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The Effect of Grinding Time on the Performance of Gold Tailings Aerated Concrete

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The properties of aerated concrete are affected by many factors such as the nature of raw materials and preparation technology. Most Tailings are a kind of inert materials, which need to be mechanically activated to improve their activity when they are used as aerated concrete raw materials. In this paper, the performance of gold tailings aerated concrete under different grinding time was analysed by comparative experiment, so as to mainly reveal the mechanism of grinding-time-varying performance of aerated concrete. The results show that the gold tailings with a grinding time of 17 min show the advantages of the products in the preparation of aerated concrete

1. Introduction

Aerated concrete is basically composed of calcium material and siliceous material. Prepared through chemical blowing approach, this autoclave-cured concrete features light weight, thermal insulation, fireproofing and environmental protection (Zhang and Gu,1992; Narayanan and Ramamurthy, 2000; Hauser et al., 1999). In view of this, it has been widely applied to industrial and civil architecture as a wall material (Rais and Raos, 2005). Gold tailings contain a large amount of quartz, which can be used as a siliceous material for the production of aerated concrete (Xia et al., 2008). This alternative not only meets the national policy requirements for comprehensive utilization of tailings, but also significantly reduces the production cost of aerated concrete. As gold tailings are inert at room temperature, alkali-silica reaction will occur more violently with grinding-activated minerals that used to be inert under autoclave pressure. To this end, this study focused on the grinding time varying performance of gold tailings aerated concrete.

2. Experiment

2.1 Materials

(1) Gold tailing — provided by Zhaoyuan Jiuqu New Type Building Materials Co., Ltd., Shandong. Table 1 and Figure 1 show its chemical component and XRD spectrum, respectively.
(2) Cement —Portland cement provided by Liuli River Cement Plant, Beijing. The chemical composition is listed in Table 1.
(3) Lime —medium-speed digested lime produced by Jinyu Aerated Concrete Company, Beijing. Its parameters are: activity— CaO 65% or so, MgO<6%; loss of ignition≤8%; fineness 0.08mm; screenings of square-mesh sieve 12% ~ 15%; digestion Time 12min, digestion temperature up to 65 °C. The main chemical composition is listed in Table 1.
(4) Gypsum — natural gypsum, whose chemical composition analysis results are listed in Table 1.
(5) Foaming agent — FQ-80B hydrophilic aluminum powder produced by Dongqing Metal Powder Industry Co., Ltd., Harbin. Its parameters are: activated aluminium content ≥90%; fineness 0.08mm; the screenings of square mesh sieve≤3.0%; foaming rate ≥80%; foaming time≤20min; hydrophila≤20s.

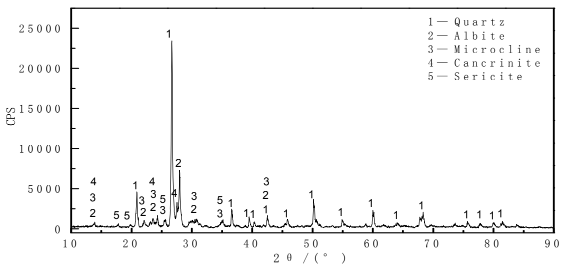


Figure 1: XRD analysis of gold tailings

Table 1: The main chemical composition of raw materials

Material	Mass fraction/%							
	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	Loss
Gold tailings	73.83	12.16	0.77	2.08	1.68	2.89	4.24	1.69
Cement	24.37	6.69	2.41	5.27	55.24	0.80	1.12	1.79
Lime	2.81	1.08	0.48	3.02	84.04	0.56	0.70	7.23
Natural gypsum	3.91	3.61	0.19	8.94	30.93	0.32	0.61	25.49

2.2 Methods

The gold tailings were dried off in CS101-3E dryer and grinded in WL-1 micro-ball dry grilling mill at the grinding time of 10min, 15min, 20min, 25min and 30min, respectively. The LMS-30 Type laser particle size analyser was used to analyse the grain size composition. Then, the grinded tailings and other raw materials were gauged and mixed with each other evenly before being poured into a bucket. After the mixture was stirred up for 120s (hot water, 55 °C), we added some aluminium powder to it and stirred them again for 40s or so. And the slurry was quickly poured into the mould and stayed undisturbed for 3h, waiting to be hardened. Then, we demould the preform and placed it in the ZCF-40 autoclave for 8-hour autoclaved curing at the pressure of 1.35MPa, temperature of 185 °C±5 °C, and the constant temperature. Finally, the test block was dried to constant weight for strength and microstructure test analysis.

3. Results and discussion

3.1 The effect of grinding time on gold tailings fineness

In mechanical grinding, under the action of mechanical force, the material overcomes cohesion to gradually reduce fineness with respect to specific surface area and particle size distribution. Table 2 shows the specific surface area of the powder in different grinding time. Figure2 shows the particle size distribution of the gold tailings in different grinding time.

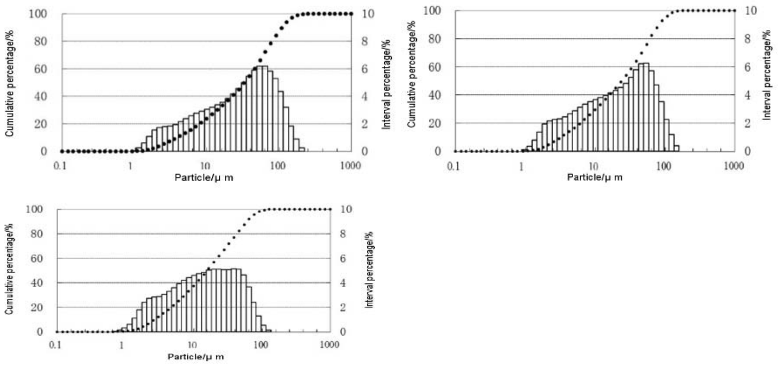
In the process of grinding, part of the mechanical energy is converted into the surface energy of the powder, and the latter one is positively correlated with the specific surface area. It can be seen from Table 2 that when the grinding time is 10~25min, the increment in the specific surface area of the gold tailing powder is large (from 0.624 m^2/g to 1.195 m^2/g), while the growth rate after 25min is low (from 1.195 m^2/g to 1.356 m^2/g). This indicates that with the increase of the grinding time, the conversion of the mechanical energy to the surface energy of the powder increases, and as the grinding time increases, the agglomeration of the powder becomes more obvious, resulting in the slow-down of the increment in specific surface area and the resultant decrease in grinding efficiency.

It can be seen from Figure2 that with the increase of grinding time, there are much less particles of 10~100μm size but instead much more particles of 10μm size. When the grinding time increases to 30min, basically the size of all particles is lower than 80μm. Specifically speaking, the number of particles at the size of 40 to 60 μm jumps up, while the accumulative number of particles at the size of smaller than 10 μm is somewhat larger than that at the grinding time of 25 min. This indicates that when the grinding time reaches a certain limit, the tailings of large particles absorb part of the mechanical energy, causing the increase in surface energy and the decrease in particle size. At the same time, fine particles agglomerate and release some surface energy in this process, which greatly reduces grinding efficiency.

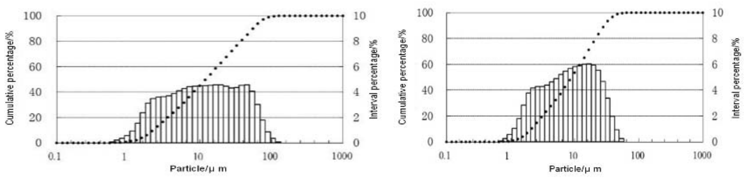
As can be seen from the data results of surface area and particle size distribution, the fineness of the gold tailings decreases gradually with the increase of the grinding time, but the grinding efficiency decreases and the downtrend of fineness becomes less sharply when reaching a certain threshold.

Table 2: The specific surface area of the grinded gold tailing powders in different grinding time

Grinding time (min)	10	15	20	25	30
Specific surface area (m^2/g)	0.624	0.754	0.963	1.195	1.356



(a) Grinding 10min (b) Grinding 15min (c) Grinding 20min



(d) Grinding 25min (e) Grinding 30min

Figure 2: Total particle size distribution of gold tailings at different grinding time

3.2 The Effect of Grinding Time on the Performance of Aerated Concrete Products

The results of the early-phase exploratory experiments on the activity of gold tailings mortar show that the increase in the grinding time of gold tailings can effectively increase its activity within a certain range. But with the increase in grinding time, other properties of gold tailings will also change as a result, which undoubtedly affect the overall performance of aerated concrete products. In light of this, in this study, with the compressive strength and specific strength of aerated concrete products as the indicators, we tested the grinding-time-varying performance of aerated concrete (10min, 15min, 20min, 25min and 30min) while remaining the raw material ratio unchanged (Table 3). The test results are shown in Figure 3.

It can be seen from Figure3 that the compressive strength and specific strength of the aerated concrete products increase first and then decrease with the increase in the grinding time of the gold tailings. The data show that when the gold tailings grinding time is 10min, the absolute dry compressive strength and specific strength of the products are 5.77MPa and 9.35MPa·m^3·kg^{-1}, respectively; and when the grinding time is 20min, the absolute dry compressive strength and specific strength reach the maximum value of respective 6.10MPa and 9.88 MPa·m^3·kg^{-1}. If we continue to prolong the grinding time, the absolute dry compressive strength and specific strength of the products decreased to 5.21MPa and 8.44 MPa·m^3·kg^{-1}, respectively, at the time of 30min. Through comparative analysis, the change of the compressive strength curve is smoother than the specific strength curve, which indicates that the effect of the grinding time of the gold tailings on the bulk density of the product is significant. In addition, since the test is carried out by point instead of by continuity, we used the data analysis software spss to fit the compressive strength and the specific strength data to obtain the fitting curve a) $Y=4.96+0.16X-0.0047X^2$ and b) $Y=5.41+0.44X-0.0116X^2$. By calculating the extremum of the compressive strength curve, we obtained the extremum point as (17.0, 6.3), meaning that at the grinding time of 17min, the compressive strength can reach the maximum 6.3 MPa. Followed by a validation experiment, the result is 6.26MPa, proved 17min is the best grinding time.

Table 3: The raw material ratio of the aerated concrete test

Dried material composition (%)				Aluminum powder (%)	Water-material ratio
Gold tailings	Cement	Lime	Gypsum		
58.17	12.94	25.89	3.00	0.05	0.61

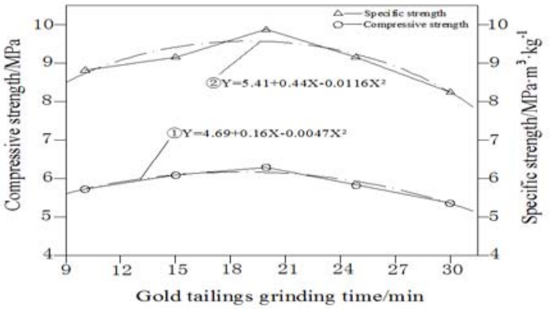


Figure 3: The relationship between gold tailings grinding time and compressive strength and between grinding time and specific strength

3.3 Mechanism analysis

3.3.1 XRD analysis of gold tailings at different grinding time

The crystal structure is composed of simplex or polygon, and the polygon is the polymerization of two or more simplexes. In the grinding process, as different simplexes (characterized by the crystal face parameters) have different thrust faces, the damage time of crystal faces varies (Pu et al.,2004). If the grinding time is prolonged, the microstructure of the gold tailings minerals will change markedly on some crystal faces while remain unchanged on others, which incurs the activity change of gold tailings reaction and thus affects the performance of aerated concrete products. The XRD analysis result of gold tailings at different grinding time is shown in Figure 3, where part of the crystal face parameters have been marked.

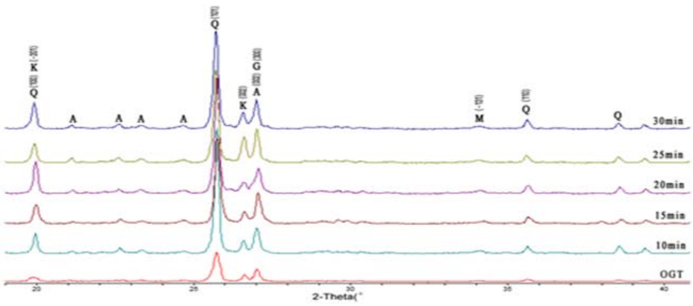


Figure 4: XRD analysis of gold tailings at different grinding time (Q-Quartz; A-sundra; K-micro-plagioclase; G-orthorhombic calcium zeolite; M-mica)

Since we used polycrystalline powder samples to observe powder polycrystalline diffraction, the diffraction spectrum is not composed of one diffraction line but a diffraction peak of a certain width. If the diffraction peak is simplified as a triangle, the peak area is equal to the product of peak height and the width of the peak at half height (also called as half-height width) (Wang, 2010). Grain refinement and micro strain will change the half-height width. As can be seen from Figure 4, the peaks of albite, mica and micro-plagioclase in the original gold tailings are unobvious. Plus, the diffraction peaks of the quartz are smooth, indicating that these crystals are not completely dissociated. A possible case is that some other minerals are adsorbed or glued to the surface of the quartz such that disturbing the formation of quartz diffraction peaks in the test. By means of grinding, mica, albite and micro-plagioclase were dissociated. The diffraction peak shows that as the grinding time is prolonged, the quartz's peak value changes a little, and the half-height width of the diffraction peak along the crystal face (-131) direction increases for a tiny amount. The spectrum strength on the crystal face of the microcline (002) and the albite (002) increases first and then decreases, reaching the top at the grinding time of 25min. There is a similarity for the overlapped diffraction peak of quartz (100) surface and microcline (-201) surface, whose maximum spectrum strength occurs at the grinding time of 20min. This indicates that in a grinding process, the simplexes that are represented by the crystal face parameters tend towards corrosion and are heavily impacted by grinding time compared to other simplexes, such that the diffraction peak fluctuates as the grinding time varies. In addition, according to some documental records (Xiao et al.,2009), the longer the grinding time is, the more noticeable the chemical bonds on the quartz surface breaks, and the thicker the thickness of amorphous SiO_2 becomes. As a summary, grinding time has a significant effect on the structure and activity of minerals. The longer the grinding time is, the greater the damage to the chemical bonds on the mineral surface is, and the more structural defects the minerals have. In terms of property, as the grinding time prolongs, the reactivity of raw materials that are composed of such minerals is greatly enhanced.

3.3.2 XRD analysis of aerated concrete products with different grinding time

The performance of aerated concrete depends on its composition and microstructure. In order to analyse the influence and its mechanism of gold tailings on the performance of aerated concrete at different grinding time, we conducted an XRD analysis of aerated concrete products prepared by gold tailings under five kinds of grinding conditions. The analysis results are shown in Figure 5 and Table 4, where Table 4 shows the possible occurrence of minerals and their characteristic peaks in accordance with the standard 2θ parameter in the PDF2 card, and Figure 5 shows the crystal face parameters of some crystals.

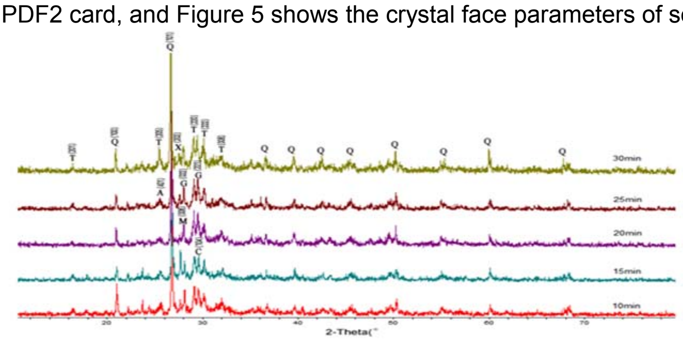


Figure 5: XRD analysis of gold tailings at different grinding time (C-calcite; A-anhydrite; Q-Quartz; T-Tropicamil; X-Hard Siliceous Stone; G-Rampant Calcium Zeolite; M-Mica)

According to the results of the analysis in Table 4 and Figure 5, it can be seen that the half-height width of the corresponding (100) face diffraction peaks of the SiO_2 crystals in the gold tailings unreacted in the hydrothermal reaction is reduced over time. The longer the grinding time is, the higher the degree of wear of the quartz (100) crystal face is, and the stronger the reactivity appears. Similar phenomenon occurs to the remaining mica on the (006) plane. As can be seen from the diffraction peak of the product of the hydrothermal reaction, the diffraction peak of the terracedite (008) crystal face does not change with the grinding time. Instead, at the grinding time of 10~20min, the characteristic diffraction peaks of the crystal face show the crystal characteristics. When the grinding time is 30 min, the diffraction peak becomes a drum package with unobvious characteristics. The presence of a small amount of xonotlite in the product also appears like that. At the grinding time of 17min, the peak strength in the direction of the hard silica (202) crystal face is the highest. This also falsifies it that the longer the grinding time of the gold tailings is, the higher the compressive strength of the aerated concrete product is. Actually, the product becomes the most compression-resistant at the grinding time of 17 min. This indicates that with the increase of grinding time, the thickness of amorphous silicon on tailings particles increases, which will reduce the rate of transformation of tometrolol to calcite in the later stage of hydrothermal reaction. What is more, when the grinding time of gold tailings is 17min, the amorphous SiO_2 content on the surface of the particles is more suitable. Some of the Ptobi mullite can effectively produce relatively complete crystalline silicite. And the longer the gold tailings grinding time is, the greater the surface energy of the powder is, and it is more likely for powders to agglomerate and encompass activated crystal faces such that improving the performance of the aerated concrete products by preventing activated crystal planes from being active. Gold tailings grinding time is so short that the mechanical chemical effect is insufficient to stimulate the activity of gold tailing powders. Also, with too few powders participating in hydrothermal reaction, there is no gel performance for the products.

Through the above tests, it can be concluded that the grinding time has different effects on the activity of gold tailings and on the performance of aerated concrete. With the increase in grinding time, the activity of the gold tailings also increases, but the contribution of the strength of the product does not obey the law of “the finer, the better". This is because the increase in grinding time can enlarge the specific surface area of gold tailings, which increases its own activity, the interface of hydration reaction, and the amount of the hydration product. However, if the grinding time is too long and the gold tailings particles are overly fine, the system reaction demands more water. In the case of the same ratio of water to material, the greater the viscosity of the particles is, the faster the green body is hardened, which in turn affects the foaming of the aluminium powder and results in uneven foams or insufficient foaming. In this way, the bulk density of the aerated concrete products increases and the compressive strength decreases. Reversely, if the grinding time is too short, the gold tailings particles will be so thick that forming dense layer of hydration products on the surface of the powders and affecting the later-phase hydrothermal reaction. In this way, the performance of the final product will be affected. As a comparison, suitable grinding time (which is 17min in our scenario) is helpful in boosting the production of hydrated products to form aerated concrete of appropriate structures and strengths on the basis that the gold tailings' activity is improved.

Table 4: XRD patterns analysis of the identified crystalline phase material

Mineral name	Card No.	Peak angle (°)
quartz	46-1045	21.04, 26.80, 50.30, 68.46
Tombomite	45-1480	16.48, 25.60, 29.18, 30.16, 32.00
Xonotlite	23-0125	21.04, 24.39, 25.60, 27.68, 29.18
Mica	18-0276	21.04, 23.72, 28.13
Calcite	05-0586	29.64, 36.13, 39.67, 47.70
Anhydrite	37-1496	25.60, 31.39, 48.67

4. Conclusion

(1) With the increase of grinding time, the specific surface area of the gold tailings gradually increase. The greater the wear and damage to the surface of the mineral is, the greater the reactivity is. Meanwhile, as the agglomeration of the powder is more and more obvious, the particle size distribution approaches 40 ~ 80μm. The grinding efficiency decreases and the downtrend of fineness becomes less sharply when reaching a certain threshold.
(2) According to the analysis result of the grinding time varying performance of aerated concrete products, the gold tailings aerated concrete has the best performance at the grinding time of 17 min.
(3) As can be seen from the XRD analysis of gold tailings aerated concrete products prepared at different grinding time, as the grinding time is prolonged, the thickness of amorphous SiO2 increases on the surface of the quartz particles of gold tailings. When the grinding time is 17min, the amorphous SiO2 content on the particle surface is suitable, which is favourable for the formation of high-hardness hydration products during the preparation of aerated concrete.

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