Impact of High-pressure Impregnation and Fire Protective Coatings on the Reaction to Fire Performance of Birch Plywood

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Abstract. Birch plywood has a wide range of applications for interior and exterior use. The demand for plywood with improved fire protection properties and good visual appearance is increasing year by year. The impregnation at high pressure of the whole plywood panels is one of the options to achieve it. The aim of this study was to develop good visual looking birch plywood product for interior design purposes as well evaluate different influencing factors to reaction to fire properties of fire-retardant treated birch plywood. This study consists of three parts. At the first stage, high pressure industrially impregnated plywood properties were studied by two influencing factors – distribution of fire retardant in plywood panel plane and sanding process influence on reaction to fire performance of product. At the second stage, seven different industrial finishing systems were selected for covering high-pressure impregnated birch plywood and their effect on fire reaction performance was studied. In addition, two surface coating systems were studied on standard birch plywood substrate. At the third stage, intumescent coating consumption effect on reaction to fire performance was studied. The reaction to fire performance of birch plywood was evaluated by performing a flammability test using the Single Burning Item test according to EN 13823:2010. It was found that high pressure impregnation of plywood cannot ensure even saturation of fire retardant throughout the sheet, which significantly affects the fire performance of product. The impact of different finishing materials to reaction to fire performance has been described by the results of this research.

Keywords: Birch plywood, reaction to fire, fire retardants, impregnation.

Introduction

Birch plywood has a wide range of applications for interior and exterior use – building and construction. Birch plywood due to its decorative properties can be used as an interior finishing panel for buildings, so it must have both good appearance and small range of thickness tolerances as well as boards have to be covered with a lacquer or similar overlay. However, it is a flammable material and therefore has restrictions on use in areas with high fire protection requirements, such as public places where materials have to meet the requirements of class B-s1, d0 according to standard EN 13501-1:2018 are required. Building materials are being classified in reaction to fire classes A1; A2; B; C; D; E and F with additional classification indexes s1; s2; or s3 for smoke development and d0; d1 or for

flaming droplets occurrence.

Untreated birch plywood ordinary is in reaction to fire class D-s1, d0 if the thickness of plywood is at least 9 mm. But thickness below 9 mm can reduce birch plywood reaction class to E in case of mounting it in test method EN 13823:2010 with ventilated air gap between plywood and substrate.

Two test methods – EN 13823:2010 and EN ISO 11925-2:2020 need to be done for building material classification in reaction to fire classes B; C or D according to EN 13501-1:2018.

The test method EN 13823:2010 (SBI test) determines the limit for Fire Growth Rate (FIGRA), expressed in W s⁻¹, and Total Heat Release (THR), expressed in MJ. Limits for different classes are shown in Table 1.

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Table 1

Risk matrix for milk production and processing in Latvia during the COVID-19 pandemic

Euroclass	FIGRA0.2, W s ⁻¹	FIGRA0.4, W s ⁻¹	THR _{600s} , MJ
B	120	-	7.5
C	-	250	15
D	-	750	-

It is not difficult to meet the requirements of EN 13501-1:2018 by test method EN ISO 11925-2: 2020 for the birch plywood as a material, so the research work described in this paper is focused only on test method EN 13823:2010, which is the main criteria for birch plywood successful classification at highest reaction to fire for wood products. Birch wood species as a material has high heat of combustion per cubic meter of product, thus burning generates a large amount of heat that exceeds the permissible THR value, and raise total heat release at too high level to pass best reaction to fire class B-s1, d0. Therefore, ensuring that birch plywood meets the requirements of class B is a challenging product development process (Bukšāns, 2010).

Fire retardants are chemical impregnating substances that in chemical, physical or combined way protect and prevent ignition, slow down the process of burning of combustible materials and eliminate undesirable causes of fire and conflagration. The principle of retardation process is based either on physical blocking of fire or initiating the chemical reaction that stops the process of combustion. Most retardants work by preventing the access of oxidizing agent (for example, air), but they are also able to affect the ratio of flammability or to upgrade flammability parameters and characteristics of impregnated material which is protected (Fanfarová, Makovická Osvaldová, & Gašpercová, 2016).

Fire-retardant treatments for wood can be classified into two general classes: 1) those impregnated into the wood or incorporated into wood composite products, and 2) those applied as paint or surface coatings (LeVan, 1984). Additionally, combinations between impregnation and surface coatings can be used to reach better surface quality.

Different salt base fire retardants on wood products were investigated by LeVan (1984); Liodakis, Vorisis, Agiovlasis (2006); Kristoffersen and Hansen (2004); Jiang *et al.* (2010) and significant improvement of fire performance of treated wood was reported. However, a weak point of salt-based fire retardants is visual appearance of wood products. Due to high wood

hygroscopicity wood surface is covered by salt residues, which makes surface of wood products look bad. The main challenge becomes to fix fire retardants inside wood cells and prevent leakage (LeVan, 1984).

Grexa (2000) has investigated fire performance of different wood species solid wood products as well as deferment species plywood in cone calorimeter (ISO 5660-1 test method) and room corner test (ISO 9705). He reported significant difference between fire retardant treated wood products and untreated wood products at different heat fluxes (15 – 65 kW m⁻²). It was observed that larger external heat flux increase heat release rate of burning wood specimen. Fire retardant treated Douglas fir plywood showed twice longer flashover time in room corner test, which plays a significant role in fire spread in real fires (Grexa, 2000).

Östman *et al.* (2006) at their research Vinnova-Tekes project InnoFireWood concluded that plywood obtained improved fire performance only when the surface veneer is fire retardant (FR) treated and only with a few FR treatments. FR additives in the glue did not obtain sufficient effect, not even if the veneer is very thin, about 0.5 mm.

Seo, Hwang and Lee (2017) have done research by using boron and phosphorous salts fire retardants applied in vacuum method and high-pressure impregnation. Authors found that peak heat release rate (HRR) of fire retardant treated wood (FRTW) – vacuum treated wood was two times less than untreated and FRTW – high pressure treated wood showed twice less peak HRR than vacuum treated wood. High concentration of fire retardants in wood can be achieved by high pressure impregnation method. When we talk about fire performance of plywood products, we can find that surface treatment methods ensure only top veneer impregnation due to glue line blocking fire retardant uptake. High pressure impregnation with fire retardants becomes an interesting option for improvement of plywood overall performance in fire (Seo, Hwang, Lee, 2017).

Bryn *et al.* (2016) has performed diffusive impregnation of birch veneer and got good fire-

retardant uptake level, when treatment was done at 22 °C temperature with immersion time 8 minutes. Bekhta *et al.* (2016) showed that increased moisture content has a positive impact on the diffusive impregnation process and can be a factor in reducing the duration of impregnation. Deeper knowledge in the field of diffusive impregnation of birch veneer with different fire-retardant chemical is needed to develop maximal fire performance birch plywood. This technology has several benefits comparing to surface treatment and high-pressure treatment of ready-made birch plywood. Distribution of fire protective chemicals in cross-section of plywood in this case should be very even (Bryn *et al.*, 2016; Bekhta *et al.*, 2016).

Architects, design engineers, builders and others must be aware of the potential problems of using FRT wood in severe environments. Specific design considerations include adjustments for temperature limitations, provision for adequate ventilation, and knowledge about the product, namely fire-retardant-treated wood. Problems can arise when fire-retardant-treated wood is used as roof sheathing. Fire retardants are designed to lower the temperature at which thermal degradation occurs. This mechanism can be activated by elevated temperatures caused by solar radiation in combination with certain types of fire-retardant chemicals and moisture (LeVan, Collet, 1989).

One of the options to improve plywood products fires safety is the usage of flame-retardant coatings. Flame retardant coatings are intended to make protective char film on the surface of wood which is different protection mechanism compared to salt-based chemicals. Best working coatings are intumescent coatings, which start protection at the moment when wood element is exposed to heat. Intumescent coatings swell and char when exposed to heat, giving carbonaceous foam that insulates the surface from the fire. The char layer is also responsible for the limitation of oxygen diffusion and the reduction of the volatilization of the fuel in order to prevent the continuation of the combustion cycle. Intumescence resulted from the application of flame-retardant coating systems to timber can reduce the char formation and heat release and also delay the onset of combustion of wood (Zhang, *et al.* 2012).

Intumescent coatings are commonly used for protecting steel structures. Their application on wood has also been studied, and some commercial products intended for wood are available. At present, however, fire protection of wooden and wood-based products with intumescent coatings is not widely employed (Mariappan, 2017). Good surface quality and resistance against moisture impact are two main problems to be solved, when intumescent coatings for wood are used.

Ali, Hussain, & Tohir (2019) has concluded that there are not many in-depth studies focusing on the effects of fire retardants on the ability of strength, durability, hygroscopicity, corrosion, machinability, gluing and paintability of different species of commercially traded timber and timber-based products across the world. We can find some scientific papers, where researchers talk about side effects of fire retardant treatment to wood physical, chemical and esthetical properties, but still the main focus remains on fire performance of wood product. Miljković *et al.* (2005), Hu *et al.* (2015) and Demir, Aydin, & Salca (2017) reported that fire retardant chemicals used in their research, significantly weakened mechanical strength of plywood, which can be a typical problem for fire retardant treated plywood.

Therefore, the aim of this research work was to develop good visual looking birch plywood product for interior design purposes as well evaluate different influencing factors to reaction to fire properties of fire retardant treated birch plywood. Distribution of fire retardant at high pressure impregnated in plywood board as well as surface treatment methods' influence on fire performance need to be investigated in this work.

The only way to change birch plywood performance in fire is to use fire retardant treatments of wood. Hundreds of research works have been published in the field of fire retardancy of solid wood, but plywood fire performance is not so widely investigated.

The focus of this research was to reach the highest reaction to fire performance birch plywood fire retardant treatment, which guarantees good surface appearance and allows to use it in interior finishing building systems. Visible salts and discoloration of product were not acceptable in the development process of this product.

Material and Methods

To achieve the highest fire performance for birch plywood, high pressure impregnation with fire retardant compound commercially available and widely used for fire retardant impregnation of wood products was used in this research. It was known that fire retardant is salt based on boron and nitrogen compound. Specific compounds of fire retardant are not known, as it is kept in secret by manufacturer and cannot be published due to commercial reasons. Specimens were treated at an industrial scale vacuum-high pressure impregnation plant. According to fire-retardant treatment company data, plywood was impregnated with atro/atro level 4.5, which means 4.5% mass of dry basis fire retardant per mass unit of plywood calculated per dry wood weight.

Impregnated birch plywood with nominal thickness

Figure 1. Plywood specimens mounting plan at reaction to fire test.

12 mm was used in the research. Birch plywood was composed of 9 layers of 1.4 mm thick veneers by cross bonding using phenol formaldehyde resin adhesive, with average density 730 kg m^{-3} and moisture content 9-10% reached after conditioning. Conditioning was performed according to the standard EN 13238:2010 at 23°C and 50% relative humidity.

All samples were made from birch plywood made in crossgrain direction of top veneer layer to exclude grain direction impact on the results.

Reaction to fire performance of material was determined by conducting a test according to the method EN 13823:2010. One test specimen consists of two pieces joined together and forms 1500 mm high corner with short edge 500 mm and long edge 1000 mm. Each product variation was tested with three replicants and average values as well as result distribution was evaluated.

The test results may be affected by different factors, such as veneer and plywood density, which were not studied in this research.

In the first part of the study, various factors which may directly affect performance in the flammability test were evaluated. The first influencing factor group was:

1. influence of region of plywood board exposed to fire (specimens were cut and positioned in SBI test in the way as shown in figure 1);
2. influence of surface sanding process after treatment.

In the second part of the study, seven different finishing systems on top of fire-retardant impregnated plywood were evaluated as well as one group with specimens prepared with intumescent coating overlay of single birch plywood. Specimen identification is

shown in Table 2.

Specimen groups were marked by 3 numbers, where the first number identifies test series of different product variations from 0 to 8, second number identifies surface sanding process and third number identifies specimen mounting plan in corner according to Figure 1. Results of each specific plywood panel were compared, because both mounting plan specimens were cut from the same plywood panel, whose initial length was 3000 mm.

Finishing systems differ in type, number of coatings and the amount of applied finishing material. All finishing systems are overlaid on production line in real factory conditions.

In test series 1, 2, 3 and 4 different standard ultraviolet curing (UV) coating materials which were applied on sanded high fire retardant impregnated birch plywood were used. UV curing primer and top coat were applied on roll coater machine. UV curing primer were used for all top coating options. As a top coat ultraviolet curing, polyurethane and acid curing lacquers were used (Table 2). Intumescent coating (specimen group 8) was applied by curtain coater technology.

For test series 5, 6 and 7, the finishing system which is declared in the market as a fire retardant overlay system ensuring B-s1, d0 reaction to fire class for wood products was used. Additionally, one intumescent coating type 8 for achieving B-s1, d0 class was used in this study (Table 2). This intumescent coating is intended to be used with minimal consumption 250 g m^{-2} on wood based substrates to reach B-s1, d0 classification.

The surface of fire-retardant treated plywood was sanded with sandpaper with a grit size P320 before applying additional coatings.

Table 2

Specification of samples

Marking	Plywood	Surface processing	Mounting plan	Primer		Topcoat	
				Type	Consumption, g m ⁻²	Type	Consumption, g m ⁻²
0-1-1	impregnated	unsanded	1	-	-	-	-
0-1-2	impregnated	unsanded	2	-	-	-	-
0-2-1	impregnated	sanded	1	-	-	-	-
0-2-2	impregnated	sanded	2	-	-	-	-
1-2-2	impregnated	sanded	2	UV	40	AC	90
2-2-2	impregnated	sanded	2	UV	40	-	-
3-2-2	impregnated	sanded	2	UV	52	UV	5
4-2-2	impregnated	sanded	2	UV	40	PU	110
5-2-2	impregnated	sanded	2	UV	106	UV	8
6-2-2	impregnated	sanded	2	UV	102	-	-
7-2-2	standard	sanded	2	UV	106	UV	8
8-2	standard	sanded	-	I	300	WB	70
UV – ultraviolet curing, AC- acid curing, PU – polyurethane overlay, I – intumescent basecoat, WB – waterborne lacquer.							

The third part of this study was related to determination of impact factor of intumescent coating consumption to birch plywood reaction to fire performance. For this study, 4 specimen variations – 300, 400, 450 and 500 g m⁻² were prepared. Minimal consumption of this product according to coating manufacturer recommendations was 300 g m⁻² which was applied on birch plywood industrially at the second part of this – specimen group No. 8. As the results of 8 replicants did not show enough fire protection properties, the third part of the study with screening test was planned. Specimens were prepared at a laboratory scale by Airmix spraying technology. Standard birch plywood with 12 mm thickness was used. One specimen per each consumption was prepared to find out consumption impact on reaction to fire performance. This was intended to be a screening test to figure out a potential impact factor. It was set up as a high coating consumption accuracy rule to ensure that intumescent basecoat did not deviate more than 10 g m⁻² from target values. The consumption of coating material was controlled by weighting method per each piece of plywood coated.

Results

Fire growth rate index (FIGRA0.2) and total heat release in first 10 minutes (THR_{600s}) were evaluated as main factors for prediction of reaction to fire performance of plywood.

At first, uncoated impregnated plywood reaction to fire performance was evaluated. FIGRA0.2 and THR_{600s} are shown in Figures 2 and 3. It was observed that fire performance of plywood with outer edge mounting in the center of corner (mounting plan 1) showed smallest deviations between replicants – specimen group 0-1-1. Only this group showed almost passing B-s1, d0 fire performance of fire retardant impregnated birch plywood (average FIGRA0.2 = 120.2 W s⁻¹ and THR_{600s} = 8.6 MJ). Increased deviation in results was observed when inner parts of plywood board were exposed to fire (mounting plan 2). FIGRA0.2 index increased by 1% to 109% as well as THR_{600s} increased by 36% to 101%.

When sanding influence on fire performance of high-pressure impregnated fire-retardant birch plywood was evaluated, FIGRA0.2 increased by 19% to 73% and THR_{600s} by 37% to 72% when specimens were

Figure 2. Fire growth rate index of fire-retardant impregnated plywood.

Figure 3. Total heat release rate of impregnated plywood.

Figure 4. Fire growth rate index of fire-retardant impregnated plywood with top coatings.

tested after surface sanding at mounting plan 1. When specimens after sanding were tested at mounting plan 1, FIGRA0.2 variation -20% to +38% compared to non-sanded plywood THR_{600s} increase by 11% to 28% was observed too. This observation shows that most of fire retardant is at the outer edge of plywood panel and

mainly in top veneer layer of plywood panel.

Non-sanded plywood visual appearance properties do not satisfy product esthetical properties at product end use; therefore, sanding becomes significant surface quality improvement technique.

From 12 test samples, only one sample showed FIGRA and THR_{600s} values which meet the requirements of class B according to the standard EN 13501-1:2018. The requirements of class C were met by 7 samples and 4 samples met the requirements of class D.

In the second part of the study, the impact of surface finishing systems on reaction to fire performance of impregnated birch plywood was evaluated on the specimens prepared according to the mounting plan 2. Reaction to fire performance main criteria FIGRA0.2 and THR_{600s} is shown in Figures 4 and 5. The average FIGRA value of the 0-2-2 series was 209.8 W s^{-1} and the THR_{600s} value 16.6 MJ which classifies this product in reaction to fire class D.

The lowest average value of $FIGRA_{0.2} = 164.9 \text{ W s}^{-1}$ was achieved with UV curing prime - sample series 2-2-2, (Figure 4). The disadvantage of the system is that it does not have a top layer. Using acid curing lacquer as the top layer (sample series 1-2-2) the average value increased to 202.9 W s^{-1} . Besides, using the top layer – UV curing lacquer (sample series 3-2-2) with very small consumption only 5 g m^{-2} , the average value was increasing to 213.1 W s^{-1} .

A similar scenario can be observed with finishing systems 5 and 6, where the coating with prime (finishing system 5) gives the second lowest average value of $FIGRA_{0.2} = 165.9 \text{ W s}^{-1}$, but the finishing system 6 with additional layer of lacquer with consumption of 8 g m^{-2} gives increment to 212.9 W s^{-1} .

The lowest average values of THR_{600s} (Figure 5) have got with fire retardant finishing systems of UV curing materials which consist of 5 and 6 layers (sample series 5-2-2 and 6-2-2). The average value of THR_{600s}

for full finishing system (sample series 5-2-2) is higher than without a top layer. It is similar to $FIGRA_{0.2} = 14.6$ which is 14.6 MJ . The finishing system 2 got the average value of THR 15.2 MJ . Using acid curing lacquer as the top layer (sample series 1-2-2) the average value was increased to 15.7 MJ . But using UV curing lacquer as the top layer (sample series 3-2-2) the average value was increased to 16.7 MJ .

Finishing system 7 just on non-fire retardant treated birch plywood (sample series 7-2-2) showed the average value of $FIGRA_{0.2} = 430.7 \text{ W s}^{-1}$, and $THR_{600s} = 21.7 \text{ MJ}$, which positioned birch plywood in reaction to fire class D-s1, d0.

The finishing system 8 was tested on non - impregnated birch plywood. The average $FIGRA_{0.2}$ value of 8 tests was 72.5 W s^{-1} with standard deviation 9.4 and $THR_{600s} = 8.2 \text{ MJ}$ with standard deviation 1.3. Individual test data was shown in Figure 6 and 7 to depict B class borderline product reaction to fire performance problem. Test results show that intumescent overlay very well decreases the parameter $FIGRA_{0.2}$, but it was not enough for the decreasing of THR_{600s} to the limits of reaction to fire class B requirements. These specimens were prepared according to fire retardant coating manufacturers' guidelines and results showed that not all replicants could pass reaction to fire class B-s1, d0 requirements – only 3 of 8 fulfilled B class requirements.

Influence of intumescent coating consumption to reaction to fire performance was investigated on four different specimens, and good correlation between consumption of fire-retardant basecoat and reaction to fire performance parameters $FIGRA_{0.2}$, THR_{600s} was found, Figures 8 and 9. The coefficient of determination was close to 1, which means very good relationship between those parameters.

Figure 5. Total heat release rate of impregnated plywood with top coatings.

Figure 6. Fire growth rate index for tests with intumescent overlay.

Figure 7. Total heat release rate for tests with intumescent overlay.

Figure 8. Intumescent basecoat consumption influence on fire growth rate index.

Figure 9. Intumescent basecoat coverage influence on total heat release.

Discussion

Most researchers have published laboratory scale obtained data of improvement of reaction to fire performance of wood products often done on cone calorimeter method studies, but this paper represents industrial scale research with fire test methods used for official building materials classification according to EN 13501-1:2018. One of the most important obstacles is economical reasons, but on the other hand it is reported that fire retardants can decrease mechanical properties of wood as well as aesthetic properties of wood. So, it becomes extremely difficult to find a solution for combining all needed properties for wood product, which should be fire proof, mechanically resistant, durable, good looking and should not emit dangerous substances. This paper covers just a small part of those properties by focusing on aesthetic properties and reaction to fire performance.

This research work has a significant impact on high-pressure impregnated plywood industry, because experiments were not completed at laboratory scale small specimens, but all specimen preparation manipulations were done at factory scale in a real production process. Previous observations showed problematic consistence of performance of high pressure impregnated fire-retardant birch plywood and this research work was intended to find impact factors on fire performance of high pressure impregnated birch plywood.

According to the European Communities' decision of 15 May 2007 (2007/348 / EC), unimpregnated birch plywood corresponds to the class D-s2, d0, so it can be concluded that the birch plywood used in the test does not show better performance as standard plywood. So the results showed that in some plywood panel surface areas almost all fire protection effect is

lost after sanding process, which returns it to natural birch plywood reaction to fire class D-s1, d0.

In fact, the highest possible fire performance was for specimen group 0-1-1, where outer edges of plywood panel were exposed to fire, but results didn't show enough fire protection performance to classify this high pressure impregnated birch plywood in B-s1, d0 reaction to fire class. Such birch plywood treatment method is widely used in market and it is sold as B-s1, d0 reaction to fire material. This research work showed significant problem with high pressure impregnated plywood products in the market. According to findings of this research work, much of high-pressure impregnated plywood in the market does not meet B-s1, d0 requirements at their end use. Experimental results showed large deviations in FIGRA0.2 index from 114.5 to 264.5 W s⁻¹ with standard deviation 53 W s⁻¹ and THR deviation from 7.5 to 18.5 MJ with standard deviation 3.7 MJ when fire retardant plywood tested in EN 13823:2010 test method, which push to hypothetical conclusion that high-pressure impregnation method cannot ensure constant compliance of plywood product properties within the declared reaction to fire class. Experimental results showed that one panel fire performance can differ more than 2 times if different panel areas are tested. It can be explained with uneven distribution of fire retardant in plywood panel during high pressure impregnation process. The fact that most of fire retardant has penetrated in plywood from edges can be easily explained by moisture movement phenomena in wood cells.

The easiest way to uptake liquid in wood cells is through the open edges of plywood panels where axial direction moisture moment in wood grains plays most significant role.

Fire retardant uptake through plywood panel surface is problematic due to glue line blocking moisture movement in inner veneer layers. Experimental results showed that in some places we can see deeper penetration of fire retardant than top veneer layer only, but some places are impregnated only at the top veneer layer level. It brings to large deviations in fire performance parameters of impregnated plywood product.

Second stage experiments were intended to show top coating influence on reaction to fire performance of high-pressure impregnated birch plywood. Hypothetical theory indicates the fact that top coatings reduce fire performance of wood product if it is fire retardant treated and is within the limits of reaction to fire class B-s1, d0. Influence of top coatings on reaction to fire performance of birch plywood was not so significant from coating systems tested in this research, which can be explained by uneven base material for application of top coatings. The first stage of the experiment showed a large distribution between replicants, and this effect comes also to the second stage as an additional influencing factor. In spite of that good surface treatment quality was achieved for birch plywood by all coating systems used in this research. Top coating systems used in this research showed good potential to maintain the reaction to fire performance of fire retardant treated birch plywood; however, the initial level of high pressure impregnated plywood was not sufficient for B-s1, d0 reaction to the fire class.

An interesting conclusion was found in studies of intumescent coatings application for birch plywood protection from fire. Intumescent coatings protect wood from heat exposure and delay ignition and pyrolysis process. Birch wood itself has shown better combustion properties than coniferous species pine or spruce as it was shown in Bukšāns (2010) Phd thesis. It was observed that birch wood emits by 50% more energy in first 10 minutes of wood under the fire than spruce wood and by 30% more than pine. This research showed that standard coating manufactures recommended consumption of intumescent coatings for protection of birch plywood will not be enough to reach B-s1, d0 class, as mostly fire performance of such products determined on coniferous wood species substrates. Intumescent coatings prevent fire growth rate index grow very well, but hardwood species can have a problem with total heat release rate; therefore, increased amounts of intumescent coatings can be needed to fulfil target requirements. For the specific intumescent coating system used in this research, it was concluded that nominal consumption of coating for birch plywood needs to be increased from 300 to 400 g m⁻².

Conclusions

Results obtained in this study show that high-pressure impregnation of birch plywood with fire retardants gives an unstable reaction to fire performance and the amount of heat released by combustion of birch wood makes difficult to find a suitable solution to meet the requirements of reaction to fire class B-s1, d0.

Experimental results showed that tested top coating systems on basis of UV curing primer and different top coatings did not increase heat release rate of high pressure impregnated birch plywood. It can be explained by initially low reaction to fire performance of impregnated birch plywood and very high deviations between repeated tests. Therefore, influence of top coatings on reaction to fire performance of impregnated birch plywood is not clearly identified by this study.

Intumescent coating systems for birch plywood protection from fire can give compliance with highest reaction to fire class B-s1, d0. Minimal consumption of intumescent coating system used in this research needs to be at least 400 g m⁻², but for safety reasons an increase in consumption of fire retardant to 450 g m⁻², for fire retardant treated wood products, who are close to classification threshold values is recommended.

Different protection systems, such as veneer impregnation and surface treatment, can be combined to ensure that birch plywood meets the status of a hardly combustible material.

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Acknowledgement

In accordance with the contract No. 1.2.1.1/18/A/004 between “Forest Sector Competence Centre of Latvia” Ltd. and the Central Finance and Contracting Agency, the study is conducted by AS “Latvijas finieris” with support from the European Regional Development Fund (ERDF) within the framework of the project “Forest Sector Competence Centre of Latvia”.