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Original Article

Predicting Lamina Yield from Logs of Different Diameters for Cross Laminated Timber Production[1]

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ABSTRACT

The goal of this study was to predict lamina yield from logs of different diameter for production of cross laminated timber. Log characteristics of red pine (*Pinus densiflora*) and Japanese cedar (*Cryptomeria japonica*), including diameter, length, volume, and defects were used for statistical and geometrical analyses, along with the lamina characteristics, including width, thickness, and defects. Based on the data obtained, the strong factors influencing the yield and grade of lamina from the two species were statistically evaluated. A geometrical approach was used for analysis of the yield from logs of given diameters. Statistical analysis showed that lamina yield was dependent on target lamina size but the grade of lamina was not related to any of the log characteristics. The suggested yield equations from the geometrical approach indicated an accuracy of less than 20% difference.

Keywords : lamina yield, hierarchical linear model, geometrical analyses

1. INTRODUCTION

Cross laminated timber (CLT) is a relatively new building material. To manufacture CLT, an optimal lamina size and grade should be chosen. The first step to utilization of wood materials to produce laminas for CLT is optimization of the laminar size in order to maximize the yield.

Many previous studies have been conducted to predict the log yield (Hallock and Lewis, 1971; Hallock *et al*., 1976; Hallock *et al*., 1979; Steele and Hallock, 1979; Richards *et al*., 1979; Stern *et al*., 1979; Steele *et al*., 1981; Gilmore *et al*., 1984; Steele, 1984; Lewis, 1985). Previous studies (Hallock and Lewis, 1971; Hallock *et al*., 1976; Steele, 1984) also analyzed the effects of different cutting methodologies, including two live sawing methods and six cant sawing methods. The results indicated that the yield of lumber is highly influenced by the different cutting methods asso-

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ciated with the log geometry. In general, the cant sawing methods resulted in higher yields than the live sawing methods.

Maness and Lin (1995) investigated the effects of saw kerfs and the target lumber sizes on mill revenue and volume recovery, through which reduction of the saw kerfs and target sizes were found to increase both mill revenues and volume recovery. Moberg and Nordmark (2006) predicted lumber volume recovery from Scots pine using the tree characteristics, including stem shape and internal knot structure. Lundahl and Grönlund (2010) studied the yield improvement by alternative rotation and lateral positions. The yield increased from 52.1 to 55.1 percent by applying the optimal rotation for every log in the batch.

In Korea, larch, red pine, nut pine, and Japanese cedar have been used for structural lumber. The logs from these four species were most common, and made up about 94% of the total log volume in Korea from 2010-2011 (Park *et al.*, 2013). The average diameters of the logs from larch, red pine, nut pine, and Japanese cedar were reported to be 15.03 cm, 16.56 cm, 15.55 cm, and 14.47 cm, respectively. Due to the small diameter of the logs, the production of engineered wood products such as CLT allows more effective utilization of these wood 20 sources.

A previous study by Jeong *et al.* (2013) analyzed the effects of lamina size on the yield and grade from Japanese cedar and red pine. Different lamina cuts with three different widths (11, 5, and 3 cm) at a thickness of 3 cm were examined for Japanese cedar with a 16.7 cm average diameter of the smaller end, and different lamina thicknesses (3, 4, and 5 cm) at a width of 11 cm from red pine with a 20.8 cm diameter of the smaller end were compared for yield estimation. The highest yield and grade were obtained from the 11 cm × 3 cm lamina cut of both varieties. However, the effects of log diameter and cutting size on the lamina yield were not examined.

Therefore, the goal of this study was to predict the lamina yield from logs of different diameters for CLT. The current study used the log and lamina characteristic data from the study of Jeong *et al.* (2013). Statistical and geometrical approaches were used for analysis. Hierarchical-linear modeling associated with Pearson linear correlation analysis was used to determine the most influential factors affecting the yield and grade, while geometrical analysis was conducted to analyze the yield according to the log dimension characteristics.

2. MATERIALS and METHODS

2.1. Experimental work

Forty-one Japanese cedar and forty red pine logs were used for yield estimation. The characteristics of each log were recorded based on KS F 4475 (KS 2004), including the diameter of the smaller end (SLD), diameter of the larger end (LLD), log length (LL), diameters of knots in the logs (KDL), the number of knots in a log (NKL), and the log volume (LV).

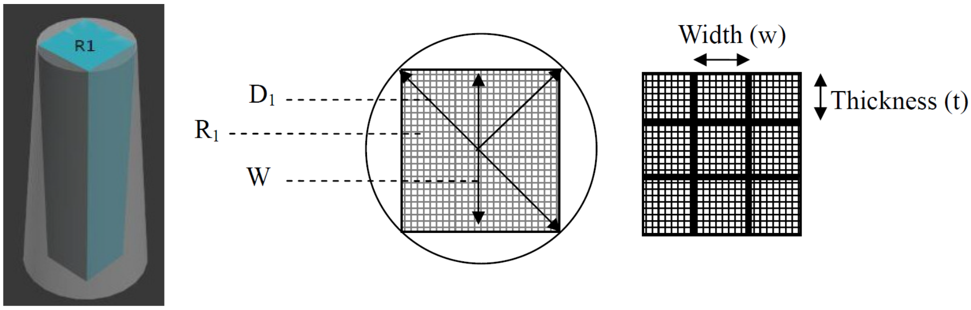


Fig. 1. Cross section of the smaller end diameter, showing Region 1 (R_1) and lamination.

Different target lamina sizes (TLAS) were cut from the two species. For Japanese cedar, the TLAS of 110 mm × 30 mm was cut from 20 logs, the TLAS of 50 mm × 30 mm from 11, and the TLAS of 30 mm × 30 mm from 10 logs. If the dimensions of the log were insufficient to meet the TLAS, smaller dimensions than the TLAS were cut. For red pine, the TLAS of 110 mm × 30 mm was cut from 20 logs, the TLAS of 110 mm × 40 mm from 9, and the TLAS of 110 mm × 50 mm from 11. Again, if the dimensions of the log were insufficient, smaller dimensions than the TLAS were cut. Visual grading was conducted for each lamina, and edge knot size, ring shake, check, ring width, bow, and twisting were recorded based on KS F 3021 (KS 2005). The full protocol followed and the results obtained are available in a previous report (Jeong *et al*., 2013). The current study used the experimental results of the log characteristics, five different grades, and yield from the two species for statistical and geometrical analysis.

2.2. Statistical Approach

A hierarchical linear model was used to compare the yield and grade obtained for different-sized laminas made from Japanese cedar and red pine. Different species were categorized at the highest rank. Each log was subcategorized under the species, and each lamina was subcategorized under the log. Using these ranks, associations of the yield and grade of different-sized laminas with the different diameters of the logs and species were systematically compared. Pearson linear correlation analysis was used to evaluate the correlations between log characteristics and yield, as well as those between log characteristics and grade.

2.3. Geometrical Approach

Fig. 1 provides an illustration of a cross section of the smaller end diameter and lamination with equal dimensions. Region 1 (R_1) was based on the smaller end diameter, with sawing through the small end of the log to provide the same length further along the log. The diameter of the smaller end of the log (D_1) was used to

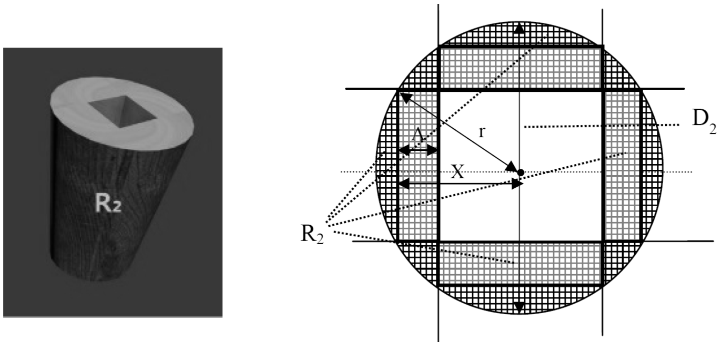


Fig. 2. Region R_2 from the larger end of a log.

ensure a consistent cross section through the length of the log. The width of a square log (W) was estimated from the log diameter (D_1), calculated from Equation 1. The width and number of laminas in the width direction was determined from Equation 2. The thickness and number of laminas in the direction of the thickness was determined using Equation 3, while the cross sections of the laminas were determined with Equation 4. The n_{1i} and n_{2i} were positive numbers, higher than 0. The total volume from the square lumber was determined by multiplying the length of the log (Equation 5). Finally, the yields of the laminas were calculated using Equation 7.

$$\frac{D_1}{\sqrt{2}} = \mathrm{W} \quad \cdots\cdots (1)$$

$$\sum_{i=1}^{\infty}\left[\mathrm{w}_{1i}\mathrm{n}_{1i} + \mathrm{st}(\mathrm{n}_{1i} - 1)\right] - \mathrm{W} \le 0 \quad \cdots\cdots (2)$$

$$\sum_{i=1}^{\infty}\left[t_{1i}\mathrm{n}_{2i} + \mathrm{st}(\mathrm{n}_{2i} - 1)\right] - \mathrm{W} \le 0 \quad \cdots\cdots (3)$$

$$W^2 - \sum_{i=1}^{\infty}\left[\begin{array}{c}(\mathrm{w}_{1i}\mathrm{n}_{1i} \times \mathrm{t}_{1i}\mathrm{n}_{2i}) + \\ (\mathrm{n}_{2i}-1)(st \times \mathrm{w}_{1i}) + (\mathrm{n}_{1i}-1)(st \times \mathrm{t}_{2i}) - (\mathrm{n}_{1i}-1)(\mathrm{n}_{2i}-1)(\mathrm{st})^2\end{array}\right] \le 0$$

$$\cdots\cdots (4)$$

$$V_{r1} = w_{1i}n_{1i} \times t_{1i}n_{2i} \times L \quad \cdots\cdots (5)$$

$$\mathrm{V}_{t1} = \mathrm{W}^2 \times \mathrm{L} \quad \cdots\cdots (6)$$

$$Yield\ from\ R_1(\%) = \frac{\mathrm{V}_{r1}}{\mathrm{V}_{t1}} \times 100 \quad \cdots\cdots (7)$$

Where,

D_1: the diameter of the smaller end of a log

W: width of sawn lumber

w_{1i}: width of lamina from R_1

t_{1i}: thickness of lamina from R_1

n_{1i}: number of lamina in the width direction of the lumber sawn from R_1

n_{2i}: number of lamina in the thickness direction of the lumber sawn from R_1

st: saw thickness

L: length of a log

V_{r1}: lamina volume from R_1

V_{t1}: R_1 volume

After calculating the lamina volume from the square lumber in the log, the diameters of the larger ends of each log were used to estimate the available lamina production. Fig. 2 shows the larger end diameter, including the square lumber, and the available region for lamina production, R_2. For the R_2 region, the length of X could be estimated using Equation 8. The width of R_2 can be estimated with Equation 9. Due to the geometry, the length of A should be much less than that of W. The width and thickness of the laminas from R_2 could be determined from Equations 10 and 11, respectively. The cross section of the laminas from R_2 could be determined using Equation 12.

$$X = \sqrt{r^2 - \left(\frac{W}{2}\right)^2} \quad \cdots\cdots \quad (8)$$

$$A = X - \frac{W}{2} \quad \cdots\cdots \quad (9)$$

$$\sum_{i=1}^{\infty}\left[w_{2i}n_{4i} + st(n_{4i} - 1)\right] - W \le 0 \quad \cdots\cdots \quad (10)$$

$$\sum_{i=1}^{\infty}\left[t_{2i}n_{5i} + st(n_{5i} - 1)\right] - A \le 0 \quad \cdots\cdots \quad (11)$$

$$4WA - \sum_{i=1}^{\infty}\left[\begin{matrix}(w_{2i}n_{4i} \times t_{2i}n_{5i}) + \\ (n_{5i}-1)(st \times w_{2i}) + (n_{4i}-1)(st \times t_{2i}) - (n_{4i}-1)(n_{5i}-1)(st)^2\end{matrix}\right] \le 0 \quad \cdots\cdots \quad (12)$$

Where,

r: the radius of the larger end of a log

A: possible length for lamina cut in the direction of thickness

w_{2i}: width of lamina from R_2

t_{2i}: thickness of lamina from R_2

n_{4i}: the number of lamina in the width direction of the lumber sawn from R_2

n_{5i}: the number of lamina in the thickness direction of the lumber sawn from R_2

Fig. 3 shows the length-wise section of the log. Because trees are tapered lengthwise, the angle (θ) could be determined via Equation 13. The available length of the laminas from R_2 was dependent upon the target thickness. The length of the laminas could be calculated based on the target thickness, the log larger end diameter, and the angle calculated from Equation 13. The sum of the available cross sectional lamina was estimated using Equation 14. The lengths of the laminas were restricted to longer than 30 cm. Since there were four R_2 regions within the log, the total sum of the laminas was estimated using Equation 15. The sum of the R_2 regions was calculated through Equation 16, while the yield of the laminas from R_2 was determined with Equation 17. Equations 18 and 19 show the two methods used to estimate the log volume. The log volume estimation in Equation 18, based on KSF2163 and JAS, was determined from the square of the smaller end diameter multiplied by the length of the log. Equation 18 was used for logs less than 6.0 m in length. The portion of the rectangle at the small end falling outside the log was considered to be equal to the tapered portion of the log outside the rectangle.

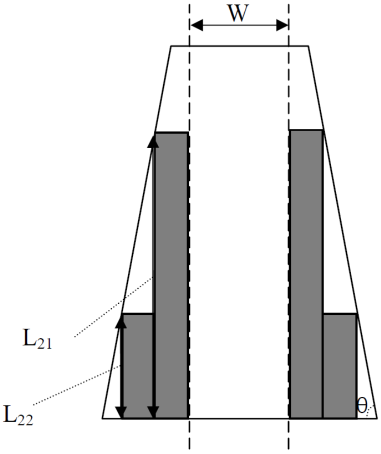


Fig. 3. A tapered log showing the length of the lamina.

The log volume in Equation 19 was determined from the tapered cylinder volume. The yield estimation of all laminas from logs based

Table 1. Pearson linear correlation coefficient values between log characteristics and lamina yield from Japanese cedar

		Log characteristics							
		TLAS	ALAS	SLD	LLD	LL	KDL	NKL	LV
Yield and grade	GR[1]	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	VYI[2]	0.8	0.9	0.2	0.2	0.1	0.0	0.2	0.2
	VYL[3]	0.1	0.1	0.6	0.5	0.3	0.0	0.0	0.6
	YPI[4]	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0
	YPL[5]	0.6	0.6	0.2	0.1	0.1	0.0	0.2	0.2
	YPA[6]	0.9	0.8	0.3	0.3	0.2	0.1	0.3	0.4

[1]GR: grading, [2]VYI: volume yield from individual lamina at the targeted lamina size cut, [3]VYL: volume yield from a log, [4]YPI: yield percent of the target lamina from the target lamina size cut, [5]YPL: yield percent of the targeted and different sized laminas from individual logs, [6]YPA: average yield percent of the targeted and different sized laminas from all logs at the targeted lamina size cut, [7]TLAS: target lamina size, [8]ALAS: actual lamina size, [9]SLD: diameter of smaller end of the log, [10]LLD: diameter of larger end of the log, [11]LL: log length, [12]KDL: knot diameter in log, [13]NKL: number of knots in log, [14]LV: log volume.

on KSF 2163 could be determined from Equation 20, while the yield estimation of all laminas from the logs based on the tapered cylinder volume could be determined via Equation 21.

$$\theta = \tan^{-1}\left(\frac{L}{\frac{D_2 - W}{2}}\right) \quad \cdots\cdots (13)$$

$$\tan\theta \times \left(\frac{\mathrm{D}_2\ \text{-}\ \mathrm{W}}{2} - t_{2i}\right) = \mathrm{L}_{2i} \quad \cdots\cdots (14)$$

$$4\sum_{i=1}^{\infty}\left[w_{2i}n_{3i} \times t_{2i}n_{4i}\right] \times L_{2i} = V_{r2} \quad \cdots\cdots (15)$$

$$\frac{1}{3}\times\pi\times\left(\frac{\mathrm{D}_2}{2}\right)^2 \times \left(\frac{\mathrm{D}_2}{2}\right)\tan\theta_1 - \frac{1}{3}\times\pi\times\left(\frac{\mathrm{D}_1}{2}\right)^2 \times \left(\frac{\mathrm{D}_1}{2}\right)\tan\theta_1 - \left(\frac{\mathrm{D}_1}{2}\right)^2 \times \mathrm{L} = \mathrm{V}_{t2} \quad \cdots\cdots (16)$$

$$\text{Yield from } R_2(\%) = \frac{\mathrm{V}_{r2}}{\mathrm{V}_{t2}} \times 100 \quad \cdots\cdots (17)$$

$$V_1 = D_1^2 \times L \quad \cdots\cdots (18)$$

$$V_2 = \frac{\pi\left(D_1^2 + D_1D_2 + D_2^2\right)L}{12} \quad \cdots\cdots (19)$$

$$Y_1 = \frac{V_{r1} + V_{r2}}{V_1} \quad \cdots\cdots (20)$$

$$Y_2 = \frac{V_{r1} + V_{r2}}{V_2} \quad \cdots\cdots (21)$$

Where,

θ : taper angle of a log

D_2: the larger diameter of a log

L_{2i}: the length of lamina

V_{t2}: volume of R_2

V_{r2}: lamia volume from R_2

V_1: estimated volume of a log from KSF 2163 and JAS

V_2: calculated volume of a log from a tapered cylinder

Y_1: yield estimation of lamina based on V_1

Y_2: yield estimation of lamina based on V_2

For comparison between the estimated yield determined experimentally and the predicted yield from simulation, laminations with equal cross sections were cut from R_1 and R_2 (Fig. 4a and 4b).

3. RESULTS and DISCUSSION

3.1. Statistical Approach

Table 1 shows the Pearson correlation co-

Table 2. Pearson linear correlation coefficient values between log characteristics and yield of laminas from red pine

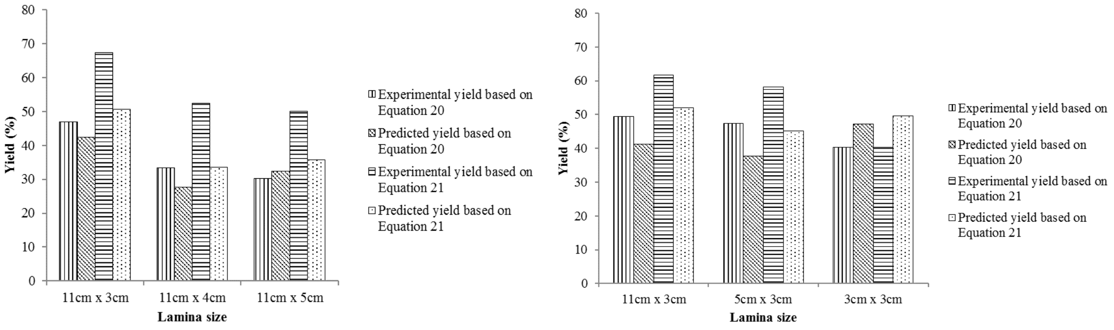
		Log characteristics										
		TLAS	ALAS	SLD	LLD	LL	KDL	B[1]	CN[2]	CW[3]	NKL	LV
Yield and Grade	GR	0.0	0.1	0.2	0.2	0.1	0.2	0.3	0.0	0.2	0.2	0.1
	VYI	0.1	0.8	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0
	VYL	0.3	0.1	0.9	0.9	0.2	0.1	0.4	0.0	0.5	0.2	0.9
	YPI	0.2	0.6	0.1	0.1	0.1	0.0	0.2	0.0	0.0	0.0	0.1
	YPL	0.2	0.0	0.3	0.3	0.2	0.1	0.1	0.0	0.2	0.2	0.2
	YPA	0.9	0.1	0.3	0.3	0.0	0.0	0.2	0.0	0.1	0.0	0.3

[1]B: bow, [2]CN: check in the narrow side, [3]CW: check in the wide side.

efficient values between log characteristics and lamina yield from Japanese cedar. The lamina yield was found to be associated with the target lamina size. Volume yield from the individual lamina at the targeted sizes cut (VYI) was strongly correlated with the target lamina size (TLAS) and the actual lamina size (ALAS). A correlation coefficient of 96.2% observed between VYI and ALAS confirmed the validity of the statistical analysis. The different correlation coefficients between TLAS and VYI, as well as the correlation coefficient between ALAS and VYI indicated that some laminas could not be cut due to the log characteristics. Volume yield from individual logs (VYL) was strongly correlated with SLD and LV. However, the yield percent of the target lamina from the target lamina size cut (YPI) was not strongly correlated with any of the log characteristics. The low correlation between YPI and log characteristics was due to the variability of YPI in the individual logs, whereas TLAS and ALAS were fixed. Conversely, the yield percent of the target and different-sized laminas from individual logs (YPL) and of the target and different-sized laminas from all logs at the targeted lamina size cut demonstrated strong correlation with both TLAS and ALAS.

Interestingly, the grade of lamina was not strongly correlated with any of the log characteristics. Lamina grade may be more associated with forest management and primary processing. Although the yield of the target lamina size may vary depending on the log characteristics, the yield of the target- and other-sized lamina from the logs could be highly dependent upon the TLAS.

Table 2 shows the values of the Pearson correlation coefficient between the log characteristics and the lamina yield from red pine. Only weak correlation was observed between lamina grade and any of the log characteristics. VYI was strongly correlated with ALAS, but not TLAS. The sizes of the majority of lamina obtained were different from the target lamina size. The target lamina sizes of 11 cm × 5 cm and 11 cm × 4 cm may be too large for red pine logs that range in diameter from 13.85 cm



a) Red pine b) Japanese cedar

Fig. 4. Comparison of the yields obtained experimentally with those predicted from geometrical analysis.

to 28 cm. VYL was found to be strongly correlated with SLD, LLD, and LV. YPI was strongly correlated with ALAS. However, YPL had no strong correlations with any of the log characteristics. The yield percent from 11 cm × 3 cm, 11 cm × 4 cm, and 11 cm × 5 cm lamina cut from red pine varied according to the log characteristics. YPA was strongly correlated with TLAS, but not with ALAS. The lamina yield from Japanese cedar and red pine depended on the association between the target lamina size and the log characteristics. Using this relationship, geometrical analysis can be performed to estimate the yield.

3.2. Geometrical Approach

Fig. 4 shows a comparison of the yield derived from the experimental results (Jeong *et al.*, 2013) and that predicted from the geometrical analysis. Two different log volumes were estimated using Equations 18 and 19. Fig. 4a shows the different lamina size yield estimations of forty red pine logs from the previous study based on Equations 20 and 21, and the predicted yield from the geometrical approach based on these equations.

The differences in yield estimation for the lamina sizes of 11 cm × 3 cm, 11 cm × 4 cm, and 11 cm × 5 cm from red pine logs from the previous study and the predicted result based on Equation 20 were 9.6%, 17.0%, and 7.7%, respectively. In contrast, these lamina sizes demonstrated differences of 24.7%, 35.9%, and 27.1%, respectively, with the predictions based on Equation 21.

Fig. 4b shows the lamina yield estimation of forty-one Japanese cedar logs from the previous study, and the predicted yield from the geometrical approach based on Equations 20 and 21. The differences in yield estimation of the lamina size of 11 cm × 3 cm, 5 cm × 3 cm, and 3 cm × 3 cm between the previous study and the predicted result based on Equation 20 were 16.5%, 20.5%, and 16.7%, respectively. Again, higher differences were observed with the predicted result based on Equation 21, at 27.1%, 22.2%, and 23.3%, respectively.

Table 3. Association of yield percent (%) of lamina with the thickness (T) and width (W) at the smaller end at a diameter (D_1) of 10 cm

		T (cm)						
		1	2	3	4	5	6	7
W (cm)	1	51.9	63.3	63.4	42.4	52.4	62.4	72.4
	2	63.3	76.0	75.8	50.4	62.4	74.4	86.4
	3	63.4	75.8	75.4	49.8	61.8	73.8	85.8
	4	42.4	50.4	49.8	32.0	40.0	48.0	56.0
	5	52.4	62.4	61.8	40.0	50.0	60.0	70.0
	6	62.4	74.4	73.8	48.0	60.0	72.0	84.0
	7	72.4	86.4	85.8	56.0	70.0	84.0	98.0

Table 4. Association of yield percent (%) of lamina with the thickness (T) and width (W) at the smaller end at a diameter (D_1) of 15 cm

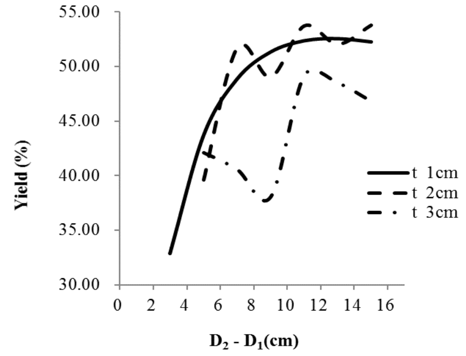
		T (cm)									
		1	2	3	4	5	6	7	8	9	10
W (cm)	1	56.7	58.6	66.3	59.2	73.7	44.5	51.6	58.7	65.8	72.9
	2	58.6	59.3	66.7	59.3	73.8	44.2	51.3	58.4	65.6	72.7
	3	66.3	66.7	74.8	66.5	82.7	49.6	57.6	65.6	73.6	81.6
	4	59.2	59.3	66.5	58.9	73.4	43.7	50.8	57.9	65.0	72.1
	5	73.7	73.8	82.7	73.4	91.4	54.6	63.5	72.4	81.3	90.2
	6	44.5	44.2	49.6	43.7	54.6	32.0	37.3	42.6	48.0	53.3
	7	51.6	51.3	57.6	50.8	63.5	37.3	43.5	49.7	56.0	62.2
	8	58.7	58.4	65.6	57.9	72.4	42.6	59.7	56.8	64.0	71.1
	9	65.8	65.6	73.6	65.0	81.3	48.0	56.0	64.0	72.0	80.0
	10	72.9	72.7	81.6	72.1	90.2	53.3	62.2	71.1	80.0	88.8

3.3. Lamina yield from Region 1

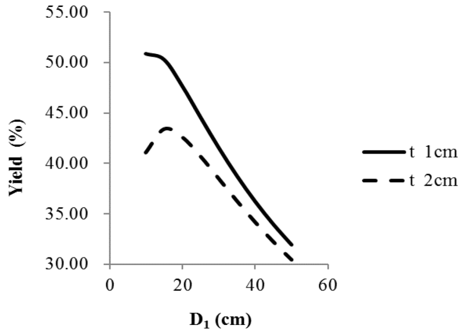
Tables 3 and 4 show the predicted yield from R_1 when the smaller end of the log was 10 cm and 15 cm, respectively. Given the diameter of the smaller end of the log, the yield associated with the width (w) and thickness (t) of the lamina could be calculated using Equations 1-7. For the log with a 10 cm smaller end, the maximum yield was obtained from a 6 cm × 6 cm cut, whereas the minimum yield was obtained from a 4 cm × 4 cm cut. For the log with a 15 cm smaller end, the maximum yield was obtained from a 10 cm × 10 cm cut, whereas the minimum yield was obtained from a 6 cm × 6 cm cut. The predicted yield differed according to the width and thickness of the lamina, as well as the diameter of the log. It is possible that the predicted yield of laminas could be made accessible in a database providing the diameters of both ends of the logs, the length of the logs, and the target lamina size.

3.4. Lamina yield from Region 2

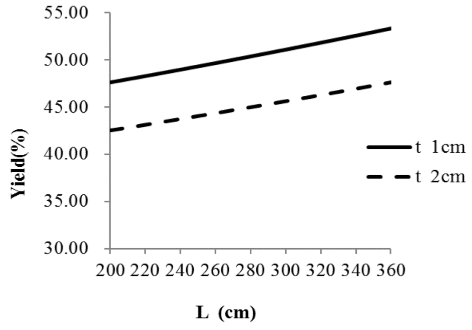
Fig. 5 shows the trends of association between the R_2 yields and the diameters of both ends, the log length, and the lamina size. The trends of the yield with an increment of the larger end of the log when the smaller end has a diameter of 20 cm and the log is 200 cm long are shown in Fig. 5a. When the difference between the two diameters increased, the width of A from R_2 increased. When the difference of the diameters increased from 3 cm to 15 cm, the yield of lamina with a thickness of 1 cm was increased by about 20%. However, when the thickness of the lamina was set to 2 or 3 cm, fluctuation in the yield was observed. Overall, as lamina thickness increased, the yield from R_2 decreased. Fig. 5b shows the trends of the yield with an increment of the smaller end of the log when the difference between the two diameters was 4 cm. As the diameter of the smaller end of the log increased from 10 cm to 50 cm, the yield of the lamina decreased. Compared to the yield of the lamina with a thickness of 1 cm, the 2 cm thick lamina demonstrated lower values. Fig. 5c shows the trends of yield with increment of the log length when the smaller end and the larger end of the log were 20 cm and 24 cm, respectively. When the log length increased from 200 cm to 360 cm, the yield of 1-cm-thick lamina increased.



a) Lamina yield with differences of 3 cm to 15 cm between both ends at a log length of 200 cm.



b) Lamina yield with an increment of the diameter of the smaller end at the difference of 4 cm between both ends and the log length of 200 cm.



c) Lamina yield with an increment of log length with a 20 cm smaller end and a 24 cm lager end.

Fig. 5. Prediction of lamina yield from R_2 with change in the diameters of both ends, and of log length.

4. CONCLUSION

Statistical and geometrical analyses were performed to estimate the lamina yield from logs with different diameters for CLT production. Statistical analysis revealed lamina yield to be dependent on target lamina size. The grade of lamina was not associated with any of the log characteristics from red pine and Japanese cedar. Therefore, the lamina grade for the parallel and perpendicular layers in CLT should be determined after primary processing. Geometrical analysis revealed that the experimentally determined lamina yield was consistent with the predicted yield. From the comparison between the yield estimation and the predicted yield, the suggested yield equations were able to predict the lamina yield from logs with different diameters with an accuracy of less than 20% difference. Use of these equations to predict lamina yield will enable wood materials to be utilized with greater efficiency.

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