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DOI 10.1016/j.matpr.2016.01.023
ESSN 2214-7853

Publisher: Elsevier

Available online at www.sciencedirect.com
ScienceDirect
Materials Today: Proceedings 3 (2016) 376 – 380

Advances in Functional Materials (Conference 2015), AFM 2015

Feasibility Study on Production of Fiber Cement Board Using Waste Kraft Pulp in Corporation with Polypropylene and Acrylic Fibers

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Abstract

This research attempts to find the cheap and accessible fibers as an asbestos replacement in the production of fiber cement board. In this research, waste Kraft pulp which gained from waste cardboard in corporation with two polymeric fibers; acrylic and polypropylene fibers which are normally used in fabric industry, were used. In both groups, nano silica was used as an additive. Mechanical characteristics of the specimens were tested and analyzed according to relevant standards.
The results showed that the specimens made out of waste cardboard and acrylic fibers could meet the standard's requirements and have adequate potential to be used as an alternative of asbestos.

Selection and peer-review under responsibility of Conference Committee Members of Advances in Functional Materials (Conference 2015).

Keywords: Cement composite; Waste Material; Natural fibers; Polymeric fibers; Cement board; nano silica

1. Introduction

Fiber cement board is one of famous construction products that can be used as an internal/external wall as well as materials for roofing. However, over the past two decades, the use of asbestos fibers has been forbidden in the production of fiber cement board in many of developed country, those carcinogenic fibers are still used in many of developing countries. Since the early 1970 after recognition of asbestos hazard on human health, a global effort was initiated to replace asbestos fibers from construction products. Depending on properties, effectiveness and cost, a wide variety of natural and synthetic fibers such as Bagasse, Wheat, Kraft pulp, Sisal, jute, Steel, Glass, Acrylic and Polyvinyl Alcohol fibers have been used as asbestos alternatives in production of fiber-cement boards.[1-3]
Alternative's fibers often contain two types of fibers; processing fibers and reinforcing fibers. Cellulose fiber which is gained by Kraft pulping methods is considered as processing fibers. Synthetic fibers which are stiffer and

2214-7853
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doi:10.1016/j.matpr.2016.01.02310.1016/j.matpr.2016.01.023

stronger, providing the reinforcing effect in the hardened composite.[3,4]
Combination of synthetic fibers with cellulose fibers have already been studies [2,3]
Ganjian et al [2] studied the combination of 3% cellulose fibers incorporation with 1% to 3% acrylic fibers and they concluded 3% cellulose fibers in combination with 2% AC lead to greater flexural strength.
It should be noted that the method of manufacturing, the amount of fiber content, length of fibers, methods of fiber treatment, methods of curing, etc. can affect the property of FCB. [3,5,6] In this research cellulose fibers gained from Kraft pulp of waste cardboard , cellulose fiber content 8% and 3% nano silica were considered as constant parameters and the variation of PP or AC fibers were considered as variables.

2. Materials and Experimental procedures

The following materials were used in the mix to produce cement composite board in the Lab.

- Ordinary Portland cement (CEM1 grade 52.5, compiled with BSEN 197-1).
- Cardboard cellulose fibers extracted from waste cardboard.
- Acrylic (AC) and Polypropylene (PP) fibers provided from fabric factories

In this research, the amount of Kraft palp fibers (8%) and Nano silica (3%) were constant in all group. Therefore, the effect of 0.5%, 1% and 1.5% Polypropylene and Acrylic fibers in corporation with 8% Kraft pulp fibers and 3% Nano silica were investigated.
The polypropylene fibers were chosen in two different lengths of 3mm and 6mm while for acrylic fiber only 6mm length was chosen due to availability in the market. Lengths of more than 6mm were not selected because primary laboratory manufacturing specimens showed that fibers with lengths of greater than 6mm cannot disperse uniformly in the cement matrix; not only do they clamp together but also the processing control of making specimens is disrupted and the specimen surface would be uneven. Also, adding more than 1.5% of polypropylene fibers in the mixes was impossible because the fibers were floated and accumulated on top surface of the specimens, resulting in an uneven surface. The properties of polypropylene and proportion of materials used in the mixes are given in table -1 and table -2 respectively. It should be noted that Nano silica fume in the amount of 3% of the cementations materials was applied in all mixes.

Table 1. Characteristic of synthetic fibers.

Fiber type	Polypropylene	Acrylic
Average length (mm)	3 ±0.5 6 ±0.5	6 ±0.5
Average diameter (micron)	18-22	18-22
Average tensile strength (MPa)	250-300	350-400
Aspect ratio	150 300	300
Specific gravity	0.91	1.18
Elongation at break (%)	15-18	2.5-4

Table 2 shows the mix design. The mix codes were structured in the following manner: The abbreviation ‘K’ ; Kraft pulp fiber ‘PP’; Polypropylene fiber, ‘AC’; Acrylic fiber, 3mm or 6mm; the length of fiber in mm, the numbers after their respective abbreviations represent the percentage of that material used by weight of the cement content. For example K8-PP1.5 -3mm denotes that there is an 8% Kraft and a 1.5% PP with the length of 3 mm.

Table 2. quantity of the materials in the mix design.

Mix	Mix code	Cement (gr)	kraft pulp fibers (gr)	Polypropylene fibers – 3mm (gr)	Polypropylene fibers – 6mm (gr)	Acrylic fibers – 6mm (gr)	Nano silica (gr)
1	K8PP0.5-3mm	150	12	0.75	0	0	7.5
2	K8PP1-3mm	145	11.6	1.45	0	0	7.25
3	K8PP1.5-3mm	140	11.2	2.1	0	0	7
4	K8PP0.5-6mm	150	12	0	0.75	0	7.5
5	K8PP1-6mm	145	11.6	0	1.45	0	7.25
6	K8PP1.5-6mm	140	11.2	0	2.1	0	7
7	K8AC0.5-6mm	150	12	0	0	0.75	7.5
8	K8AC1-6mm	145	11.6	0	0	1.45	7.25
9	K8AC1.5-6mm	140	11.2	0	0	2.1	7

2.1. Material preparation and Test

The Kraft pulp fibers gained from waste cardboard were fibrillated in a refiner before adding to the mix. Refining allowed the micro fibrils to unwind from the core stem to allow for suitable fiber fibrillation.

The specimens were subjected to flexure test. Deflection and load were recorded in all stages of loading.

Six specimens were made from each mix and were cured at 95 % RH and 20 °C. Three were tested at 7- day of curing, the rest at age of 28-day. The typical dimensions of specimens were 80mm by 180mm and varied in depth between 6 and 8 mm.

According to BS EN 12467:2004 the specimens were subjected to three points flexural test on simply supports.

The test machine was set to a constant rate of loading (fulfills criteria 7.3.2.2.1 BS EN 12467:2004) and only allowed the specimen to deflect up to 8mm. The span for flexural strength was adjusted at 160 mm.

3. Results and discussion

The average flexural strength for all specimens aged 7-day and 28-day in each group is shown in figure 1.

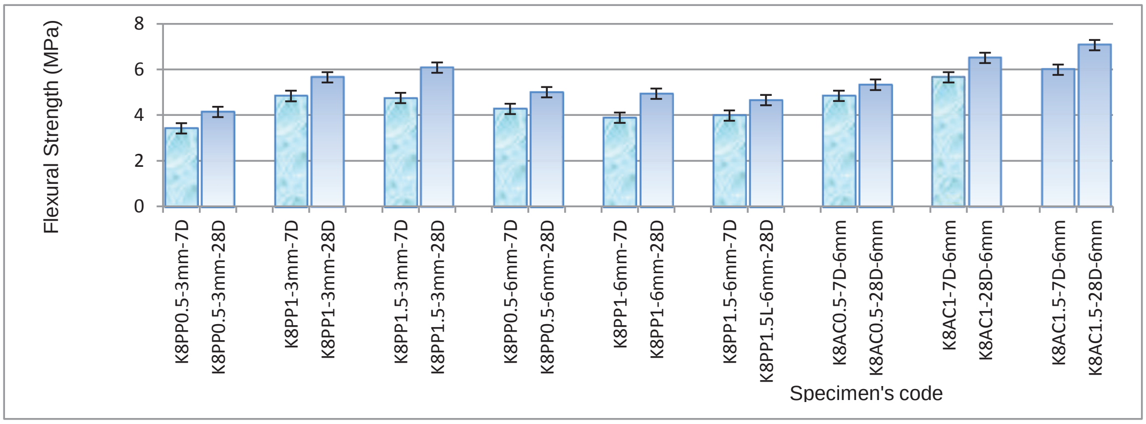
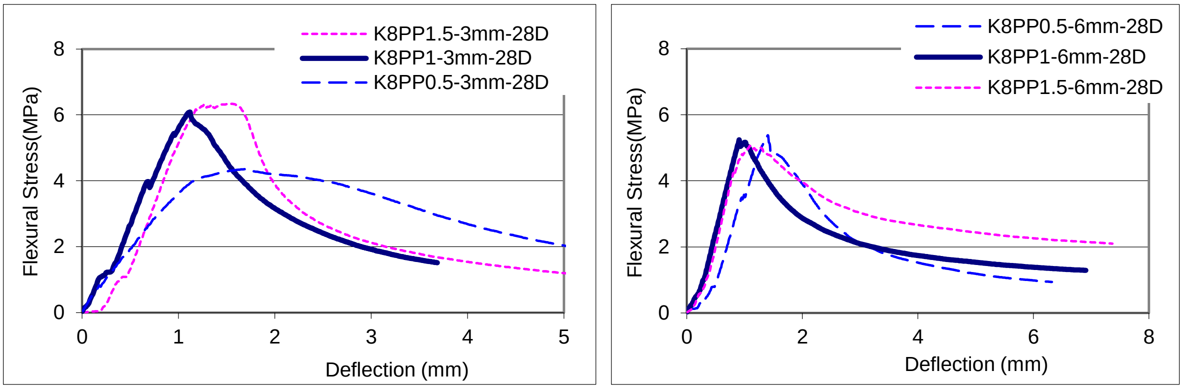


Fig. 1 Flexural strength of the specimens.

As seen in figure-1

- The flexural strength of 28-day specimens is greater than that of 7-day ones. This means flexural strength has not been affected by cement hydration. Therefore, both polypropylene and acrylic fibers are resistant in alkaline environment.
- Flexural strength of the specimens reinforced by 3 mm PP fibers increases by increasing the fiber content from 0.5 up to 1.5%. The highest flexural strength of the specimen containing PP is 6MPa and belongs to K8PP1.5-3mm at age of 28 days.
- By increasing the amount of 6 mm PP fibers, from 0.5 up to 1.5%, flexural strength doesn't change considerable and it also decreases slightly.
- Applying polypropylene (PP) fibers 6 mm in length caused a reduction in the flexural strength of the specimens compared to applying 3 mm PP fibers.
- The maximum flexural strength within all groups belongs to K8AC1.5-28D-6MM with 7MPa.

To analyze the results of flexural strength shown in figure-1, the flexural behavior of the specimens are discussed in figures 2 to 4. In figure 2 flexural behaviors of the specimens containing PP (3mm) and PP (6mm) are illustrated.



a: Polypropylene 3 mm length b: Polypropylene 6 mm length

Fig.2 Flexural performance of the specimens aged 28-day reinforced by PP

Figure 2a shows that with increasing the 3mm PP fiber content from 0.5 to 1.5%, the flexural strength of FCB increases but the flexural strength of FCB reinforced by 1 or 1.5% PP is approximately equal. Unlike 3mm PP, when 6mm PP fibers are applied with 0.5, 1 and 1.5 % in the mix (fig.2b), no significant difference is observed in flexural strength, ductility and area under the curve of the specimens. The reasons could be associated with cylindrical shape and smooth surface of PP fibers.

PP fibers are hydrophobic fibers. The hydrophobic effect in the mix which can be considered as an aqueous solution causes segregation and repulsion within water and nonpolar PP fibers. Other important factors are:

- As the density of PP fibers (0.9 gr/cm3) is less than water, in the manufacturing process, these fibers float on the top surface of the specimen. This phenomenon could create a specimen with a non-uniform fiber distribution leading weak points in the specimen.
- The elongation of polypropylene fibers in tensile test as shown in table-1 is 15-18%. This high elongation could lead to a large deformation of specimens in flexural test as illustrated in fig.2.
- The use of fibers with 6 mm in length causes 'fiber balling'. It means fibers would clamp together and this disrupts the uniformity of fibers in the mix.

The result of the flexural strength against the deflection for the specimens reinforced by different percentage of 6mm acrylic is shown in fig.3.

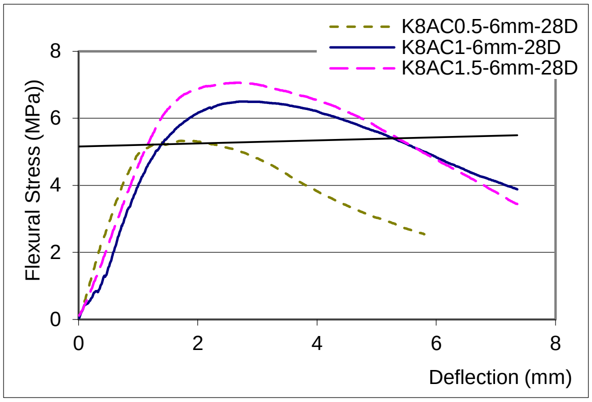


Fig.3 Flexural performance of the specimens aged 28-day reinforced by AC (6mm)

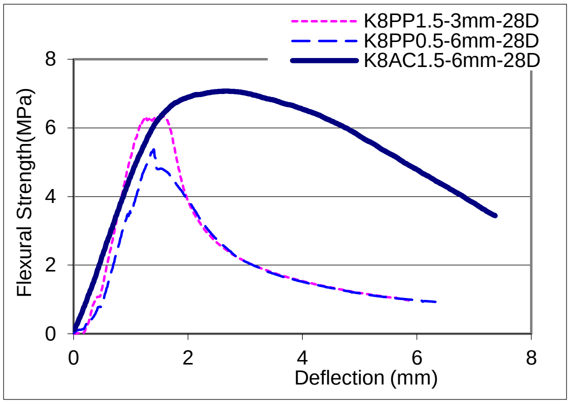


Fig.4 Comparison within specimens reinforced by acrylic and polypropylene fibers

As seen in fig.3, the higher the fiber content, the greater flexural strength. The area under the stress-deflection curve increases as the fiber content increases. It shows that the main role of fibers incorporated to the mix appears when the applied load reaches to the maximum and then the cracks occur. After initial cracks appear in the specimen, the fibers can tie two fractured interfaces and improve the bearing capacity of loading in which the sudden failure will not occur. This behavior is due to the great number of fibers so that, in maximum load, when a fiber breaks or pulls out, adjacent fibers contribute in bearing load through the crack-bridging system.

Fig.4 compares the results of the best specimens those achieved the highest flexural strength of all groups.

As can be observed in fig.4, specimens reinforced by acrylic fibers shows not only greater flexural strength but also they are more ductile and tougher in comparison to the specimens reinforced by polypropylene. As already mentioned the most important reasons for this behavior are associated with low density, less hydrophilic and higher elongation at break of PP fibers comparing to AC fibers.

4. Conclusion

In this laboratory research, the effect of two synthetic fibers (Polypropylene (PP) and (AC) acrylic fibers) on flexural strength of fiber cement board made of Kraft pulp fiber and Nano silica fume was investigated. The results show that PP fibers cannot provide an appropriate reinforcement for FCB so that all the specimens containing PP fibers showed less flexural strength in comparison to AC fibers. PP fibers although improved ductility and toughness of the specimens, they caused a reduction in flexural strength.

The proportion of 1.5% of acrylic fibers incorporated with Kraft pulp fibers could improve toughness and ductility of the specimens.

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