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Procedia Structural Integrity 48 (2023) 201–206

Structural Integrity Procedia

www.elsevier.com/locate/procedia

Second International Symposium on Risk Analysis and Safety of Complex Structures and Components (IRAS 2023)

Study of change strength and deformation properties of wood under the action of active acid environment

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Abstract

Experimental studies of birch and pine wood by axial compression along the fibers under the action of active acidic environment with different soaking time were carried out. The complete deformation diagrams "stress σ_c - longitudinal deformation u_c" of the examined wood species under such conditions were constructed. On the basis of the experiment, the actual values of ultimate strength, critical and residual (final) deformations of birch and pine wood under the action of an active acidic environment with different soaking time were determined. It was found that exposure to an acidic environment for 28 days of soaking significantly reduces the strength and increases the deformation characteristics of the studied wood samples compared to those at standard humidity. Under such conditions, the ultimate strength decreases by 42.4%; critical deformations increase by 18.5%, and residual deformations increase by 24.8%. It is also proved that the obtained mechanical characteristics depend on the soaking time with various aggressive environment and their concentration.

Keywords: wood, strength, critical and residual deformations, acidic environment, stress-deformation diagram.

1. Introduction

Wood remains one of the priority raw materials of today. It is also important to know that the pace and volume of its processing is increasing every year. Wood is actively used in the woodworking (Gomon et al. (2022); Da Silva and Kyriakides (2007)), furniture, chemical, mining, metallurgical, energy industries (Bosak et al. (2021)), construction industry (Gomon et al. (2019); Sobczak- Piastka et al. (2020); Zhou A. et al. (2018); Nsouami et al. (2022)) and others.

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10.1016/j.prostr.2023.07.149

In some cases, it is exposed to an aggressive environment. In particular, we will be interested in the performance of wood under the action of an acidic environment. Materials, parts, elements, and structures made of wood are exposed to such an environment at chemical, metallurgical, dairy, and other enterprises. Therefore, it is important to investigate the effect of an active acidic environment on the mechanical properties of pine and birch wood experimentally. In the future, the results of such studies can be taken into account when designing products, parts and elements for use in such environments.

Nomenclature

σ_c	compressive stress of wood along the fibers
u_c	relative compression deformations of wood along the fibers
$f_{c,0,d}$	ultimate compressive strength of wood along the fibers
$u_{c,0,d}$	relative critical compressive deformations of wood along the fibers
$u_{c,fin}$	relative residual (final) compression deformations of wood along the fibers

At the same time, wood is more stable when working in an active acidic environment compared to metal (Iasnii et al. (2023); Kovalchuk et al. (2017)), concrete (Dvorkin et al. (2021)), and reinforced concrete (Kovalchuk et al. (2022)).

The strength and deformation properties of wood at standard moisture content have been studied quite extensively (Galicki and Czech (2005); Green and Kretschmann (1992); Landis et al. (2002); Gomon et al. (2022)). Many studies have also been devoted to the performance of wood under the action of the aquatic environment (Báder and Németh (2019); Huang et al. (2006); Thygesen et al. (2010); Vasic and Stanzl-Tschegg (2007)). Complete deformation diagrams of hardwood and coniferous wood under such conditions have been constructed and the main mechanical characteristics have been established (Homon et al. (2023)).

On the other hand, there is a small number of works that investigate the effect of an active acidic environment on the strength properties of wood (Kiseleva et al. (2006)). In general, there are no works on the experimental study of deformation characteristics, including critical, residual deformations and their corresponding stresses.

The purpose of the work is to establish the effect of an active acidic environment on the strength and deformation parameters of birch and pine wood and to compare them with the parameters at standard humidity.

2. Methods of experimental research

For the tests, prisms with a cross-section of 30x30x120 mm were made of 1 grade birch and pine wood. The age of the wood was approximately 60 years. The trees were grown in the forests of the Volyn region. The prisms were made according to the standards (ASTM D 143-14: 2014; EN 380: 2008; DSTU 3129: 2015; DSTU EN 380-2008). Wood samples were dried in special drying chambers to a moisture content of 12%. After that, the prisms were soaked with hydrochloric (15%), acetic (9%), and lactic (40%) acids for 7, 14, and 28 days in special tanks. The number of tested samples was 72. The extent of experimental studies is given in Table 1.

Table 1. Extent of experimental studies of wood under the action of various acidic environments

Wood species	Type of soak	Soaking time, days	Number of samples, pcs
Birch	Hydrochloric acid (15%)	0, 7, 14, 28	12
Birch	Acetic acid (9%)	0, 7, 14, 28	12
Birch	Lactic acid (40%)	0, 7, 14, 28	12
Pine	Hydrochloric acid (15%)	0, 7, 14, 28	12
Pine	Acetic acid (9%)	0, 7, 14, 28	12
Pine	Lactic acid (40%)	0, 7, 14, 28	12

Experimental studies were carried out on the STM-100 testing machine (Yasniy et al. (2022); Homon et al. (2023)) by a single short-term load under axial compression along the fibers at a temperature of 20°C and humidity of 65%, see Fig. 1. The deformation rate of the samples was 1.5 mm/min. Experimental studies were conducted in accordance with current standards (ASTM D 143-14: 2014; EN 380: 2008; DSTU 3129: 2015; DSTU EN 380-2008).

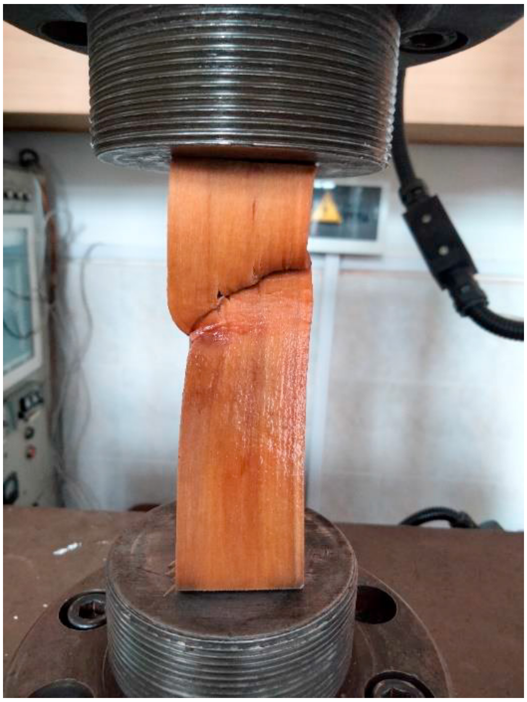

Fig 1. Destruction of a birch wood prism under the action of lactic acid (40%) with a soaking time of 28 days

3. Results and discussion

On the basis of the experiment, complete diagrams of deformation "stress σ_c - longitudinal deformation u_c" of birch and pine wood under the action of hydrochloric, acetic, and lactic acids (see Fig. 2) of different soaking time from the beginning of loading to the complete destruction of the material were constructed.

In these diagrams, we always observe two areas: ascending and descending. This indicates that wood under the action of aggressive environments works not only up to the point of maximum stress, but also has a certain residual (critical) strength after passing this point.

According to the results of the experiment, the tensile strength, critical and residual (final) deformations of birch and pine wood under the action of different active acidic environments were determined (Table 2).

Analyzing Table 2, we conclude that action of an acidic environment significantly reduces the strength and increases the deformation properties of birch and pine wood.

In particular, due to the action of hydrochloric acid (15%), after 28 days of soaking, the ultimate strength of birch prisms decreases by 42.4% compared to the strength of samples at standard humidity, pine by 41.0%; acetic acid (9%) - birch by 20.0%, pine by 21.9%; lactic acid (40%) – birch by 33.0%, pine by 26.2%.

Under the same conditions, under the action of hydrochloric acid (15%), the critical deformations of birch wood increase by 10.7% compared to the critical deformations determined at standard moisture, and pine - by 16.9%; acetic acid (9%) - birch by 13.7%, and pine - by 18.5%; lactic acid (40%) - birch by 16.4%, and pine - by 13.6% (Table 2).

The residual deformations also increase: due to hydrochloric acid (15%) - birch by 21.5% and pine by 22.7%; acetic acid (9%) - birch by 24.8% and pine by 9.7%; lactic acid (40%) - birch by 18.6% and pine by 22.4%, Table 2.

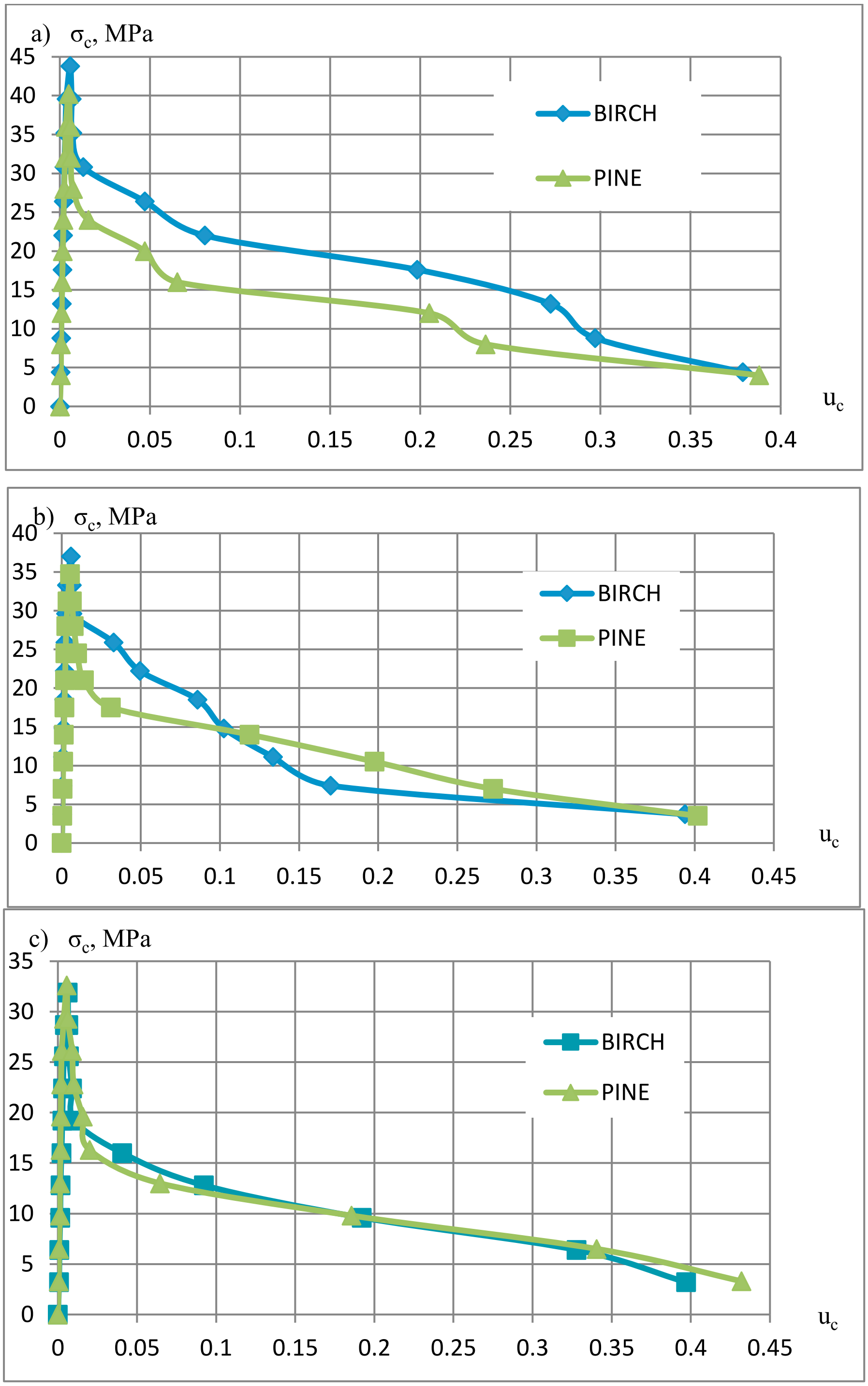

Fig. 2. Complete diagrams of deformation "stress σc,agr - deformation uc,agr" of birch and pine wood under the action of lactic acid (40%) with different soaking time: a) 7 days; b) 14 days; c) 28 days

Table 2. Results of experimental studies of birch and pine wood

Wood species	Type of environment	Soaking time, days	Ultimate strength, $f_{c,0,d}$, MPa	Critical deformations $u_{c,0,d}$	Residual deformation $u_{c,fin}$
Birch	Unsoaked	0	47.6	0.00525	0.3349
Pine	Unsoaked	0	44.2	0.00491	0.3526
Birch	HCl (15%)	7	40.1	0.00551	0.3903
Birch	HCl (15%)	14	34.8	0.00569	0.3916
Birch	HCl (15%)	28	27.4	0.00581	0.4068
Pine	HCl (15%)	7	38.5	0.00540	0.3870
Pine	HCl (15%)	14	31.4	0.00561	0.4023
Pine	HCl (15%)	28	26.1	0.00574	0.4325
Birch	CH3COOH (9%)	7	45.2	0.00568	0.4046
Birch	CH3COOH (9%)	14	40.8	0.00589	0.4142
Birch	CH3COOH (9%)	28	38.1	0.00597	0.4180
Pine	CH3COOH (9%)	7	42.1	0.00559	0.3681
Pine	CH3COOH (9%)	14	41.3	0.00578	0.3703
Pine	CH3COOH (9%)	28	34.5	0.00582	0.3867
Birch	C3H6O3 (40%)	7	43.8	0.00572	0.3796
Birch	C3H6O3 (40%)	14	37.0	0.00584	0.3940
Birch	C3H6O3 (40%)	28	31.9	0.00611	0.3972
Pine	C3H6O3 (40%)	7	40.2	0.00493	0.3859
Pine	C3H6O3 (40%)	14	34.7	0.00531	0.4025
Pine	C3H6O3 (40%)	28	32.6	0.00558	0.4317

4. Conclusions

1. New experimental data on the study of changes in the strength and deformability of birch and pine wood by axial compression along the fibers under the action of active acidic environment with different soaking time were obtained.
2. The complete deformation diagrams "stress σ_c - longitudinal deformation u_c" of the studied wood species under such conditions were constructed.
3. It has been shown that wood under the action of aggressive environment works not only up to the point of maximum stress (ultimate strength), but also has a certain residual (critical) strength after passing this point.
4. It has been established that action of an acidic environment for 28 days of soaking significantly reduces the strength and increases the deformation characteristics of the studied wood samples compared to those at standard humidity. Under such conditions, the tensile strength decreases by 42.4%; critical deformations increase by 18.5%, and residual deformations increase by 24.8%.

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