Study on the Influence Law of Various Factors on Volcanic Autoclaved Aerated Concrete

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***Abstract*—With the shortage of fly ash in south of China and rush towards sustainability, how to use of resources of volcanic powder has become a new field for experts and scholars. This paper aims to study the suitability of replacing cement by volcanics in producing autoclaved aerated concrete (AAC) and find out the influencing rule of water cement ratio , aluminum powder content, cement content and the fineness of volcanic powder. Scanning electron microscopy (SEM) investigations of the microstructure and hydration products in the autoclaved aerated concrete (AAC) provide new insights.**

Keywords-autoclaved aerated concrete; volcanic powder; dry density; water absorption rate; compressive Strength

I. INTRODUCTION

Autoclaved aerated concrete (AAC) has a long history of 90 years in commercial production. It has shown many advantages in terms of light weight, high strength, low thermal conductivity and good fire resistance[1,2]. In general, AAC is a kind of the porous silicate material. The raw materials are cement, gypsum, lime, metallic Al powder and quartz sand. These materials are mixed with water, molded and turned to be porous mixture at atmospheric pressure by the addition of gas-generating agents (Al powder). Then, the mass is cured at 200℃ using saturated steam for several hours[3], silicates reacts with CaO to form calcium silicate hydrate (CSH).

Volcanics is formed during volcanic eruptions, it is rich in resources. Volcanic powder is a kind of industrial waste residue, which can cause serious pollution. Developing volcanic powder can reduce energy consumption and waste of resources. This step will make it possible to develop materials available locally and will contribute to the social development of the area.

Fly ash is the traditional raw materials for autoclaved aerated concrete. The experiment used volcanic powder substitute for fly ash to produce autoclaved aerated concrete (AAC) in this paper and find out the influencing rule of water cement ratio , aluminum powder content, cement content and the fineness of volcanic powder.

II. RAW MATERIAL

A. Volcanic Powder

In this study, the volcanic rock was supplied by hainan, China. There are three different fineness of volcanic powder. Volcanic rock ground to 20, 25 and 30 minutes in a laboratory ball milland and dried at a temperature of 105℃ to eliminate free water. The density and specific surface area were measured by Lee pycnomete and Blaine permeability apparatus. Determined fineness by negative pressure sieve method. The relationship between grinding time and powder properties are shown in Table 1. With the increasing of grinding time,the specific surface area increases and sieve residue percentage decreases. The results show that the fineness of the volcanic rock powder becomes fine.

The chemical composition of the volcanics indicates a salic mineral (Table 2). volcanic powder's chemical composition is mainly SiO2 and A12O3, this two kinds of minerals in which are about 65% or more , and chemical composition is good. Volcanic powder would react with calcium hydroxide to form more calcium silicate hydrate. Autoclaved aerated concrete (AAC) which contain volcanic powder would exhibit considerable enhancement in durability properties.

TABLE I. THE RELATIONSHIP BETWEEN GRINDING TIME AND PROPERTIES OF VOLCANIC POWDER

Types of materials	Density (g/cm^3)	specific surface area (m^2/Kg)	Sieve residue percentage (%)
20min	2.868	463.6	3.36
25min	2.868	499.8	2.88
30min	2.868	517.1	2.68

Particle size distribution is an important physical indexes of volcanic powder. The particle size distribution of raw materials have a great influence on the performance of concrete, the three different kinds of volcanic powder fineness were detected by laser particle size analyzer. The results of the particle size distribution are shown in Figure 1, Figure 2 and Figure 3. The average particle size (mean) and median diameter (average) of each fineness were gradually decreased with the increasing of grinding time. Moreover,some difficult ground minerals show independent distribution peaks in the coarse particles.

TABLE II. CHEMICAL COMPOSITION OF VOLCANIC POWDER (WT%)

SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	Na_2O	K_2O
50.43	16.36	8.95	4.44	9.95	4.58	1.72

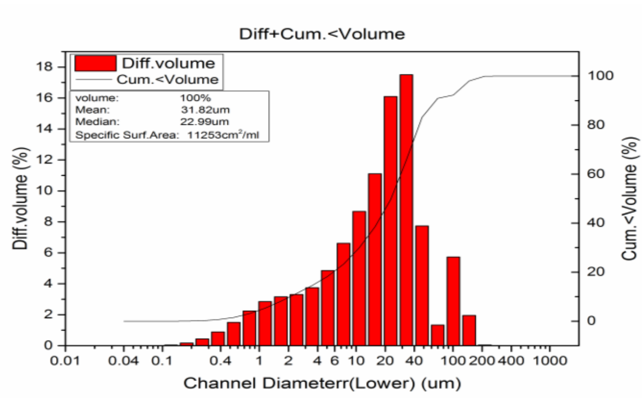

Figure 1. Laser particle size distribution of volcanics 20 min volcanic powder.

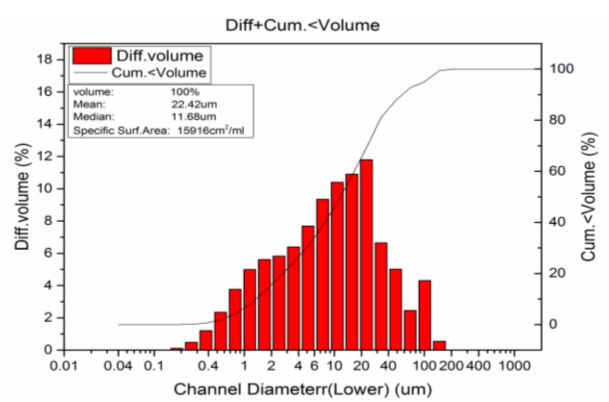

Figure 2. Laser particle size distribution of volcanics 25 min volcanic powder.

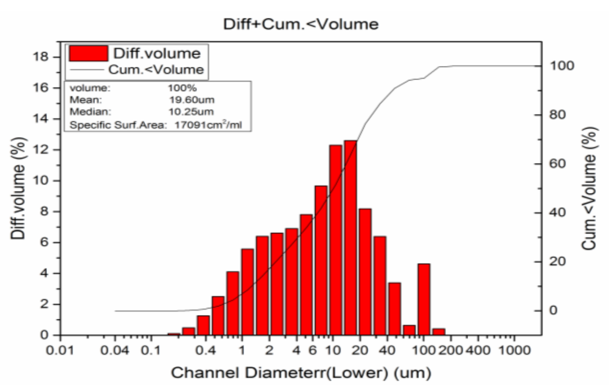

Figure 3. Laser particle size distribution of volcanics 30 min volcanic powder.

B. Other Materials

In this study, the type of Portland cement is P.O 42.5 and which was supplied by Shandong ceme supplier. Performance indexes of cement shown in the Table 3. Through the chemical composition of the lime (Table 4), the effective CaO content of the lime used in this experiment is more than 90%. The chemical composition of desulfurization gypsum is shown in Table 5. The main components of the air lead agent used are resin thermal polymer.

TABLE III. PERFORMANCE INDEXES OF CEMENT

setting time(min)		**Compressive strength(MPa)**		**Bending strength(MPa)**	
Initial setting	***final setting***	***7d***	***28d***	***7d***	***28d***
180	270	34	51	6.93	8.63

TABLE IV. CHEMICAL COMPOSITION OF RAW LIME (WT%)

CaO	**MgO**	**SiO_2**	**Fe_2O_3**	**Al_2O_3**	**SO_3**
95.17	2.36	1.02	0.44	0.63	0.21

TABLE V. CHEMICAL COMPOSITION OF DESULFURIZATION GYPSUM (WT%)

SiO_2	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**SO_3**	**Loss**
1.48	1.01	1.0	31.51	1.82	41.38	21.62

III. TEST SCHEME AND RESULTS

Using water cement ratio , aluminum powder content, cement content and the fineness of volcanic powder as variable,content of cement and volcanic powder is 80%. The study used 15 wt % of lime, 5 wt % of gypsum , 0.2% of air entrained agent and dried at 4 h for 60℃. specimens curied at 1 Mpa for 8h in autoclave. Test results are shown in Table 6.

A. Effect of Various Factors on Dry Density

From the Figure 4, we know that Effect of various factors on dry density: water cement ratio>aluminum powder>cement content>grinding time. Dry density will decrease along with the increase of water cement ratio and aluminum powder. Increase of water cement ratio make dynamic viscosity of slurry decrease. Bubble meet resistance from slurry was decrease and the block get good pore structure [4], the dry density of aerated concrete was decrease. The more holes aerated concrete had, the smaller the dry density was. And hydrogen produced by aluminum powder forms hole in aerated concrete. With the increase of aluminum powder, bubble increases obviously. Thus dry density was decrease. With the increase of cement, dry density radio increases initially and decreases afterwards. The dry density of aerated concrete which had different content of cement is different. Grinding time has little effect on dry density, with the increase of grinding time, dry density decreases. From the data from Figure 4, when water cement ratio is 0.425, the aluminum powder content is 0.10%, the cement content is 18%, the grinding time is 20 minutes, and the dry density of the block is high.

B. Effect of Various Factors on Water Absorption rate

As Figure 5 shows, affection of various factors on water absorption rate: aluminum powder>water cement ratio>cement content>grinding time. water absorption rate will increase along with the increase of aluminum powder and cement. With the increase of water cement ratio, water absorption rate increases initially and decreases afterwards. Increase of grinding time makes water absorption rate decrease. When the water cement ratio is 0.425, the aluminum powder content is 0.10%, the cement content is 18%, the grinding time is 30 minutes, and the water absorption of the block is low.

C. Effect of Various Factors on Compressive Strength

As Figure 6 shows, affection of various factors on compressive Strength : grinding time>cement content >water cement ratio>aluminum powder. With the increase of water cement ratio, compressive Strength decreases. When the water cement ratio is high, the concentration of cementations' materials is low. The excess water in the concrete will form connected pores. And increase of porosity decreases the strength. With the increase of aluminum powder, compressive Strength increases initially and decreases afterwards. The effect of grinding time on compressive strength is similar to aluminum powder. With the increase of grinding time, the volcanic powder had good filling effect, but excessive grinding will reduce the strength. The hydration calcium silicate is beneficial to the compressive strength, increase cement will increase the compressive strength. When the water cement ratio is 0.425, the aluminum powder content is 0.125%, the cement content is 23%, the grinding time is 25 minutes, the compressive strength is great.

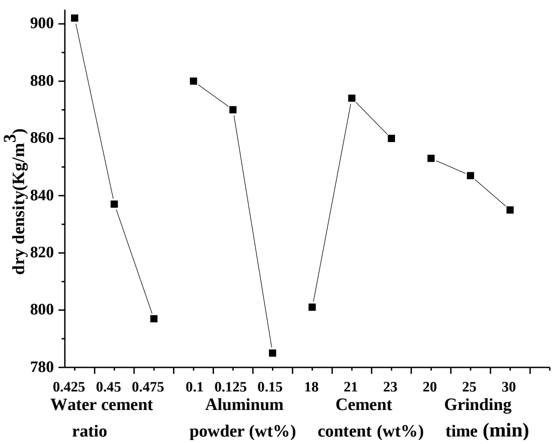

Figure 4. Effect of various factors on dry density.

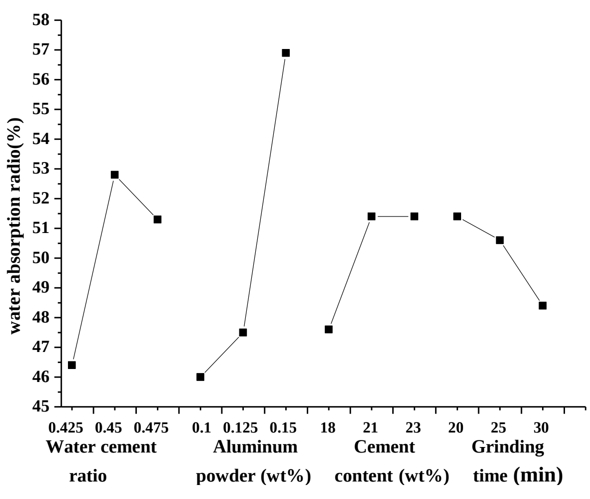

Figure 5. Effect of various factors on water absorption rate.

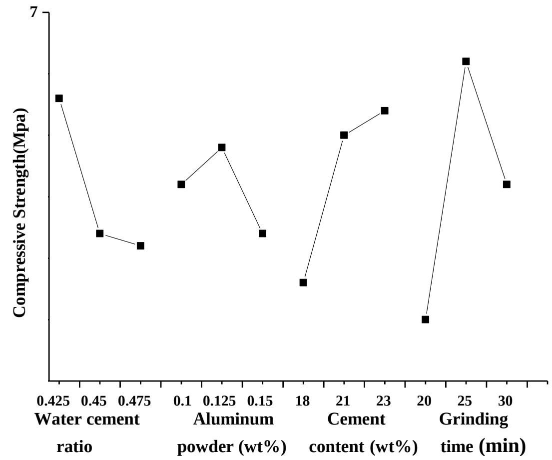

Figure 6. Effect of various factors on compressive strength.

IV. SEM ANALYSIS

The content and type of the pores and hydration products in the autoclaved aerated concrete have great influence on the mechanical properties, water absorption ratio and dry density. In this study, the surface morphology of aerated concrete hydration products was observed by SEM scanning electron microscope, and analyzed the extent of hydration. Test results are shown in Figure 7.

1 shows the whole panorama of the holes in the autoclaved aerated concrete. The pores of block is uniform distribution. 2 shown hydration products in pores after autoclaving. The structure of hydration was compact. The main hydration production are C-S-H gel and tobermorite crystals. In the left of 3 is the hydration product in pores, which is C-S-H gel. It is the hydration product of cement. Micropores can hold water in which silica can be dissolved and diffused. And extent of hydration is good. The right of 3, 4 shows acicular and threadiness tobermorite in the autoclaved aerated concrete.

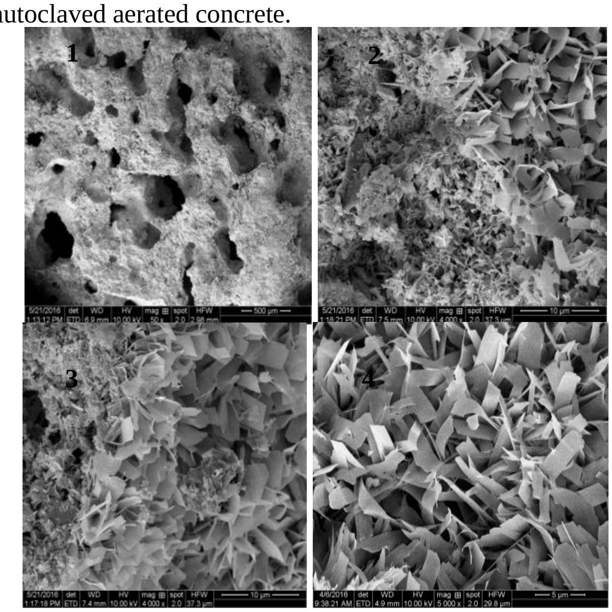

Figure 7. Microstructure of aerated concrete.

V. CONCLUSIONS

In this study,It is feasible to use volcanic powder instead of cement to produce autoclaved aerated concrete. Through analysis the test result, in a certain range,water cement ratio, aluminum powder content, cement content and grinding time has varying degrees influence on Autoclaved aerated concrete. Water cement ratio and aluminum powder content have a great influence on dry density and water absorption,the compressive strength depends on the grinding time and cement content. The main hydration production of autoclaved aerated concrete is C-S-H gel and tobermorite crystals. The structure of hydration in pores was compact after autoclaving.

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TABLE VI. THE TEST RESULTS

Number	Water cement ratio	Aluminum powder (wt%)	Cement (wt%)	Grinding time (min)	Dry density (Kg/m3)	Water absorption rate(%)	Compressive strength (Mpa)
A1	0.425	0.15	18	30	861	48.9	5.2
A2	0.425	0.125	21	25	885	45.5	7.7
A3	0.425	0.1	23	20	960	44.8	6.0
A4	0.45	0.15	21	20	740	62.1	3.8
A5	0.45	0.125	23	30	867	49.7	6.3
A6	0.45	0.1	18	25	903	46.6	5.6
A7	0.475	0.15	23	25	753	59.8	6.5
A8	0.475	0.125	18	20	859	47.4	3.6
A9	0.475	0.1	21	30	778	46.6	5.3