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SCHOOL OF ENGINEERING
Department of Materials and Environmental Technology

EFFECT OF LOG SOAKING TEMPERATURE ON VENEER STRENGTH AND VENEER LATHE CHECKS DEVELOPMENT

PALGI LEOTUSTEMPERATUURI MÕJU SPOONI TUGEVUSELE JA TREILÕHEDE TEKKELE

MASTER THESIS

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Tallinn 2021

AUTHOR’S DECLARATION

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Main speciality: Wood Technology

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CONTENTS

LIST OF ABBREVIATIONS AND SYMBOLS 7
LIST OF FIGURES 8
LIST OF TABLES 10
PREFACE 11
INTRODUCTION 12
1 LITERATURE REVIEW 13
1.1 Veneer 13
1.2 Veneer production 13
1.3 Veneer lathe checks 16
1.4 Measuring veneer lathe checks 16
1.5 Tensile strength 17
1.6 Thickness of Veneer 19
2 MATERIALS AND METHODS 21
2.1 Wood species 21
2.2 Veneer preparation 22
2.3 Veneer samples preparation 23
2.4 Tensile testing 25
2.5 Lathe check inspection 27
3 RESULTS AND DISCUSSION 31
3.1 Tensile strength 31
3.2 Lathe check depth 37
3.3 LCD: bark versus pith 41
3.4 Veneer tensile strength versus LCD 43
CONCLUSION 47
SUMMARY 49
KOKKUVÕTE 50
REFERENCES 51
Appendix 1 Aspen samples soaked for 20 °C, 24 h 54
Appendix 2 Aspen samples soaked for 40 °C, 24 h 55
Appendix 3 Aspen samples soaked for 70 °C, 24 h 56
Appendix 4 Aspen samples soaked for 20 °C, 48 h 57
Appendix 5 Aspen samples soaked for 40 °C,48 h 59
Appendix 6 Aspen samples soaked for 70 °C,48 h 61
Appendix 7 Black alder samples soaked for 20 °C, 24 h 63
Appendix 8 Black alder samples soaked for 40 °C, 24 h 64
Appendix 9 Black alder samples soaked for 70 °C, 24 h 65
Appendix 10 Black alder samples soaked for 20 °C, 48 h 66

Appendix 11 Black alder samples soaked for 40 °C, 48 h 67
Appendix 12 Black alder samples soaked for 70 °C, 48 h 69
Appendix 13 Birch samples soaked for 20 °C, 24 h 72
Appendix 14 Birch samples soaked for 40 °C, 24 h 73
Appendix 15 Birch samples soaked for 70 °C, 24 h 74
Appendix 16 Birch samples soaked for 20 °C, 48 h 75
Appendix 17 Birch samples soaked for 40 °C, 48 h 76
Appendix 18 Birch samples soaked for 70 °C, 48 h 78
Appendix 19 Grey alder samples soaked for 20 °C, 24 h 80
Appendix 20 Grey alder samples soaked for 40 °C, 24 h 81
Appendix 21 Grey alder samples soaked for 70 °C, 24 h 82
Appendix 22 Grey alder samples soaked for 20 °C, 48 h 83
Appendix 23 Grey alder samples soaked for 40 °C, 48 h 85
Appendix 24 Grey alder samples soaked for 70 °C, 48 h 87

LIST OF ABBREVIATIONS AND SYMBOLS

σ	Tensile strength
A	Area
T_g	Glass transition temperature
BA	Black alder
GA	Gray alder
BI	Birch
AS	Aspen
LCD	Lathe check depth
h	Hour
^oC	degree Celsius

LIST OF FIGURES

Figure 1.1. Influence of heating temperature on checking index (CI)(Dupleix et al., 2013a) 14
Figure 1.2. Crosswise tensile strength of different wood species veneers(Kallakas et al., 2020) 18
Figure 2.1. Peeler blocks placed in soaking bath 22
Figure 2.2. Debarked peeler block 23
Figure 2.3. Veneer cutting 24
Figure 2.4. Cutting of veneer strips for tensile testing 25
Figure 2.5. Tensile test sample gripped between clamps and equivalent lathe check sample placed alongside 26
Figure 2.6. Cutting pattern for tensile test and lathe check samples 27
Figure 2.7. A, B - Dyed veneer specimen cut to 20 x 50 mm, C - loose sides stained with Dylon dye 29
Figure 2.8. A – Dino-lite digital microscope setup, B – Nikon Eclipse microscope....................30
Figure 3.1. Boxplot indicating soak duration and soak temperature for species 32
Figure 3.2. Average tensile strength at different soak temperature and soak time for birch species 33
Figure 3.3. Average tensile strength at different soak temperature and soak time for aspen species....................34
Figure 3.4. Average tensile strength at different soak temperature and soak time for black alder species....................34
Figure 3.5. Average tensile strength at different soak temperature and soak time for grey alder species....................35
Figure 3.6. Captured images of lathe checks depth at different soak temperatures ...37
Figure 3.7. Average lathe checks depth (LCD) at different soak temperature and soak time for birch species 38
Figure 3.8. Average lathe checks depth (LCD) at different soak temperatures and soak time for aspen species. 38
Figure 3.9. Average lathe checks depth (LCD) at different soak temperatures and soak time for black alder species. 39
Figure 3.10. Average lathe checks depth (LCD) at different soak temperatures and soak time for grey alder species. 40
Figure 3.11. Boxplot indicating the variation of lathe checks depth (LCD) between veneer sheets close to the bark and pith at different soak temperatures and soak time. 41

Figure 3.12. Scatter plot showing relationship LCD and tensile strength of aspen soaked for 24 and 48 h. 43
Figure 3.13. Scatter plot showing relationship LCD and tensile strength of birch soaked for 24 and 48 h. 44
Figure 3.14. Scatter plot showing relationship LCD and tensile strength of black alder soaked for 24 and 48 h. 45
Figure 3.15. Scatter plot showing relationship LCD and tensile strength of grey alder soaked for 24 and 48 h. 45

LIST OF TABLES

Table 1.1. Tensile strength measurement (Sepp, 2015)..18
Table 1.2. Summary of some works of literature studying the strength of wood and the effect of size on it, with indicating if such as: loading parallel to the grain = || and loading perpendicular to the grain = ⊥; decreasing strength with increasing size = ↓ ; and increasing strength with increasing size = ↑ , reported size effect (yes) or not (no). (Pramreiter et al., 2021) 19
Table 2.1. Log length and diameter...21
Table 2.2 Veneer sheets selected for testing 27
Table 3.1. Average crosswise Tensile strength TS (N/mm^2) for samples soaked for 48 h 31
Table 3.2. Average crosswise Tensile strength (N/mm^2) results for soaked for 24 h ..31
Table 3.3. Pearson correlation of veneer tensile strength and LCD 43
Table 0.1. Aspen samples soaked for 20 °C, 24 h...54
Table 0.2. Aspen samples soaked for 40 °C, 24 h. 55
Table 0.3. Aspen samples soaked for 70 °C, 24 h. 56
Table 0.4. Aspen samples soaked for 20 °C, 48 h..57
Table 0.5. Aspen samples soaked for 40 °C, 48 h. 59
Table 0.6. Aspen samples soaked for 70 °C, 48 h. 61
Table 0.7. Black alder samples soaked for 20 °C, 24 h. 63
Table 0.8. Black alder samples soaked for 40 °C, 24 h. 64
Table 0.9. Black alder samples soaked for 70 °C, 24 h. 65
Table 0.10. Black alder samples soaked for 20 °C, 48 h. 66
Table 0.11. Black alder samples soaked for 40 °C, 48 h. 67
Table 0.12. Black alder samples soaked for 70 °C, 48 h. 69
Table 0.13. Birch samples soaked for 20 °C, 24 h...72
Table 0.14. Birch samples soaked for 40 °C, 24 h...73
Table 0.15. Birch samples soaked for 70 °C, 24 h...74
Table 0.16. Birch samples soaked for 20 °C, 48 h...75
Table 0.17. Birch samples soaked for 40 °C, 48 h...76
Table 0.18. Birch samples soaked for 70 °C, 48 h...78
Table 0.19. Grey alder samples soaked for 20 °C, 24 h. 80
Table 0.20. Grey alder samples soaked for 40 °C, 24 h. 81
Table 0.21. Grey alder samples soaked for 70 °C, 24 h. 82
Table 0.22. Grey alder samples soaked for 20 °C, 48 h. 83
Table 0.23. Grey alder samples soaked for 40 °C, 48 h. 85
Table 0.24. Grey alder samples soaked for 70 °C, 48 h. 87

PREFACE

This thesis focuses on veneer crosswise tensile strength and veneer lathe checks and how they change due to the act of heating logs prior to veneer peeling. Four hardwoods, heated at three different soaking temperatures and two different soak duration, were peeled into veneer and evaluated for lathe checks depth and veneer strength. The research results gave insight to hypothetical questions such as the relationship between lathe check depth and veneer crosswise tensile strength, the best soak temperature and soak duration for maximum veneer strength, variation within a log from bark to the pith, and the effect temperature and duration of soak. This thesis is made as a completion of the master's education in Wood Technology, Department of material and environmental technology, Tallinn University of technology.

The support receiver for this thesis was overwhelming. I would, therefore, firstly like to express my sincere gratitude to my supervisors. Dr. Anti Rohumaa and Dr. Heikko Kallakas for their immense contribution and valuable suggestions.

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Keywords; lathe check depth, crosswise tensile strength, pith, bark, veneer, log soaking.

INTRODUCTION

Veneer-based wood products such as plywood, laminated veneer lumber (LVL), and laminated veneer panels are popular with furniture, building, and construction industries, with steady growth in the possibility for what it can be applied. It is then important to manufacture veneers with high quality, a feat that is affected by veneer properties classified as been initiated from a) natural variance of wood such as knots, grain angle, species, density, and growth ring sizes b) production process such as superficial roughness, moisture content, thickness variation and lathe check depth (Wang et al., 2001).

In the manufacturing industries, it is a standard procedure to heat the logs to soften them before the peeling process, generally achieved by immersing the whole logs in a hot water bath or by steaming them in vats, using water as the medium to transfer heat to the log (Denaud et al., 2011), a procedure that results in both the production of veneer sheets that are smoother with lesser lathe checks (Dupleix et al., 2013a) and a production process that is less energy-dependent (Marchal et al., 2004). Researchers have carried out studies on the formation of veneer lathe checks during the log peeling process and indicated that the depth of lathe checks reduces at a higher temperature (Antikainen, 2015; Denaud et al., 2019; Denaud et al., 2011; Dupleix et al., 2013a; Pałubicki et al., 2010; Tomppo et al., 2009). However, higher temperature makes the logs softer during the peeling and leads to irreparable changes that affect plywood bond strength (Rohumaa et al., 2017).

The aim of this thesis is to study the effect of the log soaking duration and temperature on lathe check development and veneer crosswise tensile strength of Estonian hardwoods. In this thesis, four hardwood such as species Aspen (*Populus Tremuloides*), Birch (*Betula pendula* Roth), Black alder (*Alnus glutinosa),* and Grey alder (*Alnus Incana*) were used. The logs were soaked for 20 ⁰C, 40 ⁰C, and 70 ⁰C in water for a time of 24 h and 48 h. The veneer is evaluated for crosswise tensile strength and lathe check depth. The main hypothesis is:

- Elevated log soaking temperature has a positive effect on veneer tensile strength and decreases the lathe check depth.
- Longer soaking of logs improves the strength of the veneer and provides more homogenous properties throughout the veneer mat from bark to pith.
- Veneer crosswise tensile strength and lathe check depth have a strong negative correlation.

1 LITERATURE REVIEW

1.1 Veneer

Veneers are a thin wood layer of 0.5 - 5 mm cut from a log. Transforming wood into a veneer allows for maximising the added value obtained from a particularly given log (Dupleix et al., 2013a). Lutz et al. pointed out that most wood species can be cut into veneer successfully, but with a variation on the ease of the process dependent on the wood class, with hardwood class easier to cut than softwoods. Specific physical properties of wood such as specific gravity, moisture content, shrinkage, permeability, outside cell contents, figure, odour, cell type, size, and distribution are equally important when selecting wood for veneer production (Lutz JF, 1971).

1.2 Veneer production

The manufacturing of veneer is usually the pre-manufacturing part for plywood production, and it consists of seven main steps log selection and sorting, log soaking in water, log debarking, veneer peeling, and cutting to size, and drying.

The veneer manufacturing process starts with the log selection. Logs are sorted according to the kind and number of defects they have, such as knots, cracks, rots, and tabulated so that they can be graded and cut into peeler blocks that can fit into the peeling machine spindle.

The act of raising the temperature of greenwood before it is peeled is necessary not only in improving the peeling process but also in the quality of the veneer produced (Dupleix et al., 2013). The improvement of the veneer has been identified to be due to the fact that hot wood tends to be more plastic and bend over the knife with minimum checking (Dupleix et al., 2013), But this is not the only effect, according to (Rohumaa et al., 2017) heating also causes changes that are irreversible in the wood materials and which subsequently affects plywood bond strength development. Figure 1.1 shows the influence of heating temperature on the checks index.

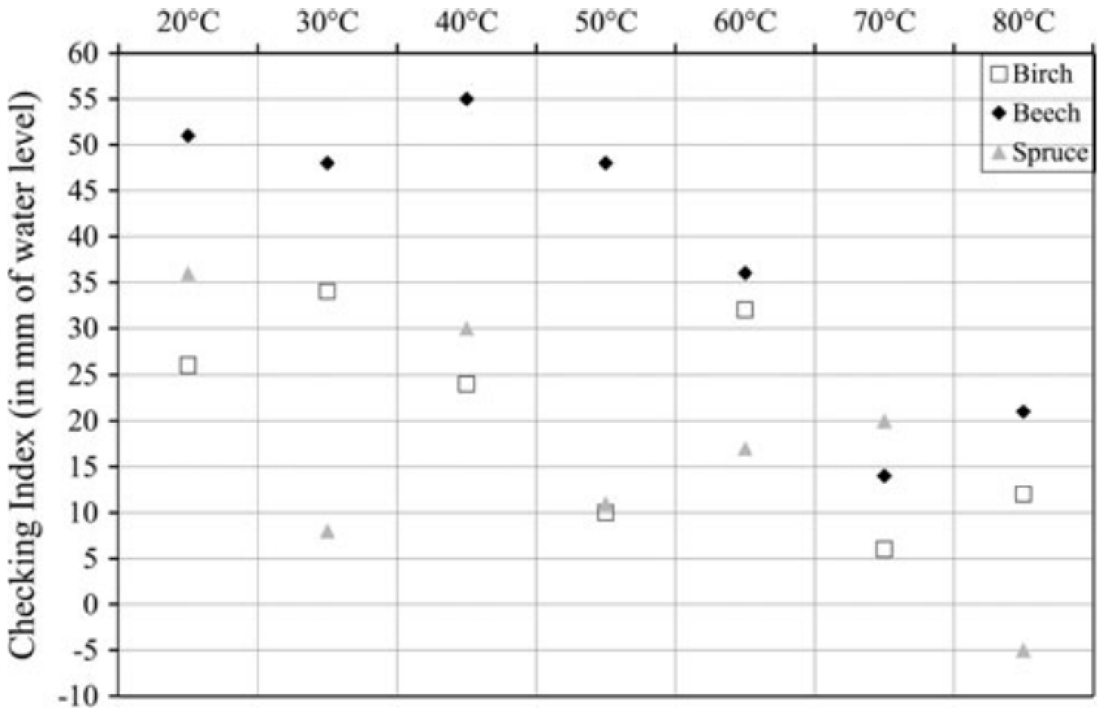

Figure 1.1. Influence of heating temperature on checking index (CI)(Dupleix et al., 2013a)

In practice, heating of wood is achieved by soaking the whole log in hot water or by steaming the log in vats, where water is used to transfer heat to the logs (Dupleix et al., 2013). Heating the logs is done by soaking the logs in water at elevated temperatures. This helps the log to soften and aids the bark to come off more quickly, making the peeling process smoother. With a softer log, there is a minimisation of knife checks; thus, the veneer sheets require a lesser adhesive coating (Robam, 2018). The colour and chemistry of the wood are also affected, thereby leading to discolouration among the veneer sheets produced (Robam, 2018).

The heating of greenwood makes it more plastic, a fact that can easily be shown when a mechanical test is conducted, and it is the basic principle of bending of wood (Lutz JF, 1974) for veneer production duration, plasticity does not depend on time, as soon as greenwood reaches a given temperature, its plasticity is the much it can get at that temperature (Lutz JF, 1974) a reason why veneer peeled from heated logs can be bent with fewer fractures more than veneer from unheated wood (Lutz JF, 1974). Research by (Robam 2018) had pointed out that wood softens when heated, and this is due to the glass transition temperature (T_g) surpassing that of the wood polymers. In its dry state, the isolated cellulose in the wood has been found to have a T_g that is around 230-250 °C, while hemicellulose has been found to have a T_g around 150 – 200 °C and lignin, starting at a lower point, has T_g of 130 – 200 °C (Rohumaa et al., 2013). However, the availability of moisture in the structure of the wood lowers these temperatures to a certain amount.

The relationship between the log peeling temperature and lathe check formation has been well studied. In Rohumaa et al. (2017), the author acknowledged that the formation of deep checks is reduced at higher peeling temperature, and results showed that the veneers obtained from logs soaked at 70 ^{o}C had substantially lower lathe check depth compared to logs soaked at 20 ^{o}C with the same production condition as the logs soaked at 70 ^{o}C. Other research by Dupleix et al. (2013a) observed checks on veneer soaked between 20 ^{o}C to 80 ^{o}C and discovered that up to a temperature of 70 ^{o}C, the check Index decreased as the temperature increased from 20 ^{o}C to 70 ^{o}C.

Debarking the act of removing the bark from a log as well as foreign materials, like soil particles, metals, and stones. Three factors were mentioned to be considered before debarking (Lutz JF, 1974), they are:

- The variability in adhesion of bark within a given species due to weather, temperature,
- The variability in adhesion of bark between different species due to difference in species (the bond between the bark to the wood of aspen has been shown to be more than 40% stronger than that of red spruce,
- The type of equipment that is used for the debarking process,

There are a lot of different ways of debarking veneer logs ranging from simple hand tools, bark saws to industrial scale such as water under high pressure, flailing chains, and rotary (ring) debarker and drum debarker (Lutz JF, 1974).

The choice of which debarking method to use depends on factors that include its purchase cost, the maintenance cost of the debarker, the kind of wood to be handled by the debarked, the amount in terms of quantity of wood to be debarked, the size in terms of maximum and minimum diameter of logs, the extent of fibre loss during debarking, the possible pollution the machine cause, and the operation and maintenance ease (Lutz JF, 1974).

Since the general trend is to harvest logs in as long length as possible, they are later sawn into bolts or peeler blocks that can fit into the spindle of the veneer peeling machine.

1.3 Veneer lathe checks

ASTM International. D1038-19 Standard Terminology Relating to Veneer, Plywood, and Wood Structural Panels defined veneer check as a thin slit running comparable to the direction of the grain of the wood, initiated by strains produced in seasoning and by stresses caused during peeling in a rotary lathe (*ASTM Compass*, n.d.).

Lathe check frequency and depth have been one of the conditions used to ascertain veneer quality. Some researchers have proposed that shallow lathe checks at a higher frequency (i.e., checks per mm), when compared to less frequent but deeper lathe checks, indicate an excellent veneer surface quality (Rahayu et al., 2016). Industries see loose veneer (veneer that has deep lathe checks) as not suitable for producing quality plywood. Tight veneer has shallow, frequent lathe checks, with more attention being on reducing the depth of lathe checks rather than the frequency of its occurrence. A too loose veneer is caused by many factors, including insufficient nose bar pressure and or horizontal or vertical gap too wide, log too cold at the time of peeling (Rohumaa et al., 2017), logs too dry during peeling, the knife bevel angle too large, the cutting speed and the clearance angle. Researchers (Rohumaa et al., 2013) have also found that in phenol-formaldehyde – bonded plywood, there was a significant reduction of the shear strength of birch veneer as a result of the deep lathe checks formed.

1.4 Measuring veneer lathe checks

Researchers have been able to measure veneer check depth using a microscope by treating the samples with textile dye. Application of dye is made on the loose side of the veneer sheet to make the lathe checks visible under a microscope. The checks were revealed by cutting a thin slice of 0.5 mm thick out from the dyed side by sawing and conditioned at 20 ºC and 65 % RH for 12 h. Under the microscope, the checks were inspected and measured, and the calculation of average check depth was done for each sample (Rohumaa et al., 2013).

In recent times, lathe check has been identified with a measurement system called SMOF (Systeme de Mesure d'Ouverture des Fissures). It uses the principle of curving veneers over a pulley to be pictured when they are subjected to a laser. A camera affixed to the device automatically captures pictures of the thickness of the veneer make it available for a continuous recording of the cross-section of the veneer (Benbrahim et al., 2020). The device has the advantage of providing the checking depth estimated as a percentage of the actual veneer thickness at the point of the check, whereas manual methods consider the minimal veneer thickness (Benbrahim et al., 2020) but also has the disadvantage of requiring a very quality sawing that deliver a distinct enough image for measurement, and additionally not being suitable for real-time measurements at the time of production due to the image is captured from the veneer side (Antikainen, 2015).

Some other methods used in measuring LCD and or LCF include (Tomppo et al., 2009) with the aid of ultrasound, measured LCD in both wetted and dry birch veneers by means of contact and non-contact measurement arrangement. The study established a relationship between the ultrasound transit time and the depth of lathe checks in both wet and dry birch veneer. Wang et al. (2001) were able to measure LCD and the total number of checks of a sample by using acoustic-ultrasonic and stress wave methods but would be required to be done on both orthogonal directions.

In the study done by Denaud et al. (2011), they were able to measure lathe check frequency (LCF) along with the veneer length of poplar and beech veneer samples by taking records of the sound emitted and cutting forces while performing a laboratory-scale peeling for the thickness of 1.3 up to 3.3 mm, but for the 1.3 mm thin veneer that had no clear extract peaks from the background noise, the method seems effective (Denaud et al., 2011).

1.5 Tensile strength

Tensile strength is a measure of the maximum load the veneer can support without fracture when it is stretched, divided by the original cross-sectional area of the veneer. In the study by Sepp (2015), the author described the procedure and compared the tensile strength of veneer from false heartwood and regular wood, see Table 1.1. Questions were raised concerning the inconsistency of false heartwood due to the significant variations observed when compared to typical veneer, implying that in production, the false heartwood cannot be trusted to be consistent (Sepp, 2015). However, it could be argued that the low tensile strength result results from conducting the test on a dry veneer.

Table 1.1. Tensile strength measurement (Sepp, 2015)

Measurement / Test specimen	**Average thickness, mm**	**Average width, mm**	**Average maximum load, N**	**Tensile strength, N/mm²**
FH veneer	1.31(0.29)	50.02(0.31)	37.48(12.68)	0.60(0.25)
Normal veneer	1.56(0.08)	50.10(0.21)	47.69(8.83)	0.61(0.11)

Although there was no mention of temperature by the author, a lot of research work has looked at the effect the temperature of the log has on veneer and, subsequently, plywood strength. Kallakas et al. (2020) compared the crosswise tensile strength of wood species: birch (*Betula pendula Roth*), grey alder (*Alnus incana L*), black alder (*Alnus glutinosa L*), and aspen (*Populus tremula L*), all soaked at 40 °C based on GOST 20800-75 standard, the result showed aspen's tensile strength to be statistically significantly different from other wood species compared, Figure 1.2 shows how the wood species varied in tensile strength.

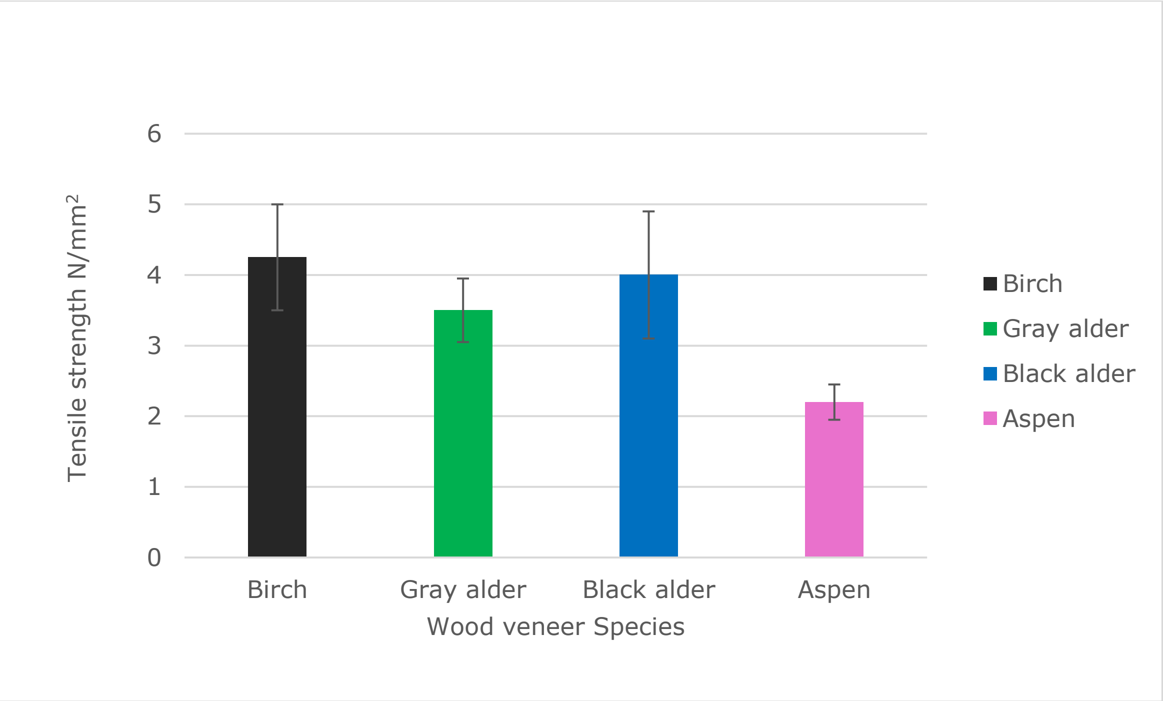

Figure 1.2. Crosswise tensile strength of different wood species veneers(Kallakas et al., 2020)

1.6 Thickness of Veneer

Wood and wood-based material mechanical properties are influenced by internal and external factors, and the general perception is that with dimension increasing, the strength of the material decreases (Schneeweiß, 1969), commonly known as the size effect. However, for wood, the influence of specimen sizes such as width, length, and thickness on the mechanical properties has been observed for the various directions perpendicular and parallel to the grain direction and with different loading types (bending, tension, and compression). Table 1.2 is an overview of some literature that investigated the effect.

Table 1.2. Summary of some works of literature studying the strength of wood and the effect of size on it, with indicating if such as: loading parallel to the grain = || and loading perpendicular to the grain = ⊥; decreasing strength with increasing size = ↓ ; and increasing strength with increasing size = ↑ , reported size effect (yes) or not (no). (Pramreiter et al., 2021) .

Reference	**Load direction**	**Tensile strength**	**comment**
(Pedersen et al., 2003)	⊥	yes ↓	tangential Loading direction
(Astrup et al., 2007)	⊥	yes ↓	radial Loading direction
(Biblis, 1970)	⊥	yes ↑	Sliced early and latewood specimens Longitudinal
(Yu et al., 2009)	||	yes ↑	stiffness in Longitudinal direction
(Pfriem & Buchelt, 2011)	|| ⊥	yes ↑ no	increase in Perpendicular, but No effect in parallel
(Živković & Turkulin, 2014)	||	yes	No tendency is described bending
(Büyüksarı et al., 2017)	||	yes ↓	increases in size, increase in Compression strength
(Barrett, 1974)	⊥	yes ↓	approach in Theory

Veneers produced by rotary peeling develop lathe checks on the loose side. The properties of the veneer lathe check are usually characterised by the lathe check interval and the lathe check depth. When peeled under the same condition, veneers with more significant peeling thickness results in veneers with deeper lathe checks and a more considerable distance between successive checks (Denaud et al., 2011; Pałubicki et al., 2010). Pot et al. (2015) demonstrated that the presence of lathe checks with the increase of the veneer thickness resulted in a decrease of the shear modulus.

Researchers (Pramreiter et al., 2021), while investigating the influence of thickness and angle of load on the tensile strength of peeled veneer in comparison to thin sawn timber, observed that the tensile strength increased significantly perpendicular to the grain when the veneer thickness is between 0.5 mm and 1.5 mm and decreased significantly when the veneer thickness is within the range of 1.5 mm and 5.0 mm (Pramreiter et al., 2021).

2 MATERIALS AND METHODS

2.1 Wood species

Selected logs length was between 2.8 m – 3.3 m, split into two peeler blocks of length between 1.2 – 1.4 m to fit the veneer lathe. The average length and diameter are shown in Table 2.1. The log sets soaked for 24 h were from the autumn fresh fell in March 2019 at Piirsalu, Lääne County, Estonia, by State Forest Management Centre. The purpose of the study Logs with quality classes B and C were selected at random. The average stand age (weighted by area) of the birch trees was 81 years, black alder 70 years, grey alder 55 years, and aspen 74 years, while those soaked for 48 h were from the winter fresh fell in September 2020 at Käru, Raplamaa, Estonia by State Forest Management Centre. For consistency, logs with quality classes B and C were selected at random for the study. The weighted (by area) average stand age was 76 years. The logs were stored outdoor at the prevailing environmental condition. Table 2.2. shows the number of logs selected for each condition. Two logs were selected for each soak temperature for both soak duration. Thus, a total of 48 logs were soaked for the research.

Table 2.1. Log length and diameter

Wood species	Average length, mm	Average diameter, mm
Aspen	1,296	347
Birch	1,293	240
Black Alder	1,292	271
Gray Alder	1,279	237

2.2 Veneer preparation

The logs were selected so that no two peeler blocks were in the same soak temperature for a given duration. The log diameter and length were measured, and the logs were inspected for warping and any defects. The log soaking was done in a specifically constructed boiling water bath Figure 2.1, and the logs were soaked in the water for 24 and 48 h, as required at temperatures of 20, 40, and 70 ºC for the different wood species.

Figure 2.1. Peeler blocks placed in soaking bath

Already soaked peeler blocks were removed at due time, and measurements of the moisture content and temperature were taken at three points on the peeler blocks and the average determined.

The peeler blocks were then debarked manually with debarking knives to avoid blunting the lathe blade and avoid getting bark-dust into the veneer lathe. Then log peeling and veneer cutting processes were performed.

Figure 2.2. Debarked peeler block

2.3 Veneer samples preparation

The debarked peeler block was then lifted between two feed paws of an industrial scale lathe manufactured by the Raute Corporation (Model 3HV66; Raute Oyj, Lahti, Finland). The peeler block was automatically lifted between two spindles, and the initial peeling process started. The block was rounded, and then the peeling process started with the peeling thickness set at 1.5 mm, peeling speed of 60 m/min, knife angle of 20º, and compression rate of 10%.

The homogeneous veneer mat was pulled away from the peeler to the veneer clipper Figure 2.3A. After cutting away 1m from the start and end part, 450 mm x 900 mm veneer sheets were cut out from the remainder Figure 2.3C.

Figure 2.3. Veneer cutting

For the 24 h soaking, the selection of the samples of the sheet to be tested for the crosswise tensile test was made such that sheets were taken from the start of the mat (close to the bark), middle of the mat, and end of the mat (close to the pith), while for the 48 h samples the sheet selection was at a minimum interval of every five sheets for logs with a smaller diameter and every ten sheets for log species with a larger diameter, the intention was to obtain a selection spread from bark to pith of each log. The sheets were coded, that was after 50 mm x 150 mm were obtained from both ends of the sheet

2.4 Tensile testing

The crosswise tensile strength of the veneer was measured on a wet veneer sample. The plywood company production method was used in terms of specimen size, with 18 test specimens cut for each 24 h species (six samples per sheet) and a minimum of 30 test specimens cut for each of the 48 h soak species. The test was conducted according to GOST 20800-75 Standard. The specimens were precisely cut using a clipper with all adjacent edges at right angles; first, 50 mm was removed from the beginning and end part of the sheet, then the 50 mm x 450 mm veneer strip for the test was cut Figure 2.4.

Figure 2.4. Cutting of veneer strips for tensile testing

The test specimens were cut into sizes 50 x 150 mm and numbered T1, T2 to T6. The crosswise tensile test was performed on a universal testing machine (Instron 1122) with a 0.5kN load cell. The distance between the clamps of the testing machine was set at 50 mm. A micrometre screw gauge was used to measure the thickness of the test piece. The 150 mm long specimen was placed vertically such that the machine clamps take up about 50 mm from both ends of the specimen so that the load can be applied in the crosswise direction. This is shown in Figure 2.5.

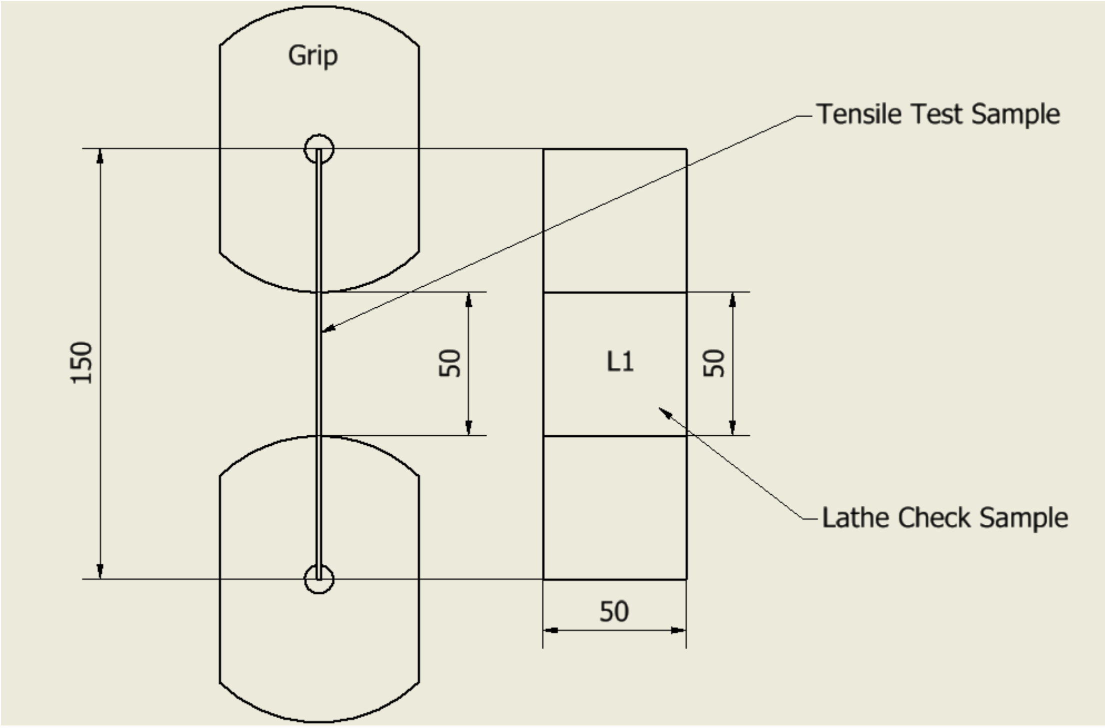

Figure 2.5. Tensile test sample gripped between clamps and equivalent lathe check sample placed alongside

When firmly clamped, a steady increasing load with a 2 mm/min speed is applied to the test piece until it fractures, the record of the maximum load was taken, and the crosswise tensile strength is calculated using the formula.

Crosswise tensile strength σ = Force (N) /Area of the test sample (veneer length x thickness mm^2)

σ is calculated as shown below:

$$\sigma = F/A \qquad 2.1$$

Where:

F represents the maximum load in Newton (N)

A is the area gotten from the width and thickness of the veneer (mm^2).

The tensile strength of the veneer should be greater than 1.2 N/mm^2 (EN 636)

The number of veneer sheets selected for testing is shown in Table 2.3.

Table 2.2 Veneer sheets selected for testing

	Number of veneer sheets selected for testing					
Duration	24 h			48 h		
Temperature	20 ºC	40 ºC	70 ºC	20 ºC	40 ºC	70 ºC
Aspen	3	3	3	11	14	9
Birch	3	3	3	10	13	11
Black Alder	3	3	3	10	11	12
Gray Alder	3	3	3	10	10	10

2.5 Lathe check inspection

The lathe check inspection was done on a dry veneer sample, and samples were taken directly after the point where the samples for the tensile strength were taken see Figure 2.6, this is to enable direct comparison of lathe check at the point where the failure occurred during the tensile strength test, e.g., T1, T2, T3 for tensile and the equivalent L1, L2, L3 for lathe check inspection.

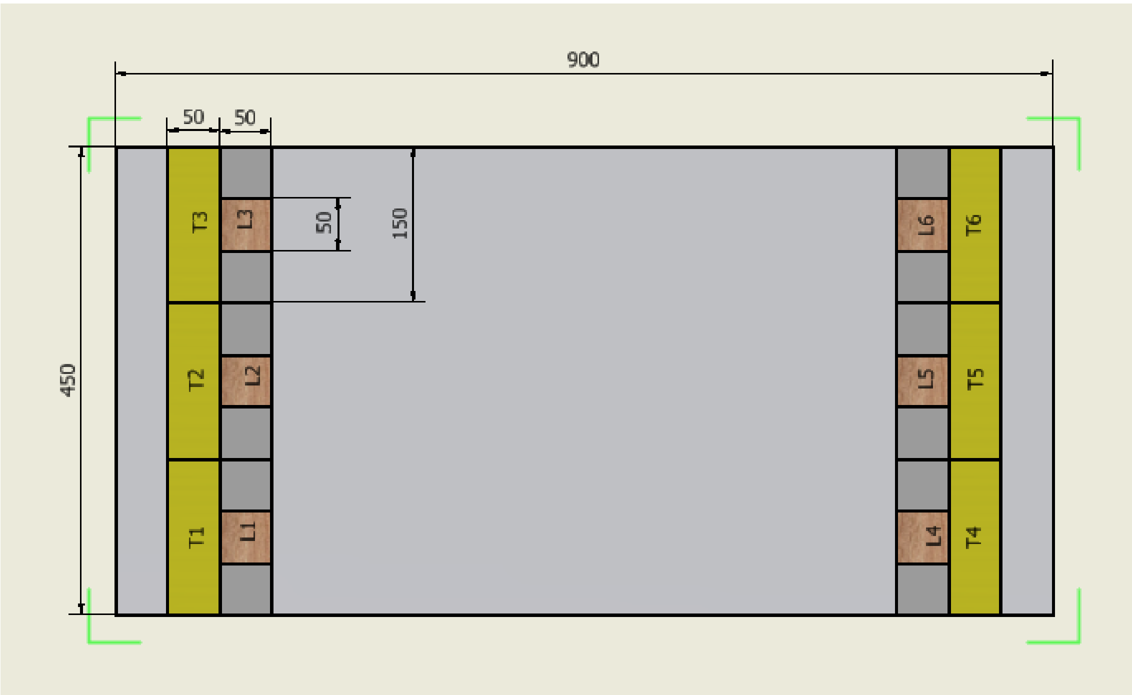

Figure 2.6. Cutting pattern for tensile test and lathe check samples

After samples for the tensile strength were cut out from the top and bottom, as shown in Figure 2.6, the remainder of the 450 x 700 mm sheets were then dried at 170 ºC.

The drying was done for an average of two minutes, then 50 x 150 mm strips were cut out before it was finally cut into the lathe check samples of 50 x 50 mm.

A better alternative was to cut the lathe check samples at the same instance of cutting the tensile test samples, then dry the lathe check samples as strips of 50 x 150 mm. This gave an added advantage of obtaining the lathe check samples in good form without distortion compared to when it was dried in the entire 450 x 700 mm sheet and eliminated the breakage of samples as encountered when cutting out the lathe check strips the dried sheets.

Since the focus of the late check inspection was to compare the failure point of the tensile strength samples with the equivalent late check samples. Therefore, the lathe checks samples were obtained considering the mid-section of the tensile test sample since the grip of the tensile tests' equipment grips 50mm from both points, leaving 50 mm of the midsection.

Application of dye was made with Dylon Tulip red dye from Henkel Ltd, Ireland. The process involved dissolving 10 g of the dye in 500 ml of warm water. Before the inspection, dye (Dylon tulip red) is then applied on the loose side of the lathe check samples and allowed for 2 mins before wiping off excess Figure 2.8C. The dyed samples were kept in a conditioned environment at 20 ºC and 65% RH for 12 h.

The dry dye samples were clamped not more than 50 pieces together, then 5 mm strip was cut out from the two ends of the cross-section using a table saw, the remaining 40 x 50 mm left was then split into two 20 x 50 mm Figure 2.8A, this was done so that the cross-section was free from dye stain and the sample piece small enough to fit conveniently in the mount for the image inspection. The cross-section is then smoothened with sandpaper.

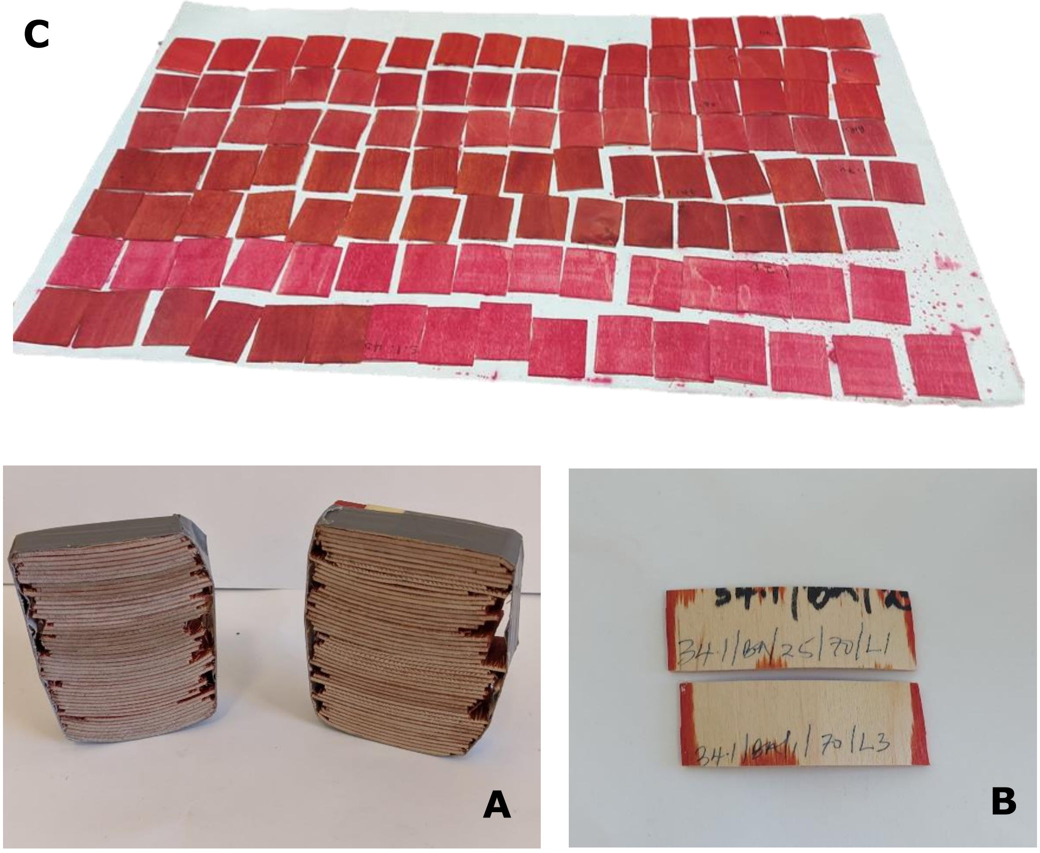

Figure 2.7. A, B - Dyed veneer specimen cut to 20 x 50 mm, C - loose sides stained with Dylon dye

The check inspection was performed using both a standard digital microscope (Nikon ECLIPSE ME600L microscope, magnification 2x, figure 2.9B) and a mini digital camera (Dino-lite digital microscope, magnification 50x Figure 2.9A). For the Nikon ECLIPSE ME600L microscope, the image was captured and checks measured using the Zeiss Axiocam 208 colour camera ZEN 3.3 (ZEN lite) software Dino-lite digital microscope an open-source app Fiji ImageJ together with the IJ webcam plugin was used. Both capturing devices were calibrated to measure distance in mm scale to the magnification used.

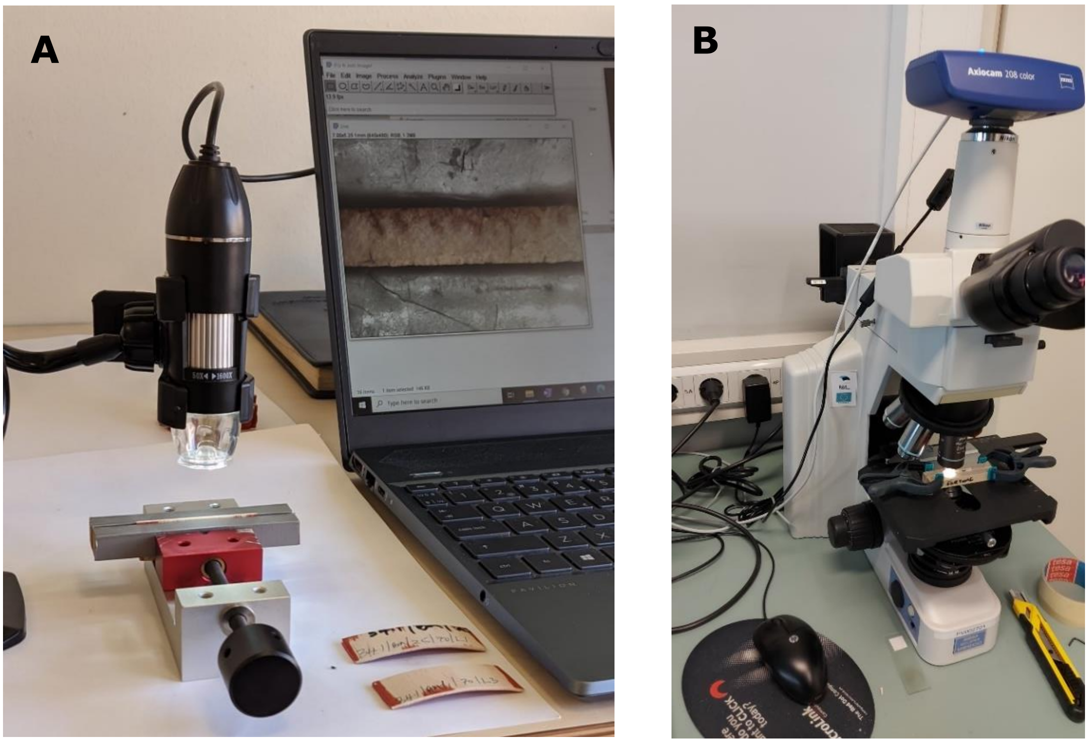

Figure 2.8. A – Dino-lite digital microscope setup, B – Nikon Eclipse microscope.

3 RESULTS AND DISCUSSION

3.1 Tensile strength

The results obtained for both the 24 and 48 h soaked samples show that the samples soaked at 70 °C had a higher crosswise tensile strength than those soaked at 40 °C and 20 °C. The black alder sample at 70 °C, 48 h, had the overall highest tensile strength of 2.37 N/mm^2 when compared to the other species. The birch species is the least affected by the duration of soak. This can be seen when the 24 and 48 h soak duration are compared. Table 3.1 and 3.2 show the mean crosswise tensile strength and standard deviation for all the 24 and 48 h samples tested.

Table 3.1. Average crosswise Tensile strength TS (N/mm^2) for samples soaked for 48 h

48 h		**70 °C**	**40 °C**	**20 °C**
Black alder	TS	2.37(0.40)	1.73(0.32)	1.59(0.31)
Grey alder	TS	2.06(0.39)	1.63(0.43)	1.42(0.19)
Birch	TS	2.05(0.39)	1.83(0.33)	1.41(0.30)
Aspen	TS	1.83(0.22)	1.75(0.29)	1.34(0.30)

Table 3.2. Average crosswise Tensile strength (N/mm^2) results for soaked for 24 h

24 h		**70 °C**	**40 °C**	**20 °C**
Black alder	TS	1.98(0.35)	1.54(0.37)	1.33(0.30)
Grey alder	TS	1.50(0.35)	1.44(0.26)	1.24(0.30)
Birch	TS	2.04(0.42)	1.68(0.45)	1.35(0.20)
Aspen	TS	1.80(0.47)	1.24(0.14)	1.25(0.15)

The difference between the mean of the different temperature conditions was evaluated for significance using analysis of variance (ANOVA). The difference in mean among pairs was segregated and compared by Tukey's test ($P < 0.05$).

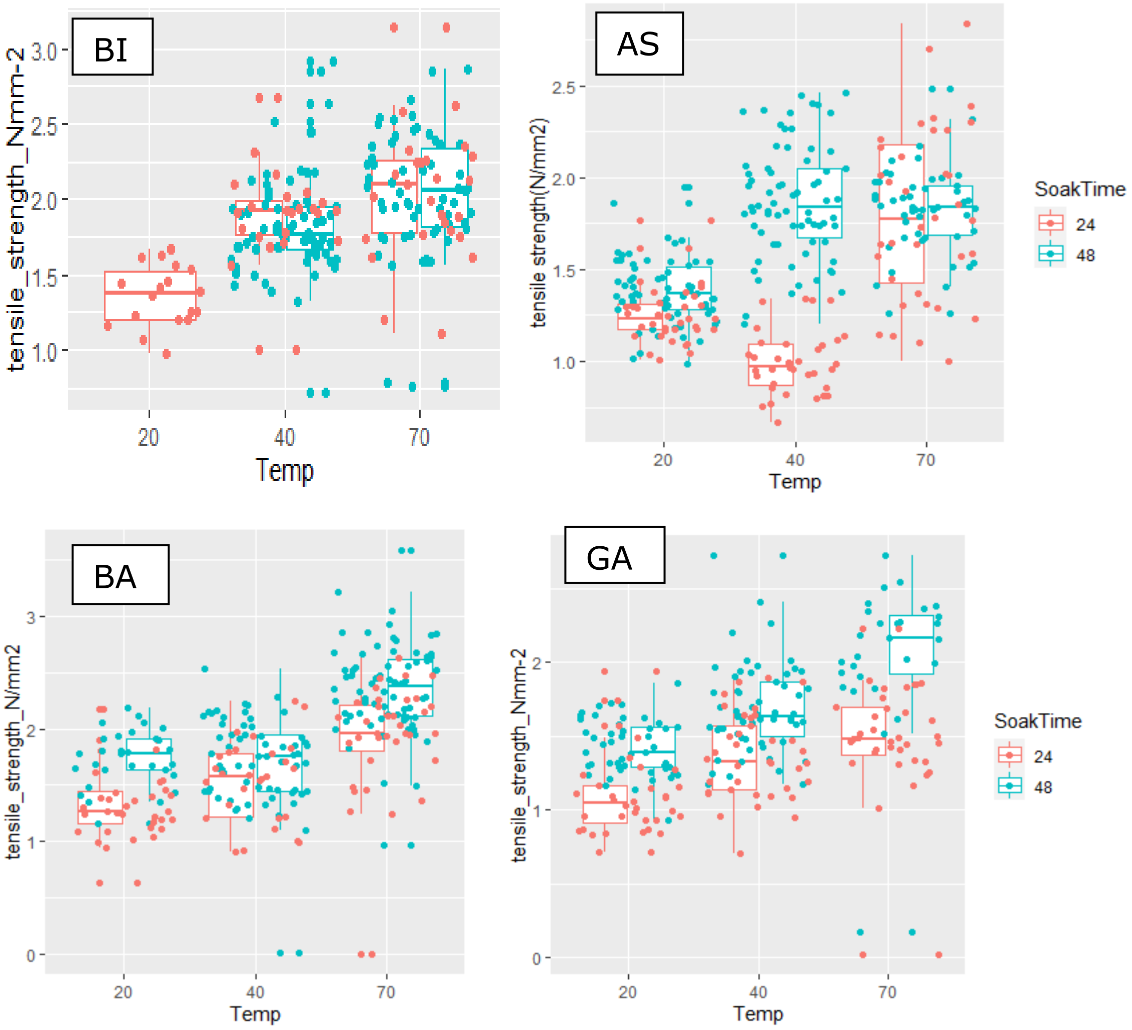

Figure 3.1. Boxplot indicating soak duration and soak temperature for species

From the data analysis for the birch samples, there was a significant difference in the tensile strength for the temperature range from 20 ºC to 70 ºC, $F (2, 201) = 30.21$, $p < 0.05$ for both samples sets soaked at 24 and 48 h the soak duration showed no significant difference. The post hoc evaluations using the Tukey HSD indicates that the mean value for tensile strength for the 24 h soaking temperatures of 20 ºC (M =1.35 , SD = 0.20),40 ºC (M =1.68 , SD = 0.45), and 70 ºC (M =2.04 , SD = 0.42) and the 48 h soaking temperatures of 20 ºC (M =1.41 , SD = 0.30), 40 ºC (M =1.83 , SD = 0.33), and 70 ºC (M =2.05 , SD = 0.39) were significantly different from each other, and the mean tensile strength increased as the soak temperature increased from 20 ºC to 70 ºC for both soak duration, see figure 3.2.

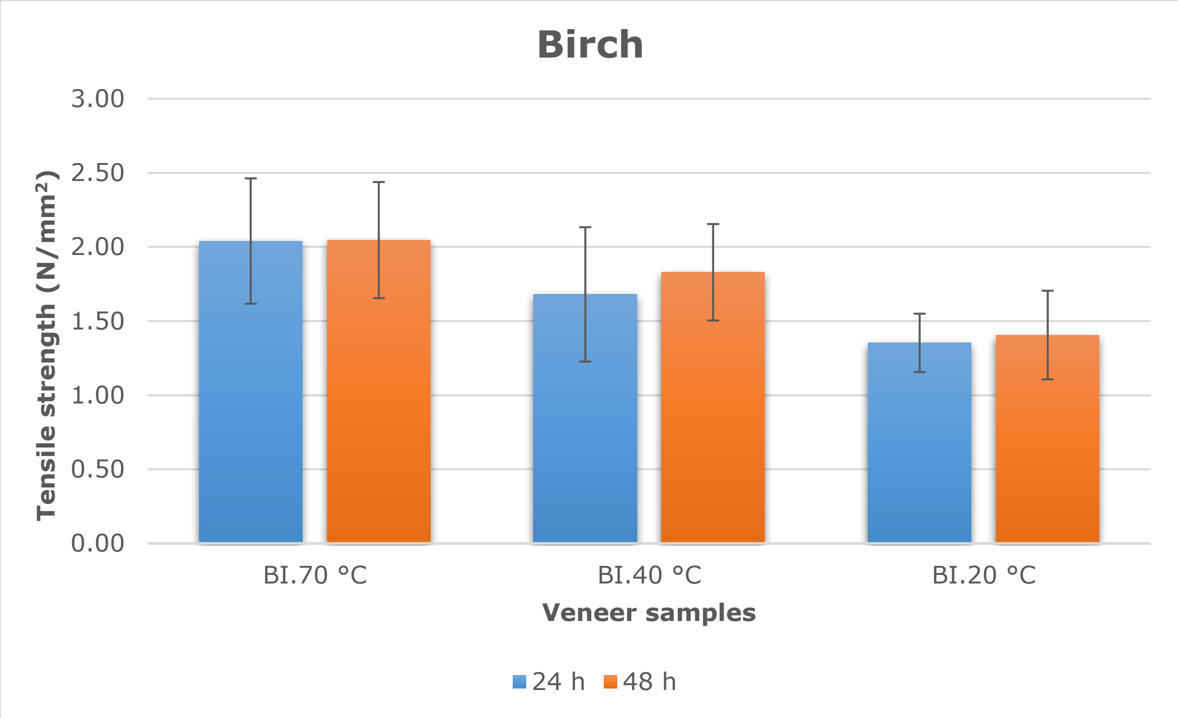

Figure 3.2. Average tensile strength at different soak temperature and soak time for birch species

There was a significant effect of the soak temperature on tensile strength at the $p < 0.001$ for the six aspen species soak conditions as determined by one-way ANOVA ($F(5,288) = 68.39$, $p < 0.001$) and soak duration of the temperature set ($F(1,288) = 121.45$, $p < 0.001$) .

The Tukey HSD test post hoc comparison returned a 95% family-wise confidence level and indicates that the mean value for tensile strength for the 24 h soaking temperatures of 20 ºC (M =1.25 , SD = 0.16),40 ºC (M =1.24 , SD = 0.14), and 70 ºC (M =1.80 , SD = 0.47) and the 48 h soaking temperatures of 20 ºC (M =1.34 , SD = 0.30),40 ºC (M =1.75 , SD = 0.29), and 70 ºC (M =1.83 , SD = 0.22) were significantly different from each other. However, there were no indication of significant difference between the conditions (70 ºC,48 h, and 40 ºC,48 h), this could be seen from Figure 3.3 showing the comparison of the mean, the mean of the aspens soaked at 20 ºC (M =1.34 , SD = 0.30) (M =1.25 , SD = 0.16) had the lowest mean value for the tensile strength for 48 and 24 h respectively.

From the results obtained for the aspen species, it can be seen that the temperature of soaking and the duration of soak have a positive effect on the crosswise tensile strength. This is because, at a longer soak duration of 48 h, the crosswise tensile strength is increased for all soaking temperatures. When temperatures of soaking are compared, it could be seen that the crosswise tensile strength is much higher at 70 ºC.

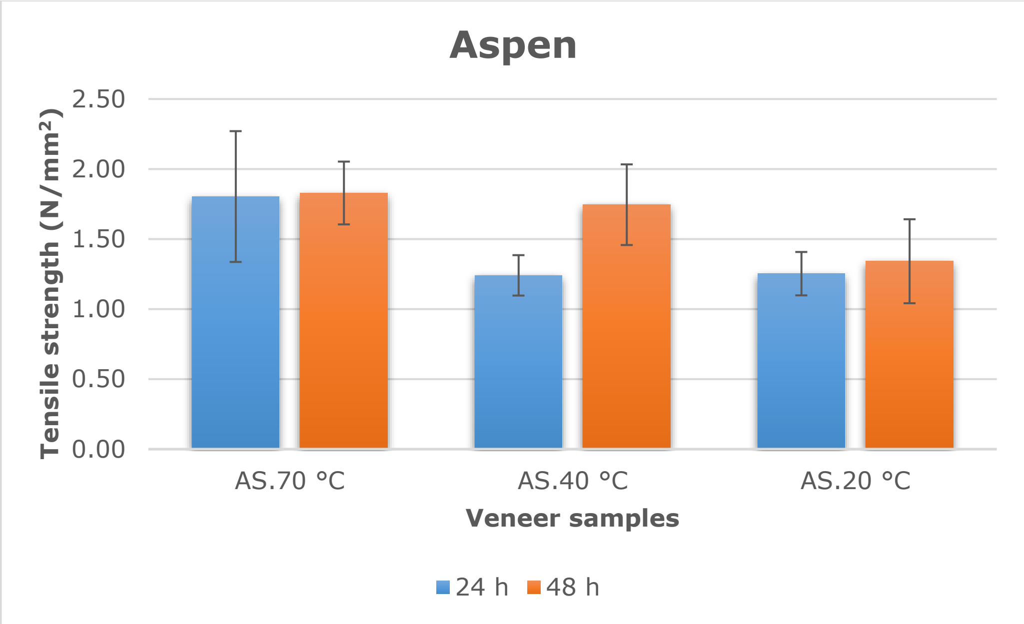

Figure 3.3. Average tensile strength at different soak temperature and soak time for aspen species

The black alder species showed similar trends for both the 24 h and 48 h soak duration, with the average crosswise tensile strength increasing with increased temperature.

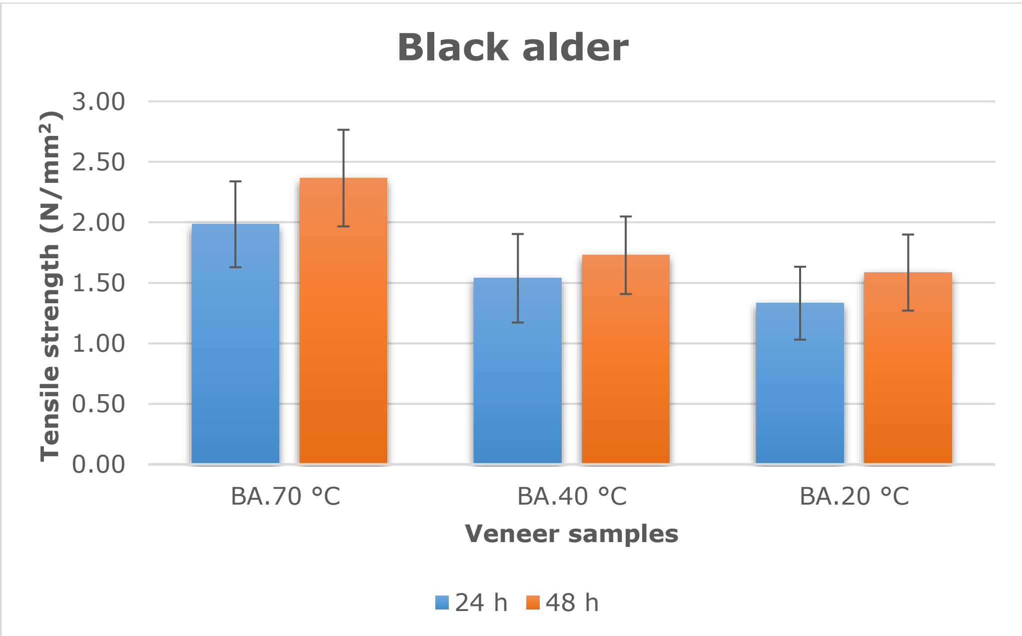

Figure 3.4. Average tensile strength at different soak temperature and soak time for black alder species

When the averages of both soak duration are compared, all the 48 h soaked sample sets had more considerably greater average tensile strength than the 24 h soaked samples for all soaking temperatures.

The post hoc evaluations using the Tukey HSD test indicates that the mean value for tensile strength for the 24 h soaking temperatures there was a significant increase at 70 ºC ($M = 1.98$, $SD = 0.36$) and the difference was significant for 20 ºC ($M = 1.33$, $SD = 0.30$) and 40 ºC ($M = 1.54$, $SD = 0.37$). At the 48 h soaking temperatures, the tensile strength at 20 ºC ($M = 1.59$, $SD = 0.31$), 40 ºC ($M = 1.73$, $SD = 0.32$), and 70 ºC ($M = 2.37$, $SD = 0.40$) were significantly different from each other with the sample soaked at 70 ºC also having the highest mean tensile strength. Figure 3.4 shows the different soak temperatures and the mean tensile strength.

Similar to what was obtained for the black alder, the grey alder samples also showed a similar trend, as can be seen in the boxplot of Figure 3.1. The analysis of variance ANOVA returned a good distribution with a significant difference for soak temperature at $p < 0.05$ for the six soak temperature ($F (2,238) = 43.29$, $p < 0.05$) and two soak duration ($F (1,238) = 95.74$, $p < 0.05$)

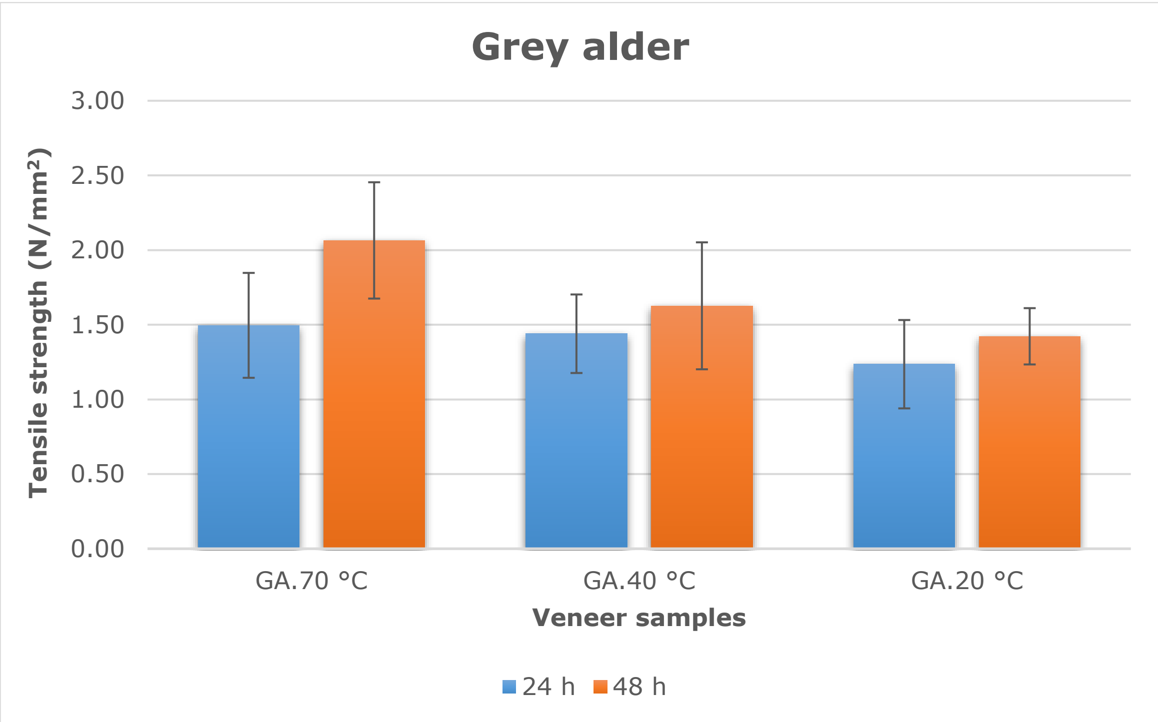

Figure 3.5. Average tensile strength at different soak temperature and soak time for grey alder species

The Tukey HSD test indicates that the mean value for tensile strength for the 24 h soaking temperatures of 20 ºC (M = 1.24 , SD = 0.30), 40 ºC (M = 1.44 , SD = 0.26), and 70 ºC (M = 1.50 , SD = 0.35) were significantly different from each other with the sample soaked at 70 ºC having the highest mean tensile strength ,this was also similar to what was obtained for the 48 h soaking temperatures of 20 ºC (M = 1.42 , SD = 0.19),40 ºC (M = 1.63 , SD = 0.43), and 70 ºC (M = 2.06 , SD = 0.39) , with the sample soaked at 70 ºC also having the highest average tensile strength. All the samples soaked for a duration of 48 h had higher tensile strength values than the equivalent 24 h samples see Figure 3.5.

Overall, the effect of elevated soaking temperature, as seen from the results and analysis, was just as expected. The samples soaked at 70 ºC had the highest crosswise tensile strength for both the 24 and 48 h soak duration. For the samples soaked for 24 h duration, the birch at 70 ºC had the highest mean value of 2.04 N/mm^2. However, for the 48 h soak duration, the black alder sample soaked at 70 ºC had the highest mean value of 2.37 N/mm^2, with the aspen species having the lowest at 70 ºC, 1.83 N/mm^2. In the literature, the aspen had a significantly lower veneer crosswise tensile strength when compared to three other species soaked at 40 ºC for 24 h (Kallakas et al., 2020). This is similar to what was obtained in this research, at 40 ºC for 24 h, the birch species had the highest crosswise tensile strength of 1.68 N/mm^2, and the aspen species having the least mean value of 1.25 N/mm^2. For all the wood species considered, an increase in the log soaking temperature resulted in the production of veneers with significantly improved crosswise tensile strength. This is similar to what was reported by Rohumaa et al. (2013, 2016, 2017).

3.2 Lathe check depth

The difference in lathe check depth can be seen in the image captured in Figure 3.6, with the samples soaked at 20 ºC having a deeper lathe check depth when compared to samples soaked at both 40 ºC and 70 ºC.

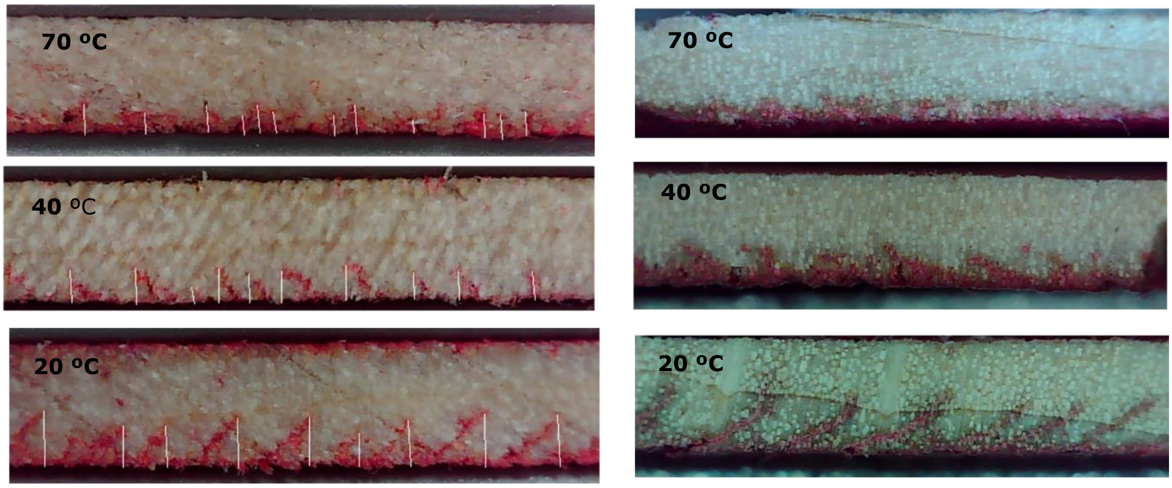

Figure 3.6. Captured images of lathe checks depth at different soak temperatures

A one-way ANOVA was done to compare the effect of veneer lathe checks on species at temperatures 20 ºC, 40 ºC and 70 ºC and the duration of soak. There was a significant difference of the lathe check depth at the $p < 0.05$ for ($F(2, 115) = 353.60$, $p = 2e\text{-}16$) grey alder, ($F(2, 120) = 114.64$, $p = 2.2e\text{-}16$) for black alder, ($F(2, 131) = 475.55$, $p = 2.2e\text{-}16$) for aspen and ($F(2, 83) = 265.50$, $p = 2.2e\text{-}16$) for birch species.

On comparing the influence of temperature on the lathe check depth for the birch, it could be seen that there is an enormous check depth at a lower temperature of 20 ºC (M = 0.65, SD = 0.09) and (M = 0.57, SD = 0.07) for both the 24 and 48 h soak duration respectively, and checks are significantly different and higher for the 24 h soak duration than the 48 h soak duration.

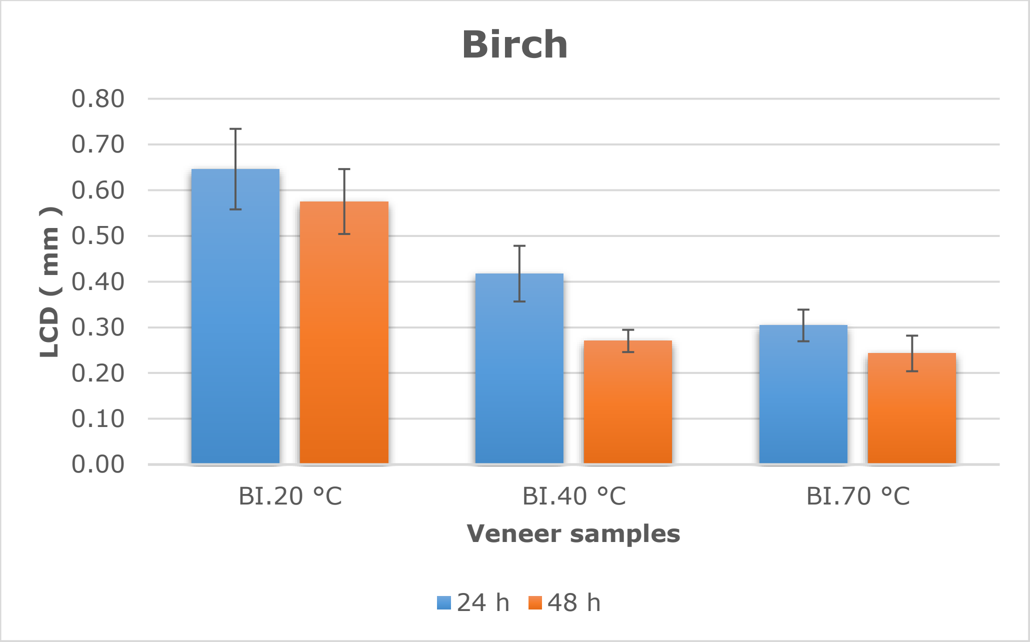

Figure 3.7. Average lathe checks depth (LCD) at different soak temperature and soak time for birch species

The same trend can be seen with the Aspen samples with an increase in lathe checks depth at a lower temperature as the temperature increase from 20 ºC to 70 ºC, and the lathe checks depth also decreases. There was a significant difference in the duration of soak also with the samples soaked and 40 ºC and 70 ºC for 48 h having lesser lathe check depth when compared to the respective samples for 24 h.

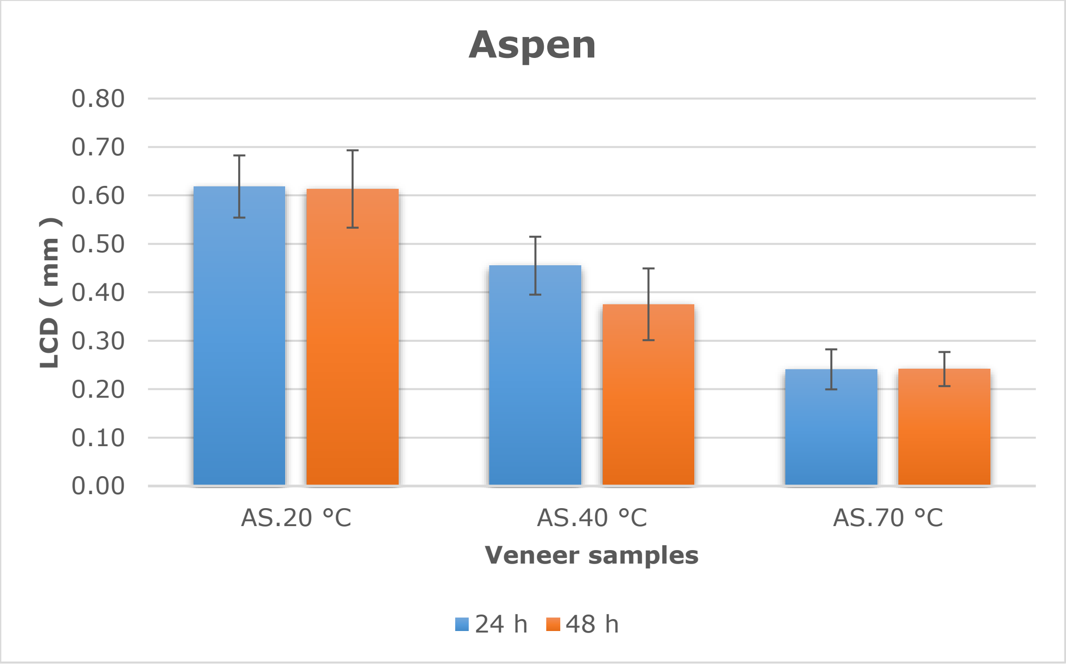

Figure 3.8. Average lathe checks depth (LCD) at different soak temperatures and soak time for aspen species.

For the Black alder samples soaked for 24 h duration, the developed checks at 20 ºC (M = 0.63, SD = 0.09), 40 ºC (M = 0.48, SD = 0.04), and 70 ºC (M = 0.20, SD = 0.04) soak temperatures had greater average depth than those soaked for 48 h at 20 ºC (M = 0.54, SD = 0.11), 40 ºC (M = 0.43, SD = 0.20) and 70 ºC (M =0.33, SD = 0.06) soak temperatures.

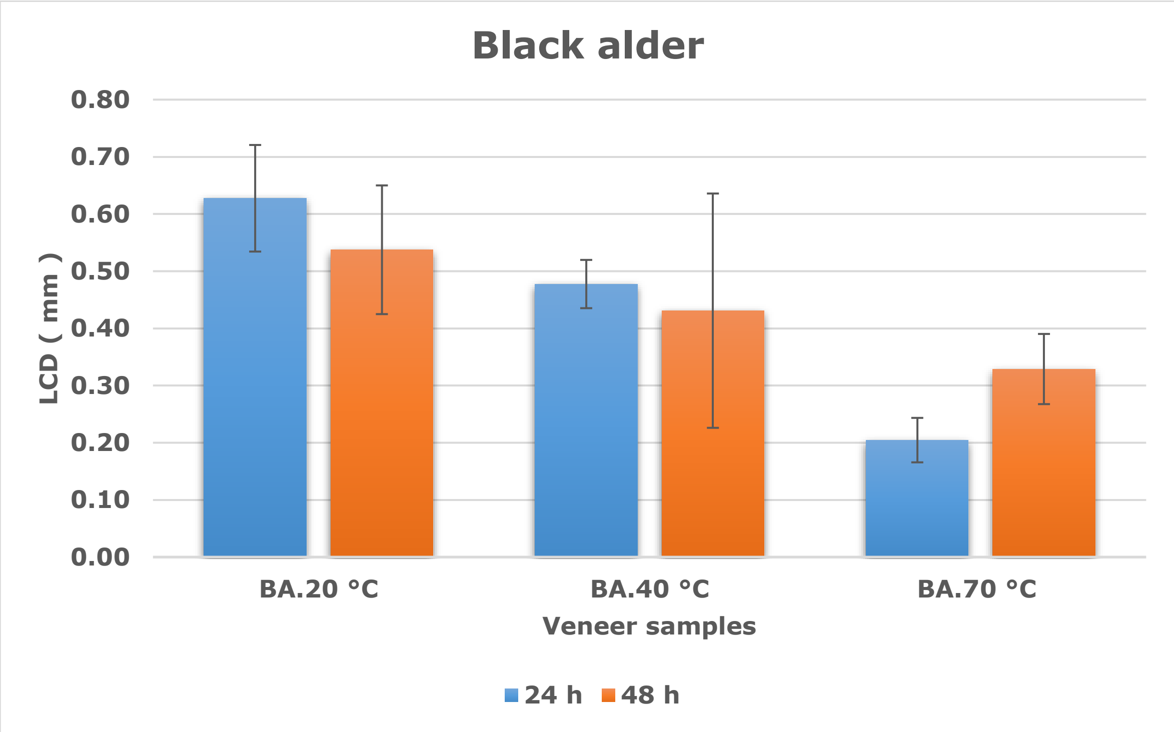

Figure 3.9. Average lathe checks depth (LCD) at different soak temperatures and soak time for black alder species.

The grey alder also showed a similar trend with a significant difference in soak time for samples soaked at 20 ºC and 40 ºC. Post hoc comparisons using the Tukey HSD test indicated that the mean LCD for samples soaked at 20 ºC (M = 0.67, SD = 0.06), (M = 0.53, SD = 0.06) 24 and 48 h respectively, had significantly higher LCD within the respective soak duration, with the soak temperature of 70 ºC (M = 0.27, SD = 0.03), (M = 0.27, SD = 0.05) 24 and 48 h respectively having the significantly lower LCD.

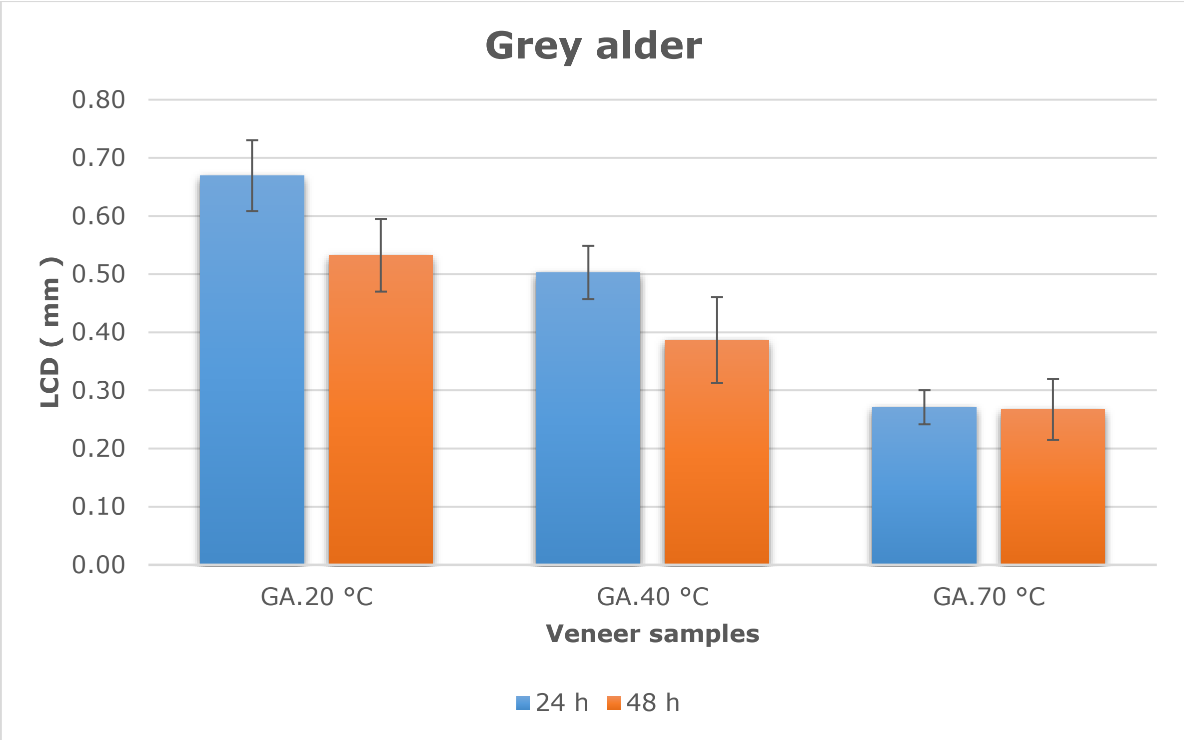

Figure 3.10. Average lathe checks depth (LCD) at different soak temperatures and soak time for grey alder species.

The results obtained for lathe checks depth is in line with what was obtained in works of literature considered (Denaud et al., 2019; Dupleix et al., 2013b; Pałubicki et al., 2010; Rahayu et al., 2016; Rohumaa et al., 2013, 2016), however, with different variation within species. As was expected, the lathe check depth of the samples soaked at 70 ºC had a minor mean lathe check depth for a given species, and this increased as the soak temperature decreased to 20 ºC. This was the same for both the 24 and 48 h soak duration. For the samples soaked at 20 ºC, the lathe checks depth was relatively easy to measure due to considerable distinct checks depth and lesser frequency of checks as against the samples soaked at 70 ºC with narrow checks depth and more significant frequency of checks within a given length of veneer (Rohumaa et al., 2017) this made it challenging to differentiate cracks on the veneer surface from the LCD.

3.3 LCD: bark versus pith

When writing this research, no literature was found that compared the lathe checks depth of the bark and the pith. However, research on the veneers from sengon and jabon wood species indicates that there is a decrease in the average frequency of lathe checks from veneer near the pith to veneer near the bark (Rahayu et al., 2016). Based on this, one could assume that this could be translated to LCD increases from veneer near the pith to veneer near the bark reason because other researches have shown that veneer with shallow checks has more frequency of checks than veneers with deeper checks (Benbrahim et al., 2020; Dupleix et al., 2013b; Pot et al., 2015).

Graphical representation of the results obtained showed inconsistent variation between the bark and the pith, contrary to the above assumption. However, a factorial ANOVA was used to compare how the LCD interacts with the veneer sheets close to the bark and close to the pith.

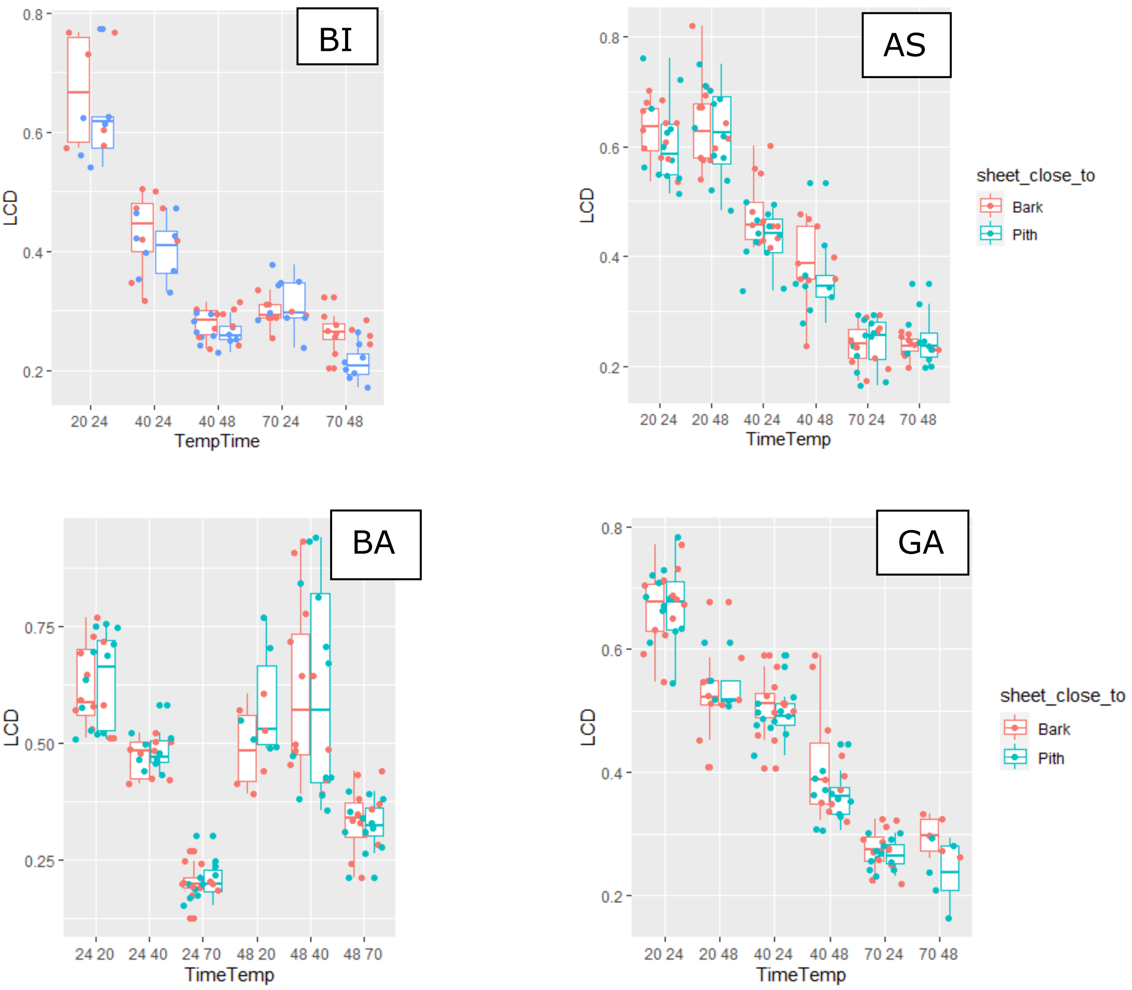

Figure 3.11. Boxplot indicating the variation of lathe checks depth (LCD) between veneer sheets close to the bark and pith at different soak temperatures and soak time.

The analysis indicates no significant difference in the LCD between the bark and pith within the log species investigated. Analysis of variance ANOVA returned values for birch ($F (4, 78) = 1.39$, $p = 0.25$), ($F (5, 109) = 2.80$, $p = 0.10$) for grey alder, ($F (5, 114) = 0.41$, $p = 0.84$) for black alder and ($F (5, 125) = 0.61$, $p = 0.69$) for aspen species. Figure 3.11 shows the boxplots from the analysis.

From the results, it could be observed that variations from bark to pith were not consistent. For instance, at 20 ºC, 24 h, for both birch and aspen species, the bark had a higher average LCD when compared to the pith. However, the reverse was the case for the black alder and grey alder species under the same conditions. Similarly, the inconsistency was also observed at 20 ºC, 48 h, with the black alder and aspen species having pith with an average LCD greater than that of the bark. A more critical observation suggests that there is more instance of the bark having a higher LCD than the pith. A clear example would be the birch species with bark having higher LCD in 80% of the sample.

3.4 Veneer tensile strength versus LCD

The result indicates the veneer crosswise tensile strength increases as the veneer lathe check depth decreases. This implies that the LCD affects the crosswise tensile strength negatively. Table 3.3 shows the summary of the correlation analysis. The analysis was done within each species with the 24 and 48 h soaked samples merged.

Table 3.3. Pearson correlation of veneer tensile strength and LCD

	Pearson Correlation	**Observations**	**df**	**P(T<=t) two-tail**
AS	-0.4869	137	136	7.24E-51
BA	-0.49904	125	124	5.52E-48
BI	-0.4082	88	87	6.45E-49
GA	-0.40052	121	120	6.59E-46

The inverse linear relationship between the crosswise tensile strength and the lathe check depth for all species is easily shown using a scatter plot.

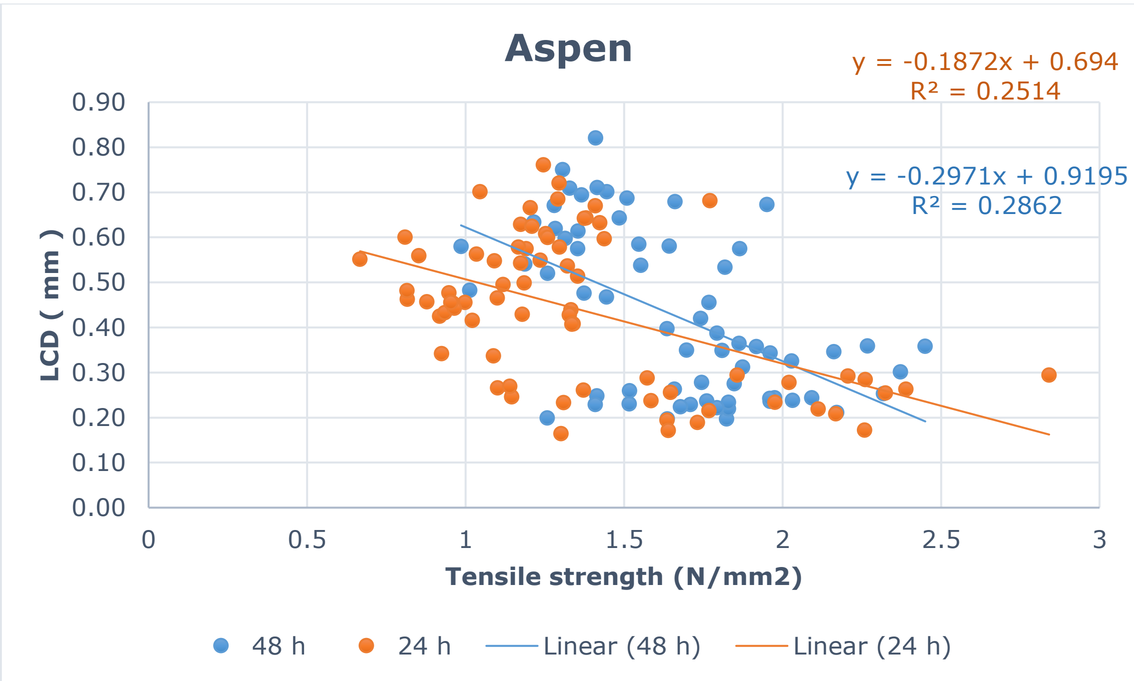

Figure 3.12. Scatter plot showing relationship LCD and tensile strength of aspen soaked for 24 and 48 h.

For the aspen species shown in Figure 3.12, the Pearson correlation of LCD and crosswise tensile strength was found to be strongly negative and statistically significant ($r = -.501$, $p < .001$) at 24 h and ($r = -.535$, $p < .001$) at 48 h soak duration.

For the birch species Figure 3.13, the Pearson correlation of LCD and crosswise tensile strength was moderately negative ($r = -.437$, $p < .001$) for the 48 h soak and strongly negative and statistically significant ($r = -.531$, $p < .001$) for the 24 h soak.

The results show that the effect of the LCD on the tensile strength for the birch species is more prominent at the lower soak duration of 24 h. The outcome can be seen from the lower tensile strength results obtained for the 24 h soaked species, as shown in Figure 3.2. The line of best fit appears to be almost parallel, suggesting that the rate at which the LCD affects the crosswise tensile strength is almost similar for both soak duration.

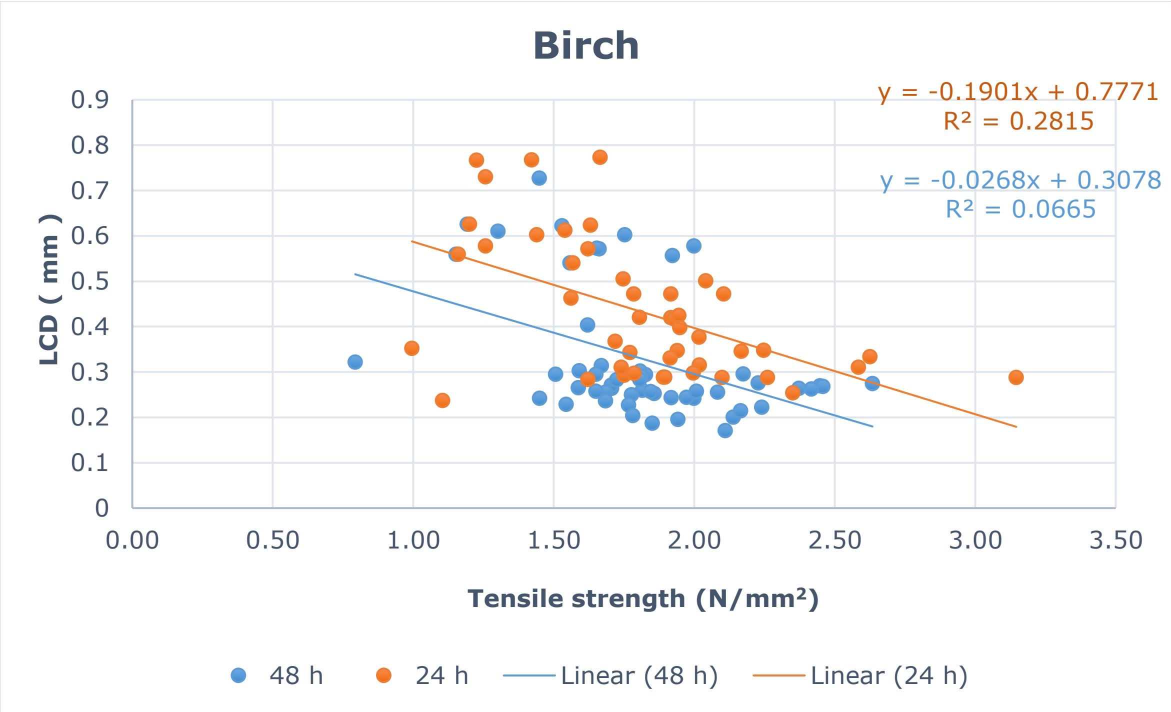

Figure 3.13. Scatter plot showing relationship LCD and tensile strength of birch soaked for 24 and 48 h.

The black alder and grey alder species also showed a statistically significant negative linear correlation in Figure 3.14 and 3.15. For the black alder the obtained Pearson correlation were negatively strong ($r = -.570$, $p < .001$) for 24 h, and ($r = -.620$, $p < .001$) for the 48 h soak duration, in contrast to the fairly negative correlation of grey alder species ($r = -.481$, $p < .001$) for 24 h and ($r = -.166$, $p < .001$) for 48 h soak duration.

This result implies that an increase in the LCD would translate into a decrease in the crosswise tensile strength of the veneer, giving rise to the production of weaker veneer. However, as the check depth decreases, the tensile strength of the veneer improves

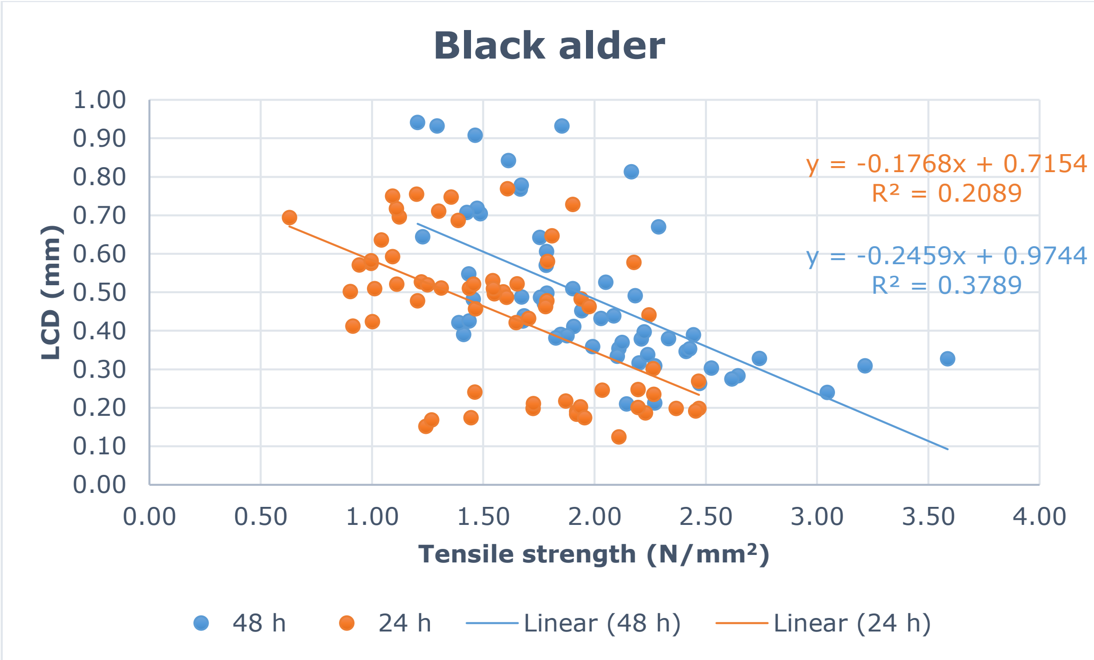

Figure 3.14. Scatter plot showing relationship LCD and tensile strength of black alder soaked for 24 and 48 h.

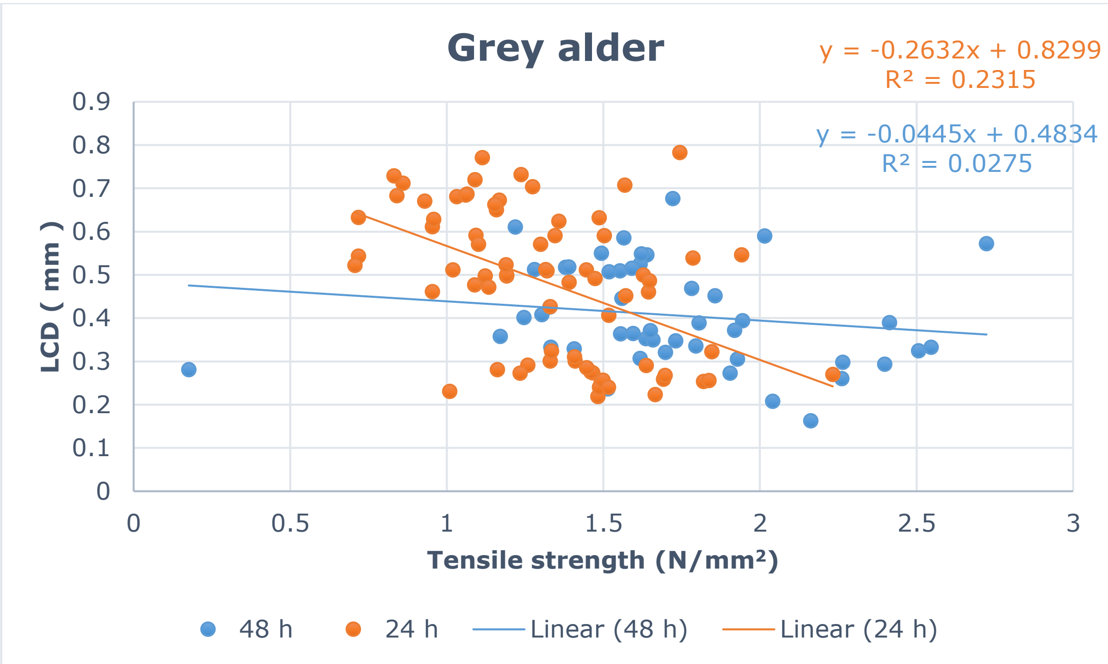

Figure 3.15. Scatter plot showing relationship LCD and tensile strength of grey alder soaked for 24 and 48 h.

Unlike the birch and black alder species, the rate at which the LCD affects the crosswise tensile strength is much higher, and this can be seen in the steepness of the line of best fit of the scatter plot.

The correlation indicates that, as the veneer lathe check depth increases, the crosswise tensile strength of the veneer decreases, since it was established in this study that the lathe check depth decreases as the temperature increases from 20 ºC to 70 ºC, similar to the work (Denaud et al., 2019; Rohumaa et al., 2017) the result supports conclusions in studies that suggest that the strength property is negatively affected by the development of lathe checks.

CONCLUSION

This study looked at a necessary veneer processing procedure, "log soaking," and its influence on the veneer crosswise tensile strength and the propagation of veneer lathe checks on four Estonian hardwoods. An optimum temperature of soaking would be challenging to define based on the results obtained. However, compared to other literature, the breakthrough in this study is the combined conditions of soak temperature (20 °C, 40 °C, and 70 °C) and soak duration (24 and 48 h) and relying on the combination of veneer crosswise tensile strength and veneer lathe check depth to define the effect log soaking temperature before peeling has on the veneer produced. For all the set processing conditions, the species had crosswise tensile strength greater than 1.2 N/mm^2.

Soaking the log species at the temperature of 70 °C produced veneers with checks that are close together with smaller depth than the lower soaking temperature of 40 °C and 20 °C that produce veneers with more profound and more widely spaced-out checks.

The 48 h logs soaked at 70 °C on all species produced the highest set of crosswise tensile strength results compared to the same species soaked at 40 and 20 °C and an identifiable decrease in strength from 40 to 20 °C. This trend is similar to what was obtained for samples soaked for 24 h, with the strength decreasing from the maximum at 70 °C to 20 °C. The duration of soaking is a factor that affected the crosswise tensile strength of the logs positively. Logs soaked for 48 h have better crosswise tensile strength than those soaked for 24 h across the temperature set and species used in this study. The significance of the difference is higher as the soak temperature is reduced.

It is very clear from the result that veneer lathe check depth is affected by the soaking temperature and soak duration. The lathe check depth is at the minimum level at a soaking temperature of 70 °C and increases from 40 °C to 20 °C, with further reduction when the soak duration increases from 24 h to 48 h. This trend translates to the effect soak temperature has on veneer crosswise tensile strength, the more profound the checks, the lesser the strength of the veneer.

Analysing each species indicates there is a varying negative linear correlation between LCD and veneer tensile strength. This negative correlation is why it is required to heat the logs, thus reducing the lathe check depth and improving the tensile strength.

The results suggest no significant difference in LCD between the bark and pith within the species in this study.

Since it is not easy to make this kind of measurement in the industry, makes this study an important one. Though the study was made in a laboratory condition, the peeling equipment and soaking condition was up to industry standard. However, the downside of measuring the LCD with the method in this study is that it is laborious and consumed much time, and as the temperature increases and checks decrease, it becomes even more challenging to recognise the checks. An alternative would be to use the SMOF described in the literature review.

Further work could establish a significant difference at the temperature of 50 to 60 ^{o}C, as this could conserve energy for industries if higher veneer strength is a factor for the production.

SUMMARY

Rotary peeled veneers are known to develop lathe checks that affect their strength properties. Soaking green wood before peeling is one way of reducing the lathe checks and improving the veneer strength. This study investigates the effect log soaking temperature has on the crosswise tensile strength of veneer and the development of veneer lathe checks by soaking aspen, birch, black alder, and grey alder hardwood species at temperatures of 20 ºC, 40 ºC and 70 ºC for the duration of 24 and 48 h and investigate for changes from bark to the pith, conditions with the best tensile strength and the effect lathe check depth have on veneer crosswise tensile strength.

Veneers of 1.5 mm peeled with an industrial lathe were used for the investigation. A crosswise tensile strength test was performed on the freshly peeled veneers, and the lathe check depth of veneer sheets close to the bark and pith of the logs was measured from images captured with the aid of a microscope. The cutting plan for the lathe check depth samples was such that it would be exactly from the same region as the samples for the crosswise tensile strength.

The study results indicated that the tensile strength improves as the temperature increases from 20 ºC to 70 ºC, and this is negatively correlated to the veneer lathe checks depth (LCD) that decreases from 20 ºC to 70 ºC. At 40 ºC, there is already a significant increase in the crosswise tensile strength, stressing the importance the heating of logs before peeling has on the strength of veneers. The comparison of the bark and pith showed no significant difference in the mean lathe check depth.

Generally, it appears that the LCD is decreased by the increase in temperature and longer soak duration. This, in turn, results in the production of veneer with higher crosswise tensile strength. The interaction between the bark and the pith of the species was not significant enough to be considered a difference when the LCD is the factor of the comparison.

KOKKUVÕTE

Spooni treimisel tekivad spooni alumisele pinnale treilõhed, mis mõjutavad spooni tugevusomadusi. Treilõhede vähendamiseks kasutatakse näiteks palkide leotamist erinevatel temperatuuridel. Magistritöös uuritakse palgi leotustemperatuuri leotuse aja mõju spooni risttõmbetugevusele ja treilõhede tekkele kase, sanglepa, hall lepa ja haava puuliikidest valmistatud spoonile. Töös kasutatavateks leotustemperatuurideks on 20ºC, 40ºC ja 70ºC ja leotusajaks 24 ja 48 tundi. Tulemustes võrreldi treilõhede muutusi koorealusest osast palgi südamikuni.

Lõputöös treiti tööstusliku spoonitreipiniga 1,5 mm paksused spooned. Kohe peale spooni treimist tehti märgadele spoonidele risttõmbetugevuse katsed. Treilõhede sügavused koorealuses puidus ja palgi südamiku puidust mõõdati mikroskoobi all. Treilõhede sügavuse katsekehad võeti täpselt samast kohast, kust võeti risttõmbetugevuse katsekehad, et oleks võimalik välja tuua seoseid risttõmbetugevuse ja treilõhede sügavuse vahel.

Lõputöö tulemused näitasid, et spooni risttõmbetugevus paraneb, kui palgi leotustemperatuur tõuseb 20°C-lt 70°C-ni, ja see on negatiivses korrelatsioonis spooni treilõhede sügavusega (LCD), mis langeb 20°C-lt 70°C-ni. 40°C juures on risttõmbetugevus juba märkimisväärselt suurenenud, mis näitab, et palkide leotamine enne spooni treimist on oluline etapp. Palgi koorealuse spooni ja südamiku spooni omavahelise võrdluses ei olnud näha olulisi erinevusi treilõhede sügavuses.

Kokkuvõtteks võib välja tuua, et spooni treilõhede sügavus väheneb palgi leotustemperatuuri ja aja kasvades. Selle tulemuseks on omakorda suurema risttõmbetugevusega spoon. Lisaks leiti, et koorealuse spooni ja palgi südamikuspooni treilõhede sügavuses ei olnud erinevusi.

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Appendix 1 Aspen samples soaked for 20 °C, 24 h

Table 0.1. Aspen samples soaked for 20 °C, 24 h.

Sample Code	sheet close to	sheet	Samples	Log Number	tensile strength(N/mm^2)	LCD
1/AS/1/20/24	Bark	1	T1	P1	1.32	0.536
1/AS/1/20/24	Bark	1	T2	P1	1.77	0.681
1/AS/1/20/24	Bark	1	T3	P1	1.38	0.643
1/AS/1/20/24	Bark	1	T4	P1	1.20	0.665
1/AS/1/20/24	Bark	1	T5	P1	1.38	0.642
1/AS/1/20/24	Bark	1	T6	P1	1.25	0.608
1/AS/2/20/24		2	T1	P1	1.18	
1/AS/2/20/24		2	T2	P1	1.30	
1/AS/2/20/24		2	T3	P1	1.18	
1/AS/2/20/24		2	T4	P1	1.11	
1/AS/2/20/24		2	T5	P1	1.13	
1/AS/2/20/24		2	T6	P1	1.30	
1/AS/3/20/24	Pith	3	T1	P1	1.35	0.514
1/AS/3/20/24	Pith	3	T2	P1	1.09	0.548
1/AS/3/20/24	Pith	3	T3	P1	1.25	0.761
1/AS/3/20/24	Pith	3	T4	P1	1.19	0.574
1/AS/3/20/24	Pith	3	T5	P1	1.30	0.721
1/AS/3/20/24	Pith	3	T6	P1	1.42	0.633
2/AS/1/20/24	Bark	1	T1	P2	1.44	0.597
2/AS/1/20/24	Bark	1	T2	P2	1.30	0.579
2/AS/1/20/24	Bark	1	T3	P2	1.29	0.685
2/AS/1/20/24	Bark	1	T4	P2	1.17	0.629
2/AS/1/20/24	Bark	1	T5	P2	1.05	0.701
2/AS/1/20/24	Bark	1	T6	P2	1.17	0.578
2/AS/2/20/24		2	T1	P2	1.23	
2/AS/2/20/24		2	T2	P2	1.19	
2/AS/2/20/24		2	T3	P2	1.61	
2/AS/2/20/24		2	T4	P2	1.01	
2/AS/2/20/24		2	T5	P2	1.09	
2/AS/2/20/24		2	T6	P2	1.14	
2/AS/3/20/24	Pith	3	T1	P2	1.24	0.549
2/AS/3/20/24	Pith	3	T2	P2	1.21	0.625
2/AS/3/20/24	Pith	3	T3	P2	1.17	0.543
2/AS/3/20/24	Pith	3	T4	P2	1.03	0.563
2/AS/3/20/24	Pith	3	T5	P2	1.26	0.600
2/AS/3/20/24	Pith	3	T6	P2	1.41	0.670

Appendix 2 Aspen samples soaked for 40 ºC, 24 h

Table 0.2. Aspen samples soaked for 40 ºC, 24 h.

Sample Code	sheet close to	sheet	Samples	Log Number	tensile strength (N/mm^2)	LCD
2/AS/1/40/24	Bark	1	T1	P2	1.00	0.455
2/AS/1/40/24	Bark	1	T2	P2	0.92	0.425
2/AS/1/40/24	Bark	1	T3	P2	1.02	0.416
2/AS/1/40/24	Bark	1	T4	P2	0.82	0.463
2/AS/1/40/24	Bark	1	T5	P2	0.93	0.433
2/AS/1/40/24	Bark	1	T6	P2	1.18	0.429
2/AS/2/40/24		2	T1	P2	1.09	
2/AS/2/40/24		2	T2	P2	1.14	
2/AS/2/40/24		2	T3	P2	1.04	
2/AS/2/40/24		2	T4	P2	0.86	
2/AS/2/40/24		2	T5	P2	0.80	
2/AS/2/40/24		2	T6	P2	1.06	
2/AS/3/40/24	Pith	3	T1	P2	1.33	0.439
2/AS/3/40/24	Pith	3	T2	P2	1.18	0.498
2/AS/3/40/24	Pith	3	T3	P2	0.92	0.342
2/AS/3/40/24	Pith	3	T4	P2	1.33	0.427
2/AS/3/40/24	Pith	3	T5	P2	1.09	0.337
2/AS/3/40/24	Pith	3	T6	P2	0.95	0.477
1/AS/1/40/24	Bark	1	T1	P1	0.85	0.559
1/AS/1/40/24	Bark	1	T2	P1	0.81	0.601
1/AS/1/40/24	Bark	1	T3	P1	0.88	0.457
1/AS/1/40/24	Bark	1	T4	P1	0.67	0.552
1/AS/1/40/24	Bark	1	T5	P1	0.82	0.482
1/AS/1/40/24	Bark	1	T6	P1	0.96	0.454
1/AS/2/40/24		2	T1	P1	1.02	
1/AS/2/40/24		2	T2	P1	0.99	
1/AS/2/40/24		2	T3	P1	0.96	
1/AS/2/40/24		2	T4	P1	0.77	
1/AS/2/40/24		2	T5	P1	0.75	
1/AS/2/40/24		2	T6	P1	0.98	
1/AS/3/40/24	Pith	3	T1	P1	1.34	0.408
1/AS/3/40/24	Pith	3	T2	P1	1.10	0.465
1/AS/3/40/24	Pith	3	T3	P1	0.97	0.443
1/AS/3/40/24	Pith	3	T4	P1	1.34	0.407
1/AS/3/40/24	Pith	3	T5	P1	1.12	0.495
1/AS/3/40/24	Pith	3	T6	P1	0.95	0.455

Appendix 3 Aspen samples soaked for 70 ºC, 24 h

Table 0.3. Aspen samples soaked for 70 ºC, 24 h.

Sample Code	sheet close to	sheet	Samples	Log Number	tensile strength (N/mm^2)	LCD
1/AS/1/70/24	Bark	1	T1	P1	1.98	0.234
1/AS/1/70/24	Bark	1	T2	P1	1.57	0.288
1/AS/1/70/24	Bark	1	T3	P1	1.15	0.246
1/AS/1/70/24	Bark	1	T4	P1	1.64	0.194
1/AS/1/70/24	Bark	1	T5	P1	2.84	0.294
1/AS/1/70/24	Bark	1	T6	P1	1.77	0.215
1/AS/2/70/24		2	T1	P1	1.58	
1/AS/2/70/24		2	T2	P1	2.30	
1/AS/2/70/24		2	T3	P1	2.29	
1/AS/2/70/24		2	T4	P1	1.78	
1/AS/2/70/24		2	T5	P1	1.24	
1/AS/2/70/24		2	T6	P1	1.93	
1/AS/3/70/24	Pith	3	T1	P1	1.30	0.164
1/AS/3/70/24	Pith	3	T2	P1	1.86	0.294
1/AS/3/70/24	Pith	3	T3	P1	2.32	0.254
1/AS/3/70/24	Pith	3	T4	P1	1.58	0.237
1/AS/3/70/24	Pith	3	T5	P1	2.21	0.292
1/AS/3/70/24	Pith	3	T6	P1	1.73	0.189
2/AS/1/70/24	Bark	1	T1	P2	1.31	0.233
2/AS/1/70/24	Bark	1	T2	P2	2.39	0.263
2/AS/1/70/24	Bark	1	T3	P2	2.17	0.208
2/AS/1/70/24	Bark	1	T4	P2	1.10	0.266
2/AS/1/70/24	Bark	1	T5	P2	2.26	0.172
2/AS/1/70/24	Bark	1	T6	P2	1.14	0.269
2/AS/2/70/24		2	T1	P2	2.01	
2/AS/2/70/24		2	T2	P2	1.45	
2/AS/2/70/24		2	T3	P2	1.00	
2/AS/2/70/24		2	T4	P2	1.29	
2/AS/2/70/24		2	T5	P2	2.70	
2/AS/2/70/24		2	T6	P2	2.01	
2/AS/3/70/24	Pith	3	T1	P2	1.64	0.171
2/AS/3/70/24	Pith	3	T2	P2	1.37	0.261
2/AS/3/70/24	Pith	3	T3	P2	2.02	0.278
2/AS/3/70/24	Pith	3	T4	P2	1.65	0.256
2/AS/3/70/24	Pith	3	T5	P2	2.26	0.284
2/AS/3/70/24	Pith	3	T6	P2	2.11	0.219

Appendix 4 Aspen samples soaked for 20 °C, 48 h

Table 0.4. Aspen samples soaked for 20 °C, 48 h.

Sample Code	Sheet close to	Sheet	Samples	Log number	Tensile strength(N/mm^2)	LCD
15/AS/10/20/48	Bark	10	T1	P15	1.64	0.58
15/AS/10/20/48	Bark	10	T2	P15	1.49	0.64
15/AS/10/20/48	Bark	10	T3	P15	1.41	0.82
15/AS/10/20/48	Bark	10	T4	P15	1.35	0.57
15/AS/10/20/48	Bark	10	T5	P15	1.28	0.67
15/AS/10/20/48	Bark	10	T6	P15	1.19	0.54
15/AS/17/20/48		17	T1	P15	1.54	
15/AS/17/20/48		17	T2	P15	1.59	
15/AS/17/20/48		17	T3	P15	1.53	
15/AS/17/20/48		17	T4	P15	1.34	
15/AS/17/20/48		17	T5	P15	1.29	
15/AS/17/20/48		17	T6	P15	1.44	
15/AS/28/20/48		28	T1	P15	1.13	
15/AS/28/20/48		28	T2	P15	1.20	
15/AS/28/20/48		28	T3	P15	1.11	
15/AS/28/20/48		28	T5	P15	1.67	
15/AS/28/20/48		28	T6	P15	1.34	
15/AS/40/20/48		40	T2	P15	1.15	
15/AS/40/20/48		40	T3	P15	1.17	
15/AS/40/20/48		40	T4	P15	1.32	
15/AS/40/20/48		40	T5	P15	1.42	
15/AS/40/20/48		40	T6	P15	1.40	
15/AS/50/20/48	Pith	50	T1	P15	0.99	0.58
15/AS/50/20/48	Pith	50	T2	P15	1.22	0.63
15/AS/50/20/48	Pith	50	T3	P15	1.01	0.48
15/AS/50/20/48	Pith	50	T4	P15	1.55	0.58
15/AS/50/20/48	Pith	50	T5	P15	1.55	0.54
15/AS/50/20/48	Pith	50	T6	P15	1.66	0.68
16/AS/1/20/48	Bark	1	T1	P16	1.35	0.61
16/AS/1/20/48	Bark	1	T2	P16	1.95	0.67
16/AS/1/20/48	Bark	1	T3	P16	1.37	0.69
16/AS/1/20/48	Bark	1	T4	P16	1.31	0.60
16/AS/1/20/48	Bark	1	T5	P16	1.86	0.58
16/AS/1/20/48	Bark	1	T6	P16	1.33	0.71
16/AS/6/20/48		6	T1	P16	1.52	
16/AS/6/20/48		6	T2	P16	1.33	
16/AS/6/20/48		6	T3	P16	1.45	
16/AS/6/20/48		6	T4	P16	1.55	
16/AS/6/20/48		6	T5	P16	1.13	
16/AS/6/20/48		6	T6	P16	1.37	
16/AS/13/20/48		13	T1	P16	1.55	

16/AS/13/20/48		13	T2	P16	1.44	
16/AS/13/20/48		13	T3	P16	1.41	
16/AS/13/20/48		13	T4	P16	1.58	
16/AS/13/20/48		13	T5	P16	1.30	
16/AS/13/20/48		13	T6	P16	1.45	
16/AS/20/20/48		20	T1	P16	1.59	
16/AS/20/20/48		20	T2	P16	1.34	
16/AS/20/20/48		20	T3	P16	1.54	
16/AS/20/20/48		20	T4	P16	1.39	
16/AS/20/20/48		20	T5	P16	1.36	
16/AS/20/20/48		20	T6	P16	1.37	
16/AS/26/20/48		26	T1	P16	1.37	
16/AS/26/20/48		26	T2	P16	1.41	
16/AS/26/20/48		26	T3	P16	1.04	
16/AS/26/20/48		26	T4	P16	1.18	
16/AS/26/20/48		26	T5	P16	1.24	
16/AS/26/20/48		26	T6	P16	1.26	
16/AS/34/20/48	Pith	34	T1	P16	1.45	0.70
16/AS/34/20/48	Pith	34	T2	P16	1.42	0.71
16/AS/34/20/48	Pith	34	T3	P16	1.51	0.69
16/AS/34/20/48	Pith	34	T4	P16	1.28	0.62
16/AS/34/20/48	Pith	34	T5	P16	1.26	0.52
16/AS/34/20/48	Pith	34	T6	P16	1.31	0.75

Appendix 5 Aspen samples soaked for 40 °C,48 h

Table 0.5. Aspen samples soaked for 40 °C, 48 h.

Sample Code	Sheet close to	Sheet	Samples	Log number	Tensile Strength (N/mm^2)	LCD
11/AS/1/40/48	Bark	1	T1	P11	1.96	0.24
11/AS/1/40/48	Bark	1	T4	P11	2.45	0.36
11/AS/1/40/48	Bark	1	T5	P11	2.27	0.36
11/AS/5/40/48		5	T1	P11	2.40	
11/AS/5/40/48		5	T2	P11	2.40	
11/AS/5/40/48		5	T3	P11	1.98	
11/AS/5/40/48		5	T4	P11	1.84	
11/AS/9/40/48		9	T2	P11	2.07	
11/AS/9/40/48		9	T3	P11	2.05	
11/AS/9/40/48		9	T4	P11	2.35	
11/AS/9/40/48		9	T5	P11	2.27	
11/AS/15/40/48		15	T1	P11	1.58	
11/AS/15/40/48		15	T4	P11	1.88	
11/AS/15/40/48		15	T5	P11	1.96	
11/AS/15/40/48		15	T6	P11	2.36	
11/AS/20/40/48		20	T1	P11	1.80	
11/AS/20/40/48		20	T2	P11	1.80	
11/AS/20/40/48		20	T5	P11	2.36	
11/AS/20/40/48		20	T6	P11	2.15	
11/AS/25/40/48		25	T1	P11	2.17	
11/AS/25/40/48		25	T4	P11	1.85	
11/AS/25/40/48		25	T5	P11	1.98	
11/AS/25/40/48		25	T6	P11	2.17	
11/AS/30/40/48		30	T4	P11	1.92	
11/AS/30/40/48		30	T5	P11	2.04	
11/AS/30/40/48		30	T6	P11	1.78	
11/AS/35/40/48	Pith	35	T4	P11	1.81	0.35
11/AS/35/40/48	Pith	35	T5	P11	1.96	0.34
11/AS/35/40/48	Pith	35	T6	P11	1.74	0.42
9/AS/15/40/48	Bark	15	T1	P9	1.37	0.48
9/AS/15/40/48	Bark	15	T2	P9	1.79	0.39
9/AS/15/40/48	Bark	15	T3	P9	1.44	0.47
9/AS/15/40/48	Bark	15	T4	P9	1.92	0.36
9/AS/15/40/48	Bark	15	T5	P9	1.64	0.40
9/AS/15/40/48	Bark	15	T6	P9	1.77	0.46
9/AS/25/40/48		25	T1	P9	1.20	
9/AS/25/40/48		25	T2	P9	1.65	
9/AS/25/40/48		25	T3	P9	1.49	
9/AS/25/40/48		25	T4	P9	1.82	
9/AS/25/40/48		25	T5	P9	1.74	
9/AS/25/40/48		25	T6	P9	1.74	

9/AS/5/40/48		5	T1	P9	1.24	
9/AS/5/40/48		5	T2	P9	1.88	
9/AS/5/40/48		5	T3	P9	1.41	
9/AS/5/40/48		5	T4	P9	1.44	
9/AS/5/40/48		5	T5	P9	1.70	
9/AS/5/40/48		5	T6	P9	2.05	
9/AS/35/40/48		35	T1	P9	1.64	
9/AS/35/40/48		35	T2	P9	1.49	
9/AS/35/40/48		35	T3	P9	1.54	
9/AS/35/40/48		35	T4	P9	1.54	
9/AS/35/40/48		35	T5	P9	1.74	
9/AS/35/40/48		35	T6	P9	1.96	
9/AS/48/40/48		48	T1	P9	1.51	
9/AS/48/40/48		48	T2	P9	1.74	
9/AS/48/40/48		48	T3	P9	1.49	
9/AS/48/40/48		48	T4	P9	1.91	
9/AS/48/40/48		48	T5	P9	2.02	
9/AS/48/40/48		48	T6	P9	1.65	
9/AS/55/40/48		55	T1	P9	1.37	
9/AS/55/40/48		55	T2	P9	1.82	
9/AS/55/40/48		55	T3	P9	1.76	
9/AS/55/40/48		55	T4	P9	2.29	
9/AS/55/40/48		55	T5	P9	2.09	
9/AS/55/40/48		55	T6	P9	2.47	
9/AS/65/40/48	Pith	65	T1	P9	2.37	0.30
9/AS/65/40/48	Pith	65	T2	P9	2.03	0.33
9/AS/65/40/48	Pith	65	T3	P9	1.82	0.53
9/AS/65/40/48	Pith	65	T4	P9	1.86	0.36
9/AS/65/40/48	Pith	65	T5	P9	2.16	0.35
9/AS/65/40/48	Pith	65	T6	P9	1.75	0.28

Appendix 6 Aspen samples soaked for 70 °C,48 h

Table 0.6. Aspen samples soaked for 70 °C, 48 h.

Sample Code	Sheet close to	Sheet	Samples	Log number	tensile strength(N/mm^2)	LCD
20/AS/50/70/48	Bark	50	T1	P20	1.82	0.20
20/AS/50/70/48	Bark	50	T2	P20	1.83	0.22
20/AS/50/70/48	Bark	50	T3	P20	1.83	0.23
20/AS/50/70/48	Bark	50	T4	P20	1.98	0.24
20/AS/50/70/48	Bark	50	T5	P20	2.32	0.25
20/AS/50/70/48	Bark	50	T6	P20	2.03	0.24
20/AS/82/70/48		82	T1	P20	1.84	
20/AS/82/70/48		82	T2	P20	1.62	
20/AS/82/70/48		82	T3	P20	2.11	
20/AS/82/70/48		82	T4	P20	1.84	
20/AS/82/70/48		82	T5	P20	1.83	
20/AS/82/70/48		82	T6	P20	1.87	
20/AS/101/70/48	Pith	101	T1	P20	1.64	0.20
20/AS/101/70/48	Pith	101	T2	P20	1.76	0.24
20/AS/101/70/48	Pith	101	T3	P20	1.70	0.35
20/AS/101/70/48	Pith	101	T4	P20	1.26	0.20
20/AS/101/70/48	Pith	101	T5	P20	1.87	0.31
20/AS/101/70/48	Pith	101	T6	P20	1.85	0.28
19/AS/6/70/48	Bark	6	T1	P19	1.66	0.26
19/AS/6/70/48	Bark	6	T2	P19	1.79	0.22
19/AS/6/70/48	Bark	6	T3	P19	1.52	0.23
19/AS/6/70/48	Bark	6	T4	P19	1.41	0.25
19/AS/6/70/48	Bark	6	T5	P19	1.41	0.23
19/AS/6/70/48	Bark	6	T6	P19	1.52	0.26
19/AS/26/70/48		26	T2	P19	1.90	
19/AS/26/70/48		26	T3	P19	1.68	
19/AS/26/70/48		26	T4	P19	1.93	
19/AS/26/70/48		26	T5	P19	1.82	
19/AS/26/70/48		26	T6	P19	1.94	
19/AS/31/70/48		31	T1	P19	1.98	
19/AS/31/70/48		31	T2	P19	1.79	
19/AS/31/70/48		31	T3	P19	1.89	
19/AS/31/70/48		31	T4	P19	2.02	
19/AS/31/70/48		31	T6	P19	1.99	
19/AS/43/70/48		43	T1	P19	1.91	
19/AS/43/70/48		43	T2	P19	1.68	
19/AS/43/70/48		43	T3	P19	2.00	
19/AS/43/70/48		43	T4	P19	1.80	
19/AS/43/70/48		43	T5	P19	2.01	
19/AS/43/70/48		43	T6	P19	2.49	
19/AS/47/70/48		47	T1	P19	1.83	

19/AS/47/70/48		47	T2	P19	1.88	
19/AS/47/70/48		47	T3	P19	1.54	
19/AS/47/70/48		47	T4	P19	1.49	
19/AS/47/70/48		47	T5	P19	1.87	
19/AS/47/70/48		47	T6	P19	1.95	
19/AS/62/70/48	Pith	62	T2	P19	1.71	0.23
19/AS/62/70/48	Pith	62	T3	P19	2.09	0.24
19/AS/62/70/48	Pith	62	T4	P19	2.17	0.21
19/AS/62/70/48	Pith	62	T5	P19	1.96	0.24
19/AS/62/70/48	Pith	62	T6	P19	1.68	0.22

Appendix 7 Black alder samples soaked for 20 °C, 24 h

Table 0.7. Black alder samples soaked for 20 °C, 24 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm^2)	LCD
1/BA/1/20/24	Bark	1	T1	P1	1.90	0.728
1/BA/1/20/24	Bark	1	T2	P1	1.79	0.580
1/BA/1/20/24	Bark	1	T3	P1	1.54	0.530
1/BA/1/20/24	Bark	1	T4	P1	1.81	0.647
1/BA/1/20/24	Bark	1	T5	P1	1.61	0.769
1/BA/1/20/24	Bark	1	T6	P1	2.18	0.578
1/BA/3/20/24	Pith	3	T1	P1	1.04	0.636
1/BA/3/20/24	Pith	3	T2	P1	1.22	0.527
1/BA/3/20/24	Pith	3	T3	P1	1.01	0.509
1/BA/3/20/24	Pith	3	T4	P1	1.00	0.575
1/BA/3/20/24	Pith	3	T5	P1	1.30	0.711
1/BA/3/20/24	Pith	3	T6	P1	1.12	0.696
2/BA/1/20/24	Bark	1	T1	P2	0.63	0.694
2/BA/1/20/24	Bark	1	T2	P2	1.44	0.510
2/BA/1/20/24	Bark	1	T3	P2	1.11	0.717
2/BA/1/20/24	Bark	1	T4	P2	1.09	0.593
2/BA/1/20/24	Bark	1	T5	P2	1.31	0.511
2/BA/1/20/24	Bark	1	T6	P2	0.94	0.571
2/BA/3/20/24	Pith	3	T1	P2	1.20	0.755
2/BA/3/20/24	Pith	3	T2	P2	1.36	0.747
2/BA/3/20/24	Pith	3	T3	P2	1.25	0.519
2/BA/3/20/24	Pith	3	T4	P2	1.09	0.750
2/BA/3/20/24	Pith	3	T5	P2	1.39	0.687
1/BA/3/20/24	Pith	3	T6	P2	1.46	0.521
1/BA/2/20/24		2	T1	P1	1.25	
1/BA/2/20/24		2	T2	P1	1.20	
1/BA/2/20/24		2	T3	P1	1.27	
1/BA/2/20/24		2	T4	P1	1.41	
1/BA/2/20/24		2	T5	P1	1.17	
1/BA/2/20/24		2	T6	P1	1.53	
2/BA/2/20/24		2	T1	P2	1.40	
2/BA/2/20/24		2	T2	P2	1.81	
2/BA/2/20/24		2	T3	P2	1.24	
2/BA/2/20/24		2	T4	P2	1.37	
2/BA/2/20/24		2	T5	P2	1.26	
2/BA/2/20/24		2	T6	P2	1.25	

Appendix 8 Black alder samples soaked for 40 °C, 24 h

Table 0.8. Black alder samples soaked for 40 °C, 24 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm²)	LCD
2/BA/1/40/24	Bark	1	T1	P2	0.90	0.502
2/BA/1/40/24	Bark	1	T2	P2	1.94	0.483
2/BA/1/40/24	Bark	1	T3	P2	1.65	0.421
2/BA/3/40/24	Pith	3	T1	P2	1.70	0.432
2/BA/3/40/24	Pith	3	T2	P2	1.79	0.478
2/BA/3/40/24	Pith	3	T3	P2	1.65	0.522
2/BA/3/40/24	Pith	3	T4	P2	1.47	0.457
1/BA/1/40/24	Bark	1	T1	P1	1.20	0.478
1/BA/1/40/24	Bark	1	T2	P1	0.91	0.412
1/BA/1/40/24	Bark	1	T3	P1	1.11	0.521
1/BA/1/40/24	Bark	1	T4	P1	1.59	0.501
1/BA/1/40/24	Bark	1	T5	P1	1.61	0.487
1/BA/1/40/24	Bark	1	T6	P1	1.00	0.424
1/BA/3/40/24	Pith	3	T1	P1	1.00	0.582
2/BA/2/40/24		2	T1	P2	1.76	
2/BA/2/40/24		2	T2	P2	1.20	
2/BA/2/40/24		2	T3	P2	1.22	
1/BA/3/40/24	Pith	3	T2	P1	1.55	0.496
1/BA/3/40/24	Pith	3	T3	P1	1.55	0.510
1/BA/3/40/24	Pith	3	T4	P1	2.25	0.441
1/BA/3/40/24	Pith	3	T5	P1	1.78	0.463
1/BA/2/40/24		2	T1	P1	1.57	
1/BA/2/40/24		2	T2	P1	1.32	
1/BA/2/40/24		2	T3	P1	1.53	
1/BA/2/40/24		2	T4	P1	1.83	
1/BA/2/40/24		2	T5	P1	1.82	
1/BA/2/40/24		2	T6	P1	2.19	
1/AS/3/40/24	Pith	3	T6	P1	1.98	0.463

Appendix 9 Black alder samples soaked for 70 °C, 24 h

Table 0.9. Black alder samples soaked for 70 °C, 24 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm^2)	LCD, mm
2/BA/2/70/24		2	T1	P2	1.95	
2/BA/2/70/24		2	T2	P2	1.48	
2/BA/2/70/24		2	T3	P2	2.15	
2/BA/2/70/24		2	T4	P2	1.89	
2/BA/2/70/24		2	T5	P2	2.11	
2/BA/2/70/24		2	T6	P2	1.37	
2/BA/1/70/24		2	T1	P1	2.07	
2/BA/1/70/24		2	T2	P1	2.63	
2/BA/1/70/24		2	T3	P1	2.11	
2/BA/1/70/24		2	T4	P1	1.96	
2/BA/1/70/24		2	T5	P1	1.96	
2/BA/1/70/24		2	T6	P1	2.26	
2/BA/1/70/24	Bark	1	T1	P2	2.47	0.269
2/BA/1/70/24	Bark	1	T2	P2	2.04	0.246
2/BA/1/70/24	Bark	1	T3	P2	1.46	0.241
2/BA/1/70/24	Bark	1	T4	P2	1.92	0.190
2/BA/1/70/24	Bark	1	T5	P2	1.45	0.174
2/BA/1/70/24	Bark	1	T6	P2	1.92	0.183
2/BA/3/70/24	Pith	3	T1	P2	2.27	0.235
2/BA/3/70/24	Pith	3	T2	P2	1.87	0.217
2/BA/3/70/24	Pith	3	T3	P2	2.20	0.247
2/BA/3/70/24	Pith	3	T4	P2	2.23	0.187
2/BA/3/70/24	Pith	3	T5	P2	2.26	0.301
2/BA/3/70/24	Pith	3	T6	P2	2.37	0.198
1/BA/1/70/24	Bark	1	T1	P1	0.00	0.198
1/BA/1/70/24	Bark	1	T2	P1	2.47	0.198
1/BA/1/70/24	Bark	1	T3	P1	1.94	0.202
1/BA/1/70/24	Bark	1	T4	P1	2.45	0.192
1/BA/1/70/24	Bark	1	T5	P1	2.20	0.201
1/BA/1/70/24	Bark	1	T6	P1	2.11	0.124
1/BA/3/70/24	Pith	3	T1	P1	1.24	0.152
1/BA/3/70/24	Pith	3	T2	P1	1.72	0.198
1/BA/3/70/24	Pith	3	T3	P1	1.96	0.174
1/BA/3/70/24	Pith	3	T4	P1	1.73	0.211
1/BA/3/70/24	Pith	3	T5	P1	1.27	0.168

Appendix 10 Black alder samples soaked for 20 °C, 48 h

Table 0.10. Black alder samples soaked for 20 °C, 48 h.

Sample Code	**Sheet close to**	**Sheet**	**Samples**	**Log Number**	**Tensile strength(N/mm²)**	**LCD, mm**
25/BA/5/20/48		5	T1	P25	1.79	
25/BA/5/20/48		5	T2	P25	1.16	
25/BA/5/20/48		5	T3	P25	1.35	
25/BA/5/20/48		5	T4	P25	2.05	
25/BA/5/20/48		5	T5	P25	1.82	
25/BA/5/20/48		5	T6	P25	1.94	
25/BA/10/20/48		10	T1	P25	1.63	
25/BA/10/20/48		10	T2	P25	1.98	
25/BA/10/20/48		10	T3	P25	1.64	
25/BA/10/20/48		10	T4	P25	1.59	
25/BA/10/20/48		10	T5	P25	2.00	
25/BA/10/20/48		10	T6	P25	1.92	
25/BA/15/20/48		15	T1	P25	1.35	
25/BA/15/20/48		15	T2	P25	1.68	
25/BA/15/20/48		15	T3	P25	1.80	
25/BA/15/20/48		15	T4	P25	1.64	
25/BA/15/20/48		15	T5	P25	1.80	
25/BA/15/20/48		15	T6	P25	2.11	
25/BA/1/20/48	Bark	1	T1	P25	1.41	0.391
25/BA/1/20/48	Bark	1	T2	P25	1.68	0.439
25/BA/1/20/48	Bark	1	T3	P25	1.78	0.570
25/BA/1/20/48	Bark	1	T4	P25	1.78	0.606
25/BA/1/20/48	Bark	1	T5	P25	1.91	0.412
25/BA/1/20/48	Bark	1	T6	P25	2.05	0.526
25/BA/20/20/48	Pith	20	T1	P25	1.67	0.488
25/BA/20/20/48	Pith	20	T2	P25	1.49	0.704
25/BA/20/20/48	Pith	20	T3	P25	1.44	0.548
25/BA/20/20/48	Pith	20	T4	P25	2.18	0.491
25/BA/20/20/48	Pith	20	T5	P25	1.67	0.768
25/BA/20/20/48	Pith	20	T6	P25	1.90	0.509

Appendix 11 Black alder samples soaked for 40 ºC, 48 h

Table 0.11. Black alder samples soaked for 40 ºC, 48 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm^2)	LCD, mm
24.1/BA/5/40/48		5	T1	P24.1	1.18	
24.1/BA/5/40/48		5	T2	P24.1	1.48	
24.1/BA/5/40/48		5	T3	P24.1	1.44	
24.1/BA/5/40/48		5	T4	P24.1	2.14	
24.1/BA/5/40/48		5	T5	P24.1	2.04	
24.1/BA/5/40/48		5	T6	P24.1	2.03	
24.1/BA/10/40/48		10	T1	P24.1	1.28	
24.1/BA/10/40/48		10	T2	P24.1	1.32	
24.1/BA/10/40/48		10	T4	P24.1	1.87	
24.1/BA/10/40/48		10	T5	P24.1	1.67	
24.1/BA/10/40/48		10	T6	P24.1	2.14	
24.1/BA/15/40/48		15	T1	P24.1	1.34	
24.1/BA/15/40/48		15	T2	P24.1	1.45	
24.1/BA/15/40/48		15	T3	P24.1	1.10	
24.1/BA/15/40/48		15	T4	P24.1	2.16	
24.1/BA/15/40/48		15	T5	P24.1	2.53	
24.1/BA/15/40/48		15	T6	P24.1	1.92	
29/BA/10/40/48		10	T1	P29	1.33	
29/BA/10/40/48		10	T2	P29	1.64	
29/BA/10/40/48		10	T3	P29	1.67	
29/BA/10/40/48		10	T4	P29	1.84	
29/BA/10/40/48		10	T5	P29	1.91	
29/BA/10/40/48		10	T6	P29	2.23	
29/BA/20/40/48		20	T1	P29	1.70	
29/BA/20/40/48		20	T2	P29	1.84	
29/BA/20/40/48		20	T3	P29	1.53	
29/BA/20/40/48		20	T4	P29	2.15	
29/BA/20/40/48		20	T5	P29	2.10	
29/BA/20/40/48		20	T6	P29	1.45	
29/BA/35/40/48		35	T1	P29	1.78	
29/BA/35/40/48		35	T2	P29	1.39	
29/BA/35/40/48		35	T3	P29	1.36	
29/BA/35/40/48		35	T4	P29	1.94	
29/BA/35/40/48		35	T5	P29	2.09	
29/BA/35/40/48		35	T6	P29	1.92	
29/BA/45/40/48		45	T1	P29	1.92	
29/BA/45/40/48		45	T2	P29	1.65	
29/BA/45/40/48		45	T3	P29	1.45	
29/BA/45/40/48		45	T4	P29	2.02	
29/BA/45/40/48		45	T5	P29	1.95	
29/BA/45/40/48		45	T6	P29	1.71	
24.1/BA/1/40/48	Bark	1	T1	P24.1	1.46	0.908
24.1/BA/1/40/48	Bark	1	T2	P24.1	1.23	0.645
24.1/BA/1/40/48	Bark	1	T3	P24.1	1.67	0.778
24.1/BA/1/40/48	Bark	1	T4	P24.1	1.29	0.932
24.1/BA/1/40/48	Bark	1	T5	P24.1	1.75	0.642
24.1/BA/1/40/48	Bark	1	T6	P24.1	1.47	0.718
24.1/BA/20/40/48	Pith	20	T1	P24.1	1.21	0.941
24.1/BA/20/40/48	Pith	20	T2	P24.1	1.61	0.842
24.1/BA/20/40/48	Pith	20	T3	P24.1	1.43	0.707
24.1/BA/20/40/48	Pith	20	T4	P24.1	1.85	0.932
24.1/BA/20/40/48	Pith	20	T5	P24.1	2.17	0.813
24.1/BA/20/40/48	Pith	20	T6	P24.1	2.29	0.670
29/BA/5/40/48	Bark	5	T1	P29	1.85	0.391
29/BA/5/40/48	Bark	5	T2	P29	1.39	0.421
29/BA/5/40/48	Bark	5	T3	P29	1.46	0.482
29/BA/5/40/48	Bark	5	T4	P29	1.94	0.452
29/BA/5/40/48	Bark	5	T5	P29	1.79	0.498
29/BA/5/40/48	Bark	5	T6	P29	1.76	0.487
29/BA/5/40/48	Pith	50	T1	P29	1.44	0.425
29/BA/50/40/48	Pith	50	T2	P29	1.77	0.471

29/BA/50/40/48	Pith	50	T3	P29	1.68	0.425
29/BA/50/40/48	Pith	50	T4	P29	2.11	0.354
29/BA/50/40/48	Pith	50	T5	P29	1.88	0.387
29/BA/50/40/48	Pith	50	T6	P29	2.21	0.379

Appendix 12 Black alder samples soaked for 70 °C, 48 h

Table 0.12. Black alder samples soaked for 70 °C, 48 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm^2)	LCD, mm
37/BA/1/70/48	Bark	1	T1	P37	2.09	0.439
37/BA/1/70/48	Bark	1	T2	P37	3.59	0.327
37/BA/1/70/48	Bark	1	T3	P37	1.83	0.381
37/BA/1/70/48	Bark	1	T4	P37	2.03	0.432
37/BA/1/70/48	Bark	1	T5	P37	2.64	0.283
37/BA/1/70/48	Bark	1	T6	P37	2.41	0.346
37/BA/25/70/48	Pith	25	T1	P37	2.20	0.316
37/BA/25/70/48	Pith	25	T2	P37	2.22	0.397
37/BA/25/70/48	Pith	25	T3	P37	2.14	0.210
37/BA/25/70/48	Pith	25	T4	P37	2.62	0.275
37/BA/25/70/48	Pith	25	T5	P37	2.33	0.380
37/BA/25/70/48	Pith	25	T6	P37	2.47	0.263
34.1/BA/1/70/48	Bark	1	T1	P34.1	3.05	0.240
34.1/BA/1/70/48	Bark	1	T2	P34.1	2.52	0.303
34.1/BA/1/70/48	Bark	1	T3	P34.1	2.12	0.370
34.1/BA/1/70/48	Bark	1	T4	P34.1	2.27	0.212
34.1/BA/1/70/48	Bark	1	T5	P34.1	2.10	0.334
34.1/BA/1/70/48	Bark	1	T6	P34.1	1.99	0.359
37/BA/5/70/48		5	T1	P37	2.08	
37/BA/5/70/48		5	T2	P37	2.00	
37/BA/5/70/48		5	T3	P37	2.12	
37/BA/5/70/48		5	T4	P37	2.60	
37/BA/5/70/48		5	T5	P37	2.60	
37/BA/5/70/48		5	T6	P37	2.33	

37/BA/10/70/48		10	T1	P37	2.13	
37/BA/10/70/48		10	T2	P37	2.56	
37/BA/10/70/48		10	T3	P37	2.44	
37/BA/10/70/48		10	T4	P37	2.69	
37/BA/10/70/48		10	T5	P37	2.68	
37/BA/10/70/48		10	T6	P37	2.46	
37/BA/15/70/48		15	T1	P37	2.18	
37/BA/15/70/48		15	T2	P37	2.56	
37/BA/15/70/48		15	T3	P37	2.40	
37/BA/15/70/48		15	T4	P37	2.52	
37/BA/15/70/48		15	T5	P37	2.68	
37/BA/15/70/48		15	T6	P37	2.66	
37/BA/20/70/48		20	T1	P37	2.35	
37/BA/20/70/48		20	T2	P37	2.48	
37/BA/20/70/48		20	T3	P37	2.11	
37/BA/20/70/48		20	T4	P37	2.24	
37/BA/20/70/48		20	T5	P37	2.85	
37/BA/20/70/48		20	T6	P37	2.52	
34.1/BA/25/70/48	Pith	25	T1	P34.1	2.24	0.338
34.1/BA/25/70/48	Pith	25	T2	P34.1	2.43	0.353
34.1/BA/25/70/48	Pith	25	T3	P34.1	2.27	0.309
34.1/BA/25/70/48	Pith	25	T4	P34.1	2.45	0.390
34.1/BA/25/70/48	Pith	25	T5	P34.1	2.74	0.328
34.1/BA/25/70/48	Pith	25	T6	P34.1	3.22	0.309
34.1/BA/5/70/48		5	T1	P34.1	1.89	
34.1/BA/5/70/48		5	T2	P34.1	2.06	
34.1/BA/5/70/48		5	T3	P34.1	2.92	

34.1/BA/5/70/48		5	T4	P34.1	2.64	
34.1/BA/5/70/48		5	T5	P34.1	1.52	
34.1/BA/5/70/48		5	T6	P34.1	2.83	
34.1/BA/10/70/48		10	T1	P34.1	0.97	
34.1/BA/10/70/48		10	T2	P34.1	2.84	
34.1/BA/10/70/48		10	T3	P34.1	2.00	
34.1/BA/10/70/48		10	T4	P34.1	2.03	
34.1/BA/10/70/48		10	T5	P34.1	2.86	
34.1/BA/10/70/48		10	T6	P34.1	2.40	
34.1/BA/15/70/48		15	T1	P34.1	1.93	
34.1/BA/15/70/48		15	T2	P34.1	2.14	
34.1/BA/15/70/48		15	T3	P34.1	2.19	
34.1/BA/15/70/48		15	T4	P34.1	2.29	
34.1/BA/15/70/48		15	T5	P34.1	2.78	
34.1/BA/15/70/48		15	T6	P34.1	2.67	
34.1/BA/20/70/48		20	T1	P34.1	2.28	
34.1/BA/20/70/48		20	T2	P34.1	1.95	
34.1/BA/20/70/48		20	T3	P34.1	1.50	
34.1/BA/20/70/48		20	T4	P34.1	2.10	
34.1/BA/20/70/48		20	T5	P34.1	2.81	
34.1/BA/20/70/48		20	T6	P34.1	2.54	

Appendix 13 Birch samples soaked for 20 °C, 24 h

Table 0.13. Birch samples soaked for 20 °C, 24 h.

Sample Code	**Sheet close to**	**Sheet**	**Samples**	**Temperature**	**Log Number**	**Tensile strength(N/mm^2)**	**LCD, mm**
3/BI/2/20/24		2	T1	20	P3	1.20	
3/BI/2/20/24		2	T2	20	P3	1.37	
3/BI/2/20/24		2	T3	20	P3	1.40	
3/BI/2/20/24		2	T4	20	P3	0.97	
3/BI/2/20/24		2	T5	20	P3	1.46	
3/BI/2/20/24		2	T6	20	P3	1.07	
3/BI/1/20/24	Bark	1	T1	20	P3	1.26	0.730
3/BI/1/20/24	Bark	1	T2	20	P3	1.42	0.768
3/BI/1/20/24	Bark	1	T3	20	P3	1.44	0.603
3/BI/1/20/24	Bark	1	T4	20	P3	1.62	0.572
3/BI/1/20/24	Bark	1	T5	20	P3	1.23	0.767
3/BI/1/20/24	Bark	1	T6	20	P3	1.26	0.578
3/BI/3/20/24	Pith	3	T1	20	P3	1.57	0.541
3/BI/3/20/24	Pith	3	T2	20	P3	1.20	0.626
3/BI/3/20/24	Pith	3	T3	20	P3	1.16	0.560
3/BI/3/20/24	Pith	3	T4	20	P3	1.63	0.624
3/BI/3/20/24	Pith	3	T5	20	P3	1.54	0.613
3/BI/3/20/24	Pith	3	T6	20	P3	1.66	0.773

Appendix 14 Birch samples soaked for 40 °C, 24 h

Table 0.14. Birch samples soaked for 40 °C, 24 h.

Sample Code	Sheet close to	Sheet	Samples	Temperature	Log Number	Tensile strength(N/mm^2)	LCD, mm
1/BI/1/40/24	Bark	1	T1	40	P1	1.75	0.505
1/BI/1/40/24	Bark	1	T2	40	P1	1.92	0.420
1/BI/1/40/24	Bark	1	T3	40	P1	1.92	0.472
1/BI/2/40/24		2	T1	40	P1	1.92	
1/BI/2/40/24		2	T2	40	P1	2.17	
1/BI/2/40/24		2	T3	40	P1	2.67	
1/BI/3/40/24	Pith	3	T1	40	P1	1.56	0.463
1/BI/3/40/24	Pith	3	T2	40	P1	1.00	0.352
1/BI/3/40/24	Pith	3	T3	40	P1	1.72	0.368
62/BI/1/40/24	Bark	1	T1	40	P62	2.02	0.316
62/BI/1/40/24	Bark	1	T2	40	P62	1.78	0.472
62/BI/1/40/24	Bark	1	T3	40	P62	1.94	0.347
62/BI/1/40/24	Bark	1	T5	40	P62	2.04	0.501
62/BI/1/40/24	Bark	1	T6	40	P62	1.93	0.417
62/BI/3/40/24	Pith	3	T1	40	P62	1.95	0.425
62/BI/3/40/24	Pith	3	T2	40	P62	1.91	0.331
62/BI/3/40/24	Pith	3	T4	40	P62	1.81	0.421
62/BI/3/40/24	Pith	3	T5	40	P62	1.95	0.398
62/BI/3/40/24	Pith	3	T6	40	P62	2.10	0.472
62/BI/2/40/24		2	T1	40	P62	2.31	
62/BI/2/40/24		2	T2	40	P62	1.68	
62/BI/2/40/24		2	T4	40	P62	1.71	
62/BI/2/40/24		2	T6	40	P62	1.98	

Appendix 15 Birch samples soaked for 70 °C, 24 h

Table 0.15. Birch samples soaked for 70 °C, 24 h.

Sample Code	Sheet close to	Sheet	Samples	Temperature	Log Number	Tensile strength(N/mm^2)	LCD, mm
1/BI/1/70/24	Bark	1	T1	70	P1	3.15	0.288
1/BI/1/70/24	Bark	1	T2	70	P1	2.26	0.288
1/BI/1/70/24	Bark	1	T3	70	P1	2.10	0.288
1/BI/1/70/24	Bark	1	T4	70	P1	2.63	0.334
1/BI/1/70/24	Bark	1	T5	70	P1	2.58	0.311
1/BI/1/70/24	Bark	1	T6	70	P1	1.75	0.293
1/BI/2/70/24		2	T1	70	P1	2.33	
1/BI/2/70/24		2	T2	70	P1	2.28	
1/BI/2/70/24		2	T3	70	P1	2.25	
1/BI/2/70/24		2	T4	70	P1	2.25	
1/BI/2/70/24		2	T5	70	P1	2.13	
1/BI/2/70/24		2	T6	70	P1	2.14	
1/BI/3/70/24	Pith	3	T1	70	P1	1.89	0.289
1/BI/3/70/24	Pith	3	T2	70	P1	2.17	0.346
1/BI/3/70/24	Pith	3	T3	70	P1	2.02	0.377
1/BI/3/70/24	Pith	3	T4	70	P1	1.77	0.343
1/BI/3/70/24	Pith	3	T5	70	P1	1.79	0.297
1/BI/3/70/24	Pith	3	T6	70	P1	2.25	0.348
2/BI/1/70/24	Bark	1	T1	70	P2	2.35	0.254
2/BI/1/70/24	Bark	1	T2	70	P2	2.00	0.298
2/BI/1/70/24	Bark	1	T3	70	P2	1.74	0.311
2/BI/2/70/24		2	T1	70	P2	1.84	
2/BI/2/70/24		2	T2	70	P2	1.20	
2/BI/2/70/24		2	T3	70	P2	1.61	
2/BI/3/70/24	Pith	3	T1	70	P2	1.90	0.289
2/BI/3/70/24	Pith	3	T2	70	P2	1.10	0.237
2/BI/3/70/24	Pith	3	T3	70	P2	1.62	0.284

Appendix 16 Birch samples soaked for 20 °C, 48 h

Table 0.16. Birch samples soaked for 20 °C, 48 h.

Sample Code	**Sheet close to**	**Sheet**	**Samples**	**Temperature**	**Log Number**	**Tensile strength(N/mm^2)**	**LCD, mm**
63/BI/1/20/48	Bark		T1	20	P63	1.30	0.610
63/BI/1/20/48	Bark		T2	20	P63	1.45	0.728
63/BI/1/20/48	Bark		T3	20	P63	1.75	0.603
63/BI/1/20/48	Bark		T4	20	P63	1.66	0.572
63/BI/1/20/48	Bark		T5	20	P63	1.92	0.557
63/BI/1/20/48	Bark		T6	20	P63	2.00	0.578
63/BI/5/20/48			T1	20	P63	1.81	
63/BI/5/20/48			T2	20	P63	1.03	
63/BI/5/20/48			T3	20	P63	1.14	
63/BI/5/20/48			T4	20	P63	1.29	
63/BI/5/20/48			T5	20	P63	1.26	
63/BI/5/20/48			T6	20	P63	1.64	
63/BI/10/20/48			T1	20	P63	1.26	
63/BI/10/20/48			T2	20	P63	1.41	
63/BI/10/20/48			T3	20	P63	1.40	
63/BI/10/20/48			T4	20	P63	1.58	
63/BI/10/20/48			T5	20	P63	1.22	
63/BI/15/20/48			T6	20	P63	1.25	
63/BI/15/20/48			T1	20	P63	1.19	
63/BI/15/20/48			T2	20	P63	1.36	
63/BI/15/20/48			T3	20	P63	1.39	
63/BI/15/20/48			T4	20	P63	0.97	
63/BI/15/20/48			T5	20	P63	1.45	
63/BI/15/20/48			T6	20	P63	1.06	
63/BI/20/20/48	Pith		T1	20	P63	1.56	0.541
63/BI/20/20/48	Pith		T2	20	P63	1.19	0.626
63/BI/20/20/48	Pith		T3	20	P63	1.15	0.560
63/BI/20/20/48	Pith		T4	20	P63	1.62	0.404
63/BI/20/20/48	Pith		T5	20	P63	1.53	0.623
63/BI/20/20/48	Pith		T6	20	P63	1.65	0.573

Appendix 17 Birch samples soaked for 40 °C, 48 h

Table 0.17. Birch samples soaked for 40 °C, 48 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm^2)	LCD, mm
12/BI/1/40/48	Bark	1	T1	P12	1.83	0.295
12/BI/1/40/48	Bark	1	T3	P12	1.67	0.314
12/BI/1/40/48	Bark	1	T4	P12	1.51	0.295
12/BI/1/40/48	Bark	1	T5	P12	1.59	0.303
12/BI/1/40/48	Bark	1	T6	P12	1.81	0.302
12/BI/5/40/48		5	T1	P12	1.76	
12/BI/5/40/48		5	T2	P12	1.90	
12/BI/5/40/48		5	T3	P12	1.76	
12/BI/5/40/48		5	T4	P12	1.96	
12/BI/5/40/48		5	T5	P12	2.12	
12/BI/5/40/48		5	T6	P12	1.93	
12/BI/10/40/48		10	T1	P12	1.88	
12/BI/10/40/48		10	T2	P12	2.17	
12/BI/10/40/48		10	T3	P12	1.67	
12/BI/10/40/48		10	T4	P12	1.91	
12/BI/10/40/48		10	T5	P12	2.18	
12/BI/10/40/48		10	T6	P12	1.97	
12/BI/15/40/48		15	T1	P12	1.90	
12/BI/15/40/48		15	T2	P12	1.71	
12/BI/15/40/48		15	T3	P12	1.82	
12/BI/15/40/48		15	T4	P12	2.12	
12/BI/15/40/48		15	T5	P12	2.06	
12/BI/15/40/48		15	T6	P12	1.84	
12/BI/20/40/48		20	T1	P12	1.73	
12/BI/20/40/48		20	T2	P12	1.95	
12/BI/20/40/48		20	T3	P12	1.80	
12/BI/20/40/48		20	T4	P12	2.19	
12/BI/20/40/48		20	T5	P12	1.66	
12/BI/20/40/48		20	T6	P12	2.10	
12/BI/25/40/48	Pith	25	T1	P12	1.82	0.260
12/BI/25/40/48	Pith	25	T2	P12	1.71	0.264
12/BI/25/40/48	Pith	25	T3	P12	1.86	0.253
12/BI/25/40/48	Pith	25	T4	P12	1.84	0.257
12/BI/25/40/48	Pith	25	T5	P12	1.70	0.271
12/BI/25/40/48	Pith	25	T6	P12	2.17	0.296
3/BI/1/40/48	Bark	1	T2	P3	2.45	0.270
3/BI/1/40/48	Bark	1	T3	P3	1.68	0.256
3/BI/1/40/48	Bark	1	T4	P3	1.68	0.237
3/BI/1/40/48	Bark	1	T5	P3	2.63	0.275
3/BI/1/40/48	Bark	1	T6	P3	2.00	0.242
3/BI/5/40/48		5	T1	P3	2.84	

3/BI/5/40/48		5	T2	P3	1.95	
3/BI/5/40/48		5	T3	P3	2.91	
3/BI/5/40/48		5	T4	P3	1.94	
3/BI/5/40/48		5	T6	P3	1.76	
3/BI/10/40/48		10	T1	P3	1.43	
3/BI/10/40/48		10	T2	P3	1.32	
3/BI/10/40/48		10	T3	P3	1.63	
3/BI/10/40/48		10	T4	P3	0.72	
3/BI/10/40/48		10	T5	P3	1.69	
3/BI/10/40/48		10	T6	P3	1.69	
3/BI/15/40/48		15	T1	P3	1.59	
3/BI/15/40/48		15	T2	P3	1.72	
3/BI/15/40/48		15	T3	P3	1.74	
3/BI/15/40/48		15	T4	P3	2.13	
3/BI/15/40/48		15	T5	P3	1.93	
3/BI/15/40/48		15	T6	P3	1.61	
3/BI/20/40/48		20	T1	P3	1.68	
3/BI/20/40/48		20	T2	P3	1.79	
3/BI/20/40/48		20	T3	P3	1.40	
3/BI/20/40/48		20	T4	P3	1.74	
3/BI/20/40/48		20	T5	P3	2.51	
3/BI/20/40/48		20	T6	P3	1.70	
3/BI/25/40/48		25	T1	P3	1.50	
3/BI/25/40/48		25	T2	P3	1.61	
3/BI/25/40/48		25	T3	P3	1.55	
3/BI/25/40/48		25	T4	P3	2.02	
3/BI/25/40/48		25	T5	P3	1.49	
3/BI/25/40/48		25	T6	P3	1.77	
3/BI/30/40/48	Pith	30	T1	P3	1.45	0.242
3/BI/30/40/48	Pith	30	T2	P3	1.72	0.283
3/BI/30/40/48	Pith	30	T3	P3	1.65	0.295
3/BI/30/40/48	Pith	30	T4	P3	1.54	0.229
3/BI/30/40/48	Pith	30	T5	P3	1.78	0.250
3/BI/30/40/48	Pith	30	T6	P3	1.65	0.258

Appendix 18 Birch samples soaked for 70 °C, 48 h

Table 0.18. Birch samples soaked for 70 °C, 48 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	tensile Strength(N/mm^2)	LCD, mm
8/BI/1/70/48	Bark	1	T1	P8	1.77	0.227
8/BI/1/70/48	Bark	1	T2	P8	1.59	0.266
8/BI/1/70/48	Bark	1	T3	P8	1.81	0.290
8/BI/1/70/48	Bark	1	T4	P8	1.97	0.244
8/BI/1/70/48	Bark	1	T5	P8	2.23	0.276
8/BI/1/70/48	Bark	1	T6	P8	2.01	0.258
8/BI/4/70/48		4	T1	P8	2.08	
8/BI/4/70/48		4	T2	P8	1.56	
8/BI/4/70/48		4	T3	P8	1.75	
8/BI/4/70/48		4	T4	P8	2.66	
8/BI/4/70/48		4	T5	P8	1.89	
8/BI/4/70/48		4	T6	P8	2.48	
8/BI/9/70/48		9	T1	P8	1.76	
8/BI/9/70/48		9	T2	P8	1.59	
8/BI/9/70/48		9	T3	P8	1.72	
8/BI/9/70/48		9	T4	P8	1.98	
8/BI/9/70/48		9	T5	P8	1.96	
8/BI/9/70/48		9	T6	P8	2.40	
8/BI/14/70/48		14	T1	P8	1.63	
8/BI/14/70/48		14	T2	P8	1.90	
8/BI/14/70/48		14	T3	P8	1.61	
8/BI/14/70/48		14	T4	P8	2.19	
8/BI/14/70/48		14	T5	P8	2.87	
8/BI/14/70/48		14	T6	P8	1.94	
8/BI/19/70/48		19	T1	P8	2.08	
8/BI/19/70/48		19	T2	P8	1.94	
8/BI/19/70/48		19	T3	P8	1.99	
8/BI/19/70/48		19	T4	P8	2.53	
8/BI/19/70/48		19	T5	P8	2.07	
8/BI/19/70/48		19	T6	P8	2.44	
8/BI/24/70/48	Pith	24	T1	P8	1.92	0.244
8/BI/24/70/48	Pith	24	T2	P8	2.24	0.222
8/BI/24/70/48	Pith	24	T3	P8	1.85	0.187
8/BI/24/70/48	Pith	24	T4	P8	2.14	0.201
8/BI/24/70/48	Pith	24	T5	P8	1.94	0.196
8/BI/24/70/48	Pith	24	T6	P8	2.17	0.215
7/BI/1/70/48	Bark	1	T1	P7	1.81	0.284
7/BI/1/70/48	Bark	1	T2	P7	2.46	0.269
7/BI/1/70/48	Bark	1	T3	P7	1.78	0.204
7/BI/1/70/48	Bark	1	T4	P7	2.42	0.263
7/BI/1/70/48	Bark	1	T5	P7	0.79	0.322
7/BI/1/70/48	Bark	1	T6	P7	2.08	0.256
7/BI/10/70/48		10	T1	P7	2.19	
7/BI/10/70/48		10	T2	P7	2.37	
7/BI/10/70/48		10	T3	P7	2.54	
7/BI/10/70/48		10	T4	P7	2.55	
7/BI/10/70/48		10	T5	P7	2.38	
7/BI/10/70/48		10	T6	P7	2.27	
7/BI/15/70/48		15	T1	P7	1.97	
7/BI/15/70/48		15	T2	P7	0.76	
7/BI/15/70/48		15	T3	P7	1.74	
7/BI/15/70/48		15	T4	P7	2.17	
7/BI/15/70/48		15	T5	P7	1.83	
7/BI/15/70/48		15	T6	P7	1.59	
7/BI/20/70/48		20	T1	P7	2.51	
7/BI/20/70/48		20	T2	P7	2.36	
7/BI/20/70/48		20	T3	P7	2.85	
7/BI/20/70/48		20	T4	P7	2.07	
7/BI/20/70/48		20	T5	P7	2.24	
7/BI/20/70/48		20	T6	P7	2.04	

7/BI/25/70/48	Pith	25	T1	P7	2.37	0.264
7/BI/25/70/48	Pith	25	T2	P7	2.11	0.171

Appendix 19 Grey alder samples soaked for 20 °C, 24 h

Table 0.19. Grey alder samples soaked for 20 °C, 24 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm^2)	LCD, mm
2/GA/2/20/24		2	T1	P2	1.08	
2/GA/2/20/24		2	T2	P2	0.85	
2/GA/2/20/24		2	T3	P2	0.99	
2/GA/2/20/24		2	T4	P2	0.87	
2/GA/2/20/24		2	T5	P2	0.96	
2/GA/2/20/24		2	T6	P2	1.29	
2/GA/1/20/24	Bark	1	T1	P2	1.36	0.624
2/GA/1/20/24	Bark	1	T2	P2	0.86	0.712
2/GA/1/20/24	Bark	1	T3	P2	1.03	0.681
2/GA/1/20/24	Bark	1	T4	P2	1.09	0.592
2/GA/1/20/24	Bark	1	T5	P2	1.24	0.732
2/GA/1/20/24	Bark	1	T6	P2	1.94	0.547
2/GA/3/20/24	Pith	3	T1	P2	0.72	0.633
2/GA/3/20/24	Pith	3	T2	P2	0.95	0.612
2/GA/3/20/24	Pith	3	T3	P2	0.72	0.544
2/GA/3/20/24	Pith	3	T4	P2	0.84	0.683
2/GA/3/20/24	Pith	3	T5	P2	1.57	0.708
2/GA/3/20/24	Pith	3	T6	P2	1.74	0.783
1/GA/1/20/24	Bark	1	T1	P1	1.06	0.687
1/GA/1/20/24	Bark	1	T2	P1	1.11	0.771
1/GA/1/20/24	Bark	1	T3	P1	1.27	0.704
1/GA/1/20/24	Bark	1	T4	P1	1.17	0.673
1/GA/1/20/24	Bark	1	T5	P1	1.16	0.651
1/GA/1/20/24	Bark	1	T6	P1	1.49	0.632
1/GA/2/20/24		2	T1	P1	0.84	
1/GA/2/20/24		2	T2	P1	1.14	
1/GA/2/20/24		2	T3	P1	0.93	
1/GA/2/20/24		2	T4	P1	1.01	
1/GA/2/20/24		2	T5	P1	0.99	
1/GA/2/20/24		2	T6	P1	0.87	
1/GA/3/20/24	Pith	3	T1	P1	0.83	0.729
1/GA/3/20/24	Pith	3	T2	P1	0.93	0.671
1/GA/3/20/24	Pith	3	T3	P1	1.06	0.685
1/GA/3/20/24	Pith	3	T4	P1	1.09	0.720
1/GA/3/20/24	Pith	3	T5	P1	0.96	0.629
1/GA/3/20/24	Pith	3	T6	P1	1.15	0.663

Appendix 20 Grey alder samples soaked for 40 °C, 24 h

Table 0.20. Grey alder samples soaked for 40 °C, 24 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm^2)	LCD, mm
1/GA/2/40/24		2	T1	P1	1.90	
1/GA/2/40/24		2	T2	P1	1.87	
1/GA/2/40/24		2	T3	P1	0.95	
1/GA/2/40/24		2	T4	P1	1.87	
1/GA/2/40/24		2	T5	P1	1.69	
1/GA/2/40/24		2	T6	P1	1.11	
1/GA/1/40/24	Bark	1	T1	P1	1.50	0.591
1/GA/1/40/24	Bark	1	T2	P1	1.64	0.461
1/GA/1/40/24	Bark	1	T3	P1	1.52	0.407
1/GA/1/40/24	Bark	1	T4	P1	1.57	0.452
1/GA/1/40/24	Bark	1	T5	P1	1.32	0.510
1/GA/1/40/24	Bark	1	T6	P1	1.63	0.500
1/GA/3/40/24	Pith	3	T1	P1	1.45	0.512
1/GA/3/40/24	Pith	3	T2	P1	1.65	0.487
1/GA/3/40/24	Pith	3	T3	P1	1.19	0.498
1/GA/3/40/24	Pith	3	T4	P1	1.19	0.500
1/GA/3/40/24	Pith	3	T5	P1	1.47	0.492
1/GA/3/40/24	Pith	3	T6	P1	1.10	0.571
3/GA/1/40/24	Bark	1	T1	P3	1.19	0.524
3/GA/1/40/24	Bark	1	T2	P3	1.02	0.512
3/GA/1/40/24	Bark	1	T3	P3	1.12	0.498
3/GA/2/40/24		2	T1	P3	1.47	
3/GA/2/40/24		2	T2	P3	1.40	
3/GA/2/40/24		2	T3	P3	1.08	
3/GA/3/40/24	Pith	3	T1	P3	1.13	0.472
3/GA/3/40/24	Pith	3	T2	P3	0.95	0.462
3/GA/3/40/24	Pith	3	T3	P3	0.71	0.522
2/GA/1/40/24	Bark	1	T1	P2	1.32	0.513
2/GA/1/40/24	Bark	1	T2	P2	1.79	0.539
2/GA/1/40/24	Bark	1	T3	P2	1.30	0.571
2/GA/3/40/24	Pith	3	T1	P2	1.35	0.591
2/GA/3/40/24	Pith	3	T2	P2	1.39	0.483
2/GA/3/40/24	Pith	3	T3	P2	1.09	0.477
2/GA/3/40/24	Pith	3	T4	P2	1.33	0.427
2/GA/2/40/24		2	T1	P2	1.70	
2/GA/2/40/24		2	T2	P2	1.15	
2/GA/2/40/24		2	T3	P2	1.29	

Appendix 21 Grey alder samples soaked for 70 °C, 24 h

Table 0.21. Grey alder samples soaked for 70 °C, 24 h.

Sample Code	**Sheet close to**	**Sheet**	**Samples**	**Log Number**	**Tensile strength(N/mm^2)**	**LCD, mm**
1/GA/1/70/24	Bark	1	T1	P1	2.23	0.270
1/GA/1/70/24	Bark	1	T2	P1	1.85	0.323
1/GA/1/70/24	Bark	1	T3	P1	1.47	0.274
1/GA/1/70/24	Bark	1	T4	P1	1.48	0.219
1/GA/1/70/24	Bark	1	T5	P1	1.46	0.276
1/GA/1/70/24	Bark	1	T6	P1	1.49	0.250
1/GA/3/70/24	Pith	3	T1	P1	1.49	0.241
1/GA/3/70/24	Pith	3	T2	P1	1.26	0.292
1/GA/3/70/24	Pith	3	T3	P1	1.33	0.301
1/GA/3/70/24	Pith	3	T4	P1	1.23	0.273
1/GA/3/70/24	Pith	3	T5	P1	1.69	0.259
1/GA/3/70/24	Pith	3	T6	P1	1.41	0.301
2/GA/1/70/24	Bark	1	T1	P2	1.41	0.311
2/GA/1/70/24	Bark	1	T2	P2	1.67	0.224
2/GA/1/70/24	Bark	1	T3	P2	1.64	0.291
2/GA/1/70/24	Bark	1	T4	P2	1.33	0.324
2/GA/1/70/24	Bark	1	T5	P2	1.45	0.286
2/GA/1/70/24	Bark	1	T6	P2	1.50	0.257
1/GA/2/70/24		2	T1	P1	1.76	
1/GA/2/70/24		2	T2	P1	1.85	
1/GA/2/70/24		2	T3	P1	1.88	
1/GA/2/70/24		2	T4	P1	1.45	
1/GA/2/70/24		2	T5	P1	1.43	
1/GA/2/70/24		2	T6	P1	0.02	
2/GA/3/70/24	Pith	3	T1	P2	1.01	0.231
2/GA/3/70/24	Pith	3	T2	P2	1.82	0.254
2/GA/3/70/24	Pith	3	T3	P2	1.52	0.241
2/GA/3/70/24	Pith	3	T4	P2	1.16	0.281
2/GA/3/70/24	Pith	3	T5	P2	1.84	0.256
2/GA/3/70/24	Pith	3	T6	P2	1.70	0.268
2/GA/2/70/24		2	T1	P2	1.86	
2/GA/2/70/24		2	T2	P2	1.61	
2/GA/2/70/24		2	T3	P2	1.54	
2/GA/2/70/24		2	T4	P2	1.39	
2/GA/2/70/24		2	T5	P2	1.32	
2/GA/2/70/24		2	T6	P2	1.31	

Appendix 22 Grey alder samples soaked for 20 °C, 48 h

Table 0.22. Grey alder samples soaked for 20 °C, 48 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm^2)	LCD, mm
22/GA/1/20/48	Bark	1	T1	P22	1.55	0.510
22/GA/1/20/48	Bark	1	T2	P22	1.49	0.550
22/GA/1/20/48	Bark	1	T5	P22	1.64	0.547
22/GA/1/20/48	Bark	1	T6	P22	1.62	0.525
22/GA/5/20/48		5	T1	P22	1.52	
22/GA/5/20/48		5	T2	P22	1.43	
22/GA/5/20/48		5	T3	P22	1.46	
22/GA/5/20/48		5	T4	P22	1.32	
22/GA/5/20/48		5	T5	P22	1.21	
22/GA/5/20/48		5	T6	P22	1.65	
22/GA/10/20/48		10	T1	P22	1.71	
22/GA/10/20/48		10	T2	P22	1.34	
22/GA/10/20/48		10	T3	P22	1.39	
22/GA/10/20/48		10	T4	P22	1.28	
22/GA/10/20/48		10	T5	P22	1.16	
22/GA/10/20/48		10	T6	P22	1.58	
22/GA/15/20/48		15	T1	P22	1.50	
22/GA/15/20/48		15	T2	P22	1.26	
22/GA/15/20/48		15	T3	P22	1.71	
22/GA/15/20/48		15	T4	P22	1.44	
22/GA/15/20/48		15	T5	P22	1.21	
22/GA/15/20/48		15	T6	P22	1.30	
22/GA/20/20/48	Pith	20	T1	P22	1.59	0.516
22/GA/20/20/48	Pith	20	T2	P22	1.38	0.518
22/GA/20/20/48	Pith	20	T3	P22	1.62	0.549
23/GA/1/20/48	Bark	1	T1	P23	1.86	0.452
23/GA/1/20/48	Bark	1	T2	P23	1.72	0.677
23/GA/1/20/48	Bark	1	T3	P23	1.28	0.513
23/GA/1/20/48	Bark	1	T4	P23	1.30	0.409
23/GA/1/20/48	Bark	1	T5	P23	1.57	0.586

23/GA/1/20/48	Bark	1	T6	P23	1.39	0.519
23/GA/5/20/48		5	T1	P23	1.30	
23/GA/5/20/48		5	T3	P23	1.24	
23/GA/5/20/48		5	T4	P23	1.56	
23/GA/5/20/48		5	T5	P23	1.66	
23/GA/5/20/48		5	T6	P23	1.50	
23/GA/10/20/48		10	T1	P23	0.93	
23/GA/10/20/48		10	T2	P23	1.13	
23/GA/10/20/48		10	T3	P23	1.29	
23/GA/10/20/48		10	T4	P23	1.29	
23/GA/10/20/48		10	T5	P23	1.62	
23/GA/10/20/48		10	T6	P23	1.31	
23/GA/15/20/48		15	T1	P23	1.23	
23/GA/15/20/48		15	T2	P23	1.31	
23/GA/15/20/48		15	T3	P23	1.25	
23/GA/15/20/48		15	T4	P23	1.53	
23/GA/15/20/48		15	T5	P23	1.31	
23/GA/15/20/48		15	T6	P23		
23/GA/25/20/48	Pith	25	T1	P23	1.52	0.507
23/GA/25/20/48	Pith	25	T6	P23	1.22	0.611

Appendix 23 Grey alder samples soaked for 40 °C, 48 h

Table 0.23. Grey alder samples soaked for 40 °C, 48 h.

Sample Code	Sheet close to	Sheet	Samples	Log Number	Tensile strength(N/mm^2)	LCD, mm
32/GA/1/40/48	Bark	1	T1	P32	2.02	0.590
32/GA/1/40/48	Bark	1	T2	P32	1.81	0.389
32/GA/1/40/48	Bark	1	T3	P32	1.79	0.336
32/GA/1/40/48	Bark	1	T5	P32	1.70	0.321
32/GA/1/40/48	Bark	1	T6	P32	1.73	0.348
32/GA/5/40/48		5	T1	P32	1.65	
32/GA/5/40/48		5	T2	P32	1.84	
32/GA/5/40/48		5	T3	P32	1.18	
32/GA/5/40/48		5	T4	P32	1.70	
32/GA/5/40/48		5	T5	P32	1.55	
32/GA/5/40/48		5	T6	P32	1.48	
32/GA/10/40/48		10	T1	P32	1.63	
32/GA/10/40/48		10	T2	P32	1.42	
32/GA/10/40/48		10	T3	P32	1.94	
32/GA/10/40/48		10	T4	P32	1.46	
32/GA/10/40/48		10	T5	P32	1.54	
32/GA/15/40/48		15	T6	P32	1.91	
32/GA/15/40/48		15	T1	P32	1.27	
32/GA/15/40/48		15	T2	P32	2.02	
32/GA/15/40/48		15	T3	P32	1.52	
32/GA/15/40/48		15	T4	P32	1.67	
32/GA/15/40/48		15	T5	P32	1.63	
32/GA/15/40/48		15	T6	P32	1.34	
32/GA/20/40/48	Pith	20	T1	P32	1.59	0.365
32/GA/20/40/48	Pith	20	T2	P32	1.64	0.353
32/GA/20/40/48	Pith	20	T3	P32	1.17	0.358
32/GA/20/40/48	Pith	20	T4	P32	1.93	0.306
32/GA/20/40/48	Pith	20	T5	P32	1.56	0.364
32/GA/20/40/48	Pith	20	T6	P32	1.33	0.333
34/GA/1/40/48	Bark	1	T1	P34	2.72	0.573
34/GA/1/40/48	Bark	1	T2	P34	1.66	0.350
34/GA/1/40/48	Bark	1	T3	P34	1.94	0.394
34/GA/1/40/48	Bark	1	T4	P34	1.33	0.426
34/GA/1/40/48	Bark	1	T5	P34	1.78	0.469
34/GA/1/40/48	Bark	1	T6	P34	1.92	0.372
34/GA/5/40/48		5	T1	P34	1.58	
34/GA/5/40/48		5	T3	P34	1.49	
34/GA/5/40/48		5	T4	P34	1.83	
34/GA/5/40/48		5	T5	P34	2.21	
34/GA/5/40/48		5	T6	P34	1.80	
34/GA/10/40/48		10	T1	P34	1.33	

34/GA/10/40/48		10	T2	P34	1.59	
34/GA/10/40/48		10	T3	P34	1.23	
34/GA/10/40/48		10	T4	P34	1.60	
34/GA/10/40/48		10	T5	P34	1.96	
34/GA/10/40/48		10	T6	P34	1.87	
34/GA/15/40/48		15	T1	P34	1.62	
34/GA/15/40/48		15	T2	P34	1.61	
34/GA/15/40/48		15	T3	P34	1.45	
34/GA/15/40/48		15	T4	P34	1.97	
34/GA/15/40/48		15	T5	P34	2.26	
34/GA/15/40/48		15	T6	P34	1.97	
34/GA/20/40/48	Pith	20	T1	P34	1.41	0.329
34/GA/20/40/48	Pith	20	T2	P34	1.25	0.402
34/GA/20/40/48	Pith	20	T3	P34	1.56	0.446
34/GA/20/40/48	Pith	20	T4	P34	1.65	0.372
34/GA/20/40/48	Pith	20	T5	P34	1.62	0.307
34/GA/20/40/48	Pith	20	T6	P34	2.41	0.390

Appendix 24 Grey alder samples soaked for 70 °C, 48 h

Table 0.24. Grey alder samples soaked for 70 °C, 48 h.

Sample Code	**Sheet close to**	**Sheet**	**Samples**	**Log Number**	**Tensile strength(N/mm^2)**	**LCD, mm**
38/GA/1/70/48	Bark	1	T1	P38	1.90	0.273
38/GA/1/70/48	Bark	1	T2	P38	2.55	0.333
38/GA/1/70/48	Bark	1	T3	P38	2.51	0.325
38/GA/1/70/48	Bark	1	T4	P38	2.26	0.298
38/GA/1/70/48	Bark	1	T5	P38	2.26	0.261
38/GA/5/70/48		5	T1	P38	2.00	
38/GA/5/70/48		5	T2	P38	2.73	
38/GA/5/70/48		5	T3	P38	2.39	
38/GA/5/70/48		5	T4	P38	1.80	
38/GA/5/70/48		5	T5	P38	2.37	
38/GA/5/70/48		5	T6	P38	1.83	
38/GA/7/70/48		7	T1	P38	2.17	
38/GA/7/70/48		7	T2	P38	2.35	
38/GA/7/70/48		7	T3	P38	1.97	
38/GA/7/70/48		7	T4	P38	2.28	
38/GA/7/70/48		7	T5	P38	1.93	
38/GA/7/70/48		7	T6	P38	2.00	
38/GA/9/70/48		9	T1	P38	2.27	
38/GA/9/70/48		9	T2	P38	2.19	
38/GA/9/70/48		9	T3	P38	1.82	
38/GA/9/70/48		9	T4	P38	2.31	
38/GA/9/70/48		9	T5	P38	2.03	
38/GA/9/70/48		9	T6	P38	1.61	
38/GA/11/70/48	Pith	11	T1	P38	1.51	0.237
38/GA/11/70/48	Pith	11	T3	P38	0.18	0.281
38/GA/11/70/48	Pith	11	T4	P38	2.40	0.294
38/GA/11/70/48	Pith	11	T5	P38	2.16	0.163
38/GA/11/70/48	Pith	11	T6	P38	2.04	0.208