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UNIVERSAL METHOD FOR DETERMINING THE MODULES OF DEFORMATION OF SOLID WOOD AND COMPOSITE MATERIALS BASED ON IT

A detailed analysis of publications on the wood work under conditions of compression along the fibers is carried out. The paper describes a technique for experimental studies of solid, glued and modified hardwood and coniferous wood of the first grade for compression along the fibers. The composite material «Silor» was adopted as a modifier. The modification was carried out in two ways: surface and deep. Experimental studies were carried out in two series with different sample sizes. Designs of prototypes are given and test facilities are described. The time of impregnation of the polymer composition into the wood body, at which the sample gains maximum strength, is determined. A universal method for determining the secant modulus of deformations of solid, glued and modified wood of different species is presented. Experimental and statistical studies of the stress-strain state of prisms made of solid, glued and modified wood of structural dimensions with high reliability confirmed the presence of linear correlation dependences between the secant modulus of longitudinal relative deformations and the stress level. The linearity of the dependences is confirmed by a good degree of correspondence between the correlation and experimental values of deformations: the absolute value of the correlation coefficient r is close to unity, its reliability r / mr is always greater than four. When constructing the dependence, research points were taken in the voltage range η = (0.2...0.8) according to the recommendations. Diagrams (secant modulus – stress level) were constructed for solid, glued and modified wood impregnated with the «Silor» composite for short-term compression along the fibers. It was found that with an increase in the stress level η, the secant modulus of the modified wood gradually decreases. In the future, it is necessary to carry out tests of glued wood for deep modification with «Silor».

***Keywords*: wood; glued and modified wood; deformation modulus, initial modulus of elasticity; «Silor»; diagram.**

Problem statement. The organic origin of wood is the main difference from artificial composites. The combination of organic composites with artificial ones in some cases leads to an improvement in physical and mechanical properties, such as an increase in strength, a decrease in deformability, and prevents biological degradation.

The use of glued and modified wood in different spheres of the national economy is justified by high technical and technological indicators of its properties as a structural material. Due to the dispersion and removal of defects of solid wood in the volume of the layered macrostructure of glued wood, its quality is improved and strength is increased. With the spread of the use of glued wood in construction, there is a need for one reason or another to strengthen the structural elements. Today, there are various methods of reinforcing, some of which involve changing the design scheme, and others – the unloading of structures. Reinforcing, due to the improvement of physical and mechanical properties, the efficiency of which we study, involves the impregnation of wood with a polymer composition «Silor» [1–3], both solid and glued wood.

Analysis of recent research and publications. Experimental and theoretical studies of solid and glued wood are found in works [4–7].

A large number of scientists have dealt with the problems of wood modification, the methods used for its modification [8; 9].

We have investigated the main strength and deformation parameters of solid and glued wood of various coniferous and deciduous species [10–12]. In our last works [13; 14], the strength and deformation parameters of glued wood modified by «Silor» were also investigated. But at the same time, the secant modulus of deformations was only partially determined at different times of impregnation with a polymer composition of solid and glued wood.

Task statement. To establish the effect of the duration of impregnation of solid wood with polymer composition «Silor» on the secant modulus of deformation of modified solid wood. To determine the initial modulus of elasticity of the obtained solid and glued wood, composite materials**.**

Methods of experimental research. Also, a series of samples of 1 grade of solid wood of structural sizes of different species in the form of prisms with a cross section of 30x30x120 mm was made. The following species of wood were tested: coniferous species – larch, pine, spruce; deciduous – birch, alder, ash. The trees from which the samples were made were grown, in particular, pine, spruce – in the forests of the

Rivne region; birch, alder, ash – in the forests of the Volyn region; larch – in the forests of Ivano-Frankivsk region.

The wood that was tested had a standard humidity of 12%. The age of the wood is 60 years. Wood blanks were dried in special drying chambers to a humidity of 12%. Humidity was monitored using a MD-814 hygrometer. Samples were cut from pre-prepared long bars. For each breed of wood 6 samples were made.

Impregnation of the prototypes with the polymer composition "Silor" was performed in two ways: naturally without additional stimulation (surface modification) and by autoclave (deep modification).

During the surface modification, the wood prisms were immersed in a vessel with a polymer composition for 720 min [13; 14].

The properties of the polymer composition are given in [13; 14].

With deep modification, the samples were placed in an autoclave for 2 hours at a pressure of 2.5 atm. The prisms were then dried for 12 hours.

Experimental studies were performed on a servo-hydraulic test machine STM-100 with an automated control and data recording system [10; 11; 12].

All samples were tested at a single short-term compression longitudinally to the fibers and at an ambient temperature of 20° C. Experimental studies were carried out in a rigid test mode with control of the increment in displacement of the test machine plate.

Presentation of the main material and test results. After processing the obtained experimental data, graphs of the relative deformation of solid and modified wood along the fibers as a function of stresses were constructed [10; 11; 12].

Experimental-theoretical studies have shown that the nonlinear stress-strain dependence (σ - u) dependence of the secant strain-stress modulus (Ej-σ) under compression along the fibers of solid, glued and modified wood can be assumed to be linear with great reliability in next form

$$E' = \frac{\sigma}{u} = E_o \pm \frac{E_o - E_{f_{c,0,d}}}{f_{c,0,d}} \cdot \sigma = E_o (1 \pm \lambda_{f_{c,0,d}} \eta), \quad (1)$$

where $\lambda_{f_{ñ,0,d}} = \frac{u_{pl,d}}{u_{l,d}}$ – the coefficient of plasticity of wood along the fibers; under $\sigma = f_{c,0,d}$, which are determined by processing experimental data by statistical methods of least squares difference;

$u_{pl,d}$ – plastic deformations of the solid, glued, modified wood along fibers; $u_{l,d}$ – elastic deformations of the solid, glued, modified wood along the fibers;

$\eta = \frac{\sigma}{f_{c,0,d}}$ – stress level in wood.

The linearity of the dependences $E' - \eta$ is confirmed by a good degree of correspondence between the correlation and experimental values of the deformations. When constructing the dependence $E' - \eta$, research points were taken in the stress range η = (0.2…0.8) according to the recommendations [15].

Diagrams $E' - \eta$ (secant modulus – stress level) wood during short-term compression along fibers of different impregnation times are shown on fig. 1, 2, on fig. 3, 4 – for glued solid wood of different species, and on fig. 5, 6, 7, 8 – for modified solid wood of deciduous and coniferous species in accordance with surface and deep modification.

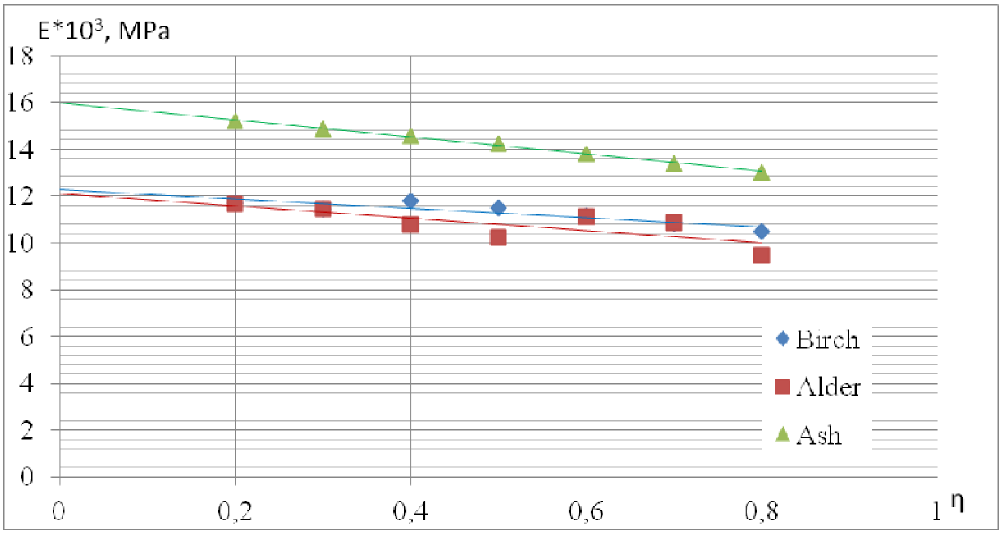

Fig. 1. Diagrams E - η (cross modulus – stress level) of hardwood under uniaxial compression along the fibers

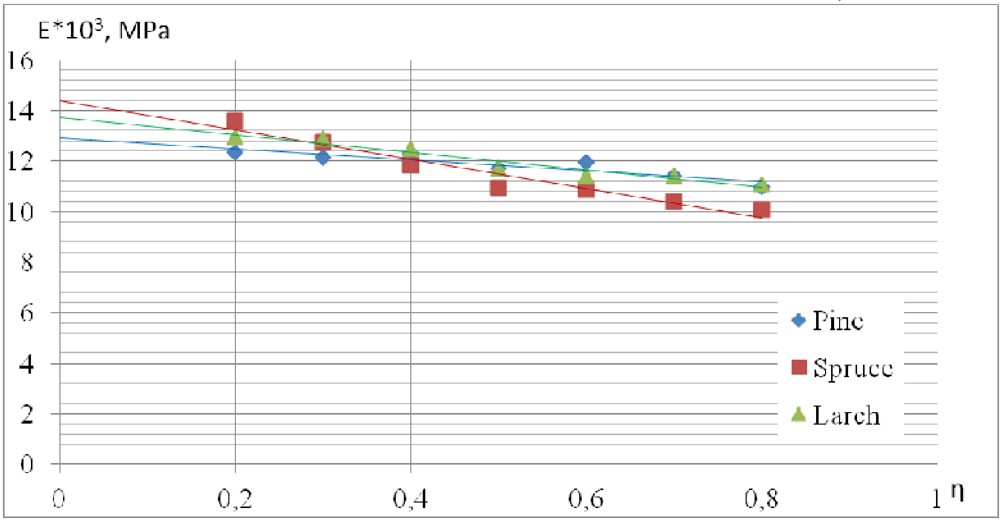

Fig. 2. Diagrams E - η (cross modulus – stress level) of solidwood under uniaxial compression along the fibers

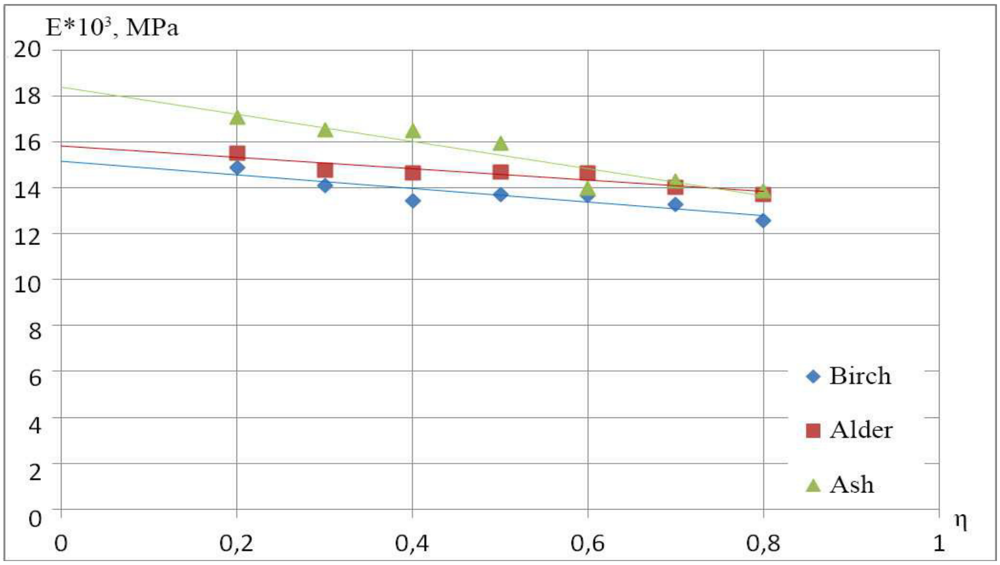

Fig. 3. Diagrams E - η (cross modulus – stress level) of glued hardwood under uniaxial compression along the fibers

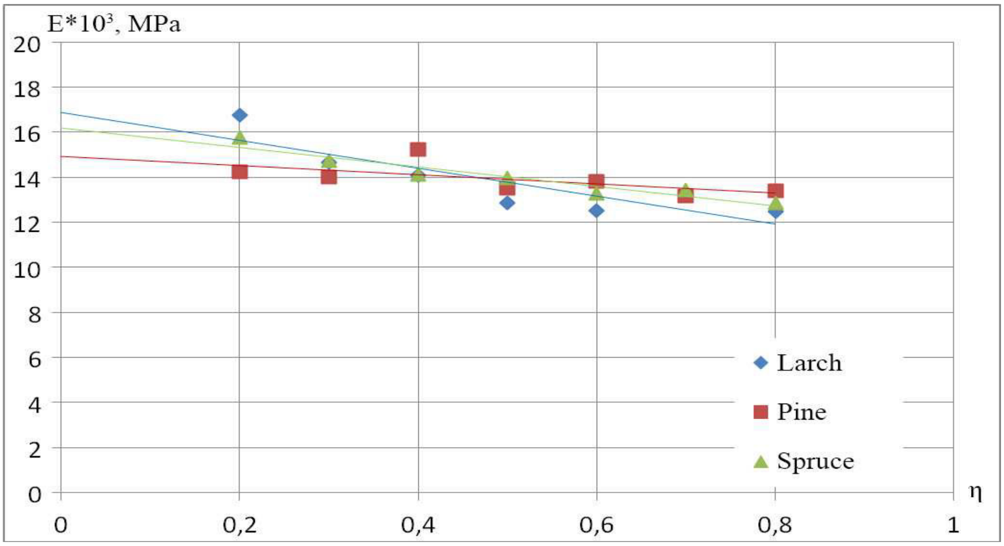

Fig. 4. Diagrams E - η (cross modulus – stress level) of glued softwood under uniaxial compression along the fibers

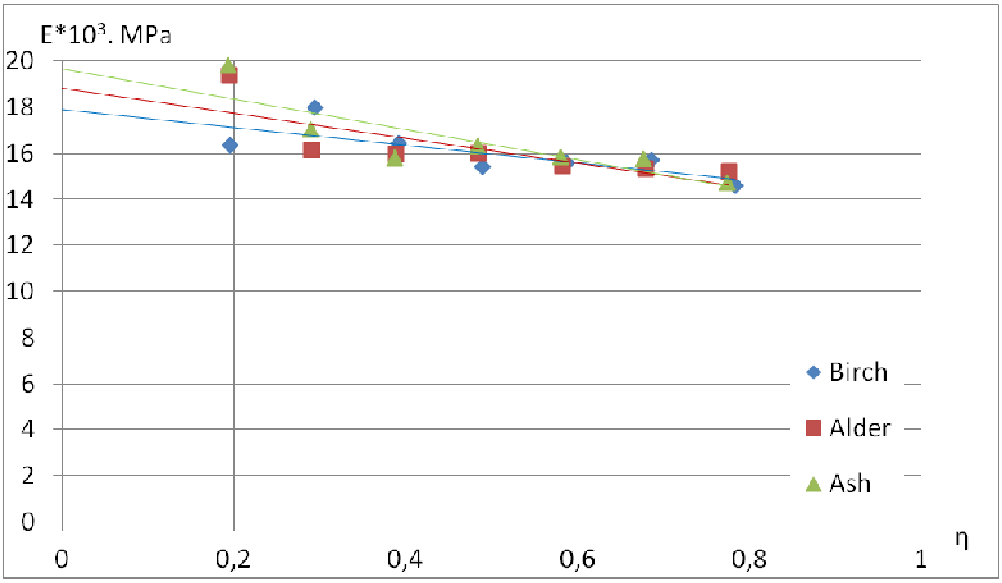

Fig. 5. Diagrams E - η (cross modulus – stress level) of the modified "Silor" of hardwood under uniaxial compression along the fibers (surface modification)

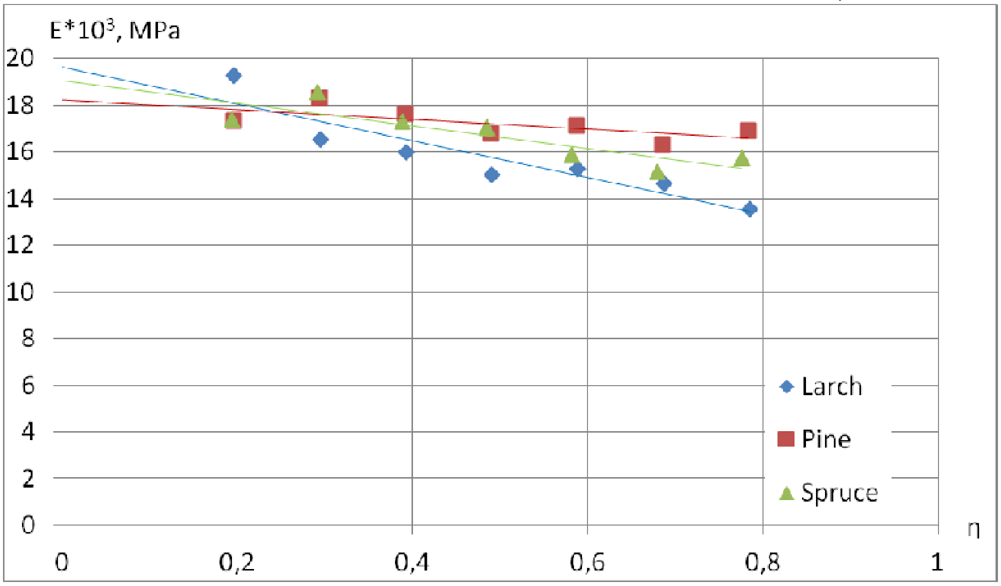

Fig. 6. Diagrams E - η (cross modulus – stress level) of the modified "Silor" of solidwood under uniaxial compression along the fibers (surface modification)

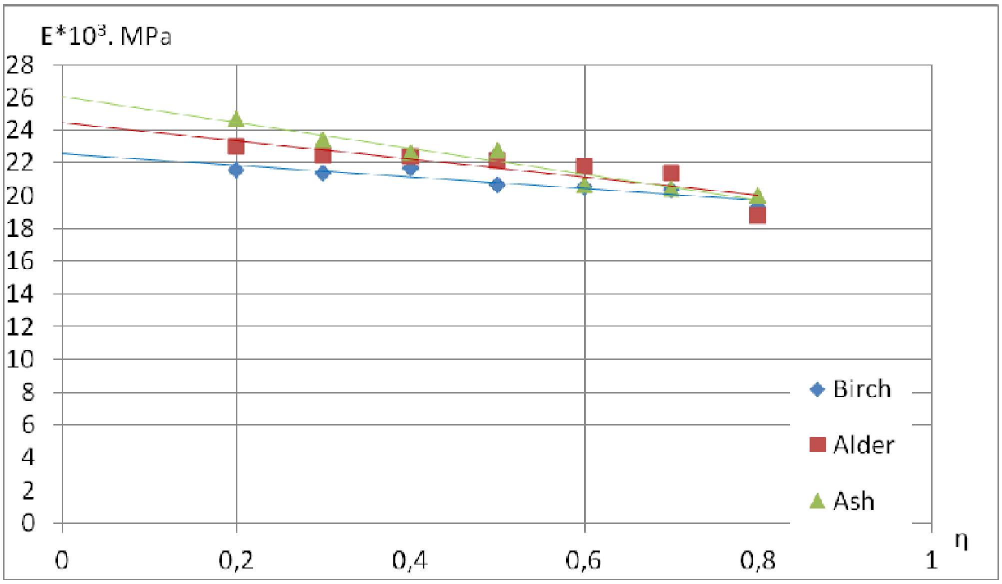

Fig. 7. Diagrams E - η (cross modulus – stress level) of the modified "Silor" of hardwood under uniaxial compression along the fibers (deep modification)

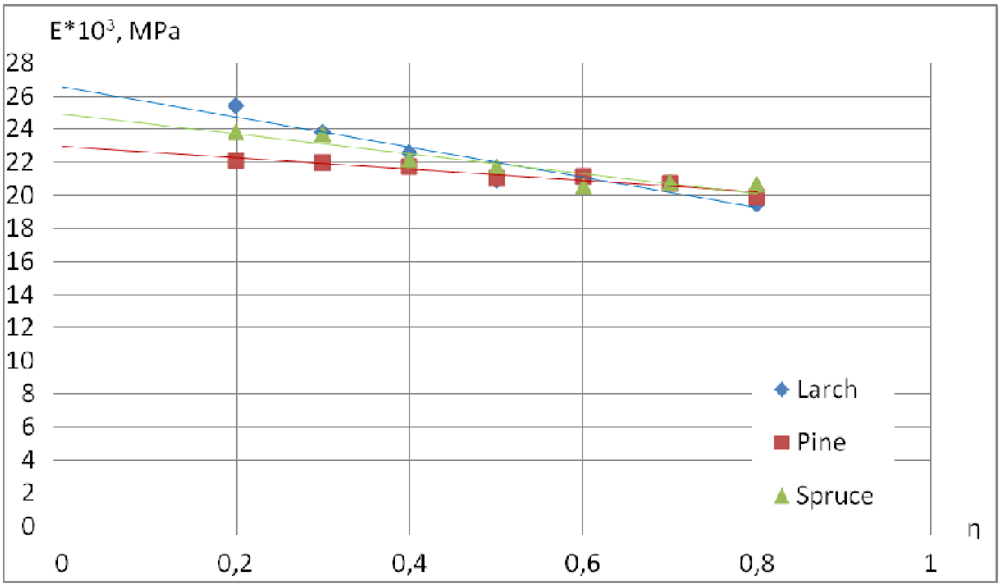

Fig. 8. Diagrams E - η (cross modulus – stress level) of the modified "Silor" of solidwood under uniaxial compression along the fibers (deep modification)

Conclusions

1. On the basis of the experimental and theoretical studies, new data were obtained on the change in the value of the elastic modulus of the solid and glued wood, of the modified "Silor" of the solid wood under load.

2. It was found that with an increase in the level of stresses η, the value of the secant modulus of the modified wood gradually decreases.

3. It is necessary to continue researching the physical and mechanical characteristics of modified wood with various methods of introducing the "Silor" composite into wood.

1. Спосіб ізоляції і зміцнення та полімерна композиція для його здійснення «СИЛОР»: пат. № 40068 А України: заяв. 16.07.2001; Бюл. № 6. **2.** ГОСТ 24329-80. Древесина модифицированная. Способы модифицирования. М. : Стройиздат, 1980. 16 с. **3.** Гомон С. С., Савчук В. О., Мельник Ю. А., Верешко О. В. Область застосування та способи модифікації композиційних матеріалів на основі деревини. *Сучасні технології та методи розрахунків у будівництві* : зб. наук. праць. Луцьк : ЛНТУ, 2019. Вип. 12. С. 44–50. **4.** Иванов А. М. Исследования диаграммы механических испытаний древесины. *Изв. вузов. Строительство и архитектура.* 1959. № 4. С. 116–122. **5.** Быков В. В. Экспериментальные исследования прочности и деформативности древесины сибирской лиственницы при сжатии и растяжении вдоль волокон с учетом длительного действия нагрузки. *Известия вузов. Строительство и архитектура.*

1967. № 8. С. 3–8. **6.** Латынин А. В. Создание клеевых соединений древесины повышенной прочности : дис. ... канд. техн. наук : 05.21.05. Воронеж, 2015. 134 с. **7.** Румянцев М. В. Определение показателей оценки качества клееной древесины с учетом дефектов склеивания : дис. ... канд. техн. наук : 05.21.05. Архангельск, 2002. 176 с. **8.** Машкин Н. В. Эксплуатационная стойкость модифицированной древесины в строительных изделиях и ее технологическое обеспечение : дис. ... д-ра. техн. наук : 05.23.05 / Новосибирск, 2000. 366 с. **9.** Шамаев В. А. Химико-механическое модифицирование древесины : монография. Москва, 2003. 260 с. **10.** Gomon S. S., Pilipaka L. M. Experimental studies of the glued wood strength and deformation properties under hard test mode. *Вчені записки Таврійського національного університету ім. В. І. Вернадського. Сер. Технічні науки.* Київ, 2020. № 3. Том 31(70). С. 130–135. **11.** Gomon S. S. Fluence of age factor on main strength and deformative properties of wood. *Сучасні технології та методи розрахунків у будівництві.* Луцьк, 2020. Вип. 13. С. 35–41. **12.** Yasniy P., Gomon S., Gomon P. On approximation of mechanical condition diagrams of coniferous and deciduous wood species on compression along the fibers. *Scientific Journal of TNTU.* Ternopil, 2020. Vol. 97. No 1. P. 57–64. **13.** Гомон С. С., Гомон С. С., Зінчук А. В. Дослідження модифікованої силором клеєної деревини на стиск вздовж волокон. *Вісті Донецького гірничого інституту* : всеукраїнський науково-технічний журнал. Покровськ : ДВНЗ «Донецький НТУ», 2017. № 1(40). С. 134–138. **14.** Гомон С. С., Гомон С. С., Зінчук А. В. Деформативність модифікованої силором клеєної деревини за роботи на стиск вздовж волокон. *Ресурсоекономні матеріали, конструкції, будівлі та споруди.* Рівне : НУВГП, 2017. Вип. 36. С. 111–117. **15.** Макаренко Л. П., Фенко Г. А. Практический способ определения модуля упругости упруго-пластических характеристик бетона при сжатии. *Известия вузов. Строительство и архитектура*. 1970. № 10. С. 141–147.

REFERENCES:

1. Sposib izoliatsii i zmitsnennia ta polimerna kompozytsiia dlia yoho zdiisnennia «SYLOR»: pat. № 40068 A Ukrainy: zaiav. 16.07.2001; Biul. № 6. **2.** GOST 24329-80. Drevesina modifitsirovannaya. Sposobyi modifitsirovaniya. M. : Stroyizdat, 1980. 16 s. **3.** Homon S. S., Savchuk V. O., Melnyk Yu. A., Vereshko O. V. Oblast zastosuvannia ta sposoby modyfikatsii kompozytsiinykh materialiv na osnovi derevyny. *Suchasni tekhnolohii ta metody rozrakhunkiv u budivnytstvi* : zb. nauk. prats. Lutsk : LNTU, 2019. Vyp. 12. S. 44–50. **4.** Ivanov A. M. Issledovaniya diagrammyi mehanicheskih ispyitaniy drevesinyi. *Izv. vuzov. Stroitelstvo i arhitektura*. 1959. № 4. S. 116–122. **5.** Byikov V. V. Eksperimentalnyie issledovaniya prochnosti i deformativnosti drevesinyi sibirskoy listvennitsyi pri sjatii i rastyajenii vdol volokon s uchetom dlitelnogo deystviya nagruzki. *Izvestiya vuzov. Stroitelstvo i arhitektura*. 1967. № 8. S. 3–8. **6.** Latyinin A. V. Sozdanie kleevyih soedineniy drevesinyi povyishennoy prochnosti : dis. ... kand. tehn. nauk : 05.21.05. Voronej, 2015. 134 s.

7. Rumyantsev M. V. Opredelenie pokazateley otsenki kachestva kleenoy drevesinyi s uchetom defektov skleivaniya : dis. ... kand. tehn. nauk : 05.21.05. Arhangelsk, 2002. 176 s. **8.** Mashkin N. V. Ekspluatatsionnaya stoykost modifitsirovannoy drevesinyi v stroitelnyih izdeliyah i ee tehnologicheskoe obespechenie : dis. ... d-ra. tehn. nauk : 05.23.05 / Novosibirsk, 2000. 366 s. **9.** Shamaev V. A. Himiko-mehanicheskoe modifitsirovanie drevesinyi : monografiya. Moskva, 2003. 260 s. **10.** Gomon S. S., Pilipaka L. M. Experimental studies of the glued wood strength and deformation properties under hard test mode. *Vcheni zapysky Tavriiskoho natsionalnoho universytetu im. V. I. Vernadskoho. Ser. Tekhnichni nauky*. Kyiv, 2020. № 3. Tom 31(70). S. 130–135. **11.** Gomon S. S. Fluence of age factor on main strength and deformative properties of wood. *Suchasni tekhnolohii ta metody rozrakhunkiv u budivnytstvi*. Lutsk, 2020. Vyp. 13. S. 35–41. **12.** Yasniy P., Gomon S., Gomon P. On approximation of mechanical condition diagrams of coniferous and deciduous wood species on compression along the fibers. *Scientific Journal of TNTU*. Ternopil, 2020. Vol. 97. No 1. P. 57–64. **13.** Homon S. S., Homon S. S., Zinchuk A. V. Doslidzhennia modyfikovanoi sylorom kleienoi derevyny na stysk vzdovzh volokon. *Visti Donetskoho hirnychoho instytutu* : vseukrainskyi naukovo-tekhnichnyi zhurnal. Pokrovsk : DVNZ «Donentskyi NTU», 2017. № 1(40). S. 134–138. **14.** Homon S. S., Homon S. S., Zinchuk A. V. Deformatyvnist modyfikovanoi sylorom kleienoi derevyny za roboty na stysk vzdovzh volokon. *Resursoekonomni materialy, konstruktsii, budivli ta sporudy*. Rivne : NUVHP, 2017. Vyp. 36. S. 111–117. **15.** Makarenko L. P., Fenko G. A. Prakticheskiy sposob opredeleniya modulya uprugosti uprugo-plasticheskih harakteristik betona pri sjatii. *Izvestiya vuzov. Stroitelstvo i arhitektura*. 1970. № 10. S. 141–147.

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УНІВЕРСАЛЬНИЙ МЕТОД З ВИЗНАЧЕННЯ МОДУЛІВ ДЕФОРМАЦІЙ СУЦІЛЬНОЇ ДЕРЕВИНИ ТА КОМПОЗИЦІЙНИХ МАТЕРІАЛІВ НА ЇЇ ОСНОВІ

Проведено детальний аналіз публікацій щодо роботи деревини в умовах стиску вздовж волокон. Наведено методику експериментальних досліджень різних порід деревини та композиційних матеріалів на її основі на стиск вздовж волокон за м'якого та жорсткого режиму випробувань. Композиційний матеріал силор використано як модифікатор. Наведено універсальний метод з визначення січного модуля деформацій суцільної, клеєної та модифікованої дере-

вини. Експериментально-статистичні дослідження з високою достовірністю показали наявність лінійних кореляційних залежностей між січним модулем деформацій та рівнем напружень.

***Ключові слова*: деревина; клеєна та модифікована деревина; модуль деформацій; початковий модуль пружності; силор; діаграма.**

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УНИВЕРСАЛЬНЫЙ МЕТОД ОПРЕДЕЛЕНИЯ МОДУЛЕЙ ДЕФОРМАЦИЙ СПЛОШНОЙ ДРЕВЕСИНЫ И КОМПОЗИЦИОННЫХ МАТЕРИАЛОВ НА ЕЕ ОСНОВЕ

Проведен детальный анализ публикаций о работе древесины в условиях сжатия вдоль волокон. Описана методика экспериментальных исследований разных пород древесины и композиционных материалов на ее основе на сжатие вдоль волокон при мягком и жестком режимах загружения. Приведен универсальный метод определения секущего модуля деформаций сплошной, клееной и модифицированной древесины разных пород. Экспериментально-статистические исследования с высокой достоверностью подтвердили наличие линейных корреляционных зависимостей между секущими модулем деформаций и уровнем напряжений.

***Ключевые слова*: древесина; клееная и модифицированная древесина; модуль деформаций; начальный модуль упругости; силор; диаграмма.**
