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Experimental Study on Mechanical Properties of Polyvinyl Alcohol Fiber Barite Concrete After High Temperature

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Abstract. In order to study the mechanical properties of barite concrete (BC) after high temperature, this experiment tested and analyzed the mass loss, compressive strength and splitting tensile strength of barite concrete at different polyvinyl alcohol fiber volume admixture (0, 0.1%, 0.2% and 0.3%) and different temperatures (25, 105, 200, 300 and 400 °C). The results indicated that the mass loss of barite concrete specimens increased with the increase of temperature. Its compressive strength and splitting tensile strength both gradually decreased. The admixture of polyvinyl alcohol fiber could improve the compressive strength and splitting tensile strength of barite concrete, among which the effect on the splitting tensile strength of specimens was greater. Among them, when the volume content of polyvinyl alcohol fiber is 0.2%, the improvement effect of barite concrete at high temperature is the best.

Keywords. barite concrete high temperature polyvinyl alcohol fiber mass loss compressive strength splitting tensile strength

1. Introduction

Compared to other construction materials, concrete is inexpensive, malleable, and has good mechanical properties. Radiation-proof concrete is one of the special concrete that has better shielding properties compared to ordinary concrete and can effectively attenuate neutron radiation, gamma radiation, and the combined fields of both[1][2]. Therefore, it is widely used in nuclear reactor vessels, nuclear waste storage and disposal buildings and other radiation resistant buildings[3]. Nowadays, high-density ores such as magnetite and barite are used in large quantities at home and abroad as coarse and fine aggregates after crushing, while adding a large amount of crystalline water and compound admixtures containing light elements[4], in which the high-density aggregates can effectively shield gamma radiation and the compounds containing light elements can effectively capture neutrons and do not produce secondary gamma

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radiation.

However, during the service period of radiation-proof concrete, it is in a high temperature environment for a long time[5][6], such as radiation-proof concrete in nuclear power plants, where the temperature is basically located at 60~120 ℃ under normal working conditions[7]. Due to the poor thermal conductivity of concrete, there is a tendency for an increased temperature difference between the inside and outside of the test block, while the water vapor generated by the decomposition of internal free water and bonded water penetrates from the high-temperature zone to the low-temperature zone, generating a large vapor pressure inside the concrete, resulting in concrete deterioration, leading to deterioration of its mechanical properties and shielding properties. Literature and literature studies have shown that the incorporation of low melting point fibers such as polyvinyl alcohol fibers can melt at high temperatures to produce fine pores is conducive to reducing the internal vapor pressure of concrete[8], which plays a suppressive role in the generation and development of cracks in concrete.

In this study, the changes in mass loss, compressive strength and splitting tensile strength of barite concrete after different temperatures (25, 105, 200, 300 and 400 °C) were investigated by varying the volume admixture of polyvinyl alcohol fibers (0, 0.1%, 0.2% and 0.3%).

2. Materials and Methods

The test cement used P·O42.5 grade ordinary silicate cement from Yu Sheng Group, Hengyang City, Hunan Province. Barite aggregates were obtained from Hengyang City, Hunan Province. The raw stone was washed and dried, screened using a standard square-hole sieve, flakes and needles were removed, and the rest was bagged and set aside. The maximum particle size of coarse aggregate used in the test is 20mm, which is mixed by 5-10, 10-16 and 16-20mm coarse aggregate in certain mass ratio, and fine aggregate is obtained by crushing coarse aggregate, and the apparent density of coarse and fine aggregate is 4238 and 4205kg/m^3 respectively. Polyvinyl alcohol fiber adopts bundled monofilament fiber from Shanghai Chenqi Chemical Technology Co. 12mm, density 1.29g/m^3, elastic modulus 37GPa, tensile strength 1500MPa.

In this test, barite concrete is formulated with the volume admixture of polyvinyl alcohol fiber of 0, 0.1%, 0.2% and 0.3%, and the concrete ratio numbers are BC, PVABC-0.1, PVABC-0.2 and PVABC-0.3. Due to the good shielding effect of light elements on neutron rays, increasing the content of water of crystallization in concrete is conducive to improving the radiation protection performance of concrete, the radiation-proof concrete ratio design should be considered so that the cement dosage is greater than 350kg/m^3[9], and finally, after repeated testing and formulation to determine the barite concrete compound such as Table 1.

The specimens were heated in a muffle furnace, and all barite concrete specimens were heated in batches from room temperature (25 ℃), heated to the target temperature (105, 200, 300, 400 ℃) at a heating rate of 5 ℃/min and then thermostated for 1h to make the internal and external temperatures of the specimens consistent, and then naturally cooled to room temperature in the furnace, and the specimens were taken out and wrapped in cling film for backup. Concrete compressive strength test and splitting tensile strength test was carried out by WAW-EY1000C microcomputer-controlled electro-hydraulic servo universal testing machine through 0.2mm/min displacement control loading method. Test methods refer to Concrete Physical and Mechanical Properties Test Methods Standard (GB/T 50081-2019).

Table 1. Mix proportion of polyvinyl alcohol fiber reinforced concrete

Type	Water-binder ratio	Mix ratio/(kg/m^3)				polyvinyl alcohol fiber/%
		Water	Cement	Coarse aggregate	Fine aggregate	
BC	0.5	192	384	1678	1119	0
PVABC-0.1	0.5	192	384	1678	1119	0.1
PVABC-0.2	0.5	192	384	1678	1119	0.2
PVABC-0.3	0.5	192	384	1678	119	0.3

3. Results and Discussion

3.1. Apparent Characteristics and Mass Loss

With the increase of the action temperature, the colors of polyvinyl alcohol fiber barite concrete specimens were grayish-blue, light gray, and grayish-white, respectively. After 105 ℃, a small amount of micro cracks and pores appeared on barite concrete specimens. After 200 ℃, the pores on the surface of the specimens became larger and large amount of fine cracks appeared. After 300 ℃, the number of cracks on the barite concrete specimens increased and became larger, and the skin and corners began to spall. After 400 ℃, the specimens showed broken and loose phenomenon, the strength is basically lost, the barite coarse aggregate appears laminated structure broken, local powdered. While the barite concrete specimens mixed with polyvinyl alcohol fiber at room temperature have obvious inhibitory effect on the generation of pores and micro-cracks, after 105 ℃ slightly increased pores, after 200 ℃, the surface of the specimen pores and cracks increased a lot. After 300 ℃, polyvinyl alcohol fiber 0.1% and 0.3% volume of the specimens appear more serious epidermal, edge spalling phenomenon, but 0.2% of the dosing specimens only a small skin peeling. After 400 ℃, the specimens are burst, loose phenomenon, the strength loss is serious.

The mass loss of polyvinyl alcohol fiber barite concrete after high temperature action is shown in Figure 1. The mass loss rate of the barite concrete shows an increasing trend as the fire temperature rises. At lower temperatures, there is a slight decrease in mass damage with the incorporation of fibers, which is due to the inhibition of crack development by the addition of fibers, which may prevent the escape of water vapor from inside the concrete, however, since the evaporation of water does not depend on the formation of wide cracks, the incorporation of fibers does not have a significant effect [10]. After 105°C, the mass loss ranges from 1.81% to 2.28% for the evaporation of free water inside the test block. After 200°C, the change in mass loss is small, which is due to the fact that the test blocks have reached a dry state after experiencing drying. After 300 ℃, the mass loss began to increase, at this time, part of the combined water inside the test block began to decompose and evaporate, and the test block with the doping amount of 0, 0.1% showed the phenomenon of skin and edge flaking. And in more than 220 ℃, polyvinyl alcohol fiber melting volatilization, the formation of pore channels conducive to the internal water vapor escape, slowing down the burst phenomenon of barite concrete. After 400 ℃, the mass loss of all barite concrete test blocks rose sharply, of which barite concrete without fiber doping reached 24.13%, and barite concrete mixed with 0.2% polyvinyl alcohol fiber was 16.48%.

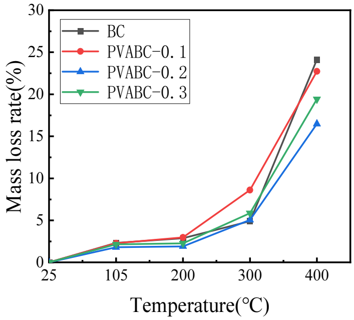

Figure 1. Mass loss rate of barite concrete after high temperature

3.2. Compressive Strength Test

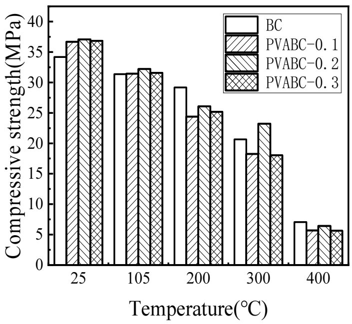

Figure 2. Compressive strength of barite concrete after high temperature

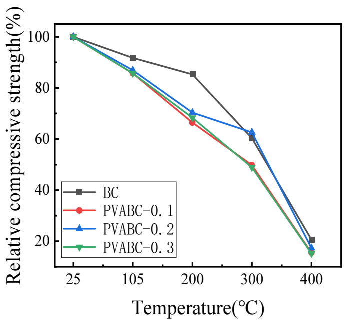

Figure 3. Relative compressive strength of barite concrete after high temperature

The compressive strength and relative compressive strength of polyvinyl alcohol fiber barite concrete after the effect of high temperature are shown in Figure 2 and Figure 3. The compressive strength of barite concrete gradually decreases as the fire temperature increases. The enhancement of compressive strength of barite concrete with polyvinyl alcohol fiber is not obvious, and the strength is lower than that of barite concrete without fiber after 200 °C. This may be due to the fact that near the melting point of polyvinyl alcohol fiber, the fiber appears to partially melt leading to loosening of the cement matrix and a decrease in strength. But after 300 ℃, polyvinyl alcohol fiber melting and volatilization reduces the internal vapor pressure of concrete, and the decomposition of crystalline water in the coarse aggregate in the barite concrete without fiber, the internal vapor pressure of concrete rises sharply causing local bursting and rapid decrease in strength, at this time, mixing 0.2% of polyvinyl alcohol fiber significantly improves the residual compressive strength. As shown in Figure 3, the compressive strength of polyvinyl alcohol fiber barite concrete decreases more sharply under high temperature action, and the improvement effect of polyvinyl alcohol fiber on the compressive strength of barite concrete is not significant under the effect of high temperature.

3.3. Splitting Tensile Strength Test

The barite concrete without fiber can be split easily, while the barite concrete with 0.1% polyvinyl alcohol fiber is rapidly formed through cracks in the splitting process, and then the internal fiber gradually breaks, and the specimen splits completely. With the increase of polyvinyl alcohol fiber dosing, the specimen gradually difficult to split. But with the fire temperature gradually exceeds the melting point of polyvinyl alcohol fiber, after 300 ℃, polyvinyl alcohol fiber melting volatile, concrete specimens can be easily split damage.

The splitting tensile strength and relative splitting strength of polyvinyl alcohol fiber barite concrete after the effect of high temperature are shown in Figure 4 and Figure 5. The splitting tensile strength of barite concrete decreases with the increase of fire temperature and increases with the increase of polyvinyl alcohol fiber admixture. With the increase of polyvinyl alcohol fiber admixture, the splitting tensile strength of barite concrete increased by 7.64%, 14.65% and 26.75%, respectively. At 105~200 ℃, although the splitting tensile strength of barite concrete increased with the increase of polyvinyl alcohol fiber admixture, it increased slowly from 0.2% to 0.3%, which is because although the admixture of polyvinyl alcohol fiber can Enhance the toughness of the cement matrix, but excessive fiber will lead to uneven distribution and entanglement into clusters, which adversely affects the strength. After exceeding the melting point of polyvinyl alcohol fiber, the concrete specimen with 0.2% by volume has the highest splitting strength, and it can be seen from Figure 5 that the decrease of polyvinyl alcohol fiber is slow at 0.2%, which indicates that the appropriate amount of fiber admixture is beneficial to improve the residual splitting tensile strength of barite concrete after the effect of high temperature action.

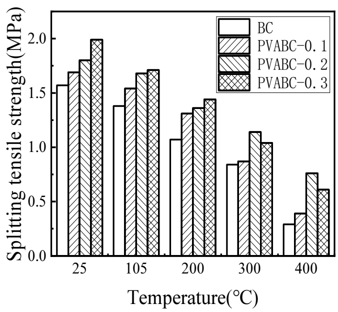

Figure 4. Splitting tensile strength of barite concrete after high temperature

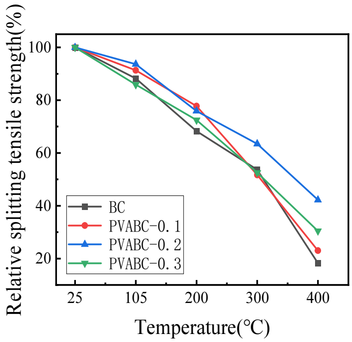

Figure 5. Relative splitting tensile strength of barite concrete after high temperature

4. Conclusions

Barite concrete is prone to bursting after experiencing high temperature action, and the incorporation of polyvinyl alcohol fiber can improve this phenomenon. As the temperature of action increases, the mass loss rate of barite concrete gradually increased, and the growth rate accelerated after 300 °C. Among them, polyvinyl alcohol fiber dose of 0.2% of barite concrete growth is the slowest, the concrete bursting phenomenon is more significant improvement effect.

The residual compressive strength and residual splitting tensile strength of polyvinyl alcohol fiber barite concrete after high temperature both decreased with the increase of fire temperature. The incorporation of polyvinyl alcohol fiber can improve the strength of barite concrete, but for the compressive strength increase is not much, the highest compressive strength at room temperature only increased by 8.42%. The splitting tensile strength of barite concrete was improved more significantly and enhanced with the increase of fiber admixture at room temperature.

Acknowledgments

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