Journal of Ceramic Processing Research. Vol. 14, No. 2, pp. 217~219 (2013)

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

Bloating of artificial lightweight aggregate using magnetically separated reject ash

Yooteak Kim* and Junyoung Park
Department of Materials Engineering, Kyonggi University, Suwon 443-760, Republic Korea.

Fly ash among many kinds of ash is currently being recycled effectively; on the other hand most of the reject ash (RA) having 5% or more unburned carbon content is being simply reclaimed in the ash pond. In order to recycle RA effectively, various kinds of aggregates were manufactured and trials for making porous aggregate by bloating have been made by using RA and dredged soil (DS). As it is, of course, more economical way to use raw material itself as bloating agent comparing to adding some bloating agents to ALA for making it light, the reject ash was separated by magnet by two parts for the purpose of using it as natural bloating agent; one is magnetic reject ash (MRA) having more ferrous components and the other is non-magnetic reject ash (NMRA) having more unburned carbon. The magnetically separated ash was mixed with dredged soil for making ALA. As a result, lightweight aggregate having less than 1.0 specific gravity could be obtained by using MRA which contains more ferrous components than as received RA and NMRA. MRA acts like an effective bloating agent itself for making ALA lighter.

Key words: Artificial lightweight aggregate, Firing, Interfaces, Porosity, Functional application.

Introduction

The coal power plants produce fly ash and bottom ash as by products which are categorized by general wastes in Korea. Reject ash (RA) is separated by cyclone type separator to distinguish it from the recyclable fly ash for cement subsidiary material. Because RA usually contains 5% or more unburned carbon contents, it is simply reclaimed to the ash pond near to the power plant. Generally speaking, refined fly ash having less than 5% of carbon could be used as concrete admixture without any modification and be applied to various kinds of secondary cement products through the active researches. Hence, most of RA is being reclaimed, causing many problems such as soil pollution and contamination of landfill area. Dredged soil (DS) is also a kind of waste obtained during the construction of coal power plants and simply being reclaimed. In fact, million tons of DS is reclaimed near the power plant in Korea. However, it can be used as raw material for artificial lightweight aggregate (ALA), for it has so good plasticity that high forming strength could be attained with.

One of the important results in this study is that effective bloating of ALA could be realized using accumulated ferrous materials and unburned carbon attained by magnetic separation of RA itself. Magnetic reject ash (MRA) which sticks to the magnet has relatively more ferrous components than those of as received RA; hence, non-magnetic reject ash (NMRA) which does not stick to the magnet contains relatively much less unburned carbon than those of as receive one. Ferrous materials (ferric oxides) in MRA can emit oxygen gas through a reduction process of iron compounds; therefore, it is thought that this is the one of the bloating mechanisms to make ALA light without adding additional bloating agent at all.

The purpose of this study is to recycle RA effectively by making ALA without adding additional bloating agent. RA was separated as MRA and NMRA by using a 2000 Gauss magnet. Dredged soil was also used as raw material for ALA to enhance the dry strength of green body, for RA itself has no good plasticity.

Experimental

Table 1 shows chemical composition of raw material. RA which is rejected after refining process of fly ash has 5% or more unburned carbon. Magnetic separation was performed with a 2000 Gauss magnet in the solution of distilled water and RA of which ratio was 10 to 3. DS generally enhances the green body strength of aggregate for its excellent plasticity. For forming aggregate, all the raw materials were grinded by using a fin-mill, and particle size of them was reduced by under the 100 μm.

One of the conditions for bloating aggregate is that oxygen gas should be emitted under the condition of reducing atmosphere by ferrous materials or/and carbon dioxide gas should be emitted by oxidizing atmosphere by unburned carbon in RA. In order to bloat aggregate without additional bloating agent, it is necessary to separate MRA having more ferrous materials from

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

Table 1. Chemical composition of raw material.

	RA	MRA	NMRA	DS
Ig. loss	1.88	0.74	0.85	6.07
SiO_2	52.66	42.6	53.16	67.3
Al_2O_3	22.42	16.98	22.66	14.66
Fe_2O_3	4.88	24.62	3.27	4.31
CaO	4.71	5.29	4.72	0.87
MgO	1.23	2.02	1.18	0.95
Na_2O	0.8	0.53	0.81	2.03
K_2O	1.15	0.84	1.18	2.2
TiO_2	1.14	0.89	1.17	0.8
P_2O_5	0.61	0.59	0.6	0.05
MnO	0	0.17	0	0.04
C	9.17	4.67	10.35	0.67
Total	99.94	99.94	99.93	99.93

Table 2. The mixing ratio of specimens by weight percent (wt %).

	RA	MRA	NMRA	DS
RD55	50			50
MRD55		50		50
NMRD55			50	50

NMRA having more unburned carbon by using a 2000 Gauss magnet. After wet separation process, both MRA and NMRA were dried in a drying oven for 48 hours. Then, RA, MRA and NMRA were mixed with DS in various compositions in a ball mill for 24 hours. The mixing ratio is shown in Table 2. Aggregate specimens were formed in spherical shape with 8 ~ 10 mm in diameter using distilled water and dried in a drying oven for 24 hours. Dried aggregate was directly inserted into an electric furnace maintained at 1050 ~ 1200 °C (with 50 °C interval) for 10 minutes. After firing, they were cooled down to room temperature in air. Specific gravity and absorption rate of aggregate were measured in Archimedes' method. The surface and cross-sectional morphology of the specimens were observed through optical microscope (Camscope^{TM}).

Results and Discussion

Fig. 1 and Fig. 2 show the specific gravity and the water absorption ratio of aggregate manufactured with various mixing at the temperature between 1050 °C and 1200 °C, respectively. As shown in Fig. 1, the specific gravity of RD55 and NMRD55 generally increased from 1050 °C up to 1150 °C and then decreased from 1150 °C to 1200 °C. However, specific gravity of MRD55 exceptionally started to decrease from 1050 °C. The various ferrous compounds were reduced to FeO and

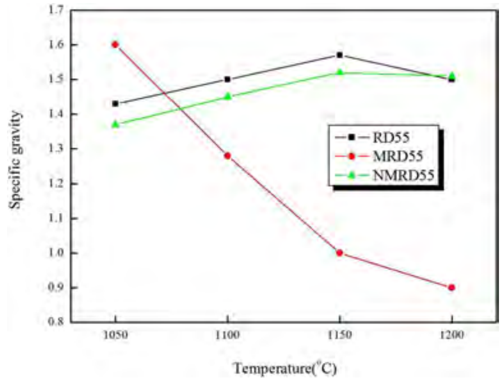

Fig. 1. The specific gravity of aggregate manufactured with various mixing ratio at the temperature between 1050 °C and 1200 °C.

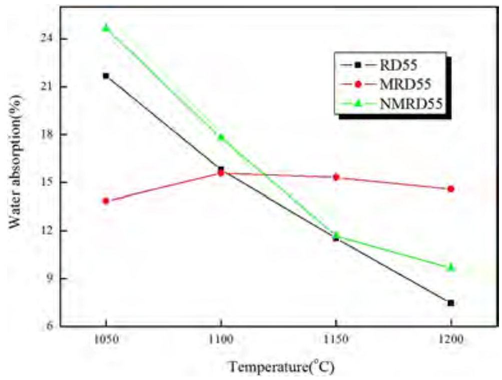

Fig. 2. The absorption rate of aggregate manufactured with various mixing ratio at the temperature between 1050 °C and 1200 °C.

emitted oxygen gas. Because melting point of FeO is 1100 °C, the glassy phase of FeO was formed from 1100 °C [4-6]. Han and Riley [7] suggested that when manufacturing aggregates, if the temperature of gas emitting corresponds with the forming temperature of glassy phase on the surface of the aggregate under a condition where there are sufficient bloating substances, gas generated during the sintering process cannot escape to the outside; therefore, expands, forming lots of air holes inside. Fig. 2 shows the water absorption rate of aggregate according to temperature variation. A decrease in absorption rate of RD55 and NMRD55 is in well accordance with an increase in density in Fig. 1 up to 1150 °C, and thereafter a further decrease in absorption rate can be explained by the formation of glassy phases on the surface above 1150 °C. On the whole, it shows that the higher the temperature is, the lower the water absorption rate is. That's because density of aggregate increases through general sintering process, so the extent of pores absorbing water becomes smaller. However, the absorption rate of MRD55 decreased with a decrease in the specific gravity because glassy phases blocked open pores of aggregate.

Fig. 3 and Fig. 4 show surface and cross-sectional images of the aggregate manufactured with various mixing ratio by the Camscope. As shown in Fig. 3,

Fig. 3. Surface morphology of aggregate made of RD55, MRD55 and NMRD55.

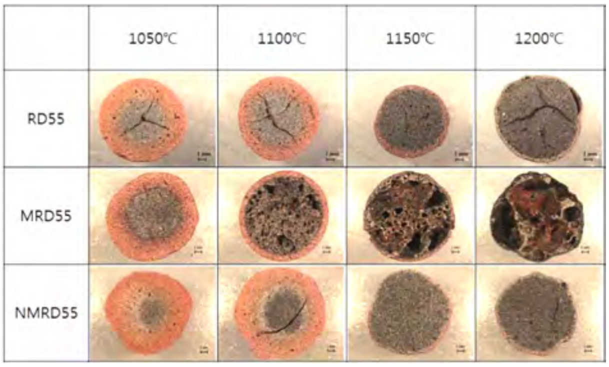

Fig. 4. Cross-sectional morphology after cutting the aggregate made of RD55, MRD55 and NMRD55.

more cracks on the surface of MRD55 were observed with an increase both in the temperature and in the contents of dredged soil. The glassy phases in the aggregate were apparently bloated from the inside of the aggregate. As shown in Fig. 4, the pore size and glassy phases also increased with an increase both in the temperature and in the contents of magnetic separated reject ash. However, it is apparent as shown in Fig. 3 that a few small pores in the specimen of RD55 and NMRD55 at 1200 °C were observed just underneath the surface which was covered by a thin layer of glassy phase, blocking the open pores and capturing the gas produced inside of aggregate. These pores are attributed to a decrease in the specific gravity of the RD55 and NMRD55 above 1150 °C.

Conclusions

It is apparent that the ferrous components in RA play a very important role for bloating of aggregate. Because DS having excellent plasticity blocked the entrance of oxygen effectively during the sintering, the various ferrous compounds in MRA concentrated by the magnetic separation were reduced and protective glassy layers of FeO were created inside of aggregate. At the same time, some of the emitted oxygen gas by reduction of ferrous compounds reacted with unburned carbon in the aggregate, emitting carbon monoxide or carbon dioxide gas, which accelerating bloating the aggregate and making large pores in it. However, too much glassy phase would not help for bloating but cause abnormal sintering, resulting in relatively high specific gravity. Through the comparison of RD55, MRD55 and NMRD55, it is clearly can be seen that the ferrous components in MRA concentrated by the magnetic separation are essential for making lightweight aggregate with the specific gravity of 1.3 or less. It was speculated that manufacturing condition of MRD 55 at 1100 °C was the best and suitable for making the aggregate of which the specific gravity is about 1.3 for the application of non-structural purpose.

Acknowledgments

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. NRF-2013R1A2A2A04014978).

References

1. R. de'Gennaro, P. Cappelletti, G. Cerri, M. de'Gennaro, M. Dondi and A. Langella, Appl. Clay Sci. 25 (2004) 71-81.
2. Y.L. Wei, J.C. Yang, Y.Y. Lin, S.Y. Chyang and H.P. Wang, Mar. Pollut. Bull. 57 (2008) 867-872.
3. Y.L. Wei and Y.Y. Lin, Hazardous Materials 171 (2009) 111-115.
4. C.C. Tsai, K.S. Wang, I.J. Chiou, J. Hazard. Mater. B134 (2006) 87-93.
5. I.J. Chiou, K.S. Wang, C.H. Chen and Y.T. Lin, 26 (2006) 1453-1461.
6. A.R. Boccaccini, P. Veronesi and C. Leonelli, J. Eur. Ceram. Soc. 21 (2001) 1073-1080.
7. C. M. Riley, J. Am. Ceram. Soc. 34 [4] (1951) 121-128.