短　報

Investigation of methods for measuring creep strain of wood under usual meteorological conditions

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木材のクリープひずみ測定方法の検討

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要　旨　木材の引っ張りひずみは小さくまたクリープひずみはさらに小さい。したがって高い測定精度が要求される。ここでは，ストレインゲージを使って引っ張りクリープひずみを検出するための方法について検討した。特に外周条件がそれほど厳密に制御されていない中でのひずみの変動を取り除く方法について検討した。

まず第一に，温度湿度の補償のため実際に負荷する試験材とエンドマッチングしている同型同一寸法の木材に，試験材に接着するのと全く同一の要領で２枚のゲージを接着し，試験材のゲージと合わせてホイストン回路を作りひずみを検出する補償方法を検討した。つづいて接着剤とストレインゲージの最適組み合せの検討，最後にパラフィンコーティーングによる防湿効果の検討をおこなった。得られた結果よりこれらを組み合せれば，短期間の試験では十分精度良く縦引っ張りクリープひずみを測定できる可能性が示された。

Abstract : Measurement–methods were investigated for obtaining an actual tensile creep strain of wood. A compensation method which was installed by the end–matched specimens and four strain gauges and a paraffin coating on wood were tested to eliminate the respective influence of a fluctuation in air temperature and a change in wood moisture content on the accuracy of the estimated strain. An applicable set of gauge and glue was selected for a precise measurement.

It is suggested that the compensation method, the paraffin coating and the prorer set of gauge and glue provide a good estimation of the tensile creep strain, even under usual meteorological conditions.

1. Introduction

For every type of stress and orientation wood strains are small and the values of that are

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usually smaller than 10^{-2}. Additional creep strain which is time dependent due to visco–elastic effects are also small. Therefore the bending creep test has commonly been used to characterize the creep properties of wood[1]. Tensile creep tests, however, are necessary to understand the time dependence of Poisson's ratio and the viscoelasticity of wood specimens involving off–symmetry axes. As creep in wood is greatly increased owing to the simultaneous moisture sorption[2], fixed air temperature and relative humidity are necessary to measure creep strain. It is, however, very expensive and difficult to maintain such a condition during long period.

The purpose of this paper is to investigate the method for measuring the accurate creep strain of wood which is put under less than ideal condition of air temperature and relative humidity (usual meteorological condition). The following three items were investigated :

a) the method to cancel the change in wood–dimension by fluctuations in air temperature and relative humidity,

b) the selection of both the optimal gauge type and glue,

c) the meghod to attenuate the change in moisture content of wood by a fluctuation in ambient condition.

2. Materials and methods

2.1 Materials

Spruce (*Picea abies*) was mainly used. For longitudinal tensile creep tests, specimens were prepared according to Japanese Industrial Standards (Z 2112). Specimens were cut from 4 cm × 30cm × 200cm board selected on the basis of straightness of grain and freedom from defects. From this board, a series of stick 2 cm square with length of 35cm were prepared and then the central part was machined to 4 mm (tangential direction) thick. The ends of specimen were reinforced with hardwood which had 19mm thick. At least two specimens were connected in longirudinal direction (end–matched specimen).

For the selection of gauge and glue, bending creep tests were made on specimens with 1000mm in longitudinal direction, 70mm in radial direction and 8 mm in tangential direction.

In order to eliminate the influence of the change in moisture content of wood, paraffin coating test was done on specimens with 100mm in longitudinal direction and 20mm in radial and tangential directions. Beech (*Fagus sylvatica*) was also used in this test.

2.2 Experimental method

2.2.1 Compensation method

To cancel the change in specimen size resulting from a fluctuation in ambient condition, the compensation method involving four gauges and two identically shaped end–matched specimens was developed. One was active specimen which was loaded at the start of experiment, the other was inactive specimen which was not loaded enen after a start of the experiment. Two gauges were glued on both specimen (A_1, A_2 and C_1, C_2 in Figure 1). The gauges were connected to form a Wheatstone bridge as shown in Figure 1. Applied voltage to the bridge was one volt in all cases. The inactive specimen was always kept at the place adjacent to the active specimen. The ambient temperature ranged between 16.0℃ and 20.5℃ over four days. During this period the drift of strain for the compensation method was always less than 8×10^{-6}.

The strain of specimens was also measured using an extensometer with two knives at 50mm spacing.

2.2.2 Selection of gauge and glue

In order to decide both the optimal gauge and glue for the wood creep test, four–point bending creep test was done. The creep strain by the mechanical method was compared with that by the compensation method for several combinations of gauge and glue. The bending strain, ε_m (strain of the exterior fibers) is given by :

$$\varepsilon_m = 4d\delta / L^2, \quad (1)$$

where d is the specimen thickness (8mm) and L is the span for measuring the deflection δ (Figure 2). The value of δ is usually so large that can be easily and accurately measured by the mechanical method. Table 1 shows the characteristics of the gauges used and the combinations of gauge and glue investigated for the compensation method. The difference between strains measured by the mechanical method and the compensation one was represented as follows ;

$$\text{Error} = | \varepsilon_m - \varepsilon_g | \times 100 / \varepsilon_m, \quad (2)$$

where ε_m is strain determined by the mechanical method and ε_g is strain by the compensation method.

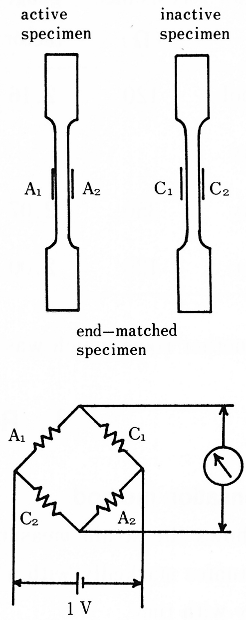

Figure 1 Compensation method by use of two same shape and end–matched specimens and Wheatstone bridge.
A_1, A_2 : Active gauges
C_1, C_2 : Compensatory gauges

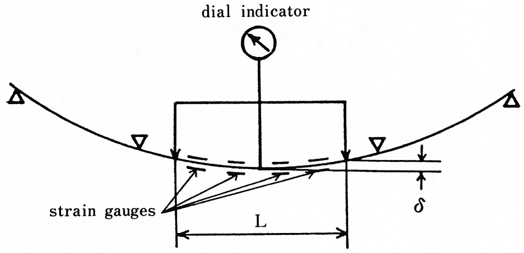

Figure 2 Check method of the compensation method by mechanical dial indicator.

2.2.3 Moisture content control by paraffin coating

The change in moisture content of specimens coated with paraffin relative to uncoated specimens was measured. Coated specimens were completely coated with parallin on all faces. Initially, uncoated and coated specimens were put in a room held at 25℃ in air temperature and 85% in RH (corresponding to about 18% EMC) during eight and thirteen days, respectively, before being

Table 1 Gatge type and the combination of gauge and glue

gauge	base	resisance (Ω)	gauge factor	lengh (mm)	width (mm)
A	phenol-epoxy	120	2.16	10	3.0
B	epoxy	350	2.07	12	4.5
C	paper	120	2.00	16	3.0

combination number	gauge	glue
1	A	Cyanoacrylate
2	C	Nitrocellulose
3	A	Epoxy
4	B	Epoxy
5	A	Polyester

transferred to another room which was held at 25℃ and 30% (EMC about 6 %).

3. Results and Discussion

3.1 Compensation method

Figure 3 shows the strain measured by the extensometer and by the compensation method. The former fluctuates markedly with a change in air temperature. On the other hand, the latter increases smoothly with time.

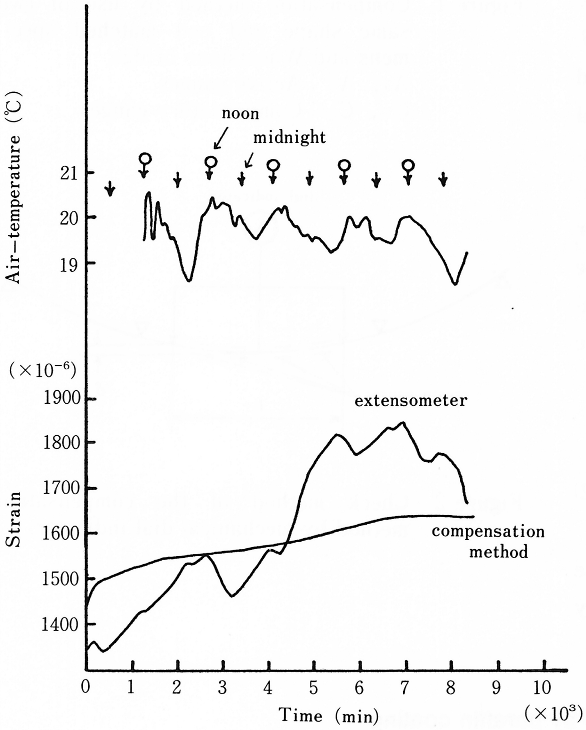

Figure 3 Comparison of the strain by compensation method and by extensometer.

The moisture content of wood varies with a change of relative humidity which is induced by the fluctuation in air temperature and wood shrinks or swells by this variation. This change in dimension of wood is considered to be strain and is included in the measurement of strain by the load in the case of extensometer. This change, however, is cancelled in the compensation method because the end−matched specimen similarly behaves against the change in the relative humidity.

This show that the compensation method is much less sensitive to a fluctuation in temperature and is therefore more suitable for the measurement in environments where temperature is not well controlled.

3.2 Optimum gauge and glue for creep test

Table 2 shows the errors calculated by Eq. (2). From the results, it is concluded that the best combination in this investigation is No. 3 , that is, optimum gauge is "A" which has phenol–epoxy resin as the gauge base and optimum glue is epoxy resin. Cyanoacrylate and polyester resin are not good for the stability after curing. Paper gauge should be not used for creep test because of the decrease in electrical insulation with the humidity.

Table 2 Error of compensation method.

combination of gauge and glue	error after 450 hrs (%)		
	environmental conditions		
	25 ℃ RH 30%	25 ℃ RH 85%	no air conditioning
1	0	20	44
2	17	306	8
3	0	0	3
4	6	0	12
5	-	7	55

3. 3 Moisture content control by paraffin coating

Even small fluctuations in air temperature and moisture content of wood considerably amplify creep phenomena because of the mechano–sorptive effects of wood [2]. Thus very precise air conditioning is generally needed.

Figure 4 shows the effect of paraffin coating on the change in moisture content. The moisture content of uncoated specimens changes rapidly with decreasing moisture content whereas that of coated specimens does not. This means that the paraffin coating attenuates the change in moisture content of wood under a fluctuation in ambient condition in short time.

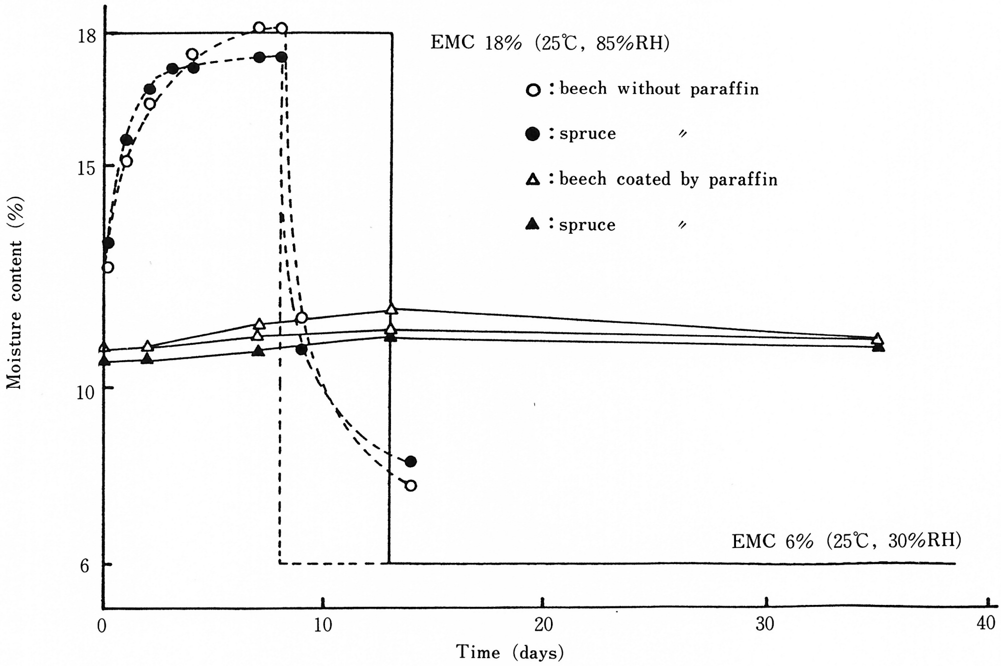

Figure 4 Effect of paraffin coating on a change in moisture content.
Solid lines are for the coated specimens and broken lines are for uncoated ones.

4. Conclusion

The compensation method which is installed by the end–matched specimens and four strain gauges cancels the dimensional change by fluctuations in ambient air temperature and relative humidity from measurement of strain by load. Gauge with the phenol–epoxy rein base and epoxy resin glue were one of the optimum combination for compensation method. Paraffin coating attenuated a change in moisture content of wood under a fluctuation in ambient condition. Combining these results, it is possible to measure the accurate creep strain of wood which is put under usual meteorological condition.

Refernces

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