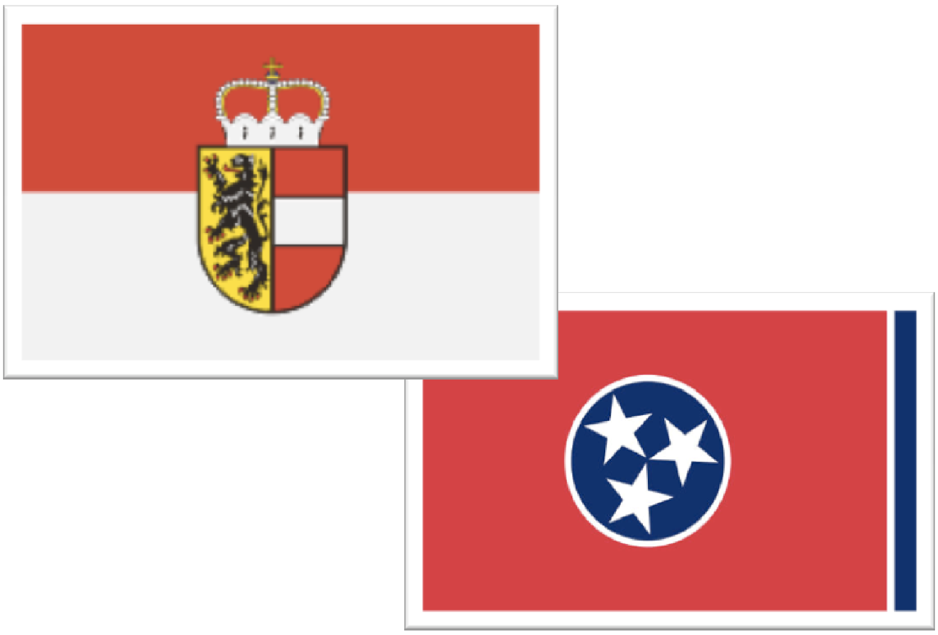
Final Report

Internship at the University of Tennessee

2008

Author

Josef Mühlbacher



Introduction

The following report was written during an internship at the University of Tennessee. The internship was carried out within the sixth term of the graduate course HTW (wood engineering and economics) at the University of Applied Sciences Salzburg. It lasted from the beginning of May till the mid of August, altogether 15 weeks.
Two supervisors guided me through that position, Dr. Alexander Petutschnigg from Salzburg and Dr. Adam Taylor from the University of Tennessee.

The aim of the internship was on one hand the chance to work in a professional scientific labor with all its possibilities. On the other hand it was an opportunity to strengthen my English language skills as well as to life in a foreign country and get to know a different culture.

My task was to work on different projects and problems that occur in the wood industry as well as in the domestic use of wood-products. I had to plan, arrange and carry out the particular projects. In the end an evaluation was made to specify the data that occurred in the projects.

I divided my projects into four different subject areas.
The biggest part dealt with moisture in wood products and lumber, which is a crucial factor in each domain of the wood industry.
Projects:

- a test if presorting of freshly cut red oak wood would lessen the effort of the seasoning the wood
- creating a function to elicit the approximate moisture content of wet bark that is meant to be used as sheathing

Further I worked on projects concerning preservation of wood, which means make wood more durable for exterior use.
Projects:

- different treated wood was compared in terms of their affinity to create splits under the influence of weathering
- the efficiency of ozone as a fungus destroying media was tested

Another field was about the allelopathic impact of different wood mulches on the germination of weeds that are not intended to grow.
Project:

- a number of experiments carried out to proof the impact of different wood species used as mulches to suppress weeds

The last topic was about showing people that are not familiar with the material the different properties of wood species.
For that reason specimen got prepared for demonstrative breaking tests.

Index

1 Drying and moisture measuring

1.1 The relative moisture content of air drying red oak lumber

Introduction

The drying of red oak lumber is time consuming, energy intensive and expensive. The initial moisture content (MC) of the green lumber is not uniform and as a result some of the lumber in any particular load is dried more slowly and/or over-dried when the drying schedule is controlled by the MC of the wettest pieces. Sorting green lumber before drying has been tried to reduce the cost and time of drying and to improve lumber quality. Sorting can be done according to initial MC or by species, provenance, sapwood versus heartwood, density, grade, dimensions and combinations of two or more of these parameters. Sorting of softwood lumber can lower drying costs by minimizing drying degrade and by shortening the drying times for lumber that has a relatively low moisture content when green (Richardson 2003). Data on the applicability of sorting to hardwood lumber are lacking.

Methods that have been studied for sorting by initial moisture content include visual sorting and technologies based on weight, infrared, lasers and near infrared spectroscopy (Kozlik and Hamlin 1972, Friesen 1989, Taylor and So 1990, Warren and Johnson 1997, Defo et al. 2007, Taylor et al. 2007). Another possibility for predicting the moisture content of rough lumber is based on the phase shift and attenuation of microwaves passed through a sample (Moschler et al. 2007). This technology has shown excellent potential when calibrated with wood samples over a wide range of MCs. This technique has not been tried when calibrating only with green lumber samples, which have a smaller range of MCs.

Presorting of freshly-cut red oak lumber by its MC could help to prevent problems of slow drying and/or degrade associated with the wide variation in initial moisture content. However, red oak is often air-dried prior to placement in the kiln. It is not known if the initial relative differences in moisture content among green boards in a stack are maintained after air-drying, i.e. whether the wet pieces initially are still the wet pieces after air-drying. The purposes of this study were to test a prototype microwave-based moisture sensor for sorting fresh-sawn red oak lumber and to assess whether presorting this lumber by moisture content would be useful if the lumber is to be air-dried.

Materials and Methods

Freshly cut red oak (*Quercus* spp.) 4/4 (nominal thickness 1”[25mm]) lumber was sawn from four 8- and 10- foot logs at a sawmill located in eastern Tennessee in mid-May of 2008. The boards were of random width and mixed grade and were untrimmed for length. After cutting, the boards were dead-stacked and immediately shipped to the nearby lab for testing. At the lab, 150 randomly selected boards were cut to a length of six feet by removing at least 1 foot from each end. Three-inch long moisture content (MC) samples were cut from the cut-off sections adjacent to the six-foot long samples. The dimensions and weight of each board sample and MC sample were recorded. The boards were end coated with a wax emulsion (“Anchorseal”, UC Coatings, Buffalo NY). The sample boards were stacked outside separated by dry, profiled red oak stacking sticks and supported by bolsters. To protect the sample lumber from direct exposure to sun and rain, protection boards were used. These boards were installed as the outer course on each layer and as the top layer of the pile. A tarp was also used to cover the pile.

The approximate MC of the big sample boards was calculated based on the average of the two MC samples, and the MC of the boards was monitored regularly during air-drying. The boards were air dried for more than 2 months in total, from the middle of May to the end of July.

A prototype microwave moisture meter (described by Moschler et al. 2007), was used to collect two spectral signals from each of the original moisture content samples (150 parent boards, with 2 samples per board. 79 were subsequently damaged and these data were discarded).

Each of the samples was then labeled as either “high” or “low” moisture content class by dividing the data based on median moisture content. A prediction model was created to relate the microwave sensor data to the moisture content class. The objective of this modeling exercise was to be able to classify the moisture contents of the samples as either “high” or “low” by using the microwave sensor data. Training and test sets of data were randomly selected from the original data set, with 177 samples used for the training (model calibration) and 44 samples are used for testing (model validation).

Models were developed relating the microwave spectral signals (independent variables) to the one response variable, MC. Because the combined spectra signals contained a large number of (correlated) variables compared with the number of samples, multivariate statistical methods were used, including wavelet data suppression, partial least squares for discriminant analysis (PLS-DA) (Jong 1993, Rosipal and Krämer 2006), kernel partial least squares for discriminant analysis (KPLS-DA) (Rosipal and Trejo 2001, Rosipal 2003), and kernel ridge regression (Saunders et al. 1998) for discriminant analysis (KRR-DA) according to procedures of PLS-DA and KPLS-DA. The PLS, KPLS, KRR and VET based wavelet-based reduction technique were implemented in the MATLAB programming environment, using the PLS, KPLS, KRR codes and WaveLab802 toolbox[1].

Table 1. Results from various models used to classify green red oak samples as either "high" or "low" moisture content, based on microwave phase shift and attenuation spectra.

Methods	Calibration accuracy (# of misclassified samples) N= 177	Validation accuracy (# of misclassified samples) N=44
PLS (PC:7)	80.79%(34)	61.36% (17)
KPLS (G:1000000, PC:1)	100% (0)	81.82% (8)
KRR (P:2, λ=0.000464)	100% (0)	84.09% (7)
Wavelet PLS (PC:8)	72.32% (49)	61.36% (17)
Wavelet KPLS (G:1000000, PC:5)	100% (0)	77.27% (10)
Wavelet KRR (P:2, λ=4.641589)	100% (0)	88.64% (5)

Results and Discussion

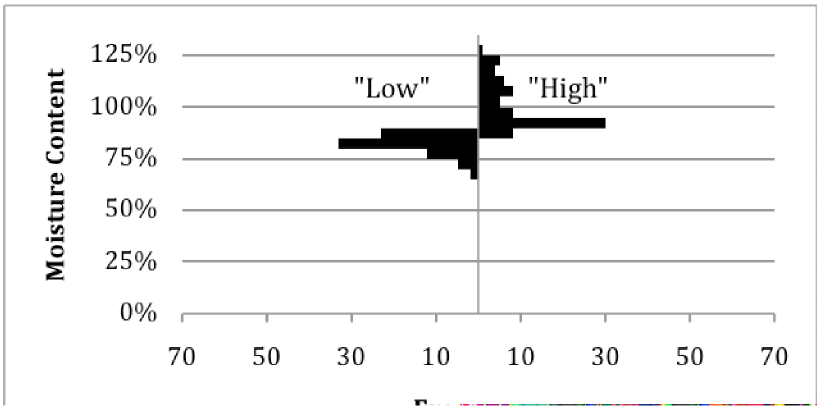
The data from the prototype microwave-based moisture meter were useful for accurately classifying samples (Table 1), with some models accurately assigning over 80% of the validation samples. A number of statistical techniques were tried; the most successful included a wavelet data pretreatment and KRR (Saunders et al. 1998).

Over the course of the 74 days, the lumber dried from an initial average of 86% to an average of 15%. The quality of the dried air-dried lumber was good; there was very little checking or warp and no honeycombing was observed on boards that were subsequently cross-cut.

To determine if the initially wetter boards remain relatively high in moisture content throughout the air drying study, the data of the initial MCs were split into two groups of 75 samples: "High" (82.6% and above) and "Low" (below 82.6%). Figures 1-4 show the drying of the "Low" and "High" groups over time. While a statistically significant difference was maintained between the groups even after 2 months of air-drying (Figure 4, p-value <0.01 from t-test), there was considerable overlap in the moisture content distribution between the two groups after only one week (Figure 2). At the end of 1 month of air drying, the separation of the two groups would not appear to be useful for practical drying purposes (Figure 3).

1 Available from http://www-stat.stanford.edu/~wavelab/index_wavelab802.html. Accessed 7 October 2008.

Figure 1.



Moisture Content
125%
100%
75%
50%
25%
0%
"Low"
"High"
70
50
30
10
10
30
50
70

Figure 3.

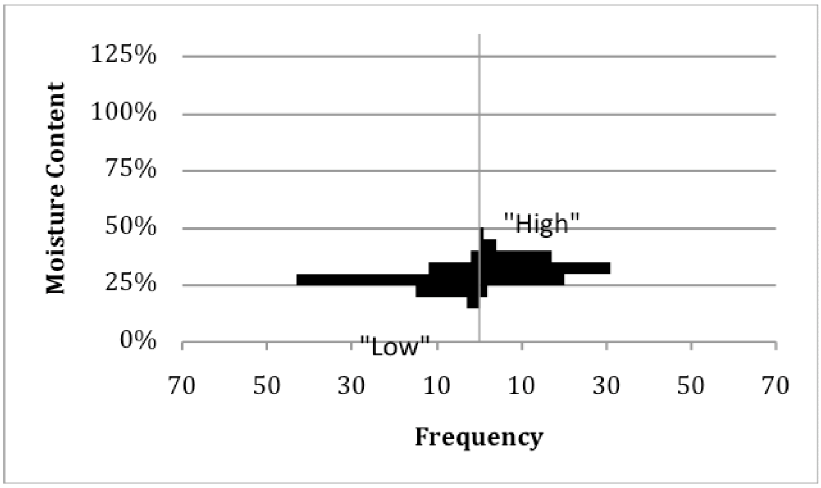
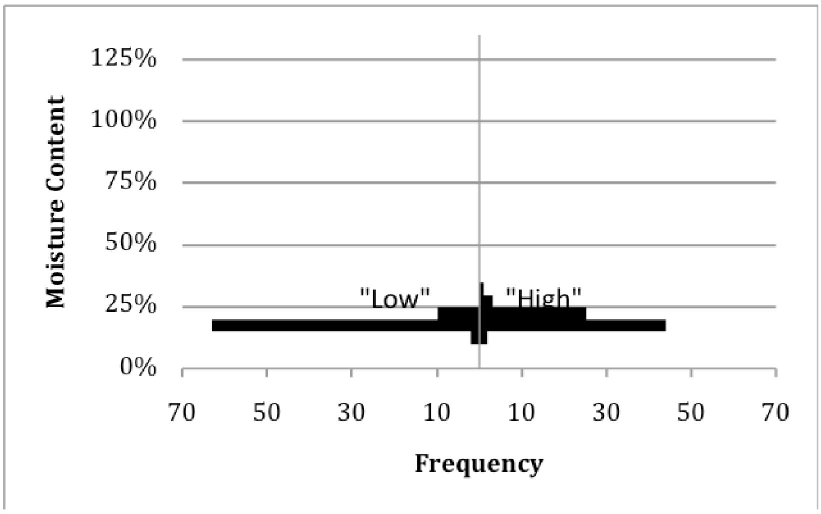


Figure 4.



Conclusion

These data suggest that, while sorting of green red oak lumber by moisture content may be possible using microwave-based technology, such sorting will not bring benefits in terms of lasting separation of moisture content levels if air-drying is employed prior to kiln drying.

1.2 A moisture meter calibration for yellow poplar bark

Abstract

Bark sheets be cut, dried flat and used as a siding material. As with lumber, moisture meters can be used for the rapid determination of moisture content during the drying process. However, while such meters are calibrated for different wood species, there is no information available on using meters with bark. Moisture meter correction values were established for yellow poplar bark for with three different meters.

Introduction

Bark has shown the possibility to be used as effective outdoor wall covering. American chestnut (C*astenea dentata)* and yellow poplar (*Liriodendron tulipifera)* have been used for this purpose.[2] Although bark siding has a long history, it remains a small, niche application and little is known about its processing characteristics.

To prepare poplar bark for use as siding, the green bark is stripped in sheets from freshly fallen trees in the spring and early summer when the vascular cambium is active and the bark can be easily removed. The strips are then cut to size and stacked flat to dry. Kiln drying may be employed. As with lumber, drying is required to ensure the dimensional stability of the bark and to reduce the risk of biodegradation.

Moisture meters are commonly used to the rapid determination of the moisture content of wood. These meters are based on the variation in electrical properties (conductance or power loss) of wood associated with variation in moisture content.[3] Variation in temperature, density and chemistry can also affect electrical properties and correction factors are applied (manually or automatically with some meters) when using moisture meters on lumber of different species or different temperatures. No information is available on the use of lumber moisture meters with bark.

This project was conducted at the request of a local manufacturer in order to determine moisture meter correction factors for yellow poplar bark.

2 Anonymous. 2008. http://www.naturalbarksiding.com/poplar_bark_history.html. Accessed September 10, 2008

3 James, W.L. 1988. Electric moisture meters for wood. USDA Forest Service Forest Products Laboratory Research Note FPL-GTR-6

Materials and Methods

17 pieces of fresh yellow popular (*Liriodendron tulipifera*) bark were collected from the manufacturer in east Tennessee, stored in plastic bags and brought to the lab in early June. To determine the moisture content (MC) difference between the dead outer bark and the living inner bark, three pieces of bark were cut at the inner/outer bark boundary and the MC measured using the oven-dry method.

For the moisture meter calibration, a 8.5” by 5.5”(22 x 14 cm) sample was cut from each of the 17 pieces using a band-saw. Each edge was sealed using a wax emulsion (Anchor-Seal, Danvers, MA). Immediately after the cutting the samples were weighed (nearest 0.01g) and monitored for monitored for MC using three different moisture meters:

1. Delmhorst RDM - 2S (Delmhorst Instrument Co., Towaco NJ). A digital-display conductance meter with an upper reading limit of 56 %. The meter was set on Douglas-fir, as this requires no correction factor with that meter. A 15-E electrode was used, which has 8 pins that penetrate 1/8” (3mm). According to the manufacturer’s website, this electrode is intended for use with veneer, cardboard, leather and paper. The two rows of four pins were oriented along the bark fiber direction. The pins were inserted into new bark at each reading; the old pin holes were avoided.
2. Delmhorst RC - 1B. An analog-display conductance meter, with a display limit of 65%. A 26-ES ‘hammer’ type electrode with ½” (12mm) uninsulated pins was used. The pins were inserted parallel to the grain direction in new holes each time.
3. Wagner L609 (Wagner Electronics, Rogue River, OR). A digital display, power loss (pin-less) meter. The output range of this system was limited from 4 % to 22 % MC. The meter was held against the inner bark surface, with the bark lying (outer bark side down) on a lab table. The lab table itself produced a reading on the meter of 11%.

The samples were measured daily for 18 days. At the time of each measurement, the samples were also re-weighted. After repeated measures while drying in ambient lab conditions, the samples were moved into a climate chamber with a temperature of 22°C and 65% relative humidity (12% EMC for wood). The samples were stored in the chamber until reaching a constant weight at which point they were measured again. After the last measurement the samples were oven-dried at 103C and re-weighed. Oven-dry (true) moisture content was calculated at each measurement time.

Results and Discussion

As expected[4,5] the initial moisture content of the inner bark was high (average 124%) and much more than the MC of the outer bark (average 33%). Figures 1-3 show the moisture meter values for the whole-bark samples plotted against the oven-dry moisture content values for each of the three meters used. The resistance meter data (Figures 1&2) were divided into high- and low-moisture content groups arbitrarily but approximately at the limits of the accuracy of the moistures meters when used with wood (~25%). Linear regression equations were then calculated for each data grouping. Using the regression equations for the lower moisture content groups, correction factors for each meter were calculated for the range from 10-25% meter readings (Table 1).

Table 1. Moisture meter correction factors for yellow poplar bark. The true moisture content value can be determined by adding the correction factor listed to the meter value.

Meter Type	Meter reading															
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Correction Factor															
RDM - 2S	3	2	2	1	1	0	0	-1	-1	-2	-2	-3	-4	-4	-5	-5
RC - 1B	3	3	2	2	1	1	1	0	0	-1	-1	-1	-2	-2	-3	-3
L609	5	4	4	3	3	2	1	1	0	0	-1	-1	-2			

There was considerable unexplained error in the relationships among the meter readings and the oven-dry values (R^2 from 0.41-0.75). This may have been due in part to the large difference in MC of the inner and outer bark initially and variations in the ratio of inner and outer bark thickness among the samples. Whatever the explanation, the (corrected) meter readings of bark MC may have a lower precision than is expected when using meters with wood. However, it is likely that highly precise determinations of moisture content will not be necessary for bark products.

The bark samples were not measured at low MC levels (<12% oven-dry) so these data do not provide correction factors for meter readings below 10%. However, bark products are generally intended for outdoor applications where equilibrium MC's (for wood) are most often above 10%.[6]

4 Koch, P. 1972. Utilization of southern pines. USDA Forest Service Agriculture Handbook No. 420.

5 Koch, P. 1985. Utilization of hardwoods growing on southern pine sites. USDA Forest Service Agriculture Handbook No. 605

6 Simpson, W.T. 1998. Equilibrium moisture content of wood in outdoor locations in the United States and worldwide. USDA Forest Service Forest Products Laboratory Research Note FPL-RN-0268

Figure 1.

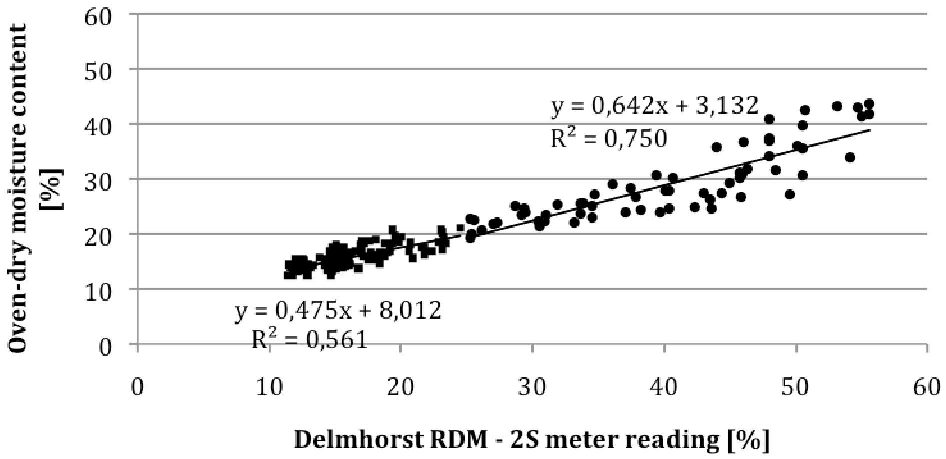


Figure 2.

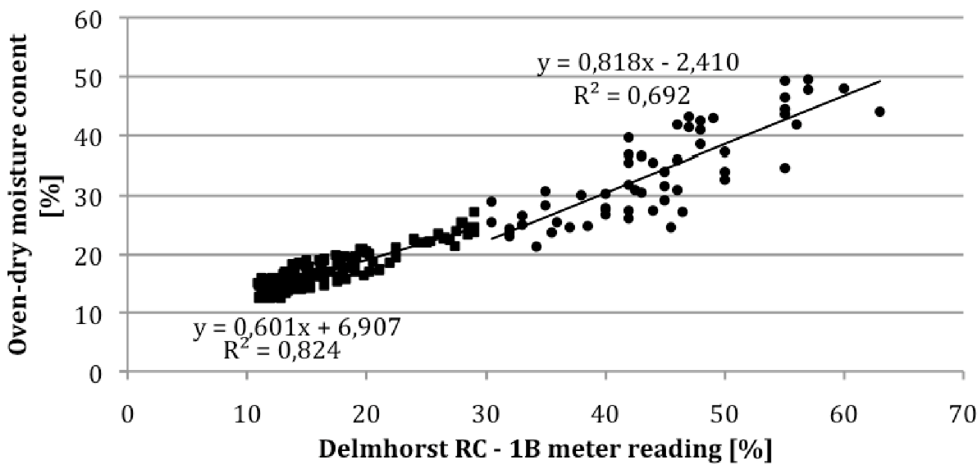
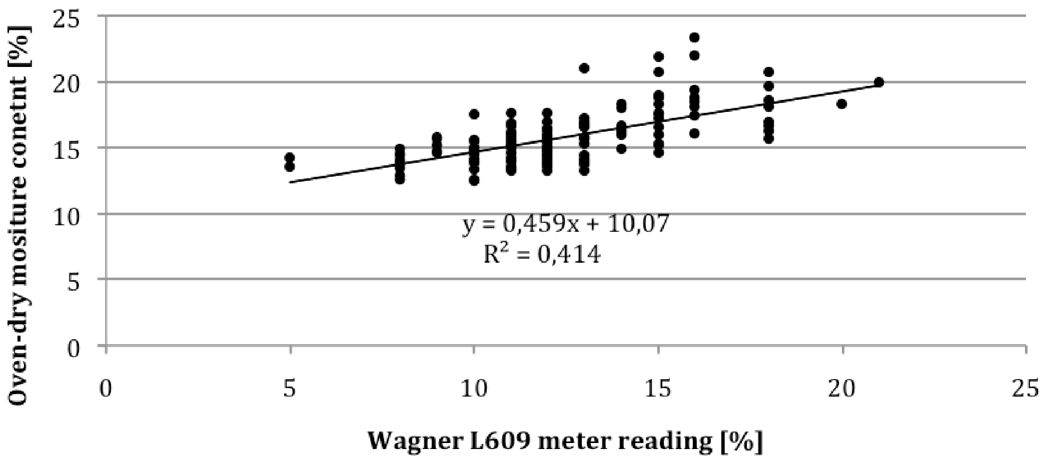


Figure 3.



2 Chemical treating of wood

2.1 Is water-repellent treated decking lumber worth the extra cost?

Materials and Methods

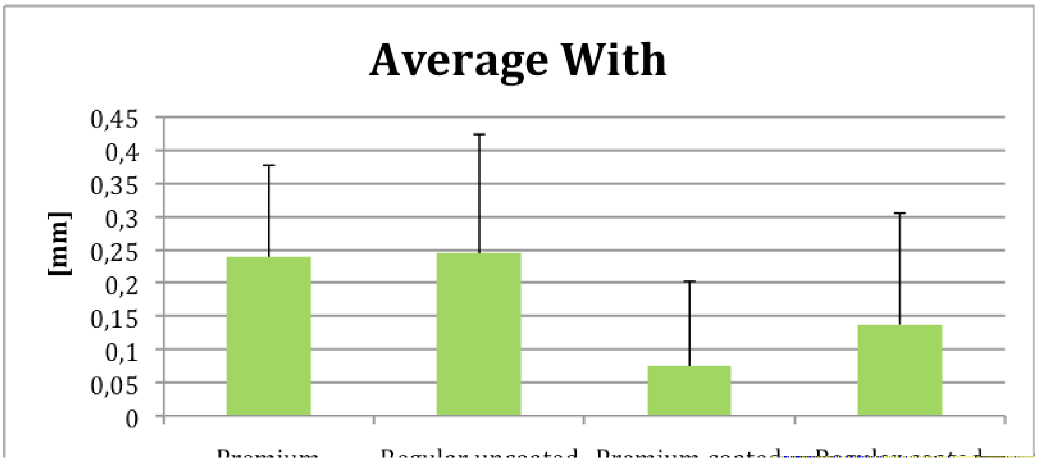
Two different kinds of pressure treated wood were purchased at Home Depot and compared in terms of resistance to weather and climate impacts such as UV rays, water exposure and temperature changes. Both of the decking board types were copper azole-treated 5/4 southern pine decking boards. The differences were that the “Thompsonized” product contains a water repellent, uses premium grade lumber and costs approximately 30% more than the regular product. This study was designed to find out if it is worth to pay more for the “Thompsonized” wood.

Ten boards of each kind were cut to a length of 20” with a radial arm saw. A 2” long slice was also cut from each board. These subsamples were used to carry out a water repellency test. The boards were screwed, bark side down, to a wooden frame and were numbered. The initial splits were counted and their length was taken. One half of each board was additionally treated by brushing on a layer of Thompson Advanced Waterseal coating. An area where the checks were counted was outlined as a $5^{1}/_{2}$” square on both the water-repellent treated and the uncoated half of each sample board. After one month the values were collected again. This time also the width of each check was considered. The length was measured using a ruler. Width was measured with a Zoom Lupe. All the data was recorded in millimeters.

Results

After one month of exposure to the weather, four different factors were calculated. The average width of the checks (Figure 1), the average shape (Figure 2), the sum of covered area (Figure 3) and the sum of the counted checks (Figure 4) were considered in the evaluation.

Because the duration of the experiment which should at least last one year of direct weathering only the bench marks were measured


Average With
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
[mm]

4 Educational supplies

4.1 Preparing wood for bending and breaking experiment

Summary

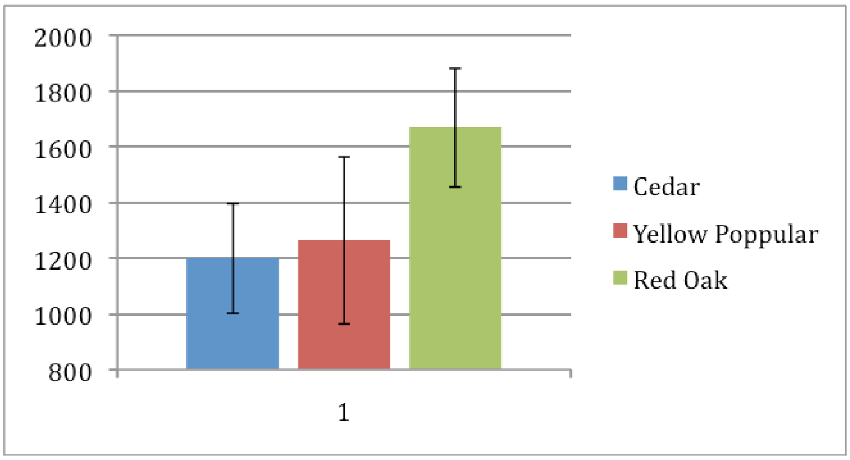
The purpose of this task was to prepare wood in dimensions suitable for different demonstrations. One part was to create disposable wood sticks which should demonstrate the strength of different wood species. Samples in larger dimensions will show how different bonding patterns affect the bending strength of wood and engineered wood products.

Method

Lumber of three different species (*Quercus* spp., *Juniperus virginiana*, *Liriodendron tulipifera*) was purchased from Home Depot. At first experiments were carried out to elicit good dimensions for the sticks. The wood was machined using a table saw. A stick length of 30” was chosen with a cross section of $^{3}/_{16}$” by $^{3}/_{16}$”. However the range for the final experiment showed to be best at a distance of 18” between the two bearings. The force which is needed for the test came from concrete blocks which were made for this experiment. One block weighs approximately 240 gram.

For the bending test pine wood (*Pinus* spp.) was purchased from a local distributor. As before, initial tests were made to get a good thickness for the samples. A length of 30”, a thickness of $^{3}/_{16}$” and a width of $1^{1}/_{2}$” was chosen. The wood was machined on a table saw. Twenty sets were made each set consists of four identical slats. Two of the slats are meant to be glued together by the person who carries out the experiment.

The initial tests showed following differences in strength of the three species.



Resume

During my time in the United States I made many new experiences. Not only in the field of work, but also in a cultural way. I got to know many new people, which were always friendly to me. So I was able to find some new friends a few thousand kilometers away from home which whom I am still in contact and plan some meets for the future.

My language skills improved dramatically during the four-month of my internship. After a short time I was able to communicate in a fluent English. This helped me in my work as well as in getting to know new people in private life.

Traveling was also a part of my stay. I visited altogether eight States from the fare south Florida until the northern Connecticut. Also here I experienced the difference of culture within the different States, from the laid-back mentality of Alabama to the busy lifestyle of New York City.

The department within the University was a nice place to work. All my colleagues were helpful and kind. Within the Forest Product Center I got the chance to work on my own. The tasks I got were always challenging and interesting. Also the field of work was broad because I had to do physical labor as well as calculating and evaluation of results. The Equipment I was able to use was state of the art and it was never a problem to buy missing parts. I learned new methods and ways to solve problems, which I was able to apply in my projects. Those methods will be important for my further life. Especially for the thesis I have to write the next two terms.

At the end I would like to say that the four-month abroad was one of the best times I got in my life and I will try to go back into my “second home”, the United States, in near future.

References

Defo, M., A.M. Taylor and B. Bond. 2007. Determination of moisture content and density of fresh-sawn red oak lumber by near infrared spectroscopy. Forest Prod. J.57(5):68-72

Friesen, D. 1989. Sorting by moisture content decreases drying costs. Forest Industries 116(7): 18-19.

Jong S. 1993. SIMPLS: An alternative approach to partial least squares regression. Chemometrics and Intelligent Laboratory Systems 18(3): 251-263.

Kozlik, C.J. and L.W. Hamlin. 1972. Reducing variability in final moisture content of kiln-dried western hemlock lumber. Forest Prod. J. 22 (7): 24-36.

Moschler, W.W., G.R. Hanson, T.M. Felix, S.M. Killough and J.B. Wilgen. 2007. Microwave moisture measurement for wood drying. Forest Prod. J. 57(10):69-74

Richardson, M. 2003. Sorting. The solution to consistent drying. NZ Forest Industries 34(10):42-46.

Rosipal R. and Krämer N. 2006. Overview and recent advances in partial least squares. In Subspace, Latent Structure and Feature Selection Techniques, Saunders C., Grobelnik M., Gunn S., Shawe-Taylor J. (eds.), Springer, 34-51, 2006.

Rosipal R. 2003. Kernel partial least squares for nonlinear regression and discrimination. Neural Network World. 13(3): 291-300.

Rosipal R., Trejo L.J. 2001. Kernel partial least squares in reproducing kernel Hilbert space. Journal of Machine Learning Research 2: 97-123.

Saunders C., Gammerman A., and Vovk V. 1998. Ridge regression learning algorithm in dual variables. Proceedings of the 15th International Conference on Machine Learning (ICML98), 515-521. Madison-Wisconsin, 1998.

Taylor, A.M., T. Young, C. Steiner and M.K Jeong. 2007. Hardwood Lumber Manufacturing Optimization Using NIR Spectroscopy. Proceedings of the International Scientific Conference on Hardwood Processing, September, 24–25–26, 2007 Quebec City, Canada. Pages 157-163.

Taylor, F.W. and W.T. So. 1990. Sorting southern pine lumber to improve drying. Forest Prod. J. 40(4):32-36.