Preliminary

The Influence of the Temperature Change Rate on the Humidity Control Effect of Wood*[1]

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Introduction

In a treasury of museums or galleries, huge amount of electric power is consumed to keep its temperature and humidity constant. It seems, however, possible to reduce electric power since almost all the walls inside standard treasuries are usually lined with wood which has remarkable humidity control effect. To estimate the humidity control effect of wood and other materials, it is necessary first to establish a useful index for this effect. The B-value[1)] is known to be an effective measure for this purpose. It is obtained from the relationship between the logarithm of relative humidity and temperature measured in a closed steel box lined with a wall material under the specified variation of ambient temperature. However, this index is known to be different at different rates of temperature change even when lined area in the box is the same.

In the present paper, we introduce first an index C which is simpler than B, and then discuss how the C-value is affected by the temperature change rates. We further propose a method to predict the C-value without information on temperature change rates.

Materials and Methods

Materials used are sugi flat grain wood with 1cm thick. Porous ceramics wall materials were also used for comparison. After a steel box with a base 20×20 cm and a height of 25 cm was lined with above materials, it was sealed carefully to prevent air leakage. The extent of lined area is expressed as the ratio of lined area A (m^2) to the volume of steel box V (m^3), A/V (m^{-1}). Seven A/V's from 0.25 to 3.0 were adopted in our experiment. To obtain the B and C-values, temperature and relative humidity inside the box were measured with time in the climatic chamber whose temperatures vary sinusoidally around 25°C at four amplitudes of 2.5 to 10°C, each of which has four wave periods of 6 to 48 hrs. To predict the C-value, we also measured absolute humidity variation by applying four step temperatures from 5 to 20°C around 15°C.

Results and Discussion

When the sinusoidal temperature changes are applied, sinusoidal relative humidity curves result. In this case, the ratio of humidity amplitude in the box lined with a material to that in the empty box can be introduced as an index to estimate humidity control effect of materials. This index, called the C-value, exhibits directly how the extent of the humidity change is reduced by the presence of materials in the box. Fig. 1 shows relationship between the C and B values for sugi wood obtained in all the conditions employed. Since the C-value was closely related to the B-value, we adopted in this report the C-value instead of B as a measure of humidity control effect. In addition to the C value, the shift of the time at maximum absolute humidity from the time at maximum temperature can also be used as an index of the humidity control effect. The Γ which was defined as this time shift divided by period was found to be proportional to C. Both C and Γ values will depend on temperature change rate as in the B-value. When the temperature changes sinusoidally, the rate of the temperature change in the chamber is made by changing (temperature) amplitude at the constant period or by changing period at the constant amplitude. In the range of period and amplitude examined, both the C and Γ values were found to change

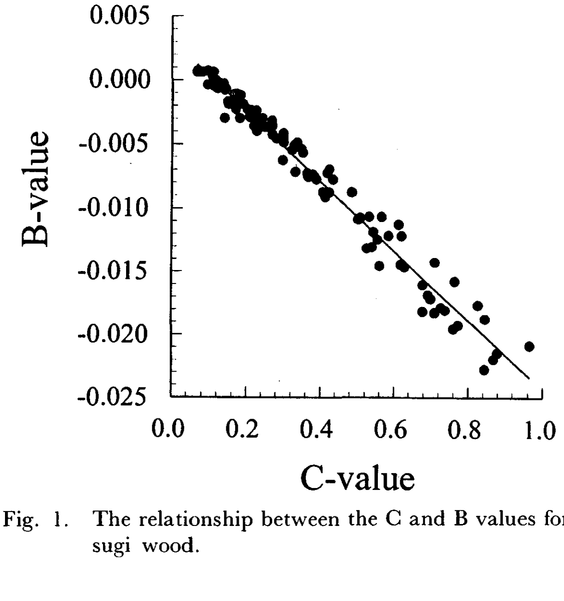

Fig. 1. The relationship between the C and B values for sugi wood.

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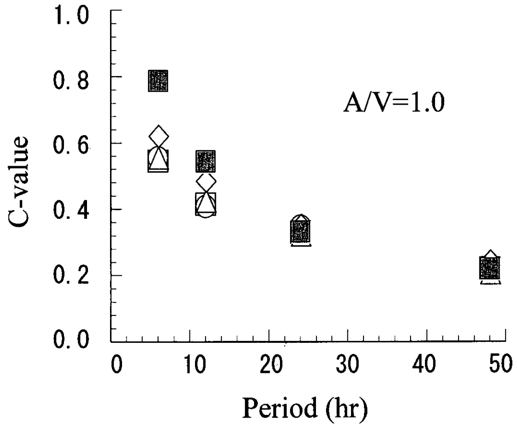

Fig. 2. The change in C value for sugi wood with period measured at $A/V=1$ at different temperature amplitude. Temperature amplitude: 2.5°C (□), 5°C (○), 7.5°C (△), 10°C (◇). Calculated value (■).

markedly in the latter. For example for the specimen with $A/V=1$, the C value fell from 0.6 to 0.2 as the period increased from 6 hr to 48 hr. In the former, on the other hand, both the C and Γ values remained almost constant irrespective of the temperature amplitude.

Based on these findings, an attempt was made to predict C and Γ by assuming following relation between temperature and absolute humidity. (1) When the step temperature θ_0 is applied at a time $t=0$, the corresponding absolute humidity $h(t)$ at a time t ($t>0$) is proportional to the absolute humidity $\Psi(t)$ obtained at a step temperature of 1C (i.e. $h(t)=\theta_0\Psi(t)$). (2) $h(t)$ at any time t, due to the previous application of step temperatures $d\theta$ in succession, is the sum of the dh which would arise at that time if each $d\theta$ had been applied independently. From these assumptions, we may express $h(t)$ at the time t as follows:

$$h(t)=\int_0^t \Psi(t-u)\frac{d\theta(u)}{du}du.$$

From this equation, when the temperature $\theta(t)$ is subject to sinusoidal wave, we can easily obtain $h(t)$ from which both C and Γ are derived. Fig. 2 shows the change in C value for sugi wood with period measured at $A/V=1$ at temperature amplitude of 2.5 to 10°C. Calculated values are also plotted in the figure. As for the measured C values, they decreased markedly with increasing periods, though they remained almost unchanged when compared at the same period. As for the calculated values, they were in good agreement with measured ones, except for the result at 6 hr. Similar results were obtained for other cases with different A/V. We further observed that the measured Γ values at various temperature change rates were corresponded well with calculated ones within the range of A/V examined. From these consideration, we may conclude that the C, Γ, and thus B at any temperature change rates can be predicted from simple step temperature experiments.

References

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