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Properties of solid wood and laminated wood lumber manufactured by cold pressing and heat treatment

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ABSTRACT

Physical, mechanical, and morphological properties of solid wood lumbers which were cold pressed in a press and then heat treated in a kiln. Two different kinds of domestic thinning small-diameter softwood (*Ginko biloba* L.) and hardwood (*Tilia amurensis Rupr.*) were used in this study. First 50 mm thick lumbers were cold pressed until 35 mm (30% of control lumber) using a stopper for 5 min. Then the cold pressed lumbers were heat treated in an electric kiln at 180 °C for 6, 12, 24, or 48 h. To increase the utilizability of woods, the LVLs were produced from 4 mm thick veneers prepared from the heat treated lumbers using a veneer saw. Each LVL sample consisted of 5 layers which were subsequently 48 h-, 24 h-, 12 h-, and 6 h-treated veneers and untreated veneer (from top layer to bottom layer). The shrinkage rates of softwood and hardwood were considerably decreased with increasing temperature. The mechanical properties of heat treated samples were better than those of unpressed control samples. The bending strength and modulus of elasticity of the LVLs manufactured from cold pressed and then heat treated lumbers were slightly lower than those of untreated woods. The colour values obtained from the heat treated wood samples showed a clear effect of the temperature on the colour changes.

1. Introduction

Heat treatment is a process that improves wood performance and leads to improved water repellency, rebuilding duced shrinkage and swelling, higher decay resistance, reduced extractive contents, lower equilibrium moisture content and increased thermal insulating capacity [1–7]. Heat treatment of wood has been developed in Europe during 1990s [5]. Various companies in Holland and France have been producing commercially heat treated wood. Heat treatment adversely influenced most of mechanical characteristics of different wood species [5]. Having higher treatment temperature would also enhance biological durability but some undesirable effects of the treatment such as reduction of strength and hardness of wood are inevitable [6]. Therefore, use of heat treated wood in structural application is not suggested due to reduction of mechanical properties of the member ranging from 10% to 30% [5].

More recently the interest in heat treatment processes has been renewed. This renewed interest is due to the declining production of durable timber, to the increasing demand for sustainable building materials, to the deforestation of especially sub-topical forests, and to the increased introduction of governmental restrictive regulations reducing the use of toxic chemicals. It is well known that the heat treatment is often used to improve the dimensional stability of solid wood, but it cases to decrease mechanical properties of solid wood [3]. This restricts the structural applications of heat treated wood. The densification of solid wood by cold pressing improves the mechanical properties of wood [8]. Based on the extensive literature search, there is no any study regarding properties of solid wood which was cold pressed in a platen press and then heat treated in an oven. Before the heat treatment application to the wood, cold pressing can minimise the decrement in the mechanical properties of heat treated wood. In this study, physical, mechanical, and colour properties of solid wood and laminated veneer lumber (LVL) manufactured by cold pressing and heat treatment were investigated.

2. Experimental details

Two different kinds of domestic thinning and small diameter softwood (*Ginko biloba* L.) and hardwood (*Tilia amurensis Rupr.*) were harvested in Taebaek Samcheok, Kangwon in Rebuplic of

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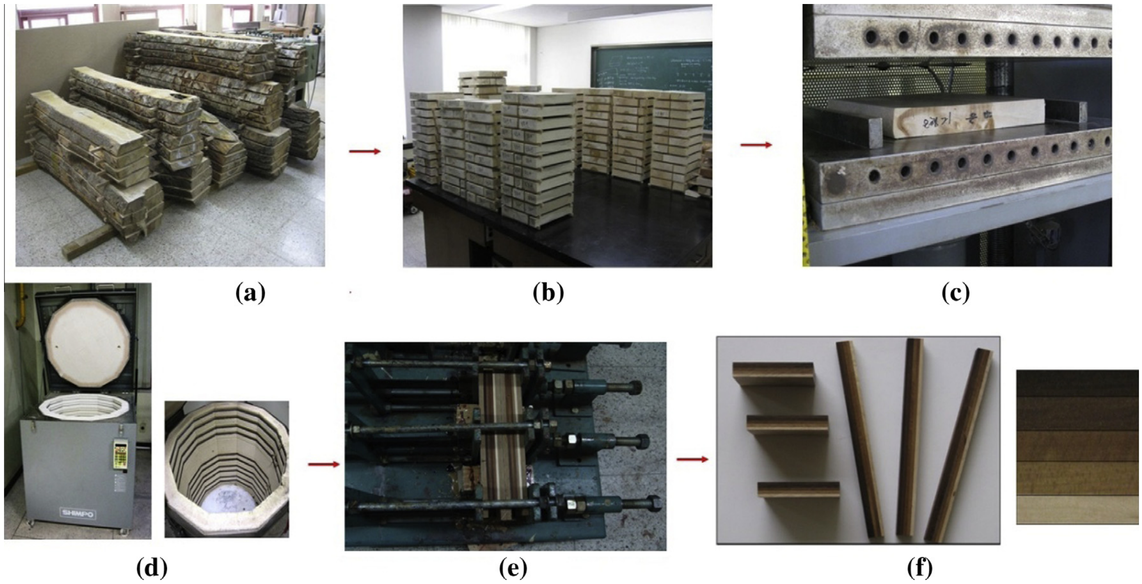

Fig. 1. Treatment process of wood samples and production of experimental LVL samples.

Korea. The tree ages and breast diameters were 28 and 43 cm for Ginko tree and 25 and 48 cm for Tilia tree, respectively. First 50 mm thick lumbers were cold pressed until 35 mm (30% of control lumber) using a stopper for 5 min. Then the cold pressed lumbers were heat treated in an electric kiln at 180 °C for 6, 12, 24, and 48 h. To increase the utilizability of woods, the LVLs were produced from 4 mm thick veneers prepared from the heat treated lumbers using a veneer saw. Each LVL sample consisted of 5 layers which were subsequently 48 h-, 24 h-, 12 h-, or 6 h-treated veneers and untreated veneer (from top layer to bottom layer) (Fig. 1f). The PVA adhesive was spread at the rate of 250 g/m^2 on a single bonding surface of the veneers using a laboratory manual cylinder. After applying the *adhesive,* five veneers were placed with their grain directions parallel to the grain direction of the neighbour veneers. The LVL mats were cold pressed at 1 MPa for 24 h using compression clamps. The physical and mechanical properties of the wood and LVL samples conditioned at 65% relative humidity and 20 °C were determined according to Korean Standards.

The effect of heat treatment on the anatomical structure of cold pressed wood samples was also investigated using scanning

Table 1
The physical, mechanical, and colour properties of the untreated and treated woods.

Wood species	Treatment			Density (g/cm^3)	Shrinkage: Green to air dry (%) (Tangential)	Shrinkage: Green to oven dry (%) (Tangential)	CS (//) (MPa)	MOE (MPa)	MOR (MPa)	Colour difference: ΔL	Δa	Δb	ΔE*ab
Ginkgo biloba L.	Unpressed wood (control)			0.53 (0.02)	5.10 (0.2)	7.40 (0.2)	32.9 (1.7)	4603 (164)	53.4 (2.4)	–	–	–	–
	Cold pressed wood			0.62 (0.03)	4.60 (0.2)	6.10 (0.2)	35.1 (1.5)	5305 (172)	58.2 (2.7)	84.5 (2.8)	7.4 (0.5)	24.4 (1.0)	–
	Cold pressed wood	180 °C	6 h	0.47 (0.02)	4.66 (0.03)	5.16 (0.03)	32.7 (1.3)	5023 (165)	58.0 (2.1)	49.3 (1.1)	16.7 (0.8)	22.6 (0.5)	30.4 (0.8)
			12 h	0.46 (0.03)	4.11 (0.02)	5.09 (0.02)	31.8 (1.1)	4852 (143)	55.4 (1.6)	45.9 (1.5)	18.0 (0.6)	20.9 (0.8)	38.9 (1.2)
			24 h	0.46 (0.01)	3.86 (0.01)	4.79 (0.02)	30.3 (1.2)	4609 (162)	49.9 (2.0)	41.2 (1.2)	15.9 (0.8)	16.4 (0.9)	44.1 (1.0)
			48 h	0.44 (0.03)	3.01 (0.01)	4.77 (0.01)	26.9 (1.0)	4507 (157)	49.5 (1.8)	30.2 (1.5)	20.8 (1.3)	8.6 (1.5)	56.6 (1.8)
Tilia amurensis Rupr.	Unpressed wood (control)			0.46 (0.02)	6.50 (0.2)	8.60 (0.01)	30.9 (1.6)	5370 (166)	58.1 (1.9)	–	–	–	–
	Cold pressed wood			0.53 (0.03)	5.90 (0.4)	8.10 (0.04)	42.1 (1.8)	6542 (190)	63.8 (2.3)	75.4 (2.6)	9.8 (0.7)	18.4 (0.7)	-
	Cold pressed wood	180 °C	6 h	0.44 (0.03)	5.97 (0.03)	7.41 (0.03)	40.9 (1.8)	6279 (183)	62.6 (2.4)	49.1 (2.2)	16.4 (1.0)	19.9 (0.9)	23.3 (0.9)
			12 h	0.43 (0.03)	5.69 (0.03)	5.98 (0.03)	40.7 (1.7)	6034 (178)	62.5 (2.0)	48.3 (2.5)	15.3 (0.9)	21.6 (1.2)	33.9 (1.3)
			24 h	0.43 (0.01)	4.23 (0.02)	5.01 (0.02)	40.4 (1.9)	5984 (162)	61.7 (2.2)	41.3 (0.7)	14.9 (0.8)	17.9 (0.5)	41.3 (1.5)
			48 h	0.41 (0.05)	4.11 (0.01)	4.92 (0.02)	32.7 (1.5)	5378 (151)	57.8 (1.6)	36.5 (1.7)	14.6 (0.8)	14.2 (1.4)	46.7 (1.4)

CS: compressive strength parallel to grain. MOE: modulus of elasticity in bending. MOR: modulus of rupture.
L: Lightness. *a*: Green–red. *b*: Blue–yellow: two chromatic coordinates. ΔE*ab: colour difference.
The values in the parentheses are standard deviations.