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CHANGE OF MECHANICAL PROPERTIES OF NORWAY SPRUCE WOOD DUE TO DEGRADATION CAUSED BY FIRE RETARDANTS

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ABSTRACT

The degradation of surface layers of wood can be caused by chemical reactions of compounds contained in fire retardants which were applied to historic wooden structures in the past. Among such chemicals are e.g. ammonium sulphate and ammonium phosphate. The paper presents the experimentally established mechanical properties measured on the surface of fibrillated wood of Norway Spruce (*Picea abies* (L.) Karst.), and their comparison with values measured on undamaged wood. The results proved a loss of cohesion in the damaged surface layer accompanied with a decrease in tensile strength by up to 50 % when compared to the values ascertained in undamaged wood. The impact of corrosion was also studied using hardness tests based on ball and pin indentation. Electron microscopy investigation revealed both the damage to the middle lamella, which mainly consists of lignin, and the damage to the secondary cell wall primarily formed by cellulose. The increasing degree of fibrillation is accompanied by an increasing proportion of cellulose in the wood, due to an appreciable loss of lignin, and an increasing proportion of carboxyl groups, presumably due to the oxidation of hydroxyl groups in cellulose and lignin. The crystalline-to-amorphous cellulose ratio also increases. Lignin oxidation appears to be the major mechanism of wood fibrillation.

KEY WORDS: wood degradation, fire retardant, mechanical properties, tensile strength, hardness.

INTRODUCTION

Paints designed to protect wood against fire have been used since ancient times and we can find their traces on the surface of historic structures (Drdácký et al. 2005). The research into chemical compounds and the development of the chemical industry during the 20th century made it possible to develop new combustion retardants and later to apply them to wooden elements of building structures. Liquid agents have been usually applied to structural elements by spraying or painting them on. The application of the agents to wooden structures in buildings took place repeatedly, namely always after the period of the expiration of their guaranteed life.

By research into wooden structures treated in the past it was ascertained that some chemicals contained in the used agents induce chemical reactions that damage wood polymers: cellulose, hemicellulose and lignin. An example may be the application of combustion retardants based on ammonium sulphate and ammonium phosphates used in the Czech Republic in the past for the repeated treatment of roof frames in historic structures (the building of the Děčín brewery, Fig. 1). The effects of agents containing these substances caused damage to the surface of historic wood referred to as "surface fibrillation of wood" or "corrosion".

From the macroscopic point of view, the fibrillation (Fig. 2) can lead to a significant deterioration of the wood mechanical properties. Currently, fibrillation is considered mostly an aesthetic defect. It causes a loss of information from the surface of wood, especially traces of its being worked by tools. However, since the structure of the wood is eroded, the fibrillation might gradually lead to a significant deterioration of strength parameters of the wooden elements and thus put the safe and reliable mechanical behaviour of historic wooden structures under threat.

Fig. 1: Fibrillated surface of structural elements of a roof frame of the Děčín brewery

Fig. 2: Detail of fibrillated wood

Nowadays the damage in structural wood caused by fibrillation is repaired so that first the fibrillated layers are mechanically removed (down to the compact wood) and then a spray with a neutralization solution is repeatedly applied. It is apparent that this manner of conserving historic structures does not provide a permanent solution to the wood corrosion problem. After a few years of neutralization, the fibrillation of the wood reoccurs. This technology of removing fire retardants is considered unsuitable for historic structures protected as ancient monuments and it leads to a constant diminution of the diameter of structural elements.

The impact of sulphate and, especially, ammonium phosphate combustion retardants on the wood strength was investigated in the past and described in more detail in the following articles: LeVan and Winandy 1990, Winandy 1995, 1997, Winandy et al. 1998. Nevertheless, the issue of corrosion has not been addressed yet in historic hewed wood and in agents that were used in Czech and Moravian historic monuments. Moreover, the impact of corrosion on other mechanical and biological degradation factors has not been paid adequate attention.

By examining damaged wooden structural elements "in situ", it has been ascertained that the fibrillated layer shows a considerable decrease in cohesion and other mechanical properties of wood. Therefore, the task was to establish the depth the corrosion reaches and to what extent it affects the strength of the mechanical properties of structural elements. The determination of the strength and hardness in individual layers of wood in the damaged elements was conducted using standard tests of wood qualities under laboratory conditions. Testing specimens were taken from a structural element removed from the roof frame structure of a historic building in Prague.

MATERIAL AND METHODS

Samples for the experiment were taken from the collar beam of a roof frame structure of an apartment house (U půjčovny 955/10, Prague 1) repeatedly (4–5 times) treated with the Pyronit agent (30 %). The element was made of Norway Spruce (*Picea abies* (L.) Karst.), the most frequently used wood for wooden structures in our territory. Mechanical tests (compression, tension, hardness) were conducted using wood samples of the surface damaged by corrosion and they were related to reference samples made of the deeper – inner (undamaged) – part of the wood. Using the dendrochronological dating method , the year when the tree, from which the tested element was made, was felled was determined as 1833 (Rybníček 2008). The production of testing specimens took place as indicated in Fig. 3. It was planned so that each side of the examined structural element provided information about all the mechanical properties that were tested (compression, tension, hardness). The selected samples did not include any defects in the material (knots, fissures, rot, ligniperdous insects).

The first explored properties were the strength and the modulus of elasticity in compression parallel to the grain; these were tested according to the ČSN 49 0110 and ČSN 49 0111 standards using prisms of 20×20×30 mm. The density was determined according to the ČSN 49 0108 standard. Prisms were made from the surface part (0–20 mm, 70 pcs) and from the inner part (25–45 mm, 76 pcs) immediately under the surface layer towards the centre of the element. To eliminate the effect of the size of the standardized testing specimens in respect of the thickness of the fibrillated layer, special specimens (plates) were also made with the size of 5×20×30 mm. The samples were again taken from the surface part (0–5 mm, 12 pcs) and from the inner part (10–15 mm, 17 pcs) under the surface layer towards the centre of the element.

Another examined mechanical property was the tensile strength parallel to the grain. The tensile micro-samples used during the test had a triangular cross-section of 5×5×7.5 mm and a length of 200 mm. These small specimens, which were specifically produced, made it possible to determine the monitored properties at various depths below the surface of the damaged wood more exactly. They were taken from the surface part (0–5 mm, 44 pcs) and for comparison, another set of triangular samples were taken from the inner part of the wood at the depth of 25 mm (25–30 mm, 38 pcs) which roughly corresponded to the previous test of the compression parallel to the grain.

The last examined property was the wood hardness, measured using the Janka test (ČSN 490136) and the resistance measuring by means of the pin penetration of Pilodyn 6J Forest spring

indentor . The measuring was performed in five layers of wood, which were gradually (by 5 mm) milled in the direction from the surface to the centre of the element. The measurement of the hardness, according to Janka as well as during the Pilodyn pin penetration, was performed for each layer at 40 measurement points.

All mechanical tests took place with the wood moisture content of 12 %, under laboratory conditions by weighing according to the universal ZWICK ZH05 testing machine 0 with the capacity of 50 kN.

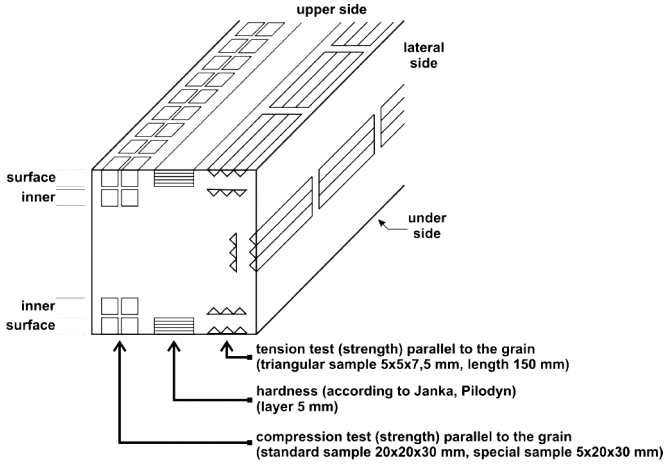

Fig. 3: Diagram of the preparation of samples

The results of changes in microscopic and chemical wood structure were obtained based on the analysis of wood samples taken from damaged roof beams of the Český Krumlov Castle, and of a house in U Půjčovny street, Prague, which had presumably never been treated by any preservation procedure, and the damaged roof beams of the Old Royal Palace (Prague Castle), which had undergone a preservation procedure, as mentioned above. Wood samples from the roof beam surface comprised loose fibres as well as wood chips split off from the surface by a surgical knife.

Changes in the wood structure were examined by electron microscopy. Chemical changes (wood corrosion) occurring in the wood structure were studied by FTIR spectrometer connected to a microscope. The reflectance technique was applied. The spectra were measured over the area of 4000-600 cm^{-1} at the resolution of 4 cm^{-1} applying 256 scans, and were normalized with respect to the absorption band at 1032 cm^{-1}. Infrared spectroscopy was applied to samples of damaged wood (fibres and chips) after their leaching in water.

RESULTS AND DISCUSSION

When comparing the results of the measuring of the strength and the modulus of elasticity in compression parallel to the grain using samples of 20×20×30 mm taken from the surface and inner parts of the beam, the following facts were ascertained.

The mechanical strength as well as the modulus of elasticity in compression parallel to the grain were for the upper as well as for the bottom parts of the beam higher in samples coming from the surface parts of the wood than in samples coming from the inner part under (Tab. 1, Figs. 4, 5).

We attribute this result to the higher density of the surface part of the wood (layer 0–20 mm), which included narrow growth rings unlike the inner part (25–45 mm) where the growth rings were wider. The increase in density is caused both by the decrease in the average width of a growth ring along the radius of the trunk as well as by the increase in the proportion of late-wood in individual growth rings, which is confirmed by the already previously mentioned papers (Gryc and Holan 2004). The increase in wood density in the direction along the trunk radius is also affected by the thickness of the cellular wall (Zobel and Sprague 1986).

In testing samples taken from the surface and inner parts of the upper side of the beam, the difference in the wood density was, as a result of the regular width of growth rings, less marked. Corresponding to this, there are small differences between the measured values of the strength and the modulus of elasticity in compression parallel to the grain. In samples taken from the surface and inner parts of the underside of the beam, the difference in the wood density was marked due to the very variable width of the growth rings. Corresponding to this, there are considerable differences between the measured values of the strength and the modulus of elasticity in compression parallel to the grain.

The wood structure had, in our case, a more significant impact on the mechanical properties in question than the fibrillation of the element surface itself. This fact is confirmed by the measured values of mechanical properties (Figs. 4, 5) being identical with the wood density (Fig. 6). The compression strength parallel to the grain was significantly related to wood density, which is confirmed by the determination coefficient R_2 = 0.7795 established for the entire number of 20×20×30 mm compression samples , i.e. 146 pcs (Fig. 7).

Tab.1: Average values of strength, modulus of elasticity and density for samples (20×20×30 mm) tested in compression parallel to the grain

Position on a beam	Measured compression (strength) parallel to the grain (20×20×30 mm)					
	σ_{max} MPa		E MPa		Density m^3	
	surface	inner	surface	inner	surface	inner
Upper side	47.16	46.09	20161.54	18363.15	442.28	438.59
Underside	50.51	43.35	21757.30	17692.91	482.03	416.29

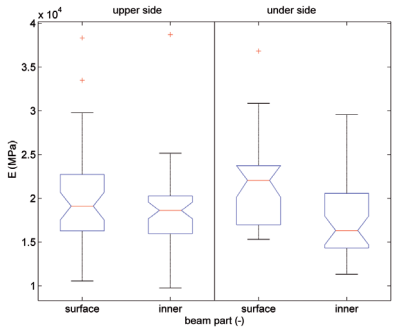

Fig.4: Strength in compression parallel to the grain for both surface and inner parts (20×20×30 mm)

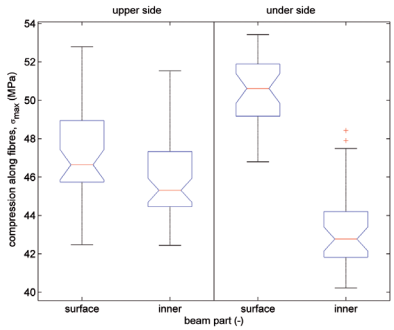

Fig. 5: Modulus of elasticity in compression along fibres, both surface and inner parts (20×20×30 mm)

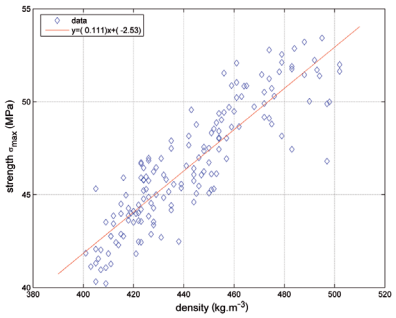

Fig. 6: Density of surface as well as inner parts parallel to the grain on the density for all samples (20×20×30 mm)

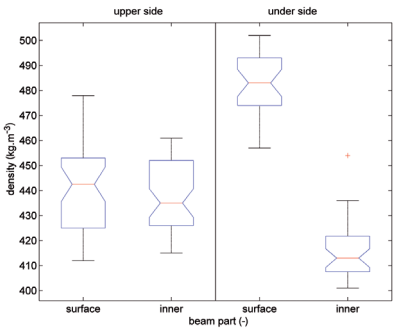

Fig. 7: Dependence of strength in compression (20×20×30 mm)

Because of the marked impact of the natural wood structure on the mechanical properties of wood, we applied the same testing procedures to smaller, non-standard specimens of 5×20×30 mm taken again from the surface and inner parts of the wood. The objective was to describe the impact of the surface fibrillation on the compression parallel to the grain more exactly.

For the samples taken from the surface and inner parts of the upper side of the beam, the difference in wood density was minimal as a result of the regular width of growth rings (Fig. 10). The difference in the values of mechanical properties measured in samples from the surface and inner parts of the wood may be attributed to the impact of the damage of the surface layer by corrosion (Figs. 8, 9; Tab. 2). In the samples taken from the surface and inner parts of the underside of the beam, the difference in wood density was still marked (Fig. 10). However, the measured values of mechanical properties do not completely correspond to this difference. There is a smaller difference in the measured values than the one which would correspond to the different density of the wood of the tested samples (Figs. 8, 9; Tab. 2). We can assume that this decrease was caused by the impact of the chemical degradation of the surface layers of the wood.

Similarly to tests on standard specimens, even here the changes in the monitored mechanical properties are closely related to the changes in the wood density, which is confirmed by the determination coefficient R_2 = 0.8015 established for the entire number of 5×20×30 mm compression samples , i.e. 29 pcs (Fig. 11). Tests of smaller specimens proved, in addition to the impact of the natural wood structure (wood density), also the impact of chemical degradation of the wood surface layer.

Tab.2: Average values of strength, modulus of elasticity and density for samples (5×20×30 mm) tested in compression parallel to the grain

Position on a beam	Measured compression (strength) parallel to the grain (5×20×30 mm)					
	Strength σ_{max} MPa		Young`s modulus E MPa		Wood density m3	
	surface	inner	surface	inner	surface	inner
Upper side	53.61	57.15	13045.30	14503.76	431.50	436.38
Underside	63.23	59.13	17182.26	15309.05	481.83	449.78

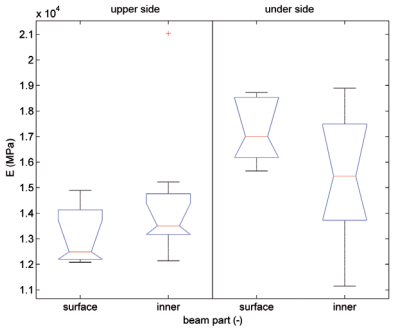

Fig. 8: Strength in compression parallel to the grain for both surface and inner parts (5×20×30 mm)

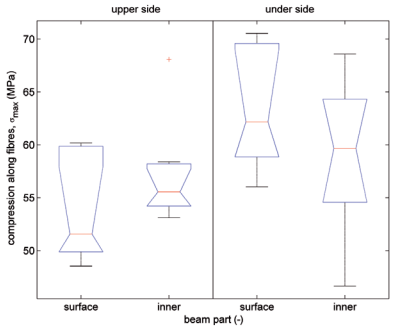

Fig. 9: Modulus of elasticity in compression parallel to the grain, for both surface and inner parts (5×20×30 mm)

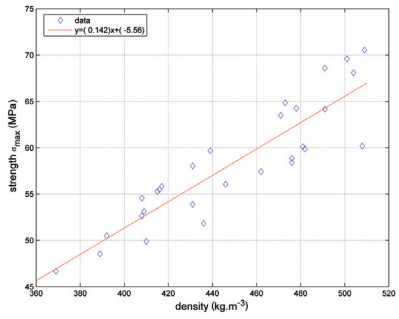

Fig. 10: Density of surface as well as inner parts parallel to the grain on density for all samples (5×20×30 mm)

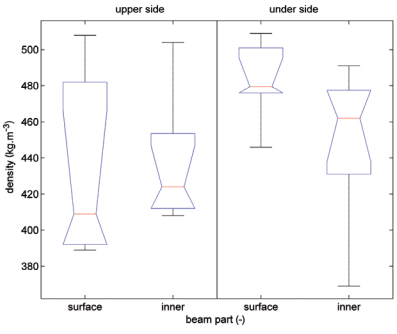

Fig. 11: Dependence of strength in compression (5×20×30 mm)

Another explored mechanical property was tensile strength parallel to the grain. Tensile specimens used in the test were taken from the surface part (0–5 mm) and from the inner part (25–30 mm) of the wood, specifically from the upper, lateral and undersides of the beam. The samples had a triangular cross-section of 5×5×7.5 mm with an active length of 150 mm. The depth from which samples were taken corresponded to the previous test for compression parallel to the grain.

From the point of view of wood density, samples made from the upper and undersides of the beam (approx. 3–5 pcs, oriented parallel to the cathetus of the triangular cross-section of the sample) contained more growth rings than samples made from the lateral surface of the beam (approx. 2 – 3 pcs, oriented parallel to the hypotenuse of the triangular cross-section of the sample). Also, there was a little difference in wood density (the number and the width of growth rings) between samples from the surface parts and inner parts of the wood. Samples from the inner part usually had one growth ring fewer.

Unlike the compression test, in the case of tension the significant decrease in strength showed this was caused by the decay of the wood mass caused by corrosion on the surface of the examined structural element. The measured strength of samples made from the surface part achieved only 20 MPa on average, despite their higher density. On the contrary, the strength of samples made from

the inner part was around 50 MPa. (Tab. 3, Fig. 12), which corresponds to the values mentioned in literature for undamaged spruce wood (Bodig and Jayne 1993). The tensile strength in samples taken from the surface fibrillated part is thus significantly lower (by up to 50 %) than in samples taken from undamaged wood from the layer at the depth of 25 mm. More significant differences in changes in tensile strength parallel to the grain were identified in the samples from the upper and undersides of the beam (samples with higher density as well as the number of growth rings oriented parallel to the cathetus of the triangular cross-section) than in the samples from the lateral side of the beam (samples with lower density as well as the number of growth rings oriented parallel to the hypotenuse of the triangular cross-section).

The value of the modulus of elasticity was higher in the samples from the upper and undersides of the beam in the surface fibrillated layer (by 15 to 18 %) when compared with the values of the samples from the inner layer (Tab. 3, Fig. 13). In the samples taken from the surface and inner parts of the wood on the lateral side of the beam, the difference in the values of the modulus of elasticity is rather opposite. This result was again affected by wood density, first of all by the small number of growth rings and the significant contribution of softer early-wood in the samples.

Tab.3: Average values of strength and modulus of elasticity for samples (5×20×7.5 mm) tested in tension parallel to the grain

Beam side	Measured tensile (strength) parallel to the grain			
	Strength σ_{max} MPa		Young`s modulus E MPa	
	surface	inner	surface	inner
Upper side	18.85	47.49	14801.66	12541.10
Underside	17.52	55.16	16116.45	13957.38
Vertical sides	20.15	40.86	12444.37	13261.16

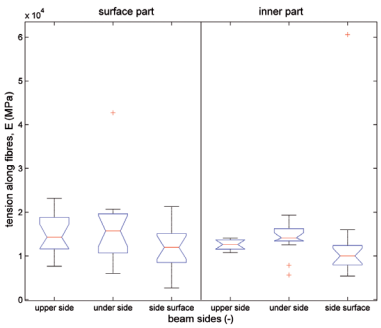

Fig. 12: Tensile strength parallel to the grain for surface as well as inner parts (5×5×7.5 mm)

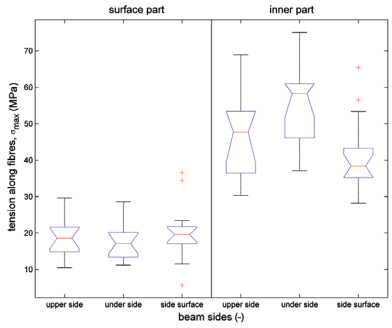

Fig. 13: Tensile modulus of elasticity parallel to the grain for surface as well as inner parts (5×5×7.5 mm)

The measurement of hardness according to Janka (ČSN 490136) and the measuring of the depth of the Pilodyn pin penetration was made for both the upper and the undersides of the beam. The measurement was made on both sides in individual layers. The thickness of one layer was 5 mm and 40 measurements were made in each layer. After having completed the measuring in one layer, 5 mm of material was milled off from the tested sample and the layer that followed was measured. Measurement points in individual layers were selected so that they were not affected by the measurement made in previous layers.

The measuring of hardness using the Janka method describes the change in properties in a relatively thin layer of wood (approx. 2–3 mm). Therefore, it can more closely monitor the changes of aproperty, on the other hand, it is more affected by the natural structure of the wood. Measuring by Pilodyn involves a deeper part of the wood along the radius of the element (in healthy spruce wood 12–15 mm, Kotlínová et al. 2008). That is why it better absorbs the density differences that significantly affect the measuring of hardness using the Janka method. The achieved results capture the impact of chemical degradation on wood hardness more comprehensively.

The results of the measuring at the upper side of the beam by both methods corresponded to each other and proved the impact of corrosion only for the first to second surface layers (Figs. 14, 15, Tab. 4); that is to the depth of roughly 7 mm of the element surface. The other tested layers did not show changes in hardness caused by corrosion. Gradually, the change in measured values started to show, caused by the influence of the increasing width of growth rings and the proportion of the early-wood increment. The used methods of measuring the hardness on the underside of the beam are less identical (Figs. 16, 17, Tab. 4). The impact of the different width and the number of growth rings in individual layers on measured values of wood hardness was more significant here. The separation of the influence of density and the influence of corrosion is difficult when the experiment is conducted using elements taken out of building structures.

Tab.4: Average values of hardness tested according to Janka and the depth of Pilodyn pin penetration

Layers	Drop layer	Measured hardness			
		Hardness by Janka		Pilodyn	
	mm	MPa		mm	
		Upper side	Underside	Upper side	Underside
1	0-5	12.90	14.98	15.25	14.23
2	5-10	14.41	16.21	14.25	14.18
3	10-15	15.07	15.99	13.60	14.60
4	15-20	16.24	14.29	13.33	15.08
5	20-25	18.06	15.69	13.10	14.58

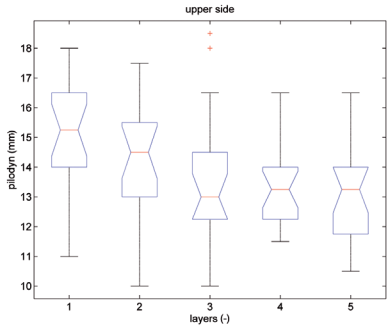

Fig. 14: Hardness measured by 5 mm layers using the Janka test (the upper part of the beam)

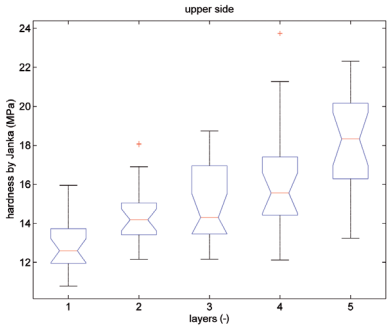

Fig. 15: Depth of Pilodyn pin penetration measured by 5 mm layers (upper part of the beam)

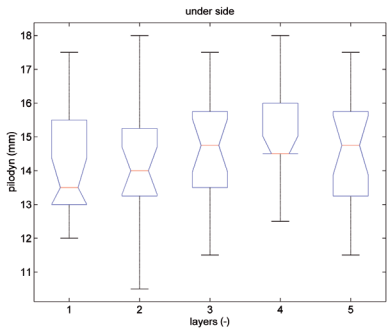

Fig. 16: Hardness measured by 5 mm layers using the Janka test (the bottom part of the beam)

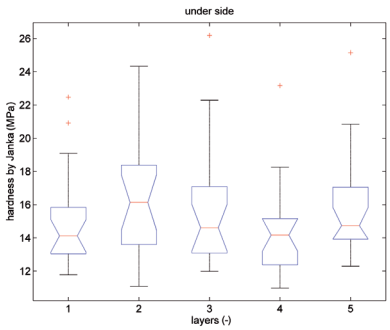

Fig. 17: Depth of Pilodyn pin penetration measured by 5 mm layers (bottom part of the beam)

The examination of the anatomical structure of the damaged wood by electron microscopy revealed that both cellulose and lignin are damaged by chemical reactions. In some cases, mechanical damage of the wood structure due to crystallization pressures is also possible. We observed the separation of cells, which was apparently caused by a damaged middle lamella(Fig. 18). Moreover, there was an apparent damage of the margo strand of bordered pits on the tracheid walls (Fig. 19). Both the middle lamella and the margo strand consist of lignin mainly. Some samples have damaged secondary cell walls, which primarily consist of cellulose. This damage is represented by various cracks in the cell walls (Figs. 19, 20). Figs. 21-22 shows the wood fibers which come from the beam surface damaged by defibring. Samples consisting of fine fibres did not exhibit any wood structure and this indicates that the cell walls had been disintegrated into a fibrous tangle - presumably supermolecular cellulose formation.

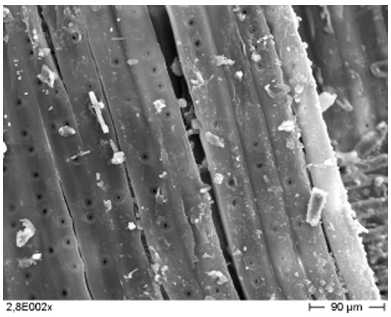

Fig. 18: Wood cells separation in the chip sample taken from defibred roof beam surface.

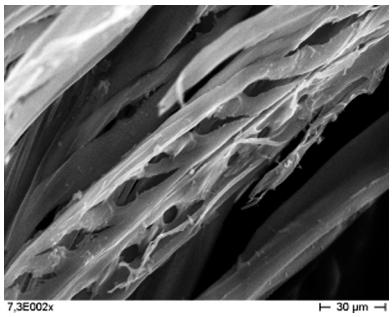

Fig. 19: The cell wall damage and a missing margo strand.

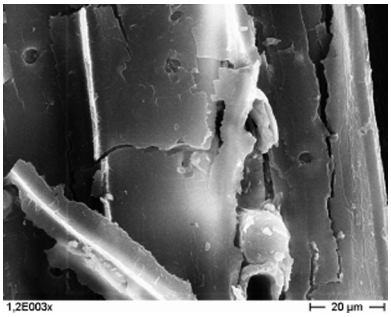

Fig. 20: Cracks in cell wall.

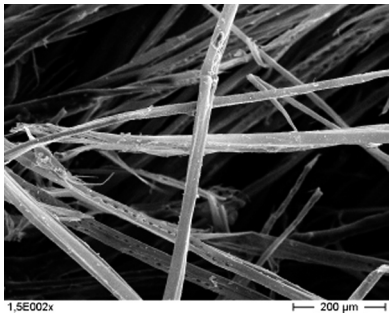

Fig. 21: Coarser (longer) fibres present on the wood surface due to the defibring.

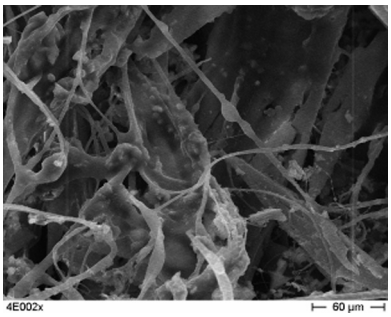

Fig. 22: Fine fibres present on the wood surface due to the defibring.

Investigation into chemical changes of wood polymers by infrared microspectroscopy is demonstrated in more detail on a series of samples from roof beams of the Český Krumlov Castle. The spectra were evaluated in dependence on the degree of wood defibring. The cellulose fraction of the wood was found to increase with the increasing extent of defibring. This is due to an appreciable loss of lignin, manifesting itself by a decrease in the infrared absorption band at 1510 cm^{-1} belonging to stretching vibrations of the double bond in the aromatic ring of lignin. This band intensity decrease (loss of lignin) was evaluated by relating it to the intensities of selected reference absorption bands of cellulose at 1428 cm^{-1} (stretching vibrations of the cellulose methylene group)

and 1372 cm^{-1} (out-of-plane bending vibrations of the CH bonds of the cellulose glycoside rings). The two band intensity ratios, I_{1428}/ I_{1510} and I_{1372}/I_{1510}, increase considerably with an increasing degree of wood defibring (Tab. 5).

Tab. 5: Loss of lignin as determined by FTIR based on the I_{1428}/I_{1510} and I_{1372}/I_{1510} band intensity ratios. Each value used is the average of triplicate measurement. Band assignment: 1510 cm^{-1} – stretching vibrations of the double bond in the aromatic ring of lignin, 1428 cm^{-1} – stretching vibrations of methylene groups in cellulose, 1372 cm^{-1} – out-of-plane bending vibrations of CH bonds at the cellulose glycoside rings.

	Sample	**I_{1372}**	**I_{1428}**	**I_{1510}**	**I_{1372}/I_{1510}**	**I_{1428}/I_{1510}**
Undamaged wood	Fir	0.1691	0.1786	0.2352	0.7190	0.7594
	Pine	0.0857	0.1240	0.1229	0.6973	1.0090
Wood chip	2	0.1265	0.1268	0.0833	1.5186	1.5222
	8	0.1109	0.1497	0.0996	1.1135	1.5030
	10	0.0606	0.0781	0.0660	0.9182	1.1833
Coarser fibres	1	0.0809	0.1656	0.0464	1.7435	3.5690
	5	0.0831	0.1175	0.0273	3.0440	4.3040
	10	0.0726	0.0975	0.0211	3.4408	4.6209
Fine fibers	8	0.1258	0.1752	0.0208	6.0481	8.4231
	12	0.0855	0.1799	0.0163	5.2454	11.0368
	13	0.1248	0.3275	0.0356	3.5056	9.1994

The relative increase in the carbonyl group content of the wood matter was evaluated based on the I_{1710}/ I_{1510} band intensity ratio where the band at 1710 cm^{-1} is related to the stretching vibrations of the carboxyl C=O bond and the band at 1510 cm^{-1} is related to the stretching vibrations of the double bond in the lignin aromatic ring (Tab. 6). This relative carboxyl group content in the wood was found to increase with the increasing degree of defibring, apparently as a result of oxidation of hydroxyl groups both in cellulose and in lignin.

Tab. 6: Relative increase in the carboxyl group content of the wood, determined based on the band intensity ratio for the bands at 1710 cm^{-1} (stretching vibrations of the carboxyl C=O groups) and 1510 cm^{-1} (stretching vibrations of the double bond in the aromatic ring of lignin), I_{1710}/I_{1510}

	Sample	I_{1510}	I_{1710}	I_{1710}/I_{1510}
Undamaged wood	Fir	0.2352	0.0360	0.1531
	Pine	0.1229	0.0275	0.2238
Wood chip	2	0.0833	0.1207	1.4486
	8	0.0996	0.0877	0.8809
	10	0.0660	0.2354	3.5667
Coarser fibres	1	0.0464	0.1505	3.2435
	5	0.0273	0.2057	7.5336
	10	0.0211	0.1137	5.3886
Fine fibres	8	0.0208	0.1354	6.5080
	12	0.0163	0.0220	1.3497
	13	0.0356	0.0877	2.4624

Furthermore, the increasing extent of wood damage is accompanied by a shift of the absorption band at 1420-1430 cm^{-1} towards higher wavelengths (see Fig. 23), suggesting that the crystalline fraction of cellulose increases in relative terms is due to a loss of the amorphous fraction.

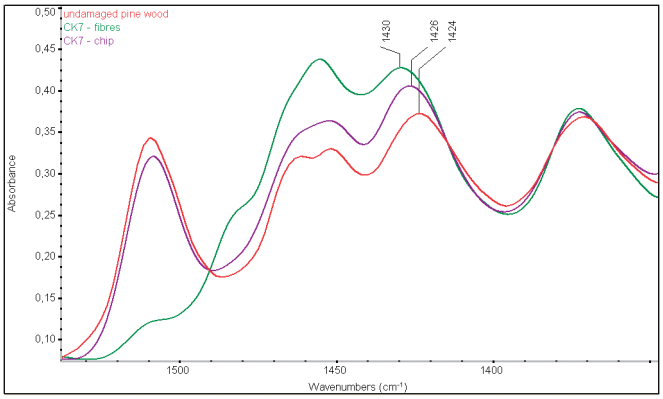

Fig. 23: Infrared spectrum of sound and damaged wood taken from a roof beam at the Český Krumlov Castle: a shift of the absorption band at 1420–1430 cm^{-1} (CH stretching vibrations of a mixture of the crystalline and amorphous cellulose phases) towards higher wavelengths suggesting that the crystalline cellulose phase increases in relative terms is due to a loss of the amorphous phase.

CONLUSIONS

Based on the performed laboratory tests, we can conclude that the decrease in mechanical properties in elements damaged by corrosion affects only the surface layers of wood in structural elements (based on our tests, at maximum to the depth of 5 mm).

The more marked decrease in mechanical properties of wood in the damaged surface layer showed first of all in the tensile test parallel to the grain where the strength decreased by up

to 50 % when compared with the values ascertained in undamaged wood. The deterioration of mechanical properties in the fibrillated surface of the wood was also detected through hardness tests when pushing the ball and shooting the pin of the Pilodyn penetration indentor. Hardness tests of mechanical properties again proved the impact of corrosion in the surface layers of the wood only.

In compression tests of the mechanical properties of wood parallel to the grain using standard samples, the impact of the surface fibrillated layer on the wood mechanical properties failed to show. In non-standard thin specimens taken from the surface layer of 5 mm thickness, the impact of corrosion was more apparent. A more significant impact on the compression strength parallel to the grain, which overlapped with the impact of corrosion, was that of the changes in the wood density caused by the decrease in the average width of a growth ring along the trunk radius and the increase in the proportion of late-wood in individual growth rings.

From the point of view of the mechanical properties of structural building elements used on a standard basis (usually with cross-sections of 100x120 mm and more), the impact of corrosion of surface layers on the bearing capacity and stiffness of elements is not considerable. However, repeated fibrillation of wood induced by abrasion of the surface or by inefficient neutralization may cause a decreased cross-section of structural elements and thus a deterioration of their mechanical properties. In addition, the fibrillation encourages increased humidity and the possible attack of the wood by fungi.

The results of optical and infrared analysis give evidence that the fibres on the wood surface mainly consist of cellulose – which can be partly damaged. Thus the obtained results show that the wood corrosion is not caused by acid hydrolysis, as suggested by some authors; instead, it seems to be caused by oxidation of the structural components of wood. Additional measuring on model wood samples are planned to complete the results obtained so far.

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