

RESEARCH ON SINTERED FLY ASH AGGREGATE OF HIGH STRENGTH AND LOW ABSORPTION OF WATER

Gao Li-xiong, Yao Yan, and Wang Ling

China Building Materials Academy, Beijing, 100024, PRC

Abstract

Research on a sintered fly ash aggregate is presented. The aggregate was manufactured through material orthogonal test and quick chilled firing schedule test. It displayed high strength (7.8 MPa) and low water absorption (4.2%). Lightweight aggregate concrete made with this aggregate reached compressive strength more than CL60, slump over 20 cm, 60 minutes slump loss less than 2 cm, and expansibility higher than 50 cm. Such properties meet the modern concrete requirements for high strength and pump-ability. This new technology has important economic and social impacts on the use of industrial waste residue and on the environmental protection.

1. Introduction

Fly ash and auxiliary raw materials—clay, canbyite-melt sludge, coal, and paper-mill waste—were used to produce a sintered fly ash aggregate. The manufacturing process was as follows: (1) drying, grinding, and mixing of raw materials; (2) palletizing and desiccating, presintering, and sintering of raw meal pellets. During sintering, raw meal pellet softens, and expanded gas forms from the chemical reaction of Fe_2O_3 and C. The expansion mechanism of sintered lightweight aggregate is a dynamic balance process of expanded gas escaping from pellet and inhibiting effect of fitting viscosity liquid [1]. The interaction described above results in the expansion of sintered fly ash

aggregate. Research on mix ratio optimum test and quick chilled firing schedule test was done. Test results have indicated the chosen technical measures are feasible.

2. Raw Materials and Test Methods

2.1. Raw materials

Nine supplementary materials were studied in this study: (1) deposition fly ash from Wuhan Qingshan Heating-and-Power Center, Hubei, China, whose 80 μ m retained percentage is 24%; (2) quality fly ash from Wuhan Yangluo Heating-and-power Center, Hubei, China, belonging to first grade according to GB 1596-91; (3) clay from Wuhan Yangluo, Hubei, China, whose index of plasticity is 3.8; (4) canbyite-melt sludge from Wuhan Steel Corporation, Hubei, China; (5) coal from Henan Pingding Mountain Coal Plant, Hunan, China, whose ash content is 18.10%, volatile content is 29.96%, and fixed carbon is 51.94%; (6) paper-mill waste from Wuhan Paper Corporation, Hubei, China; (7) 42.5R portland ordinary cement from Wuhan Huangshi Cement Plant, Hubei, China, whose specific surface is 310m²/kg; (8) sand from Wuhan Sand Plant, Hubei, China, whose fineness modulus is 2.8 and mud content is 1.0%; (9) water-reducing admixture from Wuhan Haoyuan Admixture Plant, Hubei, China. Chemical composition of deposition fly ash, quality fly ash, clay, canbyite-melt sludge, and cement are shown in the Table 1.

Auxiliary raw materials (clay, canbyite-melt sludge, coal, and paper-mill waste) were used in this test in addition to the principal raw material (deposition fly ash). The auxiliary materials were used to facilitate palletization, and expanded gas escaping from pellet and inhibiting effect of fitting viscosity liquid were matched during sintering.

Table 1: Chemical composition of raw materials (wt %)

Raw materials	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	Loss
Deposition fly ash	53.85	26.50	4.06	3.20	1.30	1.12	1.18	8.69
Quality fly ash	50.00	32.85	4.21	4.91	1.58	1.42	1.35	3.22
Clay	70.59	13.49	5.94	1.11	1.10	0.47	0.50	6.80
Canbyite-melt sludge	3.60	4.79	22.05	31.60	3.41	3.02	3.22	28.31
Cement	21.47	5.81	4.04	59.64	3.24	–	–	2.44

2.2. Test methods

In this study, correlative properties of sintered fly ash lightweight were tested according to GB/T 17431.1-2-1998. Fineness of deposition fly ash, canbyite-melt sludge, and clay was tested using the 80 μ m sieve according to GB 1345-91. Lightweight aggregate concretes were tested according to JGJ51-90. Correlative properties of lightweight aggregate concretes had been studied by measuring expansibility, slump, and compressive strength at different age according to GBJ80-85 and BGJ107-87. Test was designed by means of material orthogonal test to find out the optimum mix proportions of raw materials [2].

2.3. Factors and levels

According to the ranges of effective chemical composition and fitting dilating pressure promoted by C.M. Riley, the different factors and levels of auxiliary materials were designed as shown in Table 2.

Table 2: Factors and levels

Factors	Clay (g)	Canbyite-melt sludge (g)	Coal (g)
1	60	10	2
2	50	6	1
3	40	2	0

2.4. Test arrangement

Test was arranged with orthogonal table $L_9(3^4)$. Clay, canbyite-melt sludge, and coal were filled in line A, line B, and line C. Absorption of water, cylinder strength, and bulk density were appraisal index. Table 3 shows test arrangement and test results.

Table 3: Test arrangement and test results

No.	A Clay	B Canbyite-melt sludge	C Coal	Absorption of water (%)	Cylinder strength (MPa)	Bulk density (Kg/m ³)
1	1	1	1	14.1	3.8	776
2	1	2	2	8.6	6.5	819
3	1	3	3	5.4	7.8	834
4	2	1	2	10.2	4.5	785
5	2	2	3	6.7	7.2	827
6	2	3	1	8.0	6.4	815
7	3	1	3	8.6	5.4	806
8	3	2	1	9.6	5.8	812
9	3	3	2	7.8	6.8	822

A 300 g deposition fly ash was used in each test. Test processing parameters were as follows:

- (1) 80 μ m retained percentage: deposition fly ash was 24%, and clay and canbyite-melt sludge were 15%. The volume ratio of paper-mill waste and water was 1 : 4.
- (2) Pellets were produced by extruding. Water ratio of pellets was 25%, and size fraction of pellets was 5-20 mm.
- (3) Drying schedule of green-compact was temperature 140° and time 4 hours, and presintering schedule of green-compact was temperature 700° and time 25 minutes.

- (4) Sintering schedule of green-compact was that pellets were sintered at temperature 1250 degrees for 15min, then at temperature from 1250 to 1200° for 20 minutes, and then discharged from high temperature furnace.

3. Results and Discussion

The extreme deviation of appraisal index of absorption of water, cylinder strength, and bulk density was filled in Table 4. Analyzing the extreme deviation and appraising the aggregative index number, we chose the optimum mix ratio $A_2B_3C_3$, so the final mix ratio was that deposition fly ash : clay : canbyite-melt sludge was 150 : 25 :1.

Table 4: Extreme deviation of three performances index

Extreme deviation	Absorption of water (%)			Cylinder strength (MPa)			Bulk density (Kg/m ³)		
	A	B	C	A	B	C	A	B	C
K ₁	28.1	32.9	31.7	18.1	13.7	16.0	329	267	303
K ₂	24.9	24.9	26.6	18.1	19.5	17.8	327	358	326
K ₃	26.0	21.2	20.7	18.0	21.0	20.4	340	371	367
K ₁	9.4	11.0	10.6	6.0	4.6	5.3	110.0	89.0	101.0
K ₂	8.3	8.3	8.9	6.0	6.5	5.9	109.0	119.3	108.6
K ₃	8.7	7.1	6.9	6.0	7.0	6.8	113.3	123.6	122.3
R	1.1	3.9	3.7	0	2.4	1.5	4.3	34.6	21.3
Optimum	A ₂	B ₃	C ₃	A ₂	B ₃	C ₃	A ₂	B ₁	C ₁

Based on the raw materials optimum mix ratio and the same processing parameters, fly ash lightweight aggregates were manufactured and their performances index numbers were filled in Table 5.

Table 5: Performances results of sintered fly ash lightweight

Absorption of water (%)	Cylinder strength (Mpa)	Bulk density (Kg/m ³)	Size fraction (mm)
4.2	7.8	843	5-20

To evaluate the actual application effect of sintered fly ash lightweight, trials of lightweight aggregate concrete had been made [3]. Test mix ratio and performance results of lightweight aggregate concrete with this aggregate were filled in Table 6. Results indicated that it was easy to manufacture lightweight aggregate concrete of compressive strength more than CL60, slump higher than 20 cm, 60 minutes slump loss less than 2 cm, and expansibility higher than 50 cm with the manufactured aggregate, by adjusting W/B, fly ash dosage, S/A, and quantity of total binding material. Such properties meet the modern concrete requirements for high strength and pump-ability.

Table 6: Test mix ratio and performance results of lightweight aggregate concrete

No.	Quantity of materials (kg/m ³)					A (%)	Expansibility / slump (cm)		Compressive strength (MPa)	
	W	C	F	S	L		0min	60min	7d	28d
1	160	477	53	619	506	0.8	68/25	58/21	52.8	62.5
2	160	495	55	607	498	1.2	58/21	51/19	56.6	69.6

Note: W = water; C = cement; F = quality fly ash; S = sand; L = lightweight; A = admixture.

4. Conclusions

The following conclusions can be drawn based on the present study:

- Through material orthogonal test and quick chilled firing schedule test, sintered fly ash lightweight aggregate demonstrated high strength and low absorption of water.

- Lightweight aggregate concrete made with this aggregate may have compressive strength more than CL60, slump higher than 20 cm, 60 minutes slump loss less than 2 cm, and expansibility higher than 50 cm. Such properties meet the modern concrete requirements for high strength and pump-ability.

References

1. Yu-shun Guo et al. "Comparison of properties of high performance lightweight aggregate and normal lightweight aggregate." *Journal of Concrete (China)*, 2000(6), 22-26.
2. Wang Qing, Wang Li-jiu, and Ai Hong-mei. "Research on soda residue and fly ash high strength ceramsite." *Journal of Concrete (China)*, 2000(6), 27-29.
3. Ding Qing-jiu et al. "Pumping technology of high-strength lightweight aggregate on bridge construction." *Journal of Concrete (China)*, 2002(1), 58-60.