IIBCC
International Inorganic-Bonded Fiber Composites Conference

November 8th – 11th 2016, Fuzhou Empark Exhibition Grand Hotel, Fuzhou, China

Paper #03

DEVELOPMENT OF AIR-CURED FIBRE CEMENT TECHNOLOGY IN CHINA AND THE APPLICATION OF MICROSILCA

LIN ZHEN, ZHANG YI; XINMENG LI

Elkem Silicon Materials Fibre Cement technical centre
No.16 Guanghua Rd, Fanghezhengyuan of Zhangjiawan Industrial Zone Tongzhou District,101113,Beijing, P.R.China

lin.zhen@elkem.no

YUWEI HUNG, LINA GU, Mingzhi Zhou
SINOMA Hongbo Zhuzhou Co., Ltd

No.8 Hangkong Rd, Dongjiaduan high-tech industry zone of lusong district, Zhuzhou, Hunan of China

13707338178@139.COM

ABSTRACT

Non-asbestos fibre cement products have been developing for years in developed countries. However asbestos cement product is still allowed to be used in China, India, Sri Lanka and some developing countries, even though there is no doubt that asbestos products will be gone sooner or later because of its harmful effect on human health. In this paper, non-asbestos air-cured technology is discussed. One ongoing Chinese project is introduced as well. Besides the bending strength and other primary physical properties, the accelerated carbonation shrinkage and heat-rain resistance properties are also evaluated in this study. As a common additive in air-cured fibre cement recipes, the benefit and effect of Microsilica and its mechanism are discussed in this paper.

KEYWORDS:

Microsilica, durability, non-asbestos, fibre cement

INTRODUCTION

Even though the controversy regarding using or abandoning asbestos still exists, non-asbestos products represent the future development of the fibre cement industry in the country. More and more factories gradually transfer to the non-asbestos fibre cement from asbestos production, especially for the flat sheet production, new established factories only accept the non-asbestos product today in China[1,2,3,4]. So far, mainly Autoclaved technology has been selected as the technology for the non-asbestos flat sheet production in China. However this situation could change due to the environmental pressure. Coal got more and more restriction to be used as the fuel to make the steam for autoclaved fibre cement. Air-cured fibre cement technology was promoted gradually under this situation; many additives have been tried in the industry. Effect of different additives was tested in the lab, some trial samples were evaluated as well. Besides the bending strength and other primary physical properties were tested among these tests, the freeze-thaw resistance property, accelerated carbonation shrinkage and heat-rain resistance properties are also evaluated in this study. As a common additive in air-cured recipes, the benefit and effect of Microsilica and its mechanism are discussed in this paper.

COMPARISON OF AIR-CURED TECHNOLOGY AND AUTOCLAVED TECHNOLOGY.

Recipe and strength development of fibre cement produced by autoclaved technology and air-cured technology are different.

For the air-cured technology, the main raw materials are cement, cellulose and PVA fibre, and some additives. For the autoclaved technology, the main raw materials are calcareous materials and siliceous materials, normally it are cement or calcium oxide and quartz sand, cellulose and some additives.

Development of strength and other physical properties of air-cured recipe and autoclaved recipe are quite different. For the air-cured recipe, strength of the product mainly originates from cement hydration and additives effect. For the Autoclaved recipe, to guarantee that the chemical reaction happens between the calcareous materials and siliceous, autoclave condition is very important besides the recipe and raw materials quality. Moreover, as the calcareous materials in the autoclaved recipe, either lime or cement could be selected, and it is clear that their respective hydration mechanism is different as well.

Figure 1 shows the reaction mechanism of the cement, the main component of air-cured recipes.

Figure 2 shows the reaction mechanism of the autoclaved product.

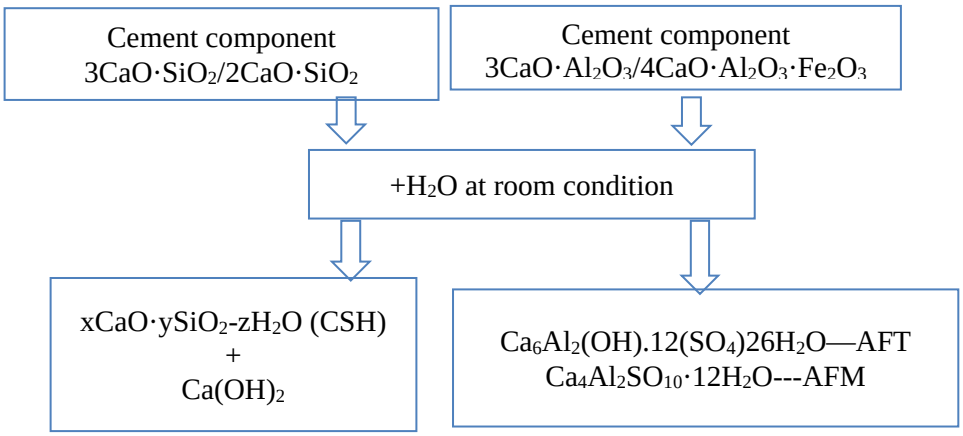

Figure 1. Cement hydration mechanism of the air cured fibre cement product

For the air-cured recipe, cement is the main component in the recipe. Its type, dosage and fineness all influence the properties of the fibre cement product. Besides the cement, additives in the fibre cement recipe will also influence the final property of fibre cement product.

For the autoclaved recipe, hydration process is little different depending on the calcareous raw material. If the calcareous raw material is only the cement in the recipe, its hydration will experience two stages during autoclaving, cement hydration and autoclaving reaction. Cement hydration is same as the air-cured product, however the hydration speed would be fast compared to the normal cement hydration for the high temperature and saturated steam condition. Second stage is the reaction between calcareous material and siliceous material (>174℃ in theory); SiO2 will react with Ca(OH)2 created by the cement hydration to create tobermorite even Xonolite, which give the strength of the product.

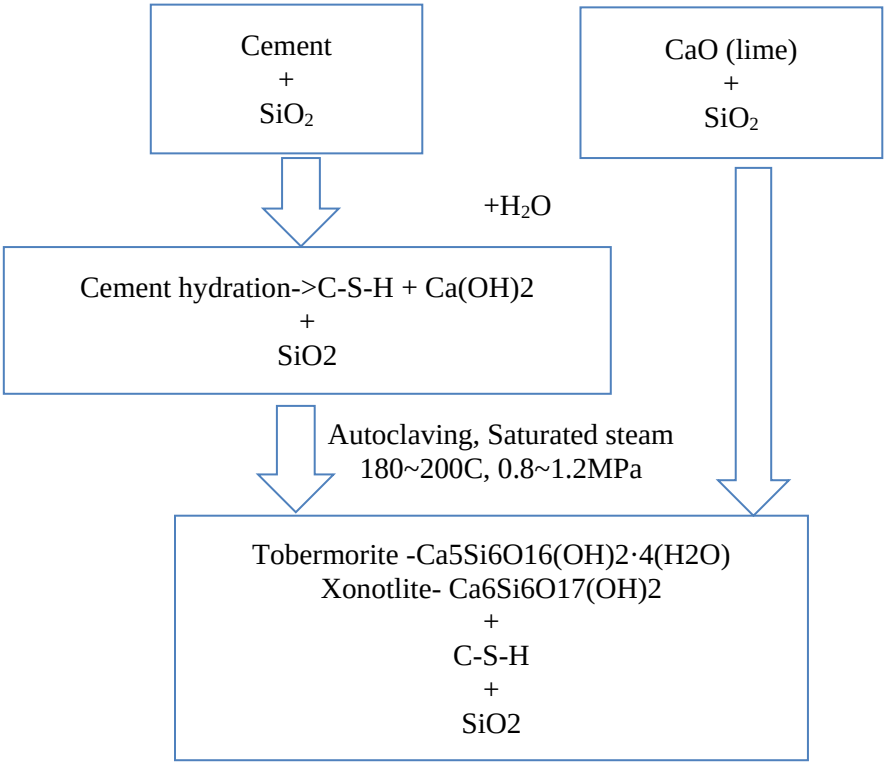

Figure 2. Hydration mechanism of Autoclaved cured fibre cement product

Summary of the effect of some additives on fibre cement product.

Besides the main raw materials, many additives could be used in the fibre cement recipe. Such as Microsilica, wollastonite, diatomite, fly ash, mica etc [5]. These additives act in different way in the fibre cement product. Elkem fibre cement technical centre has made one investigation and study on some additives and list the primary effect of some additives on the fibre cement, which is listed in the table1.

Beside the effects listed in the table 2, there are definitely more additives which could be used for the fibre cement production, and although the functions of some of the listed additives are maybe not correct or precise, it are the general feedback from the industry. [6]

In this paper, we focus on the additive Microsilica and its effect on the air-cured non-asbestos fibre cement product. Both lab sample and industry product were studied. Working mechanism of Microsilica in fibre cement was discussed.

Table 1. Some additives and its effect on non-asbestos fibre cement product

Additive	Function in fibre cement production
Microsilica®	Increase the strength and durability, improve the problem of 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 the waster papers or off-grade PULP.

TEST RAW MATERIALS AND RELATED TECHNOLOGY

According to the situation of local raw materials, we made a primary recipes development test in the lab, and Chinese fibre cement factory SINOMA Hongbo Zhuzhou Co., Ltd made the industry trial according to the test results with modified recipe.

This test is mainly to give a reference recipe for the air-cured non-asbestos fibre cement product and evaluate the reinforcement effect of Microsilica. As the common reinforcement additive, Microsilica has been used in the industry for years. In this test, 5% Microsilica was added in the recipe, its reinforcement effect was studied. Besides Microsilica, two other additives, wollastonite and mica, were also used in the recipe according to the local situation and its function.

Test recipe is listed in Table 2. Strength and other primary physical property are shown in figure 3 to figure5.

Table 2. Lab test recipe

ID	Cement	Cellulose	Microsilica (MS)	PVA	Wollastonite	Mica	Limestone (LM)
HB08	72.0%	3.5%	5.0%	0.5%	5.0%	2.0%	12.0%
HB09	71.5%	3.5%	5.0%	1.0%	5.0%	2.0%	12.0%
HB10	71.0%	3.5%	5.0%	1.5%	5.0%	2.0%	12.0%
HB14	88.5%	3.5%	0.0%	1.0%	5.0%	2.0%	0.0%
HB15	83.5%	3.5%	5.0%	1.0%	5.0%	2.0%	0.0%
HB16	83.0%	3.5%	5.0%	1.5%	5.0%	2.0%	0.0%

The strength results in the figure 3 indicate that Microsilica has visible reinforcement effect on the sheet. All the samples with 5% /Microsilica got much higher strength compared to the sample HB14 without Microsilica.

Group with 12% limestone got lower moisture movement compared to the group without limestone, figure4.

Increase of PVA fibre dosage led to the increase of the strength and bending work (toughness), figure3 & figure5.

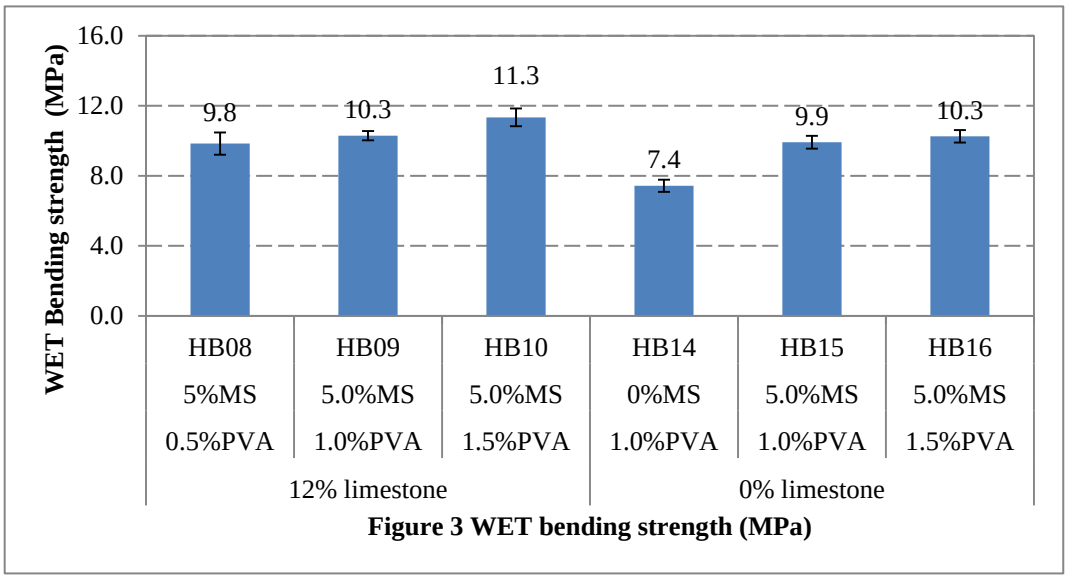

Figure 3 WET bending strength (MPa)

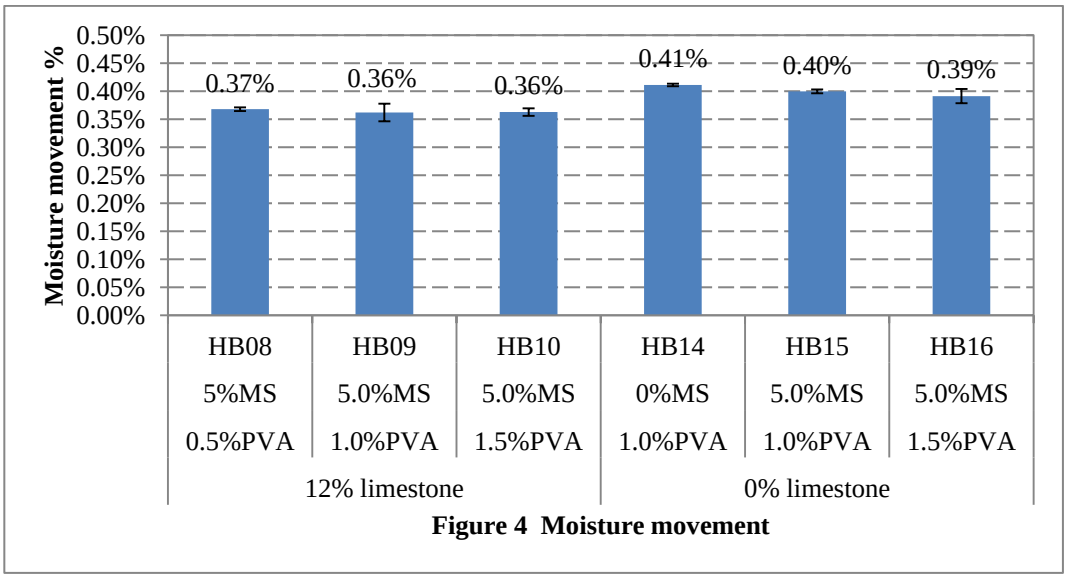

Figure 4 Moisture movement

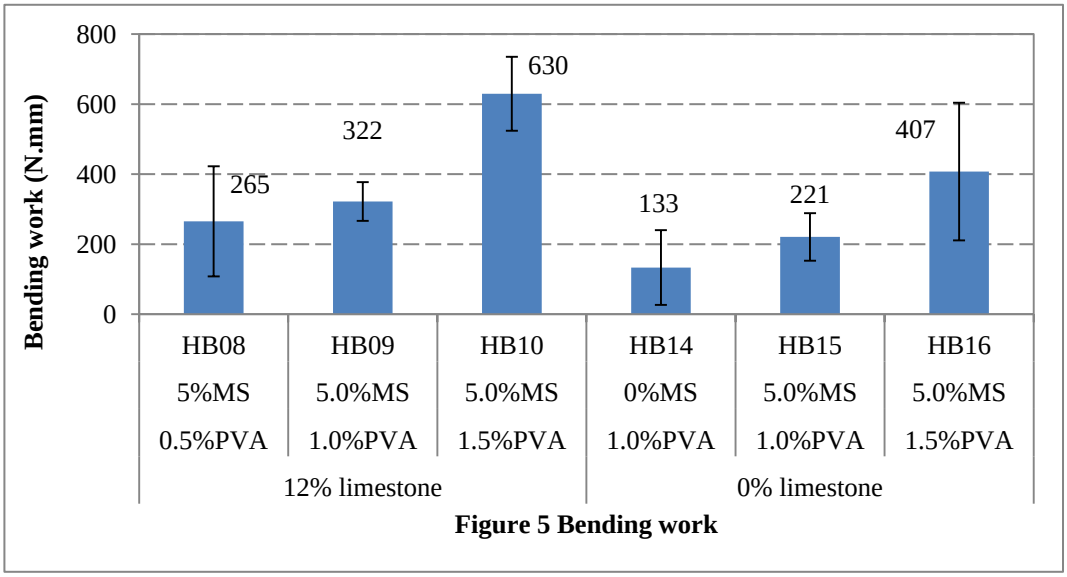

Figure 5 Bending work

TRIAL PRODUCTION

Hongbo factory made the successful trial production with the modified recipe according to the test results. Property of the trial product is listed in table 3.

According to the lab result and industry feedback, reinforcement effect of using Microsilica was confirmed again.

Table 3 Property of the trial product.

Sample ID	Dry density g/cm^3	Moisture movement	Water absorption	MOR MPa	Bending work N.mm
917WA	1.50	0.36%	26%	14.1	149
917WF	1.50	0.37%	26%	13.7	165
918WE	1.44	0.33%	30%	15.6	249
926WA	1.46	0.43%	28%	15.5	752
Standard deviation					
917WA	0.01	0.01%	0%	0.68	22
917WF	0.01	0.00%	0%	0.96	21
918WE	0.00	0.01%	0%	0.97	10
926WA	0.01	0.00%	1%	0.67	52

Some test results about the durability property

Besides the study on the primary property, effect of using Microsilica on the durability of fibre cement product had been tested, freeze-thaw, heat-rain and carbonation shrinkage etc.[7]

In this paper , some test result about the freeze-thaw resistance and heat-rain resistance property are presented.

One test to study the effect of three additives Microsilica, Metakaolin and limestone on the freeze-thaw resistance and heat-rain resistance was made in the lab. Strength reservation was measured after certain number of cycles of freeze-thaw curing and heat-rain curing. Results are listed in Table 4 and figure 6.

It was indicated from table4 that the strength of the sample with 7% Microsilica was not decreased after 132 freeze-thaw cycles; and residual strength was 89% after 60 heat-rain cycles. However the other two group samples with either Metakaolin or limestone, strength decreased a lot after freeze-thaw and heat-rain curing.

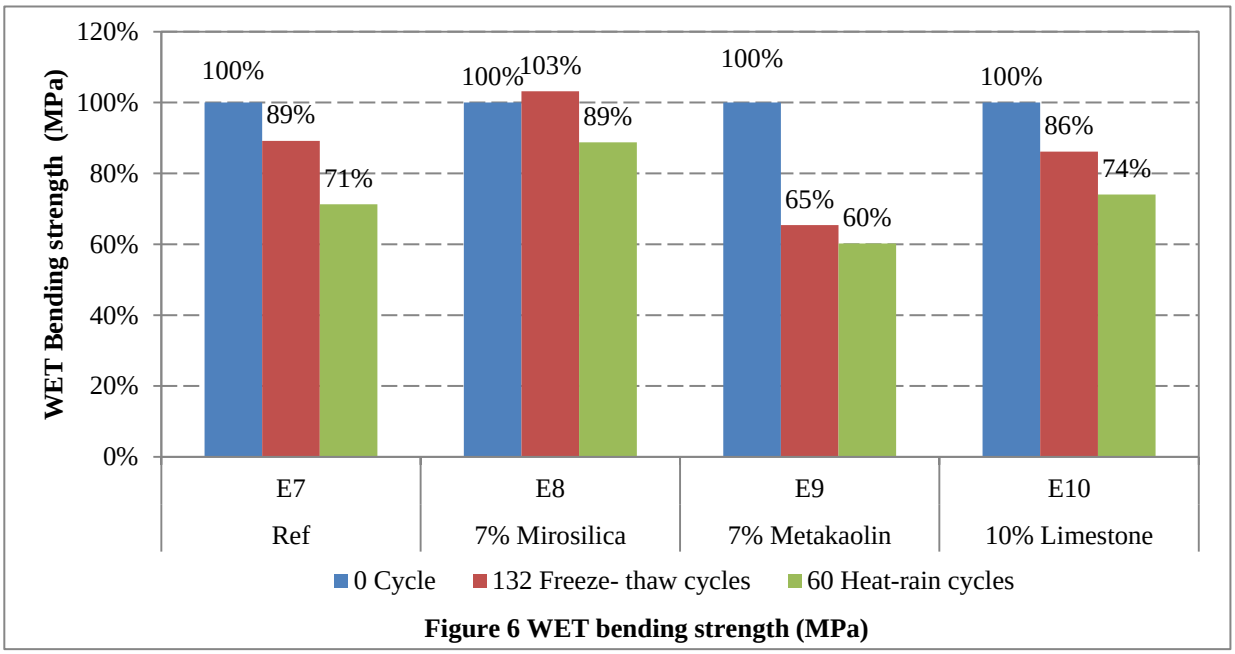

Figure 6 WET bending strength (MPa)

Table 4. Effect of the three additives Microsilica, Metakaolin and limestone on freeze-thaw and heat-rain resistence

Sample ID	MOR (MPa)		
	0 Cycle	132 Freeze- thaw cycles	60 Heat-rain cycles
E7 (Reference sample)	11.66	10.40	8.31
E8 (7% Microsilica)	14.40	14.86	12.78
E9(7% Metakaolin)	12.89	8.43	7.76
E10 (10% Limestone)	12.26	10.56	9.08

Besides the lab sample test, we also evaluated the industry product. We studied two air-cured non-asbestos industry products with different additives. 5%Microsilica and 5%Metakaolin were used. Freeze-thaw resistance property was measured. Results are presented in table 5, sample status is shown in the figure 7 and figure 8. It is clearly demonstrated by the figure 8 that the sample with 5% Metakaolin was delaminated after 150 Freeze-thaw cycles, however the sample with 5% Microsilica still has ~51% retained of its initial strength and did not shown delamination, Table 5 and Figure 7.

Table5. Freeze-thaw test on the industry product with Microsilica or Metakaolin.

Sample ID	WET MOR (MPa)		
	0 cycle	150 freeze-thaw cycles	Strength reservation%
EX1 (5% Metakaolin)	10.75	Delamination	-
EX2 (5% Microsilica)	15.54	7.90	51%

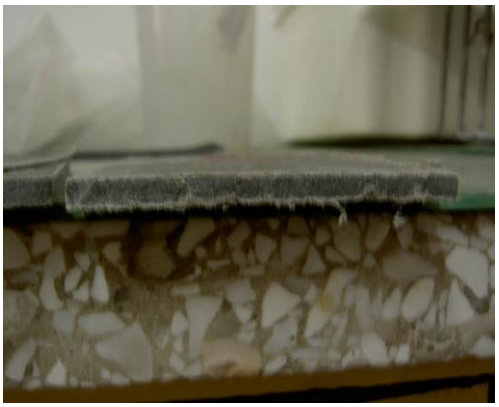

Fig 7. Sample with 5% Microsilica

Fig 8. Sample with 5% Metakaolin

MECHANISM AND DISCUSSION.

According to above test and industry application, it is proven that Microsilica is a very good process aid and property enhancer in non-asbestos fibre cement sheets. Its advantage to the fibre cement product has been proven widely. [8,9,10]

Benefit of using Microsilica is mainly attributed to its filler function and pozzolanic effect. Superfine character of Microsilica allow Microsilica particles to fill into the voids easily and the structure becomes denser; moreover high pozzolanic character of Microsilica makes it react with calcium hydroxide $Ca(OH)_2$ easily at room temperature and create more C-S-H binder, which gives denser structure and higher strength.

Figure 9 and figure 10 is a simple drawing to show how Microsilica is working in the fibre cement. For the normal fibre cement product, cement reacts with water, creating binder plus calcium hydroxide $Ca(OH)_2$ as shown in figure 9. When Microsilica was added into the recipe, the calcium hydroxide $Ca(OH)_2$ reacts with the Microsilica that fills in the voids, creating more binder and more binding points on the fibers, figure 10. It will lead the structure denser and reinforcement of the bonding strength between fibre and matrix, which result in the high strength and high durability.

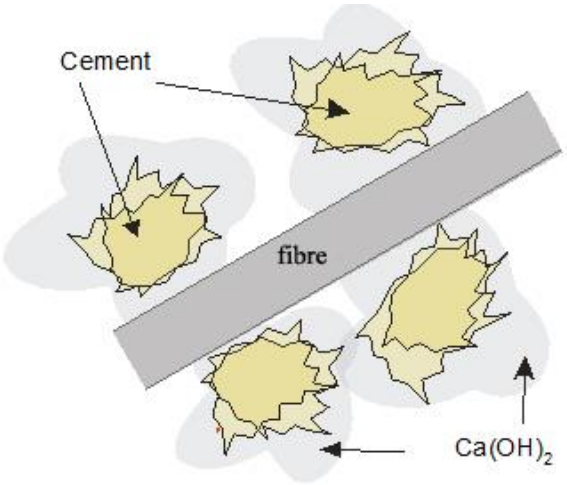

Figure 9. Normal fibre cement matrix

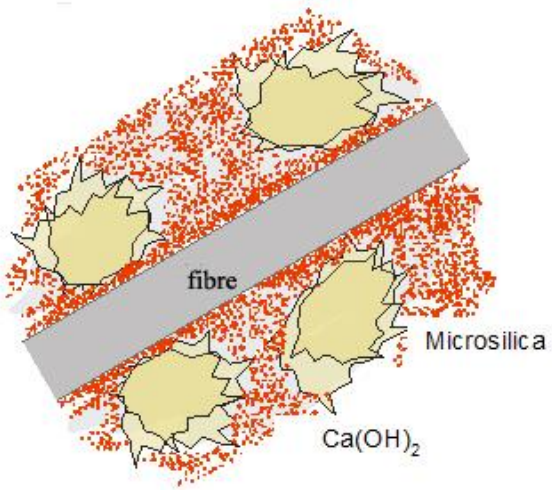

Figure10. Fibre cement matrix with Microsilica

CONCLUSIONS

- Different fillers have different function in fibre cement product. Microsilica is a very good additive for improvement of the process control as well as of the final fibre cement product's performance
- Microsilica is a very good reinforcement additive to increase the cement matrix strength and bonding strength between fibre and cement matrix. .
- Microstructure became denser and water absorption was decreased by adding Microsilica.
- Freeze-thaw and heat-rain resistance are improved by adding Microsilica.
- Microsilica improves the inter-laminar bond of fibre cement product during Hatschek process.

ACKNOWLEDGEMENTS

The author would like to thank the following peoples for supporting this study and creating the paper.

Zhang Yi

E-mail: zhang.yi@elkem.no

Li Xinmeng

E-mail: Xinmeng.li@elkem.com

Gerry. Brown

E-mail: gerry.brown@elkem.no

Simon. Wison

E-mail: simon.wilson@elkem.no

Yuwei Huang

E-mail: 13707338178@139.com

Lina Gu

E-mail: gulinalina@126.com

Mingzhi Zhou

E-mail: hbzmz123@163.com

REFERENCES

[1]. Dr. Shen Rongxi, development of non-asbestos fibre cement products in china, 9th international inorganic-bonded fibre composites conference, 2006

[2]. Rongxi Shen，Zhen Lin, International fibre cement product development and tendency，China concrete and cement products，2007，No2， 39-42

[3]. Internal annual report of China calcium silicate board, 2014 China national Calcium silicate board conference.

[4]. Zhen Lin, Yi Zhang, Wang Yuanyuan, Introduction of global fibre cement development, industry focus, China concrete, 2011 No4, 10-14

[5]. Zhen Lin, Yi Zhan, The development of non-asbestos fibre cement in china, 14th international inorganic-bonded fibre composites conference, 2014

[6]. Zhen Lin, introduction of IIBCC and the application of additives in the non-asbestos product, China national fibre cement conference, 2010

[7]. Zhen Lin, Henning Thygesen, Study On The Carbonation Effect Of The Air-cured Fibre Cement Sheet., Inorganic-bonded Fiber Composites Conference 2010, Aalborg， Denmark

[8]. Zhen Lin, Valdir Zampieri, Effect of Microsilica on the PP fibre reinforced fibre cement product, International Inorganic-Bonded Fiber Composites Conference 2008, Madrid, Spain

[9]. Zhen Lin，Yi Zhang, Development of Fibre cement product and the application of Microsilica, China concrete and cement product association, vol 2007,technology navigation, 61-65

[10]. Schreiner & Holmen, The effect of Microsilica dispersion in fibre cement mixes, 3rd international inorganic-bonded fibre composites conference, 2002