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Durability of the reaction to fire performance of fire retardant treated wood products in exterior applications – A ten years report

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Durability of the reaction to fire performance of fire retardant treated wood products in exterior applications – A ten years report

Several long term experimental studies on the maintained reaction to fire performance of fire retardant treated (FRT) wood products over time are presented. They are performed according to a European system based on earlier Nordic and North American systems and include accelerated ageing according to different procedures and natural weathering up to ten years. Main conclusions are:

- The hygroscopic properties are unchanged compared to untreated wood for most FRT wood products included in this study and used commercially
- The reaction to fire properties of FRT wood may be maintained after accelerated and natural ageing if the retention levels are high enough, but several FRT wood products lose most of their improved reaction to fire properties during weathering
- Paint systems contribute considerably to the weather protection and are usually needed to maintain the reaction to fire performance at exterior applications

Keywords: Durability, hygroscopicity, reaction to fire, weathering, wood products

Durability classes for fire performance – Principles and methods

Fire retardants may considerably improve the reaction to fire properties of wood products, but the durability in interior and exterior applications needs to be addressed. Requirements on durability of the fire performance are not mentioned in most building codes. This is probably partly caused by unawareness of the problem, but may also be due to the lack of procedures.

The problems with maintained reaction to fire performance over time have been known for a long time in the US and the UK, but are not so well known in the rest of Europe. A US study on exterior exposure of North American products during ten years [1] and a literature review [2] have been published.

Two cases of durability of the fire retardant treatment of wood products can be identified. One is the risk for high moisture content and migration of the fire retardant chemicals within the wood product and salt crystallisation on the product surface. These hygroscopic properties of the treated wood-based product can be evaluated by exposure to high relative humidity.

The other case is the risk for decreased fire performance due to loss of the fire retardant chemicals by leaching or other mechanisms. This case is mainly relevant for exterior applications, e. g. as façade claddings. Maintained reaction to fire performance over time has to be verified.

A European system with Durability of Reaction to Fire performance (DRF) classes has been developed in order to guide the potential users to find suitable FRT wood products [3], see Table 1. The system is based on a North American system [4, 5] and a previous Nordic system [6, 7, 8]. It consists of a classification system for the properties over time of FRT wood and suitable test procedures.

The technical specification CEN/TS 15912 [3] is currently being transformed to a full European standard. This paper is an extended version of a conference paper [9] and includes more test data.

Table 1. Requirements for DRF classes of FRT wood products according to CEN/TS 15912 [3]

DRF class	Intended use	Fire class Initial	Performance requirements for different end uses	
			Hygroscopic properties	Fire performance after weather exposure
ST	Short term	Relevant fire class	-	-
Interior, dry applications	- " -	Limited moisture content Minimum visible salt	-
Interior, humid applications	- " -	Limited moisture content Minimum visible salt	-
Exterior applications	- " -	- " -	Maintained fire performance

Further details are given in CEN/TS 15912

The relevant initial reaction to fire class shall be verified according to EN or IMO systems [10, 11]. Maintained fire performance after weather exposure shall be verified according to ISO 5660 [12] or the European system [10].

Experimental

Hygroscopic properties

The hygroscopic properties of wood products have been determined according to [7] or the equivalent [3]. The method includes calculation of equilibrium moisture content at two climates, 70 % RH at 25 °C and 90 % RH at 27 °C. The requirement for DRF class INT is moisture content below 28 % in the humid climate. Untreated wood has moisture content below 20 % in that climate. In addition, possible salt crystallisation at the wood surface and exudation of liquid in the wet climate is observed.

Accelerated and natural weathering

For DRF class EXT, the durability of the fire performance at exterior applications has been studied by accelerated ageing according to [8] or the equivalent [3]. Both Method A, i.e. exposure to 12 one-week cycles of simulated rain and drying and Method B, i.e. exposure to 6 one-week cycles of which also includes UV radiation have been used.

Natural field exposure has been performed with wood panels facing south, both at vertical (90°) and at 45° slope. In both cases the rear sides of the panels were open. The test field is in the Stockholm area, Sweden, see Figure 1. Results are presented for 1, 2, 3, 5 and 10 years exposure.

Fire performance

The reaction to fire performance has been determined according to ISO 5660 [12] at 50 kW/m². Duplicate tests have been run in most cases and the repeatability was very good. The time to flashover in the room corner test has been predicted [13] and used as predicted reaction to fire class according to the European system [10].

Mass loss during accelerated and natural weathering

The weight of the FRT wood panels has been measured after conditioning at 50 % RH at 23 °C, both initially and after the weathering procedures and is expressed in percentage of the total panel weight. Mass loss indicates loss of chemicals during the weather exposure.

Figure 1. Natural weathering field outside Stockholm, Sweden. The fire retardant treated panels are exposed both vertically (90°) and at 45° slope.

Wood products tested

The wood products tested are all wood panelling products, mainly spruce, vacuum pressure impregnated with different fire retardant chemicals. Untreated wood panelling has been used as reference. The initial reaction to fire performance for the FRT wood products has been determined or estimated to be equivalent to class B or at least class C according to the Euroclass system [10]. Untreated wood is Euroclass D. These data have been used as reference for the fire performance after weathering.

Two main sets of wood products have been studied, one set of commercial FRT wood products X, Y, Z, CI and CM intended for exterior application, a former commercial product VF, see Table 2, and another set of development products [14, 15],

see Table 3. All are wood panels impregnated with fire retardants to different levels of retention.

The size of the specimen for ageing may have some influence on the effects of ageing due to edge effects. 800 mm long specimen were found to be superior to shorter specimen in a pre-study [16] and have then been used together with edge seals both at accelerated and natural exposure. The panels for weathering were 800 mm long and edge sealed, first with an alkyd solvent borne primer and then with a thick coat of a silicone sealer. After the exposures, the panels were cut in a systematic way to secure consistency (with test pieces at the same position of the panels and excluding parts close to the edges) to be used for fire and other tests.

Table 2. Commercial FRT wood products – Set 1.

<i>FR ID</i>	<i>Mean FR kg/m³</i>	<i>Thick-ness mm</i>	<i>Width mm</i>	<i>Approximate initial density kg/m³</i>	<i>Type of panel</i>
0	-				Tongue and groove with notched rear side
X	25-60	20	135	540	-"
Y	45-110	20	135	510	-"
ZA	95-190	22	130	690	Tongue and groove
ZG	170	22	130	660	Tongue and groove, factory primed
VF	70-140	20	135	520	Tongue and groove with notched rear side
CI	na	21	145	410	Panel with straight edges
CM	na	22	150	470	-"

Table 3. Development FRT wood products –Set 2.

<i>FR ID</i>	<i>FR kg/m³ *</i>	<i>Thickness mm</i>	<i>Width mm</i>	<i>Approximate initial density kg/m³</i>	<i>Type of panel</i>
-	-	20	100	540	Panel with straight edges
BS	107-347	20	100	640-830	-"
FP	71-228	20	100	570-670	-"
DQ	89-290	20	100	570-875	-"
BH	87-236	20	100	635-790	-"
MA	216	20	100	585	-"
SI	84-368	20	100	625-850	-"
FF	92-169	20	100	647-657	-"
PhF	413-667	20	100	826-1007	-"
BZ-15	78- 282	20	100	470-520	-"
BZ-40	67-191	20	100	469-558	-"
BZ-30	75-229	20	100	531-544	-"
NF	115-206	20	100	541-711	-"
AF	120-251	20	100	560-677	-"
DF	125-556	20	100	629-1152	-"
LG	114-536	20	100	614-673	-"
NS	139-619	20	100	549-680	-"

* Three retention levels per FR chemical, the range is given in the table

Paint systems

Paint systems are usually needed to maintain the fire performance properties of FRT wood products for exterior applications. Four different paint systems have been used, see Table 4.

Table 4. Paint systems used.

Paint number	Paint type	Number of coats	Total amount g/m ²	Comments
1	Alkyd	4 *	530-650 **	1 coat primer oil, 1 coat alkyd primer, 2 alkyd top coats (all products solvent borne)
3	Red paint	1	200	Swedish red paint (water based)
4	Linseed oil	3	400-550 **	2 coats with diluted paint, 30 and 15 % resp, 1 top coat of undiluted paint
6	Wood oil	2	180-200 **	Pigmented oil

* only 2 top coats on factory primed panel, total amount 250 g/m²;

** the higher amount on panel type Z

Test results

Hygroscopic properties

The hygroscopic properties expressed as moisture content at higher relative humidity according to [3] of FR treatments as a function of the retention level are illustrated in Figure 2. The moisture content is unchanged compared to untreated wood for several FRT wood products.

It is evident from the test data that the moisture content may increase with increased amount of fire retardant chemical added. It is thus important to optimise the FR content not only from an economical point of view, but also to reach the intended fire performance with a safety margin to maintain the fire performance during service life of the product and not jeopardizing the moisture resistance.

Figure 2. Moisture content at high RH vs retention for FR chemicals and for untreated pine sapwood. Set 1 to the left and Set 2 to the right.

Comparisons of reaction to fire performance before and after weathering

The reaction to fire performance has been determined in the cone calorimeter ISO 5660 [12] at 50 kW/m². All results for the initial reaction to fire performance and after

accelerated ageing and natural weathering are summarised and compared in Figure 3-6. The comparison is based on predicted time to flashover [13]. Several products exhibit high initial reaction to fire performance, but it may be reduced over time during both accelerated and natural weathering.

Comparison of natural weathering exposures at vertical (90°) and at 45° slope is presented in Figure 4. No major difference can be observed.

Comparison of accelerated weathering exposures according to Method A and Method B is presented in Figure 5-6. No major difference can be observed.

Durability of reaction to fire performance

The reaction to fire performance is reduced both after accelerated ageing and natural field exposure for most of the FRT products. Only a few FRT products maintain a high fire performance after accelerated and natural exposures. The best performance is found at high retention levels and for FRT products with paint as a protective surface coat. Among the paints, the linseed oil paint (number 4) and the factory primed product ZG were found to exhibit a full maintenance of the reaction to fire performance up to three years. The other FRT products were more or less degraded during the weathering exposure, regardless of a protective coat or not. For products with low retention of FR chemicals and low initial fire class, the maintenance of the fire performance could not be evaluated.

The accelerated ageing thus seems to be equivalent to maximum five years of natural field exposure. However, it should be noted that the field exposure includes also a certain degree of acceleration. The 45° exposure was intended to include some acceleration, but no major difference to the vertical (90°) orientations was found. This may be explained by the lack of protection on the rear sides of the vertical panels, which were open to the weather exposure. On the other hand, the panels at 45° slope, were at least partly protected on the rear side from direct influence of rainfall and snow. In a real end use, e.g. as a facade cladding, the rear side is totally protected. Such conditions have to be studied further before a more clear guidance on the accelerating factors can be established.

Figure 3. Results for data set 1. Reaction to fire performance (as predicted time to flashover) before and after accelerated ageing according to NT FIRE 053 Method A, and after natural weathering at 45° slope during up to 10 years. Untreated spruce (0) and FR treated (X, Y, ZA, ZG and VF) spruce. Surface coatings with paints number 1, 3, 4 and 6 are included.

Figure 4. Results for data set 1. Reaction to fire performance (as predicted time to flashover) before and after accelerated ageing according to NT FIRE 053 Method A, and after natural weathering with wood panels vertical (90°) and at 45° slope during up to 10 years. Untreated spruce (0) and treated (CI and CM) spruce.

Figure 5. Results for data set 2a. Reaction to fire performance (as predicted time to flashover) before and after accelerated ageing according to NT FIRE 053 Method A and B, and after natural weathering at 45° slope during up to 10 years. Untreated spruce (0) and FR treated (BS, DQ and BH) spruce. Surface coatings with paints number 1 and 4 are included.

Figure 5. Results for data set 2b. Reaction to fire performance (as predicted time to flashover) before and after accelerated ageing according to NT FIRE 053 Method A and B, and after natural weathering at 45° slope during up to 10 years. Untreated spruce (0) and FR treated (NF and AF) spruce. Surface coatings with paints number 1 and 4 are included.

Mass loss during weathering

The mass loss during accelerated ageing and natural weathering may be used as an indicator of the maintained reaction to fire performance over time. Some data are presented in Figures 7-8. It is obvious that all FRT wood products loose more weight during weathering than untreated wood products.

Figure 7. Reaction to fire performance (as predicted time to flashover) vs mass loss during accelerated ageing of FRT and untreated wood according to NT Fire 053 Method A [8].

Figure 8. Mass loss during natural weathering of FRT and untreated wood up to ten years.

Conclusions and suggestions for further work

Main conclusions are:

- A system with Durability of Reaction to Fire performance (DRF) classes to evaluate the fire performance of fire retardant treated (FRT) wood products over time at humid and exterior conditions has been developed. It provides a very useful supplement to requirements on the fire performance in national building codes and enables to guide potential users to find suitable and reliable FRT wood products.
- The hygroscopicity of sufficiently durable FRT wood is about the same as for untreated wood, but much higher for simple inorganic salts.

- The fire properties of FRT wood may be maintained after accelerated ageing and natural weathering if the retention levels are high enough, but several FRT wood products lose most of their improved reaction to fire properties during weathering.
- Paint systems contribute considerably to the weather protection and are usually needed to maintain the reaction to fire performance at exterior applications.
- The mass loss during accelerated aging and natural weathering may be used as an indicator of the maintained reaction to fire performance over time.

Suggestions for further work:

- There is a need to develop new FRT wood products with improved durability of the reaction to fire performance at exterior applications.
- More experience with correlation of natural field testing and accelerated ageing methods is needed. The relationship between accelerated and natural weathering in different climates in order to further develop the conditions for accelerated weathering should be studied by international cooperation.

In the meantime, requirements on the long term durability of the fire performance of FRT wood products should be included in product specifications, certification documents and in the national building regulations in order to support the use of reliable FRT wood products. It is especially important for wood products intended for exterior use.

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