Bulk densities of materials from selected pine-site hardwoods

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Abstract

Bulk densities of hardwood materials from low and high density species were determined for green and air-dry conditions. Materials consisted of whole-tree chips, bark-free chips, bark as collected from three types of debarkers (ring, rosser head, and drum debarkers) sawdust, planer shavings, flakes, logging residues, baled branchwood, steel-strapped firewood, and technical foliage (leaves with attached stems up to 1/4-in. diameter). Significant increases in bulk densities were achieved with vibration or by compacting the materials with pressure up to 100 psi. Planer shavings increased in bulk density at each level of pressure up to 100 psi but maximum bulk density of other materials was achieved at 50 psi. As expected, applied pressure increased the bulk density of planer shavings the most (137% to 172%) and branchwood the least (10% to 20%). Bulk density of sawdust and flakes increased by 55 to 88 percent and chip bulk density increased 18 to 21 percent. Vibration increased sawdust bulk density 12 to 34 percent, flake bulk density 24 to 39 percent, and technical foliage bulk density 46.7 to 150 percent.

Our growing dependence on wood has increased to the extent that now even the previously unmerchantable pine-site hardwoods are becoming important. Competition for raw material to produce wood products and the increasing cost of energy are primary reasons for changes presently taking place in the wood products industry. Increased utilization of small diameter pine-site hardwoods has highlighted the need for more information regarding engineering considerations for transportation, handling, and storage.

One of the important properties for consideration in this regard is the bulk density (weight of raw material per unit volume). The shape and size of the raw material, method of packaging and handling, type of transportation, moisture content (MC) of material, and type (species) of raw material affect the final bulk density. Energy costs have risen to the point where it is now profitable for many wood-using industries to use wood as a fuel and reduce dependence on oil and natural gas. With increased use of wood as a fuel, it is of particular importance to know the MC of the raw material. Not only do the materials weigh more when green than when dried (thus reducing the payload of usable material) but the heating value is also reduced with increases in MC.

Many processes can utilize mixed species in their product while others must segregate by species. Few processes operate without some type of storage area to act as a buffer against a reduction or loss of raw material procurement. Thus, it is important to know the bulk density of the raw material to determine the storage capacity required for the necessary reserve supply. Knowledge of changes in bulk density as a result of vibration during transport and information about mechanical compaction are important factors if raw material is purchased by volume.

The objectives of this study were to determine bulk densities of selected pine-site hardwood materials and to study the effects of species density, MC, and degree of compaction on the bulk density. Sweetgum (*Liquidambar styraciflua* L.) was used to represent a low density species. High density species were southern red oak (*Quercus falcata* Michx.), white oak (*Quercus alba* L.), and true hickory (*Carya spp.*). Raw material was collected in the form of whole-tree chips, bark-free chips, bark, sawdust, planer shavings, flakes, logging residues, baled branchwood, steel-strapped firewood, and small stems and leaves (technical foliage).

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Materials and methods

Whole-tree chips were collected at a fully mechanized pulp chip operation. The mobile chipper was equipped with a 75-inch 3-knife disk and built-in trash separator. Bark-free chips were produced at a local hardwood mill from debarked green, sweetgum, and oak logs. The chips were not screened to remove fines and oversized pieces. Samples of the chips were size classified by the (Wennberg) slotted screen process (shaker having 12-cm in-plane circular amplitude, 165 cycles per minute).

Bark from drum debarkers, ring debarkers, rosser debarkers, and post peelers was obtained from local mills.

Oak sawdust was generated at Louisiana Tech University's sawmill using a 50-inch diameter inserted-tooth headsaw. The sweetgum sawdust was collected from a pneumatic conveyor that contained all sawdust from circle saws and bandsaws in a local hardwood sawmill.

Green planer shavings were obtained from a local hardwood sawmill producing green planed lumber for pallet manufacture. Planer shavings from kiln-dried lumber were obtained from a hardwood mill producing dimension lumber. Flakes from green wood were produced on a shaping-lathe headrig at the U. S. Forest Service, Southern Forest Experiment Station Laboratory, Pineville, La.

Logging residues were produced by cutting green limbs and tree tops into pieces approximately 6 inches long. Branchwood was obtained by cutting branches and treetops from sweetgum and oak trees into lengths of 24 inches. Maximum diameter of the stems was 4 inches for both logging residues and branchwood.

Oak and sweetgum trees were cut into firewood lengths of 24 inches to produce the steel-strapped firewood. Logs over 7 inches in diameter were split into quarters. Logs less than 7 inches in diameter were not split and were considered to be small roundwood.

Green leaves with attached stems up to 1/4-inch in diameter were cut with pruning shears during midsummer from limbs of sweetgum and oak trees. These were called technical foliage. Material for the hogged and screened condition was obtained by shredding the green foliage in a lawn and garden-type shredder, then sifting the material through a 1/2-inch mesh screen.

Bulk density determinations

Pneumatic tests. — Bulk densities of materials resulting from pneumatic conveyance to simulate blown-into-van conditions were determined from the net weight of material blown into a 2.79 cubic foot PVC (polyvinyl chloride) pipe 8 inches inside diameter by 8 feet high. The blower used for these tests was a straight blade centrifugal fan with a 4-inch diameter inlet, 4-inch square outlet, and was powered by a 1.5 horsepower electric motor. Discharge air velocity was 8,452 feet per minute which, according to Oswald,[1] is in the range normally used in pneumatic conveying of wood chips. Material was hand-fed into the inlet of the blower. These tests were performed on whole-tree chips, bark-free chips, sawdust, planer shavings, and flakes.

Vibration tests. — Determinations of the settlement due to vibration was made by mounting the PVC pipe containing the test materials onto the deck of a big-wheel-type lawnmower and running the unit in place until settlement had fully occurred. Bulk density was determined from weight of the test material and the final volume. These tests were performed on whole-tree chips, bark-free chips, sawdust, planer shavings, and flakes.

Compaction tests. — Compaction tests at pressures up to 100 psi were performed on whole-tree chips, bark-free chips, sawdust, planer shavings, and flakes using an upright steel cylinder 10 inches in diameter by 9 inches high equipped with a loosely fitted piston. A 17.5-ton hydraulic shop press was used to force the piston on the test material to develop the compaction pressure. Bulk density was determined from the weight and compacted volume of the test material in the compaction cylinder.

Baled branchwood tests. — Branchwood was placed on a platen, supported on the bedplate of the hydraulic shop press, and stacked about 20 inches high. An upper platen was placed on top on the branchwood and load was applied to the upper platen to produce baling pressures of 2, 8, 17, 25, and 73 psi.

Steel-strapped firewood tests. — Split and solid firewood was stacked into a sized bin 39.5 inches wide by 44.5 inches high. When fully loaded with 24-inch-long logs, the bulk volume of each load was 23.52 cubic feet. The firewood was then encircled with two chains secured with binders to simulate the steel strapping process. These sized loads were then weighed to determine bulk density.

Loose density tests. — Bulk density of loosely loaded bark-free chips, bark, sawdust, planer shavings, flakes, and logging residues were determined from 30.68 cubic foot loads contained in a reinforced plywood bin of inside dimensions 23.5 inches square by 8 feet high.

Transport settlement tests. — Green flakes and logging residues loosely loaded in the plywood container were transported in the bed of a one-half-ton pickup truck until settlement had fully occurred. Bulk densities were determined from the net weight and final volume of the test materials.

Three replications were used for pneumatic conveyance tests and vibration tests and five replications were used for the compaction tests.

MCs were reported for each bulk density and were based on an average of three 100-gram samples dried in an oven at 110°C for 24 hours. The samples were taken immediately after performing the bulk density tests.

Results and discussion

Bulk densities of low and high density hardwood materials for green and air-dry conditions are given in Tables 1 and 2. Except for compaction, firewood, and baled branchwood tests, all bulk density values are based on an 8-foot load height. All density values are qualified by average MC values (given in brackets).

[1]Oswald, D. 1979. Chip transportation — outside the pulp mill. Pulp and paper technology series #5, Chip quality monograph. TAPPI, Atlanta, Ga.

TABLE 1. — *Bulk densities and moisture contents of green and air-dry materials from low and high density hardwood species at various degrees of compaction.*

Product and degree of packing	Bulk density [moisture content] Low density sweetgum Green	Air-dry	High density oak, hickory Green	Air-dry
	——pcf [%]——			
Whole-tree chips				
Blown into pipe	29.6 [96][a]			
Vibration settled	26.2			
Compacted at pressures of:				
0.0 psi	22.9		23.3	
12.5	27.1		27.7	
25.0	28.8		29.0	
50.0	30.8		30.7	
75.0	30.8		31.2	
100.0	30.8		31.2	
Bark-free chips				
Blown into pipe	28.5 [107]		29.1 [74]	
Vibration settled	24.4		24.5	
Compacted at pressures of:				
0.0 psi	21.8		22.6	
12.5	25.8		26.1	
25.0	27.1		27.6	
50.0	28.8		29.6	
75.0	28.8		29.6	
100.0	28.8		29.6	
Sawdust[b]				
Loose	18.9 [108]	10.8 [11]	19.7 [84]	16.2 [44]
Blown into pipe	23.8	12.7	21.1 [75]	17.4
Vibration settled	21.2	14.5	22.0 [84]	20.2
Compacted at pressures of:				
0.0 psi	18.5	10.7 [11]	19.8 [84]	15.9 [44]
12.5	28.2	15.1	30.2	20.5
25.0	29.3	15.8	32.2	21.9
50.0	29.3	15.9	32.6	22.4
75.0	29.3	15.9	32.6	22.4
100.0	29.3	15.9	32.6	22.4
Planer shavings				
Loose	12.6 [93]			
Blown into pipe	17.0			
Vibration settled	15.6			
Compacted at pressures of:				
0.0 psi	1.3 [30]	4.6 [11]	1.4 [	6.3 [12]
12.5	5.7	8.4	5.8	12.7
25.0	6.4	9.4	6.5	13.5
50.0	7.0	11.2	7.2	14.4
75.0	8.1	12.6	7.5	15.4
100.0	8.6	13.3	8.0	16.6
Flakes 0.02 in. by 3 in. long				
Loose	14.3 [119]		7.7 [7	
Blown into pipe	6.2		5.3	
Settled in transport	18.4		10.5	
Vibration settled	10.8		7.7	2.8
Compacted at pressures of:				
0.0 psi	15.3		10.9	4.6
12.5	21.9		14.5	6.0
25.0	22.4		14.5	6.0
50.0	22.4		14.5	6.0
75.0	22.4		14.5	6.0
100.0	22.4		14.5	6.0
Branchwood				
Baled at pressures of:				
0.0 psi	35.6 [66]	21.9 [22]	41.9 [67]	33.9 [18]
2.0	37.4	22.5	43.2	34.9
8.0	37.9	23.2	44.6	35.5
17.0	39.2	23.9	46.0	36.7
25.0	39.2	24.0	49.4	37.4
73.0	39.2	24.1	49.4	37.6
0.0(load removed)	37.3	23.1	44.0	35.9

[a]Moisture content [%] values shown in brackets.
[b]Sawdust for low density tests from a bandsaw and trim saws and high density tests from a circular saw.
[c]Planer shavings from kiln-dried lumber.

TABLE 2. — *Bulk densities and moisture contents of green and air-dry materials from low and high density hardwood species in various forms.*

	Bulk density [moisture content] Green	Air-dry	High density oak, hickory Green	Air-dry
	——pcf [%]——			
Bark loaded loosely in plywood bin				
Drum debarker	24.3 [87]		20.4 [48]	16.2
Ring debarker	20.5 [62]		30.2 [56]	18.6
Rosser debarker	20.3 [50]		19.3 [55]	18.2
Post peeler	24.0 [80]		24.8 [49]	19.2
Hogged through 1/2-in. screen	16.2 [78]		14.2 [49]	9.3
Vibration settled	17.9 [78]		16.7 [49]	11.1
Logging residues				
Loose	33.3 [136]	19.5 [27]	36.7 [50]	24.0 [18]
Vibration settled		No measurable change		
Steel-strapped firewood				
Small roundwood (4 to 7-in. dia.	50.0 [117]	31.4 [38]	56.7 [67]	45.9 [26]
Split wood (7-in. dia. min.)	46.6 [104]	28.2 [23]	58.4 [70]	45.7 [23]
Technical foliage				
Loose		0.2 [25]	1.5 [144]	0.3 [16]
Vibration settled		0.5	2.2	0.6 [16]
Hogged through 1/2-in. screen		4.6	10.3	4.3 [46]
Vibration settled		5.9	12.0	6.2 [46]

TABLE 3. — *Whole-tree and bark-free chip classification by the (Wennberg) slotted screen process.*[a]

Material	Percent retained by opening of size: 45 mm round	8 mm slotted	7 mm round	3 mm round	Percent fines
Whole-tree oak					
Whole-tree sweetgum					
Bark-free oak					
Bark-free sweetgum			--		

[a]Measurements based on shaker operating with an amplitude of 12-cm in-plane motion at 165 cycles per minute.

For whole-tree chips and bark-free chips, bulk density values are given only for the green condition. Chip samples were analyzed for size distribution by the (Wennberg) slotted screen process at a local pulpmill (Table 3).

Bulk density values for green planer shavings, partially air-dried (Table 1), were found to be lower than expected. The shavings curled as drying occurred resulting in the low values reported in the compaction tests.

Bulk density was greatly affected by the form of the product, method of packaging, state of dryness, and species. The highest value reported was 58.5 pounds per cubic foot (pcf) for split green oak firewood at 70 percent MC. Shredding was found to appreciably increase bulk density of technical foliage but had the opposite effect on bark. Compaction had the effect of increasing bulk density in all tests with the largest increase (88%) being from 7.7 to 14.5 pcf for green oak flakes. With the exception of flakes, technical foliage, and certain bark treatments, the bulk density of air-dry oak products was higher than that of the same sweetgum product with the largest difference being 17.5 pcf for split firewood.

In this study, bulk density was reported for green and air-dry conditions only. To estimate bulk density at intermediate MC values, the method of linear interpolation applied to the data in Tables 1 and 2 would seem applicable. Such estimates may be somewhat inaccurate, however. Wilhelmsen, Preikschat, and Stergion[2] noted that although in most pulpmill applications the bulk density of wood chips from a given source is largely assumed to be a function of average MC, there are other variables involved. They are: 1) specific gravity (SG) of the solid wood which can vary even among individual trees, 2) size distribution of the individual wood chip particles which is influenced by MC, 3) compaction of wood under its own weight, and 4) change in wood volume as a function of MC. Although these bulk density factors are in reference to wood chips, SG and volume changes should apply to solid wood as well. Also, thin products such as flakes and planer shavings tend to curl on drying.

From observations in this study, bulk density of shavings produced from partially dried wood at a given MC will probably be higher than if the shavings were made from green wood and allowed to dry to the same MC. These factors affecting bulk density indicate that an estimate of bulk density at some MC value between green and air-dry could be in error if determined by linear interpolation from the data given in Tables 1 and 2.

[2]Wilhelmsen, L. A., E. Preikschat, and D. L. Stergion. 1976. Automatic wood chip moisture-bulk density meter. TAPPI 59(8):56-59.

'Process control' proceedings are now available

Proceedings of the "Process Control in the Forest Products Industry" symposium are now available and will be of benefit to managers of production facilities as well as to developers and implementers of new technology.

The symposium, held in Portland, Oreg., was sponsored by the Society of Wood Science and Technology, Oregon State University, and the Western Forestry Center. Its purpose was to provide an overview of the principles of process control in the forest products industries and demonstrate their effectiveness in a number of examples of practical application.

Program directors were E.L. Bryan of Decision Dynamics, G.L. Comstock of Weyerhaeuser Co., and T.D. Brown, Oregon State University. Nineteen speakers from industry and the university community covered topics in management controls, process automation, and quality control.

The first session dealt mainly with the application and benefits of computer-based models for production planning and simulation with investment analyses programs and production monitoring systems. The process automation session covered sensors and control logic as well as automation and exemplified these principles with discussions on plywood block centering, computer controlled forming of particleboard, and a manager's view of electronic technology in sawmills. The third session covered the implementation of quality control programs in lumber and plywood manufacturing and also pinpointed the important role of effective communication.

The proceedings were edited by H. Resch of Oregon State University. They may be purchased for $7 from the Society of Wood Science and Technology, P.O. Box 5062, Madison, WI 53705. ■