

Evaluation of aspen (*Populus tremula*) wood structure infected by fungi (*Phellinus tremulae*) and opportunities for wider use of timber in structural elements

Ziedonis Miklašēvičs

State Stock Company "Latvijas Valsts Meži" (Latvia's State Forests) Vaiņodes iela 1,
LV-1004, Rīga, Latvia
Rezekne Academy of Technologies. Atbrīvošanas aleja 115,
LV-4601, Rezekne, Latvia
z.miklasevics@lvm.lv

Jānis Iejavs

Forest and wood products research and Development Institute "Meka". Dobeles iela 41, LV-3001, Jelgava, Latvia
Janis.iejavs@e-koks.lv

Natālija Burnēviča

Latvia State Forest Research Institute "Silava". Rīgas iela 111, LV- 2169, Salaspils, Latvia
Natalija.burnevica@silava.lv

Kaspars Šķēle

Forest and wood products research and Development Institute "Meka". Dobeles iela 41, LV-3001, Jelgava, Latvia
Kaspars.skele@e-koks.lv

Abstract. The external characteristics of aspen (*Populus tremula*) tree give the only clue to the quality of logs, packing case timber, pulpwood and other roundwood assortments obtained in harvesting. When the tree is bucked into roundwood assortments, the cross sections at the butt and top ends of these assortments may provide additional indicators of the quality such as heart colouring, wetwood, heartwood hard rot and heartwood soft wood. Thus, it becomes important when correlating the occurrence of these imperfections with the quality of sawn timber that is produced from the aspen logs and packing case timber. Although aspen has a wide distribution throughout Europe, there are no unified quality requirements for roundwood assortments due to lack of scientifically approved information related to wood structure.

To identify the fungi caused aspen decay and describe the main anatomical changes generated by the fungi (*Phellinus tremulae*) Polymerase Chain Reaction laboratory technique were used in the investigation.

The main goal of the study is to work out the aspen roundwood, harvested in final felling sites timber strength parameters depending on timber quality characterized data based on the testing methods: moisture content - according to *ISO 13061-1:2014*; density - according to *ISO 13061-2:2014*; compression strength parallel to the grain- according to *ISO 13061-17:2017*; modulus of elasticity- according to *ISO 13061- 4:2014*; three point bending strength - according to *ISO 13061- 3:2014*.

The results of the study might help for practical applications so that this wood specie can be processed more efficiently for the value - added products and thorough knowledge of decay

patterns of *Phellinus tremulae* are likely to assist to establish more accurate quality requirements for roundwood assortments and provide useful information for optimizing tree management programs.

Keywords: *Populus tremula*, *Phellinus tremulae*, timber strength parameters.

1. INTRODUCTION

European aspen (*Populus tremula* L.) is one of the most widely spread species in the world, with a natural range stretching from the Arctic Circle in Scandinavia to north Africa, and from Britain across most of Europe and north Asia to China and Japan. In Latvia aspen is the second most common hardwood species forming 3.68 % of the total wood supply [9; 10]. Only 27% in the year 2022 of the Latvian aspen supply goes to the sawmill industry for processing and since there are no Latvia grading rules and design values for aspen timber nothing of the timber is used for structural purposes.

Aspen heart rot decays the heartwood of infected trees. In early stages of disease development, the heartwood begins to show patterns of discoloration, but remains hard and firm. As the decay advances, the heartwood decomposes and the tree loses structural strength. Although heart rot does not affect all uses of aspen, decayed wood has undesirable pulping qualities and

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stained wood is not suitable for veneers [1; 6; 11; 28; 43]. Aspen heart rot caused by fungus *Phellinus tremulae*. This pathogen occurs only on living aspen [1; 2; 3; 32; 33].

The pathogen infects branch stubs or small dead branches, eventually growing into the inner wood along the branch trace. It begins to grow out to the surface along branch traces to produce conks. Microscopic spores produced in conks are airborne and travel long distances. Spores can cause infection if they land on a suitable point. Defected trees lose an average of 70 % of wood volume in cull [4; 5; 19; 38].

Compared to other decays, conks are reliably produced and are useful indicators for detecting and estimating heart rot. 75-85% of trees with cull due to aspen heart rot have conks [31; 34]. Average cull for trees with conks is 82%, but only 40% for infected trees without conks. On a linear basis, decay generally extends 2.4-3.7m in each direction from conks. Aspen causes white trunk rot, the most important heart rot of Aspen. Although white trunk rot occurs throughout the tree's range, the disease varies in incidence and severity [40]. Damage has been related to tree age, diameter, site quality and genotypic variation [32]. Studies show that 21- to 50- year old stands found that 80% of trees had at least some advanced decay, trees with conks (14% of all trees) accounted for 64% of the decay found in the study.

The early stage of decay is characterized by a soft cream color, often with distinct dark zone (demarcation line) [6] separating it from the surrounding healthy wood. In later stages of decay the wood becomes spongy or punky, yellowish in color and the decayed wood contains a number of irregular concentric black zone lines [1; 8; 13; 21; 43].

Although aspen heartwood is normally not distinct in appearance from sapwood, discoloration or staining is common of aspen stems. It may originate as a response to wounds, frost cracks, branch stubs, insect or animal damage, incrementbore holes. In addition, discolored zones often are associated with cankers, decay columns

and other microorganism activity. Discoloration may result from the reaction of living cells of the xylem to various agents or directly from color imparted by microbial tissues or products.

Many stains occur in the heartwood before or during the development of decay. In the initial stages, the strength of affected tissues is not greatly reduced, but later these tissues may be weakened [6; 15; 16; 17; 21; 22; 23; 41]. However, because of the many fungi and bacteria associated with stain in aspen and the vagaries of stain color and other features, it is difficult to be sure of the causes of particular stains. For example stains caused by wetwood [16; 41].

Wetwood appears wet and discolored and has a high mineral content and variable bacterial populations. It is not necessarily associated with decay. In fact the anaerobic conditions and organic acids in wetwood inhibit fungal growth. Although the discoloration in aspen largely disappears when dried, the wood is brash and subject to splitting and cracking and has reduced strength. Because the color fades, it is difficult to detect and cull out these affected zones early in the manufacturing process.

The requirements of wood for matches are exacting in that the wood must combine straightness of grain, ease of splitting, easy of working, and tightness. To meet such rigid requirements, a wood must be suitable for other uses as well. The fact that aspen is not used more widely for other purposes lies not in the wood itself but in other factors, such as distribution of stands and availability in desired sizes and grades. Cost, demand, and harvesting and marketing practices change as conditions change. The fact that in the past some of these factors have been adverse to the utilization of aspen stands does not mean that the wood cannot be used more widely now and in the future at a reasonable cost and without sacrifice of the quality of the product.

General description of *Populus tremula* physico-mechanical properties on the basis of different literature sources [14; 40] are given (Table 1).

TABLE 1. PHYSICAL AND MECHANICAL PROPERTIES OF EUROPEAN ASPEN AT THE ABSOLUTE HUMIDITY 12% ON THE BASIS OF DIFFERENT LITERATURE SOURCES

Country, region	Density kg/m ³	Compressing strength N/mm ²	Hardness, N/mm ²			Compression strength paralel to the grain, N/mm ²		Bending strength, N/mm ²	Modulus of elasticity, N/mm ²	Swelling ratio, %		
			ends	radial	tangential	pressure	stretch			radial	tangential	volume
Central Russia	485	12,4	27,7	19	19,9	44,7	133	77,4		0,2	0,32	0,54
Latvia	475					42,8	97,1	71		0,13	0,32	0,47
Belarus	495	9,76	25,2	17,7	18,8	42,3		71,7		0,18	0,3	0,5
Ukraine	525	11,3			19,6	46,1	134	91		0,13	0,32	0,47
Armenia	515		24,5	19,8	20	39,5		71,4		0,11	0,26	0,39
Eastern Russia	416					35,7		65		0,17	0,24	0,43
Swedern	434	11,93						55,1				
Central Europe	450								9750			
North America	380		27						8100			

The purpose of this study was to investigate the aspen wood infected by fungi *Phellinus tremulae* using fungal identification molecular methods and according to the investigation results and taking into account the knowledge about the strength properties of aspen obtained in references (Table 1.) to determine the strength properties of aspen timber originating from Latvia sound timber, timber coloured caused by fungi when strength parameters aren't significantly affected, early stage of rot, characterized by discoloured fibres and patches in the wood, where the general texture and strength properties only start being affected. The investigations were carried out in Latvia State Forest Research Institute "Silava" and in Latvia University of Life Sciences and Technologies at the Forest and Wood Product Research and Development Institute Testing Laboratory "MEKA". The goal of this study was to supplement and synthesize the existing experience and knowledge about *Populus tremula* timber physico-mechanical properties and to work out the recommendations to improve the commercial value of roundwood assortments, to find out the possibilities of using visual and machine grading and to determine some of the mechanical properties of the material in bending and compressing.

The following objectives were set to achieve the study goal:

1. To investigate the aspen wood infected by fungi *Phellinus tremulae* using fungal identification molecular methods [6], sampling methods and general requirements for physical and mechanical testing of small clear wood specimens [21; 36], moisture content for bending specimens [17; 25], density for bending specimens [26], wood -sampling methods and general requirements for physical

and mechanical tests [27], compression strength parallel to the grain [29], three point bending strength and modulus of elasticity [30]

2. To offer the quality recommendations of aspen roundwood assortment toward heart coloration and hard rot stage identification in relation to the quality requirements not only of traditionally manufactured products (furniture manufacturing, sauna, cladding, indoor doors, wood work, core material, veneer and plywood production) but also requirements of building construction elements and glued laminated timber (GLT) [7; 12; 29; 30; 35; 44; 45].

II. MATERIALS AND METHODS

In order to investigate an aspen wood infected by fungi *Phellinus tremulae* (Fig. 1) using fungal identification molecular methods, the aspen stem quality characterized 45 wood pieces were prepared for fungal identification (Fig. 2)



Fig. 1. *Phellinus tremulae*.



Fig. 2. Preparation of selected aspen stems quality characterized wood pieces for fungal identification.

For fungal identification molecular methods (PCR) were used. One to three representatives from the unidentified fungal morphotypes were subjected to molecular identification using the universal fungal primers ITS1F and ITS4 [7]. Molecular work (DNA extraction, PCR amplification and PVR product purification) was performed in the Latvian State Forest Research Institute Silava Genetic Resources Centre. Sanger sequencing (in one direction) was performed by Macrogen Europe using

the ITS4 primer. All sequences were manually edited using the Lasergene software package SeqMan (DNASTAR, Madison, Wisconsin). BLAST searches were performed using GenBank (<https://blast.ncbi.nlm.nih.gov/Blast.cgi>). The Internal Transcribed Spacer (ITS) sequence homology was set at 98 – 100 % for delimiting fungal taxon and at 95-98% for delimiting at the genus level.

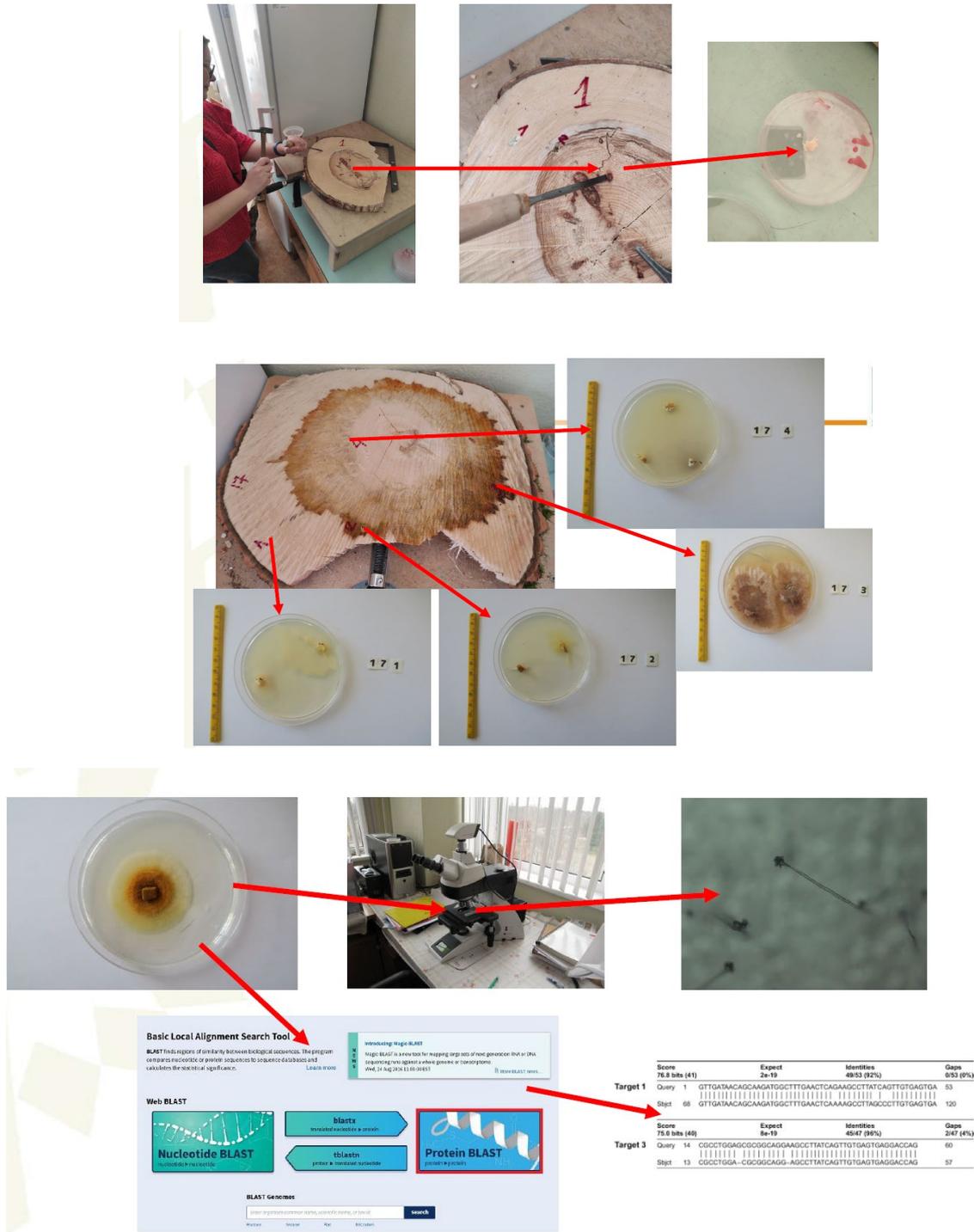


Fig. 3. Molecular research method (PCR).

In order to investigate the possibility of using sawn timber of European aspen (*Populus tremula* L.) as a structural material, 26 pieces unedged aspen boards were prepared in the sawmill "4 Plus" in the north of Latvia according to the scheme (Fig. 4).

According to the [24] principles unedged aspen boards were longitudinally cutting into edged boards of the dimension 32x1300mm). Boards were chosen to represent sound wood, heartwood colouring and hard rot stage zones [24]. Boards were dried at room temperature until the moisture content equilibrium of the indoor air which was detected by the successive weightings until reaching the constant mass.

After samples were longitudinally sawn, planed and calibrated to the actual size 22 mm x 22mm and cut in 350 mm long pieces for bending strength and modulus of elasticity testing [30], for compression strength parallel to the grain testing samples were prepared into dimensions 25x25x40mm [30]. All of the testing samples were conditioned at the standard environment of 20±2 °C and 65±5 % relative humidity [25] (Fig. 4).

All of the samples were selected into 3 groups; sound timber, heartwood coloured timber, heartwood hard rot stage timber (Fig. 5).



Fig. 4. Selection of the laboratory tested aspen wood samples.



Fig. 5. Selecting of the testing samples according to the quality, where 1 grupa- sound timber, 2 grupa- heartwood coloured timber, 3 grupa- heartwood hard rot stage timber.

Before testing moisture content according to standard [25] and density of test specimens according to standard [265] was determined. Test specimens were dried and weighed until the weight of dried timber didn't change in

2 hours more than 0.1%. The scheme of the test arrangement is given (Fig.6) .

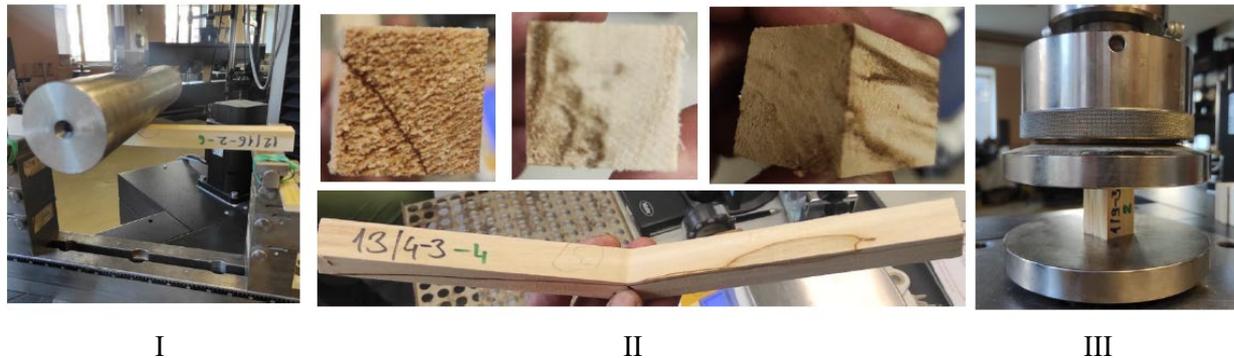


Fig. 6. The laboratory investigation process, where:
 (I)- 3. point bending strength and modulus of elasticity ISO 13061-3(4)-2014; (II)-testing samples; (III)- compression strength parallel to the grain ISO 13061-17-2017.

III. RESULTS AND DISCUSSION

The investigation results are given (Table 2) where the colouring contains 100% of the cross-sectional area of the

tested samples. Timber damaged by fungi contains 92% of the cross-sectional area of the tested samples.

TABLE 2. THE RESULTS OF THE LABORATORY INVESTIGATION PROCESS

Testing samples according to the quality	Moisture content, %	Density, kg/m ³	3. point bending		Compression strength
			Strength, N/mm ²	Modulus of elasticity, N/mm ²	Strength, N/mm ²
1.group (sound timber)	14.2 (0.256)	491.6 (45.4)	74.036 (9.56)	10536 (1529)	37.5 (4.70)
2.group (heartwood coloured timber)	14.4 (0.341)	484.6 (55.4)	66.0 (10.9)	9198 (1724)	35.2 (5.11)
3.group (heartwood hard rot stage timber)	14.8 (0.683)	429.0 (64.4)	50.3 (15.4)	6989 (1918)	29.6 (7.94)

Deviation of the mean value compared to 1. group (sound timber), %					
Testing samples according to the quality	Moisture content, %	Density, kg/m ³	3. point bending		Compression strength
			Strength, N/mm ²	Modulus of elasticity, N/mm ²	Strength, N/mm ²
2.group (heartwood coloured timber)	-	-1.4**	-10.8*	-12.7*	-6.1*
3.group (heartwood hard rot stage timber)	-	-12.7*	-32.1*	-33.7*	-20.9*

* - significant impact (p<0.05)

** - no significant effect (p≥0.05)

IV. CONCLUSIONS

1. Aspen mechanical properties in bending and compression are being significantly reduced if timber is cloured and/or damaged by fungi *Phellinus tremulae*
 2. Heartwood colouring reduces aspen timber strength in radial bending by 11%, modulus of elasticity by 13%, compression strength in fiber direction by 6% compared to sound timber strength parameters.
 3. Heartwood hard rot reduces aspen timber strength in radial bending by 32%, modulus of elasticity by 34%, compression strength in fiber direction by 21% compared to sound timber strength parameters.
 4. Stemwood density values of aspen on the basis of different literature sources are given 380- 525kg/m³. In Latvia aspen timber has the average density -475 kg/m³. Heartwood hard rot reduces aspen timber density by 13%.
 5. The study indicates that sawn timber of European aspen growth in Latvia can be visually graded and theoretically are suitable for manufacturing construction materials f.e.g. glued laminated beams (GLT).
- Based on the investigational results there are advised:
- to evaluate an aspen roundwood assortment as heartwood hard rot stage timber if the demarcation line is forming a continuous closed line at least 180 degrees.
 - to evaluate an aspen roundwood assortment as heartwood coloured timber or heartwood hard rot stage timber according to the visual features [35] if the demarcation line do not forming a continuous closed line till 180 degrees



Fig. 7. The identification of the heartwood hard rot, where: 1- demarcation line; 2- the heartwood hard rot stage timber.



Fig. 8. The identification of the heartwood coloured timber, where: 1- demarcation line; 2- the heartwood coloured timber

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