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Creep of Drift Pin Moment Resisting Joint of LVL under Changing RH[1]

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상대습도 變動下의 휨 모멘트가 作用하는 단판적층재 Drift Pin 接合部의 크리프 變形 擧動[1]

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ABSTRACT

The objective of this study was to present creep and the effects of mechano-sorptive deflection of drift pin moment resisting joint between LVL members under changing relative humidity (RH) conditions. The LVL members with steel gusset were jointed by a square pattern of eight injected drift pin. Three diameter drift pins were used to test specimens (6mm, 10mm, and 16mm). The creep test was conducted under two constant loading conditions : one at 30 kgf(840 kgf·cm) and the other at 60 kgf(1680 kgf·cm). The experiment was conducted in an open shed outside. (1)The total rotation creep model of moment resisting joint can be expressed as the sum of the creep of controlled environment (3-parameter model), dimensional change and mechano-sorptive deflection resulting from the variable environment. (2)Mechano-sorptive rotation creep is recoverable as moisture content increases during adsorption. Least squares method for linear regression analysis was performed using mechano-sorptive rotation creep as the dependent variable and moisture content as the independent variable. The slope of low moment specimens are compared with those of high moment. This means that low moment condition is more easily affected by changes in humidity than high moment conditions. (3)Although creep deflection is higher for small diameter drift pin than for large diameter drift pin, the shape of creep deflection curves for all specimens is similar.

要 約

본 研究에서는 濕度 變動下에 휨 모멘트가 作用하는 단판적층재의 drift pin 接合部의 크리프 變形 擧動을 검토했다. 3종류 직경의 drift pin을 사용하여 직경별로 사각형 배열로 8개를 사용하여 캔티레바형 라멘 구조 實驗體를 제작하였다. 2개의 荷重 條件下(840 kgf·cm, 1680 kgf·cm)에서 크리프 실험이 이루어졌다. (1)휨 모멘트가 作用하는 단판적층재 drift pin 接合部의 회전 크리프 變形은 初期의 變形曲線 (荷重에 대한 安定化 변형)을 一定한 環境(실험 初期 條件)下의 크리프 曲線으로 간주하여 3-parameter model로 해석한 量과 收縮膨脹 變異量 및 mechano-sorptive 變形의 합으로 나타내었다. 初期의 곡선을 구한 時點에서의 含水率을 기준으로하여 실험 기간중의 함수율

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변동의 差를 구하였으며, mechano-sorptive변형은 上記의 모델曲線과 실제 實驗値와의 差로 부터 구하여져 함수율 변동과의 상관 관계를 검토하였다. (2)含水率의 변화는 mechano-sorptive 변형에 영향을 미친다. mechano-sorptive 변형은 滋潤의 과정에서는 回復하였다. 荷重比가 낮을수록 습도 변화에 따른 變動의 폭은 커지는 것을 확인하였다. (3)pin의 직경이 작을수록 變形量은 컸으나 습도 변동에 대한 傾向은 모두 같았다.

Key words : mechano-sorptive deflection, 3-parameter model, corrected rotation creep

INTRODUCTION

Wood used in construction shows notable creep deflection under sustained loads, which is known to have significant effects on the safety and service-ability of wood structures over their lifetime. The structural performances of wooden buildings are related closely to the behavior of the joints or connections between the members. The effect of cyclic moisture condition can be significant and should be taken into account in design when wood structural members are exposed to cyclic moisture conditions. The viscoelastic behavior of joints is of major importance in the design of structures.

Researchers have been studying this time-dependent behavior of timber structure joints under constant environmental conditions[1-6]. Mechano-sorptive behavior of timber structure joints has been reported by Arima and others[7], Ranta-Maunus[8], Taylor and others[9] and Toratti[10]. In recent years, the use of composite wood for portal-framed buildings has become increasingly popular. Portal frames are made from laminated timber members with multinailed moment resisting joints, and may be subject to mechano-sorptive deflection. Of those, drift pin joint accompanied by insert-steel plate is likely to have a relatively wide acceptance among architecture's or builders because of its good aesthetic appearance and good fire performance. Experimental data of rotation creep in moment resisting joints deflection concerning the effect of mechano-sorptive behavior of nail-plate-jointed laminated-veneer-lumber (LVL) has been reported in a previous paper[11]. It has been shown that desorption process caused an increase of deflection and an adsorption process acting in the opposite way, and that swelling and shrinkage of LVL are related to creep deflection. The objective of this study was to present creep and the effects of mechano-sorptive deflection of drift pin moment resisting joint between LVL members under changing relative humidity (RH) conditions, especially focusing the diameter of drift pin which might be effected the distribution of deflection and mechanism in the joint.

MATERIALS AND METHODS

The members of the creep test specimens were cut from twelve LVL beams. The LVL beam was 4 cm in width by 14 cm in thickness and 180 cm in length that composed of approximately 3 mm thick Douglas-fir veneer (13 plies). The specimens had no surface coatings. Twelve LVL beams had a similar modulus of elasticity (MOE) and moisture content (MC). The MOE was determined by edgewise static four-point bending test. The average MC of specimens was approximately 11.2% and specific gravity (SG) was 0.56. Average MOE was 145(103kgf/㎠). The rotation creep testing set up of the drift pin moment resisting joints between two members of LVL under changing environmental and joint designs are

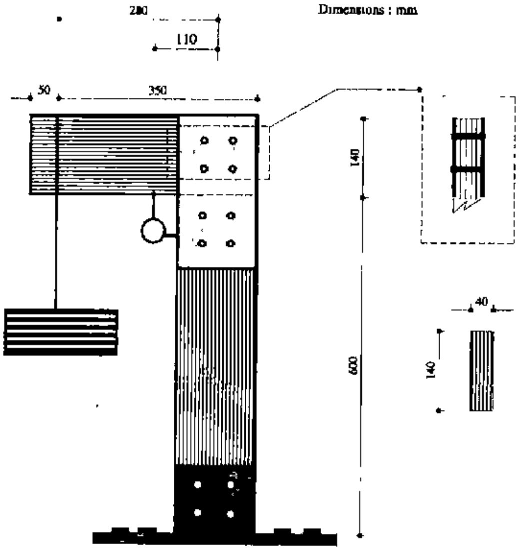
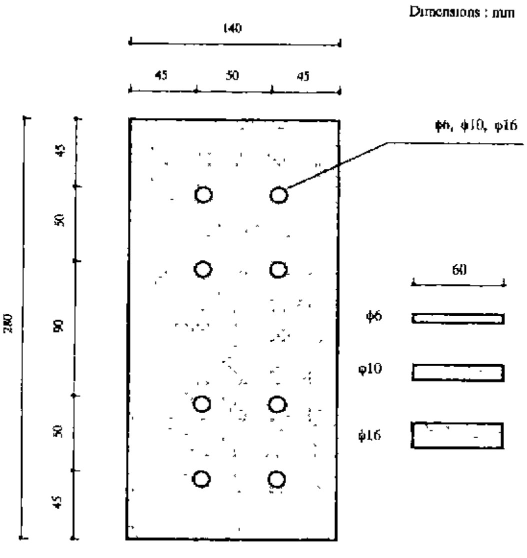


Fig. 1. Schematic representation of experiment.



Steel gusset size : 140 x 280 x 4.5

Fig. 2. Shapes of steel gusset and drift pins.

shown in Fig. 1. The LVL members with steel gusset were jointed by a square pattern of eight injected drift pin. Three different diameters of drift pins were used for making test specimens (6mm, 10mm, 16mm). The slenderness ratio(l/d) of a drift pin is defined as the length of drift pin(l) in the main member divided by the drift pin diameter(d).

The gussets were made of steel plates with thickness 4.5 mm. The gussets had been prepunched with 6 mm, 10 mm and 16 mm holes in a pattern shown in Fig. 2. Jointed specimens were divided into three groups, with the used diameter of drift pin, each group consisting of five specimens. The creep test was conducted under two constant loading conditions, one at 30kgf (840 kgf·cm) and another at 60kgf (1680kgf·cm). Two specimens of each group were tested by each loading condition. Creep deflection represents the average from 2 specimens. No jointed LVL members taken from the same general area in the LVL beam was used for determining MC, which was monitored by means of a load cell recording weight change at the same times as the measurements done on the loaded specimens.

Table 1. The dimensions and slenderness ratio of drift pin.

Diameter	Length of drift pin	Slenderness ratio
6㎜	40㎜	6.66
10㎜	40㎜	4
16㎜	40㎜	2.5

The shear force acting on the rafter member was generated by the compressive force from the leg. Deflection due to the perpendicular compressive force was measured on one side (Fig. 1). Positive values used throughout the experiment represent increasing displacement in the compressive direction. During the test period, one test specimen of each group was kept unloaded and measured deflection due to pure swelling and shrinkage under changing RH. The experiment was established in an open shed outside. Deflection was measured at time periods of 1, 5, 10, 20, 30 minutes; then at 1, 2, 4, and 8 hours, and afterward everyday at 17:00 until the test was finished. Deflection was measured to an accuracy of 0.01mm.

The following abbreviations are used for the test variables in the presentation of the results:

R30-6(10, 16) : rotation creep of joint with 6, 10 or 12 mm drift pin and a constant load 30kgf (applied moment 840 kgf·cm)

R60-6(10, 16) : rotation creep of joint with 6, 10 or 12 mm drift pin and a constant load 60kgf (applied moment 1680 kgf·cm)

RC30(60)-6(10, 16) : Corrected rotation creep obtained by subtracting the deflection of non-loaded specimens from the total creep deflection in the loaded specimens.

The results from the short-term test are given in Fig. 3. Moment-resisting joint made with 16 mm diameter drift pin showed that the joint stiffness was much higher than 10mm diameter drift pin, but failed below their full moment potential due to longitudinal splitting of LVL.

RESULTS AND DISCUSSION

The total rotation creep (radians) under changing humidity is assumed to consist of four main parts, one elastic part, one part describing pure rotation creep under constant humidity conditions, one part describing the shrinkage-swelling behavior and finally one mechano-sorptive part. The constitutive relation will then be

$$\delta t = \delta o + \delta c + \delta st + \delta ms \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where

δt is the total rotation creep

δo is the instantaneous rotation

δc is the pure rotation creep

δst is rotation due to the shrinkage -swelling behavior

δms is the mechano-sorptive rotation

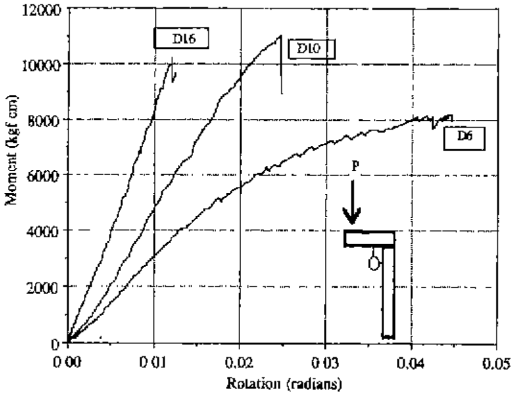


Fig. 3. Skeleton of moment-rotational angle relationship of moment resisting driftpin jointed LVL.

Fig. 4 shows result for total rotation creep (δt) of specimens under changing RH.

Fig. 6 shows rotation creep that of subtracted rotation due to shrinkage - swelling dimensional change (Fig. 5) under changing environment from the total rotation (corrected rotation creep = $\delta t - \delta st$). From this, rotation creep means excluding the effects of shrinkage and swelling of drift pin moment resisting jointed LVL under changing RH conditions. Discussions are based on the corrected rotation creep values. Rotation creep of specimens, affected by loading, increased until 50 hours into the experiment, and after that, the rotation creep was affected by the changing RH.

Fig. 7 shows relationship between relative

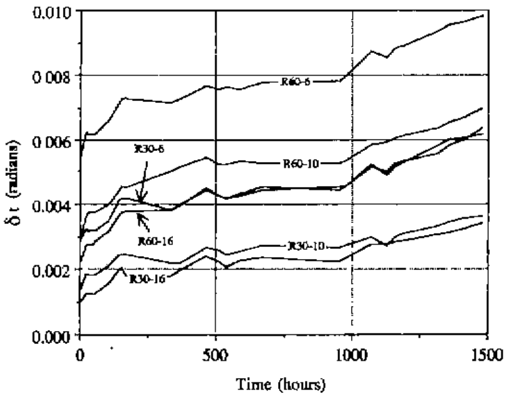


Fig. 4. Total rotation creep curves under changing relative humidity.
Each curve represents the average from 2 joints

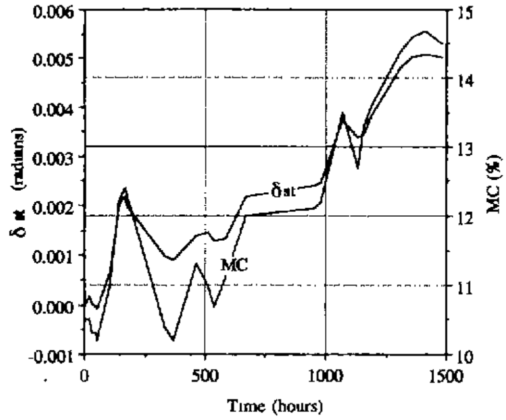


Fig. 5. Relationship between rotational angle due to shrinkage-swelling of non-loaded specimen (average from 6 specimens) and MC.

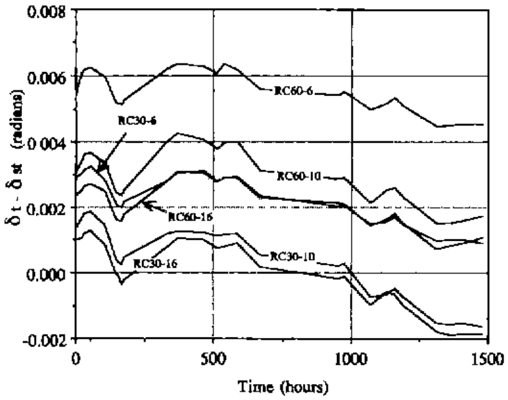


Fig. 6. Corrected rotation creep under changing relative humidity.
Correction made from the total rotation creep for the loaded specimen minus the rotation curve for the non-loaded specimen.

rotation creep ($\frac{\delta t}{\delta o}$) and MC. The desorption process causes the increase of rotation and the adsorption process acting in the opposite way. In general, rotation creep for specimens within each group are similar. It can also observed from Fig. 7 that the shape of rotation creep curves for all specimens is similar but has a different vertical shift. From the experimental data, it seems that rotation creep is higher for low moment specimens than for high moment specimens.

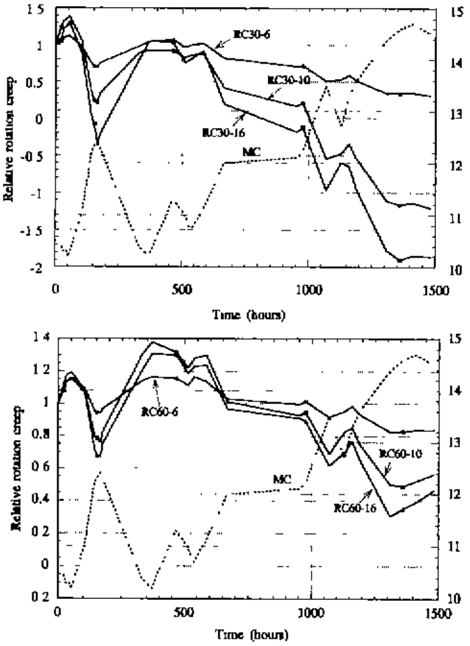


Fig. 7. Relationship between relative rotation creep and MC (relative rotation creep= $\delta t/\delta o$).

Therefore, curve fitting of total rotation creep is the sum of the rotation creep in the affected moment on controlled environment and the quantity of rotation in a varying environment. Assumption of a controlled environment is based on the experiment's initial conditions.

The rotation creep of a drift-pin-jointed LVL were affected by the applied maximum moment and time. Therefore, the drift-pin and the surrounding LVL fibers easily receive permanent rotation, which is regarded as causing the semi-rigid and viscous - viscoelastic behaviors of drift-pin-jointed LVL. From the above considerations, rotation creep of drift-pin-joint can be divided into two parts, that is, time independent and time dependent rotations Again, each part can be divided into two parts such as recoverable and unrecoverable rotations. Therefore, total rotation creep of drift-pin-joint is divided into four parts : time - independent recoverable rotation which is instantaneous elastic ; time - independent unrecoverable rotation which is instantaneous plastic ; and time - dependent recoverable rotation is delayed elastic ; and time - dependent unrecoverable rotation which is viscous. In this study, it was thought that viscous rotation could be ignored because the rotation creep of the drift-pin-joint is affected by applied maximum load and stable with the addition of plastic rotation of drift-pin-jointed in a low moment. Therefore, we applied a 3-parameter model for the determination of rotation creep on controlled environment of drift pin jointed LVL. We applied a 3-parameter model curve fitting until the 50 hours point. This equation can be expressed as follows:

(3-parameter model)

$$MD = \gamma o + \gamma 1[1 - \exp(-\beta t)] \quad (2)$$

$$\delta ms = DC - MD \quad (3)$$

where:

δo : instantaneous rotation,
$\gamma 1$ and β : coefficients,
DC: corrected rotation creep ($\delta t - \delta st$)
MD: 3-parameter model ($\delta c + \delta o$)
δms : difference of experimental data and 3-parameter model (mechano-sorptive rotation)

Fig. 8 shows plots of 3-parameter curve fittings. Rotation creep curves were obtained by fitting Equation (2) to the rotation creep data, as follows:

MD-30-6 = 0.32 + 0.1018 [1 - exp(-0.0092 t)]
MD-30-10= 0.15 + 0.0952 [1 - exp(-0.0166 t)]
MD-30-16= 0.11 + 0.0766 [1 - exp(-0.0105 t)]
MD-60-6 = 0.60 + 0.0903 [1 - exp(-0.0697 t)]
MD-60-10= 0.34 + 0.0733 [1 - exp(-0.0425 t)]
MD-60-16= 0.26 + 0.0564 [1 - exp(-0.0248 t)]

The predict of the total deflections model of joints can be expressed as the sum of the creep of controlled environment (3-parameter model), dimensional change and mechano-sorptive deflection resulting from the variable environment. The difference between corrected rotation creeps and 3-parameter model rotation creep in Fig. 8 may be interpreted as mechano-sorptive rotation. Fig. 9 shows relationships between mechano-sorptive rotation and $\triangle MC$. Changing moisture content ($\triangle MC$) is defined as

$$\triangle MC = Mt - Mo$$

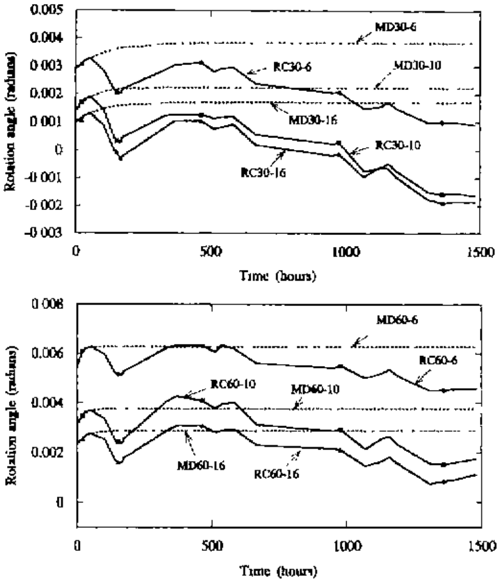


Fig. 8. Curves of pure rotation creep fitted to the 3-parameter model and corrected rotation creep.

Where Mt is the current moisture content of specimen and Mo is a reference moisture content (initial condition of rotation creep test MC (10.5%). A least squares linear regression analysis was performed using mechano-sorptive rotation creep as the dependent variable and moisture content as the independent variable (Fig. 10). The results were as follows:

DD-30-6 = -0.00071 - 0.00053 $\triangle MC$ r=0.97
DD-60-6 = -0.00071 - 0.00074 $\triangle MC$ r=0.97
DD-30-12 = -0.00054 - 0.00072 $\triangle MC$ r=0.98
DD-60-12 = -00004 - 0.00043 $\triangle MC$ r=0.95
DD-30-16 = 0.00021 - 0.0006 $\triangle MC$ r=0.95
DD-60-16 = 0.00006 - 0.00051 $\triangle MC$ r=0.95

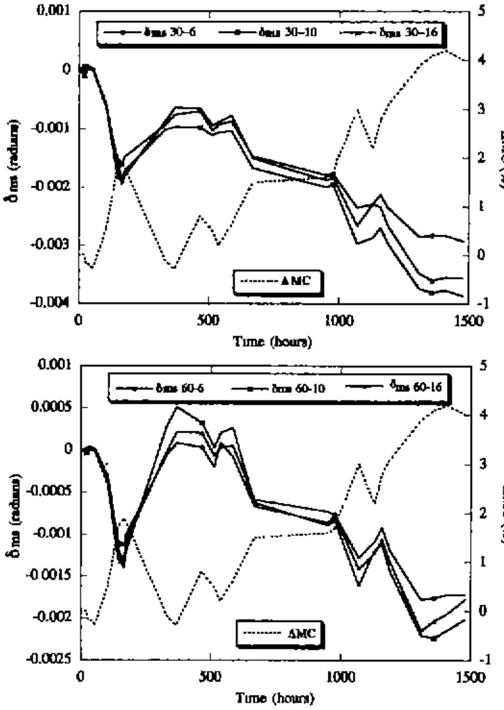


Fig. 9. Relationship between mechano-sorptive rotation creep and ⊿MC.

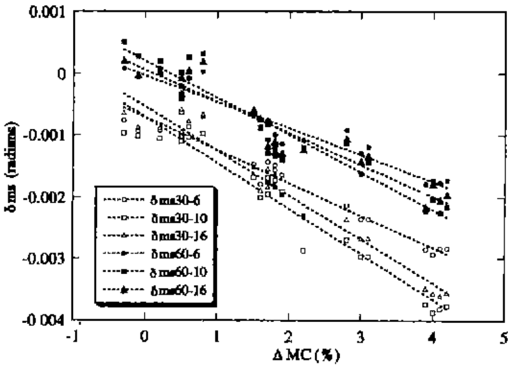


Fig. 10. Regression analysis of mechano-sorptive rotation creep as a function of ⊿MC.

Mechano-sorptive rotation creep is a function of moisture change and decreases as moisture content increases during adsorption. From the above results, we assume that mechano-sorptive rotation depends on MC change, but this has been experimentally verified only to a limited extent.

CONCLUSIONS

The mechano-sorptive rotation was linearly related to MC change over the specified MC range (Fig.10). The slope of the linear regression equation in low moment specimens are larger than those of high moment. It is well demonstrated that low bending moment specimens were strongly affected by changing RH. The mechano-sorptive behaviors are caused by the interaction of sorption and mechanical stresses The desorption process causes increases in displacement, and the adsorption process acts in the opposite way (recovery). Total rotation creep under changing RH increase in applied load. Although creep deflection is higher for small diameter drift pin than those for large diameter drift pin, the shape of creep deflection curves for all specimens is similar.

The prediction of the total rotation creep model of moment resisting joint can be expressed as the sum of the creep of controlled environment (3-parameter model), dimensional change and mechano-sorptive deflection resulting from the variable environment.

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