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Field study of thermomodified *Populus nigra* wood in contact with the ground

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Abstract: *Field study of thermomodified Populus nigra wood in contact with the ground.* Durability of wood and wood-based products against various wood-decay organisms, different weather conditions and other factors is established by many laboratory test methods as basis to determining service life prediction and possibilities of particular end-uses of individual species of wood. The investigations in laboratory conditions should be however be checked by testing in natural field conditions with direct impact of all environmental factors, e.g. in contact with the ground. The poplar woods belong to the wood species of low durability to wood destroying organisms and require protection for use in construction particularly in contact with ground. Thermomodification, besides of impregnation with wood preservatives is able to increase durability of wood against certain wood-decaying organisms. The goal of the investigation was to test according to EN 252 method the durability of thermally modified poplar wood after 4 years of field contact with the ground, in comparison to natural twin wood of the species. The attack by organisms and other factors on wood was mainly determined as rating according to EN 252, but described also with some additional data (the presence of fungi and/or the algae/mould on the top/bottom part of test samples etc.). It was stated that in test conditions thermo modified poplar wood was decayed slower in comparison to the natural wood of the species. The difference after 4 years in main rating of wood attack was quite significant (rating 3.77 and respectively 2.23).

Keywords: poplar, wood, use class 4, thermo modification, resistance

INTRODUCTION

Wood durability is considered to be an important factor which is fundamental to the scope of use of wood products. This property directly affects the service life of wooden products. Many laboratory test methods are used to determine durability of wood and wood-based products against various wood-decay organisms, different weather conditions as well as influences of contact with water, and others physical and chemical substances and factors. The wood is tested for durability against individual basidiomycetes fungi causing brown or white decomposition, against fungi causing soft rot, against filamentous fungi causing wood sapstain, wood moulding, insects attacking wood such as beetles and termites, against marine organisms of bivalves, crustaceans, against atmospheric factors, etc. Experimental data obtained during the tests ranks durability of various wood against wood-destroying organisms and others factors. The results of the test are basis and input to service life prediction of wood and wood-based products. In this way, indications are obtained regarding applications to different particular end-uses of suitable wood species. The laboratory investigations are very valuable due to the unambiguously established, controlled, repeatable test conditions. However, they are not able to reflect all the complexity of interactions occurring in natural biocenosis. Thus, a specific complement, and to a some degree verification of the results of laboratory tests, are field testing in natural conditions with direct impact of physical, chemical, atmospheric and/or biological factors, e.g. in contact with the ground. The poplar wood (account, together with some other broadleaved species besides oak, beech, hornbeam, birch, alder, and aspen, about 2% to 5.0% of the forest area in Poland depending on the form of the forest ownership) belongs to the wood species of low durability against wood-destroying organisms – classified to 5. durability class [Forests…2017, EN 350]. The main area of its use as wood of low density and hardness is raw material for veneers, plywood, pulpwood and chipboards. Regarding durability, it should be protected in conditions corresponding to the higher use classes [PN-EN 335] particularly in use in construction in contact with ground. Thermomodification, besides of impregnation with wood preservatives, is a method showing in laboratory tests improving of some wood species durability against certain wood-decaying organisms [Kollmann 1936, Fojutowski et al. 2009, 2010, Mayes 2015, PN-EN 599-1]. Each of these treatments or their combination may serve to increase the range of application of poplars, among others in building, also in contact with the ground, e.g. elements of terraces. It should however to take into account that according to Biocidal Products Regulation [BPR 2012], the use of wood preservatives should be limited. All the same, extending the scope of application of poplars particularly by thermomodification regarded as more environmentally friendly than using chemicals, may also be interesting in the future taking into account the growth possibilities of this species as fast growing trees and growing plantations. Thermomodification by reducing the amount of hydroxyl groups of cellulose and hemicelluloses, which are involved in oxidative degradation, fungal decay, and the processes of water absorption and desorption by wood increase dimensional stability and resistance to water and wood-decaying fungi of *Basidiomycetes* class. [Militz 2002]. Thermomodified wood turned out however still to some extent vulnerable to attack of filamentous fungi, although the intensity of fungi growth was lower in comparison to natural wood. The group of mold fungi may also in favorable conditions cause soft rot of wood [Fojutowski *et al*. 2009, 2010, Militz and Callum 2005].

The goal of the investigation was to test according to EN 252 method the durability of thermally modified poplar wood after 4 years of field contact with the ground, in comparison to natural twin wood of the species. The research is planned to continue for at least 5 years.

MATERIALS AND METHODS

The poplar wood described in the paper was subjected to thermal modification in a temperature up to 210^{o}C, in steam-saturated air in an industrial device in 2013. Thermo modification decreased some properties of wood: the equilibrium moisture content, density, bending strength, and MOE at bending characterising poplar wood, but increased the compression strength along the grain [Fojutowski et.al 2015, 2015a, 2016].

The main test materials were samples of natural and thermally modified black poplar wood (*Populus nigra* L.) of the dimensions of 500 (L) × 50 (T) × 25 (R) mm. Each series of the samples amounted to 30 pieces of natural or thermally modified wood of black poplar. To avoid the influence of the heterogeneity of wood on the test results, the samples were prepared as twin samples. The natural and thermally modified wood samples were adjacent to each other with side measuring 500 × 50 mm. Before samples were buried in the ground to half of their length, they had been planned all the round, sorted out to eliminate cracked and warped ones, and air-conditioned in the standard climate, i.e. at 20±1° C and 65±5% relative humidity.

The field tests of thermo modified poplar wood in contact with the ground were started in 2013 on the field established in 2010 by the Wood Technology Institute on Jarocin Forest District lands.The samples were exposed to weathering and all biological factors in the field test in contact with the ground, according to requirements of the standard [EN 252].

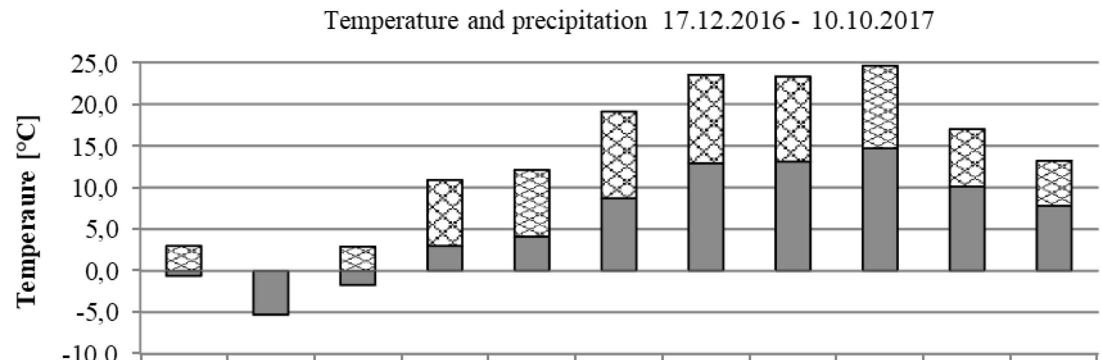
The main rating system for the assessment of samples degradation followed the EN 252:

0 – no attack – no change (if only a change of colour is observed, it shall be rated 0),
1 – slight attack – superficial degradation, limited intensity, softening of the surface (< 2mm),
2 – moderate attack – softening to ≥ 2 mm over a surface of ≥ 10 cm^2 or 5 mm over < 1 cm^2,
3 – strong attack – decay of ≥ 3 mm over a surface ≥ 25 cm^2 or softening to ≥ 10 mm over more limited area,
4 – failure – impact failure of the samples in the field.

The evaluation and the assessment of the condition of the samples was supplemented with some additional observations concerning the presence of fungi on the underground part of the stakes (samples) and/or the algae/mould presence on the above-the-ground part of the stakes etc. The climate data were also recorded.

RESULTS

The monthly average minimum and maximum temperature and precipitation characterising the climate condition on the test field during last year of test are present on Fig. 1. It should be add for better explanation hydrothermal conditions, that the average yearly values of the temperature was +11.0°C (daily minimum – 16.0°C to maximum + 35.5°C) and average precipitation referenced to days with precipitation was 6.2 mmH_2O (daily, highest value 42.0mmH_2O and the smallest one 0.5mmH_2O). Rainfall was 510 mm *i.e.* close to long-term average value.



	Dec 16	Jan 17	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct 17
temp.min	-0,6	-5,3	-1,7	3,0	4,1	8,7	12,9	13,1	14,7	10,1	7,8
temp. max	3,0	-0,4	2,9	10,9	12,1	19,1	23,5	23,3	24,6	17,0	13,2
precipitation	4,3	2,4	5,5	6,6	3,4	5,2	6,8	6,4	10,6	6,6	8,4

Figure 1. The monthly average minimum and maximum temperature and precipitation on the field test area during the fourth year of exposure of samples.

The average attack degree of natural poplar wood samples was 3.77 (Table 1). This indicates a very advanced stage of wood decomposition, worse than the grade 3 defined as ‘severe attack’ and very close to the maximum rating for wood attack, i.e. 4 ‘failure’, which occurred on 67% of samples. It is accompanied by very strong changes in macrostructure of wood occurred on 90% of samples, however the fungi on the underground part of wood were visible with naked eye only at 10% of samples. The moulds were found on the 17% of above-the-ground parts of natural poplar wood, but the algae presence was evaluated at 80% of the number of the natural wood samples. The softening of wood was measured quiet deep – on average it reached 17.7 mm, and ranged from 10-20 mm, reaffirming advanced wood decay. There were also many – 77% traces of microparticles gathered from wood surface.

The results of the attack of microorganisms and weather on thermo modified poplar wood samples were distinctly weaker than in the case of natural wood. The average degradation degree was only 2.23, meaning a less attack than moderate (grade 2). Fungi were visible to the naked eye on the surface of the underground part of the stakes only on 7% of the samples.

Table 1: The assessment of degradation of the test samples after 4 years exposition in contact with ground according to - EN 252 test.

Mean rating of tested wood after 4 years of field exposition		
Symptoms	**Black poplar wood**	
	natural	**thermo**
Evaluation rating acc. EN 252	3.77	2.23
Number of failure samples [%][a]	67	3
Deformation/loss of the wood structure [%][a]	90	3
Fungi at underground part [%][a]	10	7
Evidence of moulds at over ground part [%][a]	17	0
Evidence of algae at over ground part [%][a]	80	93
Traces of microparticles of wood gathered from wood [%][a]	77	17
Depth of softening [mm]	17.7	4.3

[a] *percentage of samples units with common symptoms*

The average depth of thermo modified poplar wood softening was only 4.3 mm (ranging from 2 mm to mostly 5mm, besides twice 20mm including one samples failure). Moulds were not present on thermally modified poplar samples, however algae were present on thermo-poplar wood to 93%, so at larger scale than was stated for natural poplar wood. The presence of microparticles gathered of wood was observed on the surface of 17% thermally modified poplar wood samples, in comparison to 77% on natural poplar wood. No fruiting bodies of fungi were found either on natural or heat-treated wood. All tested samples, of natural and thermally modified poplar wood, turned greyish and cracked on the foreheads of the samples.

Thermo modification slowed down the decay of poplar wood (Table 2), mostly in the first year of exposure. The degradation of thermomodified poplar wood after the fourth years of exposition is still distinctly lower than natural wood, although the difference in comparison to second year of exposition slightly decreased from about 1.8 to 1.3 degrees. The deterioration of poplar wood during the fourth year of field exposure was in fact insignificant compared to the changes stated after third year of exposure, particularly on thermomodified wood. The degradation of natural poplar wood reached however a maximum grade 4 = failure on hardly 70% of samples. The characteristics of thermally modified poplar wood properties after fourth years of exposure in contact with the ground were in general better than those of tested natural poplar wood. It is worth emphasizing significantly lower average depth of wood softening and deformation/loss of the structure of thermo modified wood in comparison to twin natural poplar wood samples. It is important difference, from the construction point of view. Similar to the situation after three years [Fojutowski at 2017], the biggest difference as regards aesthetics were the much smaller traces of microparticles of wood gathered from the wood surface and lack of traces of mould on thermomodified wood. It should however notice that the number of algae was greater than on natural wood and decomposition still develops.

Table 2 The assessment of degradation degree of natural and thermo modified Black poplar wood in contact with the ground according to the standard EN 252 – exposition on the test field in Jarocin Forest District in the period 2014-2017.

Black poplar wood (*Populus nigra*); Average rating acc. EN 252							
natural wood				thermally modified wood			
Evaluation after [year]				Evaluation after [year]			
1	*2*	*3*	*4*	*1*	*2*	*3*	*4*
2.93	**3.50**	**3.58**	**3.77**	**1,10**	**2,17**	**2,20**	**2.23**

The comparative research carried out almost simultaneously on this field test showed how different microorganisms exist in different environments and cause different changes in wood, and their differentiation is still investigated [Jacobs et al. 2014]. The changes of the samples of natural poplar wood as well as thermally modified poplar wood exposed in the field test in contact with the ground for 4 years indicate the presence of characteristic changes typical of wood exposed to the open air without cover and partially submerged in soil, i.e. softening, occurrence of mould and algae, and traces of decomposition and cracks, very similar but mostly more intensive to that stated during the first three years of investigations [Cooper et al. 2005, Fojutowski et al. 2015, 2015a, 2016, 2017, Link and DeGroot 1990]. The previously recognized effects of increased wood durability resulting from thermo modification treatments [Schwarze and Spycher 2005, Skyba et al. 2008, Welzbacher et al. 2008] are also similar to changes stated in this investigation. Depending on the exposure time, atmospheric conditions and/or the biological activity of the environment changes of the properties of the examined wood may naturally be different and of varying degrees.

CONCLUSIONS

1. The greatest difference between quality of thermally modified poplar wood and natural wood occurred after first year for four years exposition of wood samples in the field test in contact with the ground. The occurred changes were typical for timber located in the open air, uncovered, and partially buried in the ground, i.e. softening, greying, the presence of mould and algae, traces of decay and fungi growth, and cracks, however the changes on modified wood were less intensive than that on natural wood.
2. The condition of thermo modified black poplar wood after four years in the open air and in contact with the ground was significantly better than that of natural poplar wood – rating 3.77 and 2.23, respectively, according to the standard EN 252. It's mean that thermo modified black poplar wood, after four years of field exposure in contact with the ground, decomposed slower and to a lesser extent than natural black poplar wood.
3. The four-years field study in contact with the ground shows that the natural low biologic durability of poplar wood in contact with ground may be to some extent improved through thermal modification, increasing chance for application of those wood, in this conditions. It will however be emphasized that the stated improving of biological durability of tested wood species cannot be regarded as any guarantee of performance in any service conditions.

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Streszczenie: *Badanie terenowe w kontakcie z podłożem termomodyfikowanego drewna Populus nigra.* Trwałość drewna i materiałów drewnopochodnych wobec różnych organizmów rozkładających drewno i różnych oddziaływań zewnętrznych oraz innych czynników jest ustalana z zastosowaniem wielu metod laboratoryjnych, jako bazy wskazania przewidywanego czasu życia i możliwych zastosowań końcowych poszczególnych gatunków drewna. Badania w warunkach laboratoryjnych powinno się jednak sprawdzać testami w poligonowych warunkach naturalnych z bezpośrednim wpływem ogółu czynników środowiskowych np. w kontakcie z gruntem. Drewno topoli należy do gatunków drewna o małej trwałości wobec organizmów rozkładających drewno i wymaga ochrony przy zastosowaniu w konstrukcjach szczególnie w kontakcie z gruntem. Termomodyfikacja, obok impregnacji środkami ochrony drewna może zwiększyć trwałość drewna wobec poszczególnych organizmów rozkładających drewno. Celem pracy było zbadanie zgodnie z metodą EN 252 trwałości termomodyfikowanego drewna topoli po 4-ch latach poligonowego kontaktu z gruntem, w porównaniu z naturalnym bliźniaczym drewnem tego gatunku. Zaatakowanie drewna przez mikroorganizmy i inne czynniki było oznaczane głównie według ocen zgodnych z EN 252, ale opisano również niektóre dodatkowe dane (obecność grzybów i/lub glonów/pleśni na górnej/dolnej części próbki itp.) Stwierdzono, że w warunkach testu poligonowego termomodyfikowane drewno topoli ulegało rozkładowi wolniej w porównaniu z naturalnym drewnem tego gatunku. Różnica po 4-ch latach w głównej ocenie zaatakowania drewna była wyraźnie znacząca (ocena 3.77 i odpowiednio 2.23).

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