FLAME RETARDANT TREATED WOOD PRODUCTS

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INTRODUCTION

Wood has many good properties from the point of view of processing, physical and mechanical properties, aesthetic, enviromnental and health aspects. In many countries the wood is widely used as building material and in some areas as main construction material. In some other countries, like Slovakia the use of wood in building industry is rather rare. There are several reasons for this attitude in Slovakia but one of them is the traditional opinion that wood is not suitable material from the point of view of fire safety.

It is well known that there are possibilities to improve significantly the fire performance of wood by chemical treatment and to widen its application options. In general the amount of flame retardant uptake to the wood is directly proportional to the improvement of reaction to fire characteristics (Balog 1986). Important reaction to fire parameters in the full scale fire are heat release rate and time of flashover (Babrauskas V. and Grayson S.J. 1992). Flame retardant treated materials may have much better fire performance concerning these parameters than untreated wood products.

In this paper the comparison of flammability characteristics of FRT and untreated wood based products is done with the aim to demonstrate the fire behaviour of untreated wood products and FRT wood products. The fire behaviour was measured both in the small scale and full scale fire tests. The differences of the fire performance measured in the ISO 9705 Room/Corner Test of various wood based products are discussed as well.

The experimental works are results of the finished joint US-Slovak project no 94072 with the title “Room/Corner Test and Reaction to Fire of Wood and other Building Products”. This project was conducted under the auspices of the U.S. - Slovak Science and Technology Program.

METHODS AND MATERIALS

The flammability characteristics were measured according to the small scale test method ISO 5660 (Cone calorimeter method) and full scale Room/Corner Test ISO 9705. In the Cone calorimeter specimens orientation was horizontal. Materials tested in the room tests were installed on 3 walls only, ceiling was lined with the paper covered gypsum board. The burner protocol used was that defined by ISO 9705 standard i.e. 100 kW for 10 minutes followed by 300 kW for another 10 minutes. The Cone calorimeter tests were done at the State Forest Products Research Institute, Bratislava, Slovakia and full-scale Room/Corner Tests were done at the Forest Products Laboratory, Madison WI, USA.

Within the project 94072 fourteen different commercial wood based products were tested, from which 3 materials were FRT plywoods. In addition FRT rigid polyurethane foam and paper covered gypsum board were also tested. Characteristics of tested materials and their identification full-scale test numbers are given in Table 1.

Table 1 Characteristics of the tested materials

Material	FPL Test #	ISO Test #	Thickness (mm)	Density (kg/m^3)
Gypsum board, Type X	49	1	16.5	662
FRT Douglas-fir plywood	50	2	11.8	563
Oak veneer plywood	51	3	13	479
FRT plywood (Forintek)	52	4	11.5	599
Douglas-fir plywood (ASTM)	53	5	11.5	537
FRT Polyurethane foam	54	6	23	29
Gypsum board, Type X	55	7	16.5	662
FRT South pine plywood	56	8	11	606
Douglas-fir plywood (MB)	57	9	12	549
Southern pine plywood	58	10	11	605
Particleboard	59	11	13	794
Oriented strand board	60	12	11	643
Hardboard	61	13	6	1026
Redwood lumber	62	14	19	421
Gypsum board, Type X	63	15	16.5	662
White spruce lumber	64	16	17	479
Southern pine boards	65	17	18	537
Waferboard	66	18	13	631

RESULTS AND DISSCUSSION

Comparison of Untreated and FRT Plywood Materials

The reaction to fire characteristics measured in the Cone calorimeter for untreated and FRT plywood materials is shown in the Fig. 1-6. Rate of heat release (RHR) as the function of external irradiance for untreated and FRT Douglas fir plywood is in the Fig. 1. Two FRT Douglas fir plywoods were tested both in the Cone calorimeter and ISO 9705 Room/Corner Test (test # 50 and # 52). The FRT plywood tested in test # 52 consisted of four layers of Douglas fir and a single face veneer of yellow pine. The values of peak RHR for the FRT plywoods were much lower than the peak RHR values for untreated plywood. The RHR curve measured in the Cone calorimeter for FRT plywood materials was different than RHR for untreated plywood. Typically for wood products the RHR has double peak shape. At low irradiances the RHR for tested FRT products passed through one peak and burning was very short. At higher irradiances the shape of the RHR curve was similar to the curve for untreated wood products. Therefore the peak values of RHR for FRT products are more scattered.

The total heat released as well as the effective heat of combustion were also significantly decreased for the FRT materials in comparison to untreated plywood materials (Fig. 3-4).

Heat release rate curves of untreated and FRT plywood materials measured in the Room/ Corner Test are in the Fig. 5-6. The RHR of untreated Douglas fir plywood (test # 53) increased rapidly after the ignition during the upward flame spread (Fig. 5). When the flames reached the ceiling and flame spread mode became lateral the RHR slightly decreased. We note that the ceiling was not lined with the tested material, therefore flame spread did not occur on the ceiling. After the short plateau the flashover was reached at 474^{th} second (flashover defined as 1 MW of total heat release rate TRHR). The FRT Douglas fir plywood (test # 52) released little heat during the first part of test when the burner output was 100 kW. The average total heat release rate during the first 10 minutes of the test was 137 kW. After the burner output was raised from 100 kW to 300 kW the RHR of the FRT plywood increased. Flashover defined as 1 MW of TRHR was reached at 906^{th} second. Course of the RHR for untreated Southern pine plywood (Fig. 6) was similar to the RHR for untreated Douglas fir plywood with the difference that the flashover was reached within the shorter time. During the room/comer test of FRT Southern pine plywood (test # 56) the burner program was modified so that its output was 100 kW for 5 minutes only, followed by 300 kW for 10 minutes, During the lower burner output the average total heat release rate was 109 kW, so that the portion of heat released from the plywood was very small. The flashover of the FRT Southern pine plywood was reached during the increased burner output at the 621^{st} second (Fig. 6).

Heat release rate curves of untreated and FRT plywood materials measured in the Room/ Comer Test are in the Fig. 5-6. The RHR of untreated Douglas fir plywood (test # 53) increased rapidly after the ignition during the upward flame spread (Fig. 5). When the flames reached the ceiling and flame spread mode became lateral the RHR slightly decreased. We note that the ceiling was not lined with the tested material, therefore flame spread did not occur on the ceiling. After the short plateau the flashover was reached at 474^{th} second

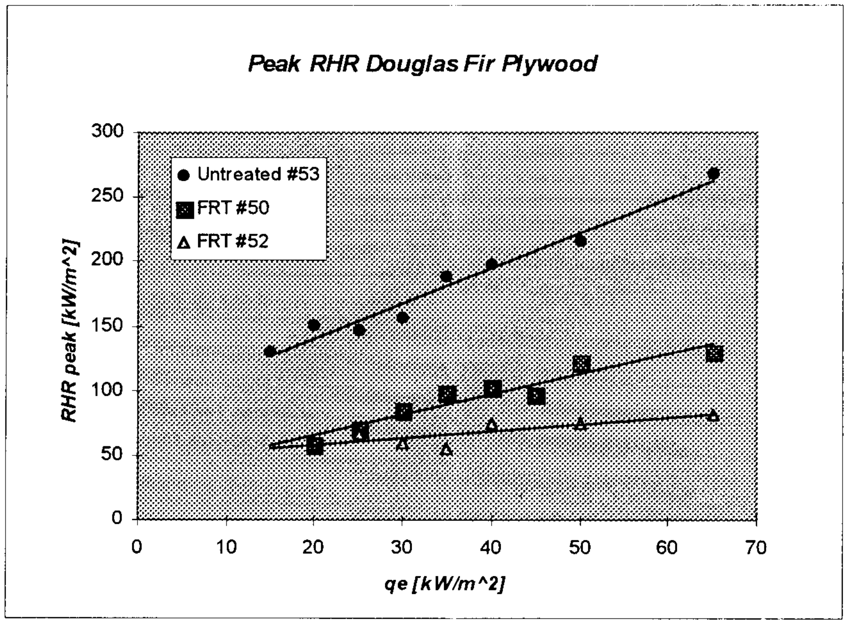

Fig. 1 Rate of heat release of the untreated and FRT Douglas fir plywood

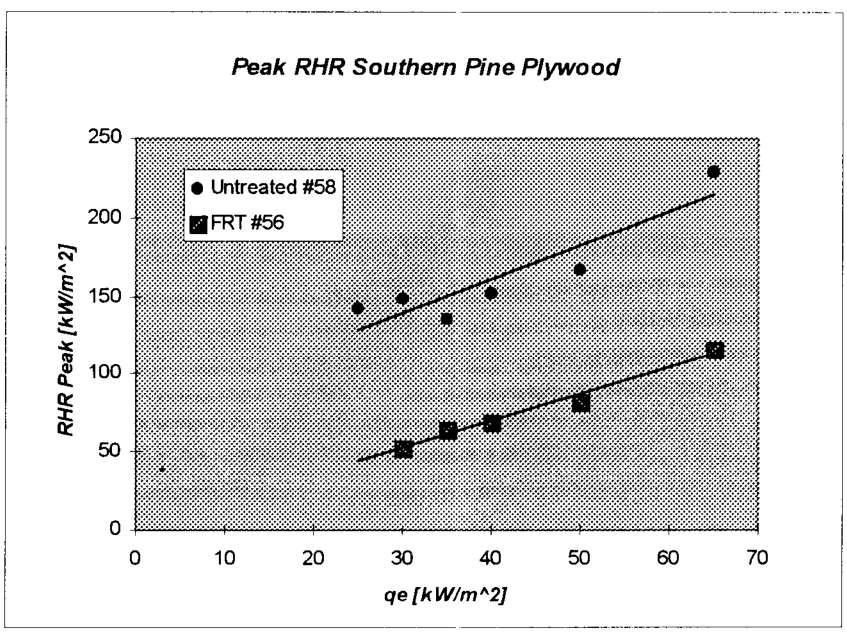

Fig. 2 Rate of heat release of the untreated and FRT Southern pine plywood

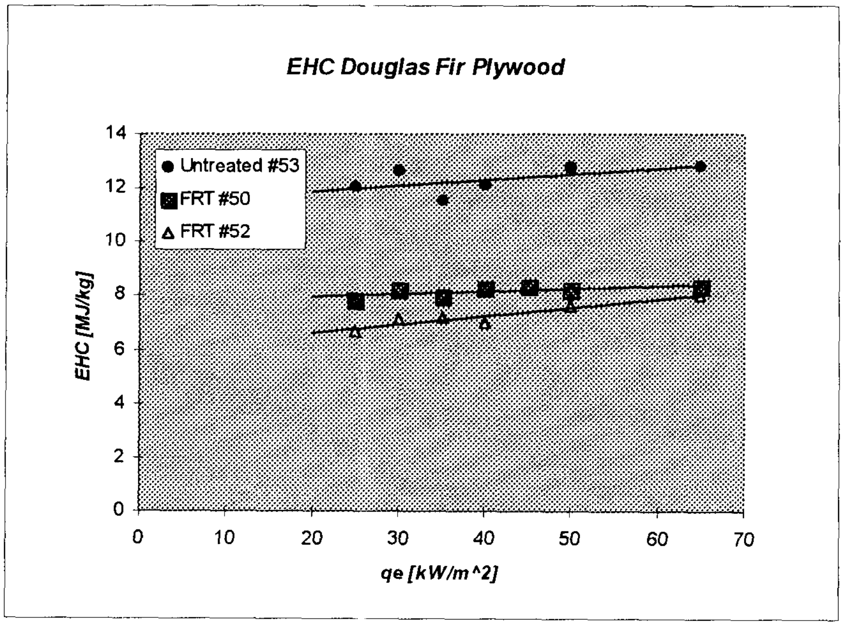

Fig. 3 Effective heat of combustion of the untreated and FRT Douglas fir plywood

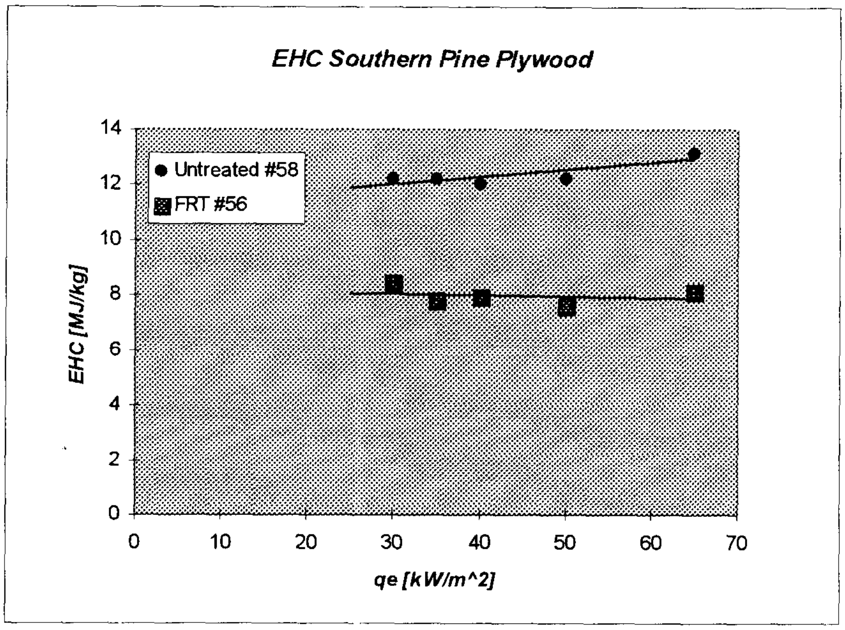

Fig. 4 Effective heat of combustion of the untreated and FRT Southern pine plywood

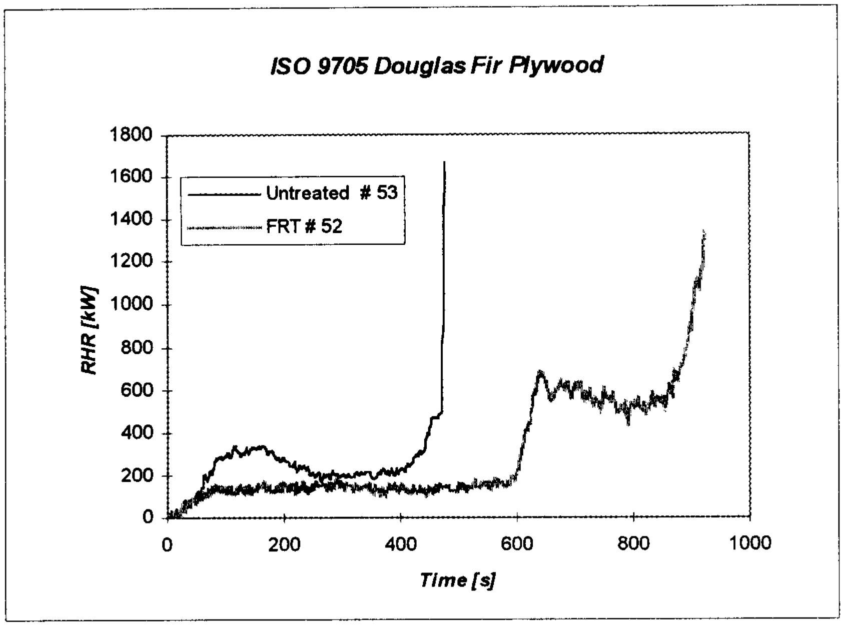

Fig. 5 Total heat release rate of untreated and FRT Douglas fir plywood measured in the ISO 9705 Room/Corner Test, burner program 100/300 kW

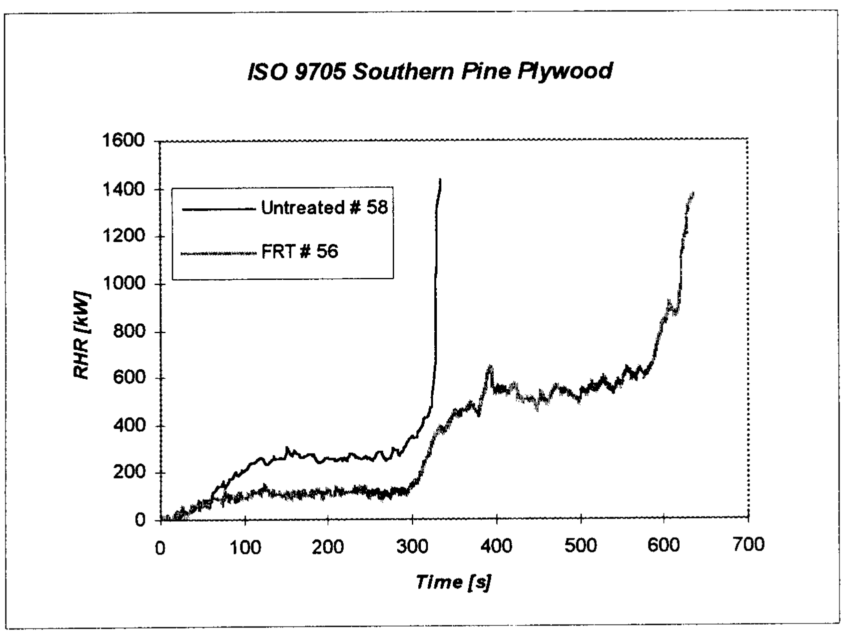

Fig. 6 Total heat release rate of untreated and FRT Southern pine plywood measured in the ISO 9705 Room/Corner Test, burner program 100/300 kW

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Room/Corner Tests of Wood Based Materials

The main parameter measured in the Room/Corner Test was the RHR. Besides the RHR, other measurements were done as well i.e. temperature profiles in the room (2 thermocouple trees in the room, 1 thermocouple tree in the door opening), temperature of the ceiling and wall locations. differential pressure inside and outside of the room (measurements done at the 4 heights), and radiation to the floor.

In our configuration of room tests (tested materials installed on walls only) the materials according to their fire behaviour can be subdivided into the 3 groups.

The shortest time to flashover was measured for the materials with accelerating RHR. To this group of materials belong hardboard, particleboard, oriented strand board and wafer-board. In the Fig. 7 there is shown temperature profile in the room for the particleboard. The thermocouple tree was located in the front corner of the room. The shape of the curves measured at the highest point of the room was similar to the shape of RHR curves.

Into the second group belong the untreated plywood materials and lumbers. The RHR for these materials after the initial raise stabilized at certain level and even small decrease was observed. The exception from these materials was Southern pine flooring lumber for which RHR was increasing from the beginning of burning until the flashover was reached. As it was discussed earlier for Douglas fir plywood the small RHR peak measured (see Fig. 5) corresponds to the upward flame spread. In the temperature measurements this peak was observed as well (Fig. 8). The process slowed down when the pyrolysis front reached the ceiling and the lateral flame spread took over. Contrary for the composite materials with the accelerating RHR (the first group of materials) lateral flame spreading remained high. The differentiation of the flashover times for the untreated wood products is closely correlated with the variations of the lateral flame spread taking place in the region below the ceiling. The lateral flame spread beyond the small belt wall region below the ceiling played little role in the flame spreading prior to flashover. The downward flame spread on walls occurred just shortly prior to flashover conditions in every test with flashover. For all untreated wooden materials the flashover took place under the lower burner output (100 kW) within the first 10 minutes.

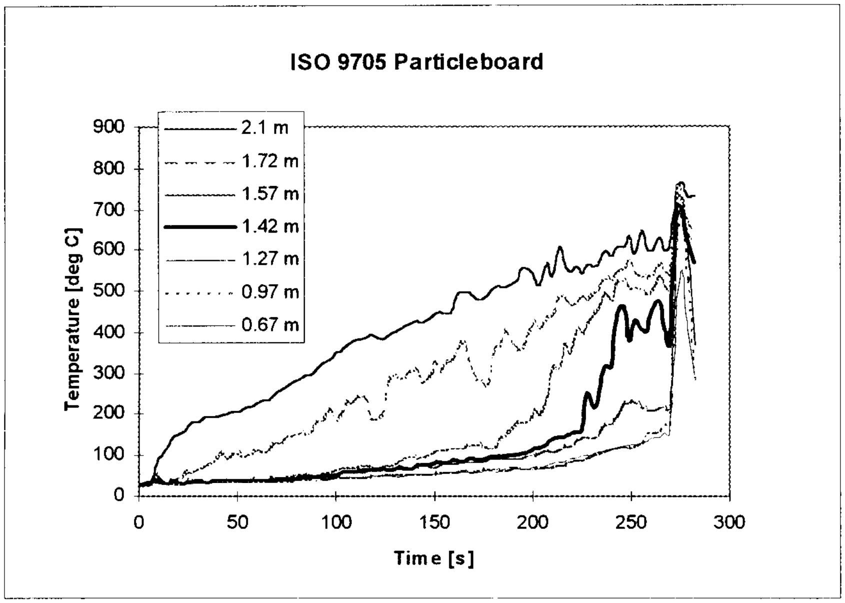

Fig. 7 Gas temperature in the room corner vs time measured by thermocouple tree for particleboard (test # 59)

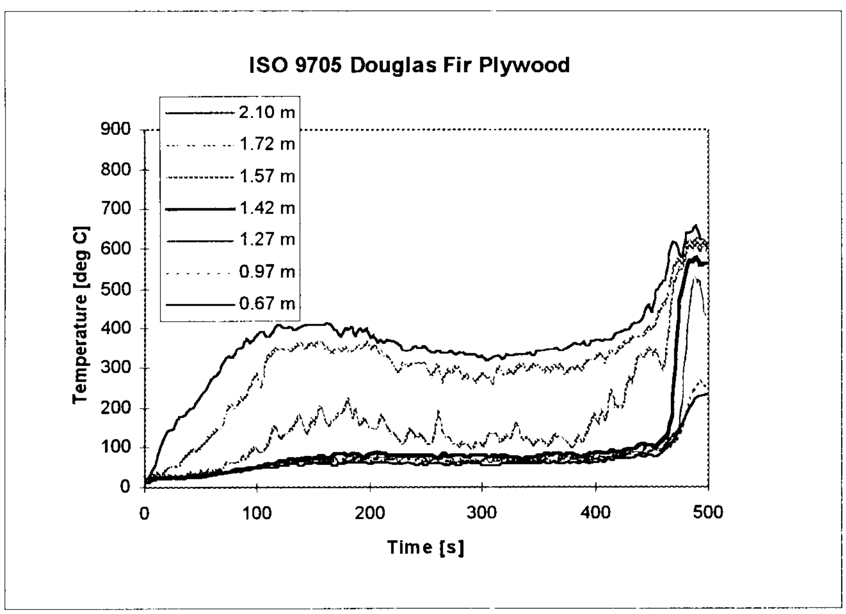

Fig. 8 Gas temperature in the room corner vs time measured by thermocouple tree for untreated Douglas fir plywood (test # 53)

The third group consisted of FRT wood materials. As it was discussed earlier the FRT wood materials released little heat during the first part of test when the burner output was 100 kW. In the second part of the test when the burner output was raised to 300 kW the RHR of FRT materials increased as well (see Fig. 5 and 6). The lateral flame spread for these materials took place mainly in the wall region below the ceiling similarly as it was observed for untreated plywood materials. Downward flame spread took place only shortly prior to flashover. All the FRT wood materials reached flashover under the increased burner output (300 kW).

The flashover times based on the different criteria for tested materials are given in Table 2. It can be seen that for the tested materials there is good agreement between the time to reach 1 MW of total heat release rate, time of radiation to floor reaching 20 kW/m^2 and time of the flames exiting the door opening.

Table 2 Flashover times in Room/Corner Test based on different criteria,

Material	FPL Test #	ISO Test #	1 MW Flashover time (s)	Flames out of door time (s)	Flux to floor > 20 kW/m^2 time (s)
Gypsum board, Type X	49	1	NFO	NFO	NFO
FRT Douglas-fir plywood	50	2	879	895	849
Oak veneer plywood	51	3	174	174	174
FRT plywood (Forintek)	52	4	906	870	873
Douglas-fir plywood (ASTM)	53	5	474	465	474
FRT Polyurethane foam	54	6	630	618	621
Gypsum board, Type X	55	7	NFO	NFO	NFO
FRT South pine plywood*	56	8	621	570	582
Douglas-fir plywood (MB)	57	9	546	520	531
Southern pine plywood	58	10	330	324	321
Particleboard	59	11	216	241	237
Oriented strand board	60	12	180	189	186
Hardboard	61	13	255	227	222
Redwood lumber	62	14	507	519	498
Gypsum board, Type X	63	15	NFO	NFO	NFO
White spruce lumber	64	16	606	594	594
Southern pine boards	65	17	258	243	240
Waferboard	66	18	174	150	141

Note: *Burner output program was 100 kW for 5 minutes followed by 300 kW for IS minutes

CONCLUSION

The flame retardant treatment significantly improves the fire safety of wood products by reducing its heat contribution to a fire and prolonging the times for flashover. Comparison of the flammability parameters for commercial untreated and FRT plywood materials was done. The RHR measured in the small scale test Cone calorimeter for untreated materials was much higher than RHR of FRT plywoods. The total heat released and effective heat of combustion was also significantly lower for treated materials. In the full scale ISO 9705 Room/Corner Test the flame retardant treatment prolonged the time to flashover. Flashover for the FRT materials was reached under the higher burner output. From the 14 tested wood based materials three types of groups concerning the fire performance in the Room/Corner Test can be traced i.e. materials with the accelerating RHR from the beginning of test until the flashover, materials reaching the plateau in RHR prior to flashover and FRT materials with very limited RHR under the lower burner output. Increased recognition of the ability of FRT wood to provide a high level of fore safety should increase the amount of wood construction.

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REFERENCES

Balog K. 1986. Study of the Flame and Non-flame Burning of the Cellulosic Materials. PhD Dissertation Thesis, Slovak Technical Univ. Bratislava 1986.

Babrauskas V. and Grayson S.J. 1992. Heat Release in Fires. Elsvier Science Publishers Ltd. London 1992.

International Organization for Standardization. 1993. Fire Tests - Full scale room test for surface products, ISO 9705: 1993(E). Geneva.

International Organization for Standardization. 1993. Fire Tests. Reaction to fire. Part 1: Rate of heat release from building products (Cone calorimeter method), ISO 5660-1: 1993(E). Geneva.

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