

Wood utilization potential of beetle-killed lodgepole pine for solid wood products

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Abstract

Several areas in the Rocky Mountains are experiencing bark beetle attacks in lodgepole pine stands. Removing dead and dying material and thinning to advised prescribed stocking levels is necessary to reduce wild fire hazards and restore vigor to the stands. The silvicultural practices required to cope with this problem call for developing appropriate markets for this resulting material. In this study the technical suitability of this material for traditional and potential products was evaluated. As a basis for comparing the dead and small thinning material with that cut from living sawtimber, various physical tests were conducted on selected 2 by 4's. The test results were then combined into property groupings that were considered to represent the most important qualities for a given product. In all, 13 products were considered. All values for dead trees and small thinnings were expressed as a percentage of the accepted value for live lodgepole pine sawtimber. The summary of properties produced a comparative index value for each material class for the various products considered.

Lodgepole pine (*Pinus contorta* Dougl.) stands in the Colorado and Wyoming region, as in other parts of the West, are experiencing losses of epidemic proportions due to the mountain pine beetle (*Dendroctonus ponderosae* Hopk.). Lodgepole pine constitutes more than 1.1 million acres of commercial forest land in Colorado and more than 1.2 million acres in Wyoming. In recent years estimates are that more than 0.2 million acres of lodgepole pine have become heavily infested with the mountain pine beetle in Colorado and Wyoming (1, 2, 10).

Silvicultural prescriptions to control these insect attacks include the removal of dead, infested, and susceptible trees, and associated green material that requires thinning. Overmature and overstocked stands are thought to be more susceptible to insect attacks. Therefore, thinning the stands should make the re-

maintaining trees more vigorous and resistant to insect infestations in the future.

These silvicultural practices result in large volumes of wood raw materials requiring removal from the forest. To make such silvicultural practices acceptable and economically feasible, outlets must be found to utilize this material. Every wood end use entails a unique group of raw material requirements essential, or at least desirable, for successful processing and product performance. Research was undertaken to determine the suitability of the various classes of raw materials resulting from the beetle treatments for conversion to products.

Background

The mountain pine beetle attacks the phloem layer of the tree. The adult beetle uses the phloem as a food source and also constructs an egg gallery. The beetle larvae feed at right angles to the egg gallery and girdle the tree causing its death (10). The beetle attacks trees in the least vigorous stands, attacking the largest diameter trees or the down trees first.

Following the insect attack, the trees are infected by a fungal stain. This fungal stain clogs the xylem contributing to the trees' death. A dark blue stain results either from the fungus hyphae or by the diffusible pigments produced (8). The stain is limited to the sapwood of the tree. The hyphae of the blue-stain fungus grow primarily in the rays. The hyphae movement between cells

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Forest Prod. J. 33(9):64-68.

is essentially through the pit structures. Blue-stain fungi derive their nourishment mainly from the soluble and semisoluble materials contained within the wood cells (11). The result is mainly discoloration which is a direct degrade for boards. The value of dimension lumber can also be affected due to buyer's preference for bright, light colored lumber.

The degradation of the ray parenchyma cell walls and the openings in the pitting microstructure made by the penetrating fungus make blue-stained wood more permeable than "bright" wood. This makes the blue-stained wood more vulnerable to decay (12). Although this increased susceptibility to decay is not critical in typical lodgepole pine climates, the beetle infested trees should be removed at the earliest possible time to reduce stand density thereby increasing the stand vigor.

Procedure

The lodgepole pine lumber used in this study was obtained from Star Studs, Inc. in Afton, Wyoming. Four classes of material were sampled: beetle-killed material from trees with tight bark, beetle-killed material from trees with loose bark, material collected from small live thinnings (5 in. to 7 in. DBH), and a sawtimber "control." Each class sample consisted of 250 2 by 4's. The thinning material was selectively sampled from a nearby stand and brought to the sawmill for manufacturing. The selection was based solely on size (5 in. to

7 in. DBH) and the obvious absence of beetle attacks. The other three classes of material were obtained by randomly marking logs from their respective material class after the logs had been debarked. All material classified as studs from a "sampled" log was collected. The principal criterion for classifying the beetle-killed logs was the excessive weathering of the bole hastened by the loosened bark in standing timber. The loosening of the bark was characteristic of a tree that had been dead longer than a tree with tight bark though the actual time-since-death is hard to accurately predict. This collection procedure was based on the assumption that any differences found in laboratory tests between live and dead wood from the same site would be applicable to other sites. All test pieces were sawed into 8-foot studs and transported to Fort Collins for drying and further testing.

The next phase of the study consisted of evaluating the suitability of the various classes of raw material for conversion into various products. The products considered were as follows: yard lumber, structural lumber, mine timbers, railroad ties, and house logs; utility poles, construction poles, corral poles, fence posts, and fencing; paneling (siding), pallets, and laminated beams and joists.

The technique used to evaluate the suitability of each class of material for a particular wood end use was

TABLE 1. — Weighting factors^a for the key evaluators^b for 13 selected products.^c

Key evaluator	Yard ^d lumber	Structural lumber	Mine timbers	Railroad ties	House logs	Utility poles	Construction poles	Corral poles	Fence posts	Fencing	Paneling (siding)	Pallets	Laminated beams and joists
Appearance	3	—	—	—	2	2	—	2	—	2	3	—	—
Bending strength (MOR) full size	—	3	3	3	—	3	3	3	3	2	—	3	—
Bending strength (MOR) small clear	1	—	—	—	—	—	—	—	—	—	—	—	3
Ease of seasoning	1	1	2	2	—	2	3	—	—	—	—	—	—
Freedom from checks	3	3	—	—	3	3	3	3	3	3	3	2	2
Freedom from warp	3	3	—	—	—	—	—	—	—	3	3	2	2
Glueability	—	—	—	—	—	—	—	—	—	—	—	—	3
Nail holding	2	2	2	2	—	—	—	2	2	—	—	3	—
Shrinkage	1	1	—	—	2	—	—	—	—	2	2	—	—
Specific gravity	—	—	2	2	—	—	—	—	—	—	—	3	—
Stiffness (MOE) full size	—	3	3	1	—	2	3	—	—	—	—	2	—
Stiffness (MOE) small clear	—	—	—	—	—	—	—	—	—	—	—	—	—
Toughness	—	—	—	2	—	—	—	—	—	—	—	2	—
Treatability	—	—	3	3	—	3	3	—	3	—	—	—	—
Uniformity	1	1	1	1	1	1	1	1	1	1	1	1	1

^aWeighting index was established by the combined judgment of the investigators.

^bKey evaluators were derived from wood properties best representing the product profile.

^cWeighting factors were 1, 2, or 3; with 1 being least important and 3 the most important. Where no weighting factor was assigned, the wood property was not used for evaluating the product.

^dYard lumber = lumber of all sizes and patterns that is intended for general building purposes having no design property requirements (15).

an adaptation of the "species profile" comparison first used by Wangaard (16) for evaluating the use potential of tropical woods. In the current study, lumber made from live lodgepole sawtimber was used as a standard for comparison. The "modified product profile" technique consisted of determining the key evaluators and their important weighting factors for each product. The key evaluators were derived from the test materials' wood properties. When needed, the reciprocal of a wood property was used as a key evaluator so that increasing values corresponded to a more desirable condition. A weighted index value was determined for each evaluator and compared to an index value of 100 for the live lodgepole pine for each product. The key evaluators and weighting factors for the products were based on the combined judgment of the investigators concerning the importance of the property in product conversion and use. An example of the rationale used to determine the key evaluators and assign the weighting factors is given in the assignment of a weighting factor of 3 for the freedom from checks evaluator for fence posts and corral poles. It was the investigators' combined opinion that the presence of checks in these types of products would allow a greater occurrence of water entry and retention thereby increasing the rate of degradation. Tables 1 and 2 show the key evaluators, their weighting factors, and

a brief description of the test used to evaluate their suitability for each product use.

Results

Table 3 displays the results of the property tests. The high coefficient of variation (c.v.) for freedom from checks and freedom from warp confounds any differences in these properties between the material classes. This high c.v. was due to the majority of the defects occurring in a few poor quality pieces of material. Table 4 summarizes the key evaluators using the live lodgepole pine sawtimber class as the standard for comparison. Table 5 illustrates how the product profile was determined for "structural lumber." In this table the material classes compared were live lodgepole pine sawtimber and dead lodgepole pine with tight bark. Table 6 tabulates the average index values from the product profiles. The four material classes are ranked for use in the 13 selected products. The ranking is based on the subjective weighting factors as described above and does not represent a finite comparison of measured values. While the specified end use of the product and the related procurement cost are important factors in determining which is the best class of material for a given application, they were not assessed in this suitability analysis.

TABLE 2. — Definitions and source of key evaluators.

Key evaluator	Definitions
Appearance	The lumber was first visually graded by a WWA certified grader as light framing material. The sum of the dollar value of each grade of lumber times the number of pieces of that grade in each material class was used as the evaluator for appearance.
MOE and MOR	From full-size specimens. The static bending test procedure was from ASTM D 198.
MOE and MOR	From small clear specimens. The static bending test procedure was from ASTM D 143 (245-252). The load was applied to the radial surface.
Ease of seasoning	The time in hours it takes 2 by 4 material to reach a 12% moisture content (using a standard kiln schedule). The evaluator was based on a percentage of the value for live lodgepole.
Freedom from checks	The reciprocal of the total area of the checks opening in square inches was used as the value for the freedom from checks evaluator.
Freedom from warp	The total warp in 16th of an inch was determined for each specimen and then an average value was determined for each class of material. The reciprocal of this value times 1000 gave the freedom from warp value.
Gluability	This test procedure consisted of gluing samples together with a urea-formaldehyde adhesive and then cutting out shear block specimens. The shear value was used for the gluability evaluator.
Nail holding	The specimen size was 1-1/2 in. by 2-1/2 in. by 6 in. Two 7-d cement coated sinker nails, with coating removed, were withdrawn from a face surface and two nails were withdrawn from an edge surface. The actual test procedure was done according to ASTM D 143 (108-113). The average load in kg required to withdraw the nails was used as the evaluator for nail holding.
Specific gravity and volumetric shrinkage	This test was determined from small sample blocks that were soaked to above the fiber saturation point and then oven-dried. The green volume, oven-dried volume, and oven-dried weight were recorded. Specific gravity was based on oven-dry weight and green volume. Volumetric shrinkage was based on $100 \times (\text{Green Vol.} - \text{Dry Vol.}) / \text{Dry Vol.}$. The shrinkage evaluator was equal to the reciprocal of the % volumetric shrinkage times 1000.
Toughness	The test procedure was based on ASTM D 143 (71-76). An Amsler-type apparatus was used. All specimens were impacted on the radial surface.
Treatability	This test procedure consisted of first determining the percent sapwood of each specimen and then placing the specimens in a cold oil soak. The amount of oil absorbed in 36 hours, after statistically correcting for the percent sapwood, was used as the evaluator for treatability.
Uniformity	This evaluator was determined by summing the coefficient of variation for all the tests. The reciprocal of the average coefficient of variation times 100 was used as the evaluator for uniformity.

$$\frac{100}{\frac{\sum c.v.}{n}}$$

*Based on market prices at the time of the study.

Property	Material class							
	Live lodgepole		Dead lodgepole (tight bark)		Dead lodgepole (loose bark)		Lodgepole thinnings	
	Mean ^a	C.V.% ^b	Mean	C.V.%	Mean	C.V.%	Mean	C.V.%
Durability	.115 (20) ^c	—	.115 (20)	—	.132 (20)	—	.119 (20)	—
Specific gravity	.387 (14)	5	.379 (29)	7	.383 (30)	8	.405 (31)	9
Stiffness (MOE) full size	1.277 (15)	2	1.133 (28)	2	1.179 (24)	2	1.484 (27)	2
Stiffness (MOE) small clear	1.474 (14)	16	1.627 (16)	19	1.360 (18)	12	2.023 (20)	16
Uniformity	5.55	—	4.78	—	4.29	—	5.31	—
Freedom from warp	9.4 (37)	40	8.2 (69)	34	9.0 (60)	34	8.6 (70)	34
Freedom from checks	73.2 (37)	61	56.8 (69)	87	37.1 (60)	130	88.9 (70)	35
Ease of seasoning	81	—	52	—	42	—	75	—
Nail holding	62.2 (21)	6	60.5 (20)	6	59.1 (20)	6	81.5 (20)	4
Toughness	102.1 (15)	20	84.2 (20)	22	97.9 (17)	25	125.7 (20)	26
Shrinkage	111.86 (14)	14	106.50 (29)	16	104.82 (30)	13	100.81 (31)	13
Appearance	196.5 (15)	19	180.5 (28)	26	181.8 (24)	15	140.0 (27)	55
Glueability	1204 (20)	13	1188 (20)	16	1237 (20)	15	1294 (20)	14
Bending strength (MOR) full size	4478 (15)	7	3540 (28)	6	2975 (24)	8	7310 (27)	4
Bending strength small clear	10889 (14)	13	10961 (16)	10	10750 (18)	12	12482 (20)	14

^aMean values and analysis of variance were obtained from log normal distribution.

^bC.V.% — coefficient of variation = standard deviation / mean.

^cThe numbers in parentheses indicate the sample size for the given property and material class.

Conclusion

The primary purpose of this project was to explore and evaluate the technical suitability for various products of timber removed during a salvage or cleanup operation following a beetle infestation. The material studied was beetle-killed material and thinnings which improve stand vigor if removed. The economic feasibility of salvage operations or of marketing this material was not included in the evaluation procedure.

The evaluation revealed that beetle-killed material maintained much of its physical integrity, with minimal observed indication of fiber degradation. Most of the loss of value of this material resulted from drying defects that occurred when the trees dried on the stump. The thinning material showed higher than normal values in most properties evaluated. This was probably due to the fact that the thinning material had a higher specific gravity. However, it did show a higher incidence of warp and wane.

From the product profiles it can be seen that the product suitability of the dead tree material decreased the longer it was dead. Beetle-killed lodgepole pine that

had tight bark showed very little change in index values as compared to the live pine. Lodgepole pine that had been dead longer (loose bark) on the other hand was less suitable for many of the products. The thinning material had as good or superior index rating when compared with the expected values for live lodgepole pine sawtimber.

Since this study was intended to evaluate the product suitability of lumber from dead trees, some of the beetle-killed logs were culled due to the presence of rot and defects. Much of the strength-reducing decay that would be present in a log was removed as slabs and edgings in the manufacturing process of making a cant. No attempt was made to measure volume and value losses due to using beetle-killed material. Other researchers (6, 7, 9, 13, 14) specifically reported on this aspect. Further, the study did not examine the potential difficulties in processing small thinning material into usable 2 by 4 studs, or the economic effect of utilizing dead timber as compared to live timber. It must be further emphasized that this was a limited study on a limited sample. The specific results are therefore not

TABLE 4. — Summary of the adjusted key evaluators for product profile.*

Property	Material class			
	Live lodgepole	Dead lodgepole (tight bark)	Dead lodgepole (loose bark)	Lodgepole thinnings
Appearance	100	91.9	92.5	71.2
Bending strength (MOR) full size	100	79.1	66.4	163.3
Bending strength small clear	100	100.7	98.7	114.6
Ease of seasoning	100	135.8	148.1	107.4
Freedom from checks	100	77.6	50.7	121.4
Freedom from warp	100	87.2	95.7	91.5
Gluability	100	98.7	102.7	107.5
Nail holding	100	97.3	95.0	131.0
Shrinkage	100	95.2	93.7	90.1
Specific gravity	100	97.9	99.0	104.7
Stiffness (MOE) full size	100	88.7	92.3	116.2
Stiffness (MOE) small clear	100	110.4	92.3	137.2
Toughness	100	82.0	95.9	123.1
Treatability	100	134.8	114.8	103.5
Uniformity	100	86.1	77.3	95.8

*Adjusted key evaluator = $\frac{\text{key evaluator of one material class}}{\text{same evaluator of live lodgepole}} \times 100$.

representative of all beetle-killed lodgepole pine or even of the lodgepole pine in Colorado and Wyoming. This study measured the difference in performance characteristics between beetle-killed and live lodgepole pine sawtimber from the same location with the assumption that the same magnitudes of these differences would occur at other locations.

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TABLE 5. — Example of a product profile for structural lumber.

Property	Weighting factor	Live lodgepole	Dead lodgepole (tight bark)	
			Evaluator	Weighted index value***
Bending strength (MOR) full size	3	100	79.1	237.3
Ease of seasoning	1	100	135.8	135.8
Freedom from checks	3	100	77.6	232.8
Freedom from warp	3	100	87.2	261.6
Nail holding	2	100	97.3	194.6
Shrinkage	1	100	95.2	95.2
Uniformity	1	100	86.1	86.1
Stiffness (MOE) full size	3	100	88.7	266.1
Index value total	17	1700		1509.5
Average index values		100		88.8

***Weighted index value = adjusted evaluator × weighting factor.

TABLE 6. — Summary of average index values for 13 products by material class.

Product	Material class			
	Live lodgepole	Dead lodgepole (tight bark)	Dead lodgepole (loose bark)	Lodgepole thinnings
Yard lumber	100	91.0	88.3	101.5
Structural lumber	100	88.8	83.8	119.6
Mine timbers	100	103.5	98.9	120.7*
Railroad ties	100	102.7	99.4	121.6*
House logs	100	86.6	75.2	97.8
Utility poles	100	99.6	90.0	115.6*
Construction poles	100	102.2	93.4	120.7
Corral poles	100	85.0	73.1	123.1
Fence posts	100	96.3	80.3	126.9
Fencing	100	85.6	78.6	106.4
Paneling (siding)	100	87.6	82.0	100.8
Pallets	100	87.8	84.9	122.1
Laminated beams and joists	100	96.1	89.4	114.2

*Lodgepole thinnings could not be used in these products since they were obviously too small.

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