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Testing timber beams after 130 years of utilization

Badania belek drewnianych po 130 latach użytkowania

Keywords: Reuse, Laboratory tests, Timber beams

Słowa kluczowe: powtórne wykorzystanie, badania laboratoryjne, drewniane belki

1. INTRODUCTION

Use of wood in buildings construction in Poland, after years of underestimation of this material, has been used more and more often. In the past obtaining wood was not difficult due to quite large afforestation of Poland. That is why the problem of reuse of whole timber beams are practically unknown in our country. In recent years the prices of this material in Poland as well as in the whole Europe have been rising. At the same time more and more structures with timber construction are being demolished or thoroughly reconstructed and renovated. Old timber beams are usually thrown out at the waste dumps or used as heating fuel. Very often these beams are in good technical condition and they could be used in other buildings however, the tests confirming their good technical properties are missing. That is why testing of such solutions has been undertaken. For this purpose timber floor beams were obtained for laboratory tests after 130 years of utilization in the floor over the ground floor (Fig. 2) from monumental building under renovation in Połomia (Fig. 1).

The subject building was constructed in 1878. It functioned as a presbytery until the 50s of 20th century. Then it was utilised by the commune as: a commune office, a kindergarten and in the 80s as a primary school. In 1995, after the new primary school was built in Połomia, the building was abandoned. The building was not utilised for 15 years and underwent destruction process. Its demolition was even considered. However, in 2010 on February 19th the building was entered to the national register of historic monuments under number A/295/10. At the moment it is being under renovation. The roof and floors have been replaced and the rooms will be used for new purposes. The subject building has got basement under part of it and it consists of three floors and usable attic.

Fig. 1. The photo of „old" school in Połomia

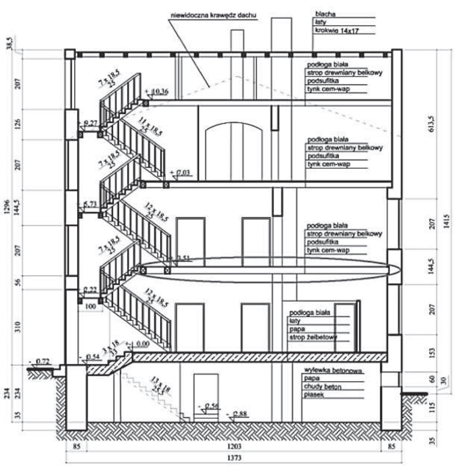

Fig. 2. Cross-section of the school in Połomia

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2. CHARACTERISTICS OF TESTED BEAMS

Eight 130-year-old beams of the length between 3.03 and 5.11 m were obtained for laboratory testing. The beams first played the role of floor bearing elements over the ground floor. Original floor was first made as beam-framed floor with sound boarding and ceiling. Testing elements delivered to the laboratory had got vivid restages of old floor – in the form of nails, sound boarding lathes and other impurities.

During the in-situ inspection the following wood properties were determined:

– The looks of the wood – beams (130-year-old) became greyish, clearly grey beams surfaces. There are no distinct protection coats (impregnants, paint coats) on the beams. Surfaces of all beams are rough and matt.
– The smell of wood – smell characteristic for wood cannot be sensed, just unpleasant smell of dust.

After the beams surfaces were cleaned it was noticed that the beams were made of spruce timber. Technical condition of the obtained beams was in the majority of cases good with visible longitudinal cracks. In some of the beams insects feeding marks were present as well as surface biological corrosion visible in the spots where beams rested against the walls. Wood tested humidity ranged 12-15%.

Due to the beams length, five wooden beams of the length ranging from 4.48 m to 5.11 m were used for bending testing. The remaining three sections of beams less than 4 m long were used for compression testing. The testing results, though, are not presented in this paper. Table 1 presents dimensions of the beams as well as brief description of technical condition of the beams used for testing. Three of the beams were subject to the test in the scheme of the beam loaded with two forces with the supports spacing l = 4.5 m, whereas two other in analogical scheme with supports spacing l = 4.0 m. Preparation to testing of the obtained 130-year-old beams consisted in removal of laths supporting sound boarding, removal of old nails, cleaning and inventory.

Table 1. Description of beams used for bending testing

No.	Designation	Dimensions [m]			Comments
		width	height	length	
1	BD2	0.195	0.250	4.93	Generally in good technical condition, visible longitudinal cracks as well as insects feeding marks.
2	BD5	0.208	0.256	5.02	Generally in good technical condition, longitudinal cracks on one side surface.
3	BD6	0.212	0.245	5.11	Generally in good technical condition, visible insignificant longitudinal cracks.
4	BD3	0.202	0.240	4.53	Generally in good technical condition, visible longitudinal sloping cracks. On one head insignificant biological corrosion.
5	BD8	0.206	0.262	4.48	Generally in good technical condition, visible insignificant longitudinal cracks.

3. TESTING OF OLD BEAMS CONDITIONS AND PROPERTIES

3.1. Testing of floor beams in natural scale

3.1.1. Testing stand and description of tests

As it was mentioned above, bending tests were carried out for two different supports spacing. Beams BD2, BD5 and BD6 were tested with supports sparing equal l = 4.5 m whereas beams BD3 and BD8 were tested with supports sparing equal l = 4.0 m. Actual length of tested beams decided about supports spacing. Scheme of the testing as well as the view of testing stand have been presented correspondingly in Figs. 3 and 4. During the testing force, deflections and strains on upper and bottom surfaces of the beam were measured.

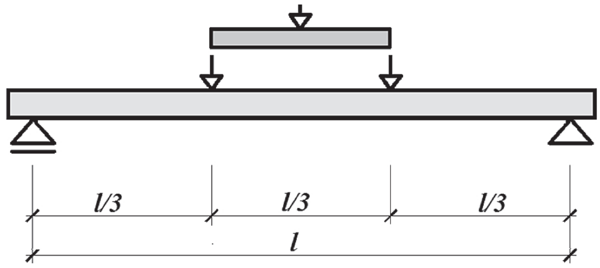

Fig. 3. General testing scheme

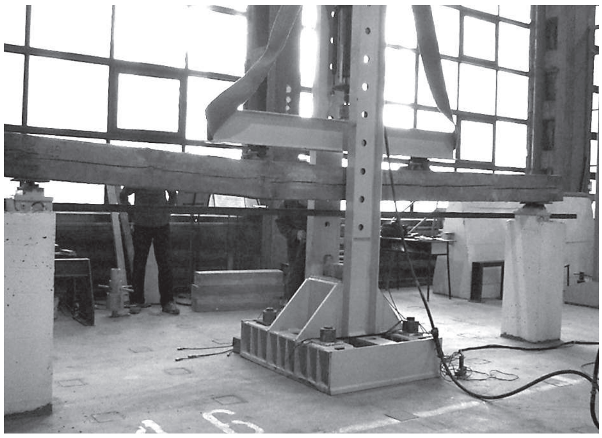

Fig. 4. View of the bending testing stand

3.1.2. Results of testing beams in natural scale

Testing results have been presented in Table 2. It includes values of the destructive force for particular testing models as well as value of the deflection at the destruction moment. For easier comparison, because of different support spacing, Table 2 includes also value of bending moment as well as stresses values at the destruction moment.

Table 2. Beams load bearing capacity

Beam designation	Mean dimension of beam cross-section [m]		Support span [m]	Destructive force [kN]	Moment at destruction [kNm]	Bending stresses at destruction [MPa]	Deflection [mm]
	Width	Height					
BD2	0.195	0.250	4.5	73.94	55.455	27.301	49.40
BD5	0.208	0.256	4.5	89.62	67.215	29.585	44.43
BD6	0.212	0.245	4.5	78.495	58.871	27.758	48.36
BD3	0.202	0.240	4.0	99.53	66.353	34.217	46.51
BD8	0.206	0.262	4.0	130.17	86.780	36.821	48.98

To estimate the class on the wood standard PN-EN 384:2004 [1] has been used. According to this standard determination of the mechanical properties of the wood has been carried out of full-size elements.

Strength characteristic value has been calculated with the use of the formula:

$$f_k = f_{05} \cdot k_s \cdot k_v \quad (1)$$

where:
f_{05} – the value of 5% of quantile,
k_s – correction factor regarding number and size of sample,
k_v – correction factor regarding machine sorting.

Value f_{05} is determined based on the formula:

$$f_{05} = f_r \quad (2)$$

where:
f_r – value corresponding to 5% of quantile of the ranged testing results

Due to the small number of samples 5% quantile has been determined based on the formula:

$$f_{05} = f_{śr} - t_\alpha \cdot s \quad (3)$$

where:
t_α = 1.64 (statistical ratio for normal distribution corresponding to probability p = 0.95%),
s – standard deviation for current sample = 4.193 MPa
where: H – sample height in mm.

Table 3. Strength properties of the tested timber

	Mean strength $f_{śr}$ [MPa]	Standard deviation s [MPa]	Correction factor k_s [–]	Correction factor k_v [–]	Characteristic strength f_k [–]
Bending	31.136	1.61	–	1.0	24.26
Bending	31.136	1.61	0.77	1.0	18.67

Based on the obtained tests result, due to the small number of the beams, only current class of wood has been estimated.

Without taking factor k_s (correction factor regarding number and size of samples) into account the wood of the beams can be ranked as class C24 according to PN-EN 338 [2]. As is has been presented in Table 3 $f_k = f_{05}$ = 24.26 MPa. However, it needs to be noted that all tested beams underwent destruction at bending stresses greater than 24 MPa.

If factor k_s, which for small sample equals 0.77, is considered, then the wood shall be classified as C18.

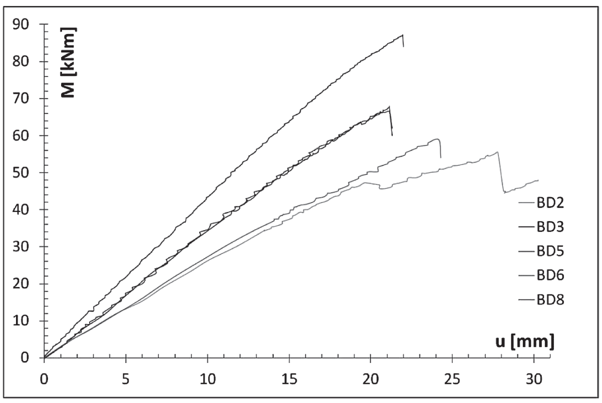

Fig. 5. Dependence: moment – deflection

Dependence of the deflection „u" on the applied load has been presented in Fig. 5 as a relationship: moment – deflection. This way of presentation results from the use of various spans in testing old timber beams and enables comparison of particular beams. As it has been shown in diagram presenting relationship moment – deflection for tested 130-year-old beams is clearly linear, different than in testing of new timber. Based on the extensometer measurements results, neutral axis lowering has not been observed either. Destruction of the beam usually happened in a violent way but it was preceded with classical cracks. Exemplary forms of destruction have been presented in Fig. 6.

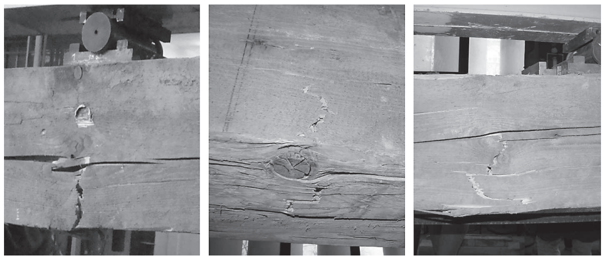

Fig. 6. Forms of beam destruction – from the left beams: BD6, BD5, BD2

3.2. Material testing on little samples

3.2.1. Testing description

In strength tests the results depend on the samples dimensions. Little samples without any defects give greater strength values than in case of bigger samples, in which wood defects are unavoidable. According to Polish Standard PN-EN 384:2004, testing of the wood strength properties shall be carried out with the use of full-dimensional elements. In case of wood properties determination for the existing constructions it is practically impossible [3]. That is why strength properties testing has also been carried out on small samples without defects in accordance with "the old" standard PN-77/D-04103, which is still very often used particularly for determination of the strength parameters of the existing structures. According to these standards samples for bending testing should have dimensions 20 × 20 × 300 mm and for compression testing 20 × 20 × 30 mm. The tests for bending were carried out on 40 small beams taken from earlier tested floor beams.

3.2.2. Results of bending and compression testing on small beams without defects

Due to quite large number of samples, only averaging test results for small samples with standard deflection have been provided and then they were recalculated for full-dimensional elements with the use of formulas (1), (2), (3) provided under item 3.1.2 of this paper (as for full-dimensional elements) and then size of samples was taken into account (formula (4)) as well as dissimilarity of testing scheme (formula (5)). Testing results have been presented in Table 4.

If the bending samples height is less than 150 mm then 5% quantile of bending and tension strength shall be corrected up to the value corresponding to 150mm of the sample height, by dividing the result by:

$$k_h = \left(\frac{150}{h}\right)^{0,2} \quad (4)$$

where:

h – sample height in mm

Testing according to standard PN-77/D-04103 and PN-79/D-04102 does not meet employed assumptions of the testing scheme provided in standard EN 408 [4], and for this reason 5% strength quantile shall be corrected by dividing the result by:

$$k_l = \left(\frac{l_{es}}{l_{et}}\right)^{0,2} \quad (4)$$

where:

l_{es} *or* l_{et} $= l+5_{af}$

$a_f = 6h$

a_f, l – dimensions adequately normative and employed in testing

As presented in Table 3 (for comparison purposes) the results of characteristic strength in testing on small samples without defects, have also been presented without taking factor *ks* into account. Comparing Tables 3 and 4 great similarity of final results of the tested wood characteristic strength estimation has been noted. It may indicate that tests on small samples and their analyses according to EN 384 are reliable. However, interpretation of such a comparison shall be careful due to small number of tested models.

Having no knowledge of the timber original parameters it is difficult to determine to what extent it reduced its strength. However, having tested the beams after the period of 130 years of their utilization, it was noted that strength parameters of the old wood are satisfactory and they can be reused. Another plus of old timber is the fact that that old beams, despite existing defects, are already dimensionally stabilized. The minus, however, is the need for additional cleaning of the beams and removal of damaged elements. Testing carried out on samples without defects of 20 × 20 mm section taken from earlier tested beams gave very promising results. Comparing strength of natural scale beams with strength of the little beams without defects determines in accordance with EN 384, great divergence of final results of the estimation of tested timber characteristic strength has been noted. For this reason testing of little samples and their analyses according to EN 384 has been reliable. However, the subject case needs to interpret this comparison carefully due to small number of the tested models.

Two damaged (destroyed) beams were repaired (strengthened) with CFRP during the testing in order to reconstruct their original load capacity and determine effectiveness of the existing old beams repair. The results of this testing will be the subject of separate paper.

When reusing timber elements after some demolition, very often decisive factor is profitability of such an activity. The basic factors which influence cost of obtaining wood from the structures demolished by the companies mediating its sale are cost of transport as well as costs related to cleaning, segregation and exposition of the obtained elements. Very often recycling of materials from demolition enables an investor to reduce cost of such a project as obtained material can be sold and cost of its utilization does not need to be incurred.

4. CONCLUSIONS

The subject of testing were 130-year-old timber beams obtained from floor construction of the monumental building, and the purpose of testing was their examination and checking their usefulness for reuse.

Based on the performed testing it can be stated that recycling of old floor beams from the demolished buildings is justified.

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Table 4. Strength properties of tested wood

	Mean strength $f_{śr}$ [MPa]	Standard deviation s [MPa]	Correction factor k_h [–]	Correction factor k_s [–]	Correction factor k_v [–]	Correction factor k_l [–]	Characteristic strength f_k [–]
Bending	65.44	10.49	1.50	–	1.0	1.32	24.36
Bending	65.44	10.49	1.50	0.77	1.0	1.32	18.76

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Abstract

In Poland, timber as a structural material is mainly associated with a historical building material of wooden cottages or sacred buildings in rural areas, as well as engineering facilities such as bridges or footbridges. In more contemporary applications, first of all timber is used for roof load-bearing structure (rafter framing in different static schemes and load carrying systems) and for timber floor load-bearing elements. In the past obtaining wood was not difficult due to quite large afforestation of Poland. However, the problems of the reuse of whole wooden elements built-in in the structures are practically unknown in our country.

Laboratory tests were carried out on 130-year-old wooden floor beams obtained from the monumental building under renovation. Original floor, whose beams were used for testing, was first made as beam-framed floor with sound boarding and ceiling. Testing elements delivered to the laboratory had got vivid restages of old floor – in the form of nails, sound boarding lathes and other impurities. Technical condition of the obtained beams was in the majority of cases good with visible longitudinal cracks. In some of the beams insects feeding well as biological corrosion marks were present.

The paper presents results of laboratory testing on timber beams after 130 years of utilization and evaluation of their technical parameters according to binding standard regulations. Additionally bending tests were carried out on little samples obtained from previously tested beams and compared to tests in natural scale.

As a results of the carried out laboratory tests it was preliminary noted that reclamation of old beams from demolished buildings is possible. If we do not know the original parameters of the timber it is hard to determine the level of strength loss. However, as a result of preliminary tests of full dimension beams obtained from 130 years old building it can be noted that strength parameters of old timber are good and they enable timber reuse. The advantage of old timber is also fact that old beams in spite of existing defects are dimensionally stabilized. The results of timber bending testing on little samples have been compared with results of testing of beams in natural scale. Having analysed the received results, great similarity of final results of estimated characteristic strength of the tested timber has been noted. It may indicate that testing on little samples and their analysis according to EN 384 is reliable. However, interpretation of such a comparison shall be careful due to small number of tested models.

Streszczenie

W Polsce, drewno to materiał konstrukcyjny kojarzony głównie jako historyczny budulec chat drewnianych lub obiektów sakralnych na terenach wiejskich, a także obiektów inżynierskich, takich jak mosty czy kładki dla pieszych. W bardziej współczesnych zastosowaniach drewno wykorzystywano przede wszystkim do wykonywania konstrukcji nośnej dachów (na więźby o różnych schematach statycznych i różnych układach nośnych) oraz jako elementy nośne stropów drewnianych. Dawniej z uwagi na stosunkowo duże zalesienie obszaru Polski, pozyskanie drewna dla inwestycji nie sprawiało trudności. Jednak zagadnienia ponownego użycia całych elementów drewnianych wbudowanych w wielu obiektach, są w naszym kraju praktycznie nieznane.

Do badań laboratoryjnych udało się pozyskać 130 letnie stropowe belki drewniane z remontowanego zabytkowego budynku. Pierwotny strop, z którego pozyskano belki do badań, wykonany był jako belkowy ze ślepym pułapem i polepą. Elementy badawcze dostarczone do laboratorium posiadały widoczne pozostałości po stropie – w postaci gwoździ, łat ślepego pułapu i inne zanieczyszczenia. Stan techniczny pozyskanych belek był w większości dobry z widocznymi podłużnymi spękaniami. W niektórych belkach były widoczne ślady żerowania owadów oraz widoczna korozja biologiczna.

W referacie przedstawiono badania laboratoryjne belek drewnianych po 130 latach użytkowania oraz ocenę ich parametrów technicznych według obowiązujących przepisów normowych. Wykonano również badania na zginanie dla małych próbek pozyskanych z przebadanych wcześniej belek oraz porównano do badań w skali naturalnej.

W wyniku przeprowadzonych badań wstępnie można stwierdzić, że odzyskiwanie starych belek z rozbieranych budynków jest możliwe. Nie znając parametrów pierwotnych trudno określić w jakim stopniu drewno obniżyło swoją wytrzymałość. Niemniej jednak w wyniku przeprowadzonych wstępnych badań na belkach pełnowymiarowych pozyskanych z 130 letniego obiektu stwierdzono, że parametry wytrzymałościowe drewna są dobre i pozwalają na powtórne wykorzystanie. Na korzyść drewna starego przemawia również fakt, iż belki stare mimo istniejących wad są już ustabilizowane wymiarowo. Porównano również wyniki badań drewna przy zginaniu na małych próbkach z badaniami belek w skali naturalnej. Po przeprowadzeniu analizy otrzymanych wyników stwierdzono dużą zbieżność końcowych wyników oszacowania wytrzymałości charakterystycznej badanego drewna. Co może wskazywać, iż wykonywanie badań na małych próbkach i ich analiza wg EN 384 jest miarodajna. Należy jednak ostrożnie interpretować to porównanie z uwagi na niewielką ilość badanych modeli.

„Badania naukowe zostały wykonane w ramach realizacji Projektu „Innowacyjne środki i efektywne metody poprawy bezpieczeństwa i trwałości obiektów budowlanych i infrastruktury transportowej w strategii zrównoważonego rozwoju" współfinansowanego przez Unię Europejską z Europejskiego Funduszu Rozwoju Regionalnego w ramach Programu Operacyjnego Innowacyjna Gospodarka."