

SULFITE PULP FOR PAPREG: Laminates From Pulps Made From Short and Standard Length Black Spruce Chips

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SULFITE PULP FOR PAPREG:

LAMINATES FROM PULPS MADE FROM SHORT AND STANDARD LENGTH

BLACK SPRUCE CHIPS¹

By

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SUMMARY

Sulfite pulp from short (1/4-inch) black spruce chips was found to have essentially the same chlorine demand as like-prepared pulp from standard length (5/8-inch) chips. The pulp from the short chips, however, was conservatively estimated to have an average fiber length 20 percent shorter than that of the normal pulp, and test sheets and impregnating papers from it had 15 to 20 percent lower bursting and tensile strengths and 25 percent lower tearing strengths than sheets and papers from the pulp from the standard length chips. Papreg made from base paper composed of "short chip" pulp, on the other hand, had closely similar strength properties in tension and flexure to those of papreg from the normal pulp, but had compressive strengths 10 percent lower. Slight processing of both types of pulp caused a slight lowering of papreg strength properties.

INTRODUCTION

The effect on the properties of papreg of changes in sulfite fiber characteristics resulting from variations in species, pulping conditions, and particularly, extent of pulp delignification was discussed in previous reports.^{2, 3} Another fiber characteristic which affects paper properties and may affect papreg properties is fiber length. The general impression of the relation between fiber length and plastic strength seems to be that the longer the fiber the stronger the plastic. Prior to this study, however, there appears to be no definite information available on this relation.

¹This mimeograph is one of a series of progress reports prepared by the Forest Products Laboratory to further the Nation's war effort. Results here reported are preliminary and may be revised as additional data become available.

²Forest Products Laboratory Mimeograph 1393. Restricted.

³Forest Products Laboratory Mimeograph 1399. Restricted.

The average length of fibers in sulfite pulp from any one species can be varied by using chips of different lengths in the direction of the grain. In experiments with western hemlock heartwood,⁴ a considerable variation in average fiber length was achieved by varying chip length from 1/8 to 1-1/8 inches. Presuming the reduction in fiber length by the chipping process was shown by values for average length of cut plus uncut fibers, the average length of fibers in pulp from normal 5/8-inch chips was approximately 1.4 times that of fibers in pulp from 1/4-inch chips. Thus the average fiber length in the pulp from short chips was nearly 30 percent less than that in normal pulp. The pulp from short chips had a preponderance of fibers below 2 mm. in length, whereas the normal pulp showed an even distribution of fibers over the fiber length range up to 5 mm.

The relations between fiber length and sheet properties have also been investigated. Recently, Clark,⁵ using a fiber measurement procedure he had developed previously,⁶ found that the following relations apparently held:

$$\text{Bursting strength} = K_2 d L$$

$$\text{Tensile strength} = K_3 d L^{0.5}$$

$$\text{Tearing strength} = K_4 L^{1.5}/d$$

where d is the density of the test sheets, L is a weighted average fiber length determined by the method described,⁶ and K_2 , K_3 , and K_4 are constants when other factors are constant.

The purpose of this report is to present data showing the effect of fiber length on the properties of two similarly prepared sulfite pulps with different average fiber lengths, the effect on the properties of the impregnating paper and, particularly, the effect on laminated paper plastics made from the two types of pulp. The two average fiber lengths were obtained by using normal (5/8-inch) and short (1/4-inch) chips of black spruce. The digestion conditions used were developed previously² as suitable for producing pulp satisfactory for conversion to papreg.

EXPERIMENTAL PROCEDURES

The black spruce (*Picea mariana*) pulpwood (shipment P-1700) used for these experiments was cut in the Algoma District, Ontario, Canada. Its properties, normal for the species, are given in a previous report.² The logs were converted into chips 5/8 inch long in the fiber direction, that is, standard length, and into chips 1/4 inch long, called short chips. Two similar digestions of each length of chips were made in an alloy-lined rotary digester of 13 cubic feet capacity equipped with a steam jacket.

⁴McGovern, J. N. and Chidester, G. H. Paper Trade Journal 98(18): 41-46 (May 3, 1934).

⁵Clark, James d'A. Paper Trade Journal 116(1): 31-38 (Jan. 7, 1943).

⁶Clark, James d'A. Paper Trade Journal 115(26): 36-42 (Dec. 24, 1942).

The digestion conditions were as follows: The chip charge, equivalent to 112 pounds of moisture-free wood, was steamed 0.5 hour before charging with 65 gallons of sulfite cooking acid having a concentration of 6.0 percent total sulfur dioxide with 1.2 percent combined sulfur dioxide. The temperature was raised to 110° C. in 2 hours, held at this temperature for 2 hours more, raised to 130° C. in 2 hours additional, and finally held at this maximum temperature for 4 hours; the total digestion time was thus 10 hours. The pulp was discharged by blowing, at 50 pounds per square inch pressure. The maximum pressure employed during the digestion was 80 pounds per square inch.

The pulps were screened through 8-cut screen plates and their chemical and physical properties were determined on representative samples according to Forest Products Laboratory standard test methods. The combined pulps from each of the two sets of duplicate digestions were divided into two portions for running over the paper machine, one without further processing and one after receiving processing for 5 minutes in a beater of 50 pounds capacity with the roll on the bedplate. The paper machine was controlled to produce paper having a directional tensile strength ratio of more than two, a ream weight of nearly 30 pounds, and a caliper less than 3 mils.

The papers were impregnated with uncured phenolic resin, dried, parallel laminated, and molded under a pressure of 250 pounds per square inch at 325° F. The laminated paper plastics, after 48 hours conditioning, were tested for strength and stiffness in tension, flexure, and compression. Specific gravity and water absorption were determined⁷.

DISCUSSION OF RESULTS

Pulping Experiments

Although fiber measurements were not made in these experiments, the reduction in average fiber length resulting from using short spruce chips can be estimated from the data on western hemlock.⁴ Since the two species have approximately the same average length of fiber in the wood itself, a conservative value of 20 percent can be set for the reduction in fiber length when using 1/4-inch instead of 5/8-inch black spruce chips. The spruce pulp from the short chips, like the corresponding hemlock pulp, would also probably have a preponderance of fibers in lengths below 2 mm., whereas the standard pulp fibers would be normally distributed over the range of fiber length.

The rate of delignification of the short and standard length spruce chips under similar sulfite pulping conditions appeared to be nearly equal, since the chlorine demands and chemical characteristics of the pulps of the two types were the same within the limits of experimental error (table 1).

⁷Tests on the plastics were made according to Federal Specifications for Plastics, Organic: General Specifications (Methods of tests) L-P-406, Dec. 9, 1942.

Table 1.--Chemical composition of sulfite pulps from standard and short length black spruce chips.

Constituent	Pulp analysis	
	Standard chips	Short chips
Digestion number	(5005) 5006	(5020) 5021
Chlorine demand (percent)	7.5	7.1
Lignin (percent)	1.05	1.45
Total cellulose (percent)	93.1	94.2
Alpha cellulose (percent)	76.6	77.9
Total pentosans (percent)	6.0	6.0
1% NaOH solubility (percent)	8.7	8.9

The strength properties of test sheets made from pulp samples obtained at regular test beater intervals were plotted against corresponding sheet density values. Strength values were then taken from the curves at densities of 0.70, 0.75 and 0.90 grams per cc. to furnish the data given in table 2. Comparison of the strength properties of test sheets having the same density show the pulps from the short chips to be significantly weaker than the normal pulps. The losses amounted to approximately 15 percent in bursting strength, 20 percent in tensile strength and 25 percent in tearing strength in the density range of 0.70 to 0.75 grams per cc. in which the pulps would probably be used. At a density of 0.90 grams per cc. the losses were not quite so high for bursting and tearing strengths.

If a 20 percent reduction in average fiber length is assumed to result from shortening the chip length, theoretical ratios between the strength values for normal and short-fibered pulps can be estimated according to the relations obtained by Clark. These are given in table 2 also. The ratios calculated in this manner showed fairly good agreement with the experimental ratios for the property of tearing strength in the density range of 0.70 to 0.90 grams per cc. for bursting strengths in the density range of 0.70 to 0.75 grams per cc. and for tensile strength at a density of 0.90 grams per cc. The theoretical ratio was higher than the experimental ratio for bursting strength at a density of 0.90 grams per cc. and lower for tensile strengths in the density range of 0.70 to 0.75 grams per cc.

Paper Properties

All of the impregnating papers made from both types of spruce pulp, both unprocessed and slightly processed, were satisfactory in regard to density, thickness, ream weight, absorbency (porosity), and tensile strength, for conversion into high-strength laminated plastics (table 3). The slight processing treatment given both types of pulp resulted in very small increases in bursting and tensile strengths and no appreciable change in tearing strength. The differences between the strength properties of the two pulps were also evident in the papers. The impregnating papers from the short-fibered pulp were lower in bursting strength by approximately 20 percent, in tearing strength somewhat over 20 percent, and in tensile strength about 15 percent when compared with the papers from the normal pulp. The ratios of these strength properties in the normal pulp to those in the other pulp were in good agreement with the theoretical ratios estimated for a reduction in average fiber length of 20 percent.

Papreg Properties

Application of Forest Products Laboratory standard resin impregnating and drying procedures to the various papers resulted in impregnated papers with practically the same contents of resin and volatile matter (table 4). These contents were considered satisfactory for subsequent laminating into plastics. All the plastics produced as described had tensile strengths which exceeded the usual minimum requirements for papreg of 35,000 pounds per square inch for ultimate strength, and 3,000,000 pounds per square inch for modulus of elasticity.

Although both the pulp test sheets and papers made from the two types of pulp reflected differences attributable to the lengths and distribution of their fibers, the laminated plastics molded from the impregnated papers made from the short-fibered pulps had closely similar values for ultimate strength and stiffness in tension and flexure to those from the normal pulps (table 4). The laminates from the short-fibered pulps, however, were 10 percent lower in ultimate compressive strength and had a somewhat lower water absorbency than those from the normal. It appeared, from the limited number of experiments made that the strength properties of the laminated plastic were independent of a relatively large change in the length of the fibers in the base papers, except possibly for a small effect on compressive strength. The papreg containing slightly processed pulp had slightly lower strength properties than the corresponding papreg containing unprocessed pulp.

CONCLUSIONS

Sulfite pulp from short, 1/4-inch chips of black spruce had an estimated 20 percent lower average fiber length than a similarly prepared pulp from standard, 5/8-inch chips. Although this relatively large departure from normal fiber length had an adverse effect on pulp and impregnating paper strength properties, it caused only a slightly lowered compressive strength in the papreg from the short-fibered pulp. The tensile and flexural properties of the papreg from the two types of pulp were closely similar.

Table 2.--Properties of sulfite pulps from standard and short length black spruce chips.

Chips used Type Length	Beating time Minutes	Freeness S. R.	Sheet Density	Bursting strength			Tensile strength			Tearing strength						
				Test Sheet	Ratio of standard to short	Loss to short	Theoreti- cal ratio	Test Sheet	Ratio of standard to short	Loss to short	Theoreti- cal ratio	Test Sheet	Ratio of standard to short	Loss to short	Theoreti- cal ratio	
Inches	Minutes	SS.	Grams per cc.	% pulp per cc.	% pulp per cc.	% pulp per cc.	% pulp per cc.	% pulp per cc.	% pulp per cc.	% pulp per cc.	% pulp per cc.	% pulp per cc.	% pulp per cc.			
Standard	5/8	11	805	0.70	1.03	1.20	16.7	1.25	8,100	1.30	23.0	1.12	1.27	1.32	24.2	1.40
Short	1/4	9	870	.70	.86				6,200				.96			
Standard	5/8	18	755	.75	1.12	1.18	15.2	1.25	9,100	1.23	18.7	1.12	1.15	1.39	28.0	1.40
Short	1/4	19	780	.75	.95				7,400				.83			
Standard	5/8	38	510	.90	1.18	1.08	7.6	1.25	11,650	1.09	8.2	1.12	.85	1.31	23.7	1.40
Short	1/4	35	610	.90	1.09				10,700				.65			

Based on reduction in fiber length of 20 percent and equations given in text.

Table 3.--Properties of sulfite papers from pulps of standard and short length black spruce chips.

Chips used Type Length	Process- ing time Minutes	Density	Caliper Mils	Forosity (Gurley Denom- eter)	Paper Points per lb.	Bursting strength			Tensile strength			Tearing strength				
						Ratio of standard to short	Loss to short	Theoreti- cal ratio	Ratio of standard to short	Loss to short	Theoreti- cal ratio	Ratio of standard to short	Loss to short	Theoreti- cal ratio		
Inches	Minutes	Grams per sq. in.	Mils	Seconds per 100 cc.	Points per lb.	Ratio of standard to short	Loss to short	Theoreti- cal ratio	Ratio of standard to short	Loss to short	Theoreti- cal ratio	Ratio of standard to short	Loss to short	Theoreti- cal ratio		
Stand- ard	5/8	0.70	2.36	12	70.92	1.26	20.6	1.25	9,290	1.18	15.2	1.12	0.91	1.26	20.6	1.40
Short	1/4	.72	2.40	13	.73				7,880				.72			
Stand- ard	5/8	.72	2.41	16	.97	1.24	19.3	1.25	9,715	1.16	13.6	1.12	.89	1.30	23.1	1.40
Short	1/4	.72	2.21	15	.78				8,335				.68			

Based on reduction in fiber length of 20 percent and equations given in text.

Table 4.--Properties of parallel laminated paper made of sulfite pulp of standard and short length black spruce chips.

Minutes	Percent	Pulp : Resin : content	Volat- : tile : content	Ultimate : Modulus : of	Ultimate : Modulus : of	Ultimate : Modulus : of	Static bending : Modulus : of	Specific : gravity	Water : absorption
				strength : elasticity : tension	strength : elasticity : tension	strength : elasticity : tension	strength : elasticity : tension		
				Lb. per 1000 lb. sq. in. per sq. in.	Lb. per 1000 lb. sq. in. per sq. in.	Lb. per 1000 lb. sq. in. per sq. in.	Lb. per 1000 lb. sq. in. per sq. in.		
Stand-ard	35.4 36.0	4.7 4.9	38060 37870	3,347 3,244	23,750 23,150	---	36,100 33,890	1.41 1.40	5.8 5.4
Short	35.1 36.9	4.5 4.5	37540 37450	3,335 3,263	20,775 21,270	3,114 2,920	38,910 35,770	1.42 1.40	4.8 3.8

1-Tested in the grain (fiber) direction.