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APPLICATION OF DIATOMITE IN LIGHTWEIGHT CALCIUM SILICATE BOARD PRODUCTION

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ABSTRACT

Lightweight calcium silicate boards were manufactured with light, porous diatomite as a raw material partly to replace quartz sand using the flow-on process which is used in the Fibre-Cement Industry. The effects of the different additions of the diatomite on the physical properties of product were investigated using laboratory mould experiments. Based on the laboratory results production trials were used to investigate the effects of different additions of diatomite on the physical properties of calcium silicate board. The production process used was a flow-on process. The results indicate that when the replacement of 100% quartz sand with diatomite, the density and the flexural strength of the board were 0.84g/cm^3 and 11.15MPa respectively. These physical properties can meet the requirements of D0.8~1.3-Ⅳ. In order to meet the needs of production capacity, the process design of calcium silicate board line using diatomite needs to consider raising dehydration and drying capacity.

KEYWORDS:

Diatomite; Calcium silicate board; Production; Flow-on; Flexural strength

1 INTRODUCTION

Diatomite consists of single-celled diatoms as a result of biological residue. It has high silicon content[1-2]. The main mineral component of diatomite is Opal and its variants, chemical constituents mainly SiO_2, and contains a small amount of Al_2O_3, Fe_2O_3, CaO, Na_2O, MgO etc[3]. Diatomite has high chemical stability, only soluble in alkali and hydrofluoric acid, insoluble in any other acid. The quality of diatomite is light, the bulk density of diatomite is 0.34 ~ 0.65g/cm^3, the specific surface area is large, generally 19 ~ 65m^2/g; the porosity is high, the pore volume is generally 0.45~0.98cm^3/g. Therefore, diatomite has strong activity and adsorption properties. Diatomite special physical and chemical properties make it widely used. The earth diatomite resources are very rich(over 20 million tons)[4-6].

The concept of building energy efficiency has received widespread attention from all over the world. Large scale, light weight, energy saving, waste recycling is a new type of building materials has been the direction of development. Light board can effectively reduce the weight of structure, and can ensure its own strength, but also can effectively reduce the cost of transportation and factory production of prefabricated parts. At present, industrial production of calcium silicate board majority are produced with high density. This paper describes a method on how to develop high-strength lightweight insulation products with a high-performance board[7-9].

2 EXPERIMENTAL

2.1 Experimental material

Diatomite: 200 mesh square hole sieve margin <1%; the main chemical composition: SiO_2: 67%; Al_2O_3: 15%; Quartz sand: SiO_2> 97%, 200 mesh square sieve margin <1%; lime powder: CaO> 70.52%, 120 mesh square hole sieve margin 2.98%, 200 mesh square hole sieve margin 10.44%. paper pulp: Kraft pulp, after refining process beating degree of 20°SR; cement; mineral fibers; inorganic fillers, etc.

2.2 Molded test: Laboratory preparation method

Using diatomite, quartz sand, cement and lime powder as the main raw material, study the effect of different amount of diatomite on the physical properties of products via molded test. Diatomite replace quartz sand ratio were 0%, 30%, 50%, 70% and 100%. Experimental procedure: first mixing raw materials, post to the size of a vibration 150mm*30mm*30mm mold ramming compaction, compaction (pressure is about 2.3Mpa) with sample testing machine and dismantling the maintenance products.

Steam curing system: boost 3.5h; constant pressure 12h; pressure reducing 3h; steam pressure: 0.95~1.02MPa; autoclave temperature: 180~190℃.

2.3 Preparation of light calcium silicate board: Industrial Flow-on machine

Lightweight calcium silicate board whose specifications is 2440*1220*8mm were prepared with diatomite, quartz sand, cement and lime powder as the main raw material partly replace quartz sand via the flow-on process. The production flow chart of lightweight calcium silicate board is shown in Figure 1.

Pre-curing system: temperature 30 ~ 45 ℃, moisture curing 6h.

Steam curing system: boost 4h; constant pressure 11h; pressure reducing 4h; steam pressure: 0.95~1.02MPa; autoclave temperature: 180~190℃.

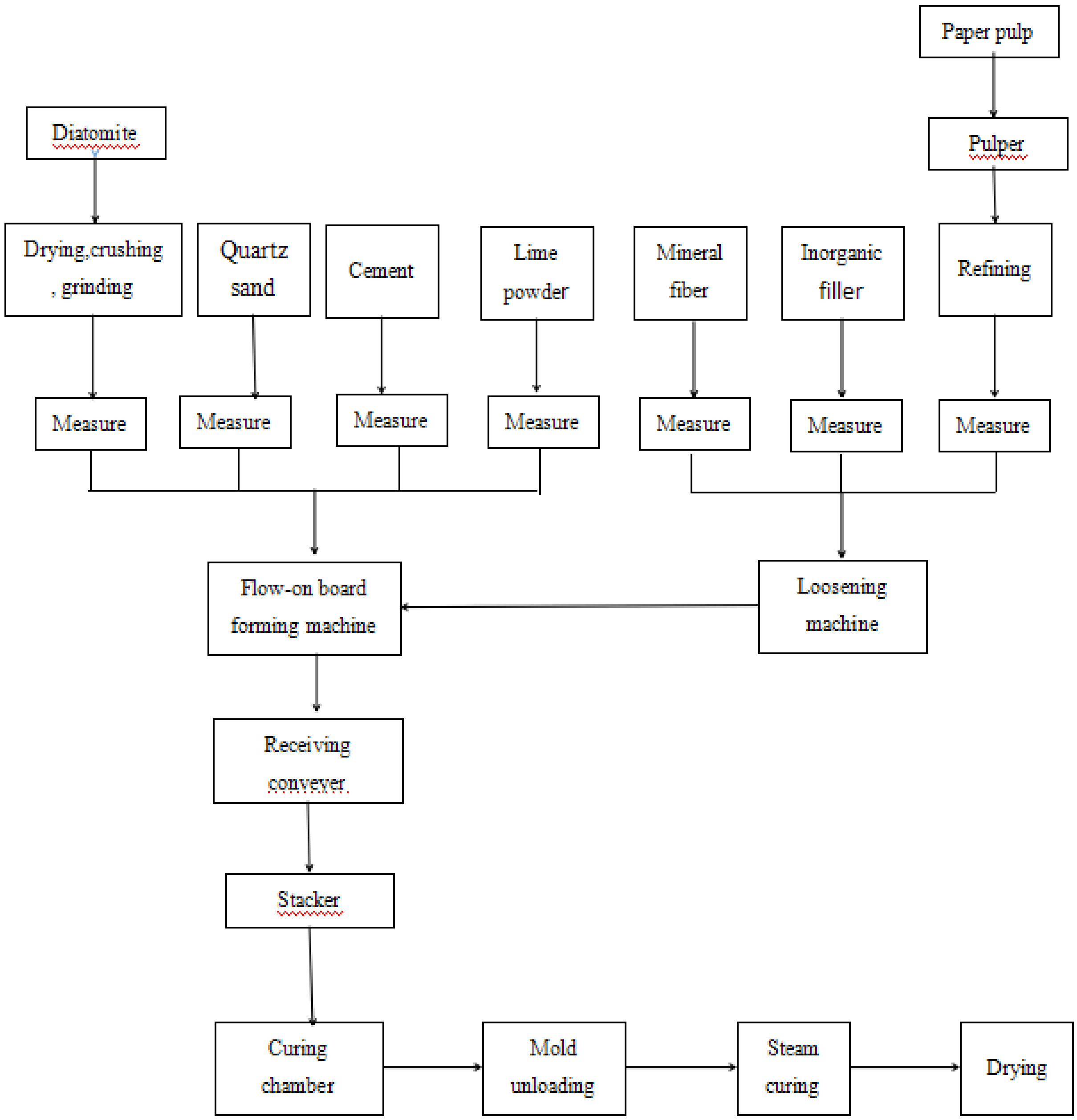

Figure 1: The production flow chart of lightweight calcium silicate board

2.4 Test formulation of the flow-on process

The test formulation is shown in table 1.

Table 1: The test formulation of the flow-on process

	Diatomite	quartz sand	cement	lime powder	Mineral fiber	Inorganic filler	Pulp paper
A	0	40%	40%	4.4%	4.4%	4.4%	6.8%
B	20%	20%	40%	4.4%	4.4%	4.4%	6.8%
C	40%	0	40%	4.4%	4.4%	4.4%	6.8%

2.5 Flexural strength testing

After autoclave curing treatment, molded test pieces in the drying chamber (105℃) drying 48h, and then the density and flexural strength performance were tested. Flexural strength of molded test piece using mainly FBK-5000N-type bending machine for testing. The testing sample size is 150mm × 30mm× 30mm, averaging several measurements. And the center distance of the measured flexural strength is 110mm.

After the pilot production stage, specimens were cut from the flat sheet after production and these were used for flexural testing according to the procedure mentioned above. Subsequently density, moisture content, water absorption, porosity and other physical properties were measured from the same sample cut for the flexural test. The flexural tests were conducted according to FBK-5000N-type bending machine, using the test procedure JC / T564.1-2008 "Fiber reinforced calcium silicate boards - Part 1: Non-Asbestos calcium silicate boards" requirement for the flexural strength of the sample for testing. The plate bending strength according to the material in the felt spread direction is divided into longitudinal flexural strength and transverse flexural strength. The testing sample size is 250mm × 250mm, averaging several measurements.

2.6 Density, moisture content, water absorption and porosity testing

According to JC/T564.1-2008 "Fiber reinforced calcium silicate boards - Part 1: Non-Asbestos calcium silicate boards" requirements of the sample density, moisture content, water absorption, porosity and other physical properties were detected. Finally, several measurements averaged.

2.7 SEM analysis

After drying and polishing of the diatomite raw materials, the gold plating process was used as the sample for SEM analysis. The microstructure of diatomite samples was analyzed by S-3700N scanning electron microscope.

3 RESULTS AND DISCUSSION

3.1 Analysis of surface morphology of diatomite raw materials

The surface morphology of diatomite was analyzed by SEM scanning electron microscope, and the results were shown in Figure 2.

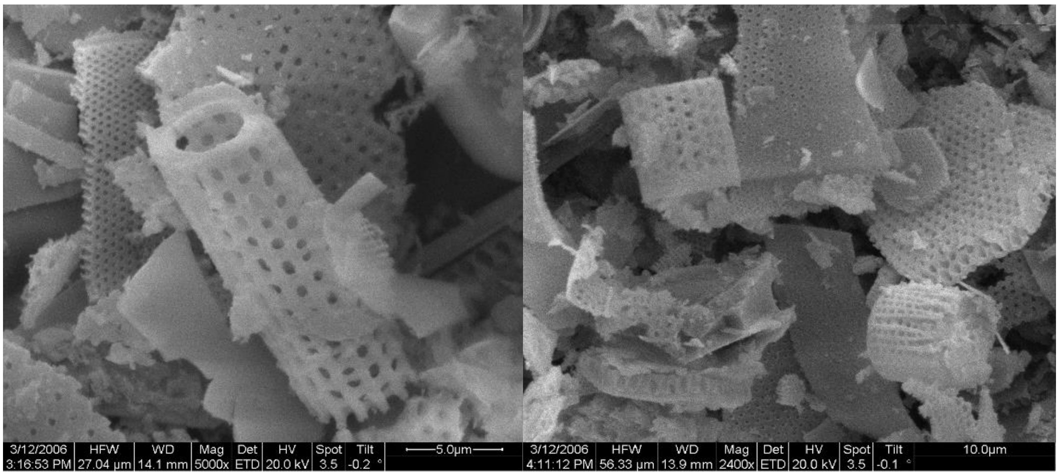

Figure 2: The SEM photographs of the surface of diatomite

From figure 2, we can see that diatomite has a diatom shell structure, mainly cylindrical, fan, and so on. The pores of diatomite are obvious, and the arrangement is orderly. The diatomite has high porosity, large surface area and good adsorption properties.

3.2 The effect of the different additions of the diatomite on the flexural strength and density of the molded product

The test pieces were prepared for flexural testing according to the procedure described in sections 2.5 and 2.6. The addition of cement and lime remained unchanged at 32% and 16% respectively, and the proportion of quartz sand replaced by diatomite was 0%, 30%, 50%, 70% and 100%, respectively. The effects of different additions of diatomite on the flexural strength and density of the specimens were studied, and the results were shown in Figure 3.

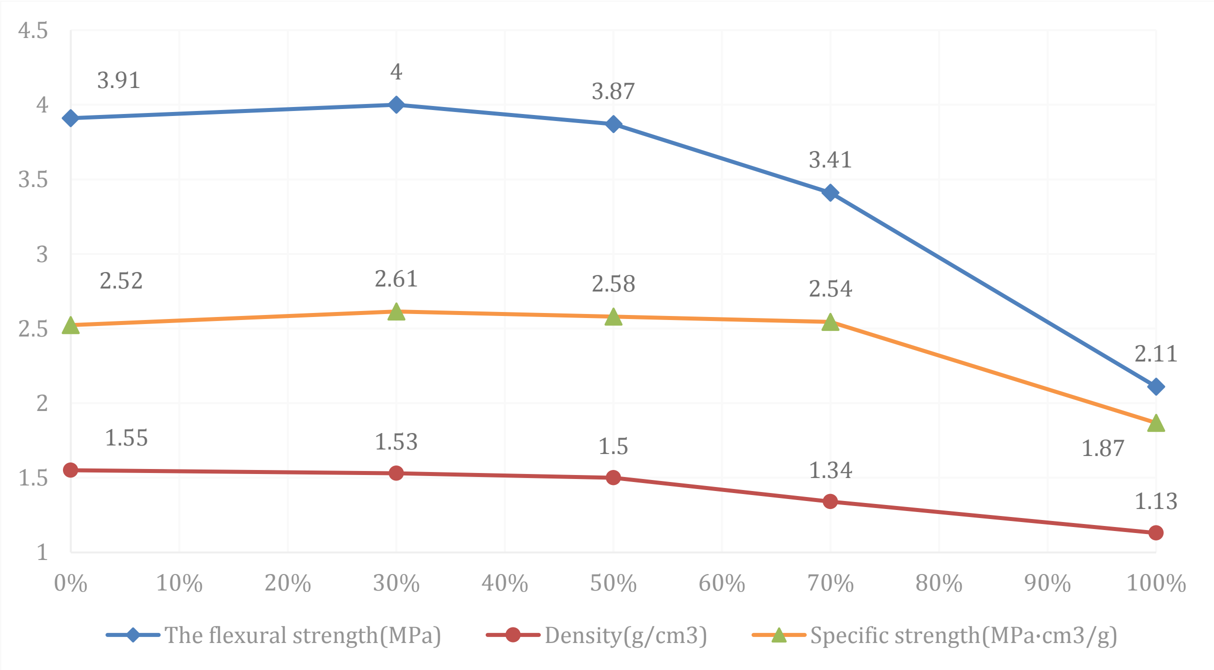

Figure 3: The effect of the different additions of the diatomite on the flexural strength and density of the molded product

From figure 3, we can see that with the increase of the quantity of diatomite, the flexural strength of the test block is decreased continuously. The flexural strength of the molded product made of quartz sand is 3.91MPa. When 30% of the silica sand was replaced by the diatomite, the strength of the molded product was 4 MPa. When the additions of the diatomite were 50%, 70% and 100% respectively, the strength of the molded product was 3.87MPa, 3.41MPa and 2.11MPa, which decreased by 1%, 12.8% and 46%, respectively.

Figure 3 also shows that, with the increase of the additions of diatomite, the density of the molded product was continually decreased. When 30% and 50% of the silica sand was replaced by diatomite, the density of the molded product reduction is not obvious. And the density of the test block was decreased by 13.5% and 27.1% respectively, when the rate of replacement of the diatomite was increased to 70% and 100% respectively.

Specific strength is the strength of the material divided by its apparent density, high-quality materials should have high specific strength, in order to try to meet the strength requirements of smaller cross-section, and can greatly reduce the structural weight of the body itself. Through the specific strength calculation analysis shows that, when with diatomite to respectively replace the 30%, 50% and 70% of the quartz sand, the specific strength of the molded product can maintain higher level, which is almost the same as specific strength of the molded product with pure quartz sand. When the quantity of replacement of the diatomite was increased to 100%, the specific strength of the molded product decreased by 25.8%.

The molding experiment shows that with the increasing amount of diatomite, the initial reduction of the flexural strength of the molded product is relatively smooth, when the amount of diatomite instead of quartz sand is more than 50%, the strength of the reduction rate is accelerated. Based on the results from the laboratory tests with molded products, production trials were designed using 50 % replacements of quartz-sand with 50 % diatomite.

3.3 The effect of the different additions of the diatomite on the flexural strength of the calcium silicate board (Production process using a flow on machine)

The flexural strength is an important property index of calcium silicate board. In the forming process of materials on the felt, because of the different fiber distribution orientation leads to the transverse and longitudinal strength of differences. According to the material in the felt direction, the flexural strength of the board divided into longitudinal flexural strength and transverse flexural strength. We often take the average value of the longitudinal flexural strength and the transverse flexural strength as the ultimate flexural strength of the board. The effect of the different additions of the diatomite on the flexural strength of the calcium silicate board is studied. As shown in figure 4.

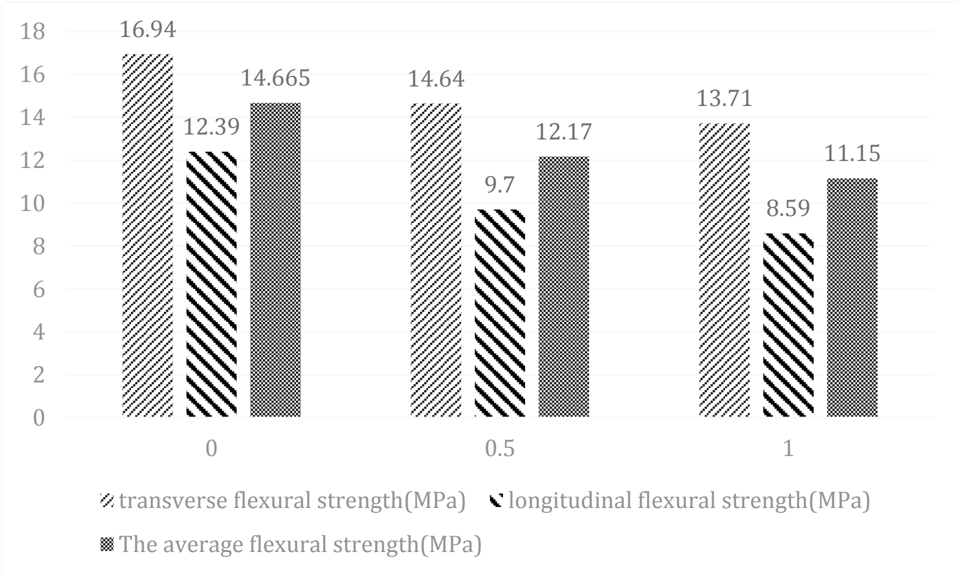

Figure 4: The effect of the different additions of the diatomite on the flexural strength of the calcium silicate board

From figure 4 we can see that with the increase of the additions of diatomite, the flexural strength of the calcium silicate board is decreased, corresponding to the above-mentioned molding experimental trends. Using 50 % and 100 % diatomite instead of 50% and 100% of quartz sand, the flexural strength of the board decreased by 17% and 24% respectively. It is also known that the ratio of the longitudinal flexural strength to the transverse flexural strength of the board is 0.73, 0.66 and 0.63 respectively, by using diatomite instead of 0%, 50% and 100% of quartz sand respectively. The flexural strength of calcium silicate board is mainly from the begging of calcareous and siliceous raw materials calcium silicate reaction to produce high strength tobermorite. When the calcium and silicon materials are mixed with water in a certain mass ratio, they are treated for a number of hours in saturated steam at 180 degrees Celsius, then water thermal reaction will occur. The reaction begins with a high CaO/SiO_2 ratio of C-S-H, and the remaining non reactive silica powder is further reacted with C-S-H to produce a low CaO/SiO_2 ratio of C-S-H(B). C-S-H (B) can generate high strength tobermorite, which is the main hydration products of autoclaved calcium silicate board. If the CaO/SiO_2 is too large, it is very easy to produce α-C_2SH crystal, which leads to a significant decrease in the strength of the product. Compared with quartz sand, the silica content of diatomite is low. Therefore, the calcium silicate board has a certain effect on the strength of the board by replacing quartz sand with diatomite, but it can meet the requirements of the D0.8~1.3-Ⅳ (the building materials industry standard of china).

3.4 The effect of the different additions of the diatomite on the density of the calcium silicate board

The effect of the different additions of the diatomite on the density of the calcium silicate board was shown below in Table 2.

Table 2: The effect of the different additions of the diatomite on the density of the calcium silicate board

	0	50%	100%
Density(g/m^3)	1.16	0.97	0.84
The average flexural strength(MPa)	14.665	12.17	11.15
Specific strength($MPa\cdot m^3/g$)	12.64	12.55	13.27

From table 2, we can see that with the increase of the addition of the diatomite the density of the board gradually decreased. Using diatomite instead of 50% and 100% of the quartz sand, the density of the board decreased by 16.38% and 27.59% respectively. When replace 100% quartz sand with diatomite, the density and the flexural strength of the board were 0.84g/cm^3 and 11.15MPa. However, the calcium silicate board with the diatomite has a higher specific strength. The density of domestic diatomite is low, the bulk density is usually 0.3~0.6g/cm^3, and the conventional density is 0.4~0.9g/cm^3. Using diatomite instead of quartz sand to prepare calcium silicate board can reduce its density. This is very attractive for the market of calcium silicate boards as there is a large demand at present for light weight fire resistant materials.

3.5 The effect of the different additions of the diatomite on the moisture content, water absorption and porosity of the calcium silicate board

The effect of the different additions of the diatomite on the moisture content, water absorption and porosity of the calcium silicate board was shown below in figure 5.

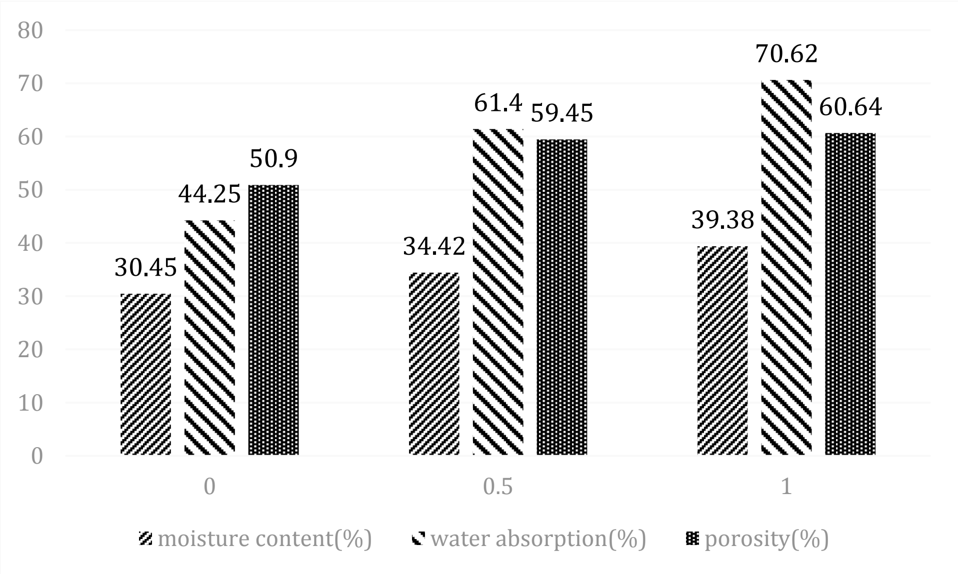

Figure 5: The effect of the different additions of the diatomite on the moisture content, water absorption and porosity of the calcium silicate board

From figure 5, we can see that the addition of diatomite has a great influence on the water absorption and porosity of the board. The water absorption and porosity of the board were increased by 38.76% and 16.8% respectively, by replacing the 50% quartz sand with diatomite. The water absorption and porosity of the board were increased by 59.6% and 19.13% respectively, by replacing the 100% quartz sand with diatomite. Because of its porous and huge specific surface area, diatomite has obvious surface adsorption, and the water absorption rate and porosity of calcium silicate board prepared by diatomite are obviously increased.

In the process of test also found that different diatomite dosage effect on the board of water retention properties also larger, such as the moisture content in figure 5. From the figure 5, we can see that with the increase of the quantity of diatomite, the moisture content of the product increases which shows that the water retention property of diatomite is good. So the process design of calcium silicate board line using diatomite needs to consider raising dehydration and drying capacity. In the design of the production line with diatomite as the main raw material, in order to meet the needs of production, we design by increasing the vacuum suction panel and increasing the power of the vacuum pump to improve the ability of early dehydration. In the design of the drying line, we can improve the drying capacity by lengthening the drying line and improving the drying temperature. The photocatalyst calcium silicate board line of Baishan city northeast Asia new building materials co., LTD was a case of our success.

The photocatalyst calcium silicate board line of Baishan city northeast Asia new building materials co., LTD was designed by Wuhan Building Material Industry Design& Research Institute Co., Ltd. The production line is using diatomite as a raw material for preparing lightweight high-strength board (Figure 6).

Figure 6: The photocatalyst calcium silicate board line of Baishan city northeast Asia new building materials

4 CONCLUSION

From the analysis of surface morphology of diatomite raw materials, we can see that diatomite has a diatom shell structure, mainly cylindrical, fan and other interesting shapes. The pores of diatomite are obvious, and the arrangement is orderly. The diatomite has high porosity, large surface area and good adsorption properties.

The laboratory molding experiment shows that with the increasing amount of diatomite, the initial reduction of the flexural strength of the molded product is relatively consistent, when the amount of diatomite instead of quartz sand is more than 50%, the strength of the reduction rate is accelerated. Based on the laboratory tests the experimental design for full scale production was made. In this case only replacements for quartz sand greater than 50 % using diatomite was chosen.

With the increase of the additions of diatomite, the flexural strength and density of the calcium silicate board is decreased. Using 50% and 100% diatomite instead of quartz sand, the flexural strength of the board decreased by 17% and 24% respectively. The results indicate that when replace 100% quartz sand with diatomite, the density and the flexural strength of the board were 0.84g/cm3 and 11.15MPa,which can meet the requirements of D0.8~1.3-Ⅳ(the building materials industry standard of china). The light board can reduce the production cost effectively, and has a good market prospect.

The water absorption rate and porosity of calcium silicate board prepared by diatomite are obviously increased. And different diatomite dosage effect on the board of water retention properties is also larger. In order to meet the needs of production capacity, the process design of calcium silicate board line using diatomite needs to consider raising dehydration and drying capacity. In the design of the production line with diatomite as the main raw material, in order to meet the needs of production, we design by increasing the vacuum suction panel and increasing the power of the vacuum pump to improve the ability of early dehydration. In the design of the drying line, we can improve the drying capacity by lengthening the drying line and improving the drying temperature.

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