Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 87, 2014: 79-83
(Ann. WULS - SGGW, For. and Wood Technol. 87, 2014)

Evaluation of the suitability of sclerometric methods in diagnostics of wooden constructions

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Abstract: *Evaluation of the suitability of sclerometric methods in diagnostics of wooden constructions.* This article presents the results of sclerometric testing conducted on the different species of timber which commonly occurring in Poland. Sclerometric testing of wood is a relatively new testing method based on measurement of the penetration depth of a steel pin upon being struck by a mechanical hammer with a constant energy of impact. Results indicate, that after right amount of research, determine supportive correlation functions for determination of the wood class will be possible.

Keywords: wooden constructions, non-destructive testing, sclerometric methods

INTRODUCTION

Under optimal conditions, wood maintains an exceptional durability, however under conditions of average exploitation of buildings, it is subject to more rapid destruction than other construction materials. This is why installed wooden parts, and particularly historical structures and elements, require more frequent repairs and reinforcement than parts made of other materials. To perform repairs and reinforcement correctly, it is necessary to determine the technical conditions of wooden parts as well as their physical and mechanical properties. This can be done through the application of destructive or non-destructive testing methods.

Non-destructive tests are usually conducted in used buildings and have the purpose of detecting the possibility of failure earlier so that the appropriate countermeasures can be taken. However, the application of non-destructive techniques requires much skill and experience and is linked to complications in the interpretation of results. It can generally be accepted that diagnostic tests of wood are a difficult process due to its structure. But the capability of determining the current strength parameters of wooden structural parts makes it possible to correctly evaluate their suitability for further exploitation and design the appropriate methods of reinforcement and reconstruction. Non-destructive tests can be divided into two groups: organoleptic (macroscopic assessment) and technical tests based on acoustic, electromagnetic, radiological, electromagnetic, and mechanical techniques (sclerometer, resistograph) [1,2,3].

Sclerometric testing of wood (fig. 1) is a relatively new testing method based on measurement of the penetration depth of a steel pin upon being struck by a mechanical hammer with a constant energy of impact. After a pin with a specific length is driven in, measurement of its penetration depth is performed using a special sensor. This makes it possible to determine the qualitative properties of the near-surface layers of a part (mainly based on its pressure strength, and thus, its hardness). Foreign manufacturers of devices for sclerometric tests provide correlation tables for specific wood species, which allow for determination of the modulus of elasticity and bending strength along the grain depending on the depth of pin penetration upon hammer impact. Correlation curves do not account for any additional factors to which wooden structures are exposed. The capability of their application under domestic conditions is limited due to the local character of the wood species for which correlations are presented (oak, poplar, chestnut). In addition, it should be noted that this device is relatively new, and there is a lack of the appropriate number of studies and papers on the subject of its suitability for testing of wooden structures[4].

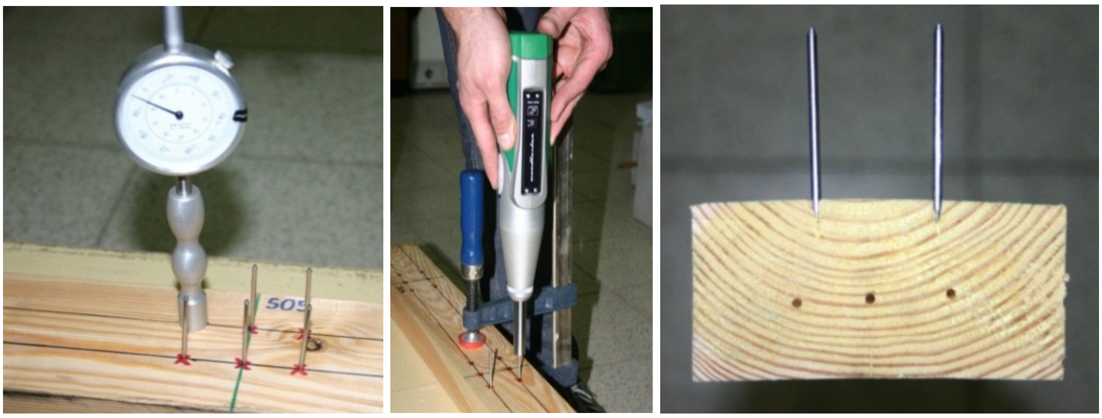


Fig. 1. From the left: sensor for measurement of pin penetration depth, followed by the testing process and the specimen after testing. Source: own studies.

OWN STUDIES

In order to evaluate the suitability of the sclerometric method in tests of wooden structures, experimental laboratory tests were conducted. Tests were conducted for the two species of coniferous timber used the most often in Poland, pine and spruce, as well as for three deciduous species: oak, beech, and ash.

Tests encompassed: macroscopic assessment (determination of defect locations), sclerometric tests, ultrasound tests, and destructive tests on a technical scale and on small specimens without defects. Control measurements of moisture content in parts were also taken before tests using the capacitive method, and after tests, the drying and weighing method was used to measure moisture content, and the density of parts was determined.

During the first stage of tests, the velocity of a wave's passage through the material was determined. This test had the purpose of determining the homogeneity of the material subject to analysis. 2 measurements of wave passage velocity were conducted for each measuring point (due to head sizes). The amplitude of the wave course was not analyzed during tests.

Next, the depth of pin penetration into the specimen material was determined. 6 measurements of penetration depth were taken for each area (1÷7), according to fig. 2. The greatest penetration depths occurred in the direction along the grain in the case of every material.

In the next stage, destructive bending strength tests were conducted along the grain on a universal press. Bending was performed using the tri-point method, and a single bending force was applied at the center of the span. Load was applied with a constant advance rate equal to 0.05 mm/s. In the case of parts tested on a technical scale, the modulus of elasticity was determined within the range of 10÷40% of destructive force.

Sample parts for non-destructive tests had dimension of 44×90×1800 mm, and seven measuring areas were designated on every part, at intervals of 30 cm (fig. 2). Destructive bending strength tests using the tri-point method and determination of the modulus of elasticity were conducted on parts with dimensions of 44×90×900 mm. Next, small specimens without defects, with dimensions of 20×20×30mm, were cut out, and the compressive strength along the grain, density, and moisture content, by the drying and weighing method, were determined.

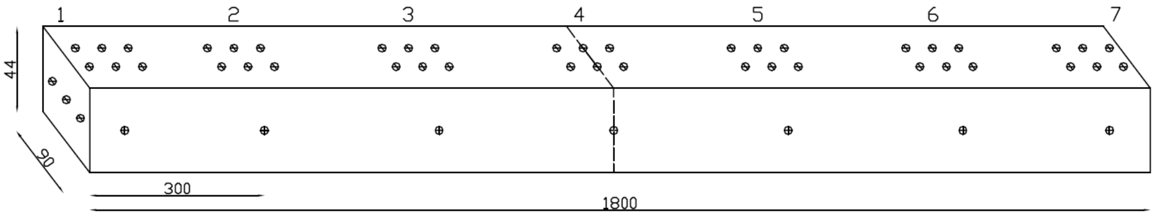


Fig. 2. Example of a tested part and the scheme of the locations of points for non-destructive tests. Source: own studies.

Non-destructive tests were carried out with consideration of the anatomical directions of the wood structure, and directions both along and across the grain were accounted for, while destructive tests were limited to the direction along the grain. The results of destructive tests and the basic physical properties determined for each of the wood species subject to study are presented in table 1 and in fig. 3. Testing of parts was performed at a comparable moisture content (air-dry state), and obtained results allow for the statement that wood from coniferous species exhibits low variation in the case of ultrasound testing, while the results of sclerometric testing differ significantly, which is in accordance with the physical parameters (density) and mechanical parameters (greater pin penetration depth - lesser compression strength and bending strength along the grain) of these parts. In turn, testing of specimens from deciduous species shows greatr variation for ultrasound wave passage velocity results, while the results of both non-destructive and destructive tests for beech and ash beams are very similar. A slight difference is observable in the results of sclerometric tests - ash wood exhibits lesser pin penetration, which is the result of its greater density than that of beech wood.

Table 1. Compilation of the mean values of destructive and non-destructive test results for individual wood species.

Wood species	Mean wave velocity II/⊥ [m/s]	Mean penetration depth II/ ⊥ [mm]	Mean compression strength II [MPa]	Mean moisture content (drying and weighing method) [%]	Mean density [kg/m^3]	Mean bending strength II [MPa]	Mean Young's modulus II [GPa]
pine	6002.25/**2231.57**	11.63/**9.01**	72.58	9.37	654.94	66.44	11.98
spruce	6003.00/**2124.29**	16.03/**11.52**	51.62	8.24	424.92	57.08	8.55
beech	5446.57/**2135.68**	7.40/**6.45**	62.19	7.73	662.03	94.42	12.44
oak	4889.60/**1911.94**	8.83/**7.14**	64.57	8.77	678.16	65.84	9.76
ash	5344.98/**2168.26**	6.57/**5.80**	67.15	7.22	734.60	104.24	11.66

Based on obtained test results, it can be stated that a dependence of increasing pin penetration depth on the density of the tested material is observable, both along and across the grain, particularly for coniferous species. The velocity of ultrasound wave passage illustrates these dependencies to a much lesser degree. Analogous conclusions can be drawn in relation to the compression strength determined along the grain.

Dependences between sclerometric tests and bending strength along the grain as well as the modulus of elasticity along the grain were taken into consideration jointly according to their mathematical relationship (the modulus of elasticity was determined based on bending strength tests). Dependences (non-linear) between the velocity of longitudinal and transverse waves and bending strength/elasticity modulus are clearly visible, particularly for deciduous species. This dependence is observed for the velocity of wave passage in the transverse direction, in the case of confierous species. For both coniferous and deciduous species, the dependence of increasing penetration depth and decreasing mechanical parameters is valid.

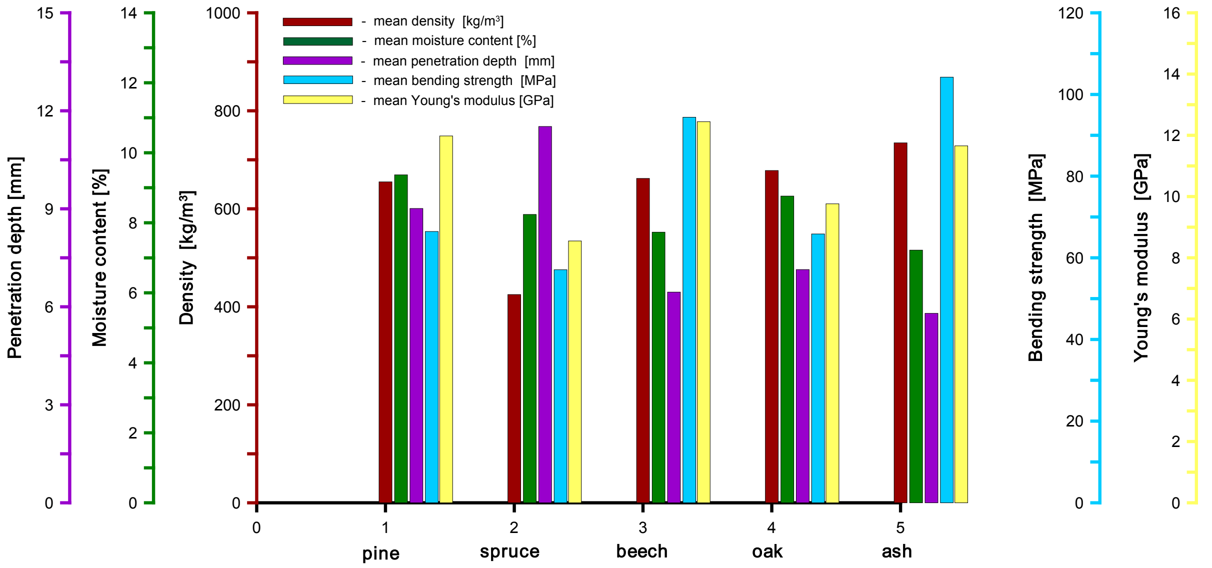
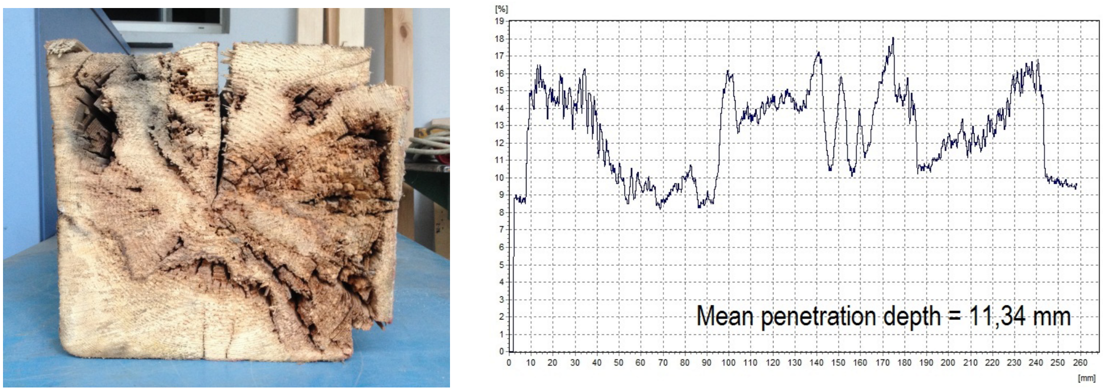


Fig. 3. Graphical interpretation of obtained results of destructive and non-destructive tests. Source: own studies.

a)



b)

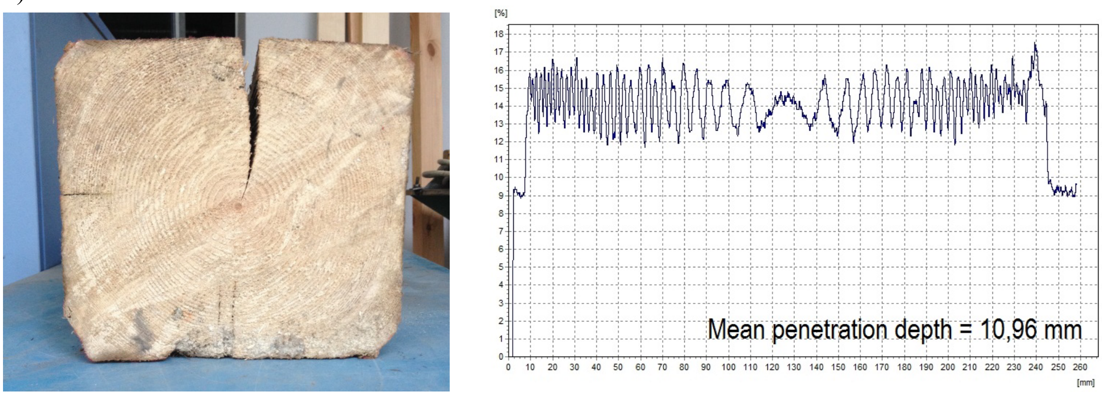


Fig. 4. Graphical interpretation of the results of tests conducted on individual cross-sections using the machining resistance method and sclerometric method, a - corroded cross-section, b - "healthy" cross-section. Source: own studies.

It should be noted that obtained test results pertained exclusively to a statistically homogenous material (new and "healthy"). In engineering practice, material subject to the impact of various factors, including atmospheric, biological, chemical, etc., is encountered most frequently, and the impact of these factors is made evident by the occurrence of lamination, discontinuities, and voids. In order to verify obtained test results, additional control tests were conducted to compare the sclerometric method, along with measurement of machining resistance, registered by a resistograph, for wooden elements originating from dismantling of a historical ceiling. The part subjected to testing was characterized by significantly different physico-mechanical properties in the longitudinal direction, as illustrated by the cross-sections presented in fig. 4 [5]. The obtained results of sclerometric tests did not show these changes due to the superficial nature of these tests, as proven in tests using the resistograph. It must therefore be emphasized that the sclerometric method should not be used without verification with the results of other tests.

SUMMARY AND FINAL CONCLUSIONS

Based on conducted tests and their results, the following conclusions can be drawn:
1. In order to evaluate the suitability of the sclerometric method in diagnostics of wooden structures, it is necessary to conduct research work on a large number of parts made of wood species occurring in a given climate zone and of a given class. This will make it possible to determine supportive correlation functions for determination of the wood class of tested parts.
2. The sclerometric method yields results that reflect the physico-mechanical parameters of wood with high homogeneity well. However, an insufficient number of tests has been conducted to unequivocally determine the parameters of wooden parts based on sclerometric tests.
3. It should be emphasized that no non-destructive method should be used without verification/correlation with the results of destructive tests or other tests (ultrasound tests, machining resistance tests). The conducted tests showed the need to conduct non-destructive tests simultaneously with different methods, with simultaneous consideration of the wood species and the impact of other factors.

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5. Resistograph. Rinntech. Operating manual

Streszczenie: *Ocena przydatności metod sklerometrycznych w diagnostyce konstrukcji drewnianych*. W niniejszym artykule przedstawiono wyniki przeprowadzonych badań metodą sklerometryczną różnych gatunków drewna konstrukcyjnego w Polsce . Badania sklerometryczne drewna są stosunkową nową metodą badawczą i polegają na pomiarze głębokości zabicia stalowego trzpienia mechanicznym młotkiem o stałej energii uderzenia. Uzyskane wyniki badań wskazują, że przy odpowiedniej ilości badań będzie można w przyszłości wyznaczyć pomocnicze funkcje korelacyjne do określenia klasy drewna.

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