Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 92, 2015: 448-454
(Ann. WULS - SGGW, For. and Wood Technol. 92, 2015)

The impact of moisture content of wood on the results of non-destructive tests

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Abstract: *The impact of moisture content of wood on the results of non-destructive tests*. Wood maintains remarkable durability under optimum conditions. However, it erodes faster than other construction materials in the circumstances of average usage of civil structures. Therefore built features made of wood, especially historical features and structures, require repairs and reinforcements more frequently than those made of other materials. Non-destructive testing is usually carried out in structures that are currently in use and is aimed at early detection of failures and taking appropriate remedial measures. This paper presents problems related to the impact of moisture content on the results of sclerometer and ultrasonic tests and cutting resistance measurements. Based on the survey found a significant effect on the results of the wood moisture of all its non-destructive testing. Was found necessary to take into account the moisture content of wood in the course of the analysis using non-destructive methods

Keywords: wooden constructions, non-destructive testing, wood moisture

INTRODUCTION

Wood maintains remarkable durability under optimum conditions. However, it erodes faster than other construction materials in the circumstances of average usage of civil structures. Therefore built features made of wood, especially historical features and structures, require repairs and reinforcements more frequently than those made of other materials. To perform these repairs and reinforcements properly, it is necessary to specify the current technical state of the wood and its physical and mechanical properties. This can be done through the use of destructive or non-destructive testing methods. Destructive tests require taking large number of samples from a structure, which is usually unacceptable in the case of historic or heritage structures. Non-destructive tests performed on wooden structures, thus, are a valuable source of information about their condition. However, it should be borne in mind that non-destructive test results are influenced by factors such as: the type of wood, its defects, moisture content, and age, as well as microbial agents. This paper presents problems related to the impact of moisture content on the results of sclerometer and ultrasonic tests and cutting resistance measurements.

NON-DESTRUCTIVE TESTS PERFORMED ON WOODEN STRUCTURES

Non-destructive testing is usually carried out in structures that are currently in use and is aimed at early detection of failures and taking appropriate remedial measures. The use of non-destructive techniques, however, requires great skills and experience and involves complexities in interpreting the results. It can be generally assumed that diagnostic testing of wood is a difficult process due to its structure. However, the ability to identify the current strength parameters of wooden structural components makes it possible to properly assess their suitability for further use and design appropriate reinforcement and reconstruction methods. Non-destructive testing can be divided into two groups: fully non-destructive and semi-destructive. The first group includes the visual method (macroscopic evaluation) and technical tests based on acoustic, electromagnetic, and radiological methods. The second group includes penetration methods, including sclerometer testing, cutting resistance measurements, and pull-off tests. The most frequently used method is the macroscopic evaluation of drilling resistance measurement test, followed by ultrasonic and sclerometer testing. Figure 1 shows the classification of the testing methods used for wooden structures.

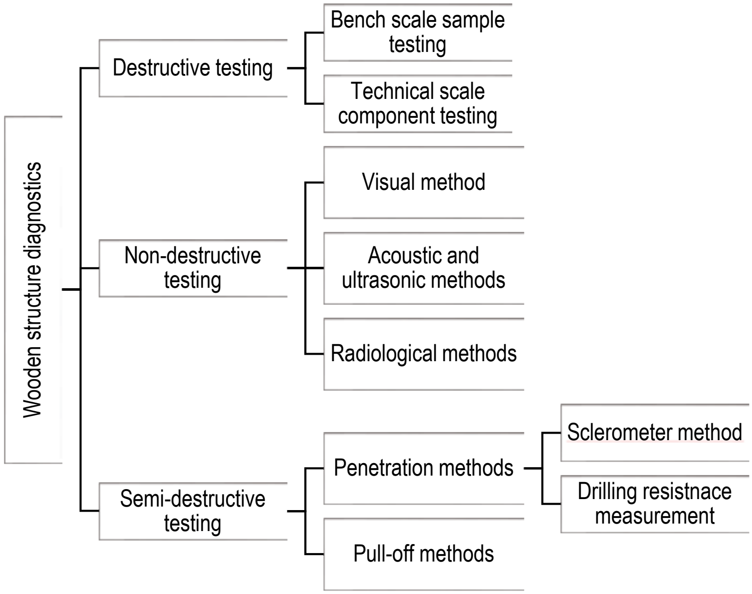

Figure 1. The classification of non-destructive testing methods used for wooden structures

MACROSCOPIC EVALUATION

Macroscopic evaluation is the simplest and most common testing method used in identification of the properties of wooden components. It is conducted during a drawing and measuring survey in the case of non-buried components, such as roof framing, or after performance of the planned uncovering, e.g. in the case of floor beams covered with floor topping or stucco and plaster coatings. Macroscopic observations allow for preliminary assessment of the technical condition of structural components, their degree of wear and the influence of biological factors, microclimate, and workmanship defects. Macroscopic evaluation makes it possible to determine whether components were attacked by fungi, meld, or insects [8].

ACOUSTIC AND ULTRASONIC METHODS

Another group of testing methods is testing based on the phenomenon of propagation of elastic waves in a medium. The most common tests of this type are ultrasonic tests. These are widely used to identify the physical, geometrical, and mechanical properties of construction materials. They use the phenomenon of propagation of waves of sufficiently high frequencies (>30 kHz). The ultrasonic waves are introduced into the material by means of a head, whose main component is the so-called transducer – a thin plate of piezoelectric material producing short-term resonant vibrations of a pre-set frequency. Stimulating the piezoelectric transducer with electrical impulses and "listening" are performed by means of an ultrasonic flaw detector. Determination of the properties of the tested material is possible by analysing the velocity of ultrasonic wave propagation in a given medium and the nature of the graph (wave impulse amplitude). Research papers present the possibility of using ultrasonic methods for the assessment of corrosion rate of wooden structures, the degree of their degradation and their bending tensile strength [3,9].

SCLEROMETER TESTING

Sclerometer tests on wood consists in measuring the depth of penetration of a 50-mm steel pin driven into the wood with a constant energy (e.g. 2.3 Nm). After the pin of a certain length penetrates the wood, a special dial gauge is used to measure the depth of the cavity. This makes it possible to determine the quality of the subsurface layers present in the component (mainly based on its resistance to pressure and thus its hardness). Foreign manufacturers of sclerometer testing equipment provide correlation tables for specific types of wood, which allow to determine the modulus of elasticity and flexural strength along the fibres, depending on the depth of the steel pin penetration. Correlation curves do not take into account any additional factors that wooden structures are exposed to, though. Their applicability is also limited in the domestic context due to the local character of the wood types for which correlations are provided (oak, poplar, chestnut) [Operation manual]. Research conducted on the usefulness of this device or devices with a similar principle of operation is presented among others in [1,5,6].

DRILL RESISTANCE TESTING

Another method of quasi non-destructive testing of the technical condition of wooden components is measurement by means of a resistograph. The device is equipped with a drill of 3 mm diameter – the holes resulting from the test do not affect the statics of the structure or the aesthetics of the surface. The measurement consists in determining the strength of the drill cutting resistance in the tested wood. The measurement of cutting resistance is a measurable indicator of the condition of wood. The maximum measurement depth is 500 mm, which in the case of typical wooden structures is sufficient [2, 5, 6]. The advantages of using a resistograph include: a short testing time, an immediate result of the measurement, testing across the entire section of the component, and ability to test components covered by other items. This method, however, requires experience in interpreting the results and should be used by people who have experience in working with wood.

THE EFFECT OF MOISTURE CONTENT OF WOOD ON THE RESULTS OF NON-DESTRUCTIVE TESTS

The condition of wooden structures depends primarily on moisture conditions prevailing in the room. Moisture content of wood, or wood moistness, is one of the most important parameters of this material. Moisture content significantly affects the mass of the wood, its dimensions, volume, physical, and mechanical properties (strength), and its resistance to attacks by fungi, meld, and insects [4].

Moisture content affects the strength of wood from hygroscopic point of view, while the effect of moisture content on the strength of wood from capillary point of view is negligible. Across the moisture content range (from air dry state to fibre saturation, the compressive strength of wood is reduced by approx. 50%, and its bending strength – by approx. 40%. However, we do not observe a significant effect of moisture content on the tensile and shear strength [7].

TEST PLAN

To quantify the effect of moisture content of wood on the destructive test results, a pilot series of non-destructive tests was conducted for samples of beech, oak, and ash wood. For each of the wood types, 4 samples were prepared. Test pieces were 40 x 44 x 900 mm and had 4 testing areas specified within, where non-destructive testing was carried out subsequently in the air dry state and then in the state of fibre saturation. The tests included macroscopic evaluation, which considered the material to be statistically homogeneous, then ultrasonic testing, sclerometer testing, and solely for beech wood – cutting resistance testing. All the tests were performed across fibres, as it was assumed that this would be a potential direction in which wooden built structural components may be tested.

ULTRASONIC TESTING

In the first phase of the testing cycle, the velocity of the ultrasonic wave propagation through the material was identified. The testing was performed using a PunditLab set manufactured by Proseq, equipped with 54 kHz transducers. For each measuring point, at least 3 measurements of the velocity of wave propagation were taken. The average velocities of wave propagation for wet and dry samples are shown graphically in Figure 2.

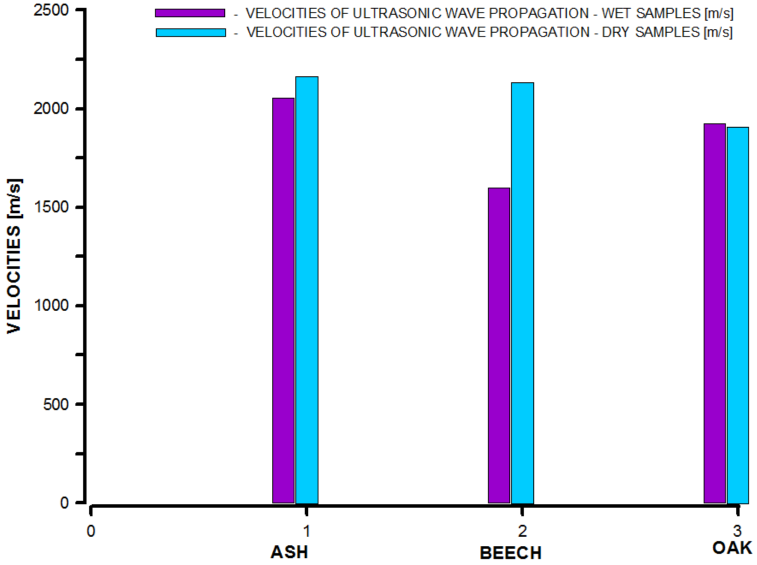

Figure 2. The comparison of the velocities of ultrasonic wave propagation for dry and wet samples

For beech and ash samples, a decrease in the velocity of ultrasonic wave propagation was recorded, respectively by 25% for beech and 5% for ash samples, whereas for the oak samples a minimal 0.06% increase in the velocity of wave propagation was observed. The results show that the impact of moisture content of wood on the results of ultrasonic tests is variable and highly dependent on the type of wood.

SCLEROMETER TESTING

Subsequently, the depth of steel pin penetration in the sample material was determined by means of a sclerometer (Woodtester-Novatest). For each point, 6 measurements of the penetration depth were taken. Figure 3 shows the average penetration depth values for wet and dry samples.

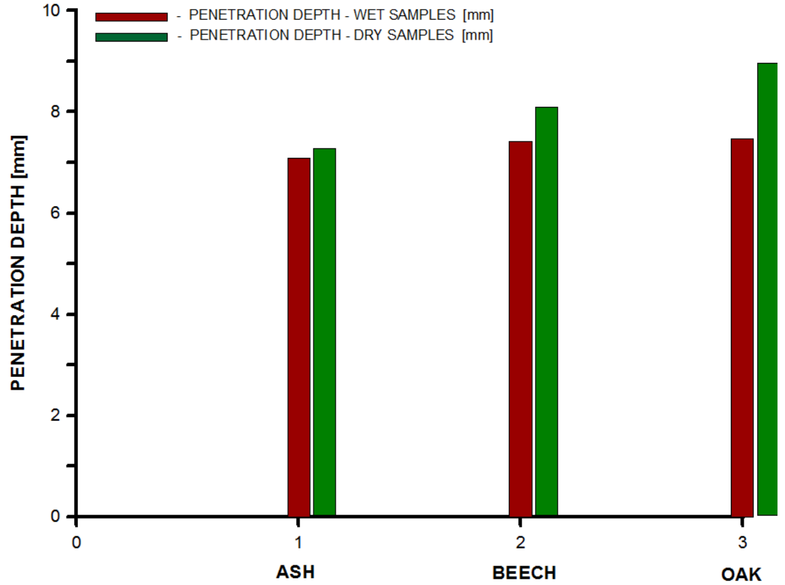

Figure 3. The comparison of sclerometer test results for dry and wet samples

CUTTING RESISTANCE TESTING

The last part of non-destructive testing included measurements of cutting resistance performed for beech samples. These tests, in contrast to those presented above, do not give an individual result. They must be analysed for the whole cross-section of the test piece. For comparative purposes, averaged test results were juxtaposed for 10 measurements of wet samples and 10 measurements of dry samples, as shown in Figure 4.

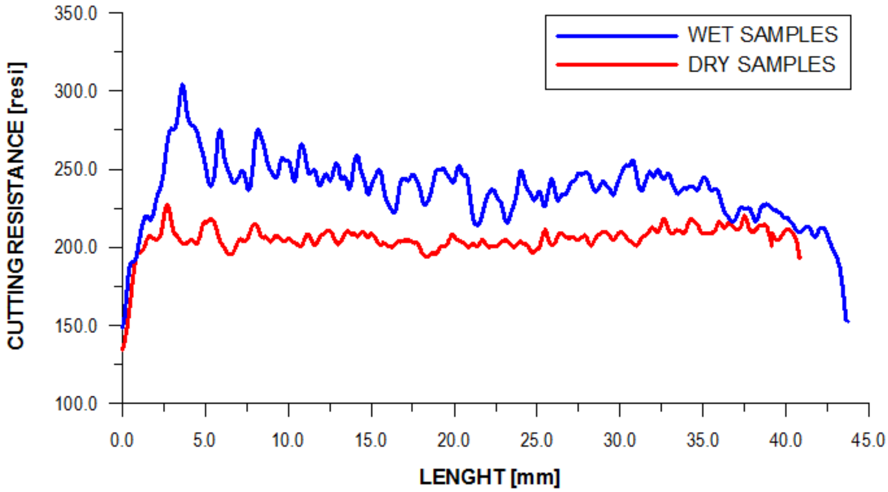

Figure 4. The comparison of cutting resistance graphs for wet and dry samples

For beech wood, cutting resistance increases with the moisture content, but exact quantitative interpretation of this result is not possible at this stage of the study. However, the cutting resistance graph shows that air dry samples exhibit much greater stability in terms of resistance than the samples in the state of fibre saturation, which confirms the significant impact of moisture content on the test results.

RESULTS

Based on the conducted tests and their results, the following conclusions could be arrived at:

- the impact of moisture content on the results of non-destructive and semi-destructive tests performed on wooden structures is significant and may not be overlooked during performance of such tests;
- in the case of sclerometer tests, it can be seen that the steel pin penetration depth increases with an increase in moisture content, and for some wood types this increase is as high as 22%;
- ultrasonic testing showed that the moisture content impacts the measurement results, however this is not as clear-cut as in the case of sclerometer tests. Depending on the type of wood, moisture content can increase or decrease the velocity of ultrasonic wave propagation;
- cutting resistance tests were performed for one type of wood only and quantitative analysis was not possible. However, it can be assumed that an increase in resistance will be observed proportionally to an increase in moisture content should further tests on other types of wood be conducted;

It should be noted that in order to perform quantitative evaluation of the effect of moisture content on the results of various non-destructive tests in the diagnosis of wooden structures it is necessary to perform testing work on a large number of components for different wood types and varying degrees of moisture content.

REFERENCES

1. GIEFING D. F., 1992. Badanie drewna urządzeniem pilodyn, Roczniki Akademi Rolniczej w Poznaniu
2. JASIEŃKO J., 2009. Analiza stanu zachowania drewnianych stropów w Auli Leopoldyńskiej Uniwersytetu Wrocławskiego oraz w budynku głównego dworca kolejowego we Wrocławiu, Wiadomości Konserwatorskie nr 26
3. KARYŚ J., 2007. Możliwości wykorzystania metody rezonansowej w ocenie postępu korozji biologicznej drewna i konstrukcji drewnianych, DREWNO nr 177
4. KOZAKIEWICZ P., 2012. Fizyka drewna w teorii i zadaniach. Wydawnictwo SGGW
5. MIELCZAREK Z., 2001. Diagnostyka konstrukcji drewnianych, Materiały konferencyjne, Awarie i katastrofy budowlane
6. NEGRO P., 2009. Combined non-destructive and destructive tests for the mechanical characterization of old structural timber elements, 3rd International conference on Advances in Experimental Structural Engineering, San-Francisco
7. NEUHAUS H., 2004. Budownictwo drewniane, Polskie Wydawnictwo Techniczne
8. RUDZIŃSKI L., 2008. Konstrukcje drewniane. Naprawy, wzmocnienia, przykłady obliczeń, Wydawnictwo Politechniki Świętokrzyskiej
9. WAŻNY J., KRUPIK W., 200. Konserwacja drewna zabytkowego w Polsce, Nauka nr 1

Streszczenie: *Wpływ zawilgocenia drewna na wyniki badań nieniszczących.* W optymalnych warunkach drewno zachowuje niezwykłą trwałość, jednak w warunkach przeciętnej eksploatacji obiektów budowlanych ulega niszczeniu szybciej niż pozostałe materiały budowlane. Badania nieniszczące, prowadzane są zazwyczaj w użytkowanych obiektach i mają na celu wcześniejszą detekcję możliwości awarii i przedsięwzięcie odpowiednich środków zaradczych. Stan zachowania konstrukcji drewnianych zależy przede wszystkim od warunków wilgotnościowych jakie panują w pomieszczeniu. Wilgotność drewna, czyli zawartość wilgoci w drewnie, jest jednym z najistotniejszych parametrów tego materiału. W celu ilościowego określenia wpływu wilgotności drewna na wyniki badań niszczących przeprowadzono pilotażową serię badań nieniszczących dla próbek drewna bukowego, dębowego i drewna jesionu. Przedstawione w pracy badania wskazują, że wpływ wilgotności na wyniki badań nieniszczących i semi-nieniszczących konstrukcji drewnianych jest znaczny i nie może być pomijany w trakcie wykonywania tych badań.

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