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Study of the deformation properties of 40-year-old hardwood

Sviatoslav Homon^{a,*}, Petro Gomon^a, Svytoslav Gomon^a, Pavlo Sunak^b, Mariia Smal^b,
Oksana Dziubynska^b, Serhii Drobyshynets^b, Oksana Peredriy^b

^aNational University of Water and Environmental Engineering, Soborna 11, 33000 Rivne, Ukraine

^bLutsk National Technical University, Lvivska 75, 43018 Lutsk, Ukraine

Abstract

Experimental studies of hardwoods (birch, alder, ash) were conducted under a single short-term axial compression load along the fibers under a rigid test regime. Complete diagrams of the deformation of hardwood wood at the age of 40 years from the beginning of loading to failure (ascending and descending branches) were constructed. The performance of wood samples in 4 deformation areas was analyzed. The main deformation parameters in the precritical (2 areas) and postcritical (2 areas) stages of work were experimentally established: deformation indicators of the end of area I, relative critical deformations (end of area II), relative limiting deformations (end of area III), relative final deformations (end of area IV – destruction). The dependences of the ratio of relative limit deformations on critical ones are proposed.

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Keywords: wood, deformation, critical deformations, limiting deformations, residual deformations, loads.

1. Introduction

Wood is an effective material in construction due to its natural properties (Antszak et al. (2025); Homon et al. (2025); Thelanderson and Larsen (2003); Omotayo et al. (2024); Pinchevska et al. (2020); Gomon et al. (2022)). It has a small mass, which reduces the load on the supporting building structures. (Han et al. (2025); Gomon et al. (2024); Shams Huq et al. (2025); Pavluk et al. (2025); Lamichhane et al. (2025); Ivaniuk et al. (2025)). Wood can work in different humidity conditions (Roshchuk et al. (2024); Wang et al. (2025); Datsiuk et al. (2024); Huang et al. (2006); Janiak et al. (2023); Matviuk et al. (2025)). This material is easy to process, which simplifies construction work (Girhammar et al. (1988); Aleksiievets et al. (2024); Köhler et al. (2007); Homon et al. (2024); Moya and Bano (2017); Heidarzadeh et al. (2026)). The use of wood allows you to reduce the construction time of buildings (Pavluk et al. (2024); Hua et al. (2025); Sobczak-Piastka et al. (2023); Bula et al. (2023); Gomon et al. (2023)). In addition, wood is an environmentally friendly and renewable raw material (Correal. et al. (2014); Gong et al. (2019)). With proper processing, it has sufficient strength and durability (Homon et al. (2024); Rowell et al. (2025); Yasniy et al. (2022); Abed et al. (2022)).

* Corresponding author. Tel.: +38-096-202-09-07; fax: +0-000-000-0000 .

E-mail address: homonsviatslav@ukr.net

In recent decades, the age of commercial forests has decreased. Humanity began to use younger wood. As a result, it is necessary to investigate the physical and mechanical characteristics of such wood. One of these parameters is its deformability, as well as operation in the pre-critical and post-critical stages and determination of the main characteristics.

Nomenclature

σ_c	wood tension;
u_c	relative deformations of wood;
σ_{cI}	wood tension at the end of area I;
u_{cI}	relative critical deformations of wood at the end of area I;
$f_{c,0,d}$	temporary ultimate strength of wood;
$u_{c,0,d}$	relative critical deformations of wood;
$\sigma_{c,u}$	wood tension at the end of area III;
$u_{c,u}$	relative limit deformations of wood;
$\sigma_{c,fin}$	wood tension at the end of area IV;
$u_{c,fin}$	relative residual deformations of wood

The purpose of the work is an experimental study of the deformation characteristics of 40-year-old hardwood in the subcritical and postcritical stages of operation.

2. Methods of experimental research

To solve the tasks set, a series of samples of solid first-grade wood of structural dimensions from various species in the form of prisms with a cross section of 30×30×120 mm was prepared. Such geometric parameters of the samples make it possible to take into account the microstructure and macrostructure of wood and eliminate the influence of friction between the press plates and the ends of the samples. The following hardwood species were selected for experimental studies: birch, alder, and ash.

The samples were manufactured in accordance with current standards (DSTU EN 518–2003; DSTU EN 336–2003)), at the same time, trees with straight trunks and a minimum number of branches were selected. This reduced the knottiness of the material and ensured greater parallelism of the fibers. After cutting, the selected trunks were transported to carpentry workshops, where they were sawn into beams and the blanks were marked.

The wood to be tested had a moisture content of 12%. The blanks were dried in special drying chambers to a humidity 12±1 %, and this indicator was monitored using a moisture meter MD-814 (DSTU 4922:2008). The samples were cut from previously prepared long bars. Each sample received met the requirements for the absence of visible defects, and if any were present, the prisms were rejected (DSTU EN 518–2003; DSTU EN 336–2003).

The scope of experimental research is given in Table 1.

Table 1. The scope of experimental research

Wood species	Cross-section of samples, mm	Humidity, %	Age, years	Loading speed, mm/min	Number of samples, number.
Birch	30x30x120	12	40	1.5	6
Alder	30x30x120	12	40	1.5	6
Ash	30x30x120	12	40	1.5	6

Experimental studies were carried out under conditions of severe loading with continuous control of the increase in plate displacements of the STM-100 testing machine in accordance with current standards (DSTU 3129: 2015), equipped with an automated control system. All samples were subjected to a single short-term load in axial compression along the direction of the wood fibers at a rate of 1.5 mm/min (DBN B.2.6-161:2017; Eurocode 5:2004). An extensometer was used to measure deformations (DSTU 3129: 2015; DSTU EN 380-2008).

The sample loading process was carried out and controlled using a personal computer and specialized software. During the prism testing, the speed of movement of the press plate was recorded. Separate experimental tests of solid wood prisms were conducted with video recording of the deformation process — from the start of loading to the moment of complete destruction of the material.

3. Results and discussion

The analysis of the obtained indicators based on the conducted experiments will be compared with the indicators of 60-year-old wood (Homon et al. (2023)) at a standard humidity of 12% in 4 areas (Fig. 1) (Homon et al. (2023); Yasniy et al. (2022)), which were carried out previously.

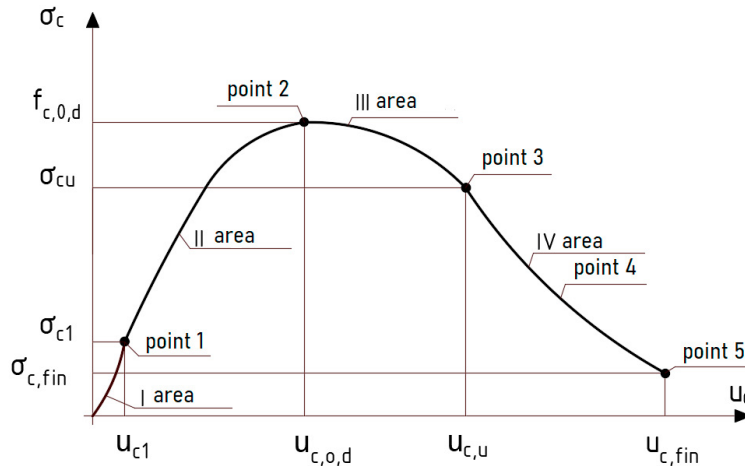


Fig. 1. Standard of the complete deformation diagram "load-displacement" in axial compression along the fibers

Based on experimental studies, complete deformation diagrams "load σ_c – displacement u_c " of solid coniferous and deciduous wood aged 40 years at a standard humidity of 12% were constructed (Fig. 2). The main indicators of strength and deformability were determined in all 4 areas. In all sections of the complete stress-strain diagrams, a slight decrease in the strength and deformation indices of all studied wood species was observed, so we will focus only on those that we will use in the future for analysis and comparison.

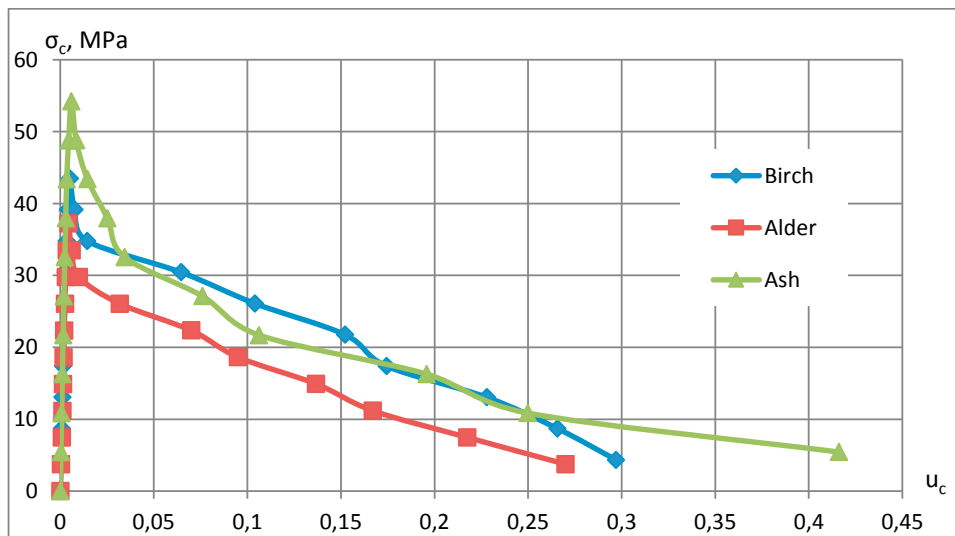


Fig. 2. Complete diagrams of deformation of hardwood wood at the age of 40 years

In the first section (the ascending branch of the diagram), the stresses and relative strains actually had the same values as for the age of 60: for birch wood samples the stress was $\sigma_{cI} = 8.7$ MPa, relative deformations reached the mark $u_{cI} = 0.00069$; alder – $\sigma_{cI} = 7.0$ MPa, $u_{cI} = 0.00074$; ash – $\sigma_{cI} = 8.2$ MPa; $u_{cI} = 0.00063$.

Let's take a closer look at the second section. So, at the age of 40, the upper maximum point of the diagram had the following values (Fig.2): for birch wood, the maximum stresses decreased by 5.9% and reached the mark $f_{c,0,d} = 43.1$ MPa, critical deformations also decreased slightly and were recorded at the mark $u_{c,0,d,exp} = 0.00509$; alder maximum stresses decreased by 9.7% ($f_{c,0,d} = 37.2$ MPa), critical deformations decreased by 4.4% ($u_{c,0,d,exp} = 0.00431$); The strength of ash decreased by 6.5% ($f_{c,0,d} = 54.2$ MPa), deformability actually remained at the same values ($u_{c,0,d,exp} = 0.00597$).

Therefore, the strength of hardwoods aged 40 years (compared to 60 years) in this area decreases by 9.7%, and deformability - up to 4.4%.

The ratio of limiting deformations to critical ones (experimental values) for solid wood at the age of 40 years was determined:
– birch $u_{c,u} = 1.48 u_{c,0,d} = 0.00753$ mm/mm;

- alder $u_{c,u}=1.61u_{c,0,d}=0.00694$ mm/mm;
- ash $u_{c,u}=1.64u_{c,0,d}=0.00979$ mm/mm.

In the fourth section, we present only the final deformations at stresses $\sigma_4=0.1f_{c,0,d}$, since the samples then underwent destruction and then their complete unloading. The relative ultimate strains also decreased somewhat, as did the critical strains, and the following values occurred: birch prisms decreased by 24.2% and reached the mark $u_{c,fin}=0.2970$; alder decreased by 4.6% ($u_{c,fin}=0.2699$); ash trees have decreased by 2.1% ; ($u_{c,fin}=0.4161$).

Thus, at the age of 40 years, a slight decrease in strength and deformability was observed in all sections of the diagram compared to the age of 60 years, except for the last section, where the final deformations of birch and spruce wood were significantly smaller.

The deformation parameters of hardwood wood at the age of 40 years at a moisture content of 12% are given in Table 2.

Table 2. Deformation parameters of hardwood wood at the age of 40 years at a moisture content of 12%

Wood species	$u_{c,l}$, mm/mm	$u_{c,0,d}$, mm/mm	$u_{c,u}$, mm/mm	$u_{c,fin}$, mm/mm
Birch	0.00069	0.00509	0.00753	0.2970
Alder	0.00074	0.00431	0.00694	0.2699
Ash	0.00063	0.00597	0.00979	0.4161

4. Conclusions

1. Experimental studies of hardwoods (birch, alder, ash) were conducted under a single short-term axial compression load along the fibers under a rigid test regime.
2. Complete diagrams of the deformation of hardwood wood at the age of 40 years from the beginning of loading to failure (ascending and descending branches) were constructed.
3. The performance of wood samples in 4 deformation areas was analyzed.
4. The main deformation parameters in the precritical (2 areas) and postcritical (2 areas) stages of work were experimentally established: deformation indicators of the end of area I, relative critical deformations (end of area II), relative limiting deformations (end of area III), relative final deformations (end of area IV – destruction).
5. The dependences of the ratio of relative limit deformations on critical ones are proposed.

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