Journal of Ceramic Processing Research. Vol. 15, No. 5, pp. 281~285 (2014)

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

Effect of the pre-heating conditions on the formation of lightweight aggregates

Yootaek Kim* and Changsub Jang

Department of the Materials Engineering, Kyonggi University, Suwon 443-760, Korea

This study was conducted to evaluate the feasibility of using bottom ash and dredged soil from power plants and electric arc furnace dust as primary materials for the production of artificial lightweight aggregates (ALAs). Preheating treatment was investigated as a means to prevent abnormal pore growth in ALAs, which occurs due to a vigorous bloating process. When the specimens were pre heated at 400 °C, absorbed water and interlayer water in the specimen were released before the sintering process, thus preventing cracks and breakage and thereby improving the quality of the ALA. However, when the specimens were preheated at 700 °C, more CO_2 and CO gases were generated owing to oxidation. As a result, abnormal water absorption drift was suppressed, and the water absorption rate was controlled to be within an acceptable range.

Key words: Artificial Lightweight Aggregates, Preheating, Reject Ash, Dredged Soil, Ferrous Materials.

Introduction

Artificial lightweight aggregates (ALAs) from industrial and post-consumer wastes not only provide an extra aggregate source, but also reduce environmental pollution. Fly ash (F/A) and bottom ash (B/A) are among the wastes that cause disposal problems as well as environmental degradation by causing air and water pollution on a large scale. Using coal ash still remains a major issue for it too causes air and water pollution. Reject ash (R/A) which is produced as a by-product during the refining process of fly ash is simply disposed and reclaimed. In recent times, many studies on recycling coal ash to make ALAs have been conducted. The manufacture ALA from coal ash is considered to be an appropriate way to utilize a large quantity of coal ash. In this paper ALA was manufactured from coal reject ashes produced by a thermoelectric power plant along with dredged soil from seaside construction areas and various ferrous materials.

Slag is the molten by-product or co-product of many metallurgical operations. Black coring is a specific phenomenon found in ALAs and is characterized by greyish black coloration of the interior of the ALAs. The primary cause of black coring has been recognized as the incomplete burning of carbonaceous material that can produce a core-like residue [1-4]. Two types of reactions are required to form ALAs from various materials by heat treatment. First, gases, which serve as bloating agents, must be released to create pores during heating. Second, a glassy surface formed by the sintering reaction is needed to encapsulate the gases released to produce ALAs [5-7]. Ferrous materials play an important role in the bloating reaction because they are known to release gases upon heating. However, ferrous materials have also exhibited the phenomenon of rapid bloating upon being heated in a narrow temperature range; such a phenomenon induces large pores and non-uniformity in ALAs. This study investigated the feasibility of preheating to prevent abnormal pore growth in ALA due to this vigorous bloating process.

Experimental Procedure

Materials

Bottom ash was collected from the Young-hung coal power plant in South Korea. It is found in the form of embedded clinkers that stick to the hot side walls of a coal-burning furnace during its operation; these clinkers require dredging and must be removed yearly. The electric arc furnace (EAF) dust used in this study was collected from the furnace at Kangwon Iron Works. Table 1 shows the elemental compositions, expressed in their oxide forms, of the raw materials. The mass ratio of reject ash, dredged soil (D/S), and EAF dust were a simple controlling parameter to optimize the components for production of ALA.

Methods

The mixing ratios of the specimens are shown in Table 2. A basic composition of 40 wt% bottom ash and 60 wt% dredged soil was used with 0-10 wt% added EAF dust. Raw materials were crushed to below 100 μm and dried. The formed specimens were directly inserted into the electric arc furnace for pre-heating at 400 and 700 °C and subsequent sintering at different

*Corresponding author:
Tel : +82-70-4024-9765
Fax: +82-31-249-9774
E-mail: ytkim@kgu.ac.kr

Table 1. The elemental compositions, expressed in oxide forms, of the raw materials.

	Bottom ash	Dredged soil	EAF dust
SiO_2	45.5	70.0	4.1
Al_2O_3	18.6	14.2	1.2
Fe_2O_3	8.1	3.8	49.0
CaO	2.2	0.8	2.0
MgO	0.8	0.2	2.3
Na_2O	0.2	2.5	0.2
K_2O	0.5	2.7	2.2
TiO_2	1.3	0.8	0
P_2O	0.2	0.1	0.10
MnO	0.1	0	2.3
ZnO	0	0	25.6
Cr_2O_3	0	0	0.1
C	18.1	0	0
Ig. loss	0	4.0	10.8

Table 2. The mixing ratios of the specimens.

Bottom ash (wt%)	Dredged soil (wt%)	EAF dust (wt%)
40	60	0
40	55	5
40	50	10

temperatures of 1050-1200 °C in increments of 50 °C for 10 min total. After sintering in the electric furnace, the ALA specimens were taken out of the furnace and directly exposed to air at room temperature to cool. The bulk density and water absorption were measured to characterize the quality of the sintered specimens. Morphological investigations of the ALAs at different sintering temperatures were carried out by optical microscope observations.

Results and Discussion

Fig. 1 shows the bulk density and water absorption of the prepared ALA specimens from EAF substitution in coal mixtures of 40 wt% bottom ash and 60 wt% dredged soil at various sintering temperatures. As seen in Fig. 1, the bulk density tends to decrease with an increase in sintering temperature. This trend is simply explained by the fact that unburned carbonaceous materials and ferrous materials formed black cores and bloated more easily at elevated temperatures.. Most studies agree that reactions of ferrous materials are responsible for bloating [8].

Fig. 2 and Fig. 3 show the bulk density and water absorption of the ALA specimens prepared with EAF substitution in coal mixtures of 40 wt% bottom ash and 60 wt% dredged soil. Specimens preheated at 400 °C showed less change in bulk density unlike the specimens not subjected to preheating, whose bulk density decreased greatly with increasing sintering temperatures. Specimens preheated at 700 °C showed that bulk density increased with increasing sintering temperature and decreased with EAF addition.

Water absorption showed little change in the case of less than 5% EAF added pre-heated specimens at 400 °C compared to non-preheated specimens. Specimens preheated at 400 °C showed a gradual decrease in water absorption with increasing sintering temperature. However, for the specimens preheated at 700 °C, water absorption showed a sharp drop at 1100 °C regardless of the EAF content. These specimens were more densified and had a lower porosity.

Fig. 4, Fig. 5, and Fig. 6 are optical images of the ALA specimens made from bottom ash, dredged soil, and EAF dust and sintered at various temperatures without preheating, with preheating at 400 °C, and with preheating at 700 °C, respectively. As seen Figs. 4-6, large pores were observed in the sintered ALA specimens prepared without preheating and with pre-heating at 400 °C and sintered at below 1100 °C; however, large pores and black-cores were not observed in specimens preheated at 700 °C. This would be because when specimens were pre-heated at 700 °C, more CO_2 and/or CO were generated by oxidation, and

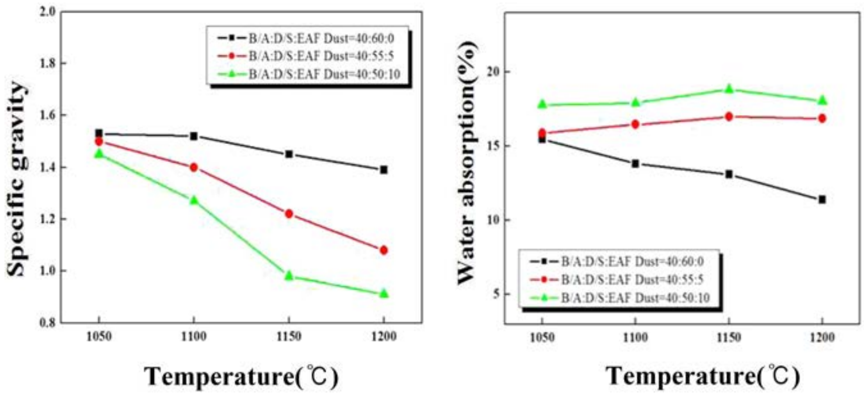

Fig. 1. The bulk density and water absorption of the ALA specimens made of B/A, D/S, and EAF dust at various sintering temperatures. (a) Bulk density and (b) Water absorption.

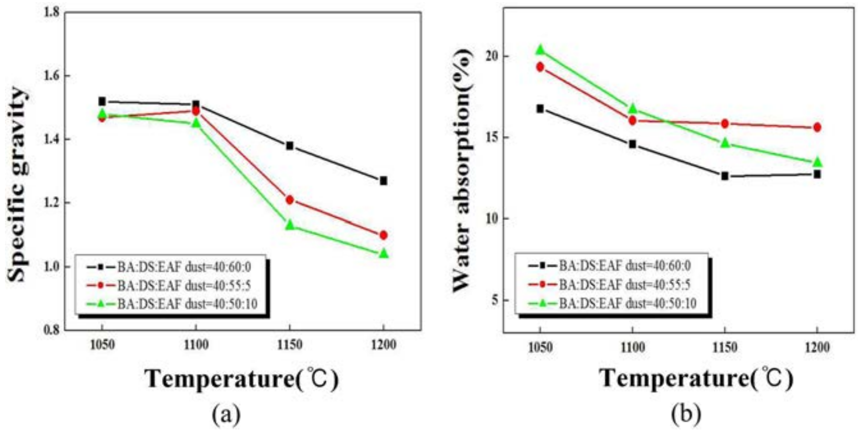

Fig. 2. The bulk density and water absorption of the ALA specimens made of B/A, D/S, and EAF dust at various sintering temperatures after pre-heating at 400 ºC. (a) Bulk density and (b) Water absorption.

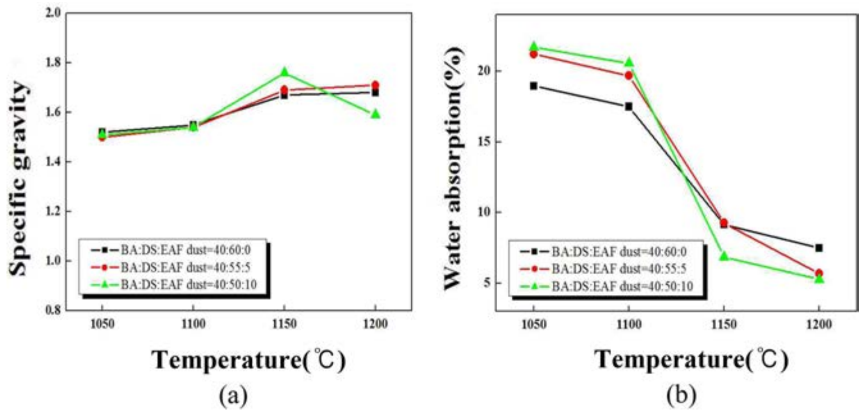

Fig. 3. The bulk density and water absorption of the ALA specimens made of B/A, D/S, and EAF dust at various sintering temperatures after 700 ºC pre-heating. (a) Bulk density and (b) Water absorption.

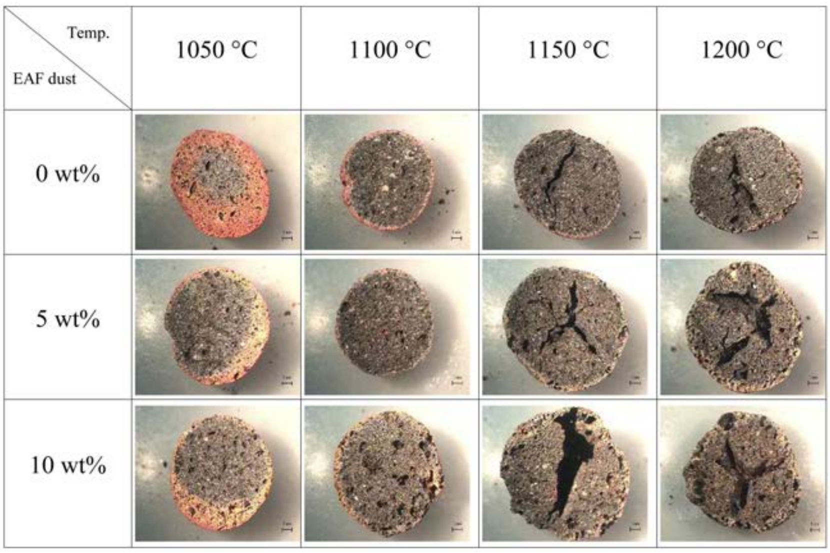

Fig. 4. The optical images of the ALA specimens made of B/A, D/S, and EAF dust at various sintering temperatures without preheating.

these gases were released before the formation of the glassy surface upon sintering, which would have been otherwise able to encapsulate these gases before being released [9].

The bloating phenomenon and black core formation were found in the specimens without pre-heating and with 400 °C preheating and sintered above 1150 ºC. Particularly, specimens preheated at 400 ºC had a uniform scattered pore distribution compared to directly sintered specimens. However, specimens preheated at

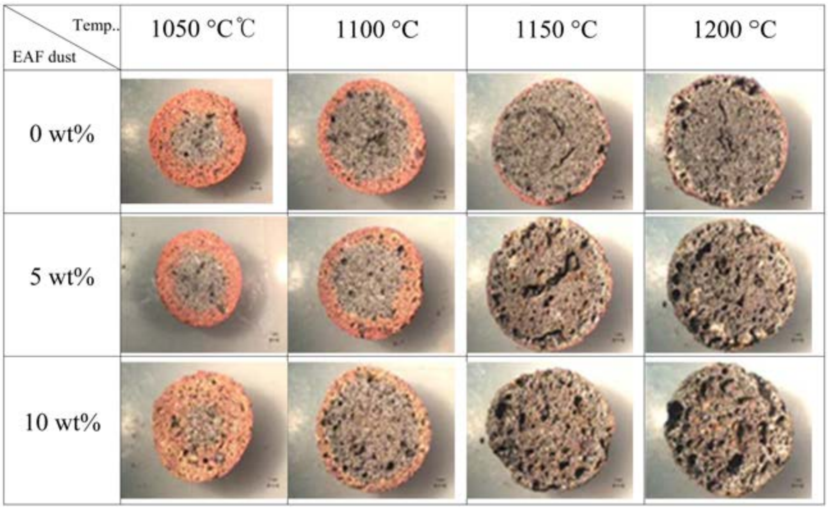

Fig. 5. The optical images of the ALA specimens made of B/A, D/S, and EAF dust at various sintering temperatures after preheating at 400 °C.

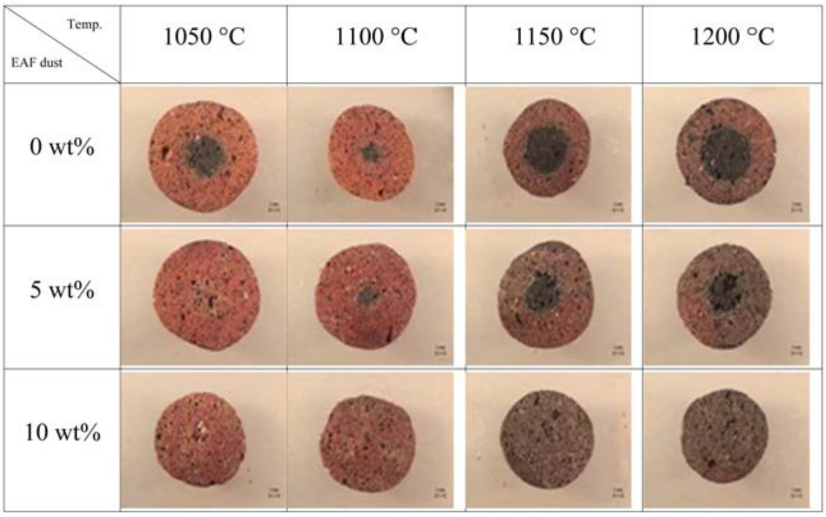

Fig. 6. The optical images of the ALA specimens made of B/A, D/S and EAF dust at various sintering temperatures after pre-heating at 700 °C.

700 °C did not exhibit bloating and a glass phase, because the carbonaceous gasses were released during preheating before the glassy surface could be formed by the sintering reaction.

Preheating at 400 °C caused the emission of absorbed water and structural water from the raw material, which occurred around 350 °C and prevented the specimens from breaking at high temperature. However, preheating at 700 °C caused the carbonaceous gasses to be released during preheating before the glassy surface could be formed by the sintering reaction.

Conclusions

Preheating is appropriate to prevent abnormal pore growth in artificial lightweight aggregate due to vigorous a bloating process. When specimens were preheated at 400 °C, absorbed water and interlayer water in the specimen were released before the sintering process, cracks and breakage were prevented, and the quality of artificial lightweight aggregates improved. When specimens were preheated at 700 °C, more CO_2 and/or CO were generated by oxidation, which were then released to the atmosphere. As a result, abnormal water absorption drift was suppressed, and the water absorption rate was controlled to within an acceptable range for application to various fields. Determining the most suitable preheating condition would be one of the aims for our future works.

Acknowledgments

This research was supported by the National Research Foundation of Korea (NRF) grant funded by the Ministry of Education, Science and Technology Korea government (MEST) (No. NRF-2013R1A2A2A 04014978).

References

1. 2000 the Whole Country Wasters Product and Treatment

Present, 11-1480000000533-10, Ministry of Environment (2001).
2. M.H. Ahnn, N.W. Lim, and K.A. Lee, J. Kor. Solid Wastes Eng. Soc. 14 (1997) 221-225.
3. J.-S. Hwang, C.H. Oh, and C.T. Lee, J. Kor. Solid Wastes Eng. Soc. 13 (1996) 96-107.
4. N.W. Lim and Y.G. Kim, J. Kor. Solid Wastes Eng. Soc. 13 (1996) 108-118.
5. C.K. Park, Y.H. Shin, and K.H. Cho, J. Kor. Solid Wastes Eng. Soc. 14 (1997) 901-909.
6. S.K. Lee, D. J. Lee, and S.M. Lee, J. Kor. Solid Wastes Eng. Soc. 16 (1999) 451-458.
7. J. Aota, "EAF Dust Treatment," U.S Patent, 567146 (1997).
8. C.M. Riely, J. Amer. Ceram. Soc. 34 (1951) 121-128.
9. Y. Qi, Q. Yue, S. Han, M. Yue, B. Gao, H. Yu, T. Shao, J. Hazardous Materials 176 (2010) 76-84.