Subfossil Waterlogged Oak-wood (Abonos) Moisture Content Estimation by Electrical Resistance Method

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ABSTRACT

Subfossil waterlogged oak-wood (Abonos) is very rare, expensive, and it is difficult to work with, with special emphasis on its drying. Additionally, information about correct procedures for moisture content estimation and monitoring of abonos is mostly scarce. In this research paper, investigation on how to conduct moisture content measurement and estimation correctly on subfossil waterlogged oak-wood from two different locations has been conducted, analyzed and discussed.

Key words: Subfossil oak-wood, Abonos, Moisture content estimation, Electrical resistance method

1. INTRODUCTION

1.1. Subfossil waterlogged oak-wood (Abonos)

Subfossil waterlogged oak-wood (*in Croatian*: Abonos) is an oak-wood (*Quercus* spp.) that has been submerged in river bottom/riverside or in wetlands, under low oxygen and high water level conditions, over a longer period of time (mostly >1000 years). Under such conditions oak-wood degradation is minimized and wood acquires (in a greater or lesser extent) black or dark brown colour, by chemical reactions due to inorganic substances precipitation within wood matrix. Tannins in oaks are precursors of colour formation.

Figure 1. Abonos logs (photo: Klarić)

Figure 2. Abonos (left) and present-day oak (right) (Sinković et al., 2009)

Figure 3. Abonos colour difference due to its age (Franjić, 2017)

As compared to present-day (recent) oak-wood, abonos has a somewhat higher density and much higher shrinkage that is almost the double than at present day oak-wood (Sinković *et al.,* 2009).

Table 1. Density and shrinkage comparison (Sinković et al., 2009)

Property	Abonos	Present-day oak
	mean ± SD	
ρ_0 [g/cm^3]	0.704 ± 0.04483	0.608 ± 0.06489
$\beta_{r\ max}$ [%]	10.5 ± 1.266	5.1 ± 1.026
$\beta_{t\ max}$ [%]	18.6 ± 1.963	9.1 ± 1.382
$\beta_{v\ max}$ [%]	27.6 ± 2.033	13.7 ± 2.014

Note: ρ_0 – density in absolutely dry state; $\beta_{r\ max}$ – total radial shrinkage; $\beta_{t\ max}$ – total tangential shrinkage; $\beta_{v\ max}$ – total volume shrinkage.

Figure 4. Abonos shrinkage and cracks (photo: Klarić)

Abonos is very valuable raw material, and it is usually used for production of highly value added products, such as furniture, ornaments, tobacco pipes, or fine decorative goods.

Figure 5. Abonos products store (Franjić, 2017)

Figure 6. Abonos electric guitar (Franjić, 2017)

1.2. Problematics

Abonos is very rare, expensive and it is difficult to work with, with special emphasis on its drying. Abonos is very difficult to dry without defects and it has to be dried very slowly, it is often air dried for several years. During long lasting drying procedure and during the production, moisture content of wood has to be controlled frequently. Oven-dry method for determination of moisture content of wood should be the most suitable and most precise method for abonos among three existing standardized methods in European Union. However, oven-dry method is time consuming, non-practical, while part of lumber has to be destroyed during the measurement. The most practical moisture content estimation method would be electrical resistance method, but the wood species code number for abonos does not exist for these type moisture meters (it is not provided by manufacturers of the moisture meters). When measuring moisture content of abonos, people often use species code number for regular, present-day oak and such a measurement is certainly not correct. In this research paper, moisture content of four different abonos samples from two different locations (river basins) has been determined by oven-dry method (reference method) and compared to six different species group code numbers provided by manufacturer of one electrical resistance type moisture meter. The research was conducted to find out, how big the deviation from oven-dry results is for each species code number and can some other species code of electrical resistance moisture meter be used for estimation of abonos moisture content; or the differences between different samples are too big to generally always use one species code.

2. MATERIAL AND METHODS

2.1. Material

In this research, four different groups of abonos wood samples from two different locations (river basins) were acquired. The wood samples were dried differently. Information about each group of samples is listed in *Table 2*.

Table 2. Information about groups of abonos samples used in this research

Group of abonos samples	Type and duration of drying	Finding site
A	Naturally air dried mainly in form of log (~5-6 years)	The surrounding area of Zagreb city (the river Sava basin)
B	Naturally air dried mainly in form of lumber (~5-6 years)	The surrounding area of Zagreb city (the river Sava basin)
C	Naturally air dried mainly in form of lumber (~1 year)	The surrounding area of Varaždin city (the river Drava basin)
D	Naturally air dried mainly in form of lumber (~2 years), then dried in vacuum dryer	The surrounding area of Varaždin city (the river Drava basin)

From sawn abonos wood, radial surface elements were cut with following dimensions: cross section 6 × 2 cm, and length from 37 to 63 centimetres. The elements were immediately vacuum-sealed to prevent uncontrolled drying or moistening. Then the vacuum-sealed elements were heated in Memmert UF 110 ventilated oven at 23 ºC for 48 hours before measurement, in order to equalize its temperature.

Figure 7. Sawing the elements (photo: Klarić)

Figure 8. Vacuum-sealed elements (photo: Klarić)

2.2. Methods

2.2.1. Electrical resistance moisture content estimation

In this research GANN Hydromette M 4050 electrical resistance type moisture meter was used, together with test plug for checking wood moisture readings, and infrared surface temperature probe IR 40 EL. Teflon insulated pins M18 (45 mm) for ram-in electrode were used to ensure the correct measurement positioning. The measurements were performed in the middle of the thickness of the sample perpendicular to the wood fibres direction. Thirty measurements (different samples) were conducted for A, B and C groups of abonos and 15 measurements (different samples) were conducted for D group of abonos. During the measurement six different wood species codes available in GANN Hydromette M 4050 were tested. The codes of wood species groups (351, 352, 353, and 354), code for oak (166) and code for African ebony (161) were used. Within elements, samples were marked with graphite pencil and after conducted measurement, elements were cut according to graphite pen marks on samples 3 cm (longitudinal direction) × 6 cm (radial direction) × 2 cm (tangential direction) on METABO BAS 260 Swift table band saw. During the measurement, temperature in the laboratory was set to 23 ºC.

GANN wood species codes in the order listed: 351, 352, 353 and 354 of used moisture meter (Hydromette M 4050) corresponds to the codes of other similar GANN types of moisture meters in order as listed: 1, 2, 3, and 4 (Ege, 2017).

Figure 9. GANN Hydromette M 4050 (photo: Klarić)

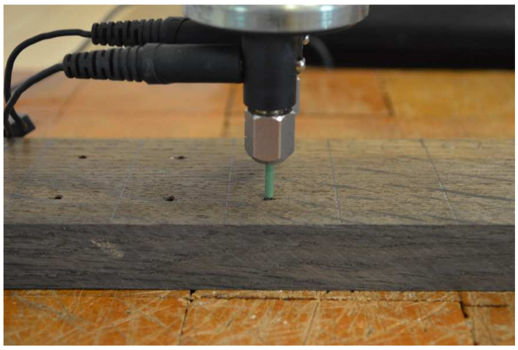

Figure 10. Measurement with moisture meter (photo: Klarić)

2.2.2. Oven-dry moisture content determination

Within the scope of implementation of oven-dry method, special procedure was used to ensure comparable data between electrical resistance method and oven-dry method. Professor Hrvoje Turkulin, PhD (Turkulin, 2017) developed the used procedure within LDG laboratory. According to the aforementioned procedure, first the moisture content was measured by electrical resistance method in the middle of the sample, than the outer four sides/layer of the sample were cut off with the axe (*Figure 11 and 12*). Then from the central piece of the sample, dust was brushed and loose splinters were removed and the central piece was used for oven-dry measurement. Essence of the procedure is that the moisture content is measured with both methods on the same place of the sample, and to avoid the negative influence of the moisture content gradient especially on the oven-dry measurement. As well, by usage of the axe, occurrence of excessive heat and subsequently water evaporation is avoided. During the gravimetric analysis the samples were weighed (Sartorius CP4202-0CE), oven dried (Memmert UF 110) until the constant mass was reached, cooled in a glass desiccator and weighed again. Moisture content was calculated according to the formula (1).

$$\omega = \frac{m_1 - m_0}{m_0} \times 100 \qquad (1)$$

Where:
ω – moisture content [%]
m_1 – the mass of the test slice before drying [g]
m_0 – the mass of the oven dry test slice [g]

Figure 11. Slicing samples (photo: Klarić)

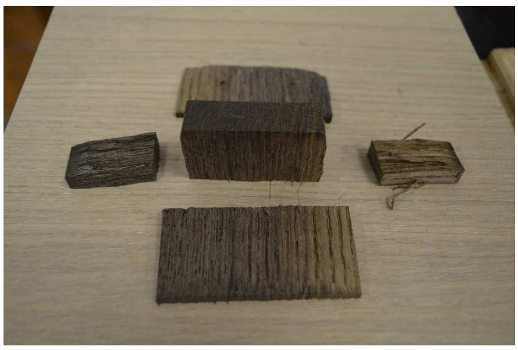

Figure 12. Sliced sample (photo: Klarić)

3. RESULTS AND DISCUSSION

On the following figures (*Figures 13 to 16*) measured values in percentage of moisture content (MC) for each group of abonos samples (A to D, see *Table 2*) are presented. Lines in graphs shows measured values by oven-dry method (as reference value) and measured values for each used wood specie code (166, 161, 351, 352, 353, and 354) from GANN electrical resistance moisture meter. All values are expressed in percentage of moisture content in relation to absolutely dry wood.

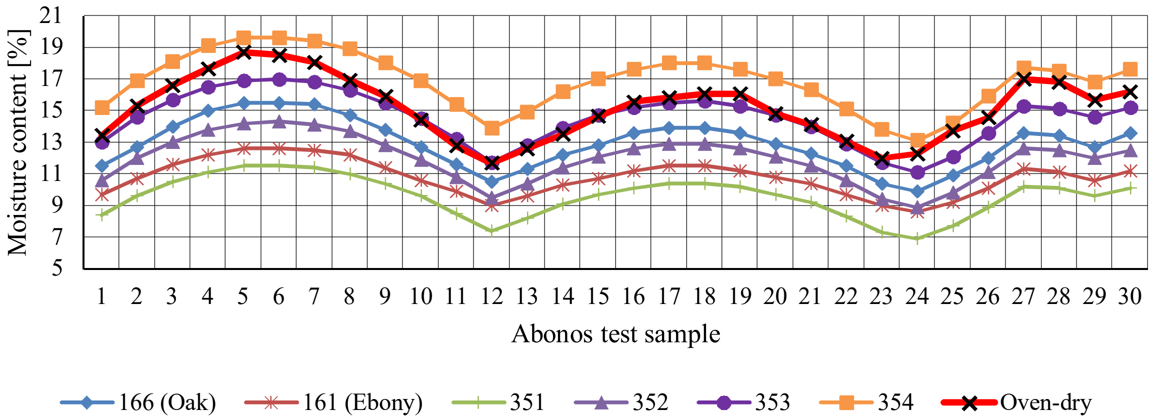

*Figure 13. Measured values of abonos samples - **group A***

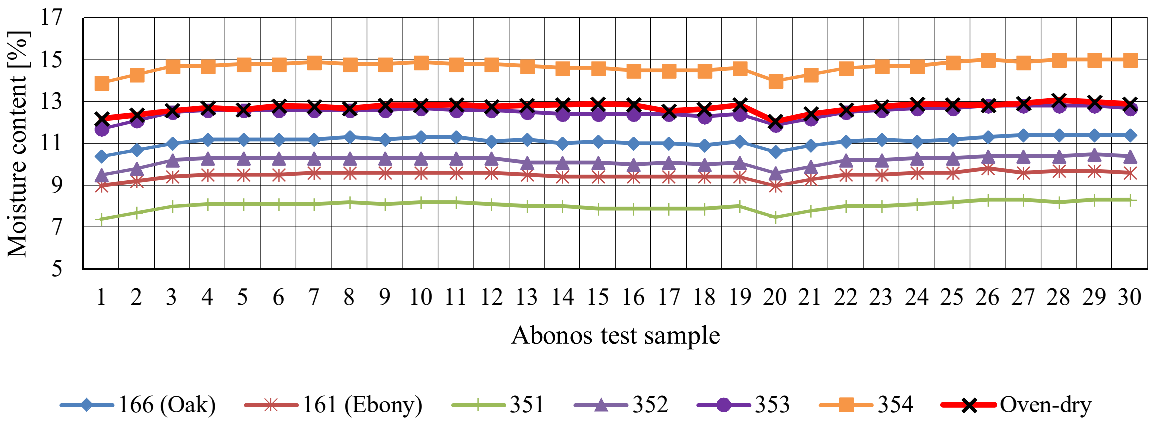

*Figure 14. Measured values of abonos samples - **group B***

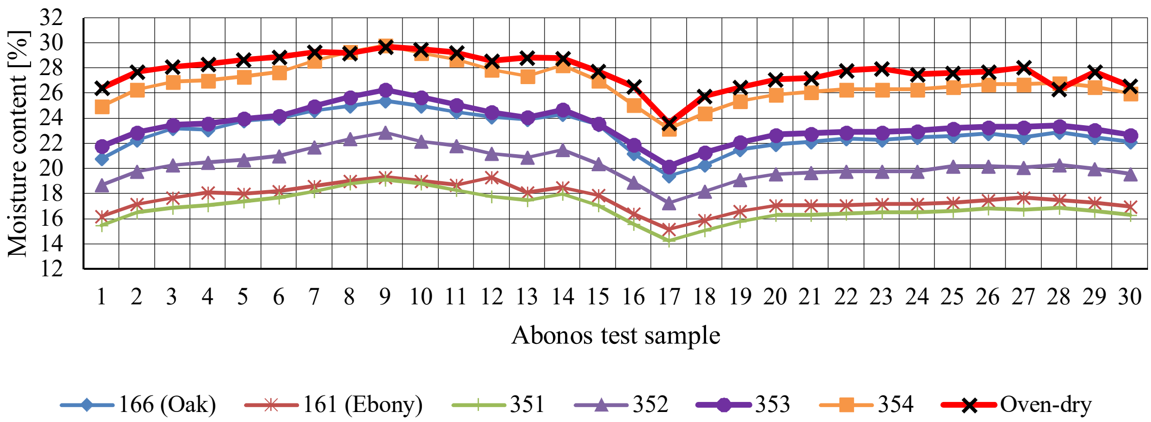

*Figure 15. Measured values of Abonos samples - **group C***

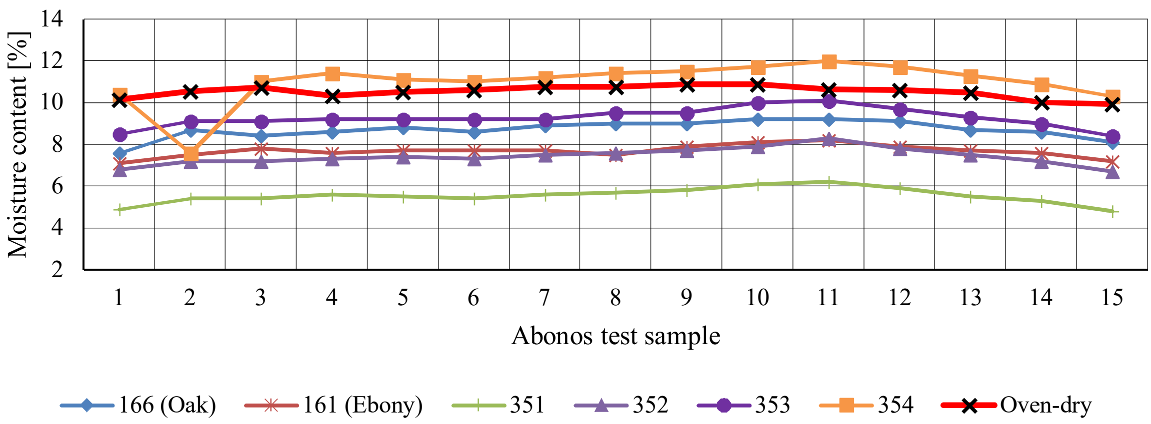

*Figure 16. Measured values of Abonos samples - **group D***

On previous *Figures 13* and *14* it can be seen that as concerns abonos samples which originates from Sava river basin (groups A and B) the best matching with oven-dry (reference) results is obtained with GANN code for group of wood species 353. The biggest deviation is obtained with the GANN code for group of wood species 351.

As can be seen in previous *Figures 15* and *16* the best matching with oven-dry (reference) results is obtained with GANN code for group of wood species 354 (for groups C and D). As concerns abonos which originates from Drava river basin (groups C and D) the biggest deviation is obtained with the GANN code for group of wood species 351.

Table 3. Difference between oven-dry method and electrical resistance method, in absolute values [% of MC]

Group of abonos samples	**Wood species code**	**N**	**MAE**	**RMSE**	**Prevailing tendency [+ or -]**	**MAD**
A	166	30	2.2	2.3	-	0.5
	161		4.4	4.5	-	0.8
	351		5.6	5.6	-	0.7
	352		3.2	3.3	-	0.6
	353		**0.7**	**0.9**	**Predominantly -**	**0.5**
	354		1.7	1.8	+	0.5
B	166	30	1.6	1.6	-	0.1
	161		3.2	3.2	-	0.1
	351		4.7	4.7	-	0.1
	352		2.5	2.6	-	0.1
	353		**0.2**	**0.3**	**Predominantly -**	**0.1**
	354		2.0	2.0	+	0.1
C	166	30	4.9	4.9	-	0.4
	161		10.2	10.2	-	0.4
	351		10.9	10.9	-	0.3
	352		7.5	7.5	-	0.4
	353		4.3	4.3	-	0.4
	354		**1.0**	**1.1**	**Predominantly -**	**0.4**
D	166	15	1.8	1.8	-	0.2
	161		2.8	2.8	-	0.2
	351		5.0	5.0	-	0.2
	352		3.1	3.1	-	0.2
	353		1.2	1.3	-	0.2
	354		**0.8**	**1.1**	**Predominantly +**	**0.4**

NOTE: ***N*** – number of samples; ***MAE*** – Mean Absolute Error; ***RMSE*** – Root Mean Square Error; ***MAD*** – Mean Absolute Deviation.

In *Table 3,* the obtained differences of measured values between oven-dry method, as reference method and electrical resistance method are presented. The smallest MAE (Mean Absolute Error) (< 1 % MC) for abonos groups A and B (river Sava basin) is obtained with

GANN electrical moisture meter wood species code 353. However, there is some difference between obtained values for abonos groups A and B (Δ_{MAE} = 0.5). While the smallest MAE (≤ 1 % MC) for abonos groups C and D (river Drava basin) is obtained with GANN electrical moisture meter wood species code 354. There is smaller difference between abonos groups C and D (Δ_{MAE} = 0.2) than between abonos groups A and B. It is clearly visible from the presented results that the smaller MEA is, the measured values with electrical moisture meter have tendency to be both negative and positive in respect to corresponding oven-dry reference value. Clearly, many factors influence the measurement with electrical resistance method. Some of those factors are location of finding site of abonos logs, soil and water chemical composition, duration of log submersion/age, possible degradation of abonos wood, probably even the method and duration of drying and possible microorganisms degradation during storage and drying, *etc*. In the case of studied logs, the most suitable of the tested wood species codes of moisture meter are determined, but for each new abonos log, the correlation between oven-dry and electrical resistance method should be determined to avoid false results readings, and to exclude erroneous measurement with electrical resistance moisture meter. Additionally, groups of abonos samples A and B were mutually similar in colour, they were black, while abonos groups C and D were mutually similar in colour, and they were dark brown. Therefore, abonos colour is certainly an approximate indicator of similarity if the logs are from the same finding site. This indicate that soil and water of these two different basins have different chemical composition, *i.e.* composition of inorganic elements.

4. CONCLUSIONS

1. In the case of investigated abonos samples, it has been determined, that the wood species code of moisture meter 353 is the most suitable for samples from Sava river basin, and the code 354 is the most suitable for samples from Drava river basin.
2. Visual similarity or difference in structure and colour between abonos wood logs from the same location of origin can be an approximate indicator of similarity or difference in their electrical properties.
3. The electrical resistance method is a practical and reliable method for abonos, if a good preparation has been done and if the method is tested in each particular case. There may be big differences in properties between each individual abonos log.
4. The recommendation is that for each abonos log should be conducted comparison of oven-dry method and electrical resistance method, regardless of the moisture meter manufacturer. In this way the one will know which code of moisture meter is most suitable, and how much the results deviate from the oven-dry method results (reference results), and especially in which direction (positive, negative or both ways).

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