FOLIA FORESTALIA POLONICA

© PAN Series B, Issue 40, 79-88, 2009

DETERMINATION OF WOOD-BASED PANELS' RESISTANCE TO WOOD ATTACKING FUNGI

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SYNOPSIS. Apart from solid wood, wood-based panels (WBP) are currently used in building as insulating and construction materials and as such they are exposed to factors creating conditions favourable for growth of wood attacking fungi. Classical tests of WBP resistance to fungi activity usually cover determination of mass loss caused by *Basidiomycotina* fungi or growth rate of mould fungi. Changes of WBP strength have been determined in research in addition to the above-mentioned indicators of WBP resistance to fungi. The mass loss of WBP caused by rotting activity of fungi was compared with mass loss of solid Scots pine sapwood. The aim of the investigation was to establish resistance to fungi activity of nowadays manufactured domestic WBP according to currently used modified method of resistance evaluation. The following wood based panels (WBP) were tested for the action of *Basidiomycotina* fungi or *Ascomycotina* and *Deuteromycotina* fungi causing wood moulding: OSB with various glues (MUF, PMDIsocyanate), regular and laminated particle boards (UF glue), and wet- and dry-process fibre boards (MDF, HDF). The resistance of tested materials to fungi activity was defined by determination of mass loss (PN-EN 113 and PN-ENV 12 083 – (*Basidiomycotina*)) as well as by determination of the degree of wood coverage with mould (ITB Instruction no 355/98), and also by determination of the effect of these fungi action and humidity on compression strength. Thanks to the test methods used significant changes in tested WBP were shown, thus knowledge about the influence of fungi on WBP properties was broadened.

KEY WORDS: fungi, panels, wood, resistance, strength

INTRODUCTION

Wood based panels (WBP) belong to one of most used building and construction materials. They are used not only as building materials but also as finishing and insulating materials for partition walls, structural ceilings, finishing panels, furniture etc. Production of WBP is characterised by an increasing trend. In 2004 global production was $225 \cdot 10^6$ m^3: plywood ca. $70 \cdot 10^6$ m^3 (Asia ca. $40 \cdot 10^6$ m^3), particleboard ca. $95 \cdot 10^6$ m^3, fibreboard ca. $45 \cdot 10^6$ m^3 (FAOSTAT database 2005,

Aderhold et al. 2006, Döry 2006). Wood decaying fungi as well as mould fungi occurring in buildings as a result of inappropriate ventilation, design errors and inappropriate maintenance may infest lignocellulosic materials causing their depreciation and degradation. The growth of fungi on wood-based materials has a negative effect on aesthetics and strength of the structures of wooden materials and products, and also on human health. Mycological analyses of building materials showed that fungi which are most common in buildings include *Aspergillus niger* (Matkowski 2002), which in medical literature is classified as a fungus dangerous to human (Baran 1998), as well as such toxic species as *Penicillium claviforme* Bainier or *Botrytis cinerea* Persoon ex Fries which causes allergies of respiratory tract. Genera of fungi dominant among fungi which most often infect wood-based materials are *Aspergillus, Penicillium, Alternaria, Paecilomyces, Phoma* (Lutomski 1995, Ważny 1994, 2003). The fungi causing rot of wood secret enzymes which depolymerises cellulose and lignin, i.e. main natural polymers of wood. Fungi are agents which decrease natural resistance of wood. Classical tests of WBP resistance to fungi activity usually cover determination of mass loss caused by *Basidiomycotina* fungi or growth rate of mould fungi (Lea and Berry 1995, Fojutowski et al. 2007, Van Acker and De Smet 2007). The objective of the investigations was determination of resistance of different wood based panels to activity of *Basidiomycotina* – wood decaying fungi or *Ascomycotina* and *Deuteromycotina* – fungi causing wood moulding. Apart from the above-mentioned indicators of WBP resistance to fungi, the basis for the research on recognition of WBP resistance to fungi was determination of WBP strength changes as an effect of fungi growth and/or higher humidity.

OBJECTIVES

The aim of this research was to determine resistance of contemporary produced wood-based panels to wood attacking fungi (*Ascomycotina* and *Deuteromycotina* or *Basidiomycotina*).

MATERIAL AND METHODS

The tested materials were WBPs: OSB with various glues (MUF, PMDIsocyanate), laminated particleboards (UF glue), and wet- and dry-process fibre boards (MDF, HDF). The description of tested WBPs is given in Table 1. WBP samples for testing were taken from sheets from whose outer parts 300 mm-wide strips were cut off. The sheets were conditioned in the laboratory in dry conditions for 3 months. Apart from samples exposed to fungi, control samples which were not exposed to any treatment and check samples kept on a sterile culture medium in conditions like the conditions in which samples exposed to fungi were kept, were prepared. The check samples were handled, sterilized in an autoclave etc., similarly to the test samples.

Table 1. Characteristics of wood-based panels

Panel code	HDF		MDF		Wet process fibreboard		OSB-3 3-layer		Particle-board 3-layer
	5	10	3	4	P	W	1	2	11
Thickness [mm]	3.2	6.0	16.5	15.0	12.0	5.0	10.0	16.0	16.0
Density [g/cm^3]	0.881	0.912	0.808	0.542	0.227	0.273	0.738	0.637	0.668
Glue	UF	UF	UF	100% PMDI			WZ-MUF, WW-PMDI	100% PMDI	UF
Finishing		laminate							laminate
Purpose		floor		insulating					

The WBP resistance to mould fungi was tested using a method based on the instruction prepared by the Building Research Institute (Instrukcja ITB... 1998). For 4 weeks samples were exposed to the action of a mixture of pure cultures of the following fungi: *Aspergillus niger* v. Tieghem, *Penicillium funiculosum* Thom, *Paecilomyces varioti* Bainer, *Trichoderma viride* Person ex Fries, *Alternaria tenuis* Link ex Fries (= the mixture); or action of a pure culture of *Chaetomium globosum* Kunze fungus. The incubation proceeded in the temperature of 27 ±1°C and relative humidity of 90%. The growth of mycelium on the surface of samples was measured after 4 weeks using the following scale:

0 – no growth of fungi on a sample, visible under the microscope

1 – trace growth of fungi on a sample, hardly visible to the naked eye but well visible under the microscope or growth limited to the edges of a sample, visible to the naked eye

2 – growth of fungi on a sample, visible to the naked eye, but less than 15% of the surface is covered with fungus

3 – over 15% of the surface is covered with fungus visible to the naked eye

Test samples were of the dimensions of 50 × 30 × thickness mm. Before and after exposure to fungi the samples were sterilized with steam in an autoclave (20 min, 121°C). 10 samples of each WBP type were used for test with the fungi mixture and Chaetomium globosum fungus and for control and check. The samples were used in strength tests as well.

The susceptibility of panels made of wood-based materials to brown rot was defined by determination of mass loss of samples of tested materials caused by Basidiomycotina fungi action. The determination was carried out acc. to methods based on PN-ENV 12 083 (special adaptation of PN-EN 113 used for determination of toxic limits of wood preservatives) and PN-EN 113. For 16 weeks samples were exposed to the action of a pure culture of *Coniophora puteana* (Schum. ex Fr.) Karst. fungus (BAM Ebw.15). For mass loss determination the following specimens were used:

- WBP specimens of the dimensions of 50 × 50 × thickness mm as treated samples and moisture content check specimens (to calculate the initial oven dry mass). Six specimens (two test specimens from each of three panels of each tested WBP type) were exposed to the fungus. Only one specimen was introduced in each culture vessel
- Scots pine sapwood (*Pinus sylvestris* L.) samples of properties in line with (PN-EN 113) and of the dimensions of 50 × 50 × appropriate WBP thickness mm, as samples for comparison of the effects of WBP decay with Scots pine sapwood, so one specimen only was introduced in each culture vessel like by WBP testing
- Scots pine sapwood (*Pinus sylvestris* L.) samples of properties fulfilling requirements of PN-EN 113 and of the dimensions of 50 × 25 × 15 mm, as samples used to control virulence of fungi strains used in tests. Two specimens were placed in one culture vessel

Two WBP specimens of the dimensions of 50 × 30 × thickness mm were placed in one culture vessel in order to prepare specimens for determination of the influence of brown rot fungus on the WBP strength. The mass losses on the specimens were also determined in order to directly establish the condition of samples tested for strength.

The mass loss of each specimen was calculated in relation to its initial oven dry mass determined by calculation method according to PN-ENV 12038 and not in relation to the final oven dry mass of the specimen after fungus action, as it was given in the standard by mistake.

Before exposure to fungi the samples were sterilised with steam in an autoclave (20 min, 121°C). Check samples were treated and sterilized in the autoclave just like the test samples. In strength test 10 samples of each WBP type were used for each type of test: with fungus infected samples, with control samples and with check samples.

The mass losses of WBP caused by dry rot fungus *Coniophora puteana* were compared with mass losses of appropriate (of the same dimensions) specimens of Scots pine sapwood (*Pinus sylvestris* L.). It allowed establishing of DSI (Decay Susceptibility Index) according to the following formula:

$$\mathrm{DSI} = \frac{\mathrm{T} \cdot 100}{\mathrm{S}} \tag{1}$$

where: T – mean loss in mass of WBP [%]
S – mean loss in mass of the appropriate set of specimens of Scots pine sapwood [%]

DSI values of 100 indicate the same decay resistance as that of wood used in the test for comparison. WBPs with lower DSI values are more resistant to attack of fungus used in the test. DSI index compensates for the differences stemming from panel thickness and makes it possible to establish a ranking of panels in terms of their resistance to wood decaying fungi.

The compression strength of WBP was tested acc. to the above-mentioned Instruction (Instrukcja ITB... 1998). Compression strength of WBP specimens

of the dimensions of 50 × 30 × thickness mm was the subject of testing and specimens were loaded along the 30 mm long side. Computerized Instron testing machine was used for strength determination. After fungal tests the specimens were cleaned by gently removing any adhering mycelium, and in the case of mould fungi the specimens were additionally sterilized on the surface with 75% ethyl alcohol. Then the specimens were oven dried before mechanical testing. Control and check specimens were treated in the same way. Significance of differences between mean values of compression strength for sets of tested, control and check WBP specimens was measured by rank-sum test (Greń 1982).

RESULTS

The virulence of strains of mould fungi used in the test was very high. The whole surface of nutrient medium in Petri dishes was completely covered by fungi after 3 days from infection.

The surface of Scots pine sapwood control specimens was grown over with mycelium in grade 3 and 100% of the surface was covered with growing mycelium. Results of tests of WBP resistance to mould fungi presented in Table 2 show that almost all tested WBP were covered by fungi in grade 3 (over 15% of surface covered) and in most cases mould fungi grown on the whole surface of the specimens. Tested WBP with such level of moulding may not be classified as mould resistant according to criteria used in the method accepted in building. The growth of moulds was less only on 16.5 mm thick MDF panel – grade 0-1.2.

Table 2. The degree of mould fungi growth of wood-based panels subjected to mould fungi action

Panel code	5	10	3	4	P	W	1	2	11
Option	The degree of mould fungi growth								
I Mixture	2.8	3.0	0.0	3.0	2.6	2.6	3.0	3.0	3.0
II *Chaetomium globosum*	2.6	2.2	1.2	3.0	3.0	3.0	3.0	3.0	3.0
	Moisture content after incubation [%]								
I Mixture	61.8	39.2	29.5	34.9	66.0	88.3	40.1	29.2	31.3
II *Chaetomium globosum*	65.1	41.5	31.5	37.8	30.2	95.7	45.4	29.8	34.3
Reference samples	54.9	37.1	32.3	29.9	61.1	91.4	32.3	26.3	34.0

Compression strength of tested WBP was different and dependent on their type (Table 3). Control particleboards, including OSB type, were characterised by high compression strength ranging from 11 to 31 N/mm^2, but compression strength of control wet-process soft fibreboard was below 2 N/mm^2. The compression strength of all particleboards tested after mould fungi action was very similar to that of check panels (on sterile culture medium), but both strength values were lower than the strength of control boards. Compression strength of tested WBP ranged from 21% (laminated particleboard) to 92% (wet-process softboard). In most cases the differences between mean values of compression strength of samples subjected to mould fungi action and of check samples were not statistically significant at

Table 3. The compression strength of wood-based panels after exposition to mould fungi action

Panel code		5	10	3	4	P	W	1	2	11
Option		Compression strength [N/mm^2]								
Check (S)	$\overline{x}$	7.47	12.53	10.52	11.56	0.53	1.22	6.63	10.94	2.52
	δ	1.5	1.6	1.1	0.9	0.0	0.1	2.3	2.8	0.2
	V	20.61	12.55	10.32	8.12	8.12	5.73	34.64	25.82	9.47
Control	$\overline{x}$	17.75	31.17	22.71	14.11	0.59	1.56	10.68	15.22	11.77
	δ	2.9	5.4	2.0	1.2	0.05	0.1	1.7	3.7	0.8
	V	16.50	17.24	8.98	8.82	8.15	4.01	15.64	24.14	6.57
M:S	IR $\alpha = 0.05$	no	no	no	no	no	yes	no	no	no
Ch:S	IR $\alpha = 0.05$	no	no	yes	no	yes	yes	no	no	no
W_1 = M·100/K [%]		40	47	50	77	92	71	61	78	23
W_2 = S·100/K [%]		42	40	46	82	90	78	62	72	21
W_3 = Ch·100/K [%]		41	44	54	78	81	56	66	77	23
Moisture content after incubation [%]										
Specimens after (M)		61.8	39.2	29.5	34.9	66.0	88.3	40.1	29.2	31.3
Specimens after (Ch)		65.1	41.5	31.5	37.8	30.2	95.7	45.4	29.8	34.3
Check (S)		54.9	37.1	32.3	29.9	61.1	91.4	32.3	26.3	34.0

W_1 – compression strength of panels after exposition to mixture of mould fungi action (M) in relation to compression strength of control panels (K) [%].

W_2 – compression strength of check panels in relation to compression strength of control panels (K) [%].

W_3 – compression strength of panels after exposition to *Chaetomium globosum* fungus action (Ch) in relation to compression strength of control panels (K) [%].

the significance level of $\alpha = 0.05$ (95%); however, they were significant at lower significance levels which may indicate some negative influence of mould fungi. The drop of compression strength in relation to control panels may be explained rather by the effect of higher air humidity and moisture content than by fungi activity. Therefore, it seems that changes caused on WBP by mould fungi are not significant for their compression strength; however, higher humidity of air and moisture content, which are favourable to fungi growth, may significantly decrease the strength of WBP.

The decaying virulence of the strain of *Coniophora puteana* (*Cp*) fungus used in the test was very high – mean loss in mass was 51.0%. The action of *Cp* fungus caused decay, i.e. mass losses of wet-process and dry-process fibreboards and particleboards ranged from 32 to 60% for most samples of panels (Table 4). It shows their lack of resistance to *Basidiomycetes fungi*. Mass losses of WBP prepared for strength testing, which were smaller and exposed to fungus action, where two specimens were placed in one culture vessel, were very similar to the mass loss caused by *Cp* fungus in the case of WBP specimens which were used only for mass loss determination (specimens were greater and placed individually in culture vessel). Similar lack of resistance to decay was observed for these two test layouts. Changes of mass caused by agents other than fungus were relatively small, between 2% and 4%. Mass losses of Scots pine sapwood specimens of dimensions similar to WBP, placed in the same culture vessels and under the same conditions, ranged

Table 4. The mass losses of wood-based panels caused by brown rot *Coniophora puteana* fungus

Panel code	5	10	3	4	P	W	1	2	11
Option	The mass losses caused by *Coniophora puteana* [%]								
Specimens for mass loss	49.55	42.07	40.36	38.79	58.00	59.95	45.67	32.32	47.95
Specimens for strength	52.43	42.3	35.7	35.2	54.99	55.73	45.88	37.26	47.31
Corrected mass loss for strength	48.69	40.42	32.53	33.28	50.70	52.66	42.93	34.87	45.31
Correction factor	3.73	1.90	3.22	1.94	4.29	3.07	2.95	2.39	2.00
Control (Scots pine sapwood)	63.3	57.1	48.3	48.3	41.2	57.1	46.50	48.30	48.30
DSI	78	74	84	80	141	105	98	67	99
Moisture content after incubation [%]									
Specimens for mass loss	130.9	87.4	74.4	54.2	40.9	87.5	94.2	89.7	168.5
Specimens for strength	163.5	86.4	59.2	53.1	89.3	127.0	85.3	45.9	74.4
Check specimens for strength	54.0	37.0	42.4	30.3	55.5	58.7	52.4	26.7	36.4

from 41.2 to 63.3%. It confirms good condition for the fungus to decay WBP. Five samples (marked 2, 3, 4, 5, and 10) from the nine tested WBP were characterised by distinctly greater resistance to decay caused by brown rot than that of Scots pine sapwood: DSI from 67 to 84. The other tested panels were characterised by DSI between 98 and 141 (Table 6). Disfigurement and delamination of some panels were the effects of *Cp* fungus activity and following drying of panel specimens at 103°C.The resistance of WBP to brown rot fungi in the tested set of boards depended to some extent on their properties. It is noticeable that in the case of the same type of boards, those of greater density or PMDI glues instead of UF glues are characterised by higher resistance, e.g. HDF board marking 10 versus marking 5 or MDF board marking 4 versus marking 3.

The compression strength of the samples of WBP subjected to *Cp* fungus (Table 5) significantly decreased in comparison to control samples and check samples stored in conditions of higher humidity (culture medium without fungi). It decreased even to only 4 to 15% of the compression strength of check boards and to 1 to 12% of the strength determined for control boards. A drop in WBP strength caused by *Cp* fungus ranged from 85% to 96%; mean value was 91% in relation to check specimen and near 94% in relation to control specimen. The higher humidity conditions (check boards on sterile culture medium – without fungi) caused also a significant drop in WBP compression strength ranging from 17% to 78% depen-

Table 5. The compression strength of wood-based panels after their exposition to brown rot *Coniophora puteana* fungus

Panel code		5	10	3	4	P	W	1	2	11
Option		Compression strength [N/mm^2]								
Check (S)	$\overline{x}$	5.38	12.41	7.08	11.72	0.45	1.30	6.24	10.74	2.54
	δ	0.9	0.8	1.2	1.2	0.1	0.2	1.30	1.85	0.32
	V	15.82	6.57	16.95	10.09	17.46	12.41	20.80	17.26	12.64
Control	$\overline{x}$	17.75	31.17	22.71	14.11	0.59	1.56	10.68	15.22	11.77
	δ	2.9	5.4	2.0	1.2	0.05	0.1	1.67	3.68	0.77
	V	16.50	17.24	8.98	8.82	8.15	4.01	15.64	24.14	6.57
Cp:S	IR $\alpha = 0.001$	yes	yes	yes	yes	yes	yes	yes	yes	yes
W_1 = Cp·100/S [%]		–	9	9	15	13	6	6	8	4
W_2 = S·100/K [%]		30	40	31	83	76	83	58	71	22
W_3 = Cp·100/K [%]		–	4	3	12	10	5	4	5	1
Moisture content after incubation [%]										
Specimens for strength		163.5	86.4	59.2	53.1	89.3	127.0	85.3	45.9	74.4
Specimens for check		54.0	37.0	42.4	30.3	55.5	58.7	52.4	26.7	36.4

W_1 – The compression strength of wood-based panels after their exposition to brown rot *Coniophora puteana* fungus (Cp) in relation to compression strength of check wood-based panels (S) [%].

W_2 – The compression strength of check wood-based panels (S) in relation to compression strength of control wood-based panels (K) [%].

W_3 – The compression strength of wood-based panels after their exposition to brown rot *Coniophora puteana* fungus (Cp) in relation to compression strength of control wood-based panels (K) [%].

Table 6. DSI (Decay Susceptibility Index) of tested wood-based panels

Characteristics of panels							DSI
panel code	type	thickness [mm]	density [g/cm^3]	glues	finishing	purpose	
2	OSB-3 3-layer	16.0	0.637	100% PMDI			67
10	HDF	6.0	0.912	UF	laminate	floor	74
5	HDF	3.2	0.881	UF			78
4	MDF	15.0	0.542	100% PMDI		insulating	80
3	MDF	16.5	0.808	UF			84
1	OSB-3 3-layer	10.0	0.738	WZ-MUF, WW-PMDI			98
11	Particle board 3-layer	16.0	0.668	UF	laminate		99
W	Wet-process	5.0	0.273				105
P	fibre board	12.0	0.227		bitumate (10%)		141

dent on the WBP type. The mean values of the WBP compression strength were lower than those of check WBP specimens. The differences between the values of mean strength of WBP exposed to *Cp* fungus were statistically significant at $\alpha = 0.01$ level in relation to check WBP specimens.

CONCLUSIONS

1. Under favourable conditions mould fungi grow very easily on the surface of wood-based panels, thus creating environmental hazard, but they do not cause a significant hazard to compression strength of wood-based panels.
2. Natural resistance of tested wood-based panels (particleboards including OSB, wet- and dry-process fibreboards, MDF, HDF with UF, MUF and PMDI glues) to brown rot fungi turned out to have been low, both in respect of mass loss and decrease in compression strength. These panels should be classified as not resistant to brown rot fungi.
3. The resistance of WBP to brown rot fungi depends also on density of boards and types of glues used for their production.
4. Compression strength of wood-based panels may become significantly lower as a result of staying in the conditions of high humidity which are favourable to fungi growth, even if no fungi occur.
5. If the danger of fungi occurrence is high wood-based panels used in buildings should be protected with anti-fungal preparations to avoid hazard connected with lowering of their strength during exploitation and creation of health hazard to people caused by mould which may grow on the WBP surface.

Acknowledgement

The investigation received financial support from the Polish Ministry of Science and Higher Education, Grant 2 P06L 031 29 in the period 2005-2007.

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Received in January 2009

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