

## Report 2

# Reliability of wood materials in environmental testing

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*The January 1995 Hanshin earthquake in Japan destroyed many homes made of wood.*

*Although that temblor showed the power of an earthquake to demolish buildings, reports also indicate that part of the problem was the decay caused by moisture absorption in the wood used in the foundations of the homes. Moisture absorption by wood influences such factors as strength and dimensions, and can be considered a major cause of degradation. Conventional environmental testing to evaluate wood materials has emphasized early period characteristics, and has been unable to evaluate changes over time. However, we noticed changes in the characteristics of wood materials due to changes in the surrounding environment, and we tested this phenomenon. The results leave room for further study, but we propose that the results can serve as useful test data using environmental testing equipment.*

### 1. Evaluating wood materials through environmental testing

Wood loses strength through decay caused by absorbing moisture, but another problem is that moisture changes such characteristics of wood as strength, dimensions, and elasticity. In general, wood materials are dried before use, but wood used in construction is susceptible to high humidity near areas using water or in places with poor ventilation, such as under the floors, or in sites with large temperature differentials, which tend to cause dew condensation to form and promote decay from insect damage. In an outdoor environment, day/night changes and seasonal changes in temperature and humidity cause repeated moisture absorption and drying, affecting the characteristics of wood. Such influences cause degradation in wood construction materials.

Table 1 shows the names of the items set by JIS (Japanese Industrial Standard) standards as methods of evaluating wood construction materials (in JIS Z2101, Methods of testing for wood).

Among these items, test methods concerning the environment apply to evaluating water and moisture absorption characteristics, but such testing cannot be considered sufficient to evaluate degradation over time. We also noticed changes in the shape of wood caused by the wood absorbing and releasing moisture due to fluctuations in the surrounding environment, and we tested this phenomenon.

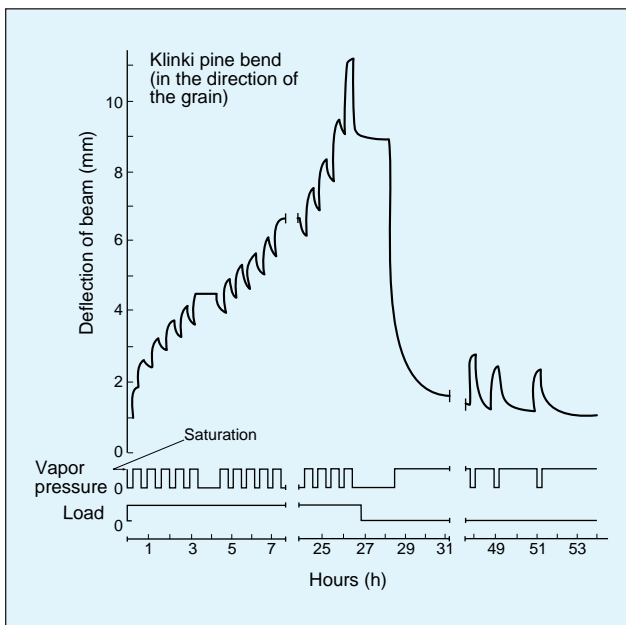
Table 1 Test items in JIS Z 2101

NO.	Items
1	Method of measuring average width of annual rings, moisture content and specific gravity of wood
2	Method of testing for shrinkage in volume of wood
3	Method of testing for water absorption of wood
4	Method of testing for moisture absorption of wood
5	Method of compression test for wood
6	Method of tension test for wood
7	Method of bending test for wood
8	Method of shear test for wood
9	Method of cleavage test for wood
10	Method of impact bending test for wood
11	Method of testing for hardness of wood
12	Method of creep test for wood
13	Testing methods for nail withdrawal for wood
14	Method of abrasion test for wood
15	Method of testing for decay of wood
16	Method of inflammability test for wood

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When considering the parameters of the life of wood, one characteristic that must be considered is creep\*1. Fluctuation in the surrounding temperature greatly affects creep in wood. In this article, we shall report on our environmental testing studies of the deformation of wood known as the “drying set”\*2 phenomenon, caused by creep due to changes in the moisture content of wood.

Changes in the ratio and velocity of creep are brought on by the surrounding humidity and the moisture content of wood. One example of this is contained in a report on accelerated testing of the drying cycle using pressure reducing equipment. According to this report, when 25 percent of the fracture load by bending is applied in the initial period, beam deflection increases to approximately 10 times the amount of deflection of the initial period. (Refer to Fig.1.)



**Fig. 1 Moisture absorption/drying cycles and creep deformation 1)**

## 2. Moisture absorption by wood

### 2-1 The relationship between wood and water

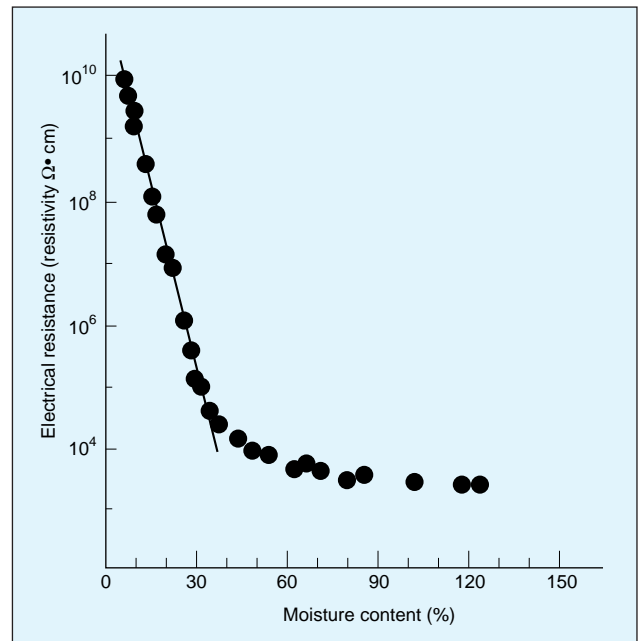
The moisture content of wood can be classified under the two major headings of bound water and free water. Bound water is absorbed into the cellular walls of the wood due to hydrogen being bound, and is deeply involved in such changes as bending and dimensional changes. Therefore, bound water can be considered to be one part of the wood. Free water, though, remains between the cells, and only affects such properties as weight, thermal conduction, and electrical conduction.

The amount of water within wood is shown as the moisture content and is calculated with the following formula.

$$\text{Moisture content (\%)} = \frac{\text{weight of bound water + free water}}{\text{weight of cellular walls}} \times 100$$

Besides measuring the weight, specific methods for measuring the moisture content include such methods as measuring electrical resistance or measuring the dielectric constant.

Fig. 2 shows one example of changes in electrical resistance with the moisture content of wood.



**Fig. 2 The moisture content of wood and electrical resistance 2)**

\*1 When constant pressure stress is continuously applied to wood, the resulting progressive distortion over time is called “creep”. Moisture fluctuations as well as the moisture content of the test materials greatly affect the ratio and velocity of creep.

\*2 Changes in the moisture content while wood is under pressure stress causes plastic distortion such as bending and twisting. Deformation permanently set into the wood by creep during the drying process is referred to as “drying set”.

When the cellular walls become saturated with bound water and there is no free water in the lumens (cellular cavities) of the cells, the condition is known as the fiber saturation point.

This value does not depend on the type of wood, and represents approximately a 30 percent moisture content. Fig. 3 shows drawings of the relationship patterns.

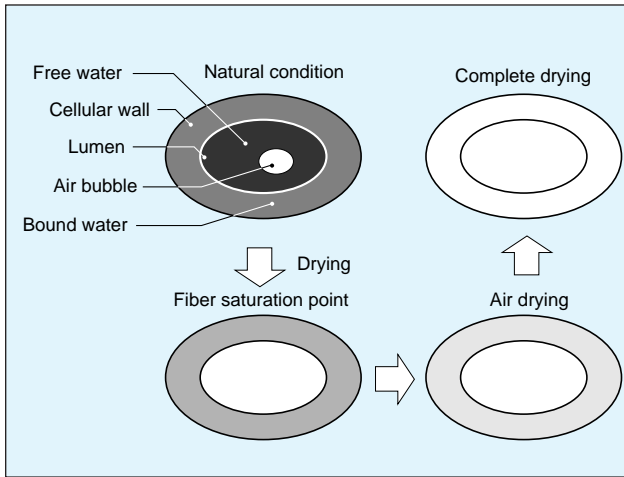


Fig. 3 Wood moisture patterns

The moisture content of wood is roughly determined by the surrounding temperature and humidity, and changes in these conditions cause repeated absorption and release of moisture. Under stable conditions of surrounding temperature and humidity, the moisture content of wood remains constant. This is called the Equilibrium Moisture Content (EMC). Fig. 4 shows a graph of the EMC of wood.

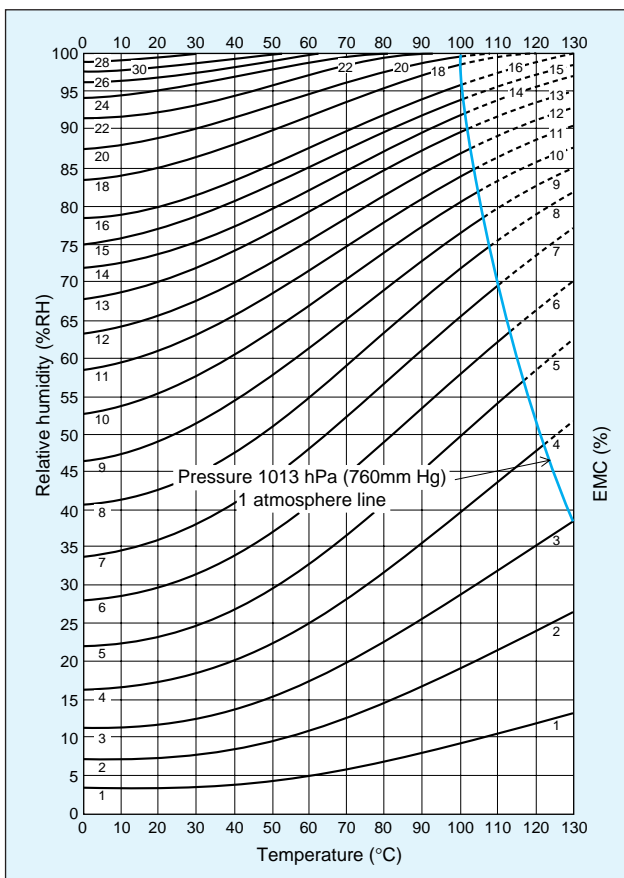


Fig. 4 Equilibrium Moisture Content of wood 2)

The EMC does not vary by type of wood, but is determined by the diverse types of habitat.

The moisture absorption and moisture release characteristics of wood stem from these properties, which cause wood to regulate the moisture of the surrounding environment. One advantage of using wood materials in home construction is this humidity regulation effect. Wood characteristics also differ according to the direction of the grain, and the moisture content affects the degree of contraction and expansion.

## 2-2 Dew condensation of wood

When a temperature differential occurs between wood and the surrounding environment, dew condensation occurs below the dew point temperature. In homes, a lot of dew condensation is caused by the surrounding concrete walls or metal items, but condensation also stems from the wood itself, and the wood gradually absorbs the water condensation. Over a long time, this process causes severe problems due to damage from decay-producing bacteria and mold. Furthermore, the tendency of dew condensation to form inside the walls of homes and the tendency of the condensation not to dry leads to long-term effects.

## 2-3 Moisture absorption characteristics in the presence of dew condensation

We investigated the moisture absorption time of wood in dew condensation environments and high humidity environments. Table 2 and Fig. 5 show the test method and the specimens. The results indicate that moisture absorption velocity is not increased in a dew condensation environment. Fig. 6 shows that the fiber saturation point is achieved at roughly the same time.

Table 2 Moisture absorption ratio measurement conditions

<b>Specimens</b>	Wood type: cedar Quantity: 20 pieces Dimensions: 30 × 30 × 5 mm (JIS Z 2101) [Refer to Fig. 5]
<b>Test conditions</b>	(1) High temperature, high humidity: 40°C, 90% RH (2) Dew condensation cycle: (30 min. each) 10°C, 60% RH ↔ 40°C, 90% RH
<b>Measurement method</b>	Moisture content measured by weight

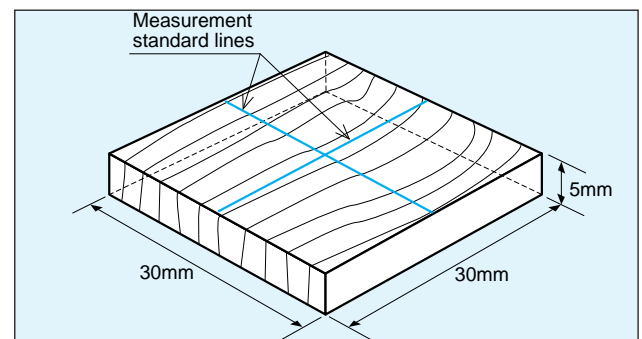


Fig. 5 Moisture absorption characteristics prescribed by JIS

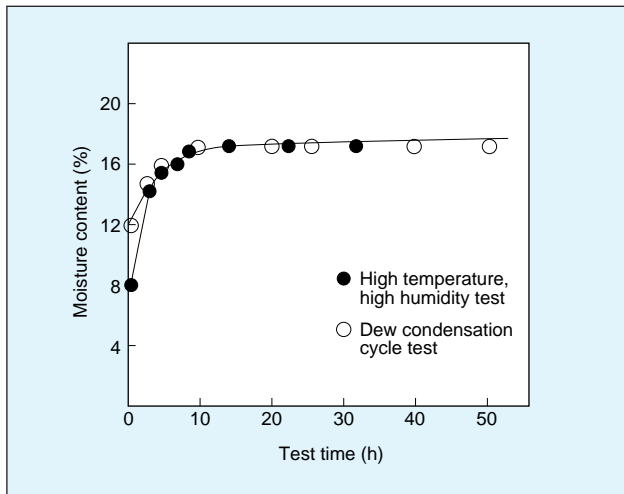


Fig. 6 Moisture absorption time

### 3. Evaluating wood characteristics through environmental testing

To perform a reproducible environmental test of creep deformation caused by drying set, we can consider the temperature and humidity cycle test using the temperature and humidity chamber or the dew condensation cycle test using the dew condensation cycle tester. These tests can apply repeated changes in temperature and humidity, and so should be effective.

#### 3-1 Test methods

To see how creep deformation changes with drying time, we strictly controlled the actual environmental changes and performed temperature and humidity cycle tests and dew condensation cycle tests repeatedly alternating drying and moisture absorption. For comparison, we also performed high-temperature, high-humidity tests and standard condition tests (at normal temperature and humidity). (The “high temperature” in these tests refers to temperature that would be felt as high by humans in normal life.) The wood specimens were tested under a continuous load applied at the center of the specimen. The test methods are shown in Table 3 and Fig.7 and 8.

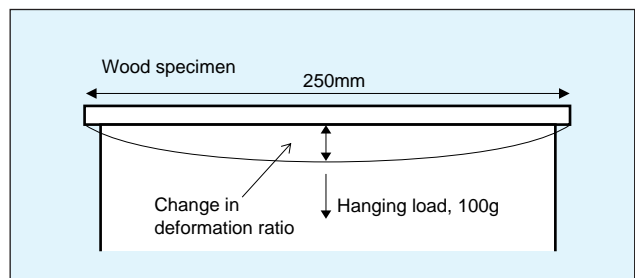


Fig. 7 Load method

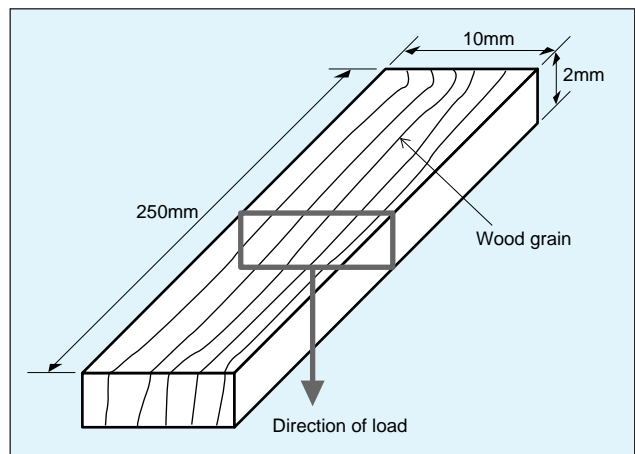


Fig. 8 Relationship between the wood grain and the direction of the load

Table 3 Measurement conditions for changes in creep characteristics due to the environment

<b>Specimen</b>	Wood type: white cedar (fixed grain direction and initial strength) Dimensions: 250 × 10 × 2 mm Quantity: 20 pieces
<b>Test conditions</b>	Pre-treatment: 24 hours at 20°C and 65% RH (1) Humidity cycle: 40°C, 30% RH ↔ 40°C, 90% RH (30 min. each) (2) Dew condensation cycle: 10°C, 60% RH ↔ 40°C, 90% RH (30 min. each) (3) High temperature, high humidity: 40°C, 90% RH (4) Standard conditions: 20°C, 65% RH
<b>Load method</b>	100 g load hung from center of specimen. Refer to Fig.7
<b>Measurement method</b>	Deformation ratio measured at each cycle.

### 3-2 Test results

Fig. 9 shows the test results. Under condition (1), the humidity cycle test, the creep ratio showed large changes, and as the test progressed the changes were much greater than those under other conditions. Under condition (4), the standard conditions, increase in the creep ratio was minimal, while there wasn't much difference in the results shown by condition (2), the dew condensation cycle test, and condition (3), the high-temperature, high-humidity test.

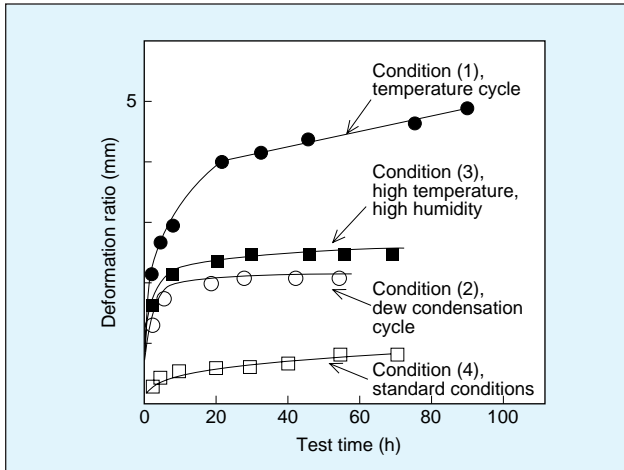


Fig. 9 Creep deformation in environmental tests

### 3-3 Considerations

We were able to reconfirm that the greater the change in moisture content, the greater the creep deformation. Furthermore, at normal temperature and humidity, the increase in the creep ratio was minimal. These results can be attributed to the temperature and moisture effects on the strength and elasticity modulus of wood.

In the dew condensation cycle test, we thought that moisture absorption would be affected by dew condensation, but the results showed almost no difference under high temperature and high humidity. We believe this can be attributed to insufficient drying in the dew condensation cycle test compared to the high-temperature, high-humidity test. Therefore, differences in the drying conditions greatly affected the creep deformation in these tests, and the test that most strongly promoted creep was the humidity cycle test. We postulate that increasing the drying capacity of the dew cycle test would accelerate the creep deformation. However, the conditions used in each test chamber had variances in such factors as wind speed and start-up temperature and humidity, so there remains plenty of room for research in these results.

## 4. Conclusion

Creep deformation due to continuous load on wood can be considerable due to repeated moisture and drying even when the load is small. This fact can be confirmed with the humidity cycle test.

Our homes constructed with wood materials are subjected to repeated changes in environmental stress due to temperature and humidity, leading to undeniable degradation of the wood materials. In areas where dampness tends to accumulate, such as under the floor, measures are already taken to keep humidity uniform by using wood materials that effectively regulate the humidity.

The naturally-occurring cycle of absorbing and releasing moisture leads to mechanical changes caused by expansion and contraction, so it is possible that absorbing distortion and increasing strength may be effective in improving drying set characteristics in complex structures in which intersecting grains from different pieces of wood enclose a layer of glue.

### [Bibliography]

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