The effect of moisture content on nondestructive probing measurements

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Abstract

When assessing existing timber structures it is not possible to obtain density as the ratio mass/volume, so nondestructive probing methods are used to predict density. As in other nondestructive techniques, moisture content influences measurements. The goal of this paper is to study the influence of timber moisture content on two nondestructive probing techniques (penetration resistance and pullout resistance). 25 large cross section specimens of laricio pine from Spain were measured. The moisture content ranged from 65.1% to 8.3%.

Penetration depth decreases and screw withdrawal strength increases when moisture content decreases below the fiber saturation point. There are lineal tendencies in both techniques. No moisture content influence was found in measures above fiber saturation point.

Keywords: moisture content, nondestructive techniques, penetration resistance, probing, pullout resistance

Introduction

Nondestructive probing methods are mainly used to evaluate existing timber structures. These techniques are used to estimate density (Bobadilla et al. 2007). Several factors affect nondestructive techniques, and one of the most important is moisture content (MC).

Some research works were found on the influence of MC over penetration depth tests. In 1978 several Pilodyn prototypes (with different diameter needles and 6, 9, 12 and 18 J energy release) were used on

Norway spruce (*Picea abies* (L.) Karst.), Scots pine (*Pinus sylvestris* L.) and European beech (*Fagus sylvatica* L.). An increase of from 1% to 2% in penetration depth for each 1% increase in MC was found in the 8% to 24% range of MC. However, above 30% of MC the increase is really low (Hoffmeyer 1978).

In another work using the Pilodyn 6J and Pilodyn 18J on 106 specimens 50 x 50 mm cross-section Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), 2 different areas of influence were found. In MC range from 6% to 30% an increase of 0.19 mm in penetration depth using the Pilodyn 6J and an increase of 0.26 mm using the Pilodyn 18J was found for each 1% MC increase. However, above 30% no significant statistical influence of MC was found (Smith and Morrell 1986).

Research work using the Pilodyn 6J Forest device (Proceq, Switzerland) on Scots pine (*Pinus sylvestris* L.), radiata pine (*Pinus radiata* D. Don) and laricio pine (*Pinus* nigra Arn.) no variation in the MC range from 8% to 14% was found. This may be due to the variability of measurements (Calderón 2012). The same work also studied the effect of MC on the Screw Withdrawal Resistance Meter (SWRM) device (Fakopp, Hungary). The increase in screw withdrawal force when MC decrease was different for each species. A second order correction equation was proposed for each species.

Other authors mention the high sensitivity of screw withdrawal techniques to MC changes (McLain 1997). Screw withdrawal force at 7% MC is approximately 50% higher than above the fiber saturation point (FSP), and there are differences between species. For sugar maple (*Acer saccharum* Marsh.) it is 71% higher, while for white pine (*Pinus strobus* L.) it is 23% higher (Cockrell 1933).

Previous studies show the MC tendency in probing measurements, and they also indicate species and source influence on MC adjustments. Therefore, specific research is required, considering these factors in one of the most widely used Spanish structural timber species: laricio pine (*Pinus* nigra Arn. Ssp. *Salzmannii*).

Material and methods

In this study 25 planed large cross-section specimens of laricio pine (*Pinus nigra* Arn. Ssp. *Salzmannii*) of Spanish provenance with nominal dimensions of 100 x 150 mm cross-section and 500 mm length were used. Green specimens were selected in the sawmill and their ends were sealed to promote uniform drying. MC was determined by the oven drying method according to standard EN 13183-1:2002.

Needle impact penetration depth using the commercial device Pilodyn 6 J Forest (Proceq, Switzerland) and screw withdrawal force using the commercial device Screw Withdrawal Resistance Meter (Fakopp, Hungary) were measured at 14 different MC. Measurements were made avoiding areas close to the pith, following the same grain and with at least a 30 mm gap between them. The first one was performed at 65.1% average MC and the final one at 8.3% average MC. 181 days were necessary from the first measurement to the last one using the natural drying process.

Results and discussion

Figure 1 shows the evolution of MC in the natural drying process. At the beginning of tests, MC values were very disperse and variable. Table 1 summarizes measurements from both techniques (penetration resistance and pullout resistance).

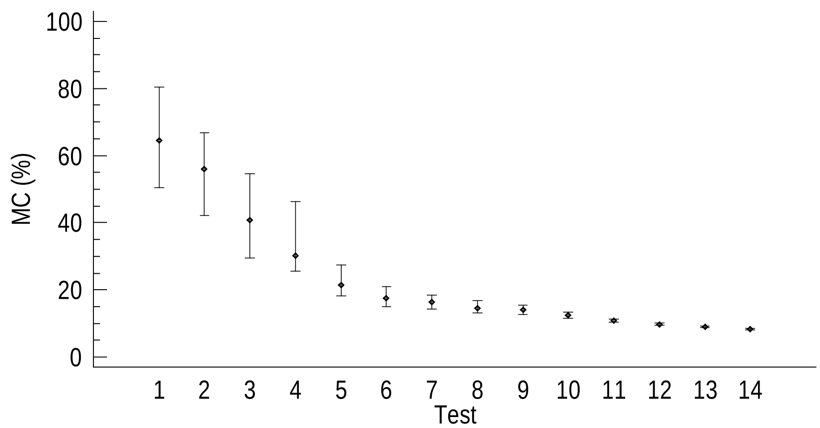

Figure 1— Average and range of MC values during the natural drying process.

Table 1— Pilodyn and SWRM mean results.

Nº Test	Day	Mean MC (%)	Mean Penetration Depth(mm)	COV (%)	Mean Screw Withdrawal Force (kN)	COV (%)
1	0	65.1	18	16.82	0.77	26.49
2	6	57.4	17	17.53	0.68	23.84
3	14	45.0	17	19.65	0.76	25.19
4	20	37.8	17	20.55	0.81	32.39
5	34	26.0	16	18.21	1.32	23.38
6	49	19.7	15	20.85	1.42	24.02
7	56	17.7	15	21.98	1.52	20.67
8	62	15.7	14	18.87	1.70	19.89
9	72	14.5	14	19.27	1.86	19.84
10	87	13.3	14	18.24	1.93	18.71
11	105	10.9	13	17.04	2.04	20.19
12	126	9.7	13	17.47	2.15	19.75
13	142	9.0	13	15.54	2.20	19.31
14	181	8.3	12	15.87	2.35	19.00

Figures 2 and 3 present the evolution of penetration depth and screw withdrawal force with MC changes. In both devices no statistical significant differences in MC range above FSP were found. The same results were found by other authors (Hoffmeyer 1978; Smith and Morrell 1986).

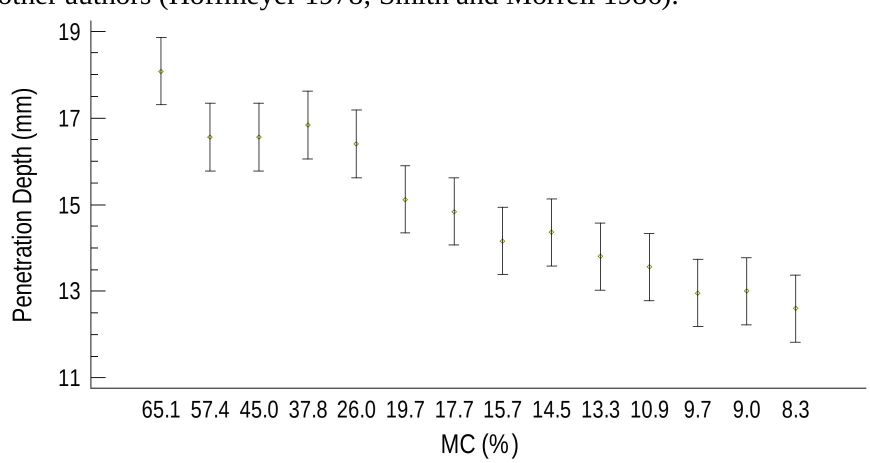

Figure 2— Means plot of one-way analysis of variance:Penetration depth vs. MC.

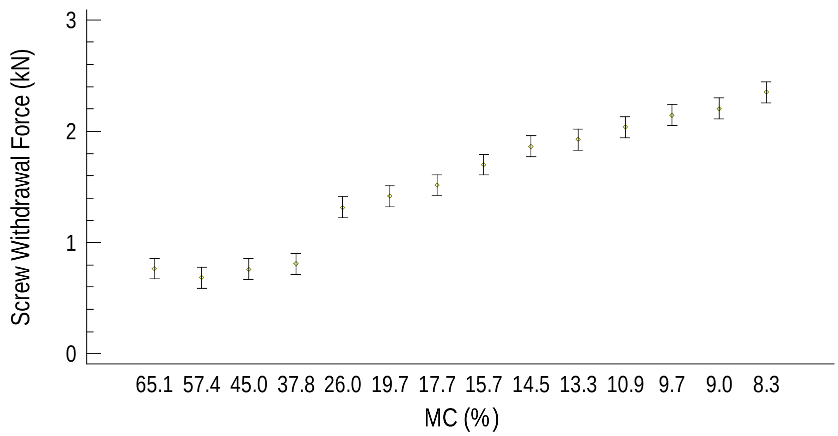

Figure 3— Means plot of one-way analysis of variance:Screw withdrawal force vs. MC.

To study tendencies below 30% of MC, figures 4 and 5 show linear regressions between penetration depth vs. MC and screw withdrawal force vs. MC, in the range from 8.3% to 30.0%. Equations and coefficients of determination are:

Pilodyn: Depth=11.4121+ 0.194262*MC R^2=15.39

SWRM: Force=2.80006-0.0701658*MC R^2=51.18

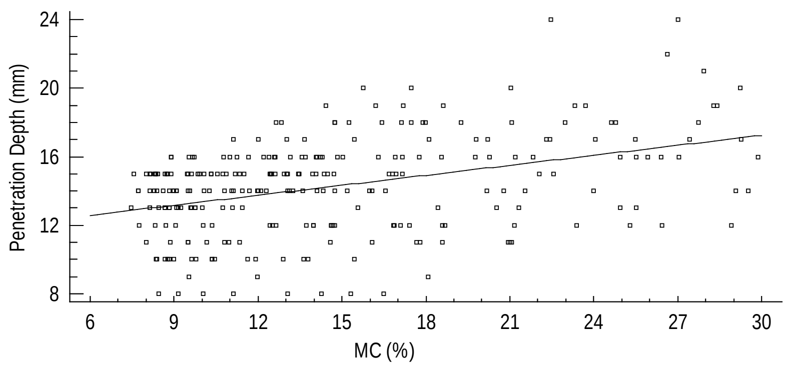

Figure 4— Linear regression: Penetration depth vs. MC.

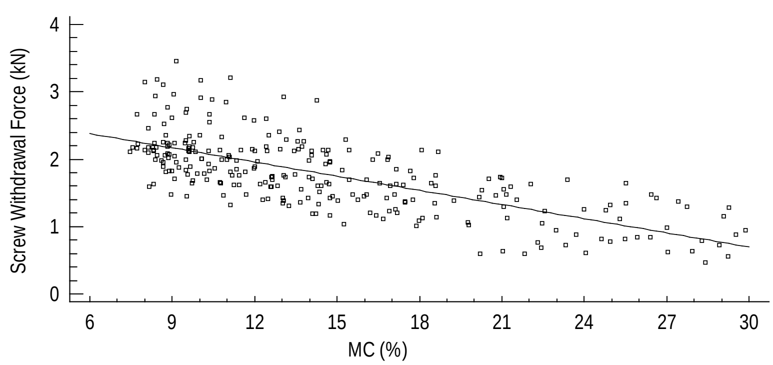

Figure 5— Linear regression: Screw withdrawal force vs. MC.

In the case of the Pilodyn 6J Forest device an increase of 0.19 mm (1.7%) was found in penetration depth for each 1% on MC increase. This is same value as was proposed by other authors (Smith and Morrell 1986) and the 1.7% increase is in the range from 1% to 2% proposed by Hoffmeyer (Hoffmeyer 1978).

In the SWRM device a decrease of 0.07 kN (2.5%) was found for each 1% MC increase. This value is inside the range 0.05 kN to 0.15 kN obtained by Calderon in laricio pine, and is within the range of 12% to 18% MC (Calderón 2012).

Conclusions

Pilodyn penetration depth and SWRM screw withdrawal force in laricio pine (*Pinus* nigra Arn. Ssp. *Salzmannii*) from Spain have a linear relationship with moisture content below 30%, although there is no statistically significant affect due to moisture content above 30%.

Penetration depth increases 0.19 mm and screw withdrawal force decreases 0.07 kN with each percentage increase in moisture content up to fiber saturation point.

These results correspond to a small number of specimens and only one species. Forthcoming studies will extend this research to cover other Spanish conifer species.

Acknowledgments

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Abstract

The 19th International Nondestructive Testing and Evaluation of Wood Symposium was hosted by the University of Campinas, College of Agricultural Engineering (FEAGRI/UNICAMP), and the Brazilian Association of Nondestructive Testing and Evaluation (ABENDI) in Rio de Janeiro, Brazil, on September 22–25, 2015. This Symposium was a forum for those involved in nondestructive testing and evaluation (NDT/NDE) of wood and brought together many NDT/NDE users, suppliers, international researchers, representatives from various government agencies, and other groups to share research results, products, and technology for evaluating a wide range of wood products, including standing trees, logs, lumber, and wood structures. Networking among participants encouraged international collaborative efforts and fostered the implementation of NDT/NDE technologies around the world. The technical content of the 19th Symposium is captured in these proceedings.

Keywords: International Nondestructive Testing and Evaluation of Wood Symposium, nondestructive testing, nondestructive evaluation, wood, wood products

Contents

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