

Flammability of plywood made from veneers protected with flame retardant based on diammonium hydrogen phosphate, citric acid and sodium benzoate

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Abstract: *Flammability of plywood made from veneers protected with flame retardant based on diammonium hydrogen phosphate, citric acid and sodium benzoate.* In this study the impact of pine and beech veneer protection with flame retardant based on diammonium hydrogen phosphate, citric acid and sodium benzoate on the flammability of plywood made from them has been determined. Retention of the agent in veneers was 47 - 50 kg per 1 m³. It was determined that impregnated plywood manufactured from veneers do not sustain burning after removal of the source of fire. When taking into account values of oxygen index, greater fire resistance characterize pine plywood (oxygen index - 49%) in comparison to beech plywood (oxygen index - 36%).

Keywords: plywood, fireproofing protection, reaction to fire, oxygen index

INTRODUCTION

Wood and wood-based materials, including plywood, still remain one of the most important materials used in construction or furniture. To use them one should be aware that their resistance to degradation is largely limited. In construction, one of the most important parameters of materials is fire resistance. It is particularly important in relation to wood and wood-based materials, which are inflammable materials. Fire resistance of these materials can be improved by applying different types of flame retardants (Osipiuk 2001, Krajewski and Witomski 2005). They can be implemented at the stage of materials production, or applied to the final product (Kartal et al. 2007). As a result, time of the material inflammation can be extended, reduced, or can eliminate flaming phase of burning, reduce the speed of fire spreading or accelerate creating a layer of charcoal on the surface of wood, which makes heat transfer inside the material harder (Drysdale 2001, Osipiuk 2001, Krajewski and Witomski 2005).

Nowadays, new impregnants, which reduce wood flammability, are available on the market. They are based on ecological and non-toxic organic ingredients, so that they can be successfully used in a human environment. One of such agents is a flame retardant based on diammonium hydrogen phosphate, citric acid and sodium benzoate (US 7736549). In this study, flammability of plywood made from veneers protected with agent mentioned above was investigated.

MATERIAL AND METHODS

Pine and beech veneers, which nominal thickness was 1.5 mm and density, respectively: 484 kg/m³ and 676 kg/m³ were impregnated with flame retardant based on diammonium hydrogen phosphate, citric acid and sodium benzoate. The type of agent used was a water solution with a concentration of 20%. Average agent retention was 50 kg per 1 m³ for beech veneer and 47.5 kg per 1 m³ for pine veneer. After impregnation, veneers were dried at 50 - 60 °C, to the moisture content of about 5%. From both, impregnated and non-

impregnated veneers, 3-layered plywood was produced on the basis of urea-formaldehyde resin. Glue recipe and bonding parameters are presented in Table 1.

Table 1. Glue recipe and parameters of plywood bonding

Parameter	Value
Glue recipe	UF resin – 100 pbw, hardener (10% solution of $(\text{NH}_4)_2\text{SO}_4$) – 4 pbw, aggregate (wheat flour) – 15 pbw, water – 10 pbw
Glue spread	160 g/m ²
Pressing temperature	110 °C
Unit press pressure	pine veneer – 1.0 MPa, beech veneer – 1.2 MPa
Time of pressing	330 s

After production, plywood was conditioned for 1 week in the laboratory. Next, samples were obtained for further tests.

Flammability of plywood was tested with two methods:

1. method of reaction to fire testing according to EN ISO 11925-2. Dimensions of samples were as followed: 250 x 90 x 4 mm³. As a result of measurement, it was recorded: whether the ignition of the sample took place, whether the top of the flame reached a height of 150 mm above the location on which the flame work, what is the visual condition of the sample.
2. oxygen index method based on the standard ISO 4589-2:1999. Oxygen index is the lowest percentage of oxygen in air mixture, which in laboratory conditions supports constant burning of the material. Tested samples had dimensions of 100 x 10 x 4 mm³. Oxygen index measurement method is used to compare the flammability of different materials while assessing the modification of the same type of material, and the impact of additional fillers including various types of flame retardants. Oxygen index does not classify materials in terms of fire risk.

RESULTS AND DISCUSSION

The test results of reaction to fire are presented in Table 2. Generally it can be stated, that both pine and beech plywood made from veneers impregnated with tested agent do not sustain burning after contact with flame for 30 sec. In the point of flame and sample contact appeared a thin, compact charred layer of wood, which limited emissions of flammable compounds from wood to the environment. In case of plywood manufactured from non-impregnated veneers, after 30 seconds of exposure to flame some samples (2 of 3 in case of pine plywood and 1 of 3 in case of beech plywood) have ignited. Flame was so large and rapid, that it had to be extinguished. In case of pine and beech plywood manufactured from impregnated veneers, flame height after 30 sec was between 59 - 82 mm, while for plywood manufactured from non-impregnated veneers this height was 62 - 154 mm. However, it should be noted, that impregnation had greater influence on the diversity of the flame height in case of pine veneers. Examples of plywood samples after the test for reaction to fire is shown in Figure 1.

Table 2. Reserach results of reaction to fire of pine and beech plywood

Sample number	Ignition of sample	Height of flame top achieved after 30 s [mm]	Overall condition of sample
Pine plywood – non-impregnated veneers			
P 1	No	62	Bad, burning visible
P 2	Yes	108	Very bad, burning of sample
P 3	Yes	148	Very bad, burning of sample
Pine plywood – impregnated veneers			
PI 1	No	59	Carbonization on the surface
PI 2	No	70	Carbonization on the surface
PI 3	No	64	Carbonization on the surface
Beech plywood – non-impregnated veneers			
B 1	No	64	Bad, burning visible
B 2	No	60	Bad, burning visible
B 3	Yes	154	Very bad, burning of sample
Beech plywood – impregnated veneers			
BI 1	No	71	Carbonization on the surface
BI 2	No	63	Carbonization on the surface
BI 3	No	82	Bad, burning visible

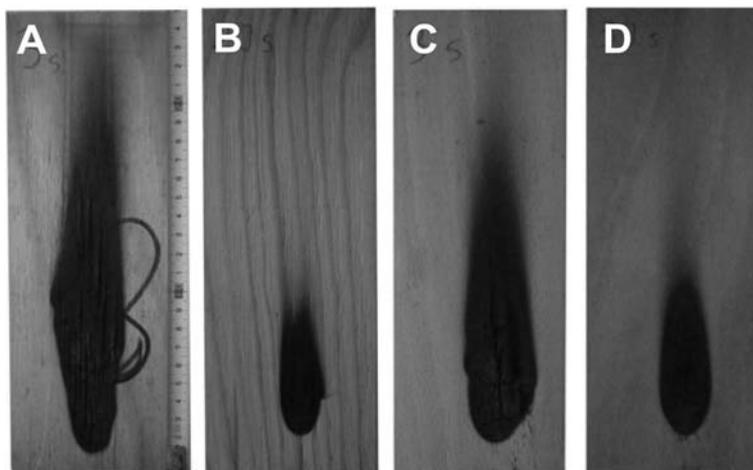


Fig. 1. Samples after examination for reaction to fire: A – pine plywood made from non-impregnated veneers, B – pine plywood made from impregnated veneers, C – beech plywood made form non-impregnated veneers, D – beech plywood made from impregnated veneers.

The results of flammability test with oxygen index method are shown in Table 3. During the test, time of burning and length of sample's burned part were difficult to compare, because they only determined if the trial could be considered as a success or failure. The test was considered successful when the sample was burning for 180 seconds, or if the flame burnt 50 mm of sample length. Oxygen index, which is the smallest percentage of oxygen in the air mixture needed for combustion of 50 mm of samples, or allowing to keep burning for 180 seconds, was the only characteristic compared in this study.

Samples of pine and beech plywood manufactured from unprotected veneers were burned (in the range tested) at concentration of approximately 28% oxygen in the air. It is worth noting, that burning 50 mm of pine plywood sample happened within 180 sec, while in case of beech it was 79 sec. In case of plywood manufactured from impregnated veneers, oxygen index values were, respectively 49% for pine plywood and 36% for beech plywood.

Table 3. The results of flammability tests for pine and beech plywood with the use of oxygen index - gray color indicates the lowest value of oxygen index for particular samples.

Sample number	Oxygen concentration (%)	Observations
Pine plywood – non-impregnated veneers		
P 1	25.0	No ignition of sample
P 2	30.0	After 97 sec. 50 mm of sample were burned
P 3	28.0	After 180 sec. 50 mm of sample were burned
P 4	27.5	After 114 sec. 34 mm of sample were burned
P 5	27.7	After 180 sec. 50 mm of sample were burned
Pine plywood – impregnated veneers		
PI 1	35.0	No ignition of sample
PI 2	40.0	No ignition of sample
PI 3	50.0	After 180 sec. 50 mm of sample were burned
PI 4	48.0	After 90 sec. 26 mm of sample were burned
PI 5	49.0	After 180 sec. 42 mm of sample were burned
Beech plywood – non-impregnated veneers		
B 1	25.0	After 13 sec. 5 mm of sample were burned
B 2	30.0	After 50 sec. 50 mm of sample were burned
B 3	28.0	After 74 sec. 38 mm of sample were burned
B 4	28.5	After 80 sec. 50 mm of sample were burned
B 5	28.2	After 79 sec. 50 mm of sample were burned
Beech plywood – impregnated veneers		
BI 1	35.0	After 56 sec. 24 mm of sample were burned
BI 2	40.0	After 30 sec. 50 mm of sample were burned
BI 3	37.0	After 48 sec. 50 mm of sample were burned
BI 4	36.0	After 68 sec. 50 mm of sample were burned
BI 5	36.2	After 57 sec. 50 mm of sample were burned

CONCLUSIONS

On the basis of conducted research, following conclusion can be drawn:

1. Plywood made of pine and beech veneers, impregnated with flame retardant based on diammonium hydrogen phosphate, citric acid and sodium benzoate, have increased fire resistance in relation to plywood made from unprotected veneers.
2. None of the attempts of exposure to fire of plywood manufactured from impregnated veneers, resulted in sustaining effect of burning.
3. While taking into account the value of oxygen index, in a similar retention of flame retardant in veneers (47 - 50 kg per 1 m³), pine plywood (oxygen index - 49%) characterizes greater fire resistance in comparison to beech plywood (oxygen index - 36%).

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Streszczenie: *Palność sklejek wytworzonych z fornirów zabezpieczonych środkiem ogniochronnym na bazie wodorofosforanu amonu, kwasu cytrynowego i benzoesu sodu. W ramach badań określono wpływ impregnacji fornirów sosnowych i bukowych preparatem ogniochronnym opartym na kompozycji wodorofosforanu amonu, kwasu cytrynowego i benzoesu sodu na palność wytworzonych z nich sklejek. Retencja preparatu w fornirach wynosiła 47 - 50 kg na 1 m³. Ustalono, że sklejki wytworzone z zaimpregnowanych fornirów nie podtrzymały palenia po usunięciu źródła ognia. Uwzględniając wartości indeksu tlenowego, większą ognioodpornością charakteryzują się sklejki sosnowe (indeks tlenowy – 49 %) w stosunku do sklejek bukowych (indeks tlenowy – 36 %).*

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