Properties Of Herbal Fiber Cement Boards For Building Partitions

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Abstract:

This paper uses bamboo fibers, coconut fibers, rice-husks and sugar cane-dregs, respectively, to make natural fiber cement boards for the building partition. Experimental consequences show that the unit weight of natural fiber cement boards are about 1430-1630 kgf/m3. The flexural power of herbal fiber cement forums is eighty% higher than that of normal building substances, except for rice-husks cement board. The duration change in the absorption check is inside the range of 0.09%-zero.16%, and the thermal conductivity with 0.201-0.296 kcal/m·oC·hr indicates a good heat-resistant capability. For B10, C10 and S10 materials after effect check, no cracks, the detachment, pinholes and the break up exist on effect surface, and the indentation diameters are beneath 26mm. besides, 3 cement boards containing 10% natural fibers fulfill the 2nd and 3rd rank of incombustibility standard.

1 INTRODUCTION

Many cement boards have been used as building partitions for over one century (Pamel & Schwarz 1979, Schwarz et al 1983, Schwarz & Simatupang 1984, MacVicar et al 1999). However, the unit weight of cement boards is still high, more than 2000 kgf/m3. In order to adapt the varieties of the functions and the space for high-rise structure, the partitions to separate building space demand to be lightweight, easy to construct fast and assembled simple.

In Taiwan, cement board, calcium silicate board and gypsum board are common used as the materials of building partition. Among them, moisture content for calcium silicate board and gypsum board gets up to 80% and 75%, respectively, due to the humid climate in Taiwan. High humidity made the partition deform and warp easily in use. One of the methods to improve the deformation of building partition affected by humidity is to add some fibers into the partition board. The useless agricultural products like rice-husks, sugar cane-dregs and coconut shell are always thrown away as the waste without any considerations in Taiwan. In fact, these agricultural wastes containing some natural fibers are valuable and can utilize to improve mechanical properties of the materials. This paper selects four natural fibers collected from bamboo, coconut shell, rice-husks and sugar cane-dregs, respectively, to produce natural fiber cement board considered as the building partition. We discuss material properties of natural fiber cement board including water absorption, bulk density, length change induced by absorption of water, impact endurance, fireproof capability and heatresistant capability. The experimental results can be used as a reference in building industry.

2 EXPERIMENTAL PROGRAM

2.1 *Materials*

Four natural fibers, bamboo fiber, coconut fiber, rice-husks and sugar cane-dregs, were added to the cement board, a kind of natural fiber cement board (NFCB). A comparison material is the cement board without adding natural fibers inside. NFCB consists
of cementitious matrix and natural fibers. The constituents of cementitious matrix include: (1) Type I Portland cement (ASTM C150); (2) slag with a specific gravity of 2.89 supplied by China Hi-Ment corporation (Taiwan); (3) river sand having a fineness modulus of 2.68, a specific gravity of 2.63, and an absorption of 2.0 %; and (4) fresh water. To prepare bamboo fibers, we first cut bamboo wood into the pieces with 40mm length, and then use the disintegrator to separate bamboo wood into the fibers, shown in Fig. 1. Sieve analysis for bamboo fibers is shown in Table 1, where dry specific gravity of 0.85, specific gravity of 0.93 with 10-12% moisture content in air and water absorption of 66% after 48 hours'absorption test. Bamboo fibers retaining in sieve 4 are shown in Fig. 2 with 13mm fiber length, passing through sieve 4 and retaining in sieve 8 are shown in Fig. 3 with 15mm fiber length, and retaining in sieve 50 with 5~15mm fiber length are shown in Fig. 4, respectively. Only the sizes of bamboo fiber between sieve 4 and sieve 50 were chosen to manufacture the fiber/cement board here.

Meanwhile, as we know bamboo fiber can retard the hydration of cement. Thereby, we need to overcome this retardant reaction in bamboo/cement boars by using following treatments. First, bamboo fibers were soaked in water, and then dried by heat. After that, bamboo fibers were also immersed in the solution with 20 to 1 of 1% organic titanium solution-tobamboo fiber ratio by weight. Finally, bamboo fibers are ready to use after drying.

Figure 1. Bamboo fibers before sieve analysis.

Table 1. Sieve analysis of bamboo fibers.

Sieve	Retaining (%)	Accumulation (%)
3/8"	0	0
#4	6.0	6.0
#8	31.1	37.1
#16	33.9	71.0
#30	18.0	89.0
#50	8.8	97.8
Pan	2.2	100.0
Total	100	—

Figure 2. Bamboo fibers retain in sieve 4 with 13mm length.

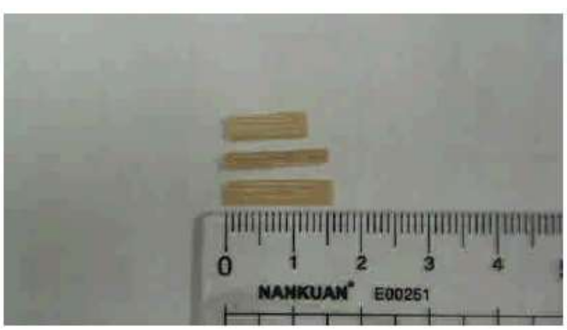

Figure 3. Bamboo fibers pass through sieve 4 and retain in sieve 8 with 15mm length.

Figure 4. Bamboo fibers retain in sieve 50 with 5~15mm length.

Because sugar cane-dregs have the same retardant hydration effect to the cement, we also need to do the same treatments as bamboo fibers before the use. Material properties of sugar cane-dregs have 68% absorption of water and specific gravity of 0.63, and shown in Fig. 5.

Figure 5. Sugar cane-dregs

Besides, coconut fiber has 92 % water content after 24 hours'absorption test and specific gravity of 0.62, respectively, shown in Fig. 6. Fig. 7 is ricehusks with 12% absorption and specific gravity of 0.53.

Figure 6. Coconut fibers.

Figure 7. Rice-husks.

2.2 *Mixture proportions*

The mixture proportions of natural fiber cement board are shown in Table 2, where the water-tocementitious matrix ratio is 0.5 by weight, and the cement-to-slag ratio is 1.5 by weight, or 60% cement and 40% slag, respectively.

In order to compare the effect of natural fibers, we add natural fibers of 10% in volume to cement board. Totally, four kinds of NFCB represented by B10, C10, R10 and S10 shown in Table 2, are referred as the cement board containing bamboo fiber, coconut fiber, rice-husks and sugar cane-dregs, respectively. Besides, the comparison material shown in Table 2 means the cement board containing no natural fibers inside.

Table 2. Mixture proportions of NFCB. (unit :kgf/m^3)

Material	Fiber*	Water	Cement	Slag	Sand	Air content
Comparison	0	360	432	288	797	10
B10	10	360	432	288	534	10
C10	10	360	432	288	534	10
R10	10	360	432	288	534	10
S10	10	360	432	288	534	10

* Fiber is in volume percent.

2.3 *Experimental method*

Natural fibers are difficult to mix well with the cementitious material. The mixture method here for NFCB is conducted as follows.

(1) Weigh the constituents shown in Table 2.

(2) Mix the cement and slag together in two minutes at dry condition, and then pour 75% water into the mixture, and finally blend two minutes by middle speed of the mixer.

(3) Turn off the mixer, add natural fibers into the mixture material, and then blend one minute by middle speed of the mixer.

(4) Turn off the mixer again, pour the remaining 25% water into the mixture, and then blend ten minutes by middle speed of the mixer.

Each batch of materials was prepared for nine samples with the size of 50×50×50mm for compressive test, three samples with 100×100×10mm for the absorption test and bulk specific gravity test, three samples with 40×160×10mm for length change induced by absorption of water, six samples with 250×350×20mm for bending test, one with 200×200×10mm for heat-resistant capability, one with 220×220×10mm for fireproof capability, and one with 300×300×10mm for impact endurance test, respectively. All samples were placed on the vibration table to shake one minute. The surface of cement boards was leveled to be smooth by the trowel, and then one hour later, a surcharge with 30g/cm2 were loaded to confine the size of NFCB. Samples were removed from the mold 24 hours later, and placed indoor for curing and for testing.

3 RESULTS AND DISCUSSION

3.1 *Bulk density and water content*

We measure bulk density and water content of NFCB in accordance with ASTM C1185, and results were shown in Table 3. In Table 3, the bulk density of the comparison material is about 1860 kgf/m3. Obviously, the bulk density of natural fiber cement boards for B10, C10, R10 and S10 are all lighter than that of the comparison material about 12.4%, 15.1%, 21.2%, and 23.1%, respectively. According to CNS 3802 requirements, the optimum density for fiber cement boards is claimed to 1300-1400 kgf/m3,

Table 3. Bulk density and water content of cement boards.

Material	Bulk density (kgf/m^3)	Water content (%)
Comparison	1860	10.7
B10	1630	12.8
C10	1580	13.1
R10	1465	11.2
S10	1430	12.6

where CNS means Chinese National Standards. It is anticipated to reduce the bulk density of NFCB if the fibers adding to cement board are more than 10% in volume.

In Table 3, the water absorption of all NFCB with the value from 11.2% to 13.1%, respectively, is higher than that of comparison material. Among them, the water content of rice-husks cement board (R10) seemly does not increase much, only 4.7% increases.

3.2 *Length change due to absorption of water*

Length change of cement board after the absorption test is shown in Table 4. The length change of the comparison material is only 0.01%, but the length change of NFCB is within the range of 0.09%- 0.16%. Although the length change of natural fiber cement boards is higher than that of the comparison material, the value of length change for NFCB is still small as compared with calcium silicate board and gypsum board. The building partition made from NFCB containing 10% natural fibers is suitable in use.

Table 4. Length change of cement boards.

Material	Length change (%)
Comparison	0.01
B10	0.13
C10	0.16
R10	0.09
S10	0.12

3.3 *Compressive strength and flexural strength*

The specimens were tested at the material age of 28 days in compression (ASTM D1037) and bending test (ASTM C1185), and the experimental results are shown in Table 5. The compressive strength of natural fiber cement boards with the value 14.2 ~ 23.8 N/mm2 is lower than that of the comparison material with 26.9 N/mm2, especially the compressive strength of R10 is 14.2 N/mm2 and decrease more than 30%. This is because the intrinsic quality of natural fibers can strengthen the tensile strength but not the compression. The compressive strength of the cement board with coconut fibers (C10) is 23.8 N/mm2, and is only 11.6% less with respect to the comparison material.

On the contrary, the flexural strength of natural fiber cement boards is higher than that of the comparison material, except for the rice-husks cement board (R10) shown in Table 5. For example, the flexural strength of bamboo fiber cement board (B10) and of the comparison material is 7.48 N/mm2 and 4.15 N/mm2, respectively. The flexural strength of B10 is almost 80% stronger.

Table 5. Strength of cement boards. (N/mm^2)

Material	Compressive strength	Flexural strength
Comparison	26.9	4.15
B10	22.1	7.48
C10	23.8	6.87
R10	14.2	3.55
S10	19.2	4.54

3.4 *Impact test*

Cement boards were tested by impact loads in accordance with CNS9961, where the dimension of the impact specimen is of 300mm× 300 ×10mm, the weight of impact ball is 530grams with the diameter of 51mm, and the drop distance of the ball is 1400mm, respectively.

The impact results are shown in Table 6, where the number marked 1, 2, 3, and 4 is represented to the defects with the crack, the detachment, the pinholes, and the split, respectively.

Table 6. Impact test of cement boards.

Material	Indentation diameter (mm)	Impact* surface	Reverse* surface
Comparison	—	1, 2, 3, 4	
B10	10	no defects	small crack
C10	15	no defects	crack
R10	—	1, 2, 3, 4	
S10	26	no defects	crack

*1: crack, 2: detachment, 3: pinholes, 4: split

Figure 8. Fracture of counterpart material after impact test.

The comparison material has the existence of defects like cracks, the detachment, pinholes and the split on the impact surface after the impact test, shown in Fig. 8. From Table 6, only the cement board with rice-husks (R10) has similar defects like the comparison material does.
After the impact test, the cement board with 10% bamboo fibers (B10) did not find the cracks, the detachment, pinholes and the split on the impact surface, and the overall indentation diameter is about 10mm, shown in Fig. 9. Meanwhile, the reverse side of impact surface (reverse surface) displayed a convex surface with some microcracks for B10 shown in Fig. 10.

Figure 9. Impact surface of B10 after impact test.

Figure 10. Reverse surface of B10 after impact test.

For C10 material shown in Table 6, the impact surface also did not discover any defects after the
impact test, and the indentation diameter is about 15mm. The reverse surface for C10 shows a convex surface containing obvious cracks.
For the cement board adding sugar cane-dregs (S10), no defects found on the impact surface, and the overall indentation diameter is about 26mm. The reverse surface for S10 also shows a convex surface with obvious cracks.

3.5 *Thermal conductivity*

To be building partitions, cement boards should have heat-resistant capability. Here, we examine the heatresistant capability of cement boards by using the thermal conductivity in accordance with ASTM C518, and results are shown in Table 7. The thermal conductivity of the comparison material was measured and is 0.826 kcal/m·oC·hr.

Table 7. Thermal conductivity of cement boards.

Material	Thermal conductivity (kcal/m·°C·hr)
Comparison	0.826
B10	0.201
C10	0.217
R10	0.266
S10	0.296

For natural fiber cement boards, the values of thermal conductivities is within 0.201 and 0.296 kcal/m·oC·hr. The thermal conductivity of B10 and C10 is only one fourth of the comparison material shown in Table 7. Therefore, NFCB have desirable heat-resistant capability compared with that the comparison material.

3.6 *Fireproof capability*

Fireproof capability is also an important index for building partitions. Cement boards were tested by incombustibility test claimed by ASTM E84 and CNS 6532, and the results are shown in Table 8.

Table 8. Incombustibility of cement boards.

Material	Incombustibility rank
Comparison	2nd standard
B10	2nd standard
C10	2nd standard
R10	—
S10	3rd standard

Figs. 11-12 show the heating surface and the reverse surface of B10 after the incombustibility test, respectively. Fireproof capability of B10 and C10 materials satisfies the 2nd standard of incombustibility claimed by CNS 3802, and is the same as that of the comparison material. For the S10 material, it reaches the 3rd standard of incombustibility. However, R10 material failed under the incombustibility Test.

Figure 11. Heating surface of B10 after incombustibility test.

Figure 12. Reverse surface of B10 after incombustibility test.

4 CONCLUSSIONS

This paper attempted to make use of natural fibers collected from useless agricultural products such as the bamboo, the coconut shell, rice-husks and sugar cane-dregs, respectively, to make natural fiber cement board as the material of building partitions. In this research, the volume fraction of natural fiber added to cement board is 10%. The mixture method of making natural fiber cement boards is also presented. Experimental results show that most of material properties for cement boards containing bamboo fiber, coconut fiber, and sugar cane-dregs are better than those of the comparison cement board (without natural fibers), including the incombustibility satisfied the national standards. Although the bulk density of natural fiber cement boards we made is about 1430-1630 kgf/m3, higher than 1400 kgf/m3 claimed by the Code, we can afford to add natural fibers more than 10% volume fraction to lower the weight of natural fiber cement boards in future. It seems that we can use those three natural fibers to make the natural fiber cement board used as building partitions in the building industry.

ACKNOWLEDGMENTS

The authors would like to thank the Taiwan National Science Council under NSC 97-2221-E-415-011- MY2, and Architecture and Building Research Institute, Ministry of the Interior in Taiwan, for the financial supports.

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