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Contents

Determination of whole-log moisture content for OSB production

Abstract

The optimum moisture content of the raw logs used in the manufacturing of oriented strand board (OSB) may be defined by a minimum requirement for fibre conversion and a maximum that will limit the cost of drying the flakes. This criterion could become the mainstay of an effective raw-log purchasing and inventory management program. However, OSB manufacturers have lacked the technology for monitoring whole-log moisture content. FERIC tested several technologies and identified time domain reflectometry (TDR) as an effective means of sampling the moisture content in a large number of logs.

Keywords

Time domain reflectometry (TDR), Moisture content, Oriented strand board (OSB), Moisture balance, Wave attenuation.

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Introduction

Over the past decade, oriented strand board (OSB) has surpassed plywood as the primary form of construction sheeting. In 1999, almost half of North America's 1.9 billion m^2 of OSB was provided by Canadian manufacturers. Most of the fibre used for OSB production in Canada comes from two poplar tree species: trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*). Both of these species have high moisture content variability that contributes to manufacturing inefficiencies for both the stranding of the logs and the drying of the flakes. Seasonal, topographical and environmental diversity, along with the length and type of exposure from the felling site to the mill, will generate high moisture content variability among trees. These factors, combined with the composition of heartwood, sapwood and the extent of rot, will also generate high variability within each tree.

In 1994, Forintek Canada Corp. concluded that a 70% minimum log moisture content (dry basis) was needed to maximize flake recovery from logs and that at 60%, the flake yield may be reduced by 5% (Brunette 1994). Conversely, excess moisture content will increase the drying cost of flakes. Unfortunately, the OSB industry does not have the technology to determine the whole-log moisture content quickly and accurately. If such a technology could be developed, log purchasing and inventories could be managed on a moisture-level basis to provide substantial improvement in OSB manufacturing efficiency.

Weyerhaeuser Company Limited asked FERIC to identify a practical solution to this problem. Starting with a review of all related technologies, the objective was to identify a simple, fast and accurate monitoring system that could be applied at any stage in the log acquisition process, from the standing tree to the log storage yard.

Methodology

The technical search involved over 20 manufacturers and their representatives, the National Research Council, the Alberta Research Council, Forintek, universities and representatives of the forest industry. The information on moisture-measuring technologies was categorized as follows:

- hand held conductance and capacitance meters
- Karl-Fischer titration
- near infrared (NIR) surface scanning
- moisture balance
- wave attenuation

Technologies included in the first three categories were rejected as either being too slow in providing results or having an insufficient measuring range or penetration.

The moisture balance category includes the standard ASTM oven-drying procedure. The 103°C temperature specified is low enough to eliminate the possibility of burning the sample. However, the typical sample size requires 24 hours or more to completely dry. The food industry uses a scaled-down version featuring an infrared, halogen or microwave heat source and a sensitive balance with a one-milligram resolution. Satisfactory results are obtainable in less than 10 minutes with a one- or two-gram sample of granulated wood. From a choice of 10 manufacturers, FERIC shop-tested the Mettler Toledo HR73.[1]

Figure 1. Mettler Toledo HR73 analyzer.

The wave attenuation category includes several concepts based on the effect that the presence of hydrogen or water has on deep-penetrating microwaves, electromagnetic waves or radioactive waves. Nader (1996) evaluated the Troxler 3241-C wood-chip isotope gauge and concluded that it was suitable for chips. However, some deficiencies were cited, such as occasional inaccuracy, inconvenience and extreme care needed in sample preparation.

In this study, FERIC tested an MC-1DR Portaprobe[2] which measures moisture by the attenuation of neutron radiation in asphalt, soil and concrete. This instrument was tested to see if this capability is transferable to logs.

FERIC also shop-tested the MP-917 moisture measuring instrument[3] that uses time domain reflectometry (TDR). The return-trip propagation time of a signal along the probe increases in proportion to the presence of water. The shop tests of the TDR were followed by a field evaluation at Weyerhaeuser's Drayton Valley, Alberta facility.

Shop testing

Moisture balance

The Mettler Toledo HR73 moisture balance analyzing instrument (Figure 1) uses a halogen heat source and fan to remove moisture, and a scale to monitor the changing weight of the sample. Its programmability provides a variety of precise control options.

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[1] Manufactured by Mettler-Toledo, Inc. of Highstown, New Jersey.

[2] Manufactured by CPN Boart Longyear of Martinez, California.

[3] Manufactured by Environmental Sensors Inc. of Victoria, B.C.

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Fibre extraction using a 44.5-mm-diameter drill bit (Figure 2) allowed discrete removal of individual samples and profiling of the moisture content. The variability of the results (Figure 3) demonstrated that a cross-sectional average would be more meaningful. To accomplish this, a 16-mm ship auger (Figure 4) was driven through the log and a granulated sample was collected.

Figure 2. Sample extraction method used in the initial test.

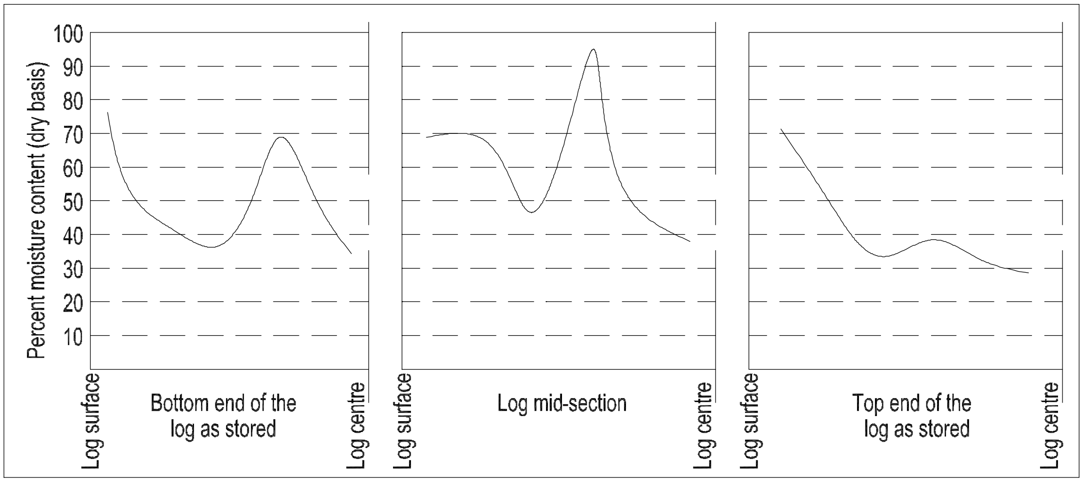

Figure 3. Moisture-content profile.

One- to two-gram portions of this sample were analyzed in the HR73 moisture balance.

The moisture balance is too delicate for the field. Samples could be held in cold storage and analyzed up to 24 hours later in a laboratory with no appreciable loss of accuracy. However, the procedure is time consuming and would require three person-days of field and laboratory time to analyze a thirty-log sample, with three readings per log.

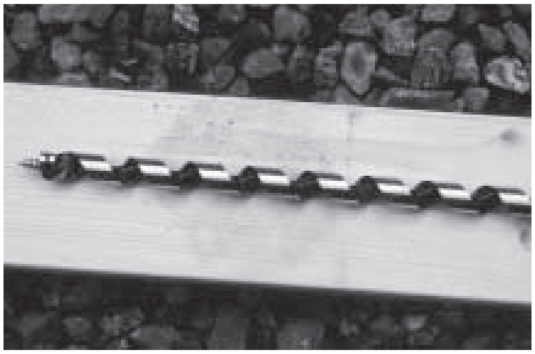

Figure 4. Ship auger.

Wave attenuation

The MC-1DR Portaprobe (Figure 5) offered the potential elimination of preparatory cutting or drilling, and a fast, one-minute read time. Moisture is detected by the velocity moderation of deep-penetrating neutrons in collision with hydrogen atoms. In inorganic material, hydrogen is a direct indication of moisture. However, wood fibre also contains hydrogen and the instrument needed calibration to differentiate between the hydrogen content of the wood and that of the moisture.

Figure 5. MC-1DR Portaprobe.

An aspen block was oven-dried and progressively monitored for weight and instrument readings. Once the sample was bone-dry, the actual moisture content continuum was known and the formula relating instrument readings to moisture content was modified for the best fit. Above 5% moisture, the variance between the actual content and that determined by the instrument was less than 2%.

For this calibration, the sample's bark was removed in the measurement area, a flat spot was prepared, and the instrument was carefully positioned in the same way for each measurement. The objective was to achieve a close calibration irrespective of the anticipated effect of bark and surface. However, subsequent testing on the sample's parent log demonstrated that bark and surface variations could produce errors of great variability and in excess of 30%. Therefore, the Portaprobe was rejected as a means of monitoring log moisture.

Time Domain Reflectometry (TDR)

TDR was originally developed for monitoring soil moisture by measuring the propagation time of an electromagnetic signal transmitted down a probe. This time increases in direct proportion to the volumetric presence of moisture.

Figure 6. MP-917 moisture measuring instrument.

Environmental Sensors lent FERIC a model MP-917 moisture measuring instrument to test the application to whole logs (Figure 6). Weighing 4.5 kg and measuring 27 × 25 × 17 cm., the instrument was very portable and rugged. A 20-cm-long probe that featured two 6-mm-diameter prongs was also provided for this application. The energy requirement to align the water molecules within the magnetic field generated between the prongs slows the transmission speed of the signal and increases its propagation time. However, testing was limited to unfrozen wood since frost will prevent molecular alignment and affect the results.

A calibration was required that determined the propagation time with the probe in the same dried sample used to calibrate the Portaprobe. The probe must always be totally enveloped. A simple jig was made for drilling two 8-mm-diameter holes radially through the log. Slightly larger than the prong diameter, the holes allowed for easy insertion of the probe without the danger of binding, while maintaining sufficient contact between the prongs and the wood.

Following calibration, measurements were taken on the sample's parent log. Conversion of these volumetric moisture content readings to the more conventional, dry-weight basis requires a value for density equal to the dry weight divided by the wet volume:

$$MC_{DW} = MC_V/D$$

Where:

MC_{DW} = Dry-weight–basis moisture content (%)

MC_V = Volumetric moisture content (%)

D = Basic density (dry weight/wet volume)

The measured density of the sample was 0.41 g/cm^3, agreeing with the published values of 0.35 to 0.41 (Eckelman 1997). Table 1 compares four TDR readings with the moisture-balance readings of samples from the same locations.

Table 1. Comparison of aspen moisture content readings taken in the shop

Propagation time (ns)	Dry-weight–basis moisture content		
	TDR (%)	Moisture balance (%)	Variance (%)
4.62	59.7	55.4	4.3
4.76	62.9	60.3	2.6
4.68	61.0	58.2	2.8
4.80	63.8	70.6	6.8

Converting from volumetric to weight-based moisture content may result in inconsistencies due to the density variability of solid wood. Density is also subject to rot, checking and other inconsistencies. These factors, combined with the normal moisture variability illustrated in Figure 3, are the most likely sources of variance between TDR and moisture balance readings. A statistical comparison of the TDR and moisture balance readings in Table 1 was made that includes the 0% readings of the instrument calibration. This resulted in an r^2 (coefficient of determination) value of .975 and a linear regression equation of $y=0.016+0.979x$, where y is the TDR and x is the moisture balance determination of moisture content.

The moisture-balance sample for the last reading exhibited rot that could have justified using a smaller value for density, thus reducing the variance. To nullify inconsistencies arising from conversion to weight-based moisture content, relating the OSB manufacturing requirements to the wood's volumetric moisture content should be a valid alternative.

Although rot is a significant cost factor in OSB manufacturing, the objective of moisture-content monitoring is to assess the convertibility of solid fibre. Therefore, the inclusion of rot in this assessment is misleading and should be avoided as much as possible by discounting those probe locations where drilling indicates the predominance of rot.

A second statistical comparison of the readings in Table 1 was made that excludes the readings taken in the rotten material. This resulted in an r^2 value of .999 and a linear regression equation of $y=0.01+1.054x$.

The three readings at each probe location were averaged. In most instances, these readings agreed to within 1%. Where this was not the case, an extra reading was taken and the three closest were averaged.

For one person, a TDR reading could be made in four minutes, including drilling time. With one person drilling and one reading, this time could be cut in half. A thirty-log sample with three readings per log should take half a day with two people.

Consistency, productivity and the robust nature of the equipment were the main factors affecting the decision for an extensive field evaluation of the TDR concept.

Field testing

The main purposes of the field evaluation were to further verify accuracy and productivity, assess the typical range and characteristics of the moisture content, and demonstrate the log-moisture monitoring potential of TDR in a field environment.

Fifty-two logs (38 aspen and 14 balsam poplar) that were representative of the OSB mill infeed were measured with the MP-917, and the results were compared to those of a moisture balance analysis. All were 2.5 m long and of sufficient diameter to envelop the full length of the probe. TDR readings were taken at five locations along each log. Low-rot samples were extracted for weight-balance analysis. Solid-wood samples were also taken for density determination. TDR readings were taken on three logs before and after a seven-hour treatment in the mill's soak pond. A rot assessment was made on each log.

The solid-wood samples were dried and weighed and a shrinkage factor was applied to an Archimedes determination of volume. The resulting average value of dry weight divided by the wet volume was 0.392 g/cm^3 for aspen and 0.367 g/cm^3 for balsam poplar.

These values were applied to the TDR measurements of volumetric moisture to determine the dry-weight–basis moisture content shown for each sample log. The percentage rot associated with the drier logs was also determined. The moisture content in both species could vary as much as 50 percentage points overall and 40 percentage points within a log. Shop tests previously showed that this variance could also occur radially (Figure 3), challenging the notion of deriving an average moisture content from a few discrete readings.

The exposed log ends in a deck suggests axial insertion of the probe as a convenient measuring practice. However, the moisture variability pattern was the main reason for inserting the probe radially at several points along the log, thus approximating the average, cross-sectional moisture content at points other than just the ends. Also, in two attempts at end measuring, the drilling was harder and the hole location was less precise than when drilling across the grain.

Table 2 shows the correlation of weight-balance samples taken at various locations.

The first three sets of readings for aspen indicate a close verification of TDR with the moisture balance. A statistical analysis of these readings was made that includes the 0% readings of the instrument calibration. This resulted in an r^2 value of .998, and a linear regression equation of $y=0.06+0.975x$. The fourth set of aspen readings showed a higher variance than that of the other readings, likely due to rot or a density variation. A statistical analysis was made including the fourth set of readings. This resulted in an r^2 value of .975 and a linear regression equation of $y=0.038+0.867x$.

The comparison of moisture content readings in balsam poplar is not as close as that for aspen. The most likely sources of variance are:

- variation in wood density
- a possibility that an instrument re-calibration is required for balsam poplar
- the true moisture-content variability previously demonstrated

Balsam poplar is known to have concentrated pockets of water that would have exacerbated moisture-content variability. A closer verification of the balsam poplar readings was sought by oven-drying a 23-cm-long by 23-cm-diameter block and measuring TDR, weight and density. This larger sample also minimized the problem with moisture-content variability. This resulted in moisture contents of 114.9% and 123.3% using TDR and moisture balance, respectively (a variance of 8%). The foregoing procedure also verified that the instrument's calibration for balsam poplar was the same as that required for aspen.

Stem and rot diameter readings were taken at both ends of each log and used to determine the average stem diameter and percentage of rot. An analysis of the data did not reveal any significantly consistent relationships among readings for moisture content, stem diameter and rot.

Logs are often soaked in water for several hours prior to flaking in an attempt to raise the moisture content and to thaw frozen wood. Table 3 summarizes the TDR results from three logs treated in the mill's soak pond. Probe holes drilled and measured before and

Table 2. Comparison of TDR and moisture balance readings taken in the field

Log species	TDR (%)	Moisture balance (%)	Variance (%)
Aspen	48.4	47.5	0.9
	59.2	59.5	0.3
	68.3	71.0	2.7
	77.5	92.6	15.1
Balsam poplar	116.3	154.8	38.5
	120.0	186.8	66.8

Table 3. Test data from aspen logs before and after soaking for seven hours

	Moisture Average (%)	Moisture Range (%)
Before soak	41.6	18.7
Same holes after soak	107.5	15.3
New holes after soak	64.5	19.2
Before soak	64.9	7.8
Same holes after soak	115.9	16.4
New holes after soak	71.9	22.1
Before soak	74.2	17.1
Same holes after soak	109.4	19.0
New holes after soak	89.8	26.7

after soaking registered a significant moisture gain. However, in solid wood this higher moisture level was not evident in holes that were drilled adjacent to the first holes after the soak. The moisture gain in the first set of holes was superficial, and this was confirmed when the reading in one of the first holes was restored to its original value after the drill was re-inserted to remove the surface moisture. Although soaking logs may produce some beneficial thawing in winter, it is questionable whether this practice has any significant effect on the moisture content of solid fibre.

The pattern of readings also indicated that the moisture penetration in rot was greater than in solid wood. The subsequent drying of this material before it is screened out in the manufacturing process and used for fuel adds to the cost of production. Also, any remaining moisture lowers the rot's calorific value.

The field tests confirmed the earlier productivity estimate of 30 readings an hour for a two-person team. It was also perceived that readings could be taken at any stage in the log acquisition process and that the ease of access to the exposed logs in a pile should provide a sufficiently large sample. However, lengthy exposure of these logs to the elements, particularly in areas where the bark has been removed, may accentuate changes in their moisture contents, making them unrepresentative of the rest of the pile.

Conclusions and implementation

If whole-log moisture content is to become an indicator of fibre convertibility in OSB manufacturing, its wide variability in aspen and balsam poplar dictates a sizeable sampling. Furthermore, the presence of rot in these species can mislead the objective of assessing only the solid fibre. Notwithstanding, a comprehensive technical search and testing has concluded that, at 30 readings per hour, TDR is fast enough for a timely evaluation of a mill's log inventory. Each reading, taken with the probe inserted radially at several points along the log, will approximate the local cross-sectional average moisture content at each setting. Therefore, after discounting probe locations where drilling indicates the predominance of rot, TDR can become a practical means for OSB manufacturers to monitor whole-log moisture content as part of a raw material purchasing and inventory control program.

The effective application of TDR for measuring whole-log moisture is limited to unfrozen wood. The probe must be fully enveloped and pass through the log's centre. Averaging at least three readings at each location will ensure accuracy.

The variability of wood density will introduce an error when converting the TDR's volumetric moisture-content readings to weight-based information. Therefore, relating the OSB manufacturing requirements directly to the volumetric information may be a valid alternative.

Rot absorbed more water in the mill's soak pond than did the solid wood. An additional manufacturing cost is incurred when this moisture is later removed before the rot is screened out and used as fuel. Also, any remaining moisture lowers the rot's calorific value. Unless the thawing of frozen fibre is the issue, it may be prudent for heavily rotted material to bypass the mill's soak pond. Also, TDR measurements indicated that a short-duration soak of solid fibre produced only a superficial moisture gain.

Monitoring early in the log acquisition process should provide for the most responsive decision making on log purchasing, inventory flow and processing. Monitoring close to the felling site, possibly at roadside, will also facilitate a history of regional and seasonal variability. In most roadside situations, the ease of access to the exposed logs in a pile should provide a sufficiently large sample. However, lengthy exposure of these logs to the elements may accentuate changes in their moisture content, making them unrepresentative of the rest of the pile.

The following questions suggest some broad areas where further experience is needed concerning sampling methodology and the utilization of moisture-content information in the manufacturing process.

- What is a suitable sample size and measuring density?
- How might age, species, piece size, harvesting methods and regional conditions affect the sampling process and the response to the information?
- What is the optimum range of moisture content?
- What are the options for processing non-compliant material and economic consequences?

The acquisition of this experience will take time. However, the potential savings in fibre recovery, drying costs and manufacturing efficiency are significant. Therefore, moisture monitoring with TDR could be an important step in the evolution of OSB manufacturing.

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