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Using Poplar Wood for Structural Lumber: The SDR Process

By

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Introduction

Poplars show perhaps the greatest potential for genetic and cultural development of any genus in the temperate and boreal zones. Not only is there tremendous potential as a source of energy wood, pulp and particle board furnish, but, a generally ignored potential is that of lumber; especially structural lumber.

The value of pulpwood, chips, and sawdust is considerably less than the value of sawlogs (Table 1).

Research at the Forest Products Laboratory has shown very good potential for using various Populus species for structural lumber. It is that research that is discussed here.

Problems in manufacture and a solution

The Populus species have not been used to a great extent as structural lumber in commercial circles because of warp. Populus lumber warps because different parts of the wood shrink at different rates. The three factors involved are tensionwood, juvenile wood and longitudinal growth stress.

Tension wood is a form of reaction wood developed on the upper sides of leaning trees or as a result of external stresses such as wind. Tensionwood causes warp because it shrinks much more longitudinally than normal wood does.

Juvenile wood is wood formed at the center of the tree and is sometimes called "crown formed wood." Generally, the juvenile wood core is composed of 10-20 rings, from pith outward. The juvenile core causes warp because it also shrinks much more longitudinally than mature wood does.

Longitudinal growth stress is stress in the direction of the length of the tree, formed as the tree grows. Longitudinal growth stress is composed of tension stress and compression stress. As new wood cells are laid down, they develop tension stress. As the tree increases in diameter the total stress level increases; high compression stresses form at the

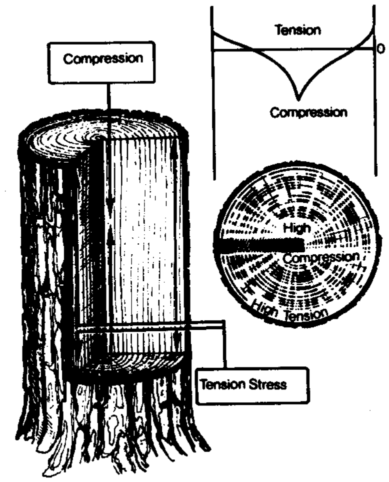

Figure 1--Longitudinal growth stress patterns in hardwood trees and logs. (ML83 5581)

center of the tree and high tension stresses at the periphery. The stresses form a balance in each radius (Fig. 1). When the log is sawn, these stresses are released (Fig. 2). The tension stressed side of a board will shorten on cutting, whereas the compression side will lengthen. This differential stress release causes warping.

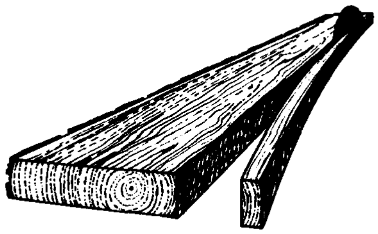

Figure 2--Lumber sawn from hardwood logs exhibits stress release (warp) on cutting. (ML83 5582)

Over the decades many manufacturers have tried to saw structural lumber from Populus species but have not been able to overcome the warp problems described above.

The Forest Products Laboratory, after examining the causes of warp, developed a process for sawing and drying low- to medium-density hardwoods that permits the manufacture of straight stable studs and other lumber. The process is called Saw-Dry-Rip (SDR) (Maeglin and Boone, 1983).

The process has been demonstrated in both laboratory and commercial settings as a viable means for upgrading the products from hardwoods.

The SDR Process

SDR is a relatively straightforward-simple process. Small logs (8-14" in diameter) are live sawn into 7/4 flitches, the flitches dried and then studs or other products are ripped from the dried flitches.

If it's so simple, why does SDR work? (Fig. 3)

What Makes SDR Work?

1. Stresses are Balanced by Live Sawing
2. Wide Flitches Restrain Warp
3. Drying Stresses Offset Growth Stresses
4. Lignin is Plasticized at High Temperature

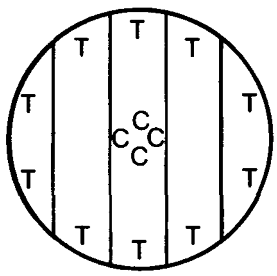

Figure 3--Four factors contribute to the success of SDR (ML84 5419)

Live sawing has been used for centuries in Europe and Asia to obtain matched hardwood lumber for cabinetry and panelling. It is easy and fast and can be accomplished in many ways. Drying flitches is not new either.

It takes a little longer than drying 2x4's but the quality yields are worth the effort. Ripping lumber to smaller widths is common in many wood using industries. So, there's nothing new here either. Putting the sawing, drying and ripping into a process is new and accomplishes great things.

Drying is a critical step in the SDR process because uniformity of moisture content and removal of stresses are so important. We recommend drying to an average moisture content (MC) of 12% and conditioning to remove surface stresses. This MC is lower than current industry practice for structural lumber but can yield quality and value benefits. Getting uniform drying in most poplars is not easy because of bacterially caused wetwood (Ward 1976; Ward & Pong, 1980). Wet pockets in the interior of a flitch can be exposed on ripping and result in after–processing shrinkage and warp, if uniform drying is not attained. Drying to 12% MC and conditioning both help to alleviate the wetwood problem. Sorting of wetwood and normal wood may be necessary to reduce drying problems.

Results of tests on Populus species

Aspen. Eighteen laboratory trials were conducted on aspen flitches, seeking to develop a suitable high temperature drying schedule, Table 2. Of the nearly 1400 studs (2x2 - 2x4) manufactured from these flitches, only 38 (2.7%) were rejected from STUD–grade warp limits (NHPMA 1978) (Table 3). Twenty four of the rejects were from trial 17, a severe drying schedule conducted on flitches from the centers of selected logs which contained wetwood (Table 4).

The studs from ten of the 18 trials were placed in storage for 60 days or more, subject to ambient outside air and moisture conditions. There was an overall increase in rejects from 0.4% initially (for the 10 trials) to 6.2% after storage (Table 4). This is in contrast to reports of up to 60% rejects which are common for conventional processing of aspen, yellow poplar, and cottonwood (Koch and Rousis, 1977; Funck et al., 1981).

Average warp indicates the quality of lumber also. It is possible to have few rejects but have average warp right at the limits of allowable crook, bow, and twist, (Table 3). For all 18 aspen trials, the averages for all sizes of studs were as follows:

Crook - 1.4/32 inch
Bow - 5.4/32 inch
Twist - 1.3/32 inch

These amounts are comparable to those found in other SDR studies of several hardwoods species (Larson 1983; Layton 1982, Maeglin and Boone, 1983 and Trachsel, 1982) and are much lower than STUD–grade limits (Table 3).

Aspen studs manufactured by SDR in a commercial trial were of exceptionally high quality. For the over 12 MBF of studs produced, nearly 30% were rejected for excessive MC. This points up the problem of drying aspen with wetwood. The pieces exceeding the MC limits (19% MC), however, were of the same grade proportions as the dry material (Table 5).

The grade recovery from the woods–run logs (8– to 15–in. diameter) was 83% STUD and BETTER for 2 x 3's to 95% Structural Light Framing No. 2 and BETTER for 2 x 6 studs. These grade proportions consider all defects including knots, slope of grain, warp, etc.

In an evaluation of SDR–processed aspen for door parts (Huber et al. 1984) average crook was reduced by 40% when the aspen was dried at 160°F and by 60% when dried at 200+°F, compared to grade–sawn (aspen) lumber dried at 160°F. Bow was reduced by 91.5% when dried at 160°F and by 21% when dried at 200+°F. Twist was not consistently reduced by SDR, but the levels of twist were extremely low (Table 6).

Cottonwood. In an early but limited trial of cottonwood SDR (Maeglin & Boone, 1980) 21 studs had no rejects based on warp and had low levels of warp (Table 7). This preliminary work led to more complete comparative research (Trachsel 1982). Trachsel's results showed SDR yields of STUD grade material based on warp were higher than conventional processing yields (76.4% vs. 51.7%) (Table 8).

Whereas it is recommended that small diameter logs (8 to 14 inch) be used for SDR, Trachsel showed straighter studs from larger (17 to 28 inches), rather than smaller diameter logs (12–16 inches). Logs in the 8 to 12 inch class were not evaluated.

The reason for recommending smaller diameter logs are smaller knot size and less cross grain than in larger logs. Trachsel (1982) shows very low STUD grade yields when knots, slope of grain and other factors are considered along with warp. This is to a large extent caused by log size.

Conclusions

Populus species have good potential as a resource for structural lumber if properly processed. The problems of warp can be greatly reduced by using the SDR process for four reasons:

1. The cutting pattern balances stresses
2. Extra width in flitches restrains warp
3. Drying stresses compensate for growth stresses
4. Lignin plasticizes at high temperatures and relieves stresses

Drying of *Populus* woods can be difficult if wetwood is present. Care should be taken to insure uniform drying to 12±3% moisture content. Sorting of wetwood may be necessary.

SDR should be tried with the various hybrid poplars to demonstrate their utility as structural material.

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Table 1.--Comparative values of products from aspen in Wisconsin[1] and the differentials between sawlogs and other products.

Product	Aspen: Value per pound	Aspen: Value relative to saw logs
Stumpage	($)	%
Sawlogs	0.0029	--
Boltwood	0.0023	79.3
Pulpwood	0.0011	37.9
Delivered to Mill		
Sawlogs (wood run)	0.0116	--
Boltwood	0.0090	77.6
Pulp chips	0.0082	70.7
Pulpwood	0.0077	66.4
Sawdust	0.0050	43.1

[1]Derived from Wisconsin Forest Products Price Review; Boltwood edition Oct. 1984; Timber edition Nov. 1984. University of Wisconsin, Madison.

Table 2--Kiln conditions and schedules for 18 aspen drying trials by SDR

Trial number	Temperature: Dry bulb	Temperature: Wet bulb	Time	Equalizing time[1]	Average moisture content
	°F	°F	h	h	%
1	235	190	28	44	15.7
2	235	190	28	48	23.8
3	260	190	28	49	20.9
4	260	190	32	44	12.4
5	235	190	48	23	17.3
[2]6	250	190	48-8	18	8.0
7	240	190	45	22	10.1
[3]8	240	190	40	30	11.7
[2]9	250	190	42-8	24	7.7
[4]10	235	190	8	17	16.2
[5]11	240	Vents open	32	24	10.4
[5]12	240	Vents open	44	29	5.9
[5]13	210	Vents open	120	24	7.9
[5]14	240	Vents open	45	29	6.1
[6]15	--	--	--	--	8.3
[6]16	--	--	--	--	8.8
[2,5]17	240	Vents open	45-9	29	19.4
[2,5]18	240	Vents open	45-9	29	9.5

[1]All equalizing was done at 200°F dry bulb and 188°F wet bulb.
[2]A split schedule with a high temperature-equalizing-high temperature cycle. The times at high temperature are in sequence under "Time."
[3]Lumber steamed in the kiln for 4 h before drying started.
[4]Lumber air dried to 28% MC before kiln drying.
[5]Vents on the kiln were held open--no wet bulb control during drying.
[6]Conventional schedule FPL T10-46 (Rasmussen 1961).

Table 3.--Warp limits for STUD grade as shown in NHPMA (1978) standard grading rules[1]

Size	Crook	Bow	Twist
	- - - - - - - in. - - - - - - -		
2 x 4	8/32	24/32	12/32
2 x 3	8/32	24/32	12/32
2 x 2	8/32	24/32	6/32

[1]Excluding pieces with excessive MC.

Table 4.--Aspen SDR drying trials for 2x4, 2x3, and 2x2 studs, showing rejects based on warp. Also. average moisture content is shown for each trial before storage.

	Trial number	η	Average moisture content	Number rejects[1] Initial	Number rejects[1] After storage
			%		
			STORED		
	1	154	17.0	0	7
	2	38	23.1	0	3
	3	48	17.3	1	1
	4	54	12.9	0	8
	5	73	17.9	0	7
	6	87	8.0	0	2
	7	52	10.0	0	3
	8	76	11.8	1	4
	9	38	7.1	0	2
	10	42	16.2	1	4
Total	1-10	662	--	3(0.4%)	41(6.2%)
			NOT STORED		
	11	102	11.1	0	
	12	55	6.3	1	
	13	86	7.2	1	
	14	64	6.0	0	
	15	142	8.3	0	
	16	129	8.6	2	
	17	93	18.1	24	
	18	66	7.3	7	
Total	1-18	1,399	--	38(2.7%)	

[1]Values in parentheses are the percentage of rejects based on total η.

Table 5.--Grade mix of aspen studs manufactured in a commercial trial[1] by SDR.

Size	Volume	Grade	Proportion in grade
in.	BF		%
2 x 3	1,350	STUD and BETTER	83
2 x 3	285	Utility and rejects	17
2 x 4	3,480	STUD and BETTER	89
2 x 4	420	Utility and rejects	11
2 x 6	2,620	No. 2 and BETTER	95
2 x 6	140	No. 3 and rejects	5

[1]Excluding pieces with excessive MC.

Table 6.--Amounts of crook, bow, and twist in aspen door-part lumber

Warp	Grade sawn/160°F	Saw-Dry-Rip/160°F	Saw-Dry-Rip/200+°F
in.		% of pieces	
Crook			
0.0	65.0	75.8	81.5
.1	22.3	17.4	15.9
.2	8.7	5.8	2.0
>.2	4.0	1.0	.6
Bow			
0.0	34.7	42.8	46.3
.1	30.4	26.0	28.7
.2	18.0	18.4	13.4
>.2	16.9	12.8	11.6
Twist			
.0	82.1	76.4	84.2
.1	15.4	16.6	13.1
.2	2.0	5.0	2.3
>.2	.5	2.0	.4

Table 7.--Cottonwood S-D-R warp data, preliminary

Stud size	Number	Average 1/32 inch	High 1/32 inch	Rejects
In.				
		CROOK		
2 x 4	13	1.62	3	0
2 x 3	6	0.83	3	0
2 x 2	2	2.50	4	0
		BOW		
2 x 4	13	5.38	13	0
2 x 3	6	5.50	9	0
2 x 2	2	4.00	5	0
		TWIST		
2 x 4	13	0.62	2	0
2 x 3	6	0.83	3	0
2 x 2	2	0.00	0	0

Table 8.--2 by 4s produced and attaining Stud grade in cottonwood.

Treatment	Number of 2 by 4s Produced	Number of 2 by 4s Attaining Stud grade[1]	Percent attaining stud grade
Conventionally sawn			
Air dired	194	95	49.0
Kiln dried			
Conventional temperature	166	84	50.6
High temperature	168	94	56.0
Total	528	273	51.7
S-D-R live sawn			
Air dried	141	104	73.8
Kiln dried			
Conventional temperature	123	102	82.9
High temperature	142	104	73.2
Total	406	310	76.4

[1] Based on warp requirements for stud grade.

Abstract

Using Poplar Wood for Structural Lumber:

The SDR Process

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Poplars can become a significant wood resource in the United States if they are used to make structural lumber. Lumber is more valuable than the products now derived from poplar--energy wood, pulp or particle board furnish. However, the problem of warp must be solved before poplars become a regular structural lumber commodity.

The Forest Products Laboratory development, Saw-Dry-Rip (SDR), reduces warp in poplar lumber. Reasons for the warp reduction and results of laboratory and commercial tests are reported for aspen and cottonwood. Aspen yields over 90% in STUD-grade materials are shown. Significant improvements in cottonwood yields are also shown using SDR.