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Research of a Snow-Melting System for Houses that Uses Porous Carbon-Material Woodceramics

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A snow-melting tile that uses the high infrared radiation properties of woodceramics was developed to enable easy construction of a snow melting system for houses. Experimental sugi woodceramics 1.0 to 1.7 mm, 1.7 to 4.0 mm, and over 4.0 mm thick were made at a sintering temperature of 800°C as aggregate materials for a snow-melting system, and their ability to absorb water was measured. The thinnest samples (1.0 to 1.7 mm) showed the highest water absorption. Then, samples of snow-melting tiles containing 10%, 20%, and 30% aggregate material with a thickness of 1.0 to 1.7 mm were made and their snow-melting rates were measured. The samples with a 20% and 30% woodceramics content had a snow-melting rate of 50%. The snow-melting system was effective with the heater surface temperature set to 25°C in an open-air test.

1. INTRODUCTION

One of the characteristics of woodceramics is their high infrared radiation properties.[1] A snow-melting tile made using woodceramic powder was developed for use as an aggregate material for a house snow-melting system that can be easily constructed. The infrared radiation properties and snow-melting effects of the tiles were tested. We also examined an indirect heating type snow-melting system that uses wood ceramics to re-examine the solar system for practical use. We also investigated the construction of a woodceramics snow-melting system for houses that uses a solar system combined with midnight electric power and general daytime electric power.

2. EXPERIMENT METHOD

2.1 Sample materials

We made woodceramics samples with a thickness of 1.0 to 1.7 mm, 1.7 to 4.0 mm, and over 4.0 mm by impregnating sugi sawdust with 50% phenol resin, drying the samples for 48 hours at 55°C, hardening for 4 hours at 135°C, then sintering at 800°C without oxygen.

Figure 1 shows a photograph of a sugi woodceramics (1.0 to 1.7 mm thick) made at a sintering temperature of 800°. The figure shows the form of sawdust. SEM photographs of the sugi woodceramics are shown in Figures 2 to 5. Figure 2 is an SEM photograph of the regular grain surface showing that tracheids and bordered pits remain without change even after carbonization. Figure 3 is an enlarged SEM photograph of a bordered pit. Figure 4 is an SEM photograph of a cut end showing that tracheids remain without change and cell walls form cores.

Figure 5 is an enlarged SEM photograph of a cut end that shows that the cell wall is a complex of glassy carbon from the phenol resin and amorphous carbon from the original sugi lumber. These photographs show that woodceramics is a stable carbon material that has the porosity of a plant material and is reinforced with glassy carbon from the phenol resin.

2.2 Water absorption test

Three kinds of woodceramics samples (1.0 to 1.7 mm, 1.7 to 4.0 mm, and over 4.0 mm thick) made at a sintering temperature of 800°C were dried completely in an oven for 4 hours at 105°C and sprayed with distilled water to measure their maximum water absorption rates. Then, the pyrolytic components were extracted from each sample with heated water for 2 hours at 105°C to measure their maximum water absorption rates in the same way as above.

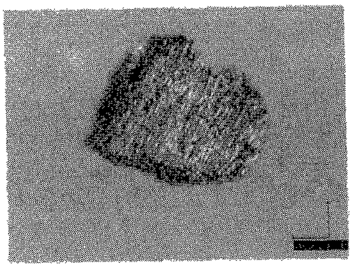
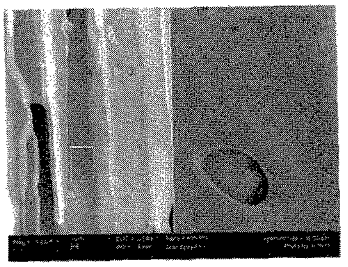


Fig. 1 Appearance of cedar WC. (800°C)



F ig.2 Cedar WC (regular grain)

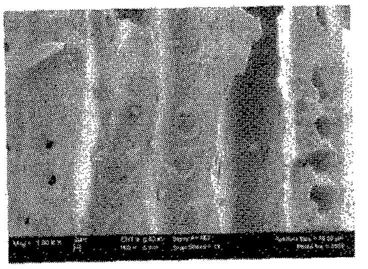


Fig.3 Cedar WC (regular grain)

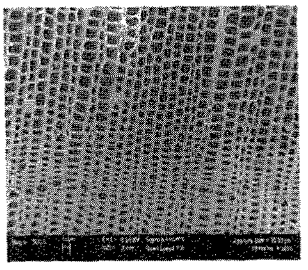


Fig.4 Cedar WC (cut end)

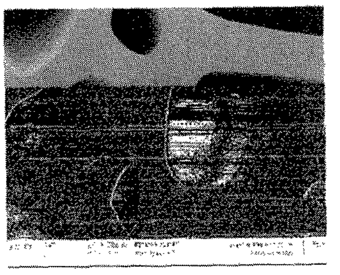


Fig.5 Cedar WC (cut end)

Table 1. Material mixing rates in upper layer

Materials	Standard mixture	Woodceramics mixture (10%)	(20%)	(30%)
Cement	40kg	40kg	40kg	40kg
Water	20kg	20kg	20kg	20kg
River sand	60kg	48kg	36kg	24kg
Wood-ceramics	-	12kg	24kg	36kg
Total	120kg	120kg	120kg	120kg

Table 2 Material mixing rates in base layer

Materials	Standard mixture	Silica mixture (10%)
Cement	160kg	160kg
Water	48kg	48kg
River sand	400kg	339.2kg
Silica	-	60.8kg
Total	608kg	608kg

2.3 Production method of snow-melting tiles

As shown in Figure 6, the top 1 cm layer of each 300 x 300 x 30 mm tile was mixed with sugi woodceramics (1 to 1.7 mm) in the ratios of 10%, 20%, and 30% to make snow-melting tiles.

The 2 cm base layers of the tiles were mixed with 10% silica. The surfaces were finished by roughly grinding them.

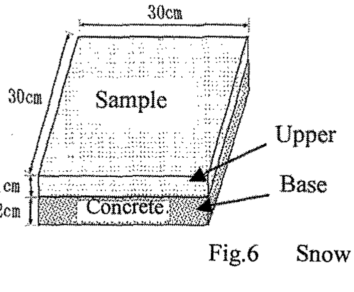


Fig.6 Snow melting tile

The material combination rates in the upper layers are listed in Table 1. The table shows that some river sand used in the basic combination is replaced with sugi woodceramics. Table 2 lists the material combination rates in the base layers.

3. RESULTS AND DISCUSSION

3.1 The snow melting test

As shown in Figure 7, the smaller the sugi woodceramics sample, the higher the water absorption rate.[2)] Especially, after the extraction with heated water, the water absorption rates of the 1.0 to 1.7 mm-thick samples were about twice as high as the 1.7 to 4.0 mm-thick samples. It is conceivable that the adhesion of pyrolytic phenol components produced by carbonization increases the absorption rate. The results showed that the water absorption rate of sugi woodceramics is also higher than that of general sugi charcoal. It is conceivable that

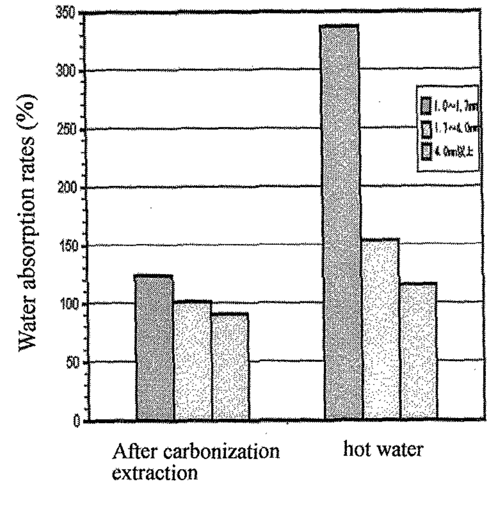


Fig. 7 Water absorption rates of cedar WC according to grain size.

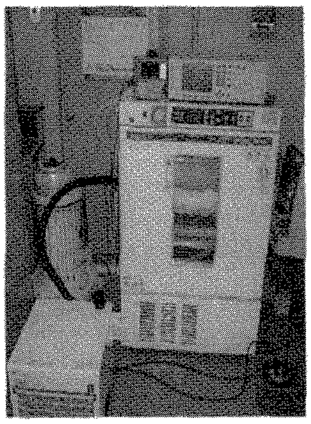


Fig.8 Snow-melting performance evaluation system

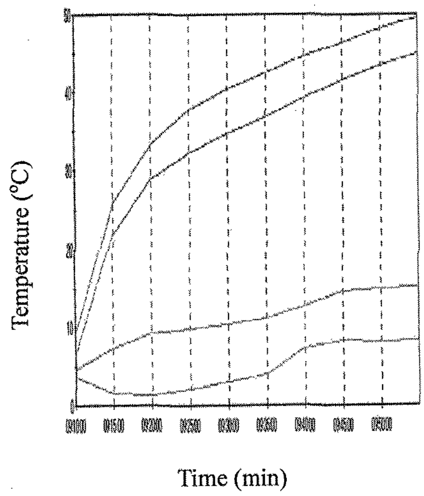


Fig.10 Surface temperature of each material during snow-melting test

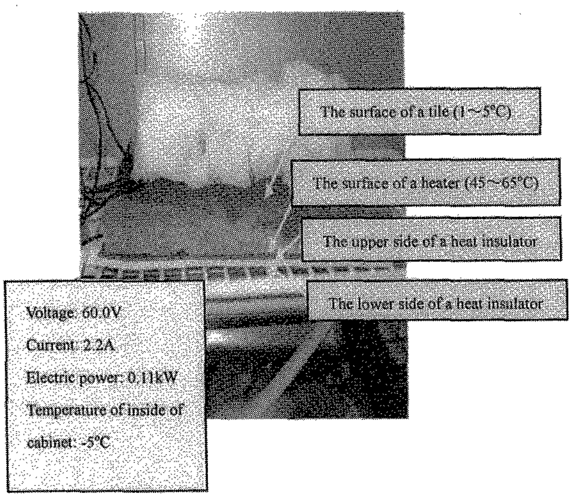


Fig.9 Snow-melting performance test

the glassy carbon from the phenol resin increases the water absorption of sugi woodceramics. The snow-melting performance evaluation system is shown in Figure 8. The environment adjustment section of this system employs an incubator and freezer to maintain an environmental temperature of -5°C. The measuring and control section consists of a wattmeter, thermometer, and transformer and is connected to a flat heater. As shown in Figure 9, a snow-melting tile was put on the flat heater and a bridged polyethylene-foam layer was laid underneath the heater as a heat insulator. About 700 g of snow was put on the snow-melting tile, the transformer was adjusted to supply the heater with 50 V at 2.2 A, and the snow was heated for 30 minutes with 0.11 kW. Then, the snow-melting rate was calculated as the ratio of the weight of melted snow to the weight of the snow before heating. The surface temperatures of each material during the snow-melting test are shown in Figure 10. As shown in this figure, when the surface temperature of the heater was about 50°C, the temperatures of the top and bottom of the heat insulating material were, respectively, about 45°C and 13.5°C and the temperature of the tile surface was about 7.5°C. These results show a heat insulating effect of about 5 to 6°C. The performance of snow-melting tiles with a sugi woodceramics (1.0 to 1.7 mm) ratio of 10%, 20%, and 30% are shown in Figure 11. As shown in this figure, the higher the sugi woodceramics ratio, the higher was the snow melting ratio. However, there was almost no difference between the tiles with a ratio of 20% and 30%. When considering the surface hardness and strength, the tiles with a 20% sugi woodceramics can be expected to be the most suitable for a snow-melting system.

Sugi woodceramics absorbs water most easily at wavelengths of 3 μm, 6 μm, and 15 μm and improves the thermal conductivity of the tile. Therefore, it is conceivable that water absorbed from snow at these wavelengths is easily heated by infrared radiation.

3.2 Open-air test of the snow-melting system

The woodceramics snow-melting system for houses is shown in Figure 12. This system uses a solar power supply, midnight electric power, and general daytime electric power. Part of the electric power is stored in a double-layer condenser. The surface temperature of the heater is measured with a temperature sensor and controlled by a temperature controller. A system that melts snow by heating snow-melting tiles can easily be installed.

The bridged polyethylene-foam heat-insulating layer under the heater improves the energy efficiency of the system. As shown in Figure 13, the heater temperature was set to 30°C at an outside air temperature of -1°C, the snow-melting system melted snow sufficiently with a heater surface temperature of 17.1°C and a tile surface temperature of 6.4°C. The system also melted snow sufficiently when the heater temperature was set to 25°C. However, at this heater temperature the tile surface temperature is affected by the outside air temperature. The solar system is not effective in winter because there are few sunny days in snowy regions. Therefore, better

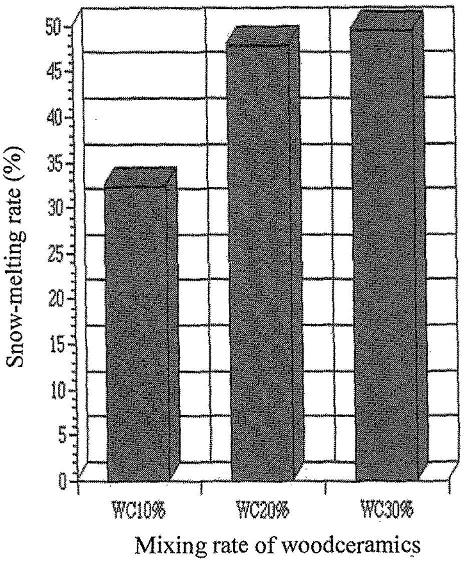


Fig.11 Snow-melting performance of woodceramics snow-melting

efficiency may be achieved by obtaining electric power from the solar system in seasons other than winter and selling the power to an electric power company to offset the cost of general daytime electric power consumed in winter, and by operating the snow-melting system as much as possible at night when the power charge is lowest.

3. CONCLUSIONS

1) In a water absorption test, the smaller the sugi woodceramics samples, the higher was the water absorption rate. Especially, after extracting the pyrolytic components with heated water, the water absorption rate of the 1.0 to 1.7 mm-thick samples was about twice as high as the 1.7 to 4.0 mm-thick samples. The test results showed that the water absorption rate of sugi woodceramics is also higher than that of general sugi charcoal. It is conceivable that the glassy carbon from the phenol resin increases the water absorption rate of sugi woodceramics.

2) In a test with 1.0 to 1.7 mm-thick sugi woodceramics tiles with 10%, 20%, and 30% mixture ratios, the higher the mixture ratio, the higher was the snow-melting rate.

3) When the heater temperature was set to 30°C at an outside air temperature of -1°C, the snow-melting system melted snow sufficiently with a heater surface temperature of 17.1°C and a tile surface temperature of 6.4°C. The system also melted snow sufficiently when the heater temperature was set to 25°C.

The following is scheduled for future investigation:

1) How to produce woodceramics at low cost and how to produce similar ceramics by using materials other than wood will be investigated to develop a more efficient snow-melting system.

2) The snow-melting system will be evaluated regarding the cost of continuous operation for a full season.

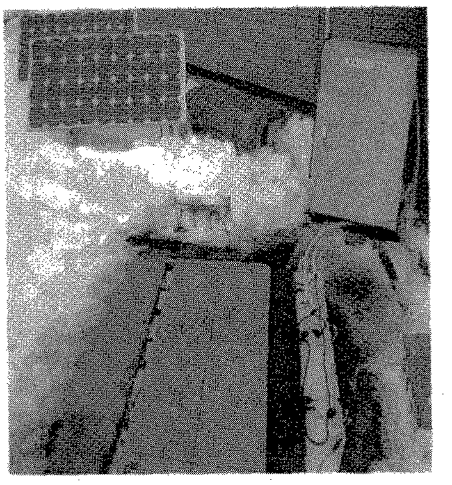


Fig.12 Snow-melting system for houses being used woodceramics snow-melting tiles

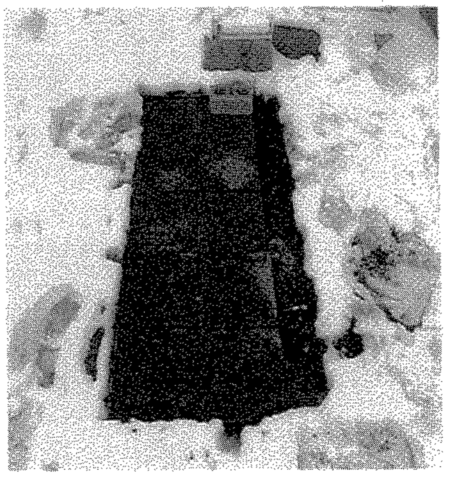


Fig.13 A result of snow-melting tests showing melted snow

3) A double-layer condenser-electrode will be developed and its performance evaluated.

4) Application of the woodceramics heater to food drying will be investigated.

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