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Estimation of the strength parameters of wood in building structures - preliminary studies

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Abstract: *Estimation of the strength parameters of wood in building structures – preliminary studies*. This paper presents the results of preliminary studies of natural scale new and old timber members subjected to bending and the results of parallel bending strength tests carried out on small timber specimens without defects. As a rule, it is not possible to carry out tests on full-sized members since it is then necessary to remove them from the structure and subject them to destructive tests. The aim of this research was to evaluate the usefulness of tests on small specimens for estimating static bending strength. On the basis of the obtained results it can be tentatively stated that tests on small specimens are useful for assessing the grade of wood in accordance with EN 384. However, because of the small number of the tested elements, the results should be considered as approximate.

Keywords: timber structures, timber beams, laboratory tests, four-point bending

INTRODUCTION

Formerly logging for the needs of the construction industry posed no problem owing to the then relatively high forestation of the area of Poland. In recent years, however, the deficit of large-sized timber in both Poland and in Europe has been increasing. Therefore there is a need to properly assess the condition of timber structures if they are to be strengthened or if some of their members are to be replaced with new ones.

In timber structures it is the timber ceilings which are most susceptible to degradation and consequently most often need repairing or strengthening. It is often the case that rash decisions are made to dismantle and utilize the old members even though their condition is good enough for them to remain in service. In order to properly assess the technical condition of old structural members it is necessary to carry out tests.

The most reliable method of assessing the condition of a structural material (timber) are destructive tests, but it is not always possible to take samples from the members of an existing structure. Then only nondestructive techniques (NDT) can be used. By carrying out nondestructive tests one can identify the mechanical and physical properties of the materials and members of a structure, detect material defects and discontinuities and determine the geometric dimensions of the members without disturbing the continuity of their structure or affecting the functional properties of the building structures. However, none of the currently known and used nondestructive techniques enables one to explicitly determine mechanical parameters (mainly bending strength and the E-modulus). This is not possible even if one uses the X-ray technique, which quite precisely estimates wood density (Kruglowa et al. 2012), because of the natural heterogeneous structure of wood (inclusions, the slope of grain, cracks).

In order for NDTs to yield not only qualitative results (the extent of decay, structural discontinuities, etc.), but also quantitative ones (density, strength, the E-modulus) it is necessary to carry out nondestructive tests accompanied by destructive tests on samples taken from structural members. By correlating nondestructive test results with strength test results one can obtain comprehensive data for structural analyses of timber structures. The proper interpretation of the results will provide a basis for the development of guidelines for designing reinforcements for, first of all, historic timber structures.

MATERIALS AND METHOD

According to [PN-EN 408], the strength properties of wood should be determined by carrying out tests on full-sized members. As a rule, this is not possible for wood in an existing structure since it is then necessary to disassemble the latter and subject its members to destructive tests [Jasieńko et al, 2012]. For this reason, the mechanical parameters of wood are determined using small samples without defects, in accordance with the old Polish standards, e.g.. PN-D-04103:1977. However, when carrying out such tests one should bear in mind that flawless wood has greater strength than wood with defects. The strength of the latter wood is determined by, e.g., the type and distribution of knots, and the oblique grain pattern. Hence the strength values determined for small samples of wood without defects are higher than the ones for the full-sized members [Krzysik, 1978].

The tests of new and old timber beams, presented in this paper, were carried out in respectively the Laboratory of the Building Engineering Institute at Wrocław University of Technology and the Laboratory of the Civil Engineering Faculty of Silesian University of Technology.

New pinewood was tested in 5 natural scale beams 120×220 mm in cross section and 4000 mm long (3800 mm between the centres of the supports). The beams freely supported at their ends were subjected to four-point bending. Fork support, preventing the members from warping, was employed at the supports. The test stand is shown in fig. 1. The moisture content in the wood, determined using an electrical resistance moisture meter, was in a range of 14.5-15.5%.

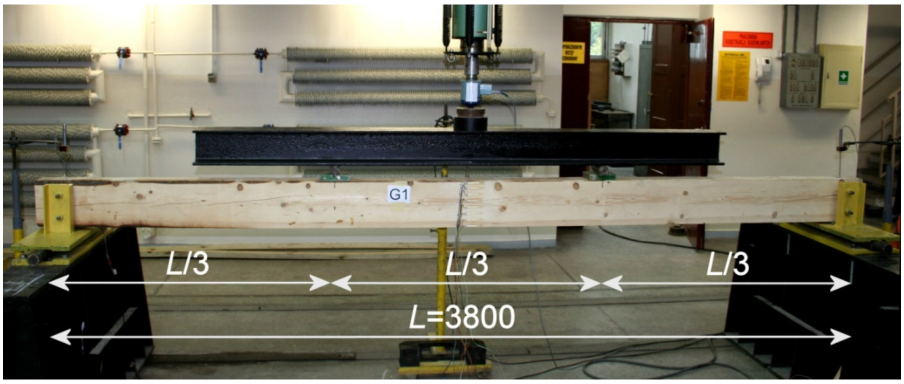

Fig. 1 Stand for testing new timber beams.

Five 4.48-5.11 m long 130-year-old timber beams, whose cross sectional dimensions are shown in table 1, were acquired for the laboratory tests. Previously the beams functioned as the load-bearing members of the ceiling above the ground floor in a historic school building in Połomia [Brol et al, 2012]. The original ceiling was a timber beam-framed one with sound boarding and pugging. The beams were made of sprucewood. Most of the beams were in good condition, showing longitudinal cracks. In some of the beams there were visible insect feeding traces, and surface biological corrosion in the places where they had rested on masonry. The moisture content in the wood amounted to 12-15%.

Three of the beams were tested by loading them with two forces, at support spacing l=4.5 m while the other beams were tested under the same load configuration, but at support spacing l=4.0 m.

For comparison purposes, static bending strength tests were also carried out on small specimens without defects. Their static bending strength was determined under three-point bending in accordance with PN-D-04103:1977 (fig. 2). Forty 20×20×300 mm small beams were made from the new timber and the same number of identical beams was made from the old timber.

Tab. 1 Dimensions of old timber beams.

Beam	Width [m]	Height [m]	Length [m]
BD2	0.195	0.250	4.93
BD5	0.208	0.256	5.02
BD6	0.212	0.245	5.11
BD3	0.202	0.240	4.53
BD8	0.206	0.262	4.48

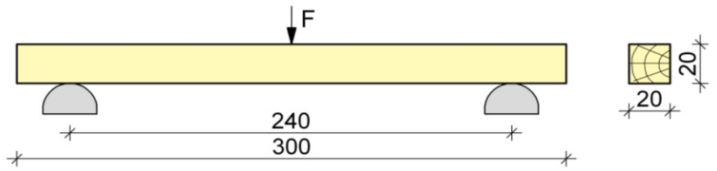

Fig. 2 Scheme of test stand and dimensions of small beams without defects [mm].

RESULTS AND CONLUSIONS

The results of the tests carried out on the natural scale specimens for the new and old timber are presented in respectively table 2 and table 3. Because of the different support spacings used, besides the ultimate force values also the values of the ultimate bending moment and the modulus of rupture are included.

Tab. 2 Load-bearing capacity of new timber beams.

Beam	Support spacing [m]	Ultimate force [kN]	Ultimate bending moment [kNm]	Modulus of rupture [MPa]
G1	3.8	58.25	36.89	38.11
G2		45.47	28.80	29.75
G3		50.75	32.14	33.20
G4		43.12	27.31	28.21
G5		63.15	40.00	41.32

Tab. 3 Load-bearing capacity of old timber beams.

Beam	Support spacing [m]	Ultimate force [kN]	Ultimate bending moment [kNm]	Modulus of rupture [MPa]
BD2	4.5	73.94	55.45	27.30
BD5	4.5	89.62	67.21	29.58
BD6	4.5	78.49	58.87	27.76
BD3	4.0	99.53	66.35	34.22
BD8	4.0	130.17	55.45	27.30

In the case of the small specimens without defects the average static bending strength was found to be equal to 78.15 MPa and 65.44 MPa for respectively the new timber and the old timber.

The grade of the wood was tentatively estimated in accordance with PN-EN 384. The testing of the small specimens without defects in accordance with PN-D-04103:1977 did not satisfy the test configuration assumptions specified in standard EN 408. Nevertheless the 5% strength quantile was corrected in accordance with EN 384, by dividing the result by a correction factor relating to length: $k_l = [48h/(l+5a_f)]^{0.2} = 1.32$ for distance $a_f = 0$ between the load application points. On the basis of the tests of the full-sized members it can be stated that the new wood satisfies the C18 grade requirements while the tests carried out on the small specimens indicate that it is of grade C22. The old wood satisfies the requirements for grade C18 in both cases.

Because of the small number of the tested elements the presented results should be considered as tentative. Nevertheless, it seems that the use of the bending strength testing methodology based on old Polish standard PN-D-04103 for the preliminary assessment of the grade of wood is a viable proposition.

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Streszczenie: *Szacowanie parametrów wytrzymałościowych drewna w konstrukcjach budowlanych - badania wstępne*. W artykule przedstawiono rezultaty wstępnych badań zginanych elementów drewnianych, w skali technicznej, z nowego i starego drewna oraz wyniki przeprowadzonych równoległe badań na małych próbkach bez wad. Z reguły nie jest możliwe wykonanie badań na elementach pełnowymiarowych ze względu na konieczność demontażu istniejących elementów konstrukcji oraz poddanie ich badaniom niszczącym. Celem opracowania jest ocena przydatności badań na małych próbkach w celu szacowania wytrzymałości na zginanie statyczne. Uzyskane wyniki pozwalają na wstępne stwierdzenie przydatności wykonywania badań na małych próbkach w celu oszacowania klasy drewna wg EN 384. Jednakże ze względu na niewielką liczbę badanych elementów wyniki należy traktować jako szacunkowe.

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