EFFECT OF DIFFERENT ADDITIVE SEQUENCES ON THE PERFORMANCE OF FIBER CEMENT PRODUCTS

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ABSTRACT

As a substitute of asbestos fibers, polyvinyl alcohol fiber has been used for many years in normal temperature cured cement products in the international market. In order to verify the influence of different additive sequences of raw materials on the performance of fiber cement products, fiber cement products with different fiber additions were prepared by different additive sequences in laboratory. The bending strength, dry density, wet density, water absorption rate, dry shrinkage rate and moisture movement were tested and compared. The results showed that the fiber cement products prepared by the sequence of "③Microsilica powder-PVA fiber-Pulp-Filler-Cement" had the best performance.

KEYWORDS:

PVA fiber; bending strength; dry and wet density; water absorption rate; dry shrinkage rate

INTRODUCTION

New building materials industry is China's key industries to encourage and support. Chinese National Development and Reform Commission on the announcement of <Directive opinions on the renovation of wall materials in "12th Five-Year Plan"> pointed out: "The developing of new wall materials to light, high-strength and composite materials is encouraged. It will be focused on promoting the production and application of multi-functional integrated new wall materials with the performance of energy-saving insulation, high strength and fire protection, waste recycling and environmental protection." With the guidance of the national policies and the promotion of relevant departments, the Chinese market of fiber cement boards and calcium silicate boards is gradually expanding. With the growing maturity of process and equipment and customer requirements for product quality improvement, how to stabilize the production and improve the product quality is the problem which every Chinese manufacturer must solve.

Asbestos dust on the issue of human suffering has caused a great shock internationally. As Europe, the United States, Southeast Asia and other countries have ceased the production and use of various types of asbestos products, the demand for non-asbestos fiber cement products in the international market for building materials is increasing day by day (Rongxi Shen, 1988). High-tenacity and high-modulus polyvinyl alcohol fiber can be made by wet spinning process with the main raw material, polyvinyl alcohol (PVA). High-tenacity and high-modulus PVA fiber has the advantages of high strength, modulus, strong alkali resistance, good hydrophilicity (Fulian Xue, 2004, Hongxing Jin, et al, 2001 and Zhangzhao Gu, et al, 1999) good adhesion with cement matrix, can be evenly distributed in the cement products. A variety of chemical fibers was used for comparative tests in the research center of Eternit in Switzerland, and it was considered that high-modulus PVA fiber was one of the best asbestos substitutes (Rongxi Shen, 1988). In the production of polyvinyl alcohol fiber cement products, how to feed the raw materials is one of the problems that plague the related customers. In this paper, the additive sequences of raw materials for preparing fiber cement products were studied.

EXPERIMENT

Materials

High-tenacity and high-modulus polyvinyl alcohol (PVA) fiber (6 mm, from Inner Mongolia Shuangxin Environment-Friendly Material Co., Ltd.), Portland cement (P·O 42.5), tap water, microsilica powder (920U), limestone powder (120 mesh), pulp and flocculants.

The properties of PVA fiber are listed in the following table:

Table 1 Properties of PVA fiber

Sample	Titer (dtex)	Tenacity (CN/dtex)	E-Modulus (CN/dtex)	Elongation (%)	Solubility（%）
PVA fiber	1.96	12.57	314.68	6.90	0.76

Experimental procedures and formulations

Samples were prepared according to Shuangxin laboratory standards of PVA fiber cement and the quality of all raw materials was based on their dry weight. The formulations of fiber cement are listed in Table 2. After the samples were prepared, they were placed in a curing box at 50 ℃ for 8 hours after being packaged in plastic bags. Then the samples with plastic bags were taken out and were cured in the natural environment. After curing for 14 days, the samples were ready for measurement.

According to the Chinese national standard GB/T 7019-2014 "Test methods for fiber cement products", the bending strength, dry and wet density, water absorption rate, dry shrinkage rate and moisture movement of fiber cement boards were tested.

The different additive sequences:

① Pulp-Microsilica powder-Filler(Limestone powder)-PVA fiber-Cement;

② Microsilicapowder+PVAfiber-Pulp-Filler(Limestone powder)-Cement;

③ Microsilica powder-PVA fiber-Pulp-Filler(Limestone powder)-Cement;

④ Pulp-Microsilica powder-Filler(Limestone powder)-Cement-PVA Fiber;

⑤ Filler(Limestone powder)+PVA fiber-Pulp-Microsilica powder-Cement;

⑥ Pulp-PVA fiber-Microsilica powder-Filler(Limestone powder)-Cement;

⑦ Pulp-Microsilica powder-PVA fiber-Filler(Limestone powder)-Cement;

⑧ Pulp-PVA fiber-Filler(Limestone powder with Microsilica powder)+Cement.

Note: "+" means to add the materials at the same time, "-" means to add the materials in order.

Table 2 The formulations of fiber cement products

Sample	PVA fiber（g）	Cement（g）	Remark
1	0	81.5%	Two parallel experiments were conducted for each formulation.
2	1%	80.5%	
3	1.2%	80.3%	
4	1.5%	80%	
5	1.8%	79.7%	
6	2.0%	79.5%	

Equipment

ELECTRONIC BALANCE, MIXER, MICROCOMPUTER CONTROLLED PRESSURE TESTING MACHINE, DIGITAL MICROMETER, ETC.RESULTS AND DISCUSSIONS

The bending strength of fiber cement products

Figure 1 shows the bending strength of fiber cement products prepared with different fiber additions in different additive sequences. It can be seen from the figure that the bending strength of the fiber cement boards prepared in the additive sequences of "②Microsilica powder+PVAfiber-Pulp-Filler-Cement" and "③Microsilica powder-PVA fiber-Pulp-Filler-Cement" are obviously higher than that of the fiber cement boards prepared by the other sequences.With fiber additions of 1.0%, 1.2%, 1.5%, 1.8% and 2.0%, the bending strength of the fiber cement boards prepared by sequence ② is respectively 42.52%, 51.43%, 53.19%, 58.28% and 63.06% higher than that of blank sample. With fiber additions of 1.0%, 1.2%, 1.5%, 1.8% and 2.0%, the bending strength of the fiber cement boards prepared by sequence ③ is respectively 40.28%, 48.90%, 52.67%, 44.04% and 62.23% higher than that of blank sample. From the view of the whole trend of all samples, the bending strength of fiber cement products is improved with the increase of PVA fiber content. According to the data of the related study shows that with the amount increase of polyvinyl alcohol fiber, the toughness and impact strength of fiber cement products are also improved (A.J.Majumar, 1987).

In the 8 tested additive sequences, the bending strength of fiber cement boards that prepared by the sequence ② and sequence ③ is superior to that of the other tested additive sequences, which is mainly because that the particles of the microsilica powder are fine, the mixing of microsilica powder and PVA fiber is performed in advance, so that the fine particles of micosilica powder adhere to the surface of PVA fiber, and the presence of micosilica powder and chemical reaction on the surface of PVA fiber change the electrochemical properties of the fiber surface, which facilitates the dispersion of PVA fiber. The fiber dispersion condition is improved, so that the contribution rate of the reinforcing effect of PVA fiber in cement boards is increased.

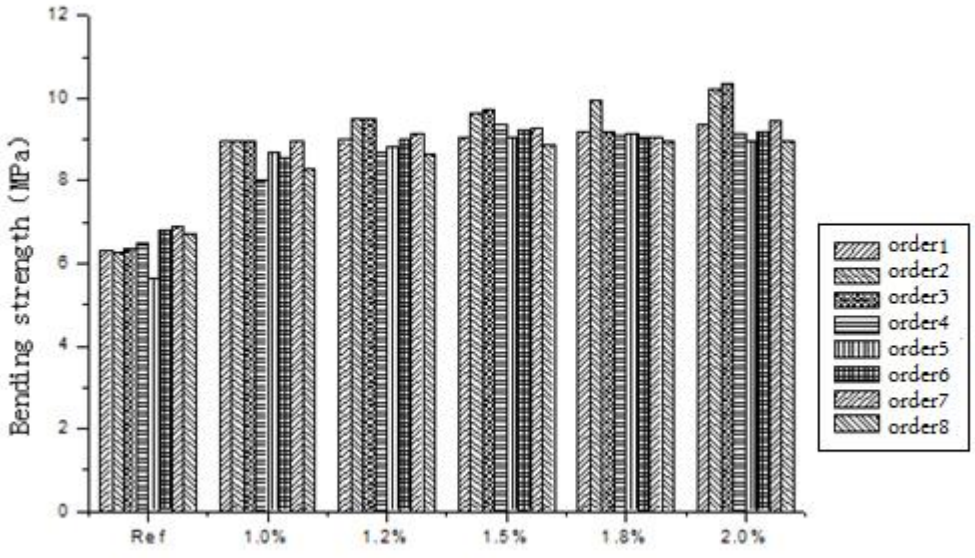

Figure 1: The bending strength of fiber cement products

The dry and wet densities of fiber cement products

The dry and wet densities of fiber cement products are shown in Figure 2 and Figure 3. The dry and wet densities of fiber cement products with the addition of PVA fiber decrease in compared with the blank samples. However, there is not much difference between the dry and wet densities of fiber cement products prepared in different

additive sequences. The reason is that under the same conditions, the fiber volume fraction increases after adding PVA fiber in the cement products in compare with the blank samples, while the density of PVA fiber is lower than the density of cement.

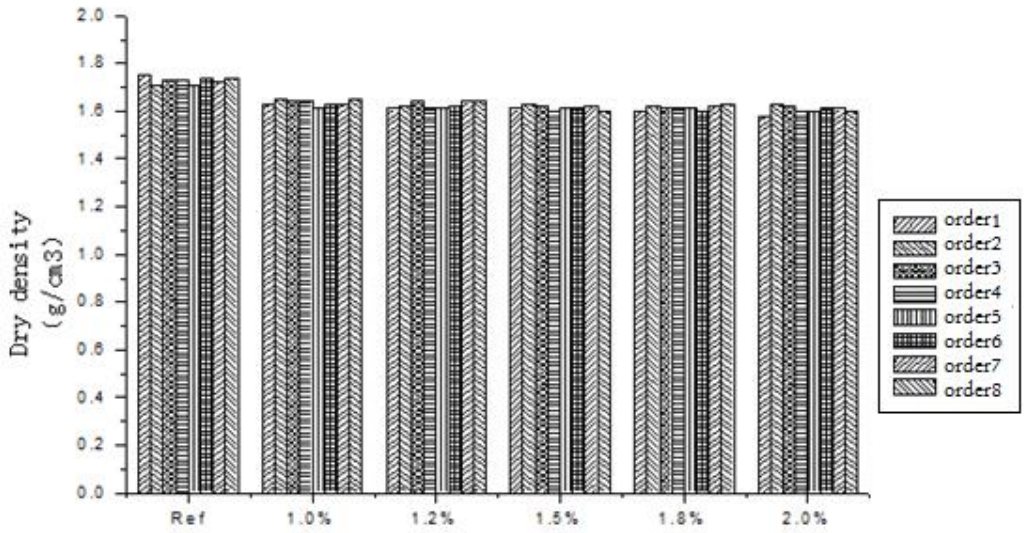

Figure 2: The dry density of fiber cement products

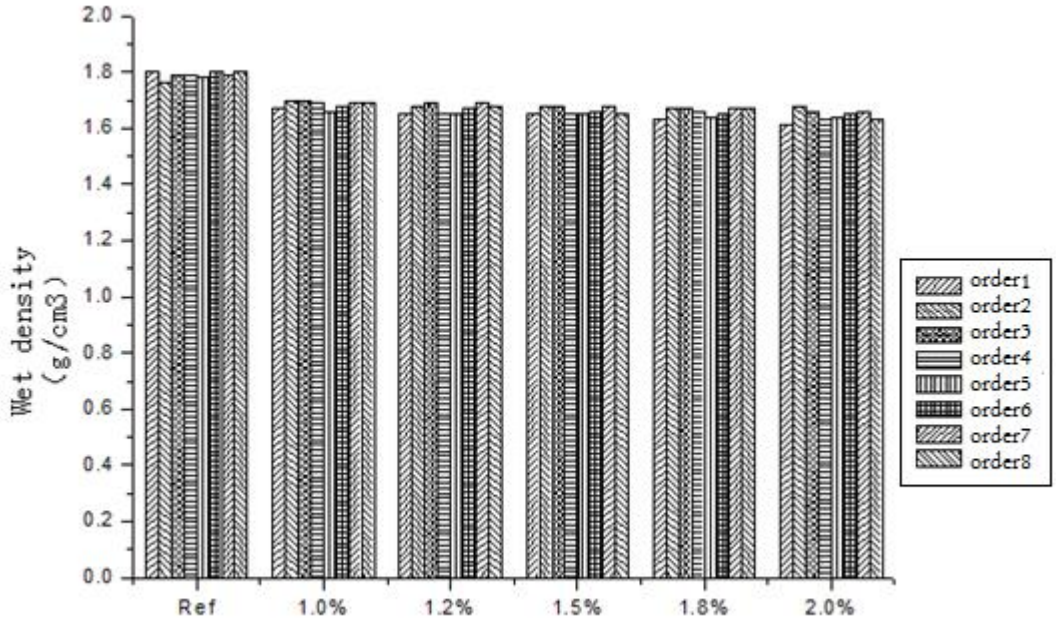

Figure 3: The wet density of fiber cement products

The water absorption rate of fiber cement products

Figure 4 shows the water absorption rate of fiber cement products. It can be seen from the figure that the water absorption rate of the fiber cement products prepared in the additive sequences of "② Microsilica powder +PVA fiber-Pulp-Filler-Cement"and "③ Microsilica powder-PVA fiber-Pulp-Filler-Cement"are closest to that of blank samples. The water absorption rate of the fiber cement products prepared in the other sequences is

higher.The lower the dry and wet density of the sample is, the higher the water absorption rate of fiber cement samples than that of the blank sample is.

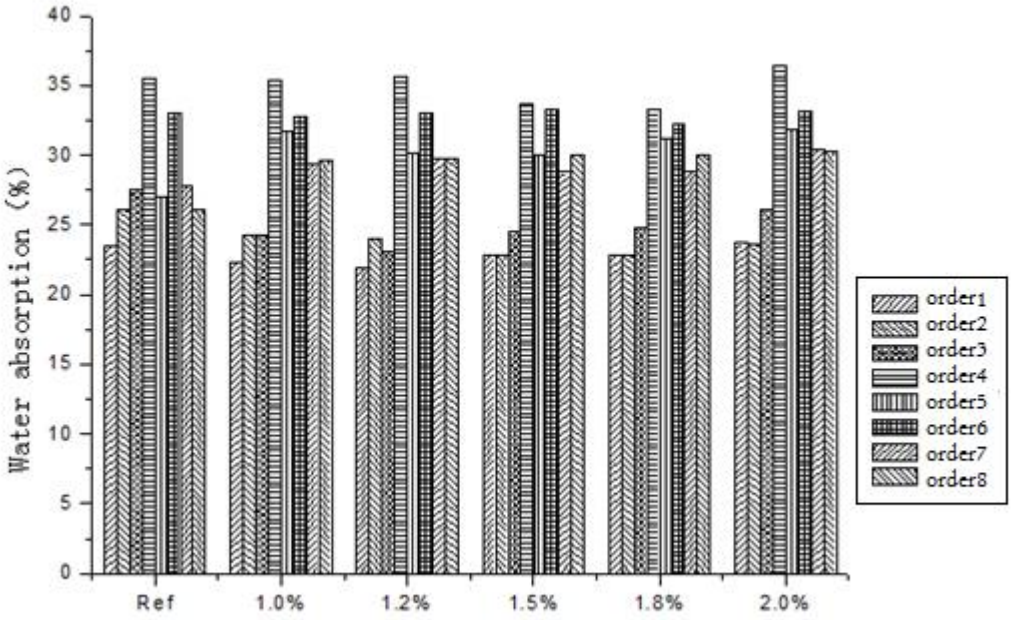

Figure 4: The water absorption rate of fiber cement products

The dry shrinkage rate and moisture movement of fiber cement products

Figure 5 and Figure 6 show the dry shrinkage rate and moisture movement of PVA fiber cement products. As can be seen from the figure: after adding PVA fiber, the dry shrinkage rate and moisture movement of the sample is basically higher than that of the blank sample, but the dry shrinkage rate and moisture movement of the sample that prepared by sequence "② Microsilica powder+PVAfiber-Pulp-Filler-Cement", and sequence "③ Microsilica powder-PVA fiber-Pulp-Filler-Cement" is relative stable. In compare with the fiber cement samples prepared by the other sequences, the fiber dispersion rate in fiber cement samples prepared by sequence ② and sequence ③ is increased, the fiber can better resist the shrinkage stress of the cement boards, and the density of the boards is increased. The dry shrinkage rate and moisture movement of the cement products can be reduced by selecting the appropriate amount of material addition and modifying the formulation of the sample, such as adjusting the amount of cement additives.

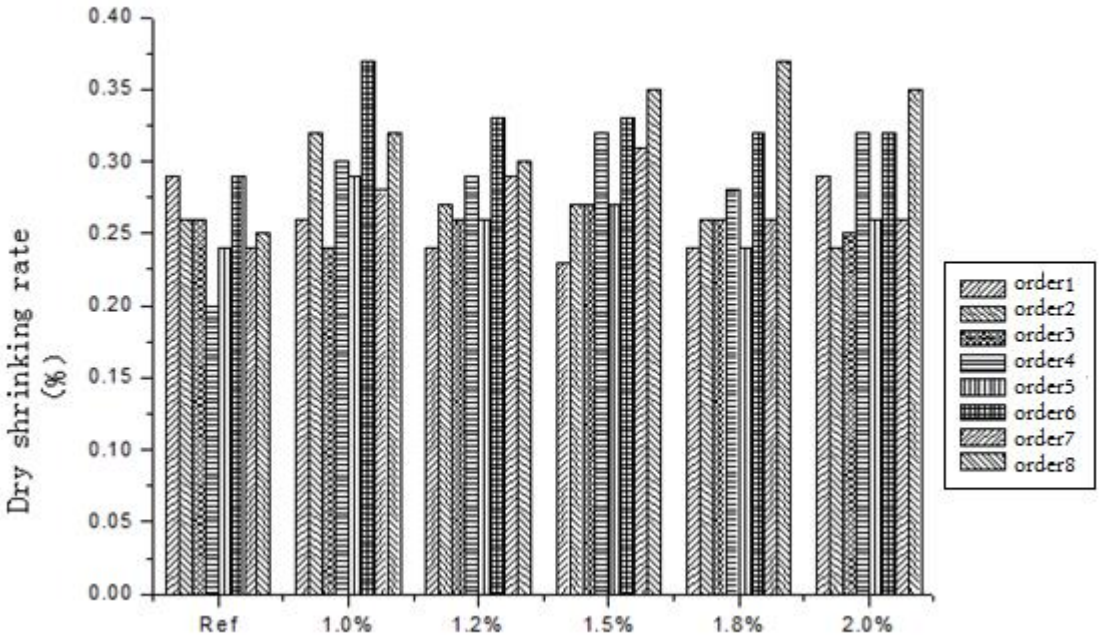

Figure 5: The dry shrinkage rate of fiber cement products

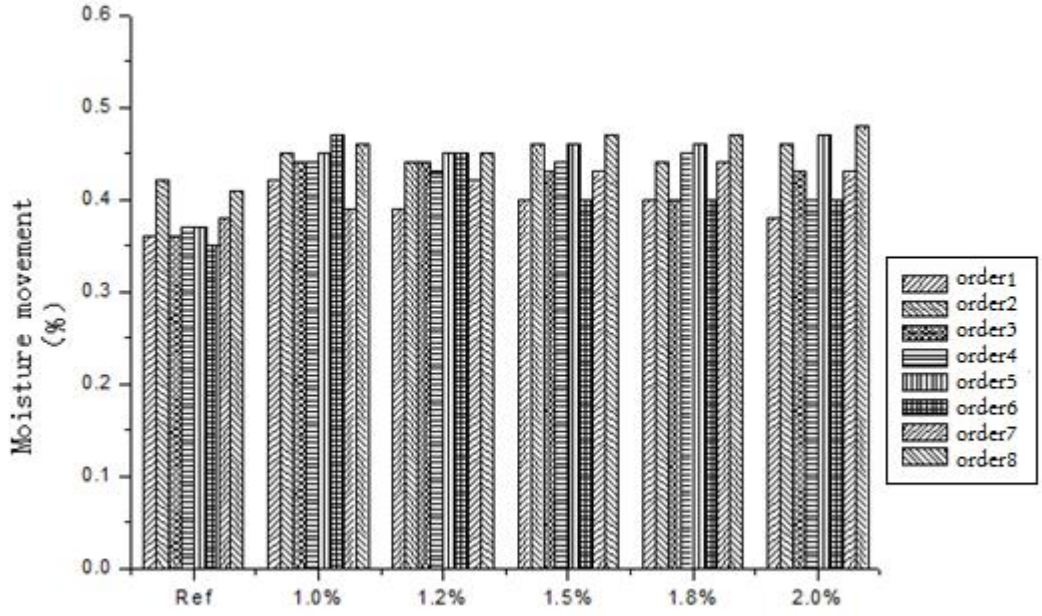

Figure 6: The moisture movement of fiber cement products

CONCLUSIONS

(1) The bending strength of the fiber cement boards prepared with the sequence "②Microsilica powder+PVA fiber-Pulp-Filler-Cement" and sequence "③Microsilica powder-PVA fiber-Pulp-Filler-Cement" are obviously higher than that of the fiber cement boards prepared by the other sequences.

(2) There is not much difference between the dry and wet densities of fiber cement products prepared in different additive sequences.

(3) The water absorption rate of the fiber cement products prepared with the additive sequence "②Microsilica powder+PVA fiber-Pulp-Filler-Cement" and sequence "③Microsilica powder-PVA fiber-Pulp-Filler-Cement" are closest to that of the blank samples.

(4) In all the tested experimental additive sequences, the additive sequence of "③Microsilica powder-PVA fiber-Pulp-Filler-Cement" is the best, followed by the sequence of "②Microsilica powder+PVAfiber-Pulp-Filler-Cement". Due to the very fine particles of microsilica powder, the defects on the surface of the fibers can be filled, so that the fibers can be dispersed more easily in water, the effect of fiber dispersion is improved, the contribution rate of fiber in cement products is increased and the performance of prepared fiber cement boards is improved.

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