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ORIGINAL ARTICLE

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Assessment of temperature and relative humidity conditioning performances of interior decoration materials

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Abstract The purpose of this study was to explore conditioning effects on wood panels (used as interior decorative materials). We examined hourly the temperature and relative humidity (RH) in a living environment based on the data of average values from 1974 to 1990 in the Taipei area. Thirty-six interior finish materials attached to one inside surface of a 35^3 cu cm simulation aluminum container were used in this study. An A/V ratio (surface area/volume) of 2.86 (m^{-1}) or various other values and the panel thickness had no significant effect on the room temperature changing ratio. The hygroscopic conditioning performances of these decorative materials were classified into four types in accordance with b values: type I ($b > 0.0200$) included four solid woods (unfinished), seven wood-based materials, three composite materials, and one inorganic material. Type II ($0.0170 < b < 0.0199$) included one solid wood, five wood-based materials, and two inorganic materials. Type III ($0.0070 < b < 0.0169$) included nine wood-based materials, and four inorganic materials. The RH changing ratio decreased curvilinearly with increasing interior decorative panel thickness and A/V values in a sealed container, whereas the b values increased with increasing interior decorative panel thickness and A/V values in a sealed container.

Key words Interior decorative materials · A/V values · Temperature changing ratio · Hygroscopic conditioning performance · Effectiveness of thickness

Introduction

It is highly desirable to live in a house with a safe and comfortable environment. In general, the interior climate of a living environment is controlled by a combination of room temperature, relative humidity (RH), circulation of air, and radiation of heat. It is recognized that these factors can be influenced by the design and construction of the building or house materials used and the facilities installed. When the relation between the materials used and the interior climate was considered, the effect of humidity was found to be greater than that of temperature. It is known that certain conditions are greatly affected by the RH in a house or building, including the presence of fungi, bacteria, and insects, fluctuation of dew points, comfort of living, dimensional stability, and durability of facilities. Therefore, from the viewpoint of quality of living, it is important to control the humidity to maintain an optimum living environment.

To provide a better understanding of the conditioning effects of interior decorative materials, Wang and Cho[1,2] investigated 31 interior finish materials attached to one of the inside surfaces of a 35^3 cu cm simulation aluminum container with an A/V ratio (interior surface area/room volume) of 2.86 (m^{-1}). The aluminum container was placed in a computer-controlled environmental chamber. A cyclic temperature for a 1-h interval each of 20°C → 35°C → 25°C → 35°C → 25°C was set inside the chamber. Wang and Cho[2] also investigated materials attached to various surfaces of inside walls in an identical aluminum container with different A/V values to explore further the hygroscopic conditioning performance of interior decorative materials.

Wang and Cho[3] investigated the effects of wood materials on the room temperature and RH using two typical residential houses that were constructed using reinforced concrete and bricks; the interior of one was finished with China fir [*Cunninghamia lanceolata* (Lamb.) Hook] lumber panels and lauan (*Shorea* sp.) lumber flooring. The other was not finished and was designated the control. The daily temperature and RH changes inside the rooms of these houses were monitored from January to December 1991.

This study provides a better understand of the conditioning effects of temperature and RH in a living environment.

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It is based on the average hourly changes in temperature and RH from 1974 to 1990 in the Taipei area. Different materials were attached to the inside walls of the sealed aluminum container, and the container was then placed in a conditioned chamber subjected to changes of temperature and RH. The data were derived from these measurements. The conditioning effects of various wood-based materials, including the thickness of wood panels and the A/V ratio, based on changes of temperature and RH were evaluated.

Materials and methods

Materials

Thirty-six materials were investigated in this study, classified into four types: wood, wood-based material, composite material, and inorganic material. Their characteristics are depicted in Table 1. An aluminum container with no specimen inside was the control.

Table 1. Decorative materials used as linings in an aluminum container and their temperature and humidity conditioning performance indexes

Specimen	Group	Surface treatment.	Thickness. (cm)	A/V (m^{-1})	$\Delta T_1/\Delta T_2$	$\Delta RH_1/\Delta RH_2$	Ave. T(°C)	Ave. RH(%)	b
Solid wood									
Taiwan red cypress (flat-sawn face)	1	None	0.9	2.93	1.11	0.29	23.4	69.9	0.0242
Japanese cedar (flat-sawn face)	2	None	0.9	2.93	1.04	0.69	23.4	69.5	0.0247
China fir (flat-sawn face)	3	None	0.9	2.93	1.05	0.53	23.4	72.0	0.0189
Taiwania (flat-sawn face)	4	None	0.9	2.93	1.07	0.40	23.4	70.3	0.0261
Red oak (flat-sawn face)	5	None	0.9	2.93	1.05	0.43	23.5	73.1	0.0203
Wood-based materials									
Plywood	6	None	0.55	2.90	1.07	0.48	23.4	70.6	0.0181
Plywood	7	None	1.1	2.95	1.08	0.52	23.5	68.7	0.0183
Particleboard	8	None	1.2	2.96	1.06	0.54	23.3	73.5	0.0213
Medium density fiberboard	9	None	0.8	2.92	1.06	0.48	23.0	74.1	0.0236
Fiberboard	10	None	0.4	2.89	1.06	0.28	23.2	69.5	0.0284
Insulation fiberboard	11	None	0.9	2.93	1.16	0.54	22.8	74.8	0.0246
Paper overlaid fiberboard	12	None	0.4	2.89	1.05	0.40	23.2	73.5	0.0233
Oriented strand particleboard	13	None	0.9	2.93	1.06	0.62	23.6	72.7	0.0188
Fancy plywood	14	Coated with NC lacquer	0.7	2.92	1.04	0.54	23.4	74.5	0.0167
China fir panel	15	Coated with NC lacquer	0.2	2.87	1.06	0.61	23.4	75.9	0.0155
Maple flooring	16	Coated with PU	1.3	2.97	1.12	0.84	23.2	77.0	0.0112
Japanese cedar flooring	17	Coated with PU	1.5	2.99	1.04	0.88	23.4	76.8	0.0121
Red oak flooring	18	Coated with PU	1.5	2.99	1.08	0.89	23.3	77.1	0.0118
Plywood	19	Coated with NC lacquer	0.9	2.93	1.10	0.62	23.3	74.9	0.0154
Plywood	20	Coated with PU	0.5	2.90	1.40	1.18	22.6	64.8	0.0144
Fire-proof plywood	21	None	0.55	2.90	1.07	0.47	23.3	69.2	0.0224
Fire-proof plywood	22	77°C, 55% RH for 80 days	0.55	2.90	1.10	0.44	23.2	69.8	0.0195
Fire-retardant plywood	23	None	1.1	2.95	1.06	0.80	23.2	68.8	0.0250
Fire-retardant plywood	24	77°C, 55% RH for 80 days	1.1	2.95	1.08	0.45	23.0	68.8	0.0197
Polyester resin overlaid plywood	25	None	1.1	2.95	1.06	0.69	23.4	75.0	0.0135
Melamin resin overlaid plywood	26	None	0.8	2.92	1.12	0.56	23.8	73.3	0.0142
Composite materials									
Cemented excelsior board	27	None	1.4	2.98	1.07	0.61	23.6	72.8	0.0240
Insulation plaster fiberboard	28	None	1.5	2.99	1.04	0.68	23.1	74.4	0.0217
Perforated plaster fiberboard	29	None	0.8	2.92	1.02	0.72	23.4	73.5	0.0239
Inorganic materials									
Glass	30	None	0.5	2.90	1.04	0.88	23.7	75.2	0.0103
Fire-retardant plastic flooring	31	None	0.2	2.87	1.07	0.74	23.3	75.4	0.0141
Concrete board	32	None	1.4	2.98	1.23	0.48	22.9	73.4	0.0197
Concrete board	33	White cement paint-coated concrete plate	1.4	2.98	1.19	0.53	23.2	72.4	0.0165
Tile	34	None	0.9	2.93	1.41	0.63	23.0	84.6	0.0181
Plasterboard	35	None	1.0	2.94	1.09	0.67	23.4	74.9	0.0206
Marble	36	None	0.9	2.93	1.26	0.87	23.3	74.2	0.0114
Control group aluminum container	37	None	–	0	1.13	0.96	23.6	76.1	0.0085
Climate condition	38	None	–	–	–	–	22.5	77.8	0.0057

T_{max}, maximum temperature; T_{min}, minimum temperature; ΔT(°C), $T_{max} - T_{min}$; ΔT_1, $(T_{max} - T_{min})_{indoors}$, ΔT_2, $(T_{max} - T_{min})_{outdoors}$; RH_{max}, maximum RH; RH_{min}, minimum RH; ΔRH(%), $RH_{max} - RH_{min}$; ΔRH_1, $(RH_{max} - RH_{min})_{indoors}$; ΔRH_2, $(RH_{max} - RH_{min})_{outdoors}$; Ave. T(°C) and RH(%), average temperature and RH within 24h in a sealed container, respectively; b, hygrosapic conditioning performance index; NC, nitrocellulose clear lacquer; PU, polyurethane resin.

Methods

Effects of various materials on temperature and RH

Test specimens were cut into 35 × 35 cm blocks, with thicknesses varying with the materials. After conditioning in 20°C/65% RH, the materials (one of each of the four types) were attached to one of the inside wall surfaces of a 35^3 cu cm aluminum container. The A/V ratio inside the container was 2.86 (m^{-1}). Because the thickness of the 36 interior decorative materials varied, when attached to one of the interior walls of the 35^3 cu cm aluminum container the A/V values ranged from 2.87 to 2.99 as shown in Table 1. These differences are due to the fact that the inside volume of the aluminum container slightly decreases with the increasing thickness of the interior decorative materials, resulting in a slight increase in the A/V value. The aluminum container was placed in a computer-controlled environmental chamber. The conditions of the chamber temperature and RH were determined by data on average hourly temperature and RH changes from 1974 to 1990 in the Taipei area (Table 2). A temperature and RH detector was installed in the aluminum container. The data for temperature and RH variations were collected by the Labdas system, developed by Adventech Company.

Effects of various thicknesses of wood panels on temperature and RH

Panels of Japanese cedar and red oak were chosen to evaluate the conditioning effects of various thicknesses of wood panels on temperature and RH. They were sliced into seven thicknesses: 0.3, 0.6, 0.9, 1.2, 1.5, 1.8, and 2.1 cm. The corresponding A/V ratios were 2.88, 2.91, 2.93, 2.96, 2.99, 3.01, and 3.04, respectively. The inside volume of the aluminum container slightly decreased with the increasing thickness of the interior decorative materials, which results in the slight increase in A/V values. An aluminum container without a specimen was the control.

Table 2. Average values of hourly changing temperature and relative humidity in the Taipei area, 1974–1990

Hour	t(°C)	RH(%)
1	21.4	83
2	21.2	83
3	21.0	84
4	20.8	84
5	20.7	85
6	20.5	85
7	20.5	85
8	20.7	84
9	21.6	81
10	22.8	76
11	23.9	72
12	24.7	69
13	25.1	68
14	25.2	66
15	24.9	69
16	24.5	70
17	24.0	72
18	23.4	74
19	22.9	76
20	22.5	78
21	22.2	79
22	22.0	80
23	21.8	81
24	21.6	82

t, temperature; *RH*, relative humidity.

Effects of A/V ratio on temperature and RH

Japanese cedar and red oak panels (thickness 0.9 cm) were chosen to evaluate the conditioning effects of the A/V ratio on temperature and RH. They were attached to one, two, three, four, or five surfaces of the inner wall of a 35^3 cu cm aluminum container. The A/V ratios inside the container were 2.93, 6.02, 9.12, 12.37, and 15.63. An aluminum container without a specimen was the control, and its A/V was 0.

Results and discussion

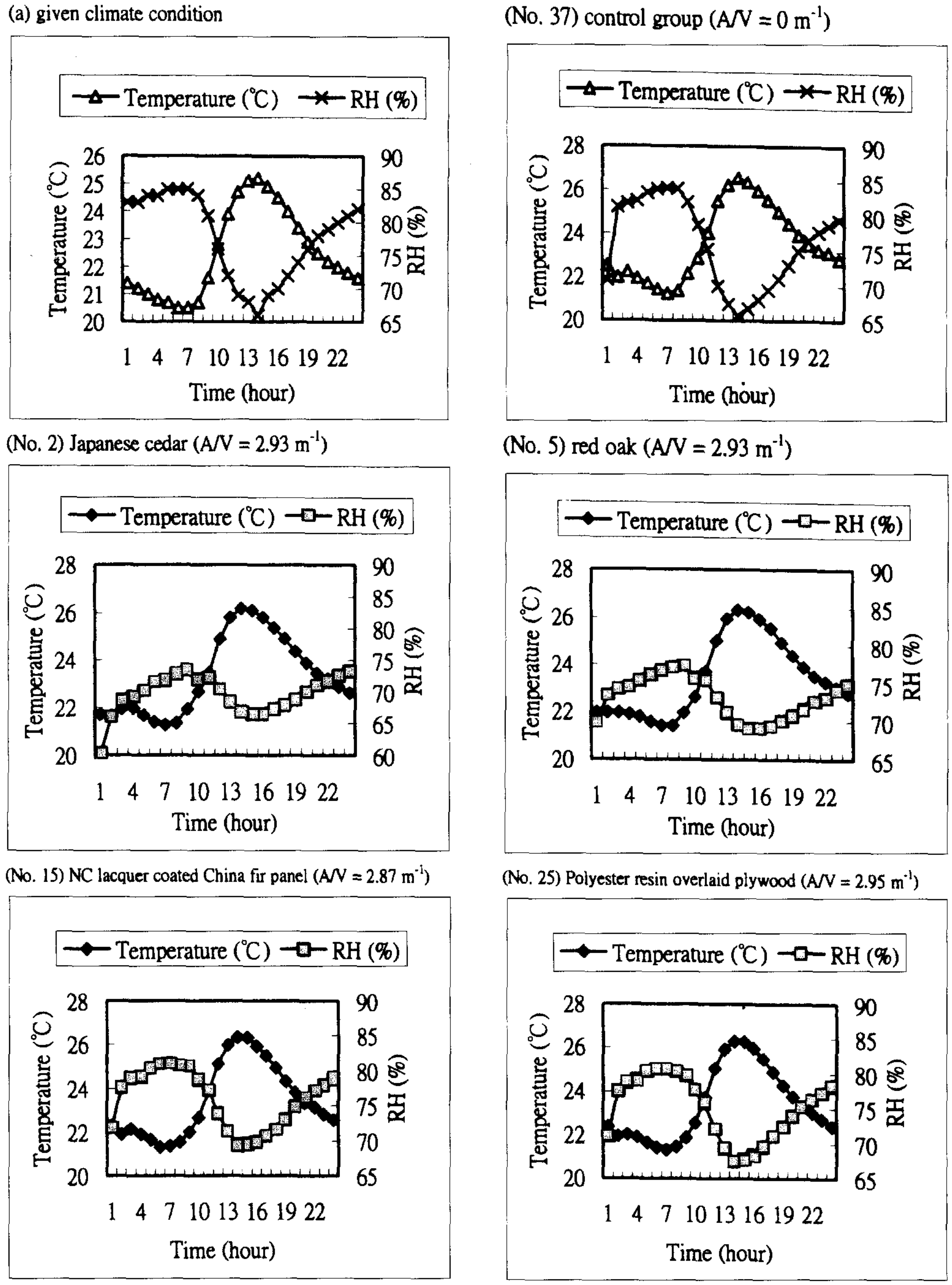
Effects of various interior decorative materials on temperature and RH

Temperature and RH changes

The typical patterns of the changing temperature and RH inside the decorated aluminum container are shown in Fig. 1. The average Taipei climate condition for 1 day showed that the lowest temperature and the highest RH occurred at 6–7 a.m. outdoors (20.5°C, 85.0%), and the highest temperature and lowest RH appeared at 1–2 p.m. outdoors (25.1°–25.2°C, 66.0%–68.0%). The differences of temperature (ΔT) and RH (ΔRH) between maximum and minimum values for temperature and RH were 4.7°C and 19.0% RH, respectively.

The control group (A/V = 0) exhibited a response to the temperature and RH changes inside the nondecorated aluminum container similar to that of the tested chambers. The lowest temperature (21.2°–21.4°C) and the highest RH (83.9%–84.0%) occurred at 7–8 a.m. The highest temperature (26.4°–26.6°C) and lowest RH (65.8%–66.7%) appeared at 2–3 p.m. Their ΔT and ΔRH values were 5.4°C and 18.2%, respectively. A comparison of climatic conditions inside and outside the container showed that there was a 1- to 2-h delay in response because the temperature variance inside responded only after the heat was transmitted from the outside through the aluminum walls owing to heat conductivity. As a result, the changing temperature inside the container could not perfectly follow the outside condition during the cycle. Furthermore, the highest temperature was 1.2°–1.3°C higher than the given highest temperature, and the lowest temperature was 0.7°–0.8°C higher than the lowest temperature. The RH varied less because the accumulated heat energy was not easily transmitted from the sealed aluminum container to the outside.

Fig. 1. Typical patterns of hourly changing temperatures (t) and relative humidity (RH) inside a 35^3 cu cm aluminum container, one side of which was coated with various materials, under the condition A/V = 0–2.95 m^{-1}



The conditioning performances altered by the various interior decorated materials was also studied. The results showed that the lowest temperature and highest RH would not occur at the same time when an effective decorated interior was in place. Two kinds of wood panel, Japanese cedar and red oak, were used to demonstrate how woody materials perform their conditioning effect inside the aluminum container. The lowest temperature (21.2°–21.3°C) and the highest RH (71.6%–72.4%) occurred at 7–8 a.m. for the Japanese cedar wood panel (A/V 2.93), with a thickness of 0.9cm in the container. The highest temperature (26.2°C) and lowest RH (64.8%) occurred at 2–3 p.m. and 1 a.m. The ΔT and ΔRH were 5.0°C and 7.6%, respectively. In the aluminum container decorated on one-side (A/V 2.93) with a wood panel of red oak with a thickness of 0.9cm, the lowest temperature (21.4°–21.5°C) and highest RH (77.3%) occurred at 6–7 a.m. and 9 a.m., respectively. The highest temperature (26.0°–26.3°C) and lowest RH (69.0%) occurred at 2–3 p.m. and 1 a.m. The ΔT and ΔRH were 4.9°C and 8.3%, respectively.

It was obvious that materials such as solid wood, plasterboard, and cemented excelsior board exerted their best conditioning effects on the RH because the highest RH did not correspond to the lowest temperature, and the lowest RH did not correspond to the highest temperature. This result occurred because the materials performed their absorption and desorption functions in the aluminum container.

In contrast, the lowest temperature (21.3°–21.4°C) and highest RH (80.9%–81.0%) occurred at 6–7 a.m. when one side of the aluminum container was decorated with a China fir panel (coated with NC lacquer) (A/V 2.87) with a thickness of 0.2 cm. Its highest temperature (26.3°C) and lowest RH (69.5%–69.6%) occurred at 2–3 p.m. The ΔT and ΔRH were 5.0°C and 11.5%, respectively. In the aluminum container decorated on one side (A/V 2.95) with a polyester resin overlaid plywood panel with a thickness of 1.1 cm, the lowest temperature (21.3°–21.5°C) and highest RH (80.2%–80.5%) occurred at 7–8 a.m. The highest temperature (26.3°C) and lowest RH (67.5%–67.9%) occurred at 2–3 p.m. Its ΔT and ΔRH were 5.0°C and 13.0%, respectively.

Evidently, the coated and polyester resin overlaid materials exhibited worse conditioning effects on the RH because the time of the highest RH was identical with that of the lowest temperature, and the time of the lowest RH was identical with that of the highest temperature. The patterns of the changing temperature and RH of one of the inside wall surfaces of a 35^3 cu cm aluminum container decorated with these materials were similar to those of the given climatic condition and the control group.

Efficiency index

Generally the temperature begins to increase from sunrise, reaching its highest point at about 1–2 p.m., when the solar radiation is strongest and the heat gain by the air secondarily radiated from the ground after the solar radiation is absorbed by the ground. Thereafter, the temperature decreases slowly as solar radiation becomes weaker. At about 4–5 a.m. it reaches its lowest point. The variance in RH shows a contrary tendency. In the building or house, the temperature and RH fluctuate correspondingly with those outdoors because of heat transmittance through the walls, ceilings, and floors.

The differences between maximum values and minimum values of temperature (ΔT) and RH (ΔRH) of various interior decorative materials using the designed conditioning cycle are summarized in Table 1. Living would be uncomfortable when the ΔT and ΔRH are too large. The values of ΔT and ΔRH change when the building or house is constructed with walls, ceilings, and floors of different materials. Therefore, the ratio of indoor ΔT to outdoor ΔT ($\Delta T_{indoor}/\Delta T_{outdoor}$) and the ratio of indoor ΔRH to outdoor ΔRH ($\Delta RH_{indoor}/\Delta RH_{outdoor}$) could be used as efficiency indexes of temperature and RH (called the temperature and RH changing ratios). There was no conditioning effect on temperature and RH when the temperature and RH changing ratios equaled 1. The lower the ratio, the better was the conditioning effect of the interior decorative materials.

Influence of various interior decorative materials on temperature and RH changing ratio

The temperature and RH changing ratios of various interior decorative materials (A/V 2.87–2.99) under the designed condition of the temperature cycle are summarized in Table 1. Generally, the changing ratios were seldom altered. Possible reasons for these results were that the A/V ratio was 2.87–2.99. The heat energy was transferred inward from the other five sides of the aluminum container owing to thermal conductivity, thermal convection, and heat radiation. Therefore, the temperature of the container was higher. Smaller RH changing ratios were found in the following test samples: five untreated solid woods of different species, insulation fiberboard, porous composite material, and plasterboard. Higher RH changing ratios were seen with the materials combined with or coated (sprayed) with adhesives, although their surfaces still had wooden characteristics; these materials included unfinished plywood, fiberboard, particleboard, oriented strand particleboard, concrete board, and plaster fiberboard. When the surface of wood-based materials was treated with resin or inorganic material (e.g., glass or tiles), relatively larger RH changing ratios were seen.

This difference might be due to the fact that the designed climatic conditions in this study were based on the average hourly temperature and RH over 24 h of the day and did not consider the changes for the four seasons: The changes in temperature and RH within 24 h are much less than those over a 1-year period. For example, the ranges of temperature and RH were 20.5°–25.2°C and 66.0%–85.0% over 24 h, whereas the ranges within 1 year (1991) were 12.2°–30.9°C and 55.0%–90.0%, respectively. Therefore in future tests, the climatic condition will be divided into four seasons, and the conditioning effects may be seen to be more significant.

Effects of panel thickness on the temperature and RH changing ratio

The changes of temperature and RH with time inside an aluminum container lined with Japanese cedar or red oak panel (A/V 2.88–3.04) with different thicknesses are summarized as follows: It was found that $\Delta T_1/\Delta T_2$ ranged from 1.01 to 1.07 for Japanese cedar panels and from 1.02 to 1.08 for red oak panels. These values are similar to that for the control (1.13). The panel thickness showed poor conditioning performance unless the climatic conditions were divided into four seasons. The $\Delta RH_1/\Delta RH_2$ value was 0.59 for Japanese cedar panel with a thickness of 0.3 cm and ranged from 0.39 to 0.50 with other thicknesses and from 0.34 to 0.51 for the red oak panel. For the aluminum container without a specimen inside, the $\Delta RH_1/\Delta RH_2$ value was 0.96. The $\Delta RH_1/\Delta RH_2$ with the panels was about 0.50; thus an A/V ratio of 2.88 and a thickness as little as 0.3 cm was enough to exert a conditioning effect on the RH.

Effects of A/V ratio on the temperature and RH changing ratio

The changes of temperature and RH with time inside an aluminum container lined with Japanese cedar panels or red oak panels (thickness 0.9 cm) with various A/V ratios were as follows: The $\Delta T_1/\Delta T_2$ ranged from 0.89 to 1.16 for Japanese cedar panels and from 1.01 to 1.11 for red oak panels. The values were similar to that of the control (1.13). There was therefore no conditioning effect on temperature even when the A/V ratio reached 15.63. In terms of the conditioning effect on RH, the $\Delta RH_1/\Delta RH_2$ decreased as the A/V ratio increased. The $\Delta RH_1/\Delta RH_2$ values were 0.40–0.24 for Japanese cedar panels and 0.43–0.28 for red oak panels. For the aluminum container without a specimen inside, the $\Delta RH_1/\Delta RH_2$ was 0.96. Thus an A/V ratio as little as 2.93 provided a conditioning effect on RH.

Index of humidity conditioning performances

In this study, the method for estimating the conditioning effect was based on the hypothesis that the total vapor content in a closed space is equal to the moisture content in the material plus the absolute vapor content in the space. If a material has no conditioning effect, the contact surface in the space would show no moisture-absorbing power, and the absolute humidity in this system would remain constant. However, the saturated absolute humidity would increase exponentially with an increase of temperature, and its relation can be expressed as:

$$\mathrm{hs}(t) \fallingdotseq 6.26 \times 10^{0.022t} \quad (1)$$

where hs(t)-saturated absolute humidity (mmHg); and t-temperature (°C). The relative humidity (RH) is defined as:

$$\mathrm{RH}(\%) = \frac{\text{absolute vapor pressure}}{\text{saturated absolute vapor pressure}} \times 100\ (\%) \quad (2)$$

In general, the absolute humidity in a sealed environment is not influenced by nonhygroscopic materials, and hence its absolute humidity may remain constant. Its saturated absolute humidity changes with changes of temperature, and so the RH is changed. Consequently, RH values decrease with increased temperature and vice versa.

For a hygroscopic material, absorption and desorption phenomena occur and oscillate with fluctuations of temperature and RH until reaching an equilibrium moisture content (EMC). Therefore, in a sealed environment when the temperature increases and the RH decreases, the moisture is desorbed from the interior material, and the absolute vapor content increases. This situation is described as a desorption phenomenon. In contrast, the absorption phenomenon occurs when the temperature decreases and the RH increases in the sealed environment.

Because the absolute humidity cannot be changed as the temperature changes in a sealed environment lined with nonhygroscopic material, the change in RH shows a tendency contrary to that of the temperature. For a sealed environment lined with hygroscopic material, the absolute humidity increases or decreases proportional to the change of temperature, but the RH shows no significant change. Therefore, the relation between the temperature and the logarithmic value of the absolute humidity in a sealed environment can be applied during a discussion of the conditioning effect as follows:

$$\log h(t) = \log h(\mathrm{a}) + b \cdot t \quad (3)$$

where h(a) = absolute humidity (mmHg) at temperature 0°C; $h(t)$ = absolute humidity (mmHg) at temperature t(°C); t = temperature (°C); and b = the slope of a linear equation. The logarithmic values of absolute humidity log $h(t)$ increase linearly with an increase of temperature, and its relation can be represented by Eq. (4).

$$\log h(t) = 0.675 + 0.028t \qquad R^2 = 0.999^{**} \quad (4)$$

With any temperature, the RH ($\phi_{(\%)}$) is the ratio of water vapor pressure [$h(t)$, mmHg] to saturated water vapor pressure [h(s)]. We can then use the formula:

$$\phi_{(\%)} = h(t)/h(\mathrm{s}) \times 100 \quad (5)$$

We then determine the absolute humidity [i.e., h(t)] by multiplying the saturated water vapor pressure [h(s), mmHg] by the RH ($\phi_{(\%)}$). Because our data were the temperature and RH for each hour, we could obtain the absolute humidity [$h(t)$] inside the container for each temperature using Eq. (4).

We found that the linear equations between the logarithmic values for the absolute humidity and temperature for various materials were highly significant at the 0.01 confidence level by the F-test. The b value varied with the material used, as shown in Table 1; and hence this value can be used as an index to predict the material's humidity conditioning performance. When the b value was 0.022, the absolute humidity in a sealed environment increased with an increase in temperature, and so the RH remained constant. This means ΔRH = 0; that is, it exhibited a perfect humidity conditioning effect. If the b values were smaller, the absolute humidity could not be changed significantly, which means that the hygroscopic conditioning performance of the material was relatively poor. On the other hand, if the b values were higher, the material exhibited a significant hygroscopic conditioning performance. Based on these observations, the unfinished and nonresin-processed wood-based materials were the best for humidity conditioning. However, when the b value was higher than 0.022, the materials with larger b values had larger RH values because the moisture in a material was desorbed during the period of temperature increase, which triggered an increase in absolute humidity from the initiation of the temperature increase.

In our study, the conditioning performances of investigated materials were classified into four types in accordance with their b values[4,5]:

Type I (best performance): $b > 0.0200$
Type II (good performance): $0.0170 < b < 0.0199$
Type III (fair performance): $0.0070 < b < 0.0169$
Type IV (poor performance): $b < 0.0069$

The materials classified as type I perform the absorption and desorption processes following their EMC behavior, as the humidity fluctuates to maintain a constant environmental condition. The type II materials exhibit a delayed action during the absorption and desorption processes, and hence their rates of absorption and desorption are relatively slow. The hygroscopic characteristics of type III materials are limited because the absorption/desorption processes occur only on the surface layers. The hygroscopic properties of type IV materials are weak or do not exist because the absorption/desorption processes almost do not occur.

According to their *b* values, the humidity conditioning performances of materials studied can be grouped as follows:

Type I: solid woods, including red oak (*Quercus* sp.), Taiwan red cypress (*Chamaecyparis formosensis* Matsum.), taiwania (*Taiwania cryptomerioides* Hay.), and Japanese cedar (*Cryptomeria japonica* D. Don.), plasterboard, particleboard, insulation plaster fiberboard, fireproofed plywood (retention 70g/m^2), paper overlaid fiberboard, medium density fiberboard (MDF), perforated plaster fiberboard, cemented excelsior board, insulation fiberboard, fire-retardant plywood (retention 69kg/m^3), and fiberboard.

Type II: tile, unfinished plywood, oriented strand particleboard (OSB), China fir (*Cunninghamia lanceolata*), heat-treated (77°C, 55% RH for 80 days) fire-proofed and fire-retardant plywood, and concrete board.

Type III: control group aluminum container, glass, PU-coated solid maple (*Acer* spp.) wood flooring, marble, polyester resin overlaid plywood, fire-retardant plastic flooring, melamin resin (MF) overlaid plywood, PU-finished plywood, NC-finished plywood, NC-coated solid China fir wooden panel, white cement-paint-coated concrete plate, PU-coated Japanese cedar flooring, PU-coated red oak flooring, and NC-coated fancy plywood.

Type IV: given climate condition.

From these findings, it seemed that the unfinished and non-resin-treated wood-based materials could be characterized as excellent interior decorative materials based on their humidity conditioning performances. However, such performances would be weakened when the surfaces of these wood-based materials were treated with resinous substances. These observations were similar to those from the study reported by Maki et al.[6] and our previous studies.[1,2,7]

Effect of wood panel thickness on humidity conditioning indexes

When one side of the sealed container was lined with various thicknesses (0.3–2.1cm, A/V 2.88–3.04) of Japanese cedar and red oak wood panels, it was found that the linear equations between logarithmic values of absolute humidity [log*h*(*t*)] and temperature could be obtained, and their correlation coefficients (*r*) were 0.931–0.979 for Japanese cedar wood panels and 0.923–0.989 for red oak wood panels. The difference was highly significant at the 0.01 confidence level by the *F*-test; the slopes of those linear equations represented by *b* values were 0.0206–0.0261 for Japanese cedar

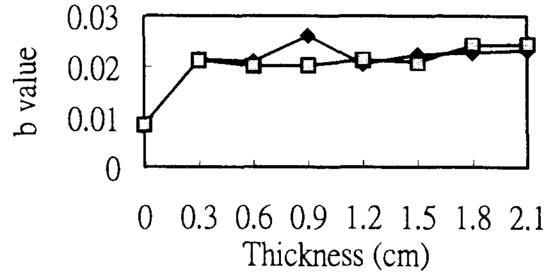


Fig. 2. Relation between the *b* value and the thickness of wood panels inside a 35^{3}cucm aluminum box lined with a Japanese cedar panel (*diamonds*) or a red oak panel (*squares*) (A/V 2.88–3.04m^{-1})

panels and 0.0202–0.0244 for red oak panels, respectively. The *b* values increased rapidly with the increasing thickness of the wood panels, as shown in Fig. 2. It was found that the *b* values were 0.0215 for Japanese cedar panels and 0.0213 for red oak panels; when the panel thickness increased to 0.3cm, the humidity conditioning was not affected by panel thickness. This suggested that the effective thickness of interior decorative panel was 0.3cm under daily cyclical changes of temperature and RH conditions in the Taipei area. This finding is consistent with the results reported by Cho.[8]

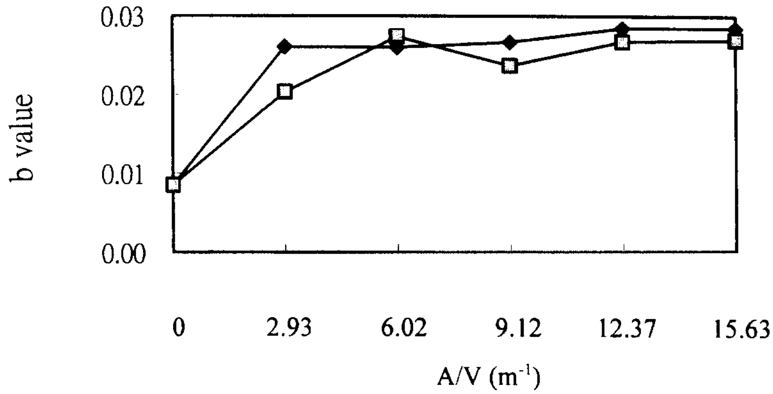
Effect of A/V ratio on humidity conditioning performances

To investigate whether the RH in a sealed space could be controlled at a designated level by lining more solid wood materials on the inside walls, Japanese cedar and red oak (0.9cm thick) panels were attached to one side (A/V 2.93) and to five sides (A/V 15.63) of the inside walls of the cylinder to observe any changes in RH. The linear equations between the logarithmic values for absolute humidity [log h(*t*)] and temperature (*t*) were obtained. Their correlation coefficients were 0.976–0.993 for Japanese cedar panels and 0.963–0.987 for red oak panels, which were highly significant at the 0.01 confidence level by the *F*-test and the *b* value; the slopes of these linear equations were 0.0260–0.0285 for the Japanese cedar panels and 0.0203–0.0274 for the red oak panels, and the *b* values increased with the increasing A/V ratio as shown in Fig. 3. These experimental results suggest that when the more solid wood materials line the interior walls, the better are the humidity conditioning effects. However, with this climatic condition, when the A/V ratio reached 2.93 – one side of sealed container was lined with a wood panel – its humidity conditioning performance was that of type I. These results are consistent with those from some previous studies.[1–3,6,7,9]

Conclusions

Based on the experimental work conducted in this study, the following conclusions are drawn. When the A/V ratio was 2.87–2.99 and one side of the sealed container was

Fig. 3. Relation between the *b* value and the A/V ratio inside a 35^3 cu cm aluminum box lined with a Japanese cedar (*diamonds*) or red oak (*squares*) panel of different A/V ratios



decorated, there was no significant effect on the room temperature changing ratio. There was a remarkable hygroscopic conditioning effect, and the hygroscopic conditioning performance of 36 interior decorative materials could be classified into four types in accordance with the *b* values: type I (best performance), including red oak, Taiwan red cypress, taiwania, Japanese cedar, plasterboard, particleboard, insulation plaster fiberboard, fire-proofed plywood, paper overlaid fiberboard, MDF, perforated plaster fiberboard, cement excelsior board, insulation fiberboard, fire-retardant plywood, and fiberboard; type II, including tile, unfinished plywood, OSB, China fir, heat-treated fire-proofed and fire-retardant plywood, and concrete board; type III, including the control aluminum container, glass, PU-coated hard maple wood flooring, marble, polyester resin overlaid plywood, fire-retardant plastic flooring, MF overlaid plywood, PU-finished plywood, NC-finished plywood, NC-coated China fir wood panel, white cement-paint-coated concrete plate, PU-coated Japanese cedar flooring, PU-coated red oak flooring, and NC-coated fancy plywood.

The thickness of the interior decorative wood panels had no significant effect on the room temperature changing ratio when the A/V ratio was 2.88. However, the RH changing ratio decreased curvilinearly with increasing thickness of the wood panels, whereas their *b* values increased linearly with the increasing thickness. This finding suggested that the effective wood panel thickness was about 0.3 cm for satisfactory hygroscopic conditioning for an environment with daily fluctuation of climate as in the Taipei area.

The A/V ratio had no significant effect on the room temperature changing ratio. The RH changing ratio decreased curvilinearly with increasing A/V, whereas the *b* values increased curvilinearly. This finding indicated that sufficient hygroscopic conditioning could be obtained when the A/V ratio reached 2.93.

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