EFFECT OF POLYVINYL ALCOHOL (PVA) FIBER ON AIR-CURED FIBER CEMENT PRODUCT

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ABSTRACT

Polyvinyl alcohol (PVA) fiber has been using as the main substitute fiber to asbestos in the air-cured non-asbestos fiber cement product for years. Shuangxin Environment-Friendly Material Co., Ltd started to produce high strength and high module PVA fiber since 2011 in China. The effects of PVA fiber on fiber cement products were investigated with different fiber length and content. The bending strength, density, water absorption, moisture movement of PVA fiber cement products was measured. The results showed that the general properties of the fiber cement products were can be significantly improved by filling PVA fibers. These included higher strength and lower water absorption. Basing on comprehensive consideration, the optimum fiber length and content of the PVA fiber is 6 mm and 1.5 wt% respectively. The use of PVA fibers as reinforcing fillers in the cement products represents a promising way for resolving the environmental pollutions and health problems.

KEYWORDS

Polyvinyl alcohol (PVA) fiber, Air-cured, Bending strength, Fiber cement product

INTRODUCTION

Asbestos fibers can hurt human's health. They have been studied and confirmed by many scientists. So lots of countries and regions have made laws to prohibit using asbestos fibers in kinds of industries. Construction industry have to find others materials to replace asbestos in maintain same quality and productivity in cement production. A wide variety of synthetic fibers, wood pulp has been investigated academically as a replacement for Asbestos fibers. Such as Polyvinyl alcohol (PVA) fiber, PET, PP, Glass fibers and soft wood pulp. Shuangxin Environment-Friendly Material Co., Ltd started to produce high strength and high module PVA fiber since 2011 in China. The effects of PVA fiber on fiber cement products were investigated with different fiber length and content. The bending strength, dry density, water absorption, moisture movement of the PVA fiber cement products were measured. The results showed that the general properties of the fiber cement product can be significantly improved by filling PVA fibers. The use of PVA fibers as reinforcing fillers in the cement products represents a promising way for resolving the environmental pollutions and health problems.

EXPERIMENT

Materials

Cement, Microsilica(GSE), pulp were purchased locally. PVA fibers were Environment-Friendly Material Co., Ltd. PVA fiber properties are listed in Table 1. The sample of SX4, SX6 and SX8 are 4 mm, 6mm and 8mm length of the PVA fiber, respectively.

Fabrication procedure

The formulation and curing method of the fiber cement product are listed in Table 2. All of the raw materials were based on DRY weight in the recipe. Sample preparation was according to Shuangxin Fiber cement lab standard. After sample production, all the samples were packaged in plastic bags and cured in a wooden box 50°C with a bottle of water inside for 24 hours, then each plastic bag was removed and the samples were transferred to an autoclave for curing. Autoclaving temperature and time were setup according to industry values and the autoclaving process was automatic. After autoclaving, the samples were cured in a climate cabinet at 23±2 centigrade and 50% relative humidity for 4 days, after which time the samples were ready for measurement.

Table 1 PVA Fiber properties

Sample	Linear density (dtex)	Tensile strength (CN/dtex)	Tensile modulus (CN/dtex)	Elongation (%)	Solubility (%)
SX4	2.16	12.49	315.16	6.49	0.66
SX6	2.22	12.74	313.65	6.57	0.59
SX8	2.16	12.49	315.16	6.49	0.66

Table 2 The formulation and curing method of the fiber cement product

Sample	PVA			cement	pulp	GSE	Limestone	Maintenance method
	SX4	SX6	SX8					
1	0.0%	0.0%	0.0%	81.5%	3.5%	5.0%	10.0%	Aircured
2	0.0%	1.0%	0.0%	80.5%	3.5%	5.0%	10.0%	Aircured
3	0.0%	1.5%	0.0%	80.0%	3.5%	5.0%	10.0%	Aircured
4	0.0%	2.0%	0.0%	79.5%	3.5%	5.0%	10.0%	Aircured
5	1.0%	0.0%	0.0%	80.5%	3.5%	5.0%	10.0%	Aircured
6	1.5%	0.0%	0.0%	80.0%	3.5%	5.0%	10.0%	Aircured
7	2.0%	0.0%	0.0%	79.5%	3.5%	5.0%	10.0%	Aircured
8	0.0%	0.0%	1.0%	80.5%	3.5%	5.0%	10.0%	Aircured
9	0.0%	0.0%	1.5%	80.0%	3.5%	5.0%	10.0%	Aircured
10	0.0%	0.0%	2.0%	79.5%	3.5%	5.0%	10.0%	Aircured

Measurements

The flexural properties of the pure cement product (without PVA fiber) and fiber cement product were measured using an electronic universal testing machine (DXLL-10000, No.4 Chemical Machinery Plant of Shanghai Chemical Equipment, Shanghai, China) at room temperature (23^{o}C) according to ISO Standards 178: 2003, respectively. Dry density, water absorption, moisture movement of the PVA fiber cement products was measured according to Shuangxin Fiber cement lab standard. The micrographs of the impact fracture surfaces of the fiber cement products were observed by the scanning electron microscopy (SEM, 1450, LEO, Oberkochen, Germany).

Results and discussion

The bending strength of fiber cement products

Figure 1 shows the bending strength of fiber cement product using fiber with different fiber length(4mm, 6mm and 8mm) and different fiber content (1.0 wt%, 1.5wt%, and 2.0 wt%). It shows that the bending strength of fiber cement product are improved significantly by adding 4mm, 6mm and 8mm of PVA fibers. The contents of the PVA fibers added in the fiber cement product can affect the bending strength of the fiber cement product. It is evident that bending strength of the fiber cement product adding the 4mm, 6mm and 8mm of PVA fibers increase with increasing fiber contents. The maximum increment of bending strength of the fiber cement product is 44.7%, 75% and 68.4%, respectively. In other word, the bending strength of cement product without addition of fiber is 7.61MPa, which is much lower than that of fiber cement product with addition of fiber.

The length of the PVA fibers added in the fiber cement product can also affect the bending strength of the fiber cement product. No matter using 4mm, 6mm and 8mm of PVA fibers, the bending strength of the fiber cement product is improved with the content increase of the PVA fiber. But under the condition of the PVA fiber is the same, the optimum PVA fiber length is 6 mm. When the content is 1.0 wt%, the bending strength of the fiber cement product using 4mm, 6mm and 8mm PVA fiber is 9.2 MPa, 10.4 MPa and 9.9 MPa, respectively. As the PVA fiber content increases to 1.5 wt%, the bending strength of the fiber cement product using 4mm, 6mm and 8mm PVA fiber further improve and is 10.7 MPa, 12.0 MPa and 10.6 MPa, respectively. When the content of PVA fiber content increases to 2.0 wt%, the bending strength of the fiber cement product using 4mm, 6mm and 8mm PVA fiber further improve and is 11.0 MPa, 13.3 MPa and 12.8 MPa, respectively. Basing on comprehensive consideration of bending properties, economy, environment and technology, the optimum fiber length and content of the PVA fiber is 6 mm and 1.5 wt% respectively.

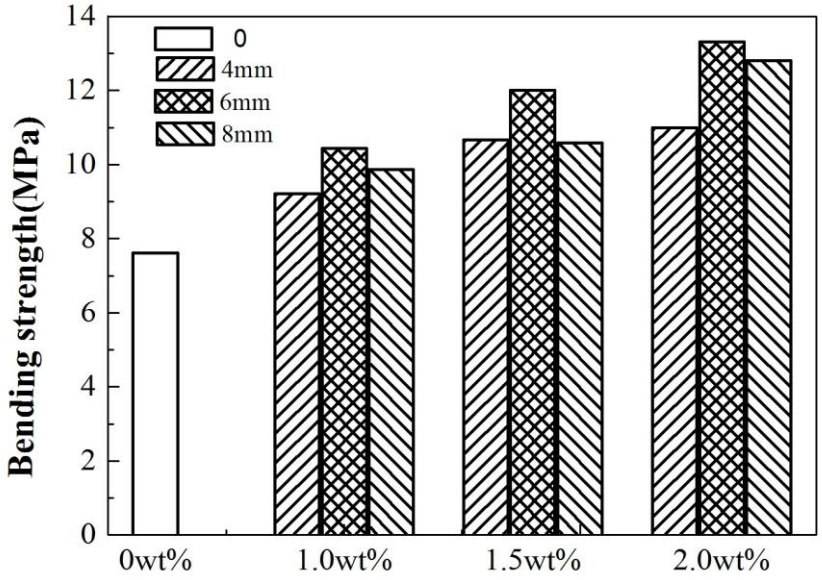


Figure 1 The bending strength of fibre cement using SX fibre

The density of the fibre cement products

The density of fibre cement products are shown in Figure 2. The density of the fibre cement products are gradually decreased with the addition of the PVA fibers compared with the fibre cement product without PVA fiber. That is mainly because the fibre's density is less than the cement and the stuff density. And the amount of hole is increasing because of the addition of PVA fibre.

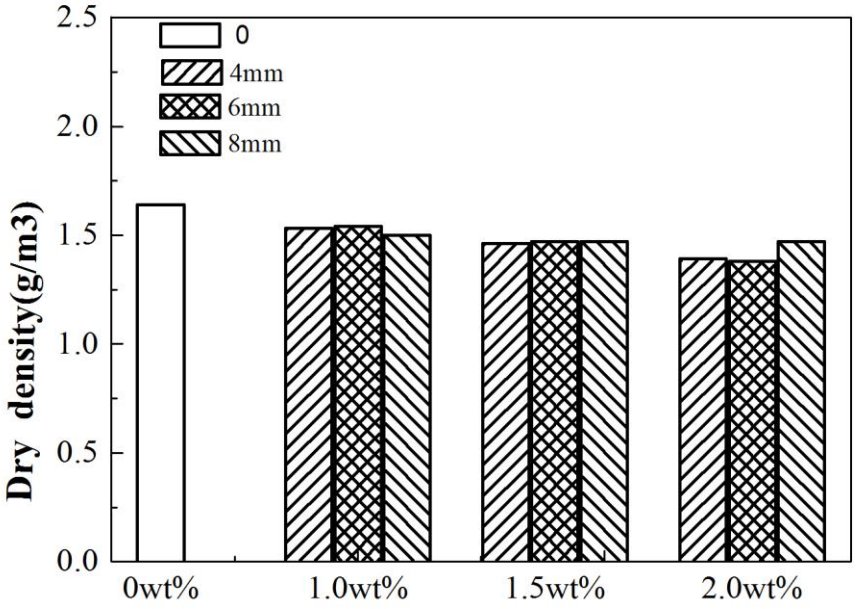


Figure 2 the density of the PVA fibre cement products

The water absorption of the fibre cement products

The absorbing water rate of the PVA fibre cement products are shown in Figure 3. The lower the density of the PVA fibre cement products is, the higher water absorption of them is.

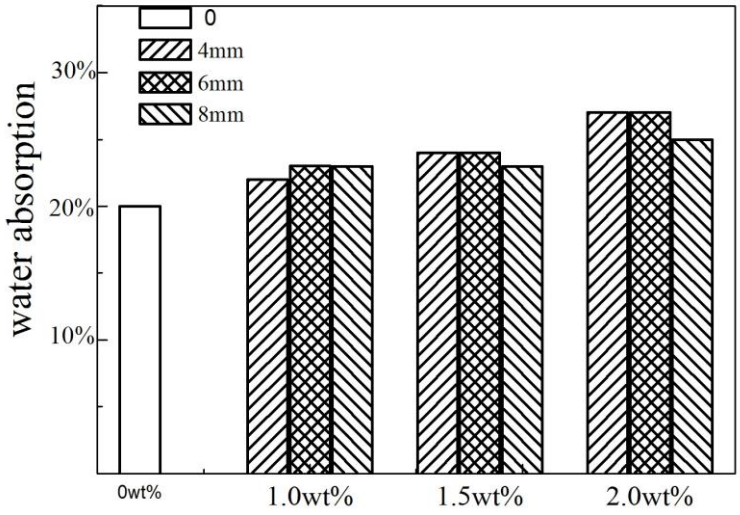


Figure 3 the water absorption of the fibre cement products

Moisture movement of the PVA fibres cement products

Moisture movement of the PVA fibre cement products are shown in the Figure 4. Adding PVA fiber tends to increase moisture movement.

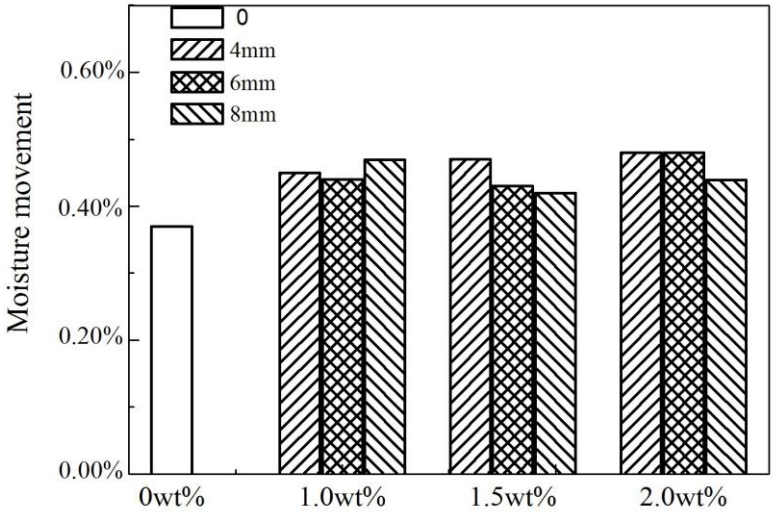


Figure 4 Moisture movement of PVAfibre cement product

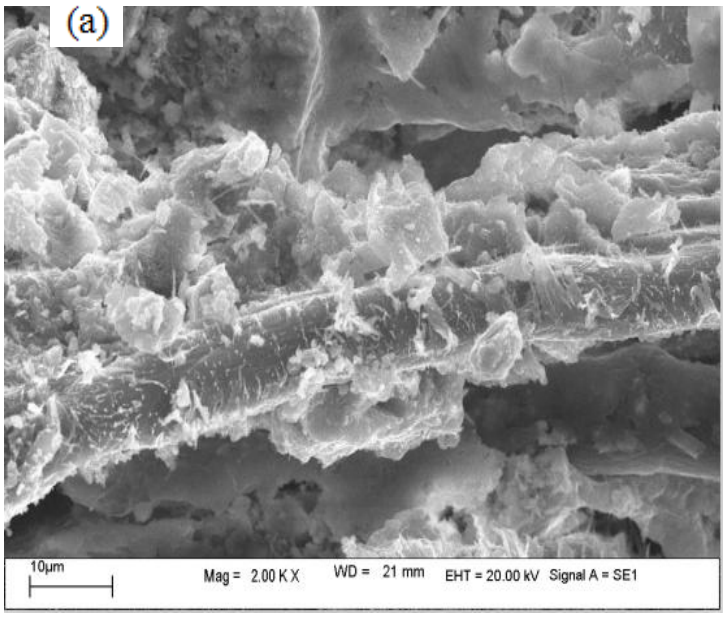
Bending fracture surfaces observation and analysis

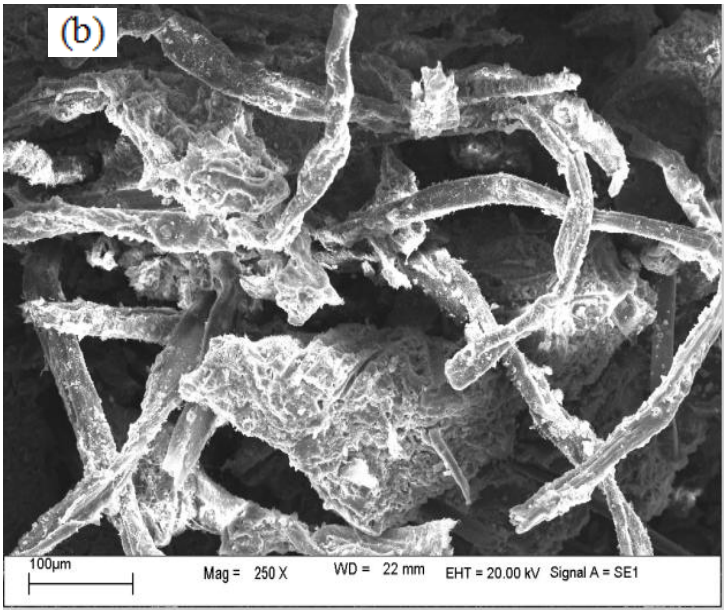
The bending properties results show that strength of the PVA fiber cement products are improved simultaneously when the PVA fiber are filled into cement products. That is mainly because the the PVA fibers possess inherent characteristics such as high length diameter ratio and high elastic modulus. Every dispersed fiber triggers effective stress concentrations and leads to mass crazes so that the weak point cannot be formed in the fiber cement products. Thus, the fiber cement products

properties are improved through the interaction of high strength particles and cement matrix. In this study, the effect of the PVA fiber is observed under SEM on the fracture surfaces of the PVA fiber cement products with 6mm PVA fiber(1.5 wt%). the results are summarized as follows.

Figure 5 shows the SEM micrographs of the bending fracture surfaces of the fiber cement products with with 6mm PVA fiber(1.5 wt%) . Figure 5(a) shows that the PVA fibers have a rough surface, indicating the strong adhesion and good compatibility between the fibers and the cement matrix. figure 5(b) shows that dispersion of the PVA fibers in the cement matrix seems to be good. The PVA fibers are intimately mixed in the cement matrix and exhibit a large extent of pullouts. All the pulled out PVA fibers have a rough surface indicating the strong adhesion, good compatibility. The bending strength of the fiber cement products depends on the crack initiation and propagation characteristics through the matrix. While the crack initiation and propagation depends on the shape, orientation of the reinforcements in the matrix and interfacial adhesion between the particles and matrix.

Results show that the PVA fibers act as the concentration of stress which leads to the formation of cracks in the matrix when they are dispersed in the cement matrix. The single PVA fibers possess high elastic modulus can first undertake the loading when the cracks propagate to the surface of the PVA fibers. Meanwhile, the PVA fibers have a larger specific surface area leading to more interfacial contact area between the filler and cement matrix. The more interfacial contact area would be beneficial to transfer the stress from the matrix to fibers. The process of the crack initiation, propagation, fiber breakage and fibers pull-outs dissipate a great amount of energy. Therefore, the bending strengths of the fiber cement products adding the PVA fibers are improved.





Conclusion

The PVA fibers can be successfully used in the air-cured non-asbestos fiber cement product. The bending strength, density, water absorption, moisture movement of PVA fiber cement products are improved significantly by adding the PVA fibers, especially the bending strength. The maximum increment of bending strength of the fiber cement product is 44.7%, 75% and 68.4%, respectively.

The PVA fibers act as the concentration of stress which leads to the formation of cracks in the matrix when they are dispersed in the cement matrix. The single PVA fibers possess high elastic modulus can first undertake the loading when the cracks propagate to the surface of the PVA fibers. The process of the crack initiation, propagation, fiber breakage and fibers pull-outs dissipate a great amount of energy. Therefore, the bending strengths of the fiber cement products adding the PVA fibers are improved.

Basing on comprehensive consideration of bending properties, economy, environment and technology, the optimum fiber length and content of the PVA fiber is 6 mm and 1.5 wt% respectively. The use of PVA fibers as reinforcing fillers in the cement products represents a promising way for resolving the environmental pollutions and health problems.

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