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Properties of the Cementitious Composite Material Containing Charcoal Particle Reinforced with Natural Fibers

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It is well known that the charcoal shows a good performance in the moisture and gas absorption. The charcoal has a possibility to be applied for the building materials as a material for the humidity control and the absorption of harmful gas such as HCHO or VOC. A fibrous bamboo and coir fiber will be able to good use as reinforcement because of its high tensile strength. The object of this paper is to develop a new building board containing the charcoal particle bound with cement paste reinforced by the bamboo fiber. The tests on the properties of the building board such as the flexural strength and the capability of humidity control containing various contents of these natural materials were carried out. Although the test results showed that the increase in the flexural strength of each specimen by these reinforcement methods was not recognized, the flexural toughness of the specimen with a length of 2cm of bamboo fiber and its content of about 4vol% had maximum value. Moreover, the specimen with the charcoal particle content of 50~60vol% showed a high value for the humidity control which was almost equal to that of the timber of Japanese cedar.

Key words: Charcoal particle, Natural fiber, Flexural toughness, Humidity control

1. INTRODUCTION

Since recently the modern houses tend to be a high air tightness and heat insulation, the atmosphere of the room becomes to be a high relative humidity condition, and therefore a mold and tick propagate easily in such room when not ventilating the room suitably. The developed mold and tick cause an allergic disease, and it is a social problem in Japan that a poisonous gas such as Formaldehyde (HCHO) or Volatile Organic Compound (VOC) exhaled from a bond which is used for bonding a wall paper causes an illness.

One of the methods to be solved above problems is to use a building material which has a good performance such as the high humidity control or the absorption of harmful gas. Since a charcoal has these good properties, the use of charcoal as a material for these building materials is very effective. Charcoal is a porous material and excellent in property such as the capability of humidity control although its strength is low. Since the strength of the building material containing a charcoal particle will be low, a bamboo fiber which has greater tensile strength is used for reinforcement.

In Japan, it is a serious problem that a bamboo invades a wood because of its very early growth. Using a carbonized bamboo as a material is one of the methods for the effective use, but in this study, a fibrous bamboo was used for reinforcement.

The object of this paper is to develop a new building board containing the charcoal particle bound with cement paste reinforced with a bamboo fiber or coir fiber, and the tests on the properties of the building board were carried out.

2. MATERIALS USED

2.1 CEMENT

Materials used shown in Table 1. High-early-strength Portland cement with a density of 3.04g/cm^3 was used.

2.1 CHARCOAL PARTICLE

Charcoal which is generally known as a porous material is divided broadly into two classifications by carbonized methods. Moreover, characteristics of charcoal such as strength, specific surface area or water absorption are dependent of the nature of wood. In this study, for the purpose of the reduction of environmental impact, charcoal particle which carbonized in low temperature and made with the lumber from thinning or the fallen tree by typhoon was used. Its grain size, oven-dry density and water absorption are 8mm, 0.22g/cm^3, 342.5%, respectively (See Fig.1).

Table 1 Materials used

Cement	High-early-strength Portland cement density 3.14g/cm^3
Admixture	Charcoal Particle (Japanese cedar): grain size 8mm oven-dry density 0.22g/cm^3 water absorption 342.5%
	Bamboo fiber (Species of thick-stemmed bamboo): length 1 or 2cm diameter about 600μm oven-dry density 0.91g/cm^3
	Coir fiber: length 2cm diameter 300~700μm oven-dry density 0.45g/cm^3
Chemical admixture	Superplasticizer

2.2 BAMBOO FIBER

When a steel had been insufficient in Japan, a bamboo was used as a reinforcement bar instead of steel because a bamboo has a greater tensile strength. Therefore, the fibrous bamboo seems to be available for reinforcement of building materials. And other noteworthy thing is that a supply of bamboo is especially easy because of its very early growth. In this study, considering the reduction of environmental impact, fibrous waste product of species of thick-stemmed bamboo which was discharged from the factory of folding fan was used. Its oven-dry density, diameter and length are 0.91g/cm^3, about 600μm and 1 or 2cm, respectively. Bamboo has sugars such as cane, grape and fruit sugar, and it is well known that these sugars make the prevention of hardening of cement. However, this bamboo fiber has no sugar because of the elution of sugar at the manufacturing process of the ribs of folding fan (See Fig.2) [1].

2.3 COIR FIBER

Coir fiber has a greater tensile strength as well as bamboo fiber. The effectiveness of reinforcement of mortar and concrete with a coir fiber has been reported [2]. Therefore, in this study, a coir fiber was used to compare with a bamboo fiber. Its oven-dry density, diameter and length are 0.45g/cm^3, about 300~700μm and 2cm, respectively (See Fig.3).

2.4 CHEMICAL ADMIXTURE

Segregation is occurred easily because of the difference in the density of the constituent material used. Therefore, the cement paste with a high viscosity was made by using a superplasticizer, and the flow was controlled at a value of 200±10mm.

3. OUTLINE OF EXPERIMENT

3.1 SPECIMEN

Mix proportions are shown in Table 2. The total number of 18 mixes obtained by changing the charcoal particle content, the fiber content, the fiber length and the kind of fiber were used. Cement, water and chemical admixture were mixed for 3 minutes using mortar mixer with a capacity of 5 liters. Then, charcoal particle and natural fiber (bamboo fiber or coir fiber) were thrown into that cement paste, and mixed sufficiently by hand.

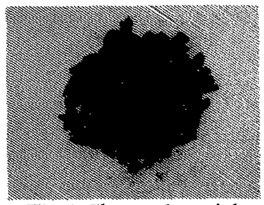

Fig.1 Charcoal particle

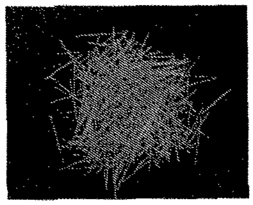

Fig.2 Bamboo fiber

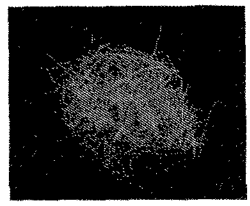

Fig.3 Coir fiber

Mixed cement paste with charcoal particle and natural fiber was placed into the steel form with a size of 500×500×10mm up to 15mm high, as shown in Fig. 4. Then, the steel lid was pressed down to 10mm high, and had been clamped with vises.

These boards were demoulded at the age of 2days, and were cured in 20℃ water until the age of 28days. Then, the boards were cut to small pieces for flexural strength test (200×40×10mm) and humidity control test (250×250×10mm). These specimens were cured in air (20℃, 60%RH) until the age of the tests.

3.2 FLEXURAL STRENGTH TEST

Flexural load-displacement curve at the age of 56 days with 5 specimens in each mix was measured by the displacement controlling testing machine, and flexural toughness was obtained by calculating the area of load-deflection curve. The test was loaded by concentrated load at the center of span, and the span of the specimen and the loading rate were 150mm and 0.3mm/min, respectively.

Table 2 Mix proportions

No.	W/C* (%)	Charcoal content (vol%)	Fiber content (vol%)	Fiber length (mm)	Unit weight (kg/m^3)					
					Cement	Water	Charcoal particle	Bamboo fiber	Coir fiber	Super plasticizer
1	30	40	0	20	970.1	286.2	88.0	0	-	4.85
2			2		937.8	276.6	88.0	18.1	-	4.69
3			4		905.5	267.1	88.0	36.3	-	4.53
4			6		873.1	257.6	88.0	54.4	-	4.37
5		50	0		646.8	190.8	110.0	0	-	3.23
6			2		614.4	181.3	110.0	18.1	-	3.07
7			4		582.1	171.7	110.0	36.3	-	2.91
8			6		549.7	162.2	110.0	54.4	-	2.75
9		60	0		485.1	143.1	132.0	0	-	2.43
10			2		452.7	133.6	132.0	18.1	-	2.26
11			4		420.4	124.0	132.0	36.3	-	2.10
12			6		388.1	114.5	132.0	54.4	-	1.94
13		50	2	10	614.4	181.3	110.0	18.1	-	3.07
14			4		582.1	171.7	110.0	36.3	-	2.91
15			6		549.7	162.2	110.0	54.4	-	2.75
16		50	2	20	614.4	181.3	110.0	-	9.0	3.07
17			4		582.1	171.7	110.0	-	18.0	2.91
18			6		549.7	162.2	110.0	-	27.0	2.75

*Water cement ratio (by weight)

3.3 HUMIDITY CONTROL TEST

Specimens cured sufficiently were used for the humidity control test. The water content of the specimen was adjusted at air dry condition (20℃, 60%RH) before the test. Each 4 side faces of every specimen were sealed with paraffin to prevent the moisture absorption or desorption from the side face of specimen. In the humidity control test, specimens were kept in the cyclic humidity range between 50%RH and 90%RH for each 24hours, and the temperature was kept 20℃ during the test, as shown in Fig.5. The change in the weight due to the moisture absorption or desorption from the specimen was measured periodically. Capability of humidity control was estimated with 10th cycle results because of the range of fluctuation became constant. And Japanese cedar board was used for comparison because its capability of humidity control was high.

4. TEST RESULTS AND DISCUSSION

4.1 FLEXURAL STRENGTH

The influence of the bamboo fiber with a length of 2cm and the charcoal particle content on the flexural strength is shown in Fig.6. The flexural strength decreases as the charcoal content increases. It is found that the flexural strength slightly increases up to the bamboo fiber content of 4vol%, although it decreases more than 4vol%.

The influence of fiber length and the kind of fiber on the flexural strength is shown in Fig.7. In comparison with the bamboo and the coir fiber on the effect of reinforcement, the coir fiber has a little more reinforcement than that of the bamboo fiber. There is no clear difference in the effects the length of bamboo fiber on the flexural strength. The flexural strength of the

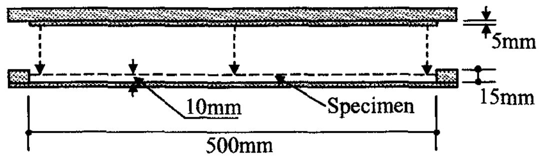

Fig.4 Section of the steel form

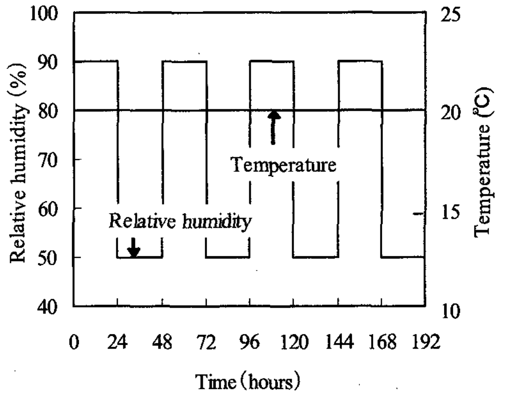

Fig.5 Condition of the humidity control test

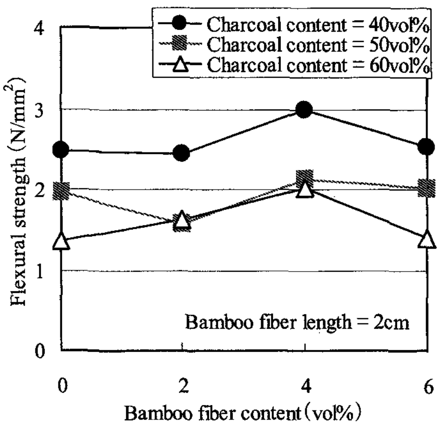

Fig.6 The influence of the charcoal and the bamboo fiber content to the flexural strength

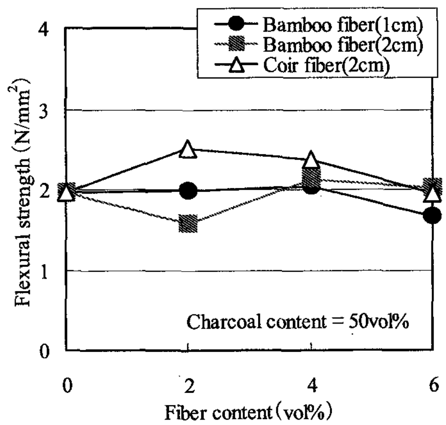

Fig.7 The influence of the fiber length and type to the flexural strength

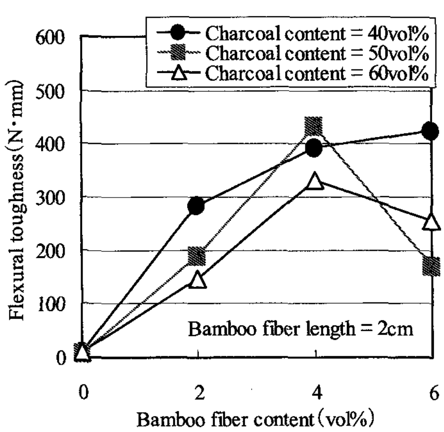

Fig.8 The influence of the charcoal and the bamboo fiber content to the flexural toughness

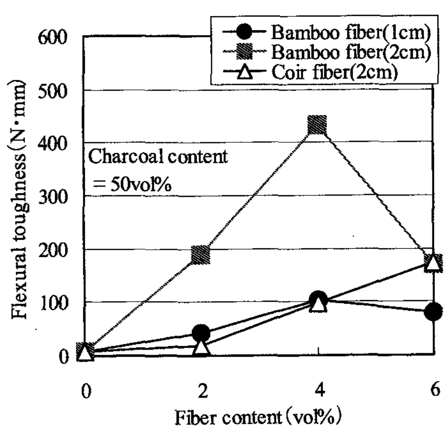

Fig.9 The influence of the fiber length and type to the flexural toughness

specimen with a charcoal content of 50~60vol% and a bamboo fiber content of 4vol% develops about 2N/mm^2, and this is almost the same as the strength of the thermal insulation board such as the cemented excelsior board (JIS A 5404) or the insulation fiberboard (JIS A 5430).

The influence of the charcoal and the bamboo fiber content and the kind of fiber on the flexural toughness is shown in Fig.8 and Fig.9. Although these figures show the great improvement of flexural toughness by containing bamboo fiber, the flexural toughness decreases when the amount of the bamboo fiber content is too much. This decrease may be caused by a weakening of the fiber–cement paste matrix bond due to the lack of sufficient matrix. Moreover, the bamboo fiber with a length of 2cm has greater effect of improvement than the coir fiber with a same length or the bamboo fiber with a length of 1cm.

From the reason mentioned above, although these natural fibers have no effect of reinforcement on the flexural strength, they have the effect of improvement on the flexural toughness when the constituent materials are mixed by volume. It is noted that the bamboo fiber with a length of about 2cm is needed in order to gain the bond strength between the fiber and the cement paste matrix.

4.2 HUMIDITY CONTROL

The quantity of absorption of moisture at 10th cycle is shown in Fig.10. The quantity of absorption of moisture increases according to the increase of charcoal particle content.

The evaluation method on the capability of humidity control is shown in fig.11. The capability of humidity control (S) was assessed with the total area which was added the both areas indicating the capability of moisture absorption (S_1) and desorption (S_2)[1].

The comparison of the calculated capability of humidity control is shown in Fig.12. The more increase the charcoal and the natural fiber content, the more increase the capability of humidity control, and coir fiber shows higher capability than bamboo fiber. The board having the almost the same proportion of Japanese cedar boards on the capability of humidity control can be made by containing the charcoal particle of 50~60vol% and the bamboo fiber of 4vol%. The reason for the increase of capability due to the addition of natural fiber is that the moisture movement probably becomes easy by the increase of the interface between fiber and cement paste matrix.

5. CONCLUSION

For the purpose of developing the new building materials which has the humidity control and the reduction of the environmental impact, the board containing charcoal particle reinforced by the natural fiber was made. Experimental studies on the flexural strength and the humidity control was conducted. The test results showed that it was possible to make the new building material with humidity control by using the charcoal particle and the bamboo fiber. A good mix proportion is that the content of charcoal particle is 50~60vol% and that of bamboo fiber 4vol%, and this mix proportion will show almost the same flexural strength as the thermal insulation board, and the same capability of humidity control as Japanese cedar.

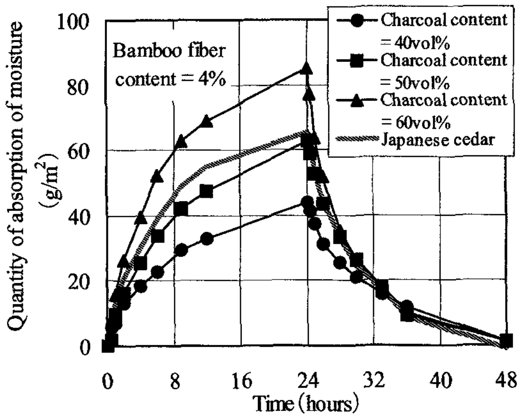

Fig.10 Quantity of absorption of moisture at 10th cycle

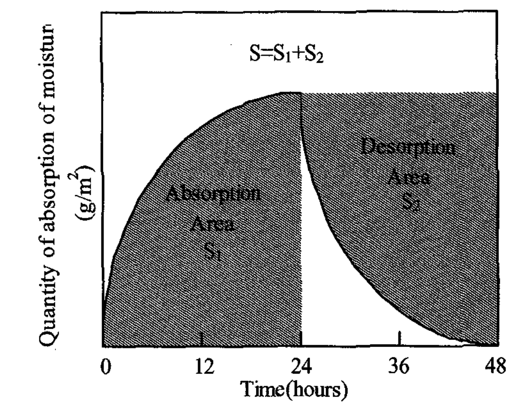

Fig.11 The evaluation method of the capability of humidity control test

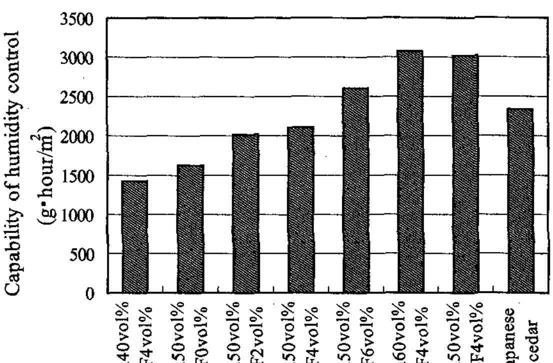

Fig.12 Comparizon of the capability of humidity control

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