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Paper #08

## STUDY OF THE EFFECT OF PVA FIBER LENGTH DISTRIBUTION ON THE FIBER CEMENT PRODUCT

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### ABSTRACT

There are certain effects for different lengths of fiber on the air-cured fiber cement products with respect to performance. Also different lengths of fiber have different distribution in the fiber cement product. The effects of 6 mm PVA fiber, and mixed fiber (4 mm and 6 mm PVA fiber) on fiber cement product were investigated. The bending strength, bulk density, water absorption and moisture movement of the different fiber cement product were measured. The results showed that the performance of the fiber cement product can be effectively improved by addition of PVA fiber. The maximum improved bending strength of the fiber cement product using mixed fiber is better than that using the same amount of 6 mm PVA fiber, respectively. Compared with the cement product without fiber, the bending strength of the fiber cement products by adding 6, 4(1/3)+6(2/3), 4(1/2)+6(1/2), 4(2/3)+6(1/3) PVA fiber were improved by as much as 50.44%, 51.02%, 54.22%, 49.13%, respectively. With the same content, using a mixture of 4 mm and 6 mm PVA fiber can bring more improvement of bending strength than using single 6 mm fiber in the fiber cement product, and the optimum mixed ratio of fibers is half of 4 mm and half of 6 mm. The 4 mm and 6 mm mixed (50/50) fibers result in optimal fiber distribution and strength.

### KEYWORDS:

Fiber length, PVA fiber, bending strength, fiber cement product

### INTRODUCTION

Adding fiber in cement based composites is an effective way to improve the strength and fracture resistance of the cement products. Since the early 1980's asbestos replacement programs have been investigated in the fiber cement industry and many companies have changed to producing asbestos free products, in particular Europe and Australia were the first countries to change in the mid-eighties[1]. In recent years, more countries have to replace it with the safe and environmentally PVA fiber used in fiber cement products. These products are fiber cement boards, tiles, pipes, etc. With comprehensive analysis of technical and economical solutions the development of fiber cement asbestos free products has been very successful. Because of high strength and high modulus PVA fiber's unique performance, it can be a good alternative material for harmful asbestos and has great significance for the environment. In this paper, the effects of PVA fiber on fiber cement products were investigated with different fiber lengths and content, and the bending strength, density, water absorption, moisture movement of the PVA fiber cement products was measured.

High strength high modulus PVA fiber is produced by the wet spinning process with PVA as main raw material. High strength high modulus PVA fiber has high tensile strength, high modulus, acid resistance, alkali resistance, salt resistance, better hydrophilic, etc[2,3,4]. High strength high modulus PVA fiber has good affinity with

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cement, and can be evenly distributed in cement products. It can prevent tiny cracks caused by plastic shrinkage effectively. It can be applied to all kinds of reinforced material.

## EXPERIMENT

### Materials

Portland cement (P·O42.5), pulp(standard bleached photocopy paper), flocculent and microsilica(from Elkem Materials) were purchased locally. PVA fibers were from Shuangxin (SX) Company. PVA fiber properties are listed in Table 1. The sample of 4 is 4 mm length of the PVA fiber. The sample of 6 is 6 mm length of the PVA fiber. The sample of 4(1/3)+6(2/3) is 33.3wt% 4 mm fiber and 66.7wt % 6 mm fiber. The sample of 4(1/2)+6(1/2) is 50wt% 4 mm fiber and 50wt% 6 mm fiber. The sample of 4(2/3)+6(1/3) is 66.7wt% 4 mm fiber and 33.3wt % 6 mm fiber.

**Table 1 - PVA Fiber properties**

Sample	Linear density (dtex)	Tensile strength (CN/dtex)	Tensile modulus (CN/dtex)	Elongation (%)	Solubility (%)
4 (4 mm)	1.94	12.82	321.26	7.06	0.65
6 (6 mm)	1.96	12.57	314.68	7.05	0.76

### Fabrication procedure

The formulation of the fiber cement product is 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 laboratory standard. The process description is as follows. Add raw materials into the water. After adding each raw material mixing for few minutes. It was applied quantitative slurry and prepared the sheet. 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 8 h, then each plastic bag was removed and the samples were transferred to natural environment for curing. After curing for 14 days, the samples were ready for measurement.

### Measurements

The flexural properties of the pure cement product (without PVA fiber) and fiber cement product were measured using an automatic cement flexural testing machine (YAW-300, Shanghai Chemical Equipment, Shanghai, China) at room temperature (~23 °C). The dimension of the samples is 210mm\*80mm\*6mm. The speed of dislocation is 50 N/s. And test the bending strength of fiber cement product by using automatic cement bending compression testing machine.. There are 24 samples tested in each group. Bulk density, water absorption, moisture movement (the shrinking percentage of fiber cement products) of the PVA fiber cement products was measured according to Shuangxin fiber cement laboratory standard.

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**Table 2 - The formulation of the fiber cement product**

Sample	pulp	PVA		Microsilica	Limestone	Portland cement	Flocculent (mL)
		4 mm	6 mm				
Ref	3.5%	0.0%	0.0%	5.0%	10.0%	81.5%	1
1.0%	3.5%	0.0%	1.0%	5.0%	10.0%	80.5%	1
	3.5%	0.33%	0.67%	5.0%	10.0%	80.5%	1
	3.5%	0.5%	0.5%	5.0%	10.0%	80.5%	1
	3.5%	0.67%	0.33%	5.0%	10.0%	80.5%	1
1.2%	3.5%	0.0%	1.2%	5.0%	10.0%	80.3%	1
	3.5%	0.4%	0.8%	5.0%	10.0%	80.3%	1
	3.5%	0.6%	0.6%	5.0%	10.0%	80.3%	1
	3.5%	0.8%	0.4%	5.0%	10.0%	80.3%	1
1.5%	3.5%	0.0%	1.5%	5.0%	10.0%	80.0%	1
	3.5%	0.5%	1.0%	5.0%	10.0%	80.0%	1
	3.5%	0.75%	0.75%	5.0%	10.0%	80.0%	1
	3.5%	1.0%	0.5%	5.0%	10.0%	80.0%	1
1.8%	3.5%	0.0%	1.8%	5.0%	10.0%	79.7%	1
	3.5%	0.6%	1.2%	5.0%	10.0%	79.7%	1
	3.5%	0.9%	0.9%	5.0%	10.0%	79.7%	1
	3.5%	1.2%	0.6%	5.0%	10.0%	79.7%	1
2.0%	3.5%	0.0%	2.0%	5.0%	10.0%	79.5%	1
	3.5%	0.67%	1.33%	5.0%	10.0%	79.5%	1
	3.5%	1.0%	1.0%	5.0%	10.0%	79.5%	1
	3.5%	1.33%	0.67%	5.0%	10.0%	79.5%	1

## RESULTS AND DISCUSSION

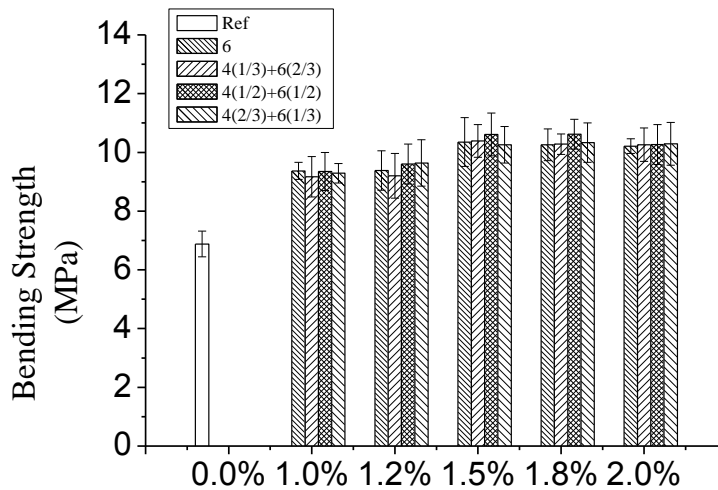
### The bending strength of fiber cement products

Figure 1 shows the bending strength of fiber cement product using fiber with different fiber length [6, 4(1/3)+6(2/3), 4(1/2)+6(1/2), 4(2/3)+6(1/3)] and different fiber content (1.0 wt%, 1.2 wt%, 1.5 wt%, 1.8 wt%, and 2.0 wt%). It shows that the bending strength of cement product without addition of fiber is 6.88MPa, which is much lower than that of fiber cement product with addition of fiber. The bending strength of cement product gradually increased with the adding fiber content from 1.0 wt % to 1.5 wt %. When the fiber content increases more than 1.5 wt%, the bending strength of cement product had little change. Therefore the optimum content of PVA fiber is 1.5 wt%. As the PVA fiber content is 1.5 wt%, the bending strength of the fiber cement reinforced

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with PVA fiber length of 6 mm, 4(1/3)+6(2/3), 4(1/2)+6(1/2), 4(2/3)+6(1/3) PVA fiber cement product is greater 50.44%, 51.02%, 54.22%, 49.13% than that of the cement product without fiber, respectively.



**Figure 1 - The bending strength of fibre cement products**

The mixed fiber (4 mm and 6 mm PVA fiber) can also improve the performance of the cement product. With the adding fiber content from 1.0 wt % to 1.5 wt %, the bending strength of the fiber cement product with mixed fiber is close to that of the fiber cement product with single 6 mm PVA fiber. With the fiber content more than 1.5 wt %, the bending strength of the fiber cement product with mixed fiber is slightly higher than that of the fiber cement product with single PVA fiber. When the addition of fiber is 1.5 wt %, the bending strength of the fiber cement reinforced with PVA fiber length of 6 mm, 4(1/3)+6(2/3), 4(1/2)+6(1/2), 4(2/3)+6(1/3) fiber cement product is 10.35 MPa, 10.39 MPa, 10.61 MPa, 10.26 MPa, respectively. The maximum increment of bending strength of the mixed fiber [4(1/2)+6(1/2)] cement product is 2.51% compared with fiber cement product filling the same content of single 6 mm PVA fiber. Thus the results indicated that the bending strength fiber cement product had significant improvement by using a mixture of 4 mm and 6 mm PVA fibers than single 6 mm fiber, and the optimum mixed ratio of fibers is half of 4 mm and half of 6 mm.

### The bulk density of the fiber cement products

The bulk density of fiber cement products were shown in Figure 2. It can be observed that the bulk density of the fiber cement product decreased with the addition of fiber. With 1.5 wt% content of the 6 mm PVA fibers, the bulk density of the fiber cement product is reduced 7.65% than that of without fiber. With 1.5 wt% content of the mixed fiber [4(1/2)+6(1/2)], the bulk density of the fiber cement product is reduced 7.65% than that of without fiber. The bulk density of the fiber cement product reinforced with PVA fiber of 6 mm is almost the same as that of the mixed fiber. That is mainly because the density of Portland cement is greater than the density of the PVA fiber.

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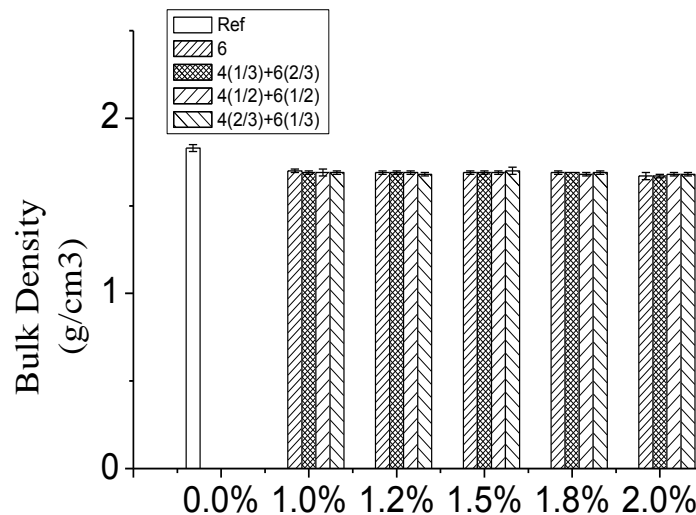


Figure 2 - The bulk density of the PVA fiber cement products

### The water absorption of the fiber cement products

The water absorption of the PVA fiber cement products is shown in Figure 3. The water absorption of PVA fiber cement product is stable. Along with the adding amount of PVA fiber increase, the water absorption of fiber cement product changes a little. That is mainly because the high strength high modulus PVA fiber has the good interface bonding force with Portland cement matrix and the result is in agreement with those of Yanhong Zheng et al. in studies of bending fracture surfaces observation and analysis. [5] The non-circular and irregular cross section of PVA fiber can contribute to expand PVA and cement matrix bonding surface. The -C-OH groups in molecular structure of the PVA fiber can form hydrogen bridge with -OH groups in cement hydrates.

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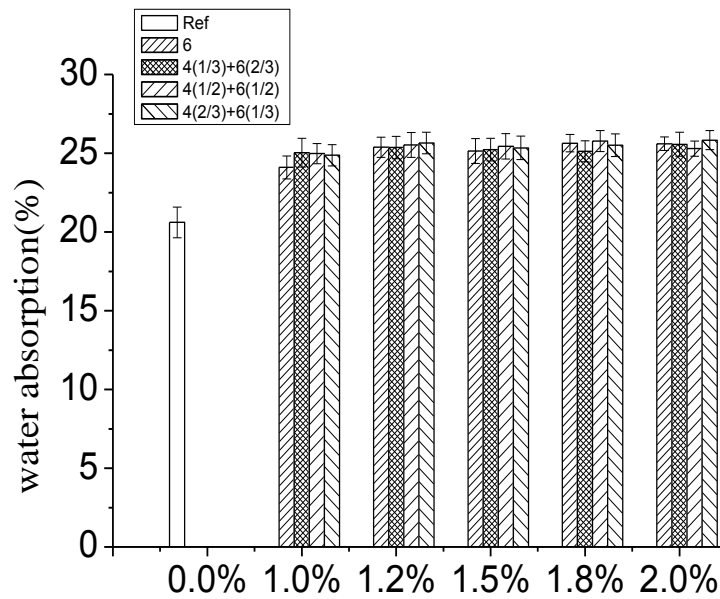


Figure 3 - The water absorption of the fiber cement products

### Moisture movement of the PVA fibers cement products

The moisture movement of the PVA fiber cement product is shown in Figure 4. It is evident that the moisture movement of the PVA fiber cement product adding the fiber increase. The amount of porosity increased because of the addition of the PVA fiber. However, with 1.5 wt% content of the fibers, the moisture movement of the 6 mm fiber cement product is almost the same as that of the mixed fiber.

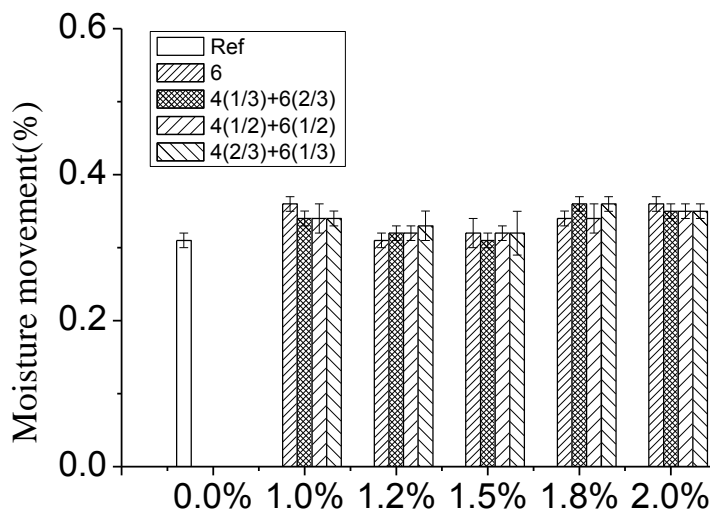


Figure 4 - Moisture movement of PVA fiber cement products

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**CONCLUSION**

When the content of fiber is 1.5 wt% in fiber cement product, compared with the cement product without fiber, the bending strength of the fiber cement products by adding 6 mm, 4(1/3)+6(2/3), 4(1/2)+6(1/2), 4(2/3)+6(1/3) PVA fiber were improved by as much as 50.44%, 51.02%, 54.22%, 49.13%, respectively.

The properties such as wet density, water absorption, of the fiber cement products adding 6 mm PVA fiber and the mixed fibers, are almost the same.

Different lengths of fiber have different distribution in the fiber cement product. With the same content, using a mixture of 4 mm and 6 mm PVA fiber can bring more improvement of bending strength than using single 6 mm fiber in the fiber cement product, and the optimum mixed ratio of fibers is half of 4 mm and half of 6 mm.

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