Study on the Influence of Diatomite with Different Shapes on the Moisture Absorption and Release Performance in Changbai Region of Jilin Province

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Abstract: In this paper, different morphologies of diatomaceous earth (disc, cylindrical) were purified, and characterized by SEM, BET and pore size distribution, and moisture absorption and desorption tests were carried out. The results show that the humidity control performance of the cylindrical diatomite sample is better than that of the disc-shaped diatomite sample. Its 24h moisture absorption, 24h moisture release, volumetric moisture content ratio, average volumetric moisture content and other indicators all exceed Disc-shaped diatomite samples; the specific surface area of cylindrical diatomite samples is higher than that of disc-shaped diatomite samples, and the pore size distribution is more reasonable. Combined with the analysis of humidity control performance, cylindrical diatomite samples are more suitable as an excellent humidity control material.

1. Introduction

The remains of a large number of diatoms and some radioactive insects undergo sedimentation and mineralization for a certain period of time, and finally form fragile light-colored sedimentary rocks [1]. This sedimentary rock is diatomite. Diatomite has excellent physical and chemical characteristics such as high porosity, high volume, chemical resistance, large specific surface area and large adsorption capacity [2-3]. Indoor humid environment has a great impact on human health and life. Too low humidity can cause furniture shrinkage and dryness, decreased human metabolism, skin cracking, and weakened respiratory resistance. Too high humidity can cause damage to buildings and affect human temperature regulation. It has become a breeding ground for bacteria and molds, making people extremely susceptible to diseases [4-6].

As people’s requirements for energy saving and living environment are getting higher and higher, people have developed humidity control materials, which rely on themselves and do not need artificial energy and mechanical equipment to absorb and release moisture, and feel the air temperature in the space to be adjusted. Humidity changes to automatically adjust the relative humidity of the air material. Humidity control materials are divided into natural humidity control materials and artificial humidity control materials, and diatomaceous earth composite materials belong to the mineral composite humidity control materials in artificial humidity control materials. In recent years, diatomite moisture-controlling materials have been widely used, but the research on the influence of diatomite with different morphologies on the moisture absorption and release performance is still blank. Therefore, this article focuses on the moisture absorption and release performance of diatomite with different morphologies. In-depth study.
2. Experimental work

2.1 Materials
This experiment uses diatomaceous earth with different morphologies (disc-shaped, cylindrical) in Baishan area of Jilin; pinestone powder unique to Jilin area; inorganic filler; cellulose ether, latex powder, polyvinyl alcohol, polypropylene fiber, nano-TiO\textsubscript{2} /White carbon black composite photocatalytic materials, etc.

2.2 Instrument and equipment
The main instruments used in this experiment are VEGA3 LMH scanning electron microscope, Vc-Sorb2800TP specific surface area and aperture tester, and FR-1245 intelligent artificial climate box.

2.3 Test process
First, the disc-shaped and cylindrical diatomaceous earth is purified, including mechanical grinding, ultrasonic pretreatment, secondary scrubbing, filtration, drying, and calcination at 600°C for 2 hours, and finally purified diatomite is obtained.

Then the purified diatomaceous earth and other materials are added to the dispersion tank according to a certain proportion and fully stirred to uniformly disperse the raw materials. Then water is gradually added to it and stirred at a certain speed to obtain a diatom material slurry. It is evenly smeared on a non-cement fiber cement slab, dried at room temperature for use.

Finally, the dried samples were tested for moisture absorption and desorption. At 23°C, the moisture absorption and desorption of the samples were tested in different time periods (3h, 6h, 12h, 24h) when the relative humidity was changed between 75% and 50%. And meet the following indicators: \( W_{a3h} \geq 20g/m^2 \), \( W_{a6h} \geq 27g/m^2 \), \( W_{a12h} \geq 35g/m^2 \), \( W_{a24h} \geq 40g/m^2 \), and the amount of moisture released in 24 hours should be less than the amount of moisture absorbed in 24 hours. The volumetric moisture content ratio (\( \Delta W \)) is the slope of the straight line when the volumetric moisture content and relative humidity are linearly regressed by the least square method. The average volumetric moisture content is to use the volumetric moisture content ratio to find the volumetric moisture content when the humidity is 55%.

3. Results and discussion

3.1 SEM analysis
Figure 1 is a scanning electron microscope picture of diatomaceous earth with different morphologies before and after purification. Figures a and b are the disc-shaped and cylindrical diatomite before purification. Figures c and d are the disc-shaped and cylindrical diatomite after purification. Shaped diatomaceous earth. It can be seen from the figure that no matter what kind of diatomite morphology, after purification, the various metal oxides and organic matter attached to the pores of the diatomite original soil are burned and melted, and the surface morphology of the diatom shell is Become clear, the surface adhesion impurities are reduced, only local locations are attached with impurities, most of the holes are exposed, and the distribution is orderly.
3.2 BET and pore size analysis
Table 1 shows the specific surface area of diatomaceous earth with different morphologies before and after purification. It can be seen from the table that the specific surface area of diatomaceous earth with different morphologies has been improved after purification, and the specific surface area of disc-shaped diatomite has increased by 5.02038 m$^2$/g, the specific surface area of cylindrical diatomite increased by 7.104716 m$^2$/g, which proves that purification can increase the specific surface area of diatomite.

Table 1. Specific surface area of different morphology diatomite before and after purification

| Sample                     | Discoid | Cylindric |
|----------------------------|---------|-----------|
| Specific surface area before purification (m$^2$/g) | 8.002340 | 47.967029 |
| Specific surface area after purification (m$^2$/g) | 13.022720 | 55.071745 |

Figure 2 and Figure 3 show the pore size distribution of BJH and SF before and after purification of diatomite with different morphologies. Diatomite is a porous mineral with a wide range of micropores (<2nm), mesopores (2-50nm) and macroporous (>50nm) structures. Purification can affect the pore size distribution of diatomite. It can be seen from Figure 2 and Figure 3 that the pore size of disc-shaped diatomite and cylindrical diatomite changes before and after purification, and the number of mesopores and micropores increases. Cylindrical diatomite distributes from 0.7nm to 2.15nm Increase to 0.6nm–2.2nm, disc-shaped diatomite distribution increases from 0.9nm–1.85nm to 0.8nm–2.0nm. Regardless of the shape of diatomaceous earth, the number of macropores increased significantly, from 1nm-10nm more significantly, and the distribution of both increased after 100nm. On the whole, the pore size distribution of the purified cylindrical diatomite is more reasonable, which is more conducive to improving the humidity control ability of the diatomite.
3.3 Analysis of humidity control performance

Figure 4 is the curve of the moisture absorption and desorption of diatomite samples with different morphologies with time. 0-24h is the moisture absorption change of the sample, and 24-48h is the moisture desorption change of the sample. It can be seen from the figure that no matter which morphology is The moisture absorption rate of diatomite samples is very fast in the early stage, and the moisture absorption rate becomes slow in the later stage. The moisture absorption capacity of the disc-shaped diatomite sample is 55.90g/m² in 24 hours, and the moisture release rate in 24 hours is 46.97g/m². Cylindrical diatomite The 24h moisture absorption of the sample is 66.77g/m², and the 24h moisture release is 57.86g/m², but both meet the standard, and the 24h moisture release is lower than the 24h moisture absorption. Table 2 shows the moisture content test results of diatomaceous earth samples with different morphologies. The moisture content in equilibrium includes volumetric moisture content ratio and average volumetric moisture content. From the table, we can see that the disc-shaped diatomite samples and cylinders The volumetric moisture content ratio of the diatomite sample is 0.20(kg/m³)/% and 0.25(kg/m³)/%, which are higher than the standard 0.01(kg/m³)/% and 0.06(kg/m³) respectively, the average volumetric moisture content is 10kg/m³ and 12kg/m³, both higher than the standard (8kg/m³). The humidity control performance of the disc-shaped diatomite sample is inferior to that of the cylindrical diatomite sample.
Fig. 4 Curves of moisture absorption and desorption of diatomite samples with different morphologies with time

Table 2 Test results of moisture content of diatomite samples with different morphologies

| Name          | Discoid | Cylindric |
|---------------|---------|-----------|
| Volume moisture content ratio ΔW [(kg/m³/%)] | 0.20    | 0.25      |
| Average volume moisture content (kg/m³) | 10      | 12        |

3.4 Humidity control mechanism

The humidity adjustment effect of diatomite samples mainly uses the large number of internal pores and large specific surface area formed by the formation of inorganic cementing materials and diatomite to complete the adsorption and desorption of H₂O molecules. The adsorption of materials is composed of physical adsorption and chemical adsorption, which can be divided into monolayer adsorption and multi-molecular layer adsorption. Under different humidity conditions, the adsorption methods used are different, but the humidity control of diatomite materials is mainly physical adsorption. In the low and medium range of relative humidity, H₂O molecules will be confined in the pores and form van der Waals forces with the pores, and they themselves will form van der Waals forces and hydrogen bonds. At this time, the specific surface area is the best parameter to measure the humidity control performance of the material. In the mid-high range of relative humidity, capillary condensation will occur, and the moisture absorption will increase sharply in a short time. Capillary condensation and multi-molecular layer adsorption together affect the moisture absorption of the material. At this time, the mesopore volume is the optimal solution to measure the humidity control effect of the material. Generally speaking, larger specific surface area and mesopore volume are the two key points to improve the humidity control ability of materials. The former provides a platform for H₂O molecules to adsorb active sites, and the latter is easier to form capillary condensation. In addition, silicon The reasonable layout of the appropriate amount of large pores in algae earth is conducive to the shuttle of H₂O molecules in the pores. Therefore, the diatomite humidity control material can well adjust the relative humidity in the control room.

4. Conclusion

(1) After purification, the surface structure of diatomaceous earth became clear by SEM observation, and most of the impurities were removed. According to BET and pore size analysis, the specific surface area of disc-shaped diatomite increased from 8.002340 m²/g to 13.022720 m²/g, and the
specific surface area of cylindrical diatomite increased from 47.967029 m$^2$/g to 55.071745 m$^2$/g. The pore size distribution of diatomaceous earth increased from 0.9nm~1.85nm to 0.8nm~2.0nm, and the pore size distribution of cylindrical diatomite increased from 0.7nm~2.15nm to 0.6nm~2.2nm.

(2) The comparison of the results after the moisture absorption and release performance test shows that compared with the disc-shaped diatomite sample, the moisture absorption capacity of the cylindrical diatomite sample is 10.87g/m$^2$ more in 24 hours, and the moisture desorption capacity is 10.89g/m$^2$ more in 24 hours. The moisture content ratio is higher than 0.05 (kg/m$^3$/%), and the average volumetric moisture content is higher than 2kg/m$^3$. It can be seen that the cylindrical diatomite sample has better moisture absorption and desorption performance than the disc-shaped diatomite sample.

Appendices
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