ΔDelta
15(2): 16–22, 2021
DOI: 10.17423/delta.2021.15.2.102

Assessment of Flame Spread on Retardant – Treated Wood

Elena Kmeťová [1], Iveta Mitterová [1*], Danica Kačíková [1]

[1] Technical University in Zvolen, Faculty of Wood Sciences and Technology, Department of Fire Protection, T. G. Masaryka 24, 960 01 Zvolen, Slovakia; xkmetovae@is.tuzvo.sk; mitterova@tuzvo.sk; kacikova@tuzvo.sk

[*] Corresponding author: mitterova@tuzvo.sk

Original scientific paper

Received: 19.11.2021; Accepted: 12.12.2021; Published: 31.12.2021

Abstract

Current trends in construction are leading to increased use of wooden structures. Wood as a natural material offers many advantages in terms of use, but it also has properties that make its use in construction not entirely ideal. Among the most problematic are its susceptibility to damage by rot, wood-destroying insects, sunlight and, finally, the influence of higher temperatures (fire). The article addresses the issue of fire protection of wood. We present examples of various solutions regarding the protective equipment used and their application possibilities. We also present the results of our own experiments, where we focused on assessing the ability of spruce wood to spread flame on the surface when it is treated with a fireproof coating and vice versa when it is unprotected. For evaluation, we selected three retardants HR-prof, Plamostop D and Plamostop D transparent and a test procedure according to STN EN ISO 11925-2. The results of the tests showed the justification for the use of retarding substances, as pure samples of spruce wood ignited, spontaneously burned, and spread flame on the surface after the initiation stimulus, on the contrary, these phenomena did not occur in retarded samples.

Keywords: spruce wood; fire protection; flame retardants; reaction to fire

1 Introduction

Wood is undoubtedly the oldest material used in construction. Due to the importance attached to the sustainable use of natural resources, wood is currently gaining in popularity. It excels in high mechanical resistance, low thermal conductivity and, in addition, it is an easily available raw material, environmentally friendly.

The disadvantage of wood as a building material is its flammability. In order not to limit the possibilities of its use for the stated reason, a necessary requirement is the implementation of fire protection, which ensures its functionality and stability during the loading of the structure by fire.

An integral part of research on fire protection of wood is to determine the effectiveness of applied protective equipment and their impact on changing its behaviour in fire conditions. For this purpose, different test methods and different evaluation criteria are used, among which we can include flame spread.

Flame propagation is a fire engineering characteristic that affects the entire combustion process. The rate at which a fire develops also depends on how fast the flame can spread over the surface of the combustible material. Unlike liquid surfaces, the solid surface can be in any orientation, which can have a significant effect on flame propagation. Flame propagation is controlled by a mechanism that transfers heat in front of the combustion zone, which is strongly influenced by surface geometry and slope (Drysdale, 1999; Huang et al., 2015; Kobayashia et al, 2001). The flame propagates across the surface of the material usually immediately after ignition, but the flame propagation is faster when there is an ascending flame propagation on the vertically oriented fuel surface. This is due to a change in the physical interaction bedlene the flame and the unburned fuel when the fuel orientation changes, i.e., a change in the direction of combustion of the released flammable gases (ascending) with respect to the direction of flame propagation (Quintiere, 2017; Drysdale, 1999).

Means of fire protection of wood

Fire protection of wood and wood construction can be provided in various ways. An important factor in its design is that it meets certain legislative, technological and also economic criteria (Buchanan, 2001).

Among the most used are the treatment of wood with paints (fire retardant) and tiles with fire-resistant materials. Intensive research to increase the durability and longevity of wood is also underway in the application of nanoparticles. The term "nano" is now an increasingly inflected term. It means extremely small particle sizes, measurable in nanometers.

This innovative technology brings new possibilities for the protection of traditional materials. Unlike conventional preparations, it does not work at the molecular level, but at the atomic level, so it is attributed a more effective effect. As far as wood is concerned, nanotechnologies make it possible to increase its photostability, resistance to wood-destroying fungi, insects, but also to fire (Kubovský et al., 2017), which is of great importance for the developing trend of wood constructions.

Fire protection coatings - with the help of them it is possible to implement quality and cost-optimized solutions (depending on the required fire resistance of the structural element). Fire protection coatings are the cheapest alternative to fire protection. Many of them allow to preserve the original appearance of wood and can be applied directly in the production, respectively. at the place of use. Appropriate types of chemical preservatives are used. These substances must have a legally approved type of designation that defines their directional effect against various degrading factors (e.g., flame retardants). In addition, the technical data sheets define their applicability, methods of application, application concentrations, properties (including reaction to fire class), storage conditions, safety measures at work and the degree of safety of the protected wood. Chemical preservatives are applied to the wood surface or to a certain depth of the wood by painting, spraying, dipping or other non-pressure technologies. It is also possible to use the vacuum-overpressure method of impregnation for requirements for greater penetration depth and greater substance uptake (Štefko, 2010).

Intumescent coatings are currently considered to be the most common means. They are widely used in the protection of wooden and steel structures, but also in the protection of cable systems. The principle of action of these coatings is the expansion and carbonization of the coating on the surface of the structure exposed to high temperatures. A heat-insulating foam layer is formed, which protects and insulates the structure from fire for a time period. During this process, the volume of the original coating increases up to 50 times. Examples of commercially available substances in this group are: PLAMOSTOP D and PLAMOSTOP D TRANSPARENT, FLAMGARD, PROMADUR, PLAMOR OK V 2026, AMONN AMOTHERM WOOD WSB and others.

Fire protection tiles - currently these also offer a wide range of fully certified applications. Most often, these are tiles using fireproof boards. These are intended for the construction of fire structures, especially fire dividers and for the protection (cladding) of load-bearing structures. They are produced on various bases. Inorganic-based boards are the most used (Netopilová, 2013). These are boards based on:

- gypsum binders (plasterboard and gypsum fibre boards, or solid gypsum boards), e.g., RF fire protection board (DF) from Rigips or Knauf FIREBOARD,
- cement binders (cement boards and the addition of various lightweight fillers, such as liapor and vermiculite), e.g., MASTERBOARD, PROMATECT,
- mineral fibre binders (boards based on basalt fibres), e.g., NOBASIL FKD.

The aim of the paper is to assess the ability of the flame spread over the surface of untreated spruce wood and treated with a flame retardant. The retardants HR-prof, Plamostop D and Plamostop D transparent and the test procedure according to STN EN ISO 11925-2 were used for evaluation.

2 Material and Methods

2.1 Sample preparation

The experiments were performed on wood spruce (*Picea abies*), as a representative of the most used wood for construction purposes. The test specimens of said wood had the dimensions 250 mm × 90 mm × 10 mm according to the requirements of the chosen test method. The retardants HR-prof, Plamostop D and Plamostop D transparent were applied to their surface in one layer so that the coating evenly covered the entire front surface of the sample. The application was performed using a flat brush on a clean, dry, and grease-free sample surface, in the amount recommended by the manufacturers: HR-prof 300 $g \cdot m^{-2}$, Plamostop D and Plamostop D transparent 200 $g \cdot m^{-2}$ and 400 $g \cdot m^{-2}$. Six representative samples were prepared for each modification, plus six samples for comparison (no adjustment). For the purposes of evaluation according to STN EN ISO 11925-2, we marked on the samples the place of application of the test flame (in our case on the front surface of the samples) and from this place the standard distance of 150 mm for observing the flame propagation using vertically oriented samples.

HR-prof - one-component, water-borne fire-retardant paint based on ferric phosphate, citric acid and special additives. It is designed for fireproof surface treatment of wooden structures, stairs, coffered ceilings, wooden floors and other wood and cellulose products in the interior and exterior. It is not intended for surface treatment of objects that come into direct contact with food, feed and drinking water. In accordance with the classification standard STN EN 13501-1, the reaction to fire of a given preparation is B-s1, d0 (colorcompany.sk).

Plamostop D - white fireproof foam coating, designed to protect wood, wood and cellulose-based materials, wooden structures, coffered ceilings and other wood and cellulose products against ignition. At a consumption of 400 $g \cdot m^{-2}$ it reaches the reaction to fire class (according to STN EN 13501-1) B - s1, d0. It is produced based on water-soluble dispensers, flame retardants, refractory fillers and blowing agents. It is designed for indoor buildings with a relative humidity of up to 80 %. (firek.sk)

Plamostop D transparent - this is a completely transparent fireproof coating, designed for wooden structures with prescribed fire resistance, to reduce flammability and limit the spread of flame on the surface. It can be applied to the substrate material by painting, spraying or roller. The application technology is chosen regarding the possibility of checking the applied amount per 1 m^2. The fabric is intended for indoor use of buildings with a relative humidity of up to 75 %. At a consumption of 200 $g \cdot m^{-2}$ it reaches the reaction to fire class (according to STN EN 13501-1) B - s1, d0 and at a consumption of 440 $g \cdot m^{-2}$ it increases the fire resistance of loaded wooden structures by 16 min. (firek.sk).

2.2 Test method

The flammability test determines the flammability of a product when exposed to a small, directed flame. This is a currently valid test, the results of which are used in the classification of the built product in terms of reaction to fire (according to STN EN 13501-1). To perform said test, a device is used, the schematic representation of which is shown in figure 1. This test is used to determine the possibility of ignition of a vertically suspended building material when exposed to a direct flame at an angle of 45 °.

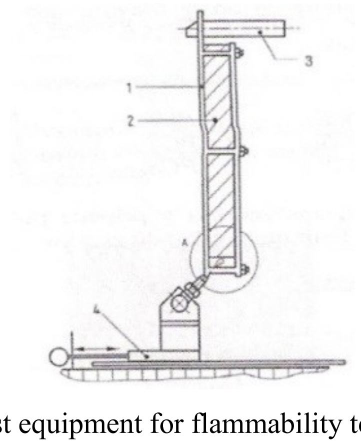

Fig. 1 Schematic diagram of test equipment for flammability test (STN EN 11925-2: 2020)
1 - test specimen holder, 2 - test specimen, 3 - support, 4 - small burner base, A - burner flame acting on the test specimen

The test piece is placed in the sample holder, which is inserted into the device in the prescribed position (Fig. 2). The required flame height is set on the burner - 20 mm. The burner is tilted at an angle of 45 ° to the vertical axis and moved horizontally until the flame reaches the point of contact with the test piece. The moment when the flame touches the test sample is the starting time of the test. Two flame exposure times of 15 s or 30 s are used, with a total test duration of 20 s and 60 s (depending on the classification class). The tests can be performed by exposing the main surface of the samples or by exposing their side surfaces. After the specified flame exposure time, the burner moved away continuously to monitor whether the test specimen ignited, whether the flame peak reached 150 mm above the flame application point and the time when this occurred, the test specimen behaviour (smoke, separation of burning fragments or drops - to determine the additional classification according to STN EN 13501-1).

Fig. 2 Demonstration of the impact of a test flame on the front face of test specimens according to STN EN ISO11925-2

3 Results and Discussion

Using the test method described in the previous section, a series of experiments were performed to monitor the spread of flame over the surface of untreated and retardation-treated spruce wood and to assess its contribution to the development of the fire to which it was exposed. The results of the monitored evaluation criteria are shown in table 1. The photo documentation of the samples after the test is shown in figure 3.

Tab.1 Evaluation of the contribution of untreated and retardation-treated spruce wood to flame spread according to STN EN ISO 11925-2

test flame application time	type of treatment	sample ignition (yes / no)	reaching a height of 150 mm at the head of the flame in a time of 60 s (yes / no)	meeting the classification criterion *Fs* ≤ 150 mm in 60 s (STN EN 13501-1)	filter paper ignition (yes / no)
30 s on the front surface of the samples	**untreated samples**	yes	no	yes	no
	HR-prof	no	no	yes	no
	Plamostop D (200 g·m^{-2})	no	no	yes	no
	Plamostop D (400 g·m^{-2})	no	no	yes	no
	Plamostop D transparent (200 g·m^{-2})	no	no	yes	no
	Plamostop D transparent (400 g·m^{-2})	no	no	yes	no

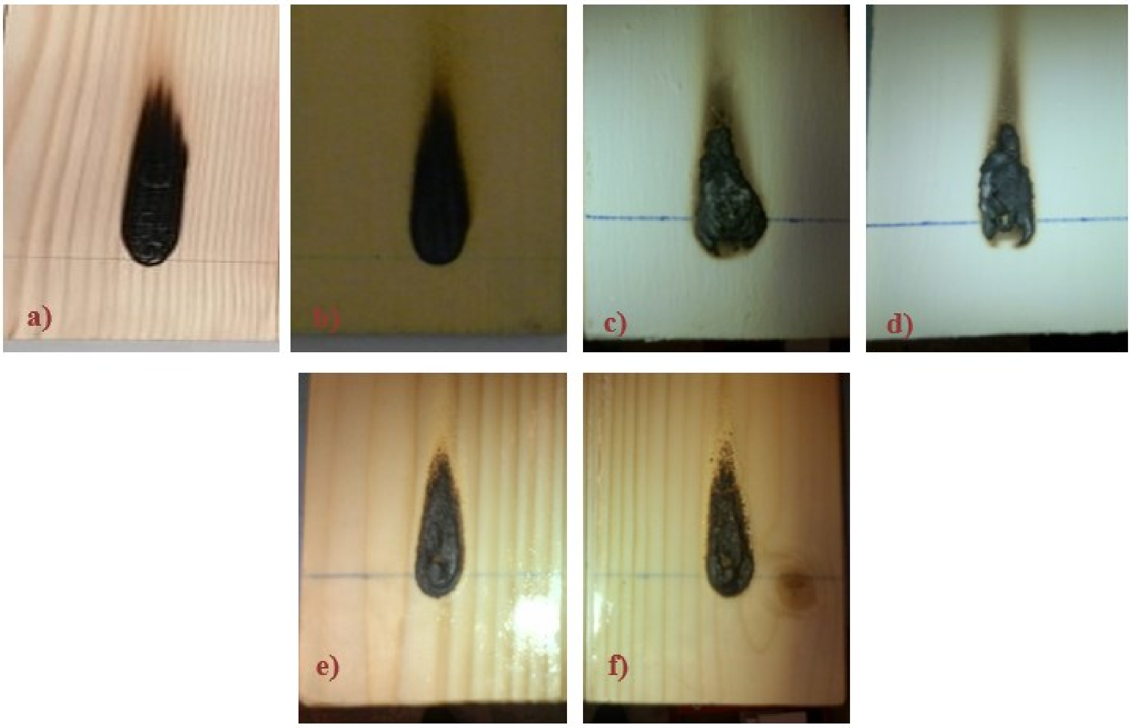

Fig. 3 Photo documentation of spruce samples after the test
a) pure samples, b) with HR-prof application, c) with Plamostop D application (200 g·m^{-2}), d) with Plamostop D application (400 g·m^{-2}), e) with Plamostop D transparent application (200 g·m^{-2}), f) with Plamostop D transparent application (400 g·m^{-2})

If we compare the effect of the applied amount of substances Plamostop D and Plamostop D transparent (200 g·m^{-2} and 400 g·m^{-2}) we can only state that in the selected test procedure there was no significant difference in the results of the monitored criteria.

Another evaluation criterion in accordance with STN EN ISO 11925-2 was the flame spread over the surface of the tested samples. From the results we can confirm that out of the whole number of tested samples, in no case did the flame spread so that the flame front reached 150 mm measured from the contact point of the test flame with the sample after a standard time of 60 s. This result logically resulted from the retardation-treated samples, as they did not ignite, but we also confirm it in the case of pure samples, which ignited. It follows from the above that in accordance with the classification standard STN EN 13501-1, which uses the result of flammability test when classifying into individual reaction to fire classes, where the criterion FS ≤ 150 mm applies, the samples tested by us met this criterion. As for the specific determination of the reaction to fire class - however, we do not know exactly this based on our results, as this determination is conditioned by meeting other classification criteria, according to other test methods, e.g., according to STN EN 13823 (SBI test).

Several authors are studying the flame spread over the surface of the samples. Zachar et al. (2012) investigated the spread of the flame over the surface of untreated spruce samples, which also met the classification criterion, and the flame did not spread above the limit of 150 mm.

Positive effects of HR-prof retardant coating in comparison with untreated spruce wood samples were also demonstrated by Zachar and Mitterová (2015), who, however, used another test method in which the evaluation criterion is mass loss.

4 Conclusions

Many research methods are aimed at increasing the fire safety of wood and wood structures. The paper presents one of the ways through paints with a retarding function. We introduced three types of retardants FR-prof, Plamostop D and Plamostop D transparent, which were used to treat spruce wood samples. We monitored the effectiveness of these substances by means of a flammability test according to STN EN ISO 11925-2, the evaluation criterion of which is flame spread in the vertical direction. The test results of the investigated material (untreated and treated spruce wood) indicate that after treatment with retardants, its resistance to the flame to which it was exposed during the test did not increase, it did not ignite and therefore did not spread the flame. Studies carried out on spruce wood treated with these substances, but other test procedures have shown that these preservatives have had a favourable effect on the fire performance of the wood, have ensured significantly lower mass loss than unprotected wood and have extended the time to ignition.

The results obtained can be used to expand knowledge about the substances and help in the selection of a wood preservative.

Acknowledgments

The authors thank the grant agency of the Slovak Republic that the submitted work was supported by the Agency for the Support of Research and Development on the basis of contract no. APVV-17-0005 (25%) and VEGA grant no. 1/0454/20 (25%) and IPA 4/2021 (50%).

References

Buchman, A. (2001) *Structural desing for fire safety*. England: John Wiley & Sons, Ltd.

Drysdale, D. (1999) *An Introduction to Fire Dynamics*. 2nd edn. England: John Wiley & Sons. ISBN 0-471-97290-8

Huang, X., Liu, W., Zhao, J., Zhang, Y., Sun, J. (2015) Experimental study of altitude and orientation effects on heat transfer over polystyrene insulation material. *Journal of Thermal Analysis and Calorimetry,* 122, 281–293. DOI 10.1007/s10973-015-4667-0

Kobayashia, Y., Huang, X., Nakaya, S., Tsue, M., Fernandez-Pello, C. (2017) Flame spread over horizontal and vertical wires: The role of dripping and core. *Fire Safety Joural*, 91, 112-122. https://doi.org/10.1016/j.firesaf.2017.03.047

Kubovský, I., Gašparík, M., Kačík, F. (2017) *Nanomateriály a vybrané oblasti ich využitia.* Available at: https://stavba.tzb-info.cz/izolace-strechy-fasady/16344-nanomaterialy-a-vybrane-oblasti-ich-vyuzitia (Accessed 15 October 2021)

Mitterová, I., Zachar, M. (2015) The protection of wood construction in buildings. *Rural buildings in European regions : architectural - construction - technology - safety III*, 128-134. https://doi.org/10.15414/2015.9788055213996

Netopilová. M., Kačíková, D., Osvald, A. (2010) *Reakce stavebních výrobků na oheň*. Ostrava: Sdužení požárního a bezpečnostního inženýrství v Ostravě. ISBN 978-80-7385-093-7

Plamostop D. Available at: https://www.firek.sk/plamostop_d.html (Accessed: 16 October 2021)

Plamostop D transparent. Available at: https://www.firek.sk/images/pdf/TL_PLAMOSTOP_D_transparent.pdf (Accessed: 16 October 2021)

Protipožiarny náter HR Prof. Available at: (https://colorcompany.sk/sk/produkt/protipoziarny-nater-hr-prof (Accessed: 16 October 2021)

Quintiere, J.G. (2017) *Principles of Fire Behaviour*. 2nd edn. Boca Raton: CRC Press. DOI:10.1201/9781315369655

STN EN ISO 11925-2:2020 Skúšky reakcie na oheň. Zápaliteľnosť výrobkov vystavených priamemu pôsobeniu plameňa. Časť 2: Skúška jednoplameňovým zdrojom.

STN EN 13501-1:2018 Klasifikácia požiarnych charakteristík stavebných výrobkov a prvkov stavieb Časť 1: Klasifikácia využívajúca údaje zo skúšok reakcie na oheň.

Štefko, J., Reinprecht, L., Jochim, S., Sedlák, P., Thurzo, I., Búryová, D., Soyka, R. (2010) *Moderné drevostavby*. Bratislava: ANTAR, spol. s r.o. ISBN 80-967718-9-2

Zachar, M., Mitterová, I., Xu, Q., Majlingová, A., Cong, J., Galla, Š. (2012) Determination of Fire and Burning Properties of Spruce Wood. Drvna Industrija, 63, 217-223. doi:10.5552/drind.2012.1141