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INVESTIGATION OF CARBONIZATION OF WOOD BEAMS WITH DIFFERENT FIRE PROTECTION SYSTEMS

This article presents a team of authors that discusses two different methods of fire protection of wooden beams, with one method characterized by deep impregnation of fire retardant solutions and the other characterized by lining with fireproof plywood made of impregnated veneer. Both methods are used for identical samples that are made of solid wood and are subjected to fire tests using a standard temperature curve to determine the depth of charcoal and charcoal formation. The experimental results of the fire resistance tests are given in this article and partly allow us to draw conclusions about the limit of fire resistance of wood beams and to determine the most effective method of fire protection for wood beams. In addition, we have to determine the strength properties of wooden beams.

Keywords: *fire proofingcoating material, fire proof, fire tests.*

1. Introduction

Fire protection of structures is part of a set of fire safety measures used in construction. According to DBN B 1.1-7-2016 [1], wooden structures must be fireproof. Different methods of fire protection can be applied to preserve the natural appearance and texture of the wood, as well as to reduce the risk of its burning.

2. Literature review and purpose of research.

A considerable amount of theoretical and experimental researches concerning fire resistance of building structures and their elements are presented in the works: Belikova AS, Antonova AV, Gorshina SM, Zhartovsky VM, Kravchenko VI, Yakovleva R. A., Fomin S.L., Shnalya T.M., Folomin A.I., Znamensky E.M., Silina V.M., Reitman M.A., Tzapko Y.V., Sizikova O.O. ,Pozeeva SV, White RH, Lie TT, Silcock GWH, Forauter A., Bartelemi V., Kruppa G., Harmathy T.
It should be noted that these studies did not address the characteristics of wood beams with fire protection. Therefore, scientific research to address the issue of fire resistance of wood beams with fire protection remains relevant [2-4].

The purpose of this article is to reveal the regularities of changing the geometric parameters of the charcoal charcoal zone depending on the method of fire protection against the time of fire exposure with a standard temperature regime as the scientific basis for determining the most effective method of fire protection for the assessment of fire resistance of wooden beams.

According to the goal, the following tasks are defined:

1) describe the method of experimental study of the behavior of wood beams with fireproof impregnation in the fire conditions of fire with a standard temperature regime, and the results obtained;

2) identify patterns of change in the geometric characteristics of the charcoal charcoal zone, depending on the method of fire protection, depending on the exposure time of fire exposure to fire with a standard temperature regime.

3. Basic theoretical provisions for the calculation

According to [5], the fire resistance of a structure is the ability of a structure to retain supporting and (or) enclosing functions in the event of fire. The indicator of fire resistance is the class of fire resistance. The limit of fire resistance of a structure is an indicator of fire resistance of a structure, which is determined by the time (in minutes) from the beginning of the fire test according to the standard

temperature regime (1.1) to the onset of one of the fire resistance norms for this design [5].

The most common wooden structures are beams. The fire resistance of the beams is determined by the loss of bearing capacity. Wooden beams lose their bearing capacity as a result of their strength, charcoal depth.

In addition, glued wood is not commonly used, but the issues of fire resistance of the glued wood elements are also not fully addressed. Adhesive materials for structures must provide a combination of such strength and durability that the integrity of the joint is maintained throughout the required time of exposure to fire.

There are four stages to the process of cellulose pyrolysis:

– molecular reaction that leads to degradation (dehydration);

– severing of C - O - C bonds with the development of polymerization and the formation of other compounds that determine the resin fraction;

– decomposition of dehydration products to coal and organic volatile products;

– formation of carbon, water and hydrogen oxides.

Scheme of the process of thermal transformation of cellulose, where heating is due to an external source or reversed heat flow of the products of combustion of materials.

As with liquids, the lowest temperature of wood at which decomposition products can be obtained from the ignition source is called the wood's flammability temperature.

The main factors that influence the behavior of wood under conditions of temperature rise are the following [3]:

- the wood species, its properties (density, permeability, composition) vary considerably, and different wood species behave differently during combustion;
- sample size;
- bo moisture content;
- pyrolysisrate;
- charcoalformation.

To obtain fire retardant wood, the following fire protection methods are used [6-8]:

- impregnation under pressure;
- autoclave diffusion impregnation;
- impregnation in baths;
- surface impregnation;
- impregnation with the help of supercoats;
- plastering method;
- application of blowing materials.

In [9-11], the depth of carbonization of fragments of wood beams with fireproof impregnation after fire tests at standard temperature conditions was considered. The method of deep impregnation "Vacuum-pressure-vacuum" was chosen for fire protection of wooden beams. The overall appearance of all samples after fire tests at different exposure times for visual comparison, are given in table. 1 and fig. 1.

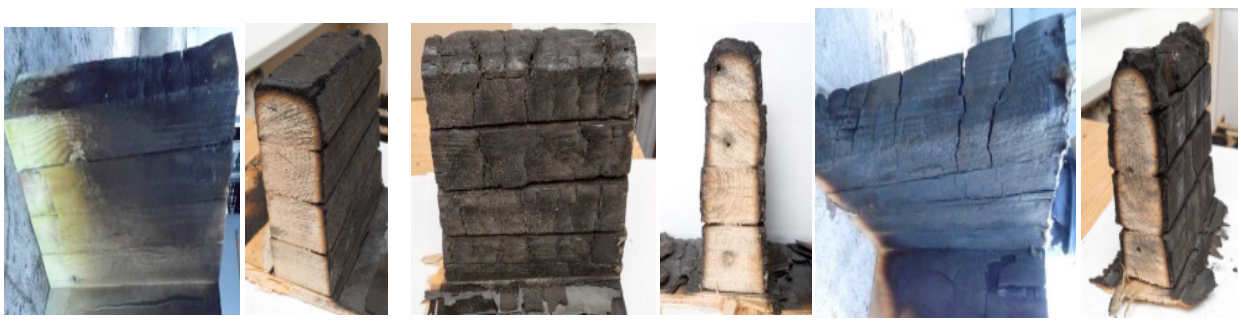

Figure 1 – Photo samples after fire tests.

Table 1 – The value of the thickness of the charcoal layer

	Sample number	Time exp, min	B_0, мм	B_1, мм	B_2, мм	B_3, мм	B, мм	L, мм	L_0 мм
Withou timpregnation	4.1	15	43	45	46	49	65	200	188
	4.2		50	50	50	53	65	200	187
	4.3		43	43	45	48	65	200	186
	4.4	30	52	54	55	57	65	200	179
	4.5		50	52	53	55	65	200	184
	4.6		57	58	59	59	65	200	185
	4.7	60	21	23	24	33	65	200	145
	4.8		10	11	16	23	65	200	123
	4.9		19	45	46	56	65	200	163
Type I fireproof impregnation	1.1	15	50	55	57	58	65	200	199
	1.2		46	55	59	61	65	200	186
	1.3		54	57	57	59	65	200	191
	1.4	30	47	52	54	54	65	200	194
	1.5		49	50	59	59	65	200	189
	1.6		41	45	47	51	65	200	185
	1.7	60	30	40	44	46	65	200	165
	1.8		34	44	46	47	65	200	173
	1.9		22	41	47	55	65	200	183
Type II fireproof impregnation	2.1	15	52	54	55	59	65	200	188
	2.2		55	57	58	58	65	200	193
	2.3		48	53	58	58	65	200	186
	2.4	30	46	49	54	54	65	200	186
	2.5		50	54	54	56	65	200	184
	2.6		54	54	57	58	65	200	184
	2.7	60	40	47	50	52	65	200	183
	2.8		23	50	50	53	65	200	182
	2.9		27	44	46	48	65	200	182
Type III fireproof impregnation	3.1	15	50	57	59	62	65	200	198
	3.2		55	57	57	60	65	200	197
	3.3		55	56	59	62	65	200	196
	3.4	30	51	54	56	59	65	200	194
	3.5		50	52	53	55	65	200	195
	3.6		54	56	57	59	65	200	194
	3.7	60	49	51	52	54	65	200	188
	3.8		54	58	59	62	65	200	190
	3.9		23	53	53	55	65	200	188

To determine the class of fire resistance of wooden beams, the results were obtained of the charcoal depth of the wood beam fragments with lining with flame retardant after fire tests according to the standard temperature regime, which are presented in Fig. 2. and Table 2.

a) b) c)

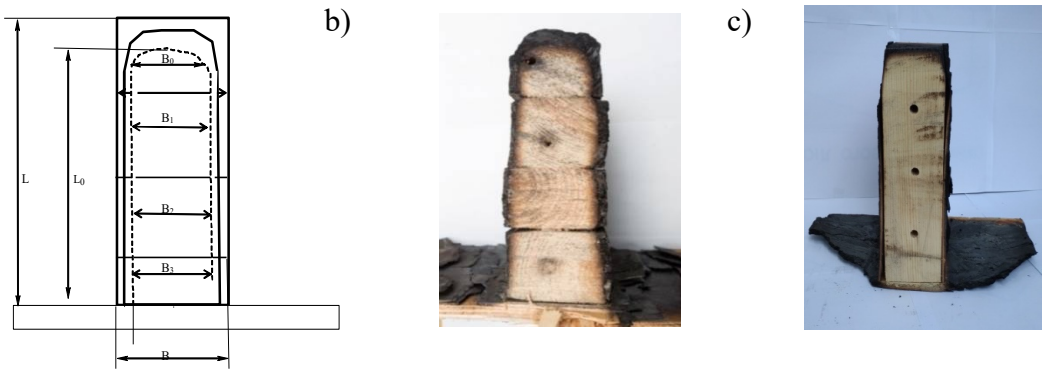

Figure 2 – Schematic representation of the measurement areas on the sample: L - length of the sample before the test begins; L0 is the length of the charred portion of the sample; L1 - sample length after fire test; Bs0, Bs1, Bs2, Bs3 - width at each fragment of glued bar after fire test; B is the width of the specimen prior to the fire test a) schematic view; b) a sample with type III fireproof impregnation; c) specimen with lining fireproof plywood.

Table 2 – The value of the thickness of the charcoal layer

	Sample number	Time exp, min	B_0 мм	B_1 мм	B_2 мм	B_3 мм	B мм	L_0 мм	L мм
With 1 layer Fireproof plywood 10 mm	1.1.	15	70	70	70	64	70	243	250
	1.2.		70	70	70	62	70	244	250
	1.3.		70	70	70	62	70	245	250
	2.1.	30	56	54	50	45	70	231	250
	2.2.		56	55	54	44	70	236	250
	2.3.		56	55	53	43	70	235	250
	3.1.	60	51	48	44	28	70	206	250
	3.2.		49	46	42	27	70	208	250
	3.3.		52	49	45	29	70	207	250
With 1 layer Fireproof plywood 20 mm	1.4.	15	70	70	70	70	70	250	250
	1.5.		70	70	70	70	70	250	250
	1.6.		70	70	70	70	70	250	250
	2.4.	30	65	65	65	60	70	240	250
	2.5.		70	70	66	62	70	243	250
	2.6.		70	70	68	65	70	245	250
	3.4.	60	55	50	46	36	70	227	250
	3.5.		53	51	48	44	70	215	250
	3.6.		53	50	47	42	70	215	250

4. The method of determining the depth of charcoal

The following procedures should be followed to determine the carbonation depth of wooden beams.

1. determine the performance of the sample. 2. the obtained sample is subjected to one of the methods of fire protection of wooden structures. 3. Conduct fire tests on a standard temperature curve for 15, 30, 60 minutes. 4. after the end of the experimental part, measurements of the depth of charcoal using the caliper according to Figure 2 (a) are made and recorded in table 2. 5. conclusions are drawn as to the effectiveness of the fire retardant method for wooden structures and the depth of charcoal of wooden beams.

5. Conclusions

Thus, we determined the temperature distributions in cross section of a wooden beam

fragment, which was tested using recommendations containing an appropriate standard for the calculation methods of fire resistance of timber structures. The calculation results allow us to determine the effective method of fire protection.

REFERENCES

1. DBN V. 1.1.7(2016) *Fire safety of construction sites.* (Kyiv: Gosbud Ukraine)
2. Antonov GA. V., Borisov O.V., Orel V.P. 2004. *Extinguishing media: manual* K .: Pozhinformtekhnika. P. 176.
3. Nizhnik EC. V., Zhartovsky S.V., Tyshchenko O.M., and others - 2010. Substantiation of the use of some water extinguishing agents for the fire extinguishing system for dome wooden structures of religious buildings: *scientific bulletin*. K .: UkrNIPIP. 2 (22). P. 1-4.
4. Investigation of peculiarities of the formation of combustible gases in the process of thermal decomposition of wood and their fragmentation 2005. *Scientific Bulletin of the Ukr Research Institute*. №1 (11). P.14-18.
5. Gorbachenko YA. 2014. Investigation of the behavior of wood beams with fireproof impregnation: scientific article Collection of scientific works. *Fire safety: theory and practice*. Cherkasy ChIPB 7. P 8-13.
6. Krivtsov, Yu. V. 2008. Comparative evaluation of test methods for fire retardant compositions for wood *Fire safety*. 2. P. 87-91
7. Luneva NK Pat. 1628475, MIK 08 V 5/00, V 27 K 5/00 Method of treatment of wood materials of coniferous and deciduous breeds
8. GOST 20022.2-80.*Wood protection. Classification*. Moscow, P. 20.
9. GOST 30219-95. *Wood is fireproof. Test methods, transportation and storage* . Moscow, P. 20.
10. Kislov YS 2000. Physical models of combustion in a fire prevention system: *A monograph*. St. Petersburg. P.263.
11. Likov AV 2012Heat-mass transfer in caillary-porous bodies . *in the book.* Problems of heat exchange. M .: Avtomizdat, P. 332

ПЕРЕЛІК ПОСИЛАНЬ

1. ДБН В. 1.1.7 (2016) Пожежна безпека будівельних майданчиків. (Київ: Держбуд Україна)
2. Антонов Г.А. В., Борисов О.В., Орел В.П. 2004. Засоби пожежогасіння: посібник К .: Пожинформтехніка. С. 176.
3. Нижник К. В., Жартовський С. В., Тищенко О. М. та інші - Обґрунтування використання деяких засобів для вогнегасіння для системи пожежогасіння для купольних дерев'яних споруд культових споруд: науковий вісник. К .: УкрНІПБ. 2010. 2 (22). С. 1-4.
4. Дослідження особливостей утворення горючих газів у процесі термічного розкладання деревини та їх фрагментація 2005. Науковий вісник Укр. НДІ ім. №1 (11). С.14-18.
5. Горбаченко Я.В. 2014. Дослідження поведінки дерев'яних балок з вогнестійким просоченням: наукова стаття Збірник наукових праць. Пожежна безпека: теорія та практика. Черкаський ЧІПБ 7. Р 8-13.
6. Кривцов, Ю.В.. 2008. Порівняльна оцінка методів випробувань вогнестійких складів для деревини Пожежна безпека. 2. С. 87–91.
7. Лунева Н.К. Пат. 1628475, МІК 08 V 5/00, V 27 K 5/00 Спосіб обробки деревних матеріалів хвойних та листяних порід.
8. ГОСТ 20022.2-80. Захист деревини. Класифікація. Москва, С. 20.
9. ГОСТ 30219-95. Деревина вогнестійка. Методи випробувань, транспортування та зберігання. Москва, С. 20.
10. Кислов Ю. С. 2000. Фізичні моделі горіння в системі запобігання пожежі: Монографія. Санкт-Петербург. С.263.
11. Ликов А.В. 2012Тепломасаж в капілярно-пористих тілах. у книзі. Проблеми теплообміну. М .: Автомиздат, С. 332

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ДОСЛІДЖЕННЯ ОБВУГЛЮВАННЯ ДЕРЕВ'ЯНИХ БАЛОК ІЗ РІЗНИМИ ВОГНЕЗАХИСНИМИ СИСТЕМАМИ

В даній статті розглянуто два різних методи вогнезахисту дерев'яних балок які були піддані вогневим випробуванням за стандартною температурною кривою для визначення глибини обвуглювання.

Отримані експериментальні результати випробувань на вогнестійкість приведенні в даній статті, та частково дають можливість зробити висновки про визначення найбільш ефективного методу вогнезахисту.

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ИССЛЕДОВАНИЕ ОБУГЛИВАНИЯ ДЕРЕВЯННЫХ БАЛОК С РАЗЛИЧНЫМИ ОГНЕЗАЩИТНЫМИ СИСТЕМАМИ

В данной статье рассмотрены два различных метода огнезащиты деревянных балок, которые были подвергнуты огневым испытаниям по стандартной температурной кривой для определения глубины обугливания.

Полученные экспериментальные результаты испытаний на огнестойкость приведены в данной статье и частично дают возможность сделать выводы об определении наиболее эффективного метода огнезащиты.