Manufacturing lightweight aggregate uses high content of sewage sludge for non-structural concrete

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ABSTRACT

Sewage sludge and clay used as raw materials in the study. Green aggregates contain different contents by dried weight of the sewage sludge, up to 80 percent is manufactured and burned in different burning conditions of soak temperature, soak time and rate of temperature increase. Influence of burning condition and mixing ratio on specific gravity of burned aggregate are discussed. The appropriate burning condition to all aggregates is evaluated. Aggregates result from the thermal treatment get specific gravity under 0.8, water absorption fewer than 7.5 percent, and aggregate crushing value from 28 to 53. As the result, aggregates can be available as the lightweight aggregate for non-structural concrete.

1. Introduction

The big problem happens to the management in develop city is big amount of sewage sludge, which increases proportionally to develop level and stylization of the city. The present concerned solution to solve this problem is direct using of sewage sludge for manufacturing lightweight aggregate, which uses the amount of sewage sludge under 50% by dried weight for mixtures [1]. For continuously exploiting benefits of this solution, the study on using higher content of sewage sludge for making lightweight aggregate is necessary. For lightweight aggregates using for non-structural concrete, the most important target is specific gravity, which bring to the concrete desired weight, sound and thermal insulation. The lower required specific gravity of aggregate, the more difficult manufacture.

To make aggregate obtains low specific gravity, it is necessary to make more closed bubbles in the mass. Distribution, size and amount of these bubbles have an important role in the quality of aggregate of low specific gravity, low water absorption and high strength. Bubbles attend in the mass is an affect of the gases trapped inside the liquidized mass, called by glass. The viscosity and surface tension of this glass and the molar amount of gas influence on bubble growth as well [4]. In other meaning, the burning regime and chemical composition of the mixture affect to either an open or closed cell structure inside the mass [6]. Since the amount of physically dissolved gases in the glass is low [2], the redox potential of the glass, meaning the chemical dissolved oxygen, which can be released by a reduction reaction, plays an important role in making molar amount of gas. Ferric iron oxide significatively reduces gas forming temperature, which is CO, in the glasses at over 1000°C. The reason is presumably reduction reaction of ferric to ferrous iron and of ferrous iron to elementary iron. [3]. Excess of residual carbonaceous matter causes a reduction of the iron oxides at too low a temperature. Thus, gases can freely escape before a high viscosity melt is formed [5].

2. Experimental

Sewage sludge get from a sewage sludge treatment plan in Korea is dried and tested physical, mineral property. The result of XR-Diffraction test and thermal analysis of the sewage sludge is shown in the Fig 1 and Fig 2 respectively. Clay is dried, crushed and then passed through the sieve of N° 30. The chemical composition of the ignited sewage sludge and ignited clay is analyzed by XR-Florence machine and shown in Table 1.

Mixtures of different contents by dried weight of 60, 65, 70, 75 and 80 percent of the sewage sludge and 40, 35, 30, 25, 30 percent of the clay respectively are manufactured. Each mixture is mixed with appropriate amount of water and then poured into a circular roller compression mixer to produce a uniform plastic. It is then extruded and cut at a relative diameter and size of 5 mm by pelletizer machine, and a rolling drum is used to form the pellet into a perfect sphere. After pelletizing, mixtures are called green aggregates. There are 5 green aggregates, belong among 5 mixtures, marked G60, G65, G70, G75, and G80 in this study.

Each green aggregate is put into the sintering machine at starting temperature of 950°C. It then is burned in different burning conditions, which include rates of temperature increase of 10°C/min, 20°C/min, 40°C/min, soak temperatures at 1150°C, 1200°C, 1230°C, 1250°C, 1270°C and 5 minutes of maintenance at the soak temperatures (soak time of 5 minutes). Continuously, green aggregates are tested in burning conditions include rates of temperature increase of 20°C/min, soak temperatures at 1230°C, 1250°C, 1270°C and soak time of 15 minutes. After stage of maintenance, they are naturally cooled to 950°C in the atmosphere of sintering machine and then are taken out of the machine to cool in the atmosphere of room. Burned aggregates are then evaluated on specific gravity to tend to the appropriate choices of burning conditions to mixing proportions and getting appropriate aggregates. Continuously, water absorption and aggregate crushing value are examined on appropriate aggregates as a concern with the quality of the optimum products.

All tests on burned aggregates of specific gravity, water absorption and aggregate crushing value are performed accordance with those specified in Korean Standard (KS).

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3. Results and Discussions

3.1. Raw materials:

3.1.1. Sewage sludge: As shown in Table 1 and Fig 2, sewage sludge contains a big amount of organic mater, which not only can be burned out to form the gas from 200°C to 700°C, but also have an important role in reduction of iron oxide forms to form the gas. That shows the potential of sewage sludge not only to be a foaming agent in this interval of temperature but also to be a caloric agent. Fig 1 shows that minerals exist in the sewage sludge are similar to those in common clay. Ignited sewage sludge contains higher content of network modifiers in comparison with clay. They both show together that using sludge in mixture can reduces softening point of the green aggregate.

3.1.2. Clay: According to the chemical composition of the clay in the Table 1, clay used in the experiment is common type of hill clay. The clay has good fine size, plastic characteristic and has not impurities of grit, gravel. The clay shows good characteristics as a plastic material.

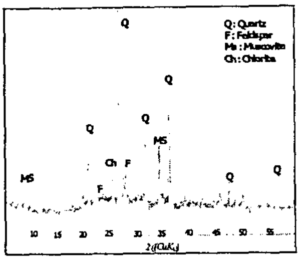


Fig. 1 XRD analysis of sewage sludge

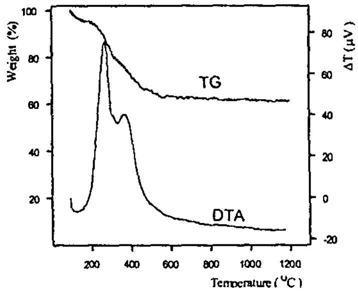


Fig 2. Thermal analysis of sewage sludge.
Rate of increase in temperature is 10°C/min

Table 1: Chemical, physical properties of sewage sludge and clay

Raw materials	Water content (%)	Organic contents (%)	Inorganic Contents (%)	Higher calorific value (cal/g)	Chemical composition of the ignited materials (%)									
					SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5
Sewage sludge	83.08	10.17	6.75	3,314	52.00	20.94	0.94	8.98	2.21	4.06	1.30	3.11	0.12	5.31
Clay	-	7.13	92.87	-	66.73	19.28	0.98	6.63	1.63	0.43	0.95	3.13	0.13	0.11

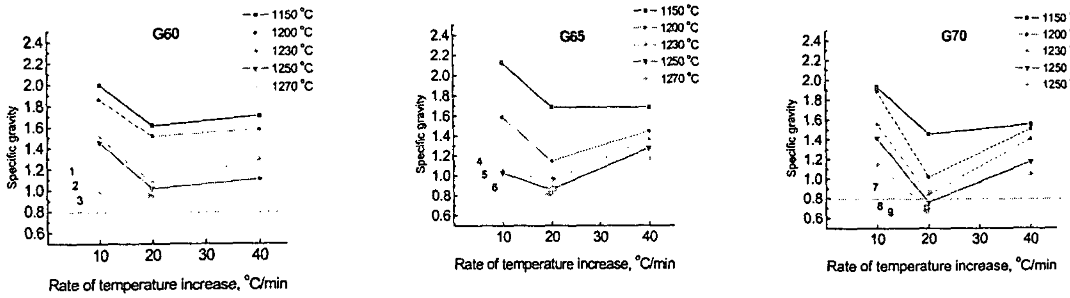
3.2. Green aggregates:

From G60 to G80, content of organic matter contained in green aggregates gradually increases. Content of network former contained in burned aggregates gradually decrease, whereas content of neutral oxide and network modifiers increase from G60 to G80.

3.3. Burning condition:

3.3.1. Influence of the rate of temperature increase on specific gravity:

Fig 4 shows clearly that, the rate of temperature increase at 20°C/min seems to be a minimum point of specific gravity in the relationship to the rate of temperature increase. At this rate, for almost the burned aggregates at almost the soak temperatures, specific gravity is considerably reduced more than at other rates. However, low rate of burning at 10°C/min indicates more achievement of reducing specific gravity on burned aggregates marked G80 at soak temperatures over 1230°C. The fast rate of burning at 40°C/min brings the highest specific gravity to all burned aggregates in comparison with other rates. Thus, the rate of temperature increase at 20°C/min should be the most expected rate of gradually reducing specific gravity for all these aggregates. The rate of temperature at 10°C/min is appropriate to burning green aggregate remarked G80 at soak temperature over 1230°C.



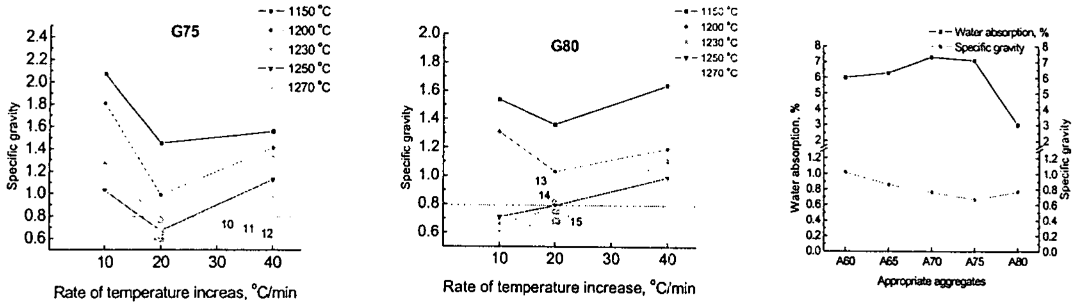
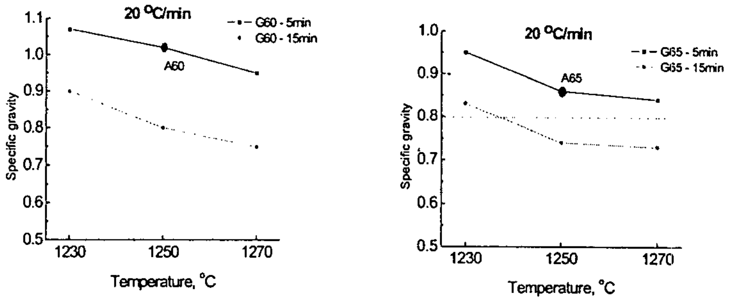


Fig 4. Series of burned aggregates which burned in 5 minutes at soak temper



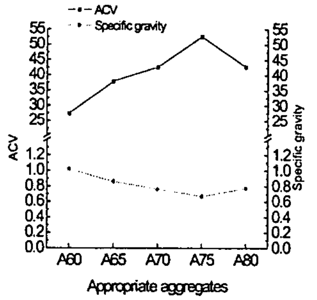


Fig 6. Quality of burned appropriate aggregates

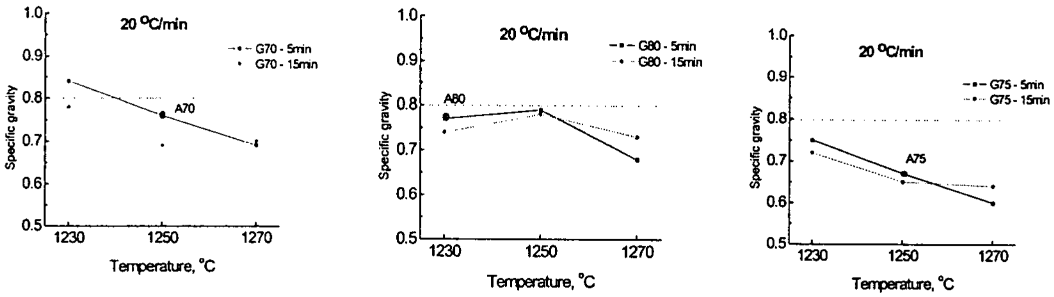


Fig 5. Series of burned aggregates which burned in 15 minutes at soak temperature

3.3.2. Influence of soak temperatures on specific gravity:

According to the Fig 4, it is clear to see the influence of soak temperature on specific gravity that the higher temperature, the lower specific gravity. It happens to all most the burned aggregates and at all most rates of temperature increase. However, its efficiency depends upon rates of temperature increase and green aggregates. The soak temperature higher than 1230°C is efficient to intensively bloat aggregates according to the requirement of specific gravity under 0.8.

3.3.3. Influence of types of green aggregate on specific gravity:

As shown in the Fig 4, each green aggregate shows an appropriate range of soak temperatures and rate of temperature increase to significantly decrease of specific gravity. It is clear to see that all burned aggregates is intensively reduced specific gravity in the range of soak temperature higher than 1230°C at rate of temperature increase of 20°C/min.

Although green aggregate marked by G60 is burned in all different burning conditions of the experiment, but it does not reach to the required specific gravity under 0.8. Green aggregate marked by G65 reveals better character in comparison with green aggregate marked by G60 through much more decrease of its specific gravity in range of soak temperature higher than 1230°C and starting this phenomenon at the lower temperature. The same result is found out for remaining green aggregates that, G70 is better than G65, G75 is better than G70 and G80 is better than G75.

3.3.4. Influence of soak time on specific gravity:

Fig 5 indicates that soak time of 5 minutes significantly influences to specific gravity of all aggregates burned in the rate of temperature increase at 20°C/min and three soak temperatures of 1230°C, 1250°C and 1270°C. Although positive or negative effect of long soak time depends on different green aggregates and ranges of soak temperature, but for all mixtures, burned aggregate obtains specific gravity under 0.8 can be achieved at soak time of 15 minutes.

The long soak time intensively reduces specific gravity of burned aggregates remarked G60 and G65 to value lower than 0.8 which could not achieve by the best burning conditions of soak temperature and the rate of temperature increase. This reduction occurs at all soak temperatures. The long soak time and high soak temperature may further reduce specific gravity of these aggregates.

The reduction of specific gravity of burned aggregates G70, G75, G80 is gradually in little along with increase of soak temperature. For each green aggregate, long soak time starts increasing specific gravity at any soak temperatures. They may be some thing lower than 1270°C, higher than 1250°C and lower than 1250°C for burned aggregate marked G70, G75, G80 respectively.

3.4. Quality of burned appropriate aggregates:

3.4.1. Specific gravity:

Fig 6 shows values of specific gravity of appropriate aggregates. Although they are not the lowest achieved values in this experiment, but they show real possibility to manufacture the aggregates obtain required specific gravity under 0.8 .

3.4.2. Water absorption:

As shown in the Fig 6, all burned aggregates have value of water absorption lower 7.5%. It is seen that the lower specific gravity, the higher water absorption in comparison with different burned aggregates. Burned aggregate remarked A80 shows the lowest value of water absorption (3.01%) results from much more closed bubbles exist inside the mass.

3.4.3. Crushing value:

As shown in the Fig. 6, all burned aggregates have aggregate crushing value in the range 28 to 53. In comparison with different burned aggregates, it is seen that the lower specific gravity, the higher ACV.

4. Conclusion

1/. Lightweight aggregate using for non-structural concrete is possibly manufactured by high content from 60 to 80 percent of the sewage sludge. The burned aggregates have specific gravity under 0.8, water absorption under 7.5% and aggregate crushing value from 28 to 53.

2/. Value of aggregate crushing value is inversely proportional to value of specific gravity.

3/. Value of water absorption is directly proportional to value of specific gravity.

4/. The appropriate burning conditions to manufacture lightweight aggregate range as follow:

- Soak temperature from 1230°C to 1250°C
- Rate of temperature increase from 10°C/min to 20°C/min
- Soak time from 5 to 15 minutes

5/. The higher soak temperature of burning condition, the lower specific gravity of burned aggregate.

6/. A long soak time reduces specific gravity of burned aggregate. However, a long soak time can increase specific gravity at any soak temperature.

7/. A higher content of sewage sludge allows reducing soak temperature of burning condition and specific gravity of burned aggregate.

8/. The rate of temperature increase at 20°C/min should be the most expected rate to reduce specific gravity.

9/. Experience of "Influence of fineness of mixture powder to quality of burned aggregate" should be carried out in future study.

References

1. G. J. Mun, Y. S. Soh, Development of Super Lightweight Aggregate for Non-structural concrete using sewage sludge, Proceedings of the Korea Concrete Institute, Vol 14, No 1, 2002.5, pp. 619-624
2. Scholze H., Glas Natur, Struktur an Eigenschaften, 1988, Springer-Verlag, Berlin Heidelberg New Work.
3. A. Steiner and R. G. C. Beerkens, Foam Glass from fly ash melts, Proceedings of the ICG annual meeting, July 1-6, 2001, Edinburgh, Scotland.
4. S. Köse, G. Bayer, Schaumbildung im System Altglas-SiC und die Eigenschaften derartiger Schaumgläser, Glastech. Ber. 55 7) (1982) 151–160.
5. J. Decleerl and W. Viaene, Rupelian Boom clay as raw material for expanded clay manufacturing, Applied Clay Science, Volume 8, Issues 2-3, August 1993, Pages 111-128.
6. V. Ducman, A. Mladenovic, J.S. Suput, Lightweight aggregate based on waste glass and its alkali-silica reactivity, Cement and Concrete Research 32 (2002), p.223-226.