains more pores than AAC. Therefore, it is lightweight and has high insulation performance [4].

Materials and Methods

Low materials

In this study, in order to fabricate mineral hydrate insulation material, high blaine cement, quartzite, lime, anhydrite were used.

Mix design

Based on the chemical components, it was possible to create a mix design shown in table 2. The content of mixing water was fixed at 130% of mixture weight.

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Table 1. Chemical components of raw materials.

Material	SiO_2	CaO	Al_2O_3	Fe_2O_3	SO_3	MgO
Quartzite	99.3	0.02	0.48	< 0.01	0.03	0.01
Cement	17.6	59.4	5.17	2.72	6.69	3.15
Lime	1.68	90.4	0.39	0.43	0.70	0.87
Anhydrite	1.71	39.3	0.45	0.18	53.2	–

Table 2. Mixture proportion.

Material	No.1	No.2	No.3	No.4
Quartzite	40	35	30	25
Cement	45	50	55	60
Lime	10	10	10	10
Anhydrite	5	5	5	5

Fabrication of specimens

After mixing of the raw materials, water was applied, followed by 0.5% of aluminum powder which was used as a foaming agent [5]. Foamed slurry was cured at 20 ~ 30 °C and 40 ~ 50% relative humidity. Finally, the mixture, what is termed 'green cake', was autoclaved for 5 hours at 180 °C, 11 atm. Then compressive strength and XRD patterns were measured.

Physical properties of mineral hydrate insulation

Characteristics of slurry

Compared to AAC, analysis of mineral hydrate slurry is more important because of the considerable amount of pores. The slurry contains a large quantity of water in order to have a lower thermal conductivity which causes the slurry to collapse and segregate. There are two different types of segregation.

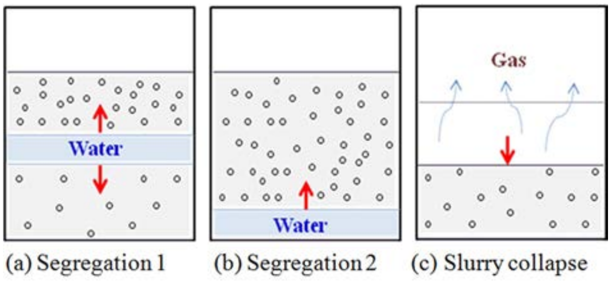


Fig. 1. Material segregation and slurry collapse.

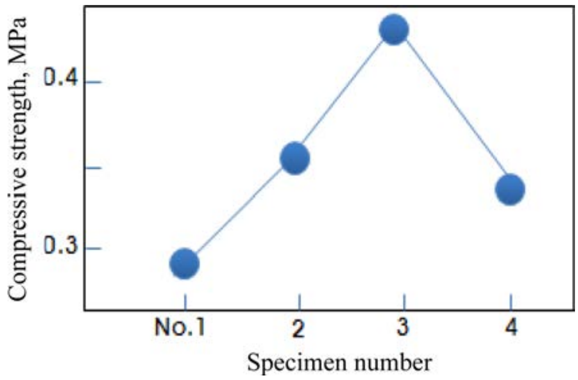


Fig. 2. Compressive strength by mixture design.

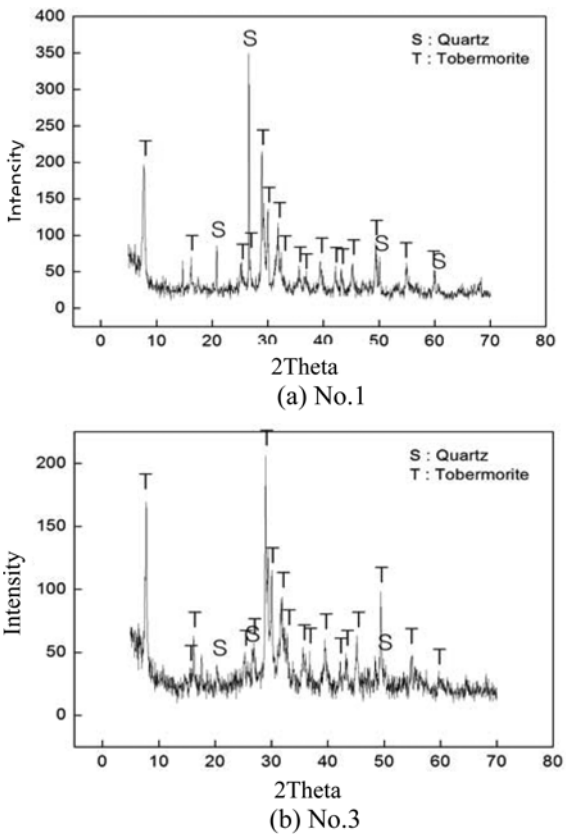


Fig. 3. XRD patterns of No. 1, No .3.

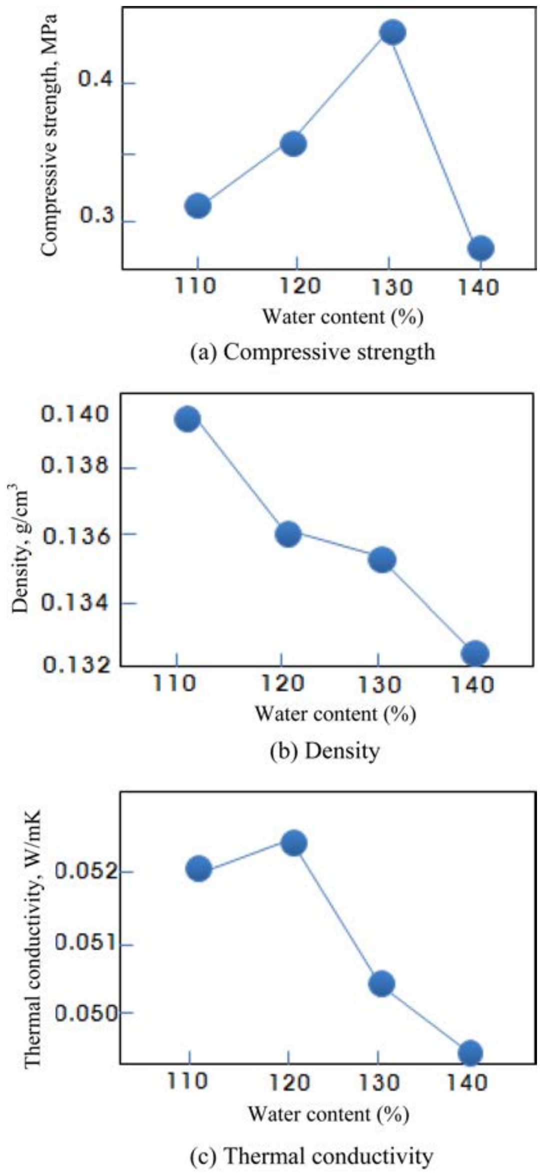


Fig. 4. Physical properties by water proportion.

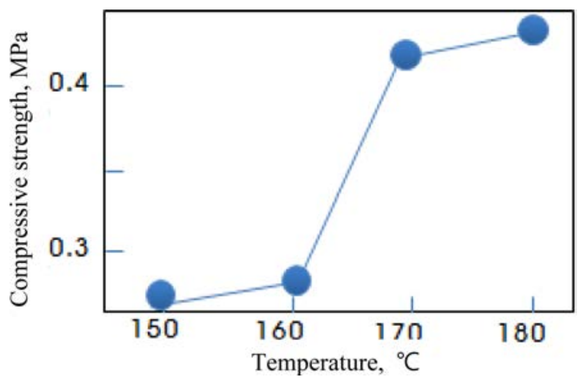
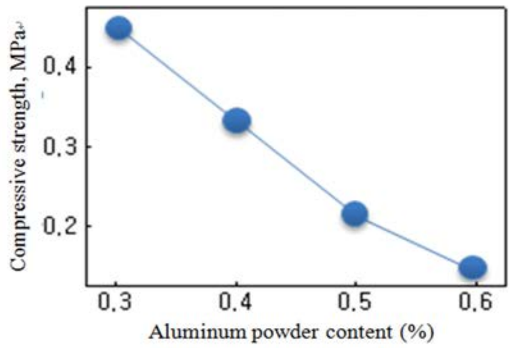


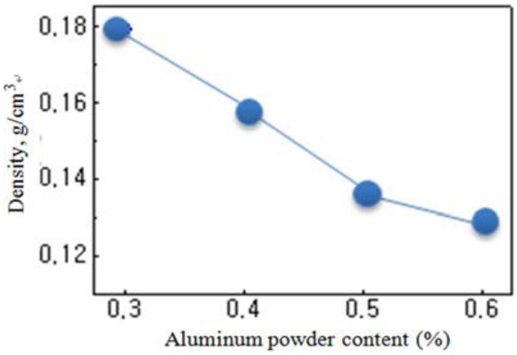
Fig. 5. Compressive strength according to autoclave temperature.

Segregation 1 is divided by water in the center of slurry and in segregation 2, water falls to the bottom of slurry mixture. In addition, Fig.1-(C) explains the collapse of slurry.

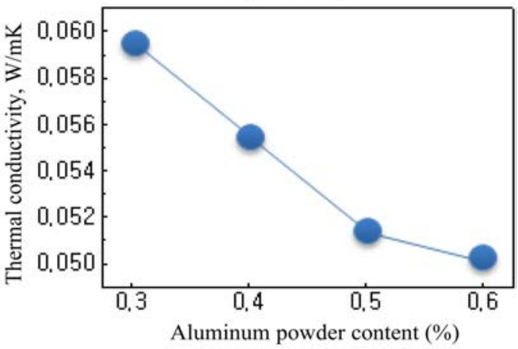
Segregation 1 is caused by a density difference of the materials. The top layer of slurry consists of relatively light-weight materials, such as anhydrite and quartzite.



(a) Compressive strength

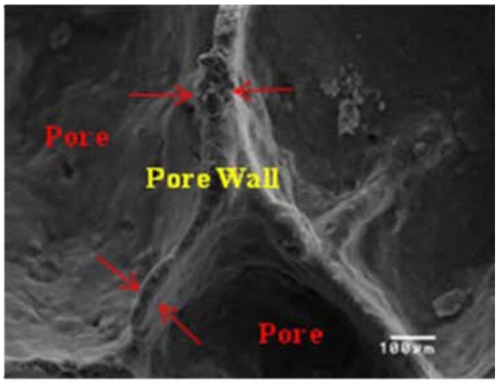


(b) Density

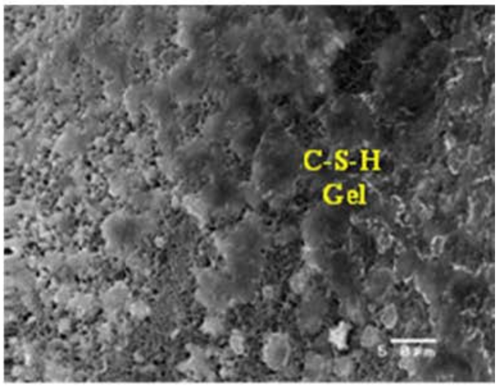


(c) Thermal conductivity

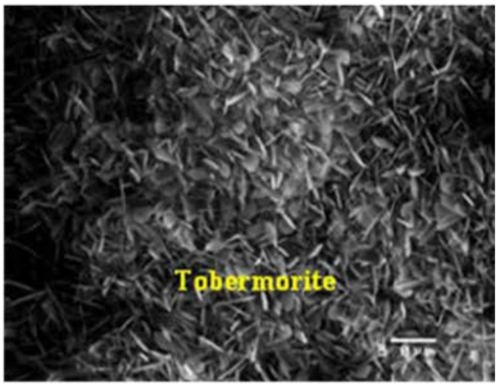
Fig. 6. Physical properties by aluminum powder proportion.



(a) Pore structure



(b) C-S-H gel



(c) Tobermorite

Fig. 7. Magnified images of mineral hydrate insulation.

Basically the segregation is due to the excess water in slurry. Segregation 2 is not only due to the excess water but also high viscosity. High viscosity interrupts slurry's mixing process, therefore water is located at the bottom and in contrast, slurry rises to upper part.

Slurry collapse happens due to low viscosity. Overabundance of foaming agent reduces viscosity of slurry. Accordingly, it contains hardly any gas and as a result of this, it collapses.

Foaming reaction in slurry tends to be faster as temperature rises [6]. Especially when the temperature is over 50 °C and foaming reaction is completed within 30 minutes, slurry collapse occurs. Viscosity of slurry is one of the main factors of the collapse and it is related to particle size of raw materials and amount of water. Through the experiments, it is found that optimum condition of slurry is 2,000 ~ 4000 cP (Centi-Poise) of viscosity. The ideal condition of slurry is 2,000 ~ 4,000 cP of viscosity with a temperature below 50 °C.

Compressive strength

As quartzite's content declines (No.1 → No.3), the compressive strength increases (Fig. 2). However, specimen No.4 containing 25% of quartzite shows low compressive strength. Fig. 3 shows XRD patterns. The main peak of No.1 was SiO_2 and No.3 was tobermorite.

Quantity of water

Based on mix design No.3, specimens were manufactured with different amounts of water. The content of mixing water was controlled from 110% to 140%. Characteristics of the specimens (thermal conductivity, density, compressive strength) were measured.

The compressive strength increased, as the water content increased by 130% (Fig. 3). However values of thermal conductivity and density decreased, but did not show large difference. 130% of water content showing the highest compressive strength was considered as the fittest water content.

Autoclave temperature

Fig. 5 shows difference of compressive strength as different autoclave temperatures. The more the temperature increased, the greater the strength development occurred [7]. The specimen autoclaved at 180 ^{o}C shown the highest strength value.

Properties as the amount of foaming agent

Properties as the amount of foaming agent (Y250N, Aluminum powder) are shown on Fig. 6. The contents of the agent were 0.3%, 0.4%, 0.5%, and 0.6%. As the content increased, values of all characteristics (compressive strength, thermal conductivity, density) decreased. On the contrary, pore quantity increased. Although the strength decreased, 0.5% of foaming agent was used to meet the required insulation performance. Fig.7 shows the fine structure of mineral hydrate insulation. The thickness of pore wall was 10 ~ 100 μm. C-S-H gel and tobermorite were observed.

Conclusions

In this study, physical characteristics of mineral hydrate insulation material were analyzed for its usefulness.

1) In order to fabricate mineral hydrate insulation, the foaming time and viscosity of slurry are the most important factors for compressive strength and thermal conductivity.

2) The optimum condition of slurry is 2,000 ~ 4000 cP of viscosity and a temperature below 50 ^{o}C. In this conditions, the mineral hydrate insulation contains 500~3000 μm of pore size and 10 ~ 100 μm of pore wall thickness.

3) The results show that all characteristics (compressive strength, thermal conductivity, and density) have similar tendencies depending on how much foaming agent is used. If the content of foaming agent increases, the values of the characteristics decrease.

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