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Original Research Article

DETERMINATION OF THE STRENGTH PARAMETERS OF PINEWOOD BASED ON THE NON-DESTRUCTIVE SCLEROMETRIC TEST WITH A WOOD HAMMER

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A b s t r a c t

To assess the technical condition of a structure and design it using existing elements, it is necessary to know its parameters. For existing facilities, it is often not possible to get a sample of material and examine it directly in the laboratory. For this reason, in situ non-destructive testing is very important.

The main goal of the paper is to present the issues related to determining the strength parameters of a particular wood based on the non-destructive sclerometric test performed with a wood sclerometric hammer. The study also presents the results of the impact of pinewood density on its compressive strength.

Keywords: wood, non-destructive tests, sclerometric tests, wood compressive strength

1. INTRODUCTION

Wood as a construction material has been used almost since the very beginning of the construction of dwellings. Due to its widespread occurrence, easy processing, and relatively good strength characteristics, wood was used in the first man-made constructions and remains a crucial element of contemporary building projects.

Wood as a material is completely anisotropic. By virtue of its natural origin, it is not possible to influence the physical and mechanical properties of this material.

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It is also characterized by high variability of parameters even within one element, which is often a problem and can be an obstacle to its use.
Due to issues over safety of use and durability of buildings, materials used in construction are subjected to the strictest requirements. Currently, in the case of wooden materials, there are a number of standards describing the basic criteria for the application of the material in the construction industry.
Buildings erected today are made of wood previously selected, tested, and properly marked. All these prior treatments allow the determination, with very high probability and guaranteed physical and mechanical properties, of the material used. Thanks to this, it is possible at the design stage to conduct appropriate static and strength analyses which allow ensuring the safe use of the facility.
One significant problem lies in attempts to determine the strength characteristics of any wood previously built in, where there is no design documentation. For adaptation or renovation works, it is necessary to adopt structural classifications for the calculations. Practice shows that in such cases, the class of elements is often underestimated. Consequently, the requirement to meet applicable standards means that existing structures, for several dozen or even several hundred years, have required reinforcement despite being in good technical condition.
The authors of the publication performed experimental tests, checking the possibility of estimating the compressive strength of wooden elements embedded in objects using a non-destructive method (this method is desirable in the case of historic objects and in the absence of the possibility of taking samples for laboratory tests).

2. NON-DESTRUCTIVE TESTING OF WOOD

Non-destructive testing of wood is widely used in wood assortment plants to verify the physical and mechanical characteristics of products. Compared to the classical methods, the test procedure is less complex and time-consuming, and the sample itself does not get damaged. Based on these tests, the density of wood, its hardness, and any defects can be determined.

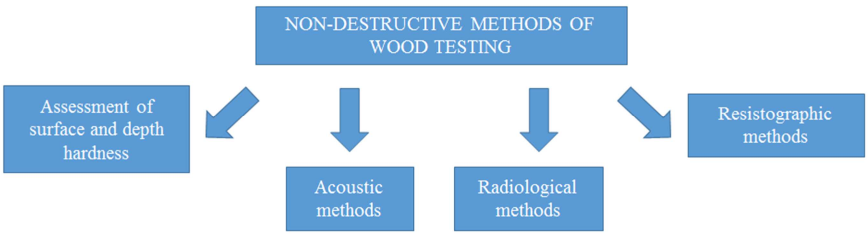


Fig. 1. Location of measurement sites

However, wood tests are relatively expensive compared to the value of wood as a building material. Due to the cost of these specialized tests, it is often more economical to replace a wooden element with an element having guaranteed strength parameters than to test the wooden element and try to keep it. The methods marked in the diagram above as the acoustic, radiological, and mechanical-electrical methods are intended to assess the technical condition of the element structure and not to determine its strength characteristics.

The sclerometric method has many advantages: it is a non-destructive test, it is possible to perform it on a built-in element, there is no need to prepare the element before the test, it is possible to perform it in hard-to-reach places and, above all, it is probably the cheapest of all available methods.

3. EXPERIMENTAL STUDIES

The authors of the paper conducted an experimental study of wood hardness using the sclerometric method of assessment, creating an original program for estimating the strength characteristics of a wooden element on this basis. The research covered the most commonly used type of wood in civil engineering – pinewood.

The scope of experimental tests included performing a wood moisture test by means of a drier-weight method, a wood density test using a stereometric method, a sclerometric test performed with a wood hammer, and a compressive strength test on a hydraulic press – CONTROLS ADVANTEST 9. The testing of moisture and density were to determine the physical properties of the samples obtained and to check their compliance with the requirements of the standards for wooden structures 6.

The experimental tests carried out were intended to determine the compressive strength of the wood using the sclerometric method.

3.1 Description of the method

Wooden samples were tested using the sclerometric method which involves the use of the relationship between the resistance of the material to a local concentrated force and the strength of this material. The sclerometric method is also used to test the concrete strength using the Schmidt’s hammer. The principle of the hammer for wood and Schmidt's hammer is similar; in both cases, the measurement is performed using a spring steel beater, which, depending on the type of device, hits with a certain force. However, the methods vary in terms of the way the final result is obtained. In the Schmidt’s hammer test, the result is the distance between the hammer's reflection from the mandrel, which is measured using a scale on the housing of the device, whereas, the result of the hammer test for wood is the difference between the needle length (5 cm)

and the depth of its penetration. This value is measured using special apparatus included in the set.
The main purpose of the research was to determine the relationship between the wood's compressive strength and the results obtained during the sclerometric tests with a wood hammer.

3.2 Samples preparation

50 samples of the same wood species were prepared for the study. The test was carried out on pinewood samples measuring 30x60x180mm. The samples were precisely cut using a thickness gauge from HAFEN, the TP 630 D model. The samples were dried to a constant weight before testing. Due to the significant influence of humidity on the wood strength parameters, all samples were tested as completely dried (dried to constant weight). The average density of wooden samples was 513 kg/m^3, which meets the requirements for wooden elements in the instructions of the Wood Technology Institute**Błąd! Nie można odnaleźć źródła odwołania.**.

3.3 Wood sclerometric test

The wood sclerometric test was carried out using a wood sclerometer. The measuring kit includes a WOODPecker DRC 15 MO233N wood hammer, a 5 cm long penetration needle with a 35° conical tip made of 60HRC steel, and a penetration-depth measuring system.
16 measuring sites were determined on each of the 50 samples, 4 on each side. The exact location is shown in the figure below.

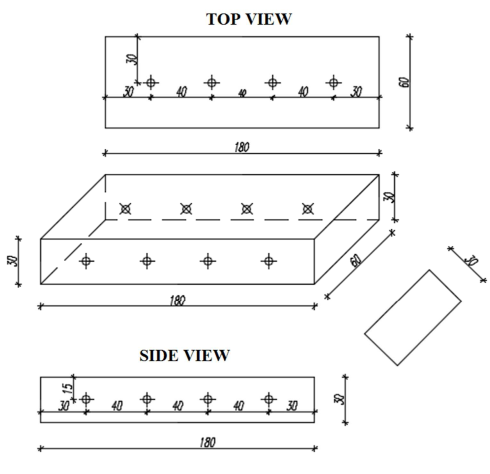


Fig. 2. Location of measurement sites

Before measurement, the sample was immobilized in a vice to reduce measurement inaccuracy due to the elasticity of the substrate. At each measuring site, the result was obtained by striking three times with a sclerometer and then reading the value from the measuring device. An average value was determined for each of the sides, which then formed the basis for calculating the result for the sample tested.

Photograph 1. Wood test sclerometer

Photograph 2. Examination of sample

3.4 Compressive strength test using a strength machine

In order to obtain the real strength of the wooden elements being tested, destructive tests were carried out for all 50 samples. Compressive strength along the fibers was tested on 30x60x180mm samples, and the test itself was consistent with the algorithm contained in the standard for testing wooden elements 10.

The course of the study was as follows:

1. Examination of the standard sample in order to determine device parameters.
2. Setting the hydraulic press force increase to obtain destruction within 300±120s.
3. Placing the sample centrally in the CONTROLS ADVANTEST 9 hydraulic press.
4. Gradual application of the load.
5. Destruction of the sample.
6. Noting the strength, time, and method of sample destruction.

Photograph 3. Testing of wooden samples on the hydraulic press

Photograph 4. Sample after testing

4. ANALYSIS OF THE RESULTS

Considering the heterogeneity of the wood, the samples were divided into two groups after destructive testing; those with visible construction defects and those with no visible defects, with the correct destruction model in the strength machine. The correct destruction model assumed destruction at the weakened cross-section with holes remaining after the sclerometric test. Of the 50 samples tested, 11 (approx. 22%) were rejected which, due to the defects and heterogeneity of the structure, significantly stood out from the results of the compressive strength. It was considered that the impact of these factors may distort the results of the study and reduce its accuracy.

Photographs 5, 6, 7, 8. Samples rejected due to wood defects

After selecting the samples, the dependence of the wood compressive strength on the density and the wood compressive strength on the results of the sclerometric test was compared. On this basis, statistical analyses were carried out to determine the relationships between these parameters. The analysis of the relationship between the compressive strength and the results of the wood sclerometric test was performed using the STATISTICA software. Graphs describing the optimal relationship were prepared and mathematical formulas were determined for them.

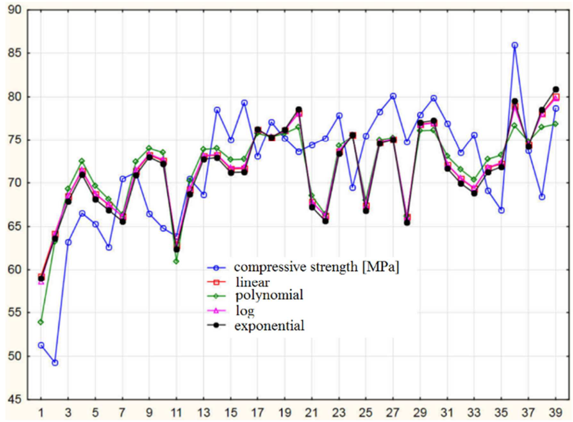


Fig. 3. Graph of matching of the functions to the test results using the STATISTICA software

The smallest absolute error (MAPE) was obtained for the equation in the polynomial form and is 6.8%, which means that it is at a satisfactory level.

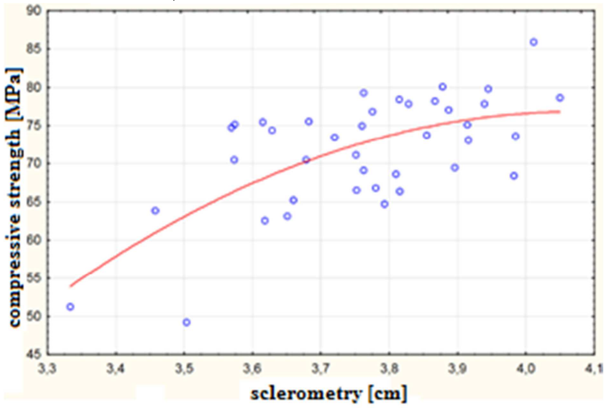


Fig. 4. Graph of the dependence of the wood compressive strength on the results of the sclerometric test – the STATISTICA software

The graph in the form of the polynomial best describes the dependence of the compressive strength on the results of the sclerometric test. It has the form:

$$f_{o,scler} = -41.6x^2 + 338.9x - 613.7 \qquad (4.1)$$

where:
$f_{o,scler}$ – the compressive strength obtained on the basis of the sclerometric test,
x – the needle penetration depth in the sclerometric test.

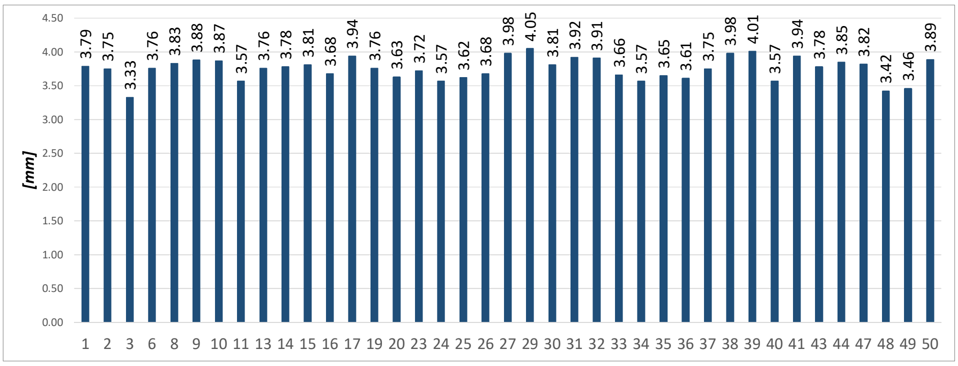
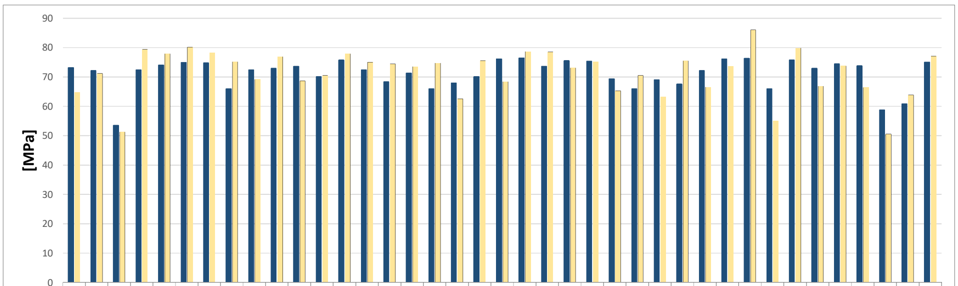


Fig. 5. Average needle penetration depth for the sclerometric test

After determining the dependence of the depth of the needle penetration during the sclerometric test on the strength of the samples on the strength machine, the strength from the sclerometric test was calculated. The sclerometric strength results are summarized in the chart below together with the results of the laboratory compressive strength. The results were only compiled for 39 samples (no results were compared for samples disturbed by wood defects).



	1	2	3	6	8	9	10	11	13	14	15	16	17	19	20	23	24	25	26	27	29	30	31	32	33	34	35	36	37	38	39	40	41	43	44	47	48	49	50
A	73	72	54	72	74	75	75	66	72	73	74	70	76	72	68	71	66	68	70	76	77	74	76	75	69	66	69	68	72	76	76	66	76	73	74	74	59	61	75
B	65	71	51	79	78	80	78	75	69	77	69	71	78	75	74	74	75	63	76	68	79	78	73	75	65	71	63	75	67	74	86	55	80	67	74	66	51	64	77

Fig. 6. Relationship of wood compressive strength - fibers for laboratory and sclerometric tests

A - f_o – results of the compressive strength – the laboratory test
B - $f_{o,scler}$ – results of the compressive strength – the sclerometric test

Based on the summary, it was found that the results of the sclerometric test are strongly associated with the laboratory results. The values obtained in these studies differ, however, they are very biased. In the samples for which lower strength results were obtained on the strength machine, after conversion, lower results were also obtained from the sclerometric test. This means that there is a relationship between the compressive strength and the sclerometric test.

5. CONCLUSION

- The available non-destructive methods of wood testing mainly serve to assess its technical condition and its internal structure. There are no reliable non-destructive methods determining the strength parameters of the wood.
- Wood is an anisotropic and heterogeneous material. Due to this, all tests carried out on wooden elements should be carried out on a larger number of samples as in the case of the other construction materials (e.g., steel or reinforced concrete).
- The adopted number of test samples allowed determination of only an approximate formula describing the relationship between the sclerometric test and the strength tests. The dependence of the compressive strength on the sclerometric test results was confirmed based on the conducted experimental tests. To determine a more precise algorithm for assessing the mechanical parameters of wood, the tests should be extended to include samples from a different type of wood, other mechanical parameters, and different humidity. The research carried out by the authors of the paper was of an experimental nature and form the basis for further trials and analyses using the sclerometric method in the case of wooden objects.
- Sclerometric testing of wood can significantly facilitate the diagnosis of wooden elements in existing facilities, which will have a positive impact on the economic aspect in the case of works carried out in such facilities.

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