Development of Insulation Material Using Natural Tree Bark

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In Japan, Sugi(*Cryptomeria japonica*) has been widely used as a building material. Its most bark is thrown away. However, the use of Sugi bark, which is fibrous and durable, as insulation material would be effective from the standpoint of using materials that are friendly to the environment. Therefore, the heat conductivity ratio of insulation material made from processed Sugi bark has been calculated experimentally; and its possibilities for such usage have been reviewed. Experiments were conducted on the following: (1) coarsely frayed Sugi bark, (2) Sugi bark finely blended in a mixer, (3)extruded polystyrene insulation board STYROFOAM used for comparison purposes. The laboratory at Utsunomiya University calculated the coefficient of thermal conductivity resulting from the experiment by calibrating the temperatures above and below the experimental subject plus the ambient temperature surrounding it. The results of the experiment were as follows: (1) using STYROFOAM board, the coefficient of thermal conductivity was 0.045 W/mK. In the cases of (2) coarse Sugi bark and (3) fine Sugi bark, the coefficients of thermal conductivity were not all that different from each other, at 0.073 W/mK and 0.076 W/mK respectively. When the high temperature was set at 76 ℃, condensation was observed inside the experimental material involving tree bark by the water contained in the material.
Key words:Sugi(*Cryptomeria japonica*) bark, Thermal insulation material, Waste curtailment, Practical use of a natural material

1. Introduction

In Japan, Sugi(*Cryptomeria japonica*) has been widely used as a building material. Its bark has long been recognized as something to be used for a roofing material because of its durability. Today, that kind of roofing has been replaced by industrial material, with the result that most Sugi bark is thrown away. However, the use of Sugi bark, which is fibrous and durable, as insulation material would be effective from the standpoint of using materials that are friendly to the environment. Therefore, the heat conductivity ratio of insulation material made from processed Sugi bark has been calculated experimentally; and its possibilities for such usage have been reviewed.

2. Outline of the experiments

Table 1 The formula for thermal physical-properties value of Sugi bark

■Thermal flow, heat transfer coefficient and thermal conductivity of Sugi bark

Qu[W/m²], K[W/m²K], λc[W/mK]

$$Qu = K(t_3 - t_1) \quad \cdots(1)$$

$$K = 1/\{1/\alpha + 2\times(d_A/\lambda_A) + d_C/\lambda c\} \quad \cdots(2)$$

$$\lambda c = (Qu \cdot d_C)/\{(t_3 - t_1) - Qu\cdot(1/\alpha + 2d_A/\lambda_A)\} \quad \cdots(3)$$

here, Qu: Thermal flow (top of test piece)[W/m²]
t_1, t_3: temperatures at the bottom of the specimens, and the ambient air temperature [K]
K : heat transfer coefficient [W/m²K]
α : Total heat transfer rate [W/m²K]($\alpha c + \alpha r$)
$\alpha c, \alpha r$: convective, radiative heat transfer rate[W/m²K]
d_A、d_C: Thickness of acrylics board, Sugi bark [m]
λ_A、λc: thermal conductivity of acrylics board and Sugi bark[W/mK]

In Japan, JIS A 1412-1~3[1] is used in experiments concerning the calculation of thermal conductivity ratios; but figure 1 illustrates a simple calibration method involving the locations on the test pieces at which their thermal flows were calibrated and a formula by which their thermal physical properties were calculated. It installed so that the test pieces might be stuck on the lid (0.3mm griddle) of the can into which hot water was put. In other words, the heat capacity and the highest and lowest temperatures of the test pieces and the ambient air temperature are calibrated in order to calculate the thermal conductivity ratio. Table 1

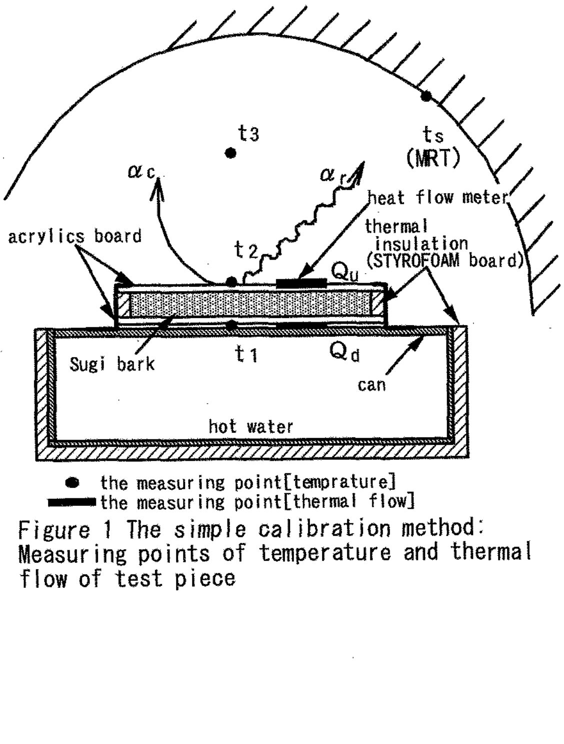


Figure 1 The simple calibration method: Measuring points of temperature and thermal flow of test piece

illustrates the computation formula.

Experiments were conducted at the Utsunomiya University laboratory using three types of test pieces: (1) coarsely frayed Sugi(*Cryptomeria japonica*) bark, (2) Sugi bark finely blended in a mixer, and (3) extruded polystyrene insulation board STYROFOAM (Dowkakoh K.K.,IB) used for comparison purposes. Figure 2 illustrates the size of test piece.Sugi bark, which was torn into appropriate pieces and naturally dried up for 4 months in the laboratory, was used for the test piece. As it also was broken using a mixer for home use, the test piece contained pieces of bark with the original state remained and fiber-like ones. The Sugi bark sized 2 to 4 mm wide ×10 to 30 mm long at maximum was defined as a coarse piece and the fiber-like piece sized 5 to 10 mm long at maximum was defined as a fine piece. Table 2 illustrates the test period of the experiments, and the test pieces weights. Figures 3 and 4 illustrates Sugi bark used in this study. Figures 5 and 6 illustrates the test pieces of Sugi bark and STYROFOAM board.

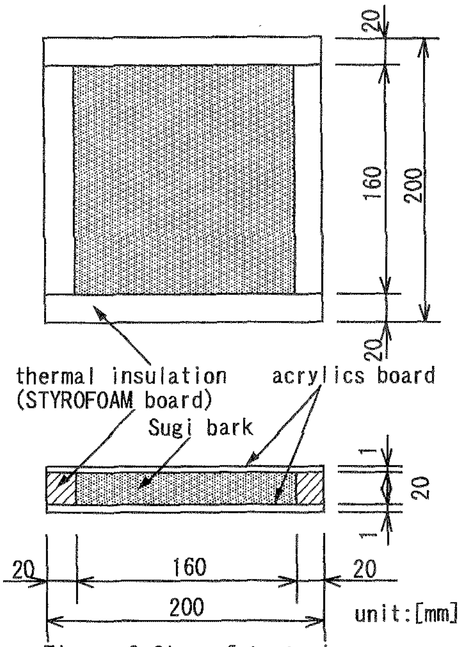


Figure 2 Size of test piece

3. Results of the experiments

Figure 7 illustrates the test pieces surface temperatures, taken by thermal cameras during the experiments. In contrast to the surface temperatures, the surrounded squarely of the test pieces remained constant at 35.72~40.70 ℃. Also, horizontal heat flow was controlled by the insulation material. The weights of the test pieces did not change.

Figures 8~10 illustrate the fluctuation of temperatures, thermal flows, and thermal conductivity ratios during experiments periods.

As for the STYROFOAM board, the temperature above the "can"(t1) reached 80 ℃, while the temperature above the test pieces (t2) was only 30 ℃. The temperatures gradually decreased to the point that t1 was 40 ℃ and t2 became 17 ℃, indicating a temperature differential of about 25 ℃. During that time, the thermal flow was 140~40 W/ m² although the flow was somewhat different at the test piece' s top and bottom; and the thermal conductivity ratio was 0.055~0.045 W/mK.

In the case of the Sugi(*Cryptomeria japonica*) bark (coarse), the temperature above the can (t1) was 76 ℃, while the temperature above the test piece (t2) was 30 ℃. The temperature t1 eventually dropped to 53 ℃, while

Table 2 Weight, Density and Moisture content of test piece and test period

No.	Test piece	Weight [g]	Density [kg/m³]	Moisture content [%]	Test period
1	STYROFOAM Board (Dowkakoh K.K., IB)	134.9	28.2	—	5.February 2003(WED)14:52~ 6.February 2003(THU) 8:21
2	Sugi Bark (coarsely frayed)	204.0	163.2	9.1	6.February 2003(THU) 9:00~ 6.February 2003(THU)16:47
3	Sugi Bark (finely blended)	219.5	193.5	10.0	6.February 2003(THU)17:05~ 7.February 2003(THU) 8:17

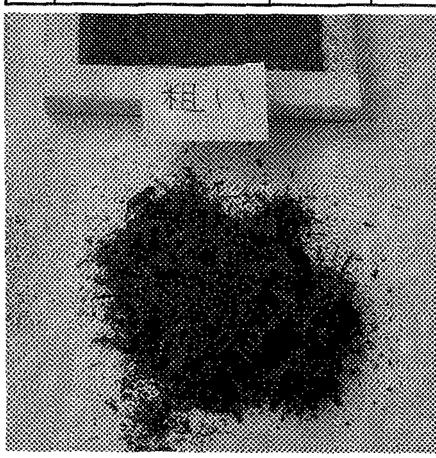


Figure 3 Sugi bark (coarsely frayed)

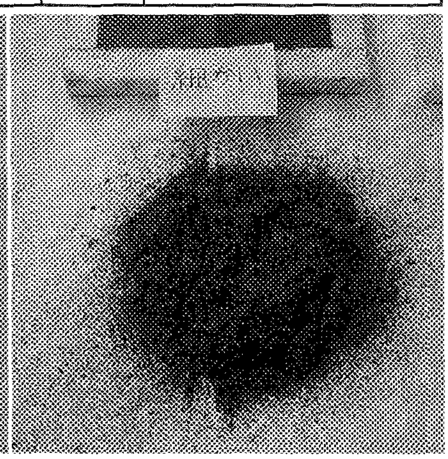


Figure 4 Sugi bark(finely blended)

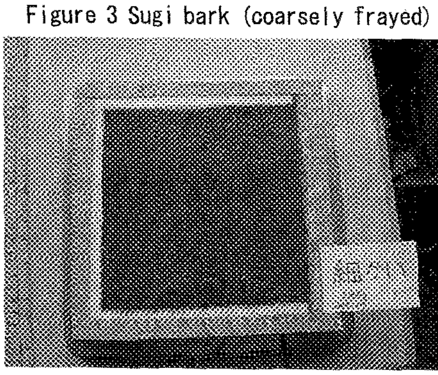


Figure 5 Test piece 3 (finely blended)

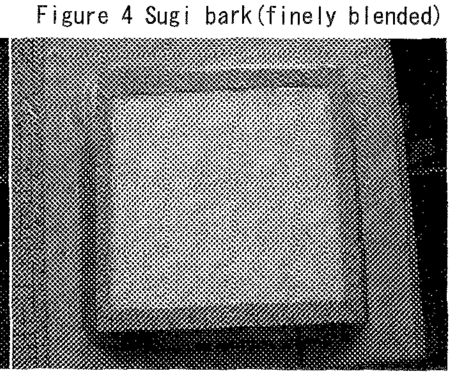
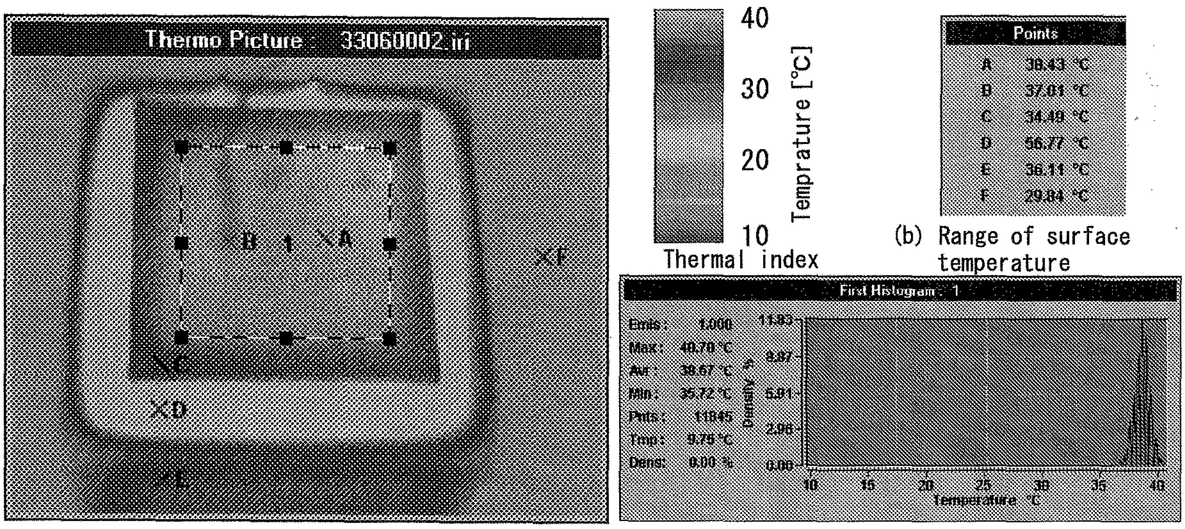


Figure 6 Test piece 1 (STYROFOAM Board)



(a) Thermography

(b) Range of surface temperature

(c) The degree distribution of examination temperature

Figure 7 Range of surface temperature of Sugi bark by thermo-camera

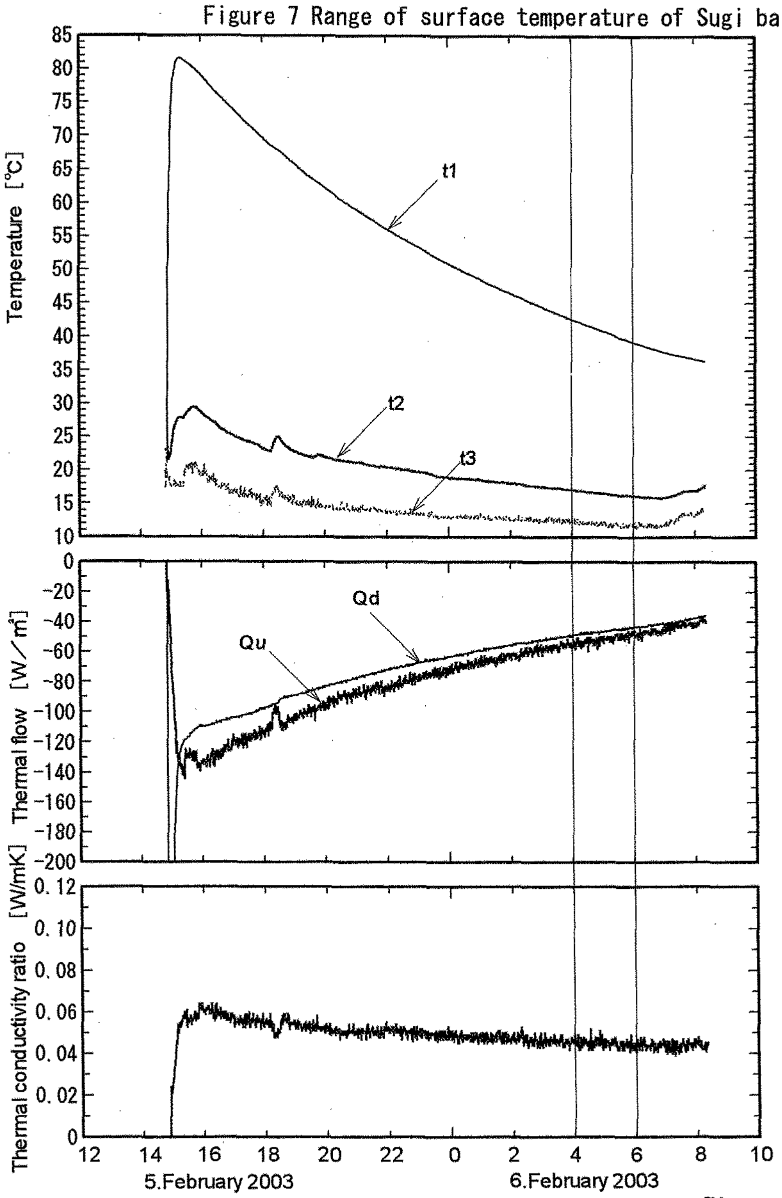


Figure 8 Fluctuation of temperature, thermal flow and thermal conductivity of STYROFOAM test piece

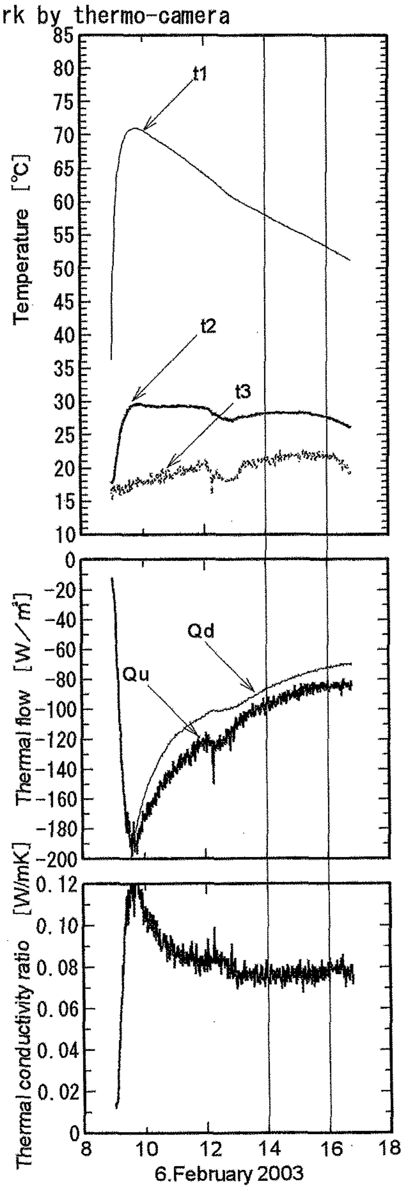


Figure 9 Fluctuation of temperature, thermal flow and thermal conductivity of Sugi bark(coarsely frayed) test piece

t2 dropped to 28 ℃, resulting in a temperature differential of 25 ℃. During that time, the thermal flow, which differed at the top and the bottom of the test piece, was 100~80 W/㎡. The thermal conductivity ratio was 0.10~0.08 W/mK. However, 30 minutes after the start of the experiment, condensation occurred inside the test piece. It probably occurred because of water in the Sugi bark reaching a high temperature (figure 11).

Then, in the case of the Sugi bark (fine), the experiment was conducted with the water temperature being lukewarm. The temperature above the can (t1) was 47 ℃ and the temperature above the test piece (t2) was 25 ℃. The temperature t1 eventually dropped to 28 ℃, while t2 dropped to 16 ℃. During that time, no condensation occurred, and the thermal flow as 100~40 W/㎡, with the thermal conductivity ratio being 0.10~0.07 W/mK.

Table 3 illustrates the thermal conductivity ratios of the test pieces.

(1)In the case of the STYROFOAM board, the mean value from 4 to 6 on February 6 was used.

(2)In the case of the Sugi bark (coarse), the mean value from 14 to 16 on February 6 was used

(3)In the case of the Sugi bark (fine), the mean value from 4 to 6 on February 7 was used.

The thermal conductivity ratio for the STYROFOAM board was 0.045 W/mK, showing a somewhat larger value than the commonly considered value [2]. The thermal conductivity ratios for the Sugi bark were 0.073 W/mK and 0.076 W/mK.

Some points to be noted following the experiments are that it took some time to stuff the Sugi bark and that internal condensation might occur as a result of sunlight heating the inside of the wall. Therefore, tree bark needs to be thoroughly dried.

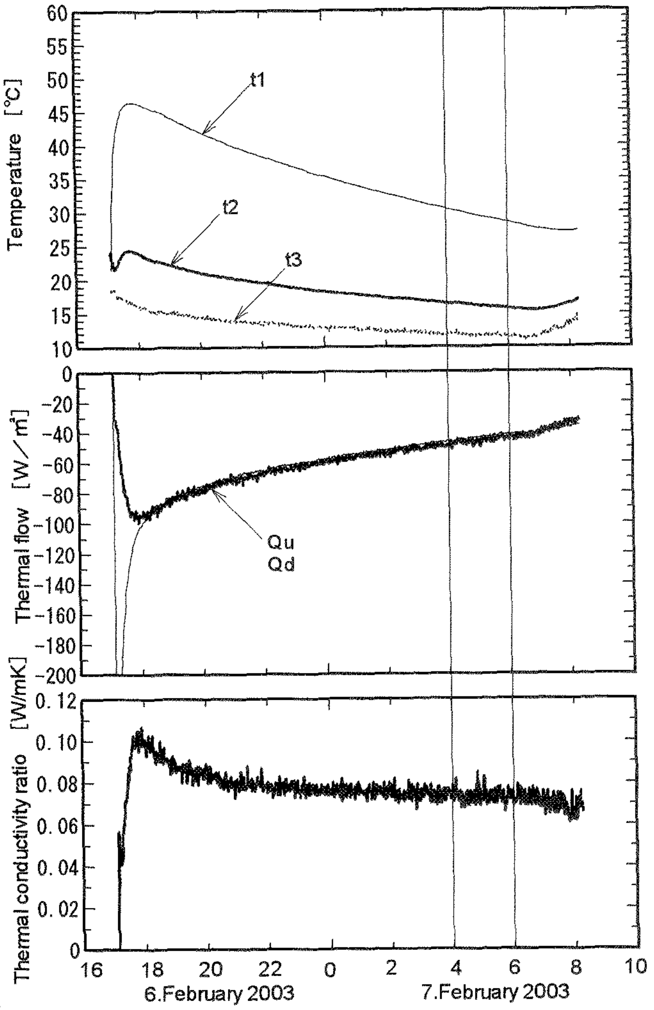


Figure 10 Fluctuation of temperature, thermal flow and thermal conductivity of Sugi bark(finely blended) test piece

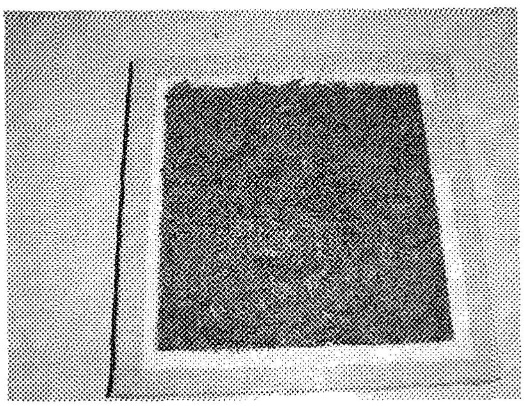


Figure 11 Test piece: dew condensation situation of Sugi bark(coarsely frayed)

4. Conclusion

Regardless of the size of the Sugi(*Cryptomeria japonica*) bark, the thermal conductivity ratios were 0.073 W/mK and 0.076 W/mK. Thus, the use of Sugi bark as an insulation material is quite effective from the standpoint of environmental friendliness.

References

[1]JAPANESE INDUSTRIAL STANDARD A 1412-1~3,1999

[2]The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan:Manual of Heating, Air-Conditioning and Sanitary II,p36,1987

Table 3 Thermal conductivity of the Sugi bark

No.	test piece	The time zone of the experiment data adopted as calculation (average value)	t1 [℃]	t2 [℃]	t3 [℃]	Qd [W/㎡]	Qu [W/㎡]	λc [W/mK]
1	STYROFOAM Board (Dowkakoh K.K., IB)	6. February 2003, 4- 6 o'clock	40.9	16.6	12.0	-46.0	-51.3	0.045
2	Sugi Bark (coarsely frayed)	6. February 2003, 14-16 o'clock	55.7	28.3	21.7	-78.4	-89.6	0.076
3	Sugi Bark (finely blended)	7. February 2003, 4- 6 o'clock	29.5	16.1	11.7	-43.4	-45.5	0.073

※The rate of heat transfer of test piece surface side was calculated as 9.3 [W/㎡K]
※The thermal conductivity of an acrylics board was calculated as 0.2 [W/mK]

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