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MEASURING THE ELECTRIC RESISTANCE OF AIR DRYING THICK RED PINE AND LARCH TIMBER

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ABSTRACT

The objective of this study was to evaluate the moisture profile and drying period of air drying the red pine and Japanese larch timbers with the cross section of 14.0 cm × 14.0 cm and 16.5 cm × 16.5 cm by measuring the electric resistance of the wood. The drying curves determined by measuring electric resistance and by oven-dried method were nearly identical at last drying stage, and had almost same moisture profiles and same drying period after the end of air drying. Therefore, the drying curve determined by measuring electric resistance can be used to predict the drying period and moisture profile of air drying the red pine and Japanese larch timbers with large cross sections.

KEYWORDS: Red pine (*Pinus densiflora*), Japanese larch (*Larix leptolepis* G.), electric resistance, air drying.

INTRODUCTION

Many researches (Rietz et al. 1971, Denig et al. 1982, Marinescu et al. 1999, Pordage et al. 1999, Jung et al. 1986, 1997, 2003, Simpson 2000, Haque et al. 2005, Cai et al. 2012, Ratanawilai et al. 2015, Hua et al. 2016, Turkan et al. 2019) on air drying lumbers have been extensively conducted. However, the thickness of lumbers in all previous studies on air drying was less than 5 inches (12.7 cm). Meanwhile, the limit of possible thickness of kiln drying coniferous lumbers was generally less than 10 cm (Jung et al. 2003). As the thickness of lumber increased, the occurrence of drying defects, drying period and energy requirement markedly increased. Thus, it was difficult to apply kiln drying to the thick lumber. In practice, only vacuum drying or air drying can be applicable for the thick coniferous lumber drying. Because the demand for building of wooden country houses and restoration of traditional Korean houses etc. has increased, the demand for more than five inches thick timbers has been increasing in Korea for a decade. Unfortunately, the research on air drying of the thick timbers is lacking.

Oven-dried method has been usually used to measure moisture content (MC) of wood because of its accuracy, but it was a destructive and heavy measuring method (Helmuth et al. 1989, Simpson et al. 2001, Herritsch et al. 2012). Therefore, it was unreasonable and unrealistic for commercial use. One of the methods to measure MC as a simple method without destruction of wood was a method of measuring electrical resistance. Research on such method was conducted since long time ago (Skarr 1964, William 1988), but research on quickly and effectively measuring MC of the thick timber during air drying at industry site was few.

In this study, employing measuring electric resistance and oven-dried method, the drying curves, moisture profile and drying period were evaluated in order to predict air drying the red pine and Japanese larch with the cross section of 14.0 cm × 14.0 cm and 16.5 cm × 16.5 cm.

MATERIAL AND METHODS

Preparation of specimens

Red pine (*Pinus densiflora*) and Japanese larch (*Larix leptolepis* G.) timbers, which are extensively used as structural timbers in Korea, were selected for this study. The dimension of timbers was 14.0 cm × 14.0 cm × 240 cm and 16.5 cm × 16.5 cm × 240 cm. The total number of timbers was 32 pieces, 8 pieces for each species and size. The properties of timbers are shown in Tab. 1.

Tab. 1: Fundamental properties of timbers.

Property	Red pine		Japanese larch	
	14.0 × 14.0 cm	16.5 × 16.5 cm	14.0 × 14.0 cm	16.5 × 16.5 cm
Average ring width (mm)	5.0 ± 1.1	6.0 ± 1.6	5.7 ± 1.1	5.0 ± 1.1
Sapwood proportion (%)	26.0 ± 29	10.0 ± 15	6.0 ± 6	7.0 ± 13
Basic specific density ($g \cdot cm^{-3}$)	0.40 ± 0.012	0.40 ± 0.013	0.46 ± 0.007	0.48 ± 0.007
Initial MC (%)	55.1	52.7	40.5	34.7

Testing equipment

The 10.2 cm long nails with an electrode, a diameter of which was 0.42 cm, were used to measure the electric resistance of wood. The electric resistance of timber during air drying was measured using a digital Mega ohmmeter with the resistance deviation of ± 2 ohm (Carll et al. 1996). The timbers during drying were weighed by a direct-reading balance with the precision of 10 g. The small quadrangular cross sections were weighed using a direct-reading balance with the precision of 0.01 g.

Stacking and drying condition

The timbers were stacked, using 2.5 cm thick sticker, in 4 rows and 8 layers in the shade below the front door of the laboratory to prevent rain and sunniness (Fig. 1), and were air dried for 44 weeks starting on October 13, 2018 (Fig. 2) (Rietz 1972).

Fig. 1: Staking of timbers and nails inserted in stacking pile.

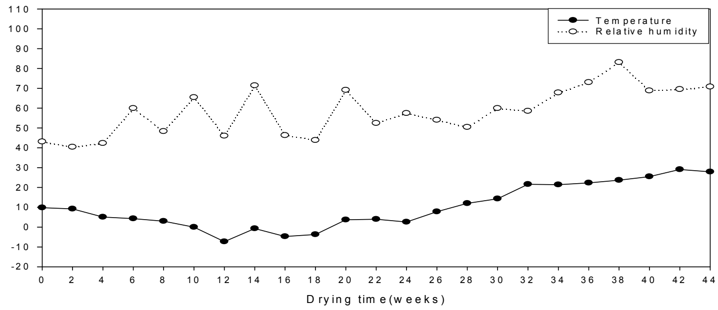

Fig. 2: Temperature and relative humidity during air drying.

Measurement of moisture content

After the end of drying, 9 pieces of 2 cm thick cross sections were cut at interval of 27 cm in longitudinal direction of a timber. From the 2 cm thick cross sections, 81 pieces of small quadrangular cross sections were obtained after nine-fold division in the direction of thickness and nine-fold division in the direction of width of 14.0 cm thick timbers, while 121 pieces of small quadrangular cross sections were obtained after eleven-class division in the direction of thickness and eleven-class division in the direction of width of 16.5 cm thick timbers. Then small quadrangular cross sections were oven dried and their MCs were calculated in order to obtain the final MC distribution in the transversal direction of the timbers (Thomas et al. 1979). All timbers were weighed every two weeks during drying and the MC of each timber was calculated by oven-dried method, which was called actual MC in this study.

Measurement of electric resistance

Twenty four nails divided into 4 groups were inserted at 4 places within 120 cm length from the end surface of a timber. In one place, six nails in each group were inserted at interval of 5 cm from the end surface of a timber in the depth of 17.5 mm (t/8), 35 mm (t/4) and 70 mm (t/2) of 14.0 cm thick timbers, and in the depth of 20.6 mm (t/8), 41.3 mm (t/4) and 82.5 mm (t/2) of 16.5 cm thick timbers. The total of 8 pieces of timbers, 2 pieces from each species and cross section, were used for measuring electric resistance. In the contact area of nails and timber was sealed with silicon to prevent moisture. When the timbers were weighed every two weeks, the electric resistance of the timbers was measured by Mega ohmmeter after the electrode pin of the meter was contacted with in pairs of nails.

The MC of timber was calculated by applying the values of electrical resistance at the different depth of timber to the experimental formula of Keylwerth et al. (1956), which was called calculated MC in this paper:

$$\log[\log(R)\text{ - }4] = 1{,}009 - 0{,}0322M \quad (1)$$

where: R is electrical resistance (Ω), M is moisture content (%).

The calculated MC in transversal direction was average MC at the same depth of 4 positions in longitudinal direction of timber. The calculated MC in drying curve was average MC of each group in the longitudinal direction of a timber.

RESULTS AND DISCUSSION

Actual MC distribution

Actual MC distribution in the thickness direction of 14.0 cm and16.5 cm thick timbers after the end of drying is presented in Fig. 3 and Fig. 4, respectively.

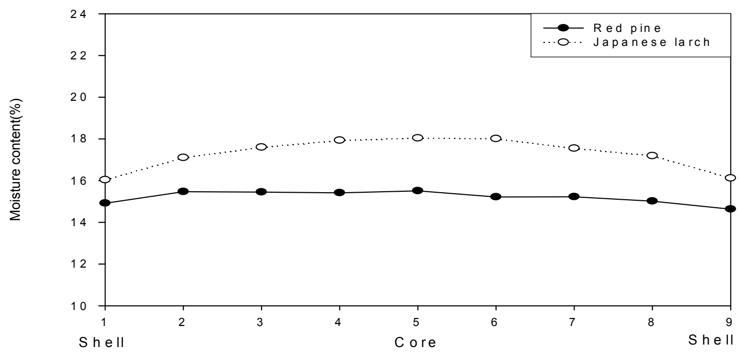

Fig. 3: Actual MC distribution in the thickness direction of air dried 14.0 cm thick timbers.

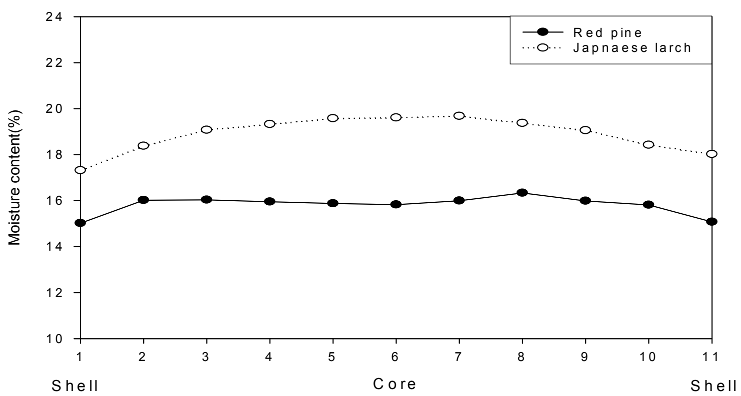

Fig. 4: Actual MC distribution in the thickness direction of air dried 16.5 cm thick timbers.

For 14.0 cm thick timbers, the MC deviation was 0.9%, the highest of 15.5% in core and the lowest of 14.6% in shell, for red pine timbers while that was 2%, the highest of 18% in core and the lowest of 16% in shell, for Japanese larch timbers. For 16.5 cm thick timbers, the MC deviation showed 1.3%, the highest of 16.3% in core and the lowest of 15.0% in shell, for red pine timbers while that showed 2.3%, the highest of 19.6% in core and the lowest of 17.6% in shell, for Japanese larch timbers. From the observation above, it can be found that MC deviation in Japanese larch timbers is higher than that in red pine timbers, which can be attributed to low permeability inside Japanese larch timbers due to there being more resin to hinder moisture to move, and that MC deviation in the timbers with large cross section is higher than that in the timbers with small cross section because long distance reduces moving rate of moisture from core to shell.

Calculated MC distribution

Calculated MC distribution in the thickness direction of 14.0 cm and 16.5 cm thick timbers after the end of drying is shown in Fig. 5 and Fig. 6, respectively. As seen in Fig. 6 and Fig. 7, the calculated MC deviation of 14.0 cm timbers was 1.3% for red pine, which is 0.4 % more than that of oven-dried method, and 3.15% for Japanese larch, which is 1.15% more than that of oven-dried method, while that of 16.5 cm timbers was 2.6% for red pine, which is 1.3% more than that of oven-dried method, and 3.3% for Japanese larch timbers, which is 1.0% more than that of oven-dried method. These indicate that measured deviation by electrical resistance method is larger than (0.4% ~1.3%) that by oven-dried method regardless of species and size of cross section in this study. This may result from the measuring error of electrical resistance method although the MC is within the scope of low MC.

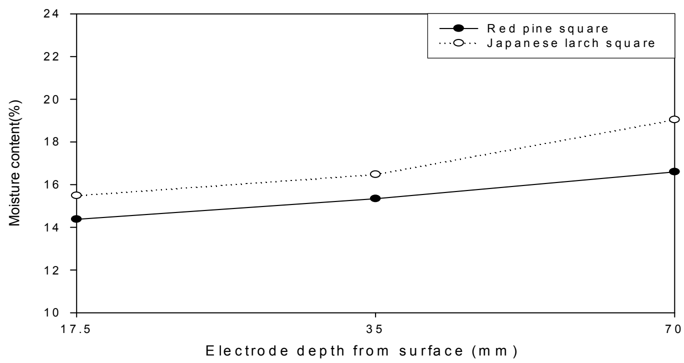

Fig. 5: Calculated MC distribution in the thickness direction of air dried 14.0 cm thick timber.

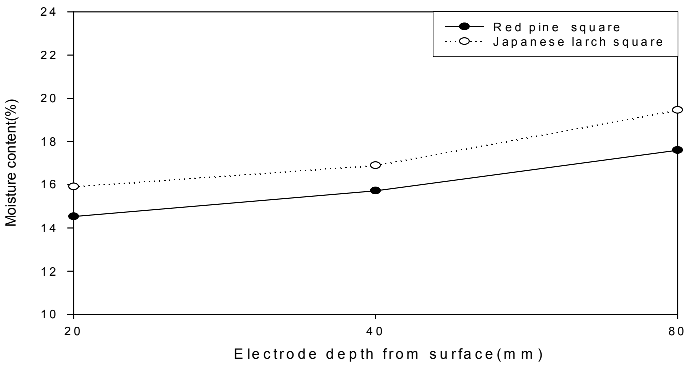

Fig. 6: Calculated MC distribution in the thickness direction of air dried 16.5 cm thick timber.

Drying curve

The actual drying curves and calculated drying curves of red pine and Japanese larch timbers after air drying of 44 weeks are presented in Fig. 7 and Fig. 8, respectively. The initial actual MCs of red pine timbers were 55.1% for 14.0 cm and 52.7% for 16.5 cm thick timbers while those of Japanese larch timbers were 40.5% for 14.0 cm and 34.7% for 16.5 cm timbers. The final actual MCs of red pine timbers were 16.11% for 14.0 cm and 17.0% for 16.5 cm thick timbers while those of Japanese larch timbers were 18.3% for 14.0 cm and 18.8% for 16.5 cm timbers.

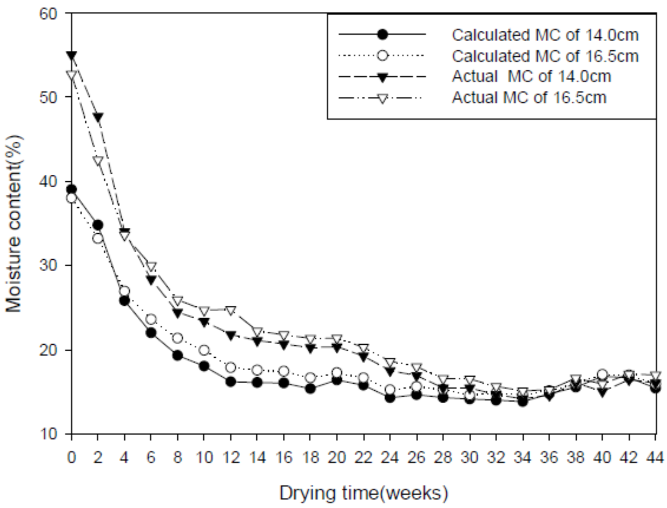

Fig. 7: Actual and calculated air drying curve of red pine timbers.

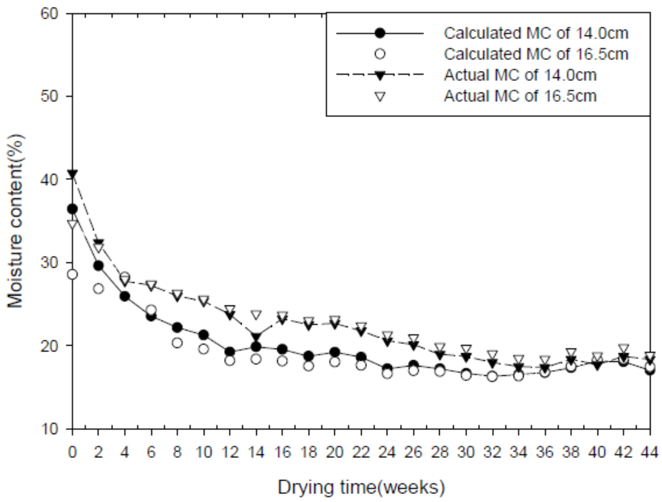

Fig. 8: Actual and calculated air drying curve of Japanese larch timbers.

The initial calculated MCs of red pine timbers were 39.0% for 14.0 cm and 38.0% for 16.5 cm thick timbers while those of Japanese larch timbers were 36.4% for 14.0 cm and 28.5% for 16.5 cm timbers. The final calculated MCs of red pine timbers were 15.4% for 14.0 cm and 15.9% for 16.5 cm thick timbers while those of Japanese larch timbers were 17.0 % for 14.0 cm and 17.4% for 16.5 cm timbers.

At the beginning of drying, the initial calculated MC of red pine timbers were 16.1% (for 14.0 cm) and 14.7% (for 16.5 cm) lower than the initial actual MC while those of Japanese larch timbers were 4.1% (for 14.0 cm) and 6.2% (for 16.5 cm) lower than the initial actual MC. From initial to middle drying stage (about 25% MC), calculated drying curves kept a certain distance with actual drying curves, and presented lower MC compared to actual MC. This tendency proves that there is a certain measurement error by electrical resistance method because of non-linear relationship between the MC and the electrical resistance in wood above the fiber saturation point (Simpson 1994, Skarr 1988, William 1994). However, from about 25% MC to final drying stage, calculated drying curve and actual drying curve approached to nearly same. For example, the final calculated MCs of red pine timbers were 0,7% (for 14.0 cm) and 0.5% (for 16.5 cm) lower than the final actual MC while those of Japanese larch timbers were 1.3% (for 14.0 cm) and 1.4% (for 16.5 cm) lower than the final actual MC. This tendency shows that the measurement error by electrical resistance becomes less below the fiber saturation point.

The correlation between actual and calculated drying curve of red pine and Japanese larch timber is presented in Tab. 2. As seen in Tab. 2, the data showed that the relation between actual drying curve and calculated drying curve was positive correlation because the correlation coefficient (R^2) was close to one.

Tab. 2: Correlation between actual and calculated air drying curves of red pine and Japanese larch timbers.

Species	Cross section (cm)	Drying curve	R^2
Red pine	14.0 × 14.0	Actual drying curve	0.98
		Calculated drying curve	0.97
	16.5 × 16.5	Actual drying curve	0.99
		Calculated drying curve	0.98
Japanese larch	14.0 × 14.0	Actual drying curve	0.98
		Calculated drying curve	0.99
	16.5 × 16.5	Actual drying curve	0.98
		Calculated drying curve	0.87

CONCLUSIONS

This study was conducted to investigate the drying curve, moisture profile and drying period of air drying the red pine and Japanese larch timbers with the cross section of 14.0 cm × 14.0 cm and 16.5 cm × 16.5 cm by measuring the electric resistance inside the wood. The result of this study was as following: *(1)* At the end of air drying, the measured MC deviation by electrical resistance method was 0.4% ~1.3% larger than that by oven-dried method in the transversal direction of red pine and Japanese larch timbers. *(2)* The final calculated MCs were 0.5% ~1.4% lower than the final actual MCs of red pine Japanese larch timbers. *(3)* The relation between calculated drying curve and actual drying curve was positive correlation. The calculated drying curve and actual drying curve were almost identical at final drying stage although there was considerable MC difference between them during initial and middle drying stage. *(4)* The calculated drying curve and actual drying curve had almost same moisture profiles and same drying period after drying. Thus, the calculated drying curve can be used to predict the drying period and moisture profile of air drying the red pine and Japanese larch timbers with large cross section.

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