XII DBMC
International Conference on Durability of Building Materials and Components
PORTO - PORTUGAL, April 12th-15th, 2011

Durability of the Reaction to Fire Performance for FRT Wood Products in Different End Use Applications – A Ten Years Report

Birgit A.-L. Östman [1]
Lazaros D. Tsantaridis [2]

ABSTRACT

A long term experimental study on the maintained reaction to fire performance of fire retardant treated (FRT) wood products over time is presented. It is performed according to a Nordic system and includes 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

- The reaction to fire properties of FRT wood may be maintained after accelerated and natural ageing if the retention levels are high enough

- Several FRT wood products loose most of the improved reaction to fire properties during weathering

- Paint systems contribute considerably to maintain of the fire performance at exterior application

KEYWORDS

Durability, Hygroscopicity, Reaction to fire, Weathering, Wood products.

[1] SP Trätek / Wood Technology, Stockholm, SWEDEN, birgit.ostman@sp.se
[2] SP Trätek / Wood Technology, Stockholm, SWEDEN, lazaros.tsantaridis@sp.se

1 DURABILITY CLASSES FOR FIRE PERFORMANCE - PRINCIPLES AND METHODS

Fire retardant treatments (FRT) may considerably improve the reaction to fire properties of wood-based products and the highest fire classifications for combustible products can be reached, but the maintained reaction to fire performance e g in exterior applications needs to be addressed in order to form a basis for new and reliable wood products with improved fire performance.

Requirements on the durability of fire retardant treatments are not yet mentioned in most national building codes. This is partly caused by unawareness of the problem and new procedures have to be implemented in order to increase the reliability and confidence of fire retardant wood products.

1.1 Interior and Exterior Durability of the Reaction to Fire Performance

Two cases of durability of the fire retardant treatment of wood-based 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 for exterior applications, e g as façade claddings. Maintained fire performance over time has to be verified. Some background information on these cases has been published [Östman *et al.* 2001]. A US study on exterior exposure in ten years is also available [LeVan & Holmes 1986].

A Nordic 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, see Table 1. The new system has been developed upon Nordic initiatives from industry and research [Östman *et al.* 2002]. It consists of a classification system for the properties over time of FRT wood [NT FIRE 054] and suitable test procedures [NT BUILD 504], [NT FIRE 053], all published as Nordtest methods. A draft European standard prEN 15912 [2009] has been on enquiry within CEN.

Table 1. Requirements for DRF (Durability of Reaction to Fire performance) classes of FRT wood products in interior and exterior end use applications according to NT Fire 054.

DRF class		*Existing fire requirements*	*Additional performance requirements at different end use of fire retardant wood-based products* [a]	
	Intended use	*Reaction to fire class, initial*	*Hygroscopic properties*	*Reaction to fire performance after weather exposure*
0	Short term	Relevant fire class	-	-
Int 	Interior applications	- " -	- Moisture content < 30 % - No visible salt at surface - No exudation of liquid	-
Ext 	Exterior applications	- " -	- " -	Maintained reaction to fire performance [b] after - Accelerated ageing or - Natural weathering or - Other referenced ageing method

a) To be fulfilled using material produced using the same manufacturing process and having a similar retention level as for the reaction to fire performance.

b) Criteria for fire testing according to ISO 5660 after weather exposure: RHR ≤ 100 kW/m^2 during 1200 s testing time or THR_{1200s} not increased more than 20 % compared to testing before weather exposure.

The test methods [NT BUILD 504], [NT FIRE 053] to verify the DRF classes are based on ASTM standards [ASTM D 32014], [ASTM D 2898]. The relevant fire class should be tested according to EN or IMO systems [EN 13501-1 2002], [IMO FTP Code]. The problems with maintained reaction to fire performance over time have been known for a long time in the US and the UK.

1.2 Fire Performance

Main fire test method has been the Cone Calorimeter [2002]. In most cases, duplicate tests have been run, since the repeatability has been very good. The time to flashover in the room corner test has been predicted [Östman and Tsantaridis 1994].

1.3 Hygroscopic Properties

The hygroscopic properties of wood products have been determined according to NT Build 504. The method includes the calculation of equilibrium moisture content at two climates, 50 % RH at 23 ^{o}C and 90 % RH at 27 ^{o}C. The requirement for DRF class Int is moisture content below 30 % in the humid climate. Ordinary untreated wood has moisture content below 20 % in the same climate. In addition, possible salt crystallisation at the wood surface and exudation of liquid in the wet climate is observed.

1.4 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 NT Fire 053. Both Method A, i e exposure to 12 one-week cycles of simulated rain and drying and Method B which also includes UV radiation have been used.

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

1.5 Mass Loss During Accelerated and Natural Weathering

The weight of the FRT wood panels has been measured after conditioning at 50 % RH at 23 ^{o}C, both initially and after the weathering procedures. The mass loss during weathering has been calculated as percentage of the total panel weight.

2 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 has been determined and estimated to be equivalent to class B or C according to the Euroclass system [EN 13501-1] for the FRT wood products. Untreated wood i Euroclass D. These data have been used as reference for the fire performance after weathering.

Two sets of wood products have been studied, one set of commercial FRT wood products, X, Y and Z, intended for exterior application, a former commercial product, VF, and another set of development products [Östman *et al.* 2006]. All are wood panels impregnated with fire retardants to different levels of retention, see Tables 2 and 3.

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 and have then been used together with edge seals both at accelerated and natural exposure. After the exposures the panels have been cut in a systematic way (with test pieces at the same position from the panels to secure consistency) and used for fire and other tests.

Table 2. Commercial FRT wood products.

FR ID	*Mean FR kg/m^3*	*Thick-ness mm*	*Width mm*	*Approximate initial density kg/m^3*	*Type of panel*
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

Table 3. Development FRT wood products.

FR ID	*FR kg/m^3 **	*Thickness mm*	*Width mm*	*Approximate initial density kg/m^3*	*Type of panel*
-	-	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

2.1 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. 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.

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/m^2;
** the higher amount on panel type Z

3 HYGROSCOPIC PROPERTIES

The hygroscopic properties of FR treatments as a function of the retention level are illustrated in Figure 1. 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 but not jeopardizing the moisture resistance.

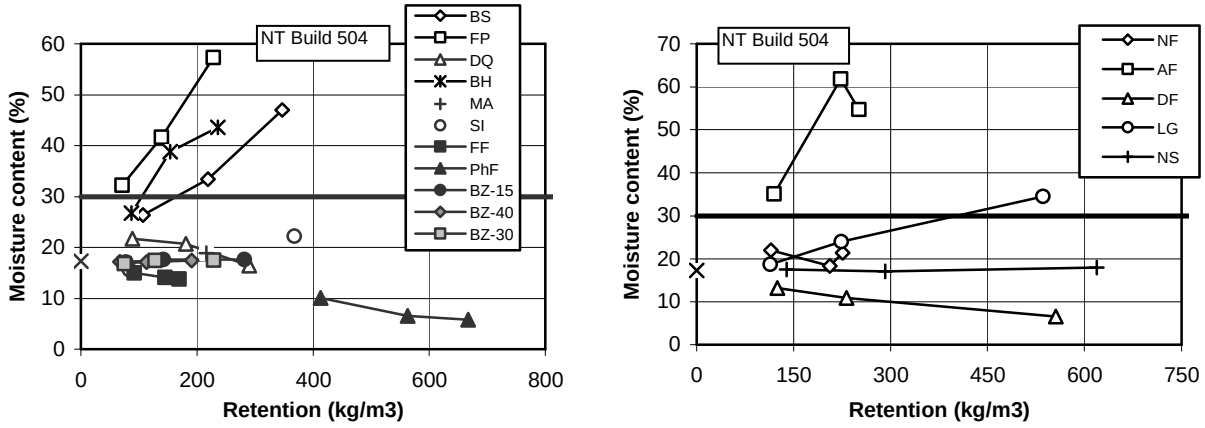

Figure 1. Moisture content at high RH vs retention for FR chemicals and for untreated pine sapwood.

4 COMPARISONS OF REACTION TO FIRE PERFORMANCE

The reaction to fire performance has been determined in the cone calorimeter at 50 kW/m^2. All results for the initial reaction to fire performance and after accelerated ageing and natural weathering are summarised and compared in Figure 2. The comparison is based on predicted time to flashover [Östman and Tsantaridis 1994]. Several products exhibit high initial reaction to fire performance, but it may be reduced over time during both accelerated and natural weathering.

Comparison of weathering exposures at vertical (90º) and at 45º slope is presented in Figure 3. No major difference can be observed.

5 DURABILITY OF THE 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 and the factory primed product were found to exhibit a full maintenance of the reaction to fire performance. 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 according to NT Fire 053 seems to be equivalent to maximum 5 years natural field exposure. However, it should be noticed that the field exposure includes also a certain degree of acceleration. The 45^o exposure was intended to include some acceleration, but no major difference to the vertical (90^o) orientations was found, see Figure 3. One of the products, ZG, indicates instead a

more severe degradation at the vertical orientation. This may be explained by the lack of protection on the rear side 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.

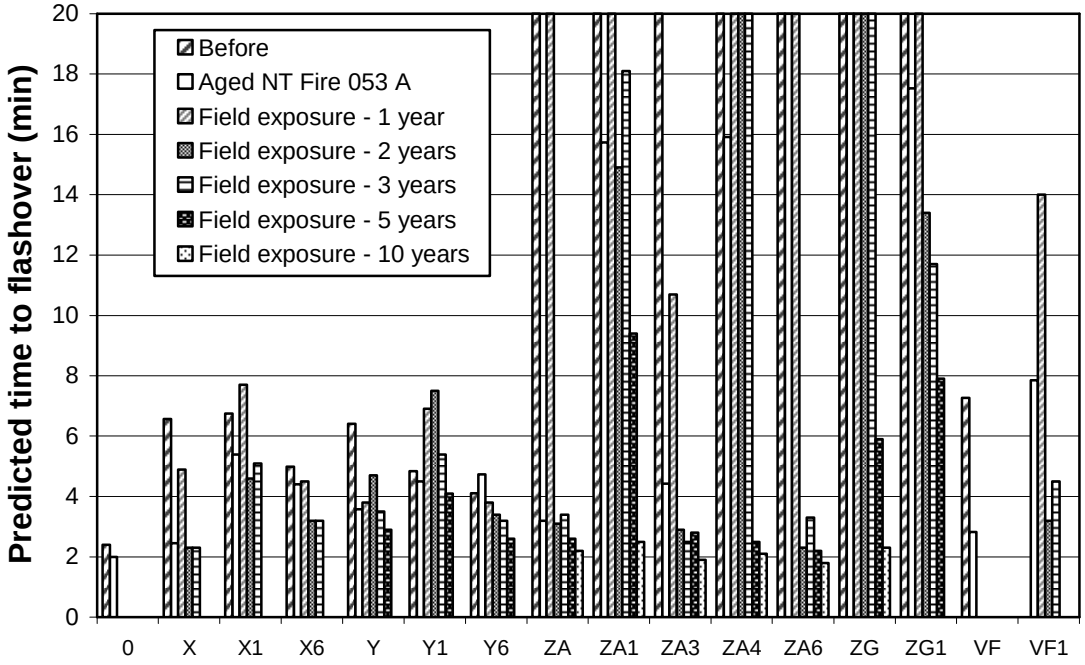

Figure 2. Reaction to fire performance (as predicted time to flashover) before and after accelerated ageing according to NT FIRE 053 Method A and after natural weathering at 45º slope during up to 10 years. Untreated spruce (0) and FR treated (X, Y, ZA, ZG and VF) spruce. Surface coatings with paints nr 1, 3, 4 and 6 are included.

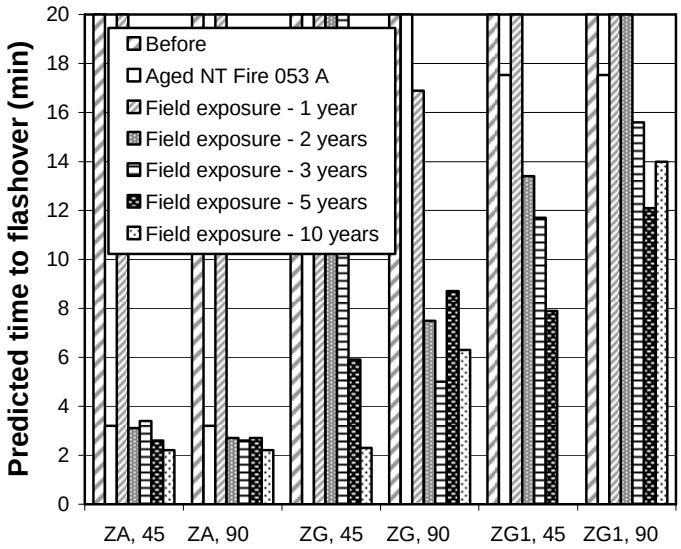

Figure 3. Comparison of reaction to fire performance after natural field exposure during up to 10 years with wood panels vertical (90º) and at 45º slope.

6 MASS LOSS DURING WEATHERING

The mass loss during accelerated aging and natural weathering may be used as an indicator of the maintained reaction to fire performance over time. Some data are presented in Figures 4-5.

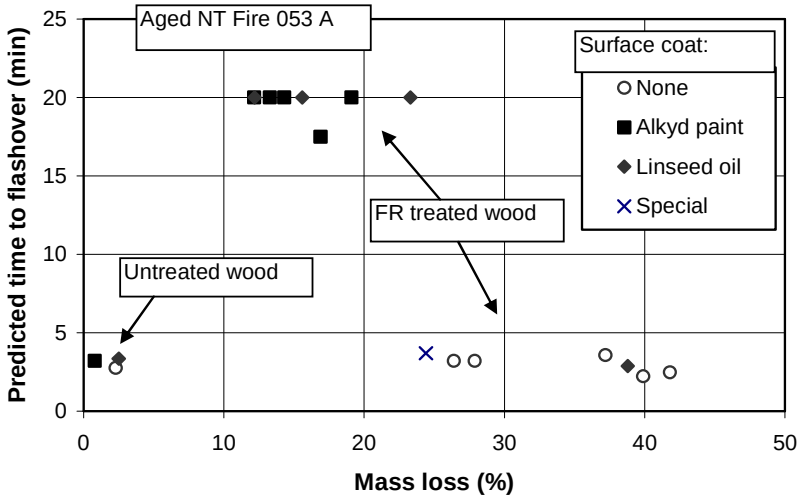

Figure 4. Reaction to fire performance (as predicted time to flashover) vs mass loss during accelerated ageing of FRT and untreated wood according to NT Fire 053 Method A.

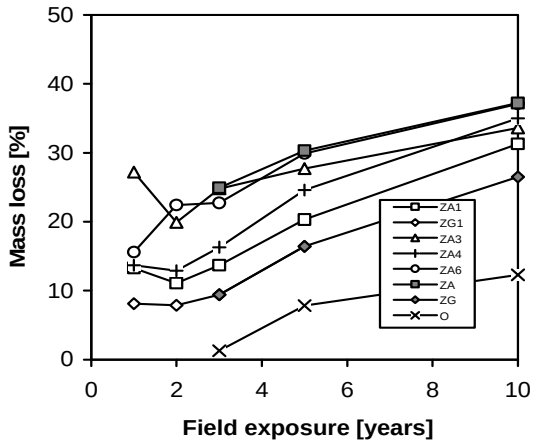

Figure 5. Mass loss during natural weathering of FRT and untreated wood up to ten years.

7 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 FRT wood over time at humid and exterior conditions has been developed. It provides a supplement to requirements on the fire performance in national building codes and enables to guide potential users to find suitable 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.
- Several FRT wood products loose most of the improved reaction to fire properties during weathering.
- Paint systems contribute considerably to maintain of the 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.
- More experience with correlation of natural field testing and accelerated ageing methods is needed.

REFERENCES

Östman B, Voss A, Hughes A, Hovde PJ, Grexa O, 2001, Durability of fire retardant treated wood at humid and exterior conditions. Review of literature. Fire and Materials, vol 25, 95-104.

LeVan S, Holmes C A, 1986, Effectiveness of fire-retardant treatments for shingles after 10 years of outdoor weathering. Research Paper FPL 474.

Östman B, Tsantarids L, Mikkola E, Hakkarainen T, Nilsen T-N, Evans F, Grexa O, 2002, Durability of fire retardant wood - New test methods and round robin. Nordtest project 1527-01. Trätek Swedish Institute for Wood Technology Research, Report P 0211040.

Nordtest method NT FIRE 054. 2006, Durability of Reaction to Fire - Performance classes of fire-retardant treated wood-based products in interior and exterior end use applications.

Nordtest method NT BUILD 504, 2003, Hygroscopic properties of fire-retardant treated wood and wood-based products.

Nordtest method NT FIRE 053, 2003, Accelerated weathering of fire-retardant treated wood for fire testing.

prEN 15912, 2009, Durability of reaction to fire performances – Classes of fire retardant treated wood-based product in interior and exterior end use applications.

EN 13501-1, 2002, Fire classification of construction products and building elements – Part 1: Classification using test data from reaction to fire tests.

IMO FTP Code (MSC 61/67), International Code for Application of Fire Test Procedures.

ASTM D 3201, Standard Test Method for Hygroscopic properties of fire-retardant treated wood and wood-based products. American Society for Testing and Materials.

ASTM D 2898, Standard Methods for Accelerated weathering of fire-retardant-treated wood for fire testing. American Society for Testing and Materials.

ISO 5660-1, 2002, Fire tests – Reaction to fire – Part 1: Rate of heat release from building products.

Östman B A-L, Tsantaridis L D, 1994, Correlation between cone calorimeter and time to flashover in the room fire test, Fire and Materials, vol 18, 205-209.

Östman, Tsantaridis, Mikkola, Hakkarainen, Belloni, Brumer and Piispanen, 2006, Innovative eco-efficient high fire performance wood products for demanding applications. Final report for Vinnova-Tekes project InnoFireWood. SP Technical Research Institute of Sweden, SP Report 2006:30.