THE EFFECT OF DIFFERENT FILLERS ON FIBRE CEMENT

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ABSTRACT

Many fillers have been used in the fibre cement industry for years. Different fillers show different effects during use. Some of them provide the benefit of additional strength, such as pozzolanic additives like Microsilica, fly ash and rice-husk-ash. Some of them enhance other properties, such as the silicone-based product providing better water-resistance. Some of them are just used as a process aid, such as the flocculant, which adjusts the slurry property for better pick-up during the Hatschek process. Some of them are only used as inert filler for cost saving. In this paper, the effect of fillers on fibre cement is evaluated. The working mechanism of pozzolanic fillers is discussed.

KEYWORDS:

Filler, pozzolanic additive, fibre cement

INTRODUCTION

Application of fibre cement has been developing fast in recent years, more and more factories gradually transferring to non-asbestos fibre cement, especially for flat sheet production. New factories only accept non-asbestos product today in China[1,2,3,4]. Besides the main raw materials, such as cement, and quartz sand, many fillers have been used in the product. Some of them are used as the beneficial additive, some of them are used as the process aid, some of them could be used as fillers for cost saving. Different fillers have different function during production. Their working mechanism is also different depending on the curing process. Some of them, like quartz sand, are inert fillers at room temperature, but will react under autoclaving condition. In this paper, most of the common industry fillers are discussed, and the mechanism of some pozzolanic fillers in fibre cement has been studied.

EXPERMENT

Test materials

Cement and PVA fibre and cellulose fibres are common industry product in the market. Fly ash, rice-husk-ash and other fillers were collected from the market, Microsilica was supplied by Elkem. Specification of raw materials are shown in the appendix.

Test procedure

All of the raw materials were based on DRY weight in the recipe.

Sample preparation and measurement was according to Elkem Fibre cement lab standard. (Elkem Fibre cement technical centre standard, MAT-FC-20110105.801~806)

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 the required curing stage.

After curing stage, 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.

Primary test on the different fillers

With regards to non-asbestos air-cured product from local factories, waste cement bags and different fillers were tested. These fillers are commonly used or tried by different factory in different regions. Microsilica, fly-ash, rice-husk-ash, Metakaolin, limestone, Bentonite, diatomite were evaluated in the test. Test recipe are shown in table 1.

Table 1. Test recipe on different fillers

Sample ID	Cement	Cellulose (Cement bag)	PVA fibre	Bentonite	Metakaolin (MK)	Microsilica (MS)	Rice Husk Ash (RHA)	Diatomite (DE)	Fly Ash (FA)	Limestone (LM)
Ref	95%	3%	2%	0%	0%	0%	0%	0%	0%	0%
Filler-1	89%	3%	2%	1%	5%	0%	0%	0%	0%	0%
Filler-2	89%	3%	2%	1%	0%	5%	0%	0%	0%	0%
Filler-3	89%	3%	2%	1%	0%	0%	5%	0%	0%	0%
Filler-4	89%	3%	2%	1%	0%	0%	0%	5%	0%	0%
Filler-5	84%	3%	2%	1%	0%	0%	0%	0%	10%	0%
Filler-6	84%	3%	2%	1%	0%	0%	0%	0%	0%	10%
Filler-7	89%	3%	2%	1%	2%	3%	0%	0%	0%	0%

The strength results in figure 1 indicate that Microsilica, Rice-husk-ash and fly ash has shown a beneficial effect on the sample. Other fillers have no visible effect on the sample. In this test, bending strength of the sample filler-2 with 5% Microsilica increased bending strength to 12.4MPa from 9.3MPa for the reference sample. Sample filler-3 with 5% rice-husk-ash reached 10.1MPa, and sample filler-5 with 10% fly ash reached 11.0MPa. Among the three fillers of Microsilica, fly ash and rice-husk-ash, Microsilica was the best with the respect to improvement in the bending strength. Density and water absorption results are shown in figure 2 and figure3. It is in line with the result of bending strength, the high strength sample showing high density and low water absorption. In this test, sample filler-2 with 5% metakaolin has relative higher density 1.40g/cm3 and lower water absorption 27% compared to reference sample, but strength was not increased, it is more like the inert filler in the test.

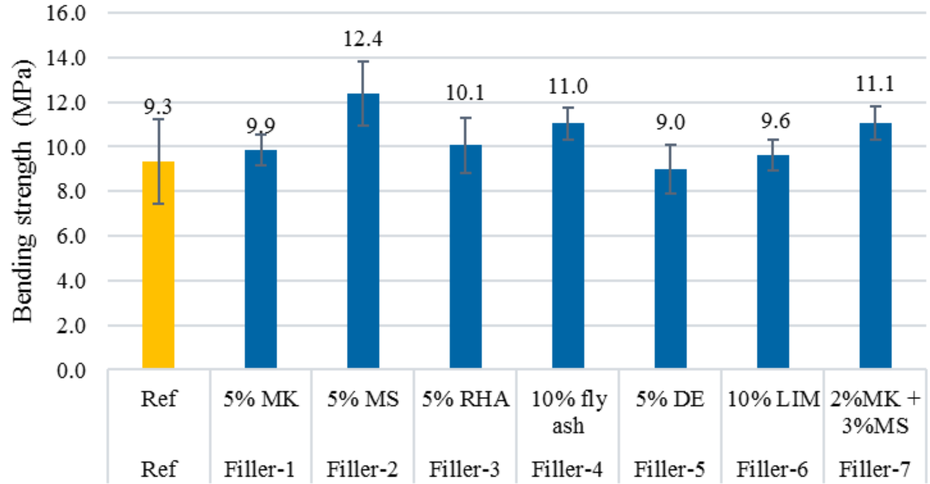

Figure1 Bending strength

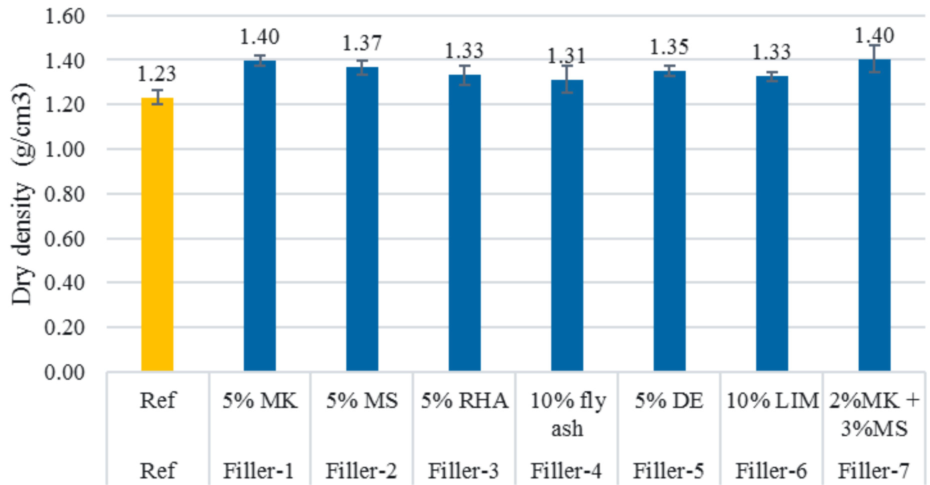

Figure2 Dry density

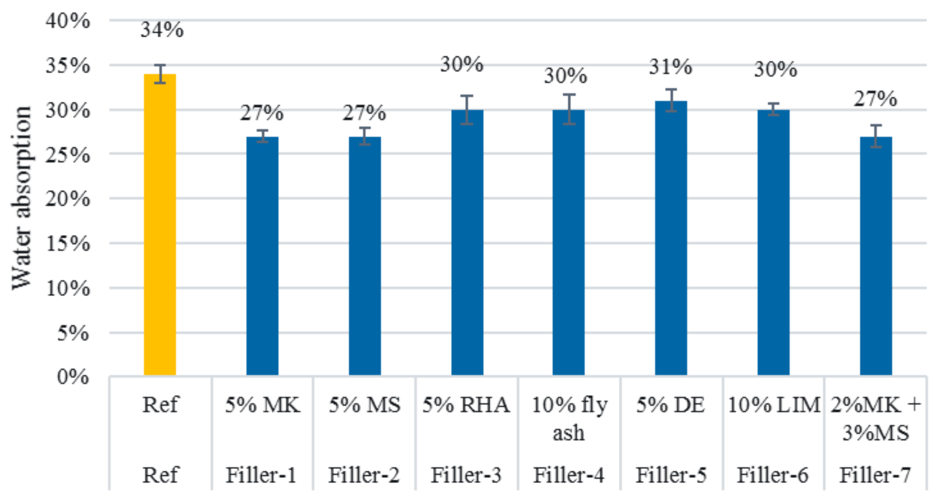

Figure3 Water absorption

Pozzolanic fillers Microsilica, rice-husk-ash and fly ash

Generally speaking, Microsilica, rice-husk-ash and fly ash are used as pozzolanic additives in cement-based products. Pozzolanic effect means the siliceous component of these fillers and calcareous component created by the cement hydration react together and create more binder, which creates a denser structure and higher strength product. One test to study the effect of the three pozzolanic fillers was conducted in the lab. Two types of fly ash and two types of Rice-husk-ash were tested. Test recipe was shown in table2.

Table 2 Test recipes of three pozzolanic fillers

Sample ID	Cement	Pulp	PVA	Fly ash 1 (PFA 1)	Fly ash 2 (PFA 2)	Rice-husk-ash 1 (RHA1)	Rice-husk-ash 2 (RHA2)	Microsilica (MS)
Pozz-ref	**95.00%**	**3.5%**	**1.5%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Pozz-2	**90.00%**	**3.5%**	**1.5%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**5.0%**
Pozz-3	**90.00%**	**3.5%**	**1.5%**	**5.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Pozz-4	**90.00%**	**3.5%**	**1.5%**	**0.0%**	**5.0%**	**0.0%**	**0.0%**	**0.0%**
Pozz-5	**90.00%**	**3.5%**	**1.5%**	**0.0%**	**0.0%**	**5.0%**	**0.0%**	**0.0%**
Pozz-6	**90.00%**	**3.5%**	**1.5%**	**0.0%**	**0.0%**	**0.0%**	**5.0%**	**0.0%**

It was indicated in figure 4 that only Microsilica increased the strength. Sample pozz-2 with 5% Microsilica reached 10.4Mpa bending strength, a 6% increase compared to 9.6MPa of the reference sample. In this test, strength of all samples containing fly ash or rice-husk-ash was decreased compared to the reference sample. Sample Pozz-3 and pozz-4 containing fly ash reached 8.8MPa and 9.0MPa respectively, and sample pozz-5 and pozz-6 containing rice-husk-ash reached 9.1MPa and 9.3MPa respectively, which were all lower compared to the reference sample pozz-ref or equivalent to the level of the reference sample.

Some factories try to grind fly ash to improve the reactivity for better strength gain. One test to compare the effect of fineness of fly ash on the strength performance was conducted. Two types of fly ash with different fineness were tested, Microsilica was tested as reference. Ground fly ash samples are named as G-PFA 1 and G-PFA2 respectively in the test, corresponding normal fly ash sample was named as PFA1 and PFA 2 respectively. Test recipe was shown in table4. Fineness of the four fly ash samples was presented in table 4. Bending strength result was shown in the figure 5.

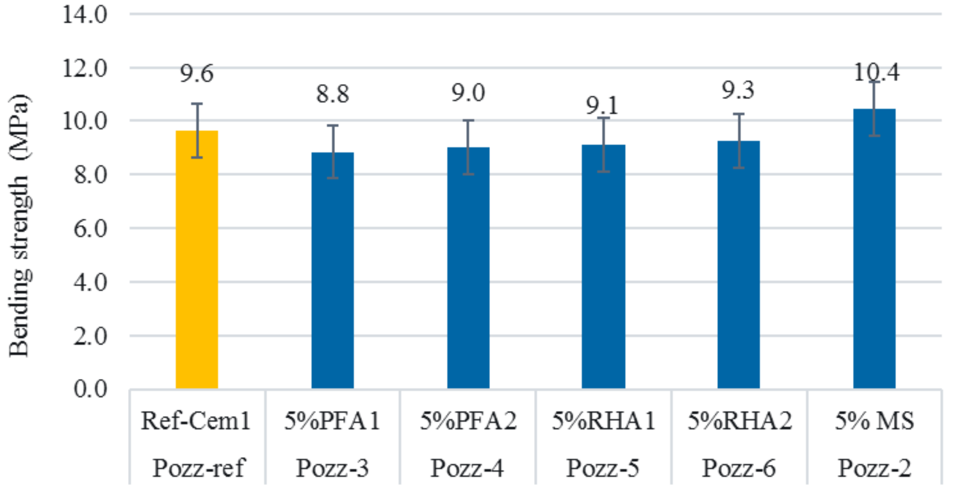

Figure4 Bending strength

Table 3 test recipe of different fineness of fly ash

Sample ID	Standard Cement	Pulp	PVA	PFA1	PFA2	PFA1-Ground (G-PFA1)	PFA2-Ground (G-PFA2)	Microsilica
Ref	95.00%	3.5%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%
F-MS	90.00%	3.5%	1.5%	0.0%	0.0%	0.0%	0.0%	5.0%
PFA1	90.00%	3.5%	1.5%	5.0%	0.0%	0.0%	0.0%	0.0%
PFA2	90.00%	3.5%	1.5%	0.0%	5.0%	0.0%	0.0%	0.0%
G-PFA1	90.00%	3.5%	1.5%	0.0%	0.0%	5.0%	0.0%	0.0%
G-PFA2	90.00%	3.5%	1.5%	0.0%	0.0%	0.0%	5.0%	5.0%

Table 4 Fineness of fly ash samples

Sample ID	Specific Surface Area (m^2/kg)	D50(um)
PFA 1	309	60.0
PFA 2	246	32.8
G-PFA1	475	29.0
G-PFA2	340	12.5

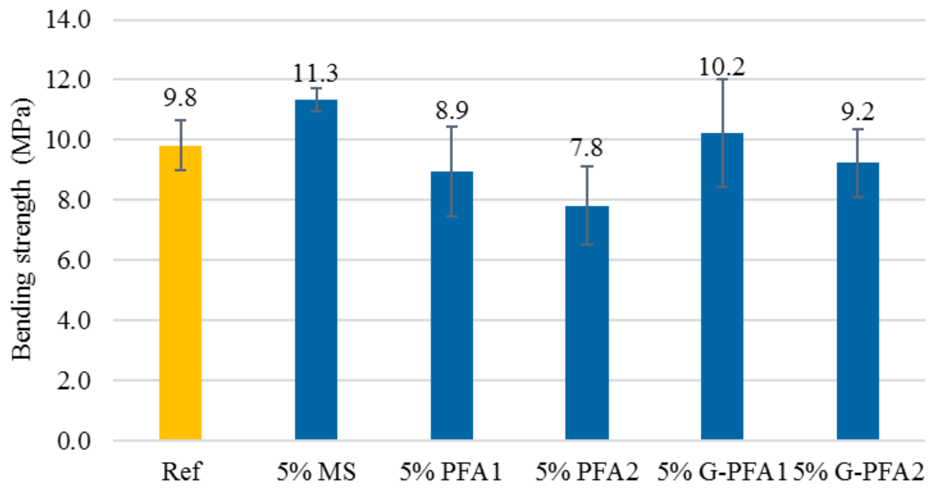

Figure5 Bending strength

The strength results in the figure 5 indicated that beneficial effect of fly ash was improved through the grinding process. Bending strength of the sample G-PFA1 by adding ground fly ash was increased to 10.2MPa from 8.9MPa of the sample PFA1 with non-grinding fly ash. Bending strength was increased to 9.2MPa (G-PFA2) from 7.8MPa (PFA2) when using ground fly ash 2.

Although the beneficial effect was improved after fly ash was ground, its final strength was often still lower than that of the reference sample. In this test, only the sample containing ground fly ash 2 (G-PFA2) and sample with Microsilica (MS) showed the beneficial effect, its strength was higher than that of reference, all the other sample's strength was lower compared to the reference sample. Sample with Microsilica got the highest bending strength among this group, 11.3MPa, increased 16% from the reference strength 9.8MPa.

Besides the effect on the strength and other physical property, one test to study the effect of rice-husk-ash on the durability was conducted. Strength retention and dimension variation of sample after freeze/thaw cycles and heat/rain treatment was measured. Microsilica was tested as reference. Test recipe are shown in table5.

Table 5 test recipe of durability with regarding the freeze-thaw and heat-rain resistance

Sample ID	Cement	Microsilica	Rice-husk-ash (RHA)	Cellulose	PVA fibre
Blank	**94%**	**0%**	**0%**	**4%**	**2%**
REF-AIR	**89%**	**5%**	**0%**	**4%**	**2%**
RHA-3	**89%**	**0%**	**5%**	**4%**	**2%**
RHA-11	**88%**	**2%**	**4%**	**4%**	**2%**

Figure 6 shows the strength retention of the sample after 360 freeze-thaw cycling curing and 228 heat-rain cycle.

It was indicated from figure 6 that the reference sample and sample with 5% Microsilica had high strength retention after 360 F/T cycling curing, sample with combination of 2% Microsilica and 3% rice-husk-ash also has above 90% strength retention, however the sample with 5% rice-husk-ash only got 77% strength retention. Heat-rain test also shows the similar result. Furthermore, reference sample and sample with 5% Microsilica even got higher strength after 228 heat-rain cycles, it could be due to the accelerated hydration for the high temperature.

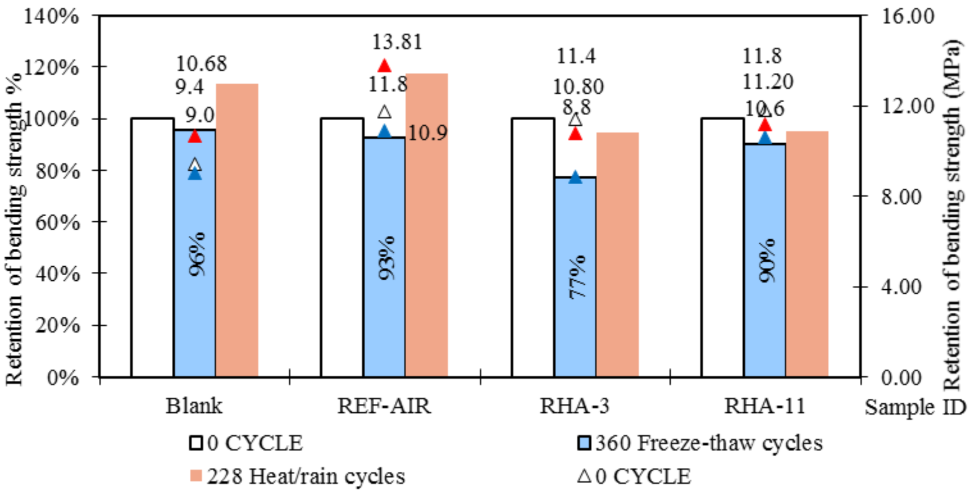

Fig 6: Bending strength after 360 F/T and 228 H/R curing cycles

Dimension variation of the sample during freeze-thaw cycling curing was shown in the figure 7. It was indicated in the figure 7 that sample with Microsilica was shown the best performance among the group, its dimension variation was lower than that of the reference sample. Sample with 5% Microsilica only got about half value compared to the sample with 5% rice-husk-ash during heat-rain cycles. Combination of Microsilica and rice-husk-ash was shown improved performance compared to use rice-husk-ash alone, but it was still lower than that of the sample with use Microsilica alone.

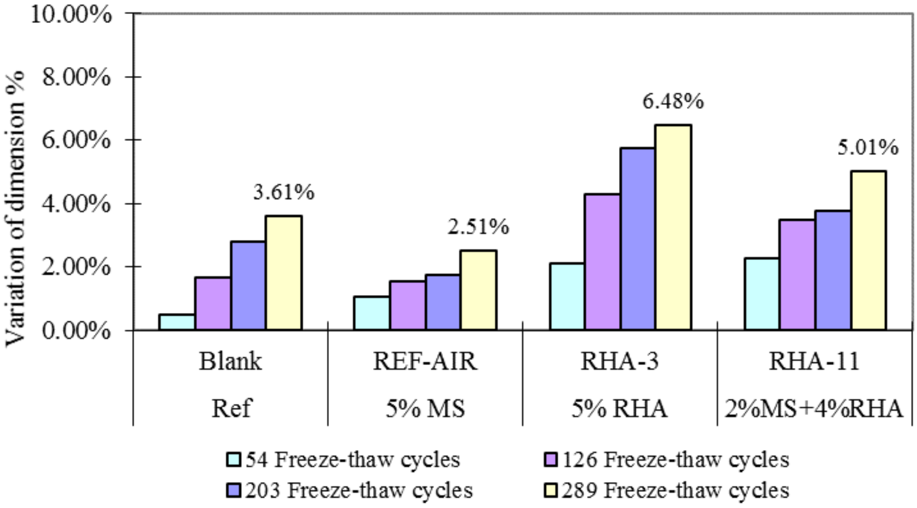

Fig 7 Variation of dimension after F/T

Appearance of the sample after 360 freeze-thaw cycles was shown in Figure 8. It was indicated in Figure 8 that the appearance of the sample containing Microsilica was no visible crack on the sample, compared with rice-husk-ash.

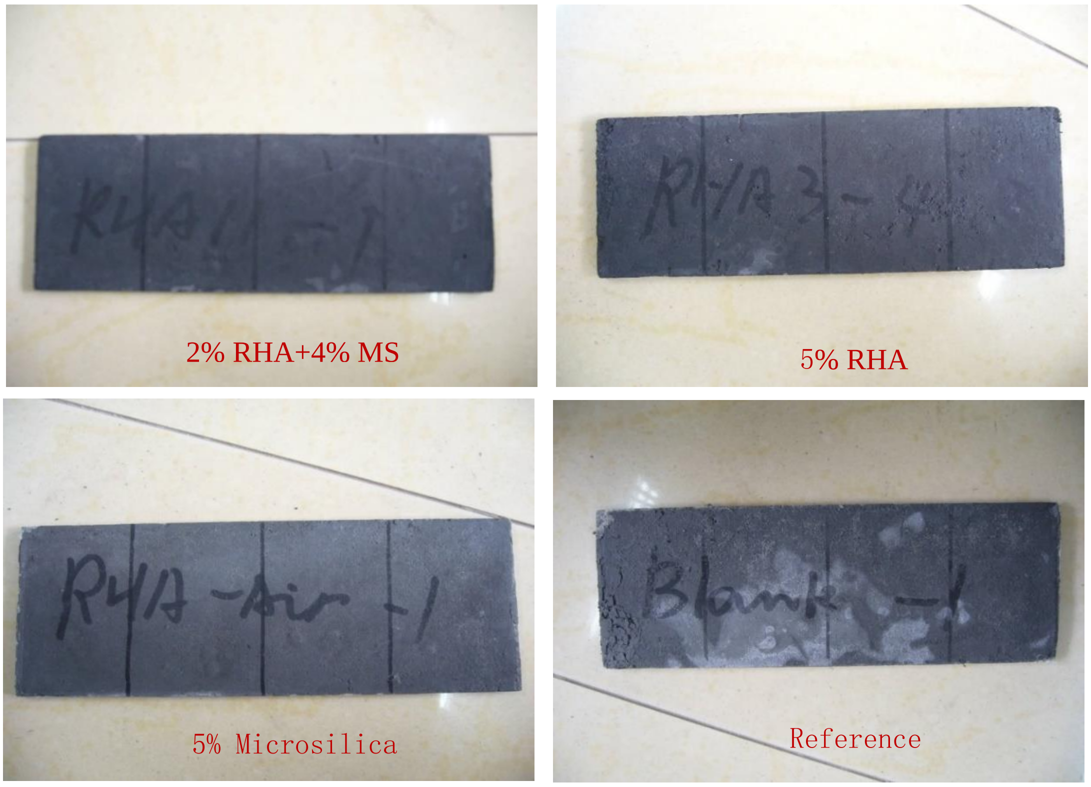

Figure 8 appearance of the sample after 360 freeze-thaw curing

DISCUSSION

Pozzolanic fillers theoretically will improve the strength of cement-based product, but this beneficial effect was not always visible as presented in the above test results. It was indicated that beneficial effect of pozzolanic fillers was affected by many factors. Fibre cement production is very complex slurry technology, all of the component in the recipe will influence each other, its final product property could be very variable. As the main raw materials, cement, cellulose fibre and PVA fibre always play the important role in the final performance of the product.

With the respect of pozzolanic additives, its pozzolanic reaction was much depending on the two factors, one is the amount of siliceous component and calcareous component in the system, another is the activity of these siliceous and calcareous component. Content of siliceous component is offered from the fillers, such as Microsilica, fly ash and rice-husk-ash, and calcareous component is created by the cement hydration.

For the air-cured recipe, if the cement content was replaced by the pozzolanic fillers, beneficial effect will be controlled by two mechanisms. One positive effect is the pozzolanic reaction between filler and calcium hydroxide Ca(OH)2 offered by cement hydration, which create more binder and increase the density of the structure, strength will be increased. On the other hand, one negative effect could be the less hydrated phase in the matrix due to the reduced cement content, which may lead to an overall strength decrease. The balance of the two effects will decide the final beneficial performance of a pozzolanic filler.

For autoclaved recipes, behaver of these pozzolanic fillers is complex because the hydration process and final phase is different compared to the air-cured recipe. Development of strength and other physical properties of air-cured recipe and autoclaved recipe are quite different, and its hydration mechanism is different as well.[5] Fillers is more complex under autoclaved curing regimes, some inert filler will be involved in the reaction and could give more effect on the final property of the product. It will be discussed in future research.

With the respect of beneficial effect, Microsilica is the best additive among the all common fillers to be used in the industry. Its advantage to the fibre cement product has been proven widely [6,7,8,9]. Elkem Fibre Cement

Technical Centre has made an investigation and study of some common additives [10]. The primary effect of the additives on fibre cement are listed in table 6.

Table 6. Some additives and their effect on non-asbestos fibre cement

Additive	**Function in fibre cement production**
Microsilica®	Increase the strength and durability, reduce delamination
Mica	Improve the volume stability and reduce the drying shrinkage.
Limestone	Improve the durability and reduce the drying shrinkage
Fly ash	Partial replacement of some raw materials for saving cost. It might give contribution in the strength, but quality of fly ash was very variable and difficult to control.
Rice husk ash	Could increase strength and other performance if quality is controlled in good way.
Wollastonite	Adjust the fibre cement slurry property, as well as some contribution to reduce the drying shrinkage and the thermal shrinkage in a fire
Sepiolite	Adjust the fibre cement slurry for easy control during Hatschek process.
Diatomite	Partial replacement of siliceous raw materials for saving cost，sometimes could adjust the FC slurry property; also acts as density reducer
Bentonite	Adjust FC slurry property.
Vermiculite	Used for light density product.
Perlite	Used for light density product
Flocculent	Polyacrylamide polymer product normally, it’s mainly used to adjust the FC slurry for easy picking up and reduce the amount of particles lost during the Hatschek process.
Defoamer	Generally used to avoid too much foams in the FC slurry, which might be created by recycled papers or off-grade PULP.

CONCLUSIONS

- Different fillers have different function in fibre cement product.
- Beneficial effect of pozzolanic filler is influenced by many factors.
- Grinding fly ash has a beneficial effect, but it was still not good enough to guarantee product performance.
- Compared with fly ash and rice-husk-ash, Microsilica is the best with the regards to strength increase and improving the freeze-thaw and heat-rain resistance.

APPENDIX.

Specification of Cement

SiO2	Al2O3	Fe2O3	CaO	MgO	SO3	Na2O eq	f-CaO	Loss	Cl
22.01	4.47	3.45	64.31	2.45	2.45	0.512	0.9	1.27	0.01

Physical performance of cement

Fineness 0.08/%	Density (g/cm3)	Specific Area m3/kg	Standard Consistency %	Setting Time (min)		Bending Strength (MPa)	Compressive Strength (MPa)
				Initial set	Final set	3 days	3 days
0.8	3.15	343	25.8	142	202	6	27.7

Specification of cellulose

Brand	Kappa	Fibre Length (mm)		
		Max	Min	(Ave)
Usutu	25	4.71	1.08	2.33

Specification of the three pozzolanic fillers

%	Microsilica	Rice-husk-ash	PFA 1	PFA2
SiO2	96.1	88.16	64.15	46.21
H2O	0.61	1.48	0.27	0.13
LOI950	1.12	4.56	3.16	0.11
+0.045mm	0.14	1.72	2.13	2.72
SiC	0.11	2.72	0.05	0.05
Fe2O3	0.02	0.40	4.37	>5.5
Al2O3	0.14	0.29	>1	>1
CaO	0.34	0.52	>2	>2
MgO	0.4	0.31	0.52	1.59
Na2O	0.2	0.04	0.29	1.09
K2O	0.92	1.71	0.98	1.92
P2O5	0.1	>0.11	>0.11	>0.11
SO3	0.51	0.14	0.97	>3
Cl	0.02	0.20	<0.006	<0.006

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