IIBCC
International Inorganic-Bonded Fiber Composites Conference

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

Paper #09

MECHANICAL PROPERTIES OF AIR-CURED FLAT PVA FIBER CEMENT SHEETS BASED ON HATSCHEK PROCESS

DO QUOC QUANG, NGUYEN DINH KIEN

Viet Trust Engineering Consulting Co. Ltd., Hanoi Vietnam

ABSTRACT

PVA fiber are widely used as asbestos replacement in manufacture of environment-friendly building products. The dimension change and cost of air-cured flat PVA fiber cement sheets are, however relatively higher than that of the autoclave fiber cement counterparts. This paper reports an investigation on the use of local fly ash and micro silica sand to replace a part of Portland cement for improvement of the dimension change and the cost performance of the air-cured flat PVA fiber cement sheets. Flat PVA fiber cement samples with various contents of fly ash and micro silica sand employed as cement replacement are prepared by using a self-developed mini-Hatschek machine. The green sheets are (optionally) pressed, before curing, and then tested for flexural strength and dimension change. The results show that the flexural strength of the PVA fiber cement sheets with 30% fly ash is still comparable with that of the autoclave ones. It is also shown that the use of the micro silica sand as partial cement replacement leads to a significant improvement in the dimension change of the air-cured PVA fiber cement sheets.

KEYWORDS:

PVA fiber cement sheets; Fly ash; Silica fume; Micro silica sand; Hatschek process.

INTRODUCTION

The use of asbestos in the construction industry in Vietnam has been restricted by the government for more than ten years. In the circumstance, Vietnamese fiber-cement manufacturers have carried out investigations on finding new materials and fabrication techniques to replace asbestos in their fiber-cement products. As a result, some manufacturers in the country are successful in manufacturing asbestos free fiber-cements products, in which PVA fiber are used as a replacement for asbestos. The PVA fiber cement products, especially the corrugated sheets, have shown good mechanical properties, and their breaking bending loads are comparable with that of their asbestos cement counterparts.

Regarding the flat fiber cement sheets discussed in this paper, two main methods, namely the autoclave and air-cured methods, are widely used to manufacture the sheets. The autoclave-based sheets are light and good in dimension stability, but they are relatively brittle, which are appropriate for indoor applications only. On the other hand, the air-cured product, usually used PVA fiber as reinforcement, has good mechanical properties, especially the bending strength and impact resistance, but its dimension change is relative high. In addition, the cost of the air-cured flat PVA fiber cement sheets are relative high due to the high price of PVA fiber. To ensure the mechanical strength to meets standard requirements, most of fiber cement manufactures in Vietnam use around 1.5%wt. content of PVA fiber in their mix proportions in manufacturing flat PVA fiber cement sheets without press. This content of PVA fiber contributes considerably to the cost of the final product.

Reducing the fiber content and using cheap local materials are common ways to improve the cost performance of the air-cured flat PVA fiber cement sheets. In order to decrease the fiber content, but still keep the breaking load, the manufacturing procedures should be modified. To this end, before curing a press procedure is applied to all the green sheets for increasing the density and to improve the mechanical strength. With this press, we can decrease 40%wt., of the PVA fiber content, but are still able to keep the breaking loads of the sheets meeting the standard requirements.

In this paper, an attempt on improvement of the cost performance and dimension change of air-cured flat PVA fiber cement sheets based on Hatschek process by using the local fly ash and micro silica sand to replace a part of Portland cement is made. The flat PVA fiber cement samples with various contents of fly ash and micro silica sand used as partial cement replacement are prepared by using a self-developed mini-Hatschek machine. The press, an optional procedure in making fiber cement sheets, is employed to improve the mechanical properties of the sheets and to reduce the PVA fiber content. The test samples, after the first steam curing, are kept in room environment, and then tested for flexural strength and dimension change. The effects of fly ash and micro silica sand contents on the flexural strength and dimension change are examined and highlighted.

SUBSTITUTION MATERIALS

Cement admixtures like fly ash and silica fume are widely used as cement substitution for improvement of properties and cost performance of cement based material composites (Ramachandran, 1995). Recently, Fuji Vietnam – a well-known fiber cement company in Vietnam was successful in using a large amount of the local fly ash to replace the Portland cement in its PVA fiber cement roof-tile product. We try to convey this idea to the flat PVA cement sheets.

Mixes for PVA fiber cement sheets, in addition to Portland cement and PVA fiber used, respectively, as binder and reinforcement, requires other materials and additives. The aim of using the additional materials and additives is to support the Hatschek process and to improve the properties of final products. The common added materials and additives are Kraft pulp, silica fume, bentonite, polyacrylamide. These added materials require careful pre-treatment before mixing with cement and PVA fiber (Do and Nguyen, 2010). In the mentioned materials, PVA fiber (KURALON of Kuraray Co., Japan) and Portland cement considerably contribute to the cost of the final products. Thus, reducing PVA fiber content and Portland cement in the mix proportion is an effective way to improve the cost performance. As above mentioned, a press procedure is used to reduce the PVA fiber content. For cement substitution, the local fly ash and micro silica sand are used herein. The compositions of the fly ash and micro silica sand used in the investigation are given in Table 1.

In order to examine the effect of fly ash and micro silica sand on the properties of the flat PVA fiber cement sheets, the content of the additional materials in the mix proportion is kept unchanged, namely 3.5% Kraft pulp, 4.5% for silica fume and bentonite less than 1.0%. The content of PVA fiber is decreased to 60% of the current amount content used by the manufacturers. Various contents of fly ash and micro silica sand are used to replace Portland cement. The contents of these materials and Portland cement are given in Table 2.

Table 1 - Chemical compositions of fly ash and micro silica sand

No.	Name of chemical	Fly ash	Micro silica sand	Note
1	SiO_2 (%)	53.92	99.20	Tests are performed in accordance with Vietnamese standards TCVN 9183-9186, 2012
2	Fe_2O_3 (%)	6.54	0.03	
3	Al_2O_3 (%)	25.81	0.62	
4	CaO (%)	1.13	0.03	
5	MgO (%)	0.90	-----	
6	SO_3 (%)	0.25	-----	
7	K_2O (%)	3.01	-----	
8	N_2O_3 (%)	0.26	-----	
9	TiO_2 (%)	0.32	0.007	
10	Lost on ignition (%)	6.68	0.04	

Table 2 - Contents of fly ash, micro silica sand and Portland cement in the test mix proportions

Test name	Fly ash (%)	Micro silica sand (%)	Portland cement (%)
MIX-1A	15	0	75
MIX-1B	30	0	60
MIX-2A	30	15	45
MIX-2B	30	20	40

TEST SPECIMENS AND METHODS

A mini-Hatschek machine as depicted in Figure 1 is used in making the test samples. The machine produces flat sheets with size of 2400 x 600 x 4.5 mm. The green sheets are pressed with a pressure of 50 kgf/cm^2 by using a press machine. The sheets are subjected to steam curing at 55 – 60^{o}C and 100% RH for 8 hours, and then kept in the room for one week before. Test samples with size of 200 x 40 x 4.5 mm are cut out from the cured sheets.

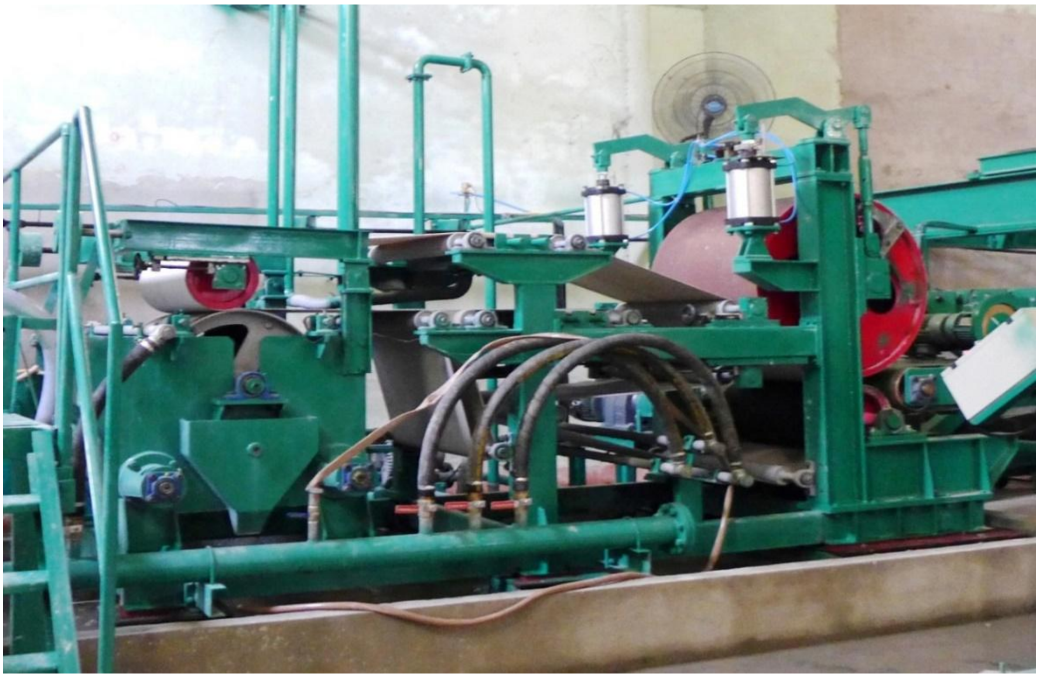


Figure 1 - Mini-Hatschek machine for making flat PVA cement test samples

The breaking flexural load of the samples are determined by a universal testing machine. Three-point bending test with a span of 135mm is used for determination of the breaking load. The stress-deflection curve, maximum breaking stress, critical deflection and fracture energy of the test are automatically recorded by the machine and stored in a computer. In order to determine the dimension change, the length the samples in dried and wet conditions is measured. In the dried condition, the samples are kept in an oven at 100°C for 16 hours at 0% RH, and in the wet condition the dried samples are immersed in water for 24 hours at the room temperature. The dimension change is calculated as the relative change of the specimen length in the two conditions as follows

$$\text{Dimension change (\%)} = \frac{L_1 - L_2}{L_1}\, x\, 100$$

where L_1 and L_2 are the length of the specimens in the wet and dried conditions, respectively.

RESULTS AND DISCUSSION

Figure 2 to Figure 5 show the stress-deflection curves of the MIX-1A, MIX-1B, MIX-2A and MIX-2B of the air-cured flat PVA fiber cement sheets, respectively. In order to compare the properties of the air-cured PVA fiber cement sheets with that of the autoclave product, the flexural test is also performed for typical sample autoclave cement sheets which were imported from an Asian country, and the result is depicted in Figure 6.

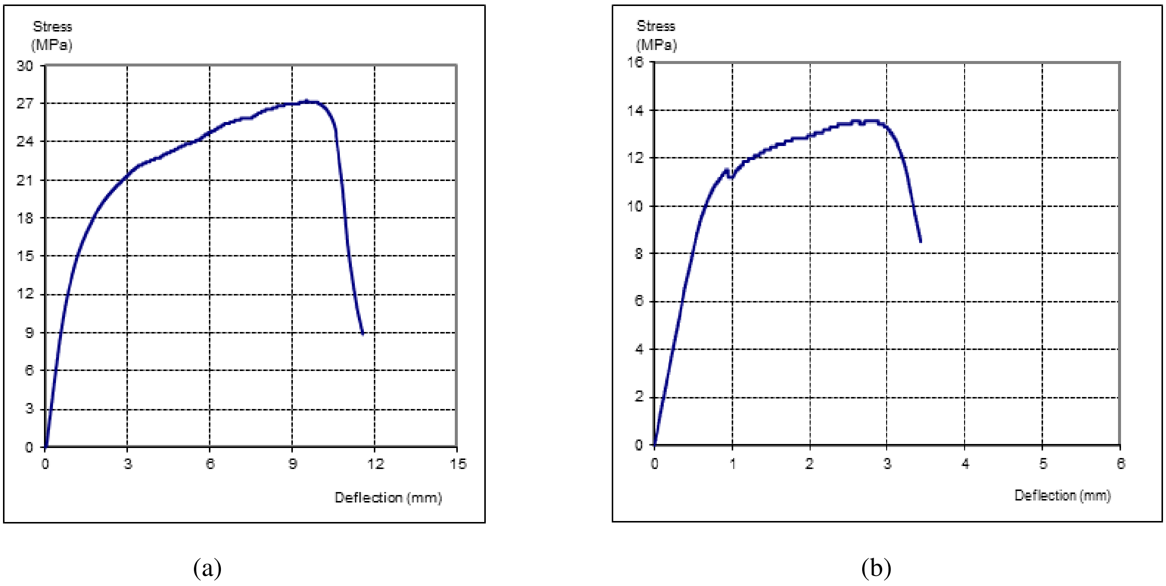


Figure 2 – Stress-deflection curves of MIX-1A: (a) Machine direction, (b) Cross direction

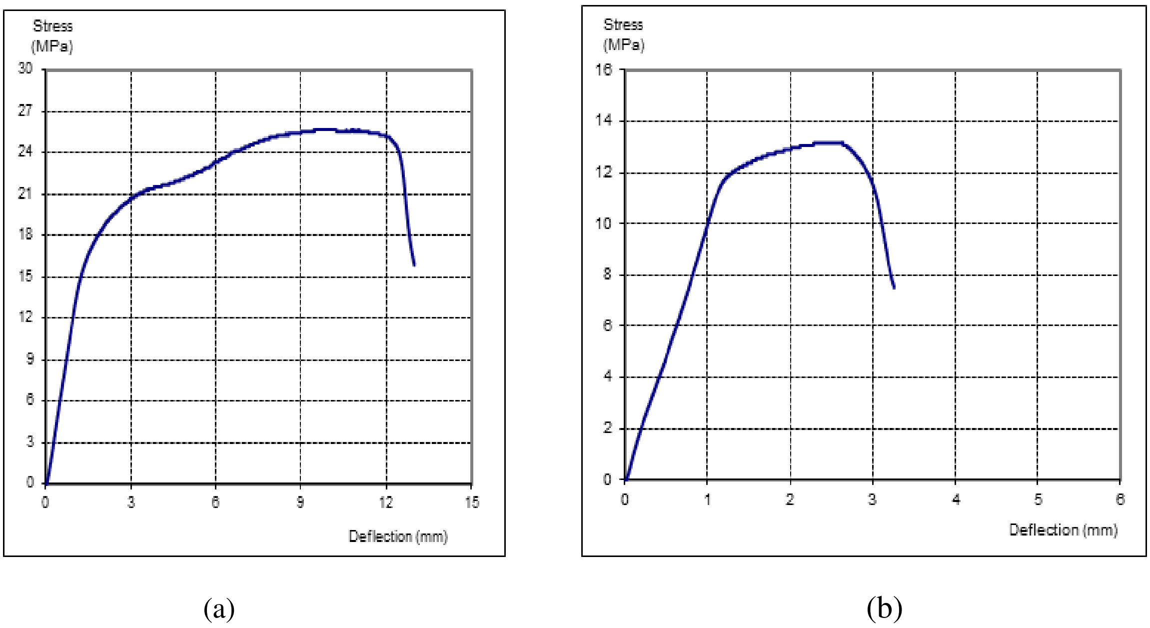
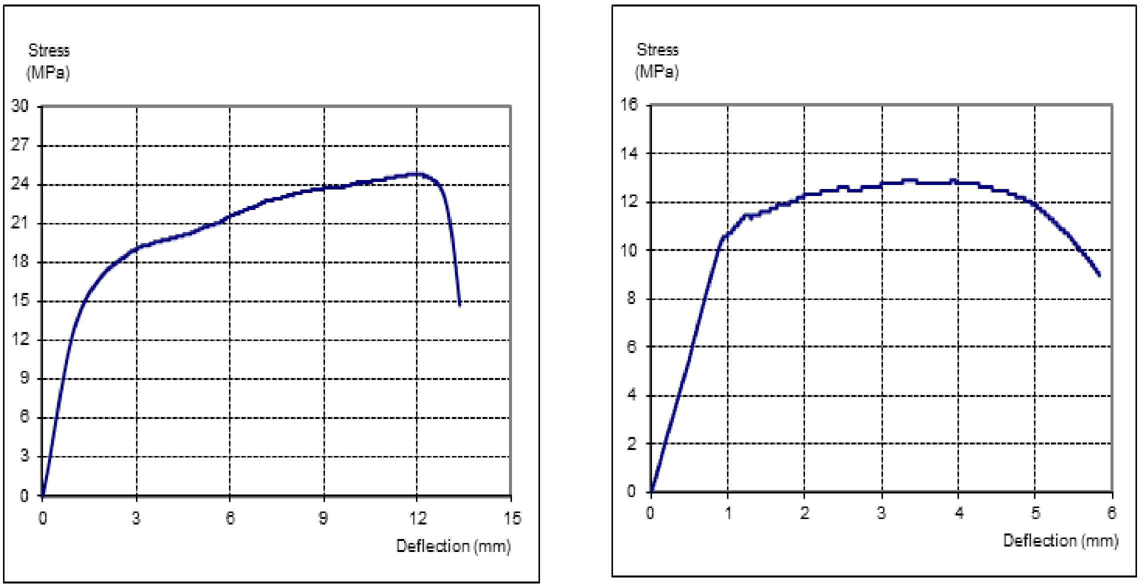
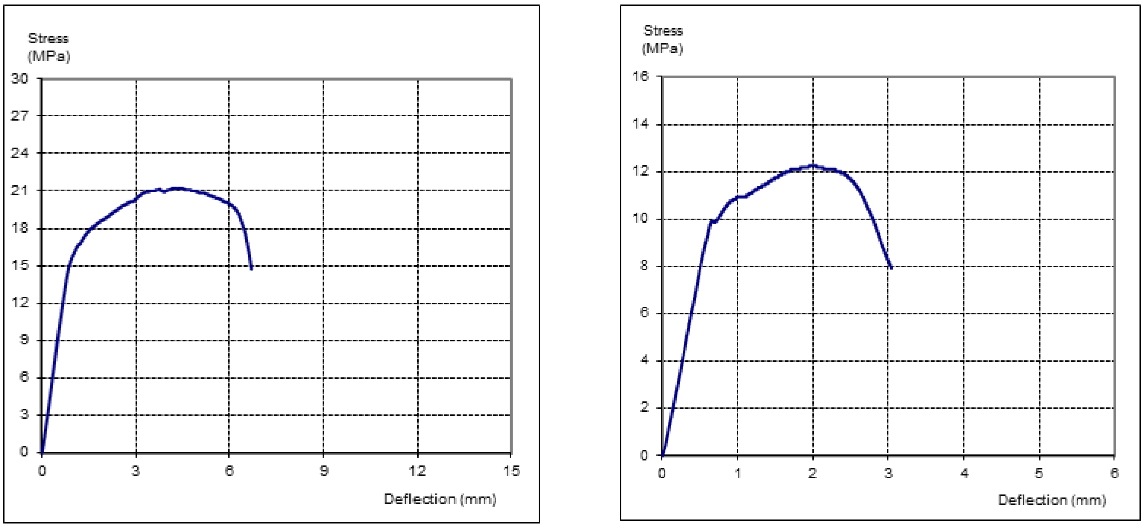


Figure 3 – Stress-deflection curves of MIX-1B: (a) Machine direction, (b) Cross direction



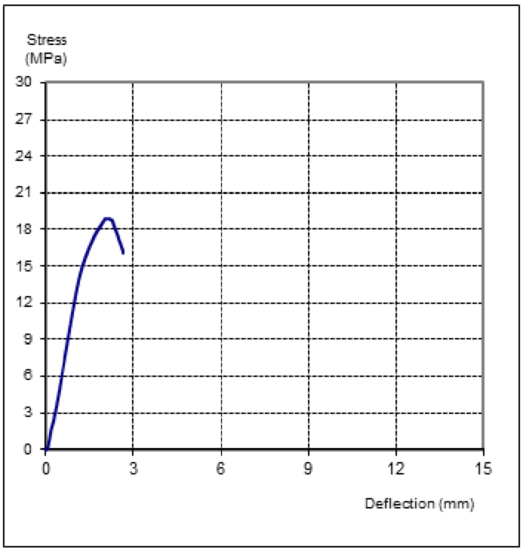
(a) (b)

Figure 4 – Stress-deflection curves of MIX-2A: (a) Machine direction, (b) Cross direction

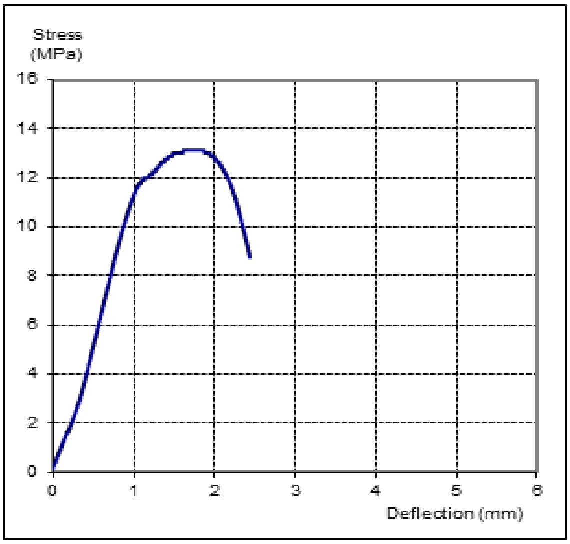


(a) (b)

Figure 5 – Stress-deflection curves of MIX-2B: (a) Machine direction, (b) Cross direction



(a)



(b)

Figure 6 – Stress-deflection curves of autoclave sheets: (a) Machine direction, (b) Cross direction

The following remarks can be drawn from Figures 2 to 6:

- The flexural strength of the air-cured PVA fiber cement sheets in both the machine and cross directions is slightly decreased by increasing the fly ash content, but it is still higher than that of the autoclave sheets. By comparing the test results of MIX-1A and MIX-1B shown in Figures 2 and 3, one can see that the effect of the fly ash on the flexural strength of the air-cured PVA fiber cement sheets in the cross direction is more significant than in the machine direction. The critical deflection, at which the bending stress reaches the peak is almost unchanged by the change of the fly ash content.
- The use additional 15% micro silica sand (MIX-2A), as seen from Figure 4, hardly affects the flexural behavior of the PVA fiber cement sheets. The change of the maximum stress and critical deflection is unnoticeable by using this amount of the micro silica sand to replace cement. The maximum flexural strength of the sheet, however, as seen from Figure 5, considerably decreases when using 20% of micro silica sand (MIX-2B) to replace the cement. The proportional limit is also remarkably decreased in this case.
- Comparing to the autoclave sheets (Figure 6), the flexural strength of the air-cured PVA fiber cement sheets with fly ash and micro silica sand used as partially cement substitution is higher, irrespective of the fly ash and micro silica sand content. In addition, the fracture toughness, measured in term of area below the tress-deflection curves (Balaguru and Shah, 1992), of the air-cured flat PVA fiber cement sheets is much higher than that of the autoclave ones, regardless of the fly ash and micro silica sand content.

Table 3 – Physico-mechanical of flat fiber cement sheets

Property	MIX-1A	MIX-1B	MIX-2A	MIX2B	Autoclave
Density (g/cm3)	1.645	1.602	1.518	1.504	1.384
Max strength (N/mm2)	27.28/13.56*	25.75/13.17	24.81/12.92	21.28/12.27	18.69/13.17
Water absorption (%)	19.04	20.43	22.29	23.49	30.24
Fracture energy (J)	0.886/0.138*	1.016/0.191	0.946/0.217	0.712/0.180	0.146/0.086
Dimension change (%)	0.249	0.214	0.175	0.165	0.194

*Note: Strengths and Fracture energy in machine/cross directions

Table 3 lists the physico-mechanical properties of the air-cured PVA fiber cement sheets, where the properties of the autoclave sheets are also given for the purpose of comparison. As seen from the Table, the dimension change of the air-cured sheets is considerably improved by using micro silica sand as partially cement replacement. The dimension change of the air-cured sheets is greatly decreased by using micro silica sand, even lower than that of the autoclave sheets. The maximum strength of the air-cured PVA fiber cement sheets with 30% of fly ash and 20% of micro silica sand (MIX-2B) is relatively lower than that of the sheets without micro silica sand (MIX-1A and MIX-1B). However, the strength and fracture energy of the sheets with micro silica sand are still much higher than that of the autoclave sheets. Because of the low water absorption, high flexural strength and fracture energy compared to the autoclave sheets, the air-cured PVA fiber cement sheets are preferable for outdoor applications.

CONCLUSION

An investigation on using fly ash and micro silica sand to replace a part of Portland cement in mix proportions of air-cured flat PVA fiber cement composite was carried out. The flat PVA fiber cement sheets with various contents of fly ash and micro silica sand are prepared using a mini-Hatschek machine. A press procedure is used to press the green sheets for reducing the PVA fiber content in the mix proportions. The test samples are cut out from the sheets are test for flexural strength and other properties. The test results show that the fly ash and micro silica sand remarkably affect the strength and other properties of the composite. A combination of the use of fly ash and micro silica sand can improve the dimension change of the air-cured PVA fiber cement sheets considerably. The flexural strength of the sheets slightly decreases by using micro silica sand, but it is still higher than that of the autoclave sheets. Since the strength and fracture toughness of the air-cured PVA fiber cement sheets are considerably higher than that of the autoclave counterparts, the air-cured products have potential for use as both indoor and outdoor applications. Because of the low price of fly ash and micro silica sand, the use of these materials can help to improve the final cost of the air-cured PVA fiber cement sheets.

REFERENCES

Balaguru, P.N. and Shah, S.P. 1992. "Fiber-reinforced cement composites". McGraw-Hill Inc. New York.

Do, Q.Q. and Nguyen, D.K. 2010. "Hatschek machine and equipment for non-asbestos fiber reinforced cement sheets". In "Proceedings IIBCC 2010 International Inorganic-bonded Conference". Aalborg, Denmark.

Ramachandran, V.S. 1995. "Concrete admixtures handbook. Properties, science and technology". Noyes Publications, New Jersey.