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Marshall Plan Scholarship

Final Report:

Bark-based Insulation Boards

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2 Acknowledgements

I would first like to take this opportunity to thank the Austrian Marshall Plan Foundation for your generosity in funding the Marshall Plan scholarship. This provided me with the opportunity to participate in research at the international level. I am honored and grateful to be a recipient of this award.

Secondly I would like to thank my mentor Prof. Marius Barbu at the Fachhochschule Salzburg for enabling my research opportunities to participate in the project and providing great mentorship along the way. I would like to thank you for your support in all areas of my life as I conducted my research. He was able to put me in contact to learn not only about one topic of wood technology but to gain a understanding of a wide range of topics that pertain to my future as a professional in wood technology.

Next I would like to thank Mag. Teresa Rieger, Mag. Ulrike Hofmann, and Michele Justice for their helpful support with all administrative task related to coming to Austria and once I arrived. They not only supported me in the educational environment but in my personal life as well.

Similarly I would like to thank all the students of the Fachhochschule Salzburg especially Kerstin Wagner that I got the pleasure of knowing and who helped me in not only gaining knowledge in wood products but with life abroad in general.

Additionally I would like to thank my family for their constant support of my educational endeavors including my trip across the world to Austria. They were constantly encouraging me to continue gaining as much knowledge as possible. This trip wouldn’t have been possible without the support of my family in all aspects of my life.

In conclusion I would like to thank Dr. Lech Muszyński for his constant encouragement in applying for this scholars program, living abroad, and the research as a whole. He has been a mentor my entire college education so far providing me with great opportunities as well as beneficial advice.

3 Overview

3.1 Introduction

I received the Marshall Plan Scholarship that allowed me to travel from Oregon State University in Corvallis, OR USA to Fachhochschule Salzburg University of Applied Sciences in Kuchl, Austria to spend 3 months working with wood technology and products. I spent June to September 2015 in Kuchl, Austria completing research in various topics that include bark-based insulation boards, straw-based composite boards, wood impregnation, tannin glue application, and thin-layer lightweight boards.

It is important to mention that a majority of the research project results that I was a part of in Austria are confidential and exclusive. This report therefore only includes an overview and will not dive into extremely specific detail. Besides research, I was able to look at the Austrian wood industry in comparison to that within the United States while there.

I chose to complete my research project at Fachhochschule Salzburg University of Applied Science because of its work in the wood technology field and outstanding opportunities that were in place. I noticed that they had a lot of experience and research available in various wood technology topics which encouraged choosing this particular University. Prof. Barbu being focused on the wood technology field made him a great advisor for my research stay. His experience in the field gave me the ability to enhance my own knowledge in a lot of wood technology aspects while in Austria.

Something that I found very valuable and important to my overall experience in Austria was Prof. Barbu ability to connect me with great master degree seeking students. I was able to learn a lot from these students and even participate in a wide variety of projects because of these connections due to Prof. Barbu.

3.2 Background

Wood is a great renewable material source that is found near a majority of areas of the Earth. Trees contain the wood that is used to make a lot of materials for human consumption and many other parts including the outside of the tree, known as the bark. Bark is the outer most layer of tissues outside the vascular cambium. Bark protects the tree from the outside environment including from animals, creating less risk for disease infestation. Bark is essential to the tree and the overall production of wood products.

Just as trees are very diverse, so is the bark of the trees due to location and adaptations that the trees have made. The diversity of bark makes different types better than others in various applications. Bark like that of a cedar tree may be more appealing for mulch applications because of its distinct smell and color. The qualities of the bark are important to analyzing where it can best be utilized. These bark qualities are especially important for building applications such as in insulation boards.

Bark protects trees from the outside environment just as insulation is needed to protect heat and cooling systems of various buildings including homes. Without insulation, buildings become similar temperatures to the outside environment. This can be compared to how bark acts as a protectant to the inner layers of trees. Interest in bark being used in insulation material is shown because of it being environmentally friendly and showing promising qualities for the particular application.

3.3 Research Goals

During my research stay in Austria I had some goals I strived to obtain in regards to the research that I was completing. My main goal was to be able to figure out if bark was a good candidate for insulation material by looking at its properties and responses during various different types of testing. This includes making sure that the research is conducted both effectively and within the time constraints of my research stay in Austria. This goal was important to looking at its future potential as an insulation material.

During the process of looking towards achieving my main goal I also found ways to gain a global perspective of the wood products industry. This brings me to my next goal which was to gain knowledge about the global wood products industry through research and student interaction. This goal was important to my overall educational experience as well as personal growth.

My next research goal was to work with a team to obtain valuable wood product research. In scientific research you are often working with a team of fellow professionals to obtain a goal in research or within your field. I thought that having the goal of gaining team research experience was an important contribution to my experience in Austria.

4 Objectives of the Research Visit

4.1 Motivation

The population of the world continues to rise causing natural resources use to increase at a much faster rate. This means that in order to conserve and not use up the resources we must create more sustainable products including in the insulation material industry. Current insulation materials used in buildings today include a wide range from fiberglass, rock and slag wool, cellulose, and natural fibers to rigid foam boards and sleek foils [1]. Fiberglass insulation, made up of fine glass fibers, currently dominates the market despite it not being an environmental friendly product and taking a lot of energy to produce. Currently the materials used in insulation materials that are of natural origin are not very effective in both cost and properties compared to the less environmentally friendly alternatives.

Throughout history some insulation materials which are off the market now have had a lot of health risk. Currently we are working to take the materials off the market that are a risk environmentally through research and development of new material applications. Part of what makes this a huge challenge is the cost of natural materials being much higher currently than others and their performance is not as good as the non-natural based materials. Studying products like bark for use as a future insulation material is important to the environmental impact we are making on the planet. The effective use of lower grade material like bark could be a solution to creating sustainable products.

5 Events

5.1 Wimmer Woods Tour

Besides just working on research during my time in Austria I wanted to also see the Austrian wood industry. I was lucky to live in a community filled with various wood product companies including Wimmer Wood “WIHO” which specializes in domestic hardwood species. The company began very small and then has continuously expanded due to the increase in demand. Hardwood specialization companies are not nearly as common as the building product producing softwood companies due to the demand.

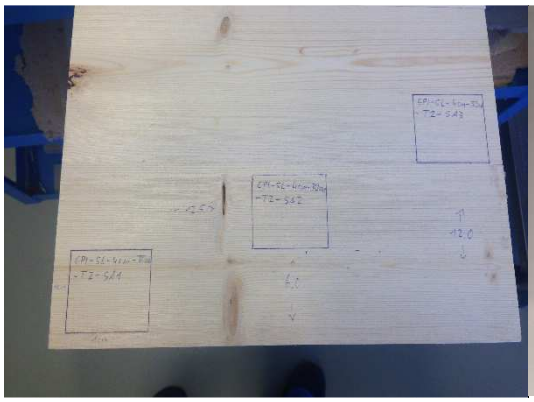
As I was touring through the facility I noticed that they have a lot of experience in producing specialized products for certain customer specific needs. Some things I noticed they focus on and specialize in include the incision, as well as drying and steaming of domestic hardwood species. These domestic species include beech, maple, oak, and ash. As far as the manufacturing process is concerned I noticed that due to their specialization they focused much more on quality of their product than productivity of the process. They were able to produce a huge variety of product including custom hardwood flooring which I found to be extremely interesting. I was very happy to get to tour, see the daily operations, and products that the company has to offer. I think it was important to see the differences between the much more common softwood mills and this particular hardwood specialization facility.

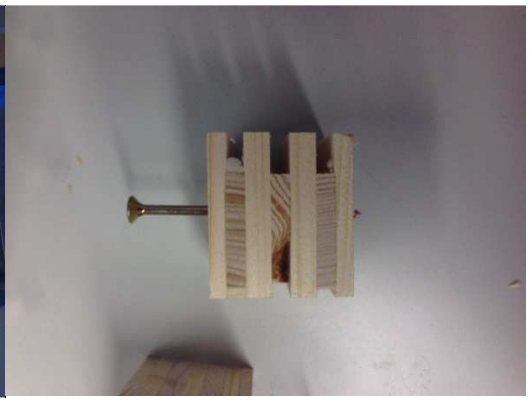
5.2 Thin-Layer Lightweight Boards

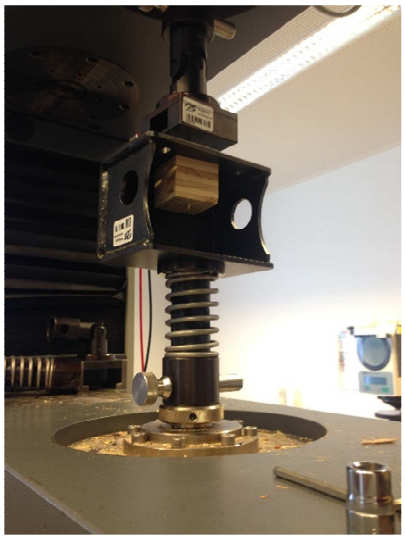
A key component of the development and improvement of wood products is trying to make use of lower quality materials in applications like building. Thin layer boards are very lightweight for their size and combine the use of higher grade materials with those that are much lower grade. This makes the product much cheaper to produce while having great quality still. The more layers and the less space between, the heavier the panels will be. Shown below is the panels being glued together and then pressed for maximum strength while using lower quality materials that are much cheaper.

A crucial part of this research was using different types of glue to test the strength of the glue bonds as well. MUF (melamine-urea-formaldehyde) contains lower amounts of environmental toxins than the UF (urea- formaldehyde) glue that was also used. The MUF is desired for use in these panels because it aids in the reduction of formaldehyde emissions.

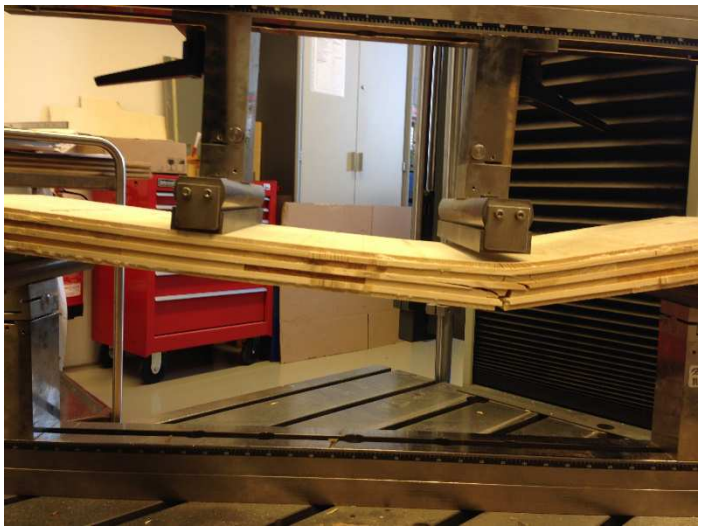
The glue was tested using internal bond testing, where the UF glue was able to withstand slightly better than the MUF glue. This result was expected as UF glue is stronger than the more environmentally friendly MUF glue. Below is pictures of how the testing pieces were sawn out and tested by drilling a nail through the center of the testing piece and then pulled apart using a machine.







The strength of the actual lightweight boards was done using a three point bending test machine. The test shows if the glue fails before the actual board or vice versa. Below shows the board failing on the right side during the three point bending test. The type of breaking shows that the board failed before the glue bonds.



From all this testing we were able to determine that the difference between boards using MUF and UF glue wasn't as important as we originally thought it to be. It was determined that the empty spaces between the pieces of wood (shown in the first picture) was important to the overall strength of the board. Denser boards with less air space performed better than lighter boards with more space. This conclusion makes sense due to having a greater volume of wood and glue bonding available.

More testing will have to be done with more variation in glue types, number of layers, and size of spacing to determine a better relationship for future applications. Lower grade materials combined with the higher grade materials currently used in building shows a promising outlook for future applications as well.

5.3 Tannin Glue Application

Working with glue made using tannin and other materials is a very challenging as well as interesting topic within the wood technology field. Tannin, a natural product, is being strived for use in wood products because of its natural origination. Tannin is a naturally occurring polyphenol found in plants, seeds, bark, wood, leaves and fruit skins [2]. About 50% of the dry weight of plant leaves are tannins [2]. In this particular research project mimosa tannin was used. Mimosa tannin is found in the black wattle tree a species of Acacia native to Australia [3].

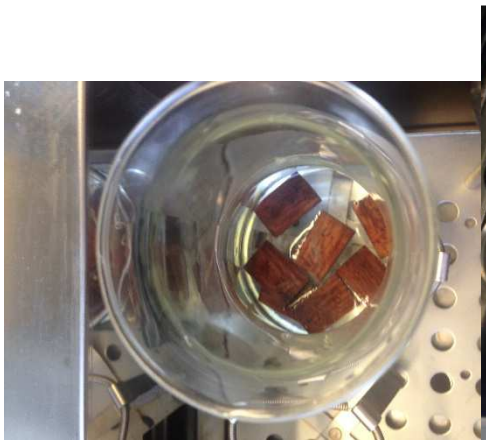
The tannin which comes as a powder based material was combined with a hexamine solution to make a glue. This glue is placed between two small flat sawn pieces of beech wood and pressed. The pieces are then cut to sample size and then tested using internal bond strength machine to test the strength of the glue bonds.

The testing of multiple different glues and mixtures proved to be challenging as the samples all fell apart before the strength test could be done. This means the strength of the glue was very low and it just caused the two pieces to fall apart easily.

In the future the ratio of tannin in the glue must be changed to get the appropriate glue mixture for a quality strength of glue. A lot of research must continue to go into this for it to be successful in the future, as the quality is still very poor shown with the samples falling apart before testing in this particular case.

5.4 Wood Impregnation

Wood impregnation is interesting to study due to the anatomical wood differences from species to species. These differences in the pore size of the particular wood species is important to the impregnation process and effects. This controls how quickly the impregnation of the particular wood species is lost, thus the loss of properties the process provided. In this particular study the wood was impregnated with a natural solution. Currently the tar that is used today for this application is not environmental friendly so a natural product is being strived for. After impregnation with heat and proper drying allowed in the climate room the testing can proceed. The testing was completed over a three day period due to time of placing the impregnated samples into a water tumbler and completing mass analysis. Below is pictures of the samples in the water and tumbler



Below is the results for the testing various types of impregnated wood including beech and spruce.

Sample	Mass before(g)	Mass After(g)
0A-1	1.558	1.374
0A-2	1.462	1.296
0A-3	1.508	1.334
0A-4	1.515	1.337
0A-5	1.64	1.455
0A-6	1.578	1.4
0A-7	1.516	1.342

4A-1	1.521	1.345
4A-2	1.559	1.381
4A-3	1.468	1.293
4A-4	1.501	1.33
4A-5	1.496	1.327
4A-6	1.452	1.286
4A-7	1.49	1.322
8A-1	1.427	1.268
8A-2	1.482	1.322
8A-3	1.493	1.323
8A-4	1.499	1.329
8A-5	1.49	1.324
8A-6	1.465	1.299
8A-7	1.557	1.383
10A-1	1.369	1.173
10A-2	1.634	1.42
10A-3	1.466	1.264
10A-4	1.497	1.287
10A-5	1.575	1.355
10A-6	1.682	1.456
10A-7	1.599	1.376

After analyzing the results of the testing it was determined that each sample lost a very similar ratio of impregnated material when comparing it to the rest of the samples. No samples or sample groups really stood out very much. The samples lost an average of between 12 and 15 % of their mass after they were saturated in water and then dried. This means that the samples lose the impregnated material fairly easily and quickly compared to the less environmentally friendly methods.

This testing shows that even despite a lot of continued work in making more environmentally friendly impregnation materials and methods, they currently are not very effective. The methods must continue to be improved upon through research and development.

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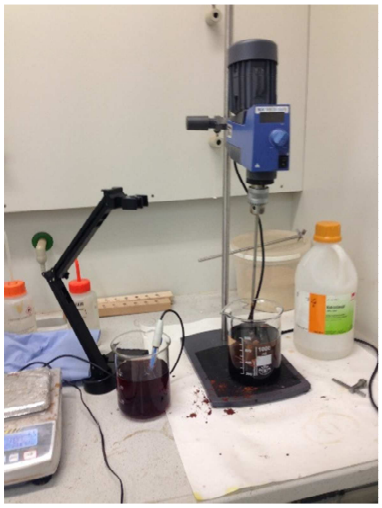
5.5 Straw-based Composite Boards

The process of using straw and glue that is pressed together to form a board is similar to that of the bark-based insulation boards. Straw proved to be much easier than bark for application and mixing with the glue than bark which has a much greater surface area for coverage. The straw had a mass of 3042 grams before application of the tannin glue mixture. The tannin glue mixture that was to be blended with the straw consisted of fifty percent water, and 50 percent all other ingredients. These other ingredients included mimosa tannin powder, hexamine, and hydroxide solution. The solution ended up containing just 1 to 3 percent hexamine overall. These ingredients once being blended effectively were adapted until they reached a pH of 9. After the pH of 9 was reached the tannin glue mixture was added to the straw and blended together. In order to get the best results the mixture needed to be as uniform as possible making sure to coat the straw. This mixture was then placed into a forming box with dimensions of 45 by 45 cm. This forming box was placed on top of a metal flat piece for placement into the press. After appropriate hand pressing and making sure it was as uniform as possible the board was ready for pressing.

The board was pressed at a temperature of 120 degrees Celsius for 22.5 minutes to a thickness of approximately 4 cm. This pressing ensured a density of approximately 400 kg/m cubed which would theoretically help the material stay together.

The results of the creation of this straw-based composite board were much different than expected. The amount of tannin glue applied wasn’t enough for the straw that was used, resulting in the entire board falling apart very easily before any testing could be completed. This application of straw I thought would perform much better than this particular trial showed.

Below are some pictures of the process for creating straw-based composite boards:





5.6 Project Meetings

A majority of the time completing research takes involves the planning and meetings before you can actually complete the project, then after the testing to look at what occurred during the trials. For my research project it was essential that each day I planned what I was going to accomplish during that day. Working with master students all on different schedules made it challenging for organization of laboratory times throughout the week. It was important I met with my advisor, Prof. Barbu, at the University to make sure that deadlines as well as task were being completed both effectively and efficiently for my project.

Project meetings made the organization of laboratory times much quicker and easier than without the meetings. These meetings typically happened at least two times during a given week and at some points were even daily. Prof. Barbu was able to check in on my progress as well as offer advice for the task at hand.

These meetings proved to be a crucial part of making sure that my summer was organized effectively and efficiently. It helped me to stay on track with research and complete all essential task during my three months in Austria.

6 Research Project

6.1 Research Proposal

Bark-based Insulation Boards

Wood despite being a renewable material resource faces a lot of challenges throughout the world as the resource availability is limited. In order to keep a successful resource supply we must develop new raw material sources or an improved efficiency in industrial wood use [4]. Even despite tree barks current uses as bark mulch, absorption material, and various fertilizers, there is still a call for alternative uses that could increase the value of the material. Heating and cooling of buildings requires high amounts of energy. In Europe 40% of the entire energy consumption is caused by buildings, thus the need for more effective insulation is crucial. The energy consumption must be reduced in not just Europe but worldwide, which can be aided with a bark-based insulation board. There is a lot of bark contained on a tree, as it is approximately 10% of the total stem volume of a tree. There is a huge volume of bark available each year globally as 1.6 billion solid cubic meters of wood is logged each year, making available 160 million cubic meters of bark each year [5]. Despite bark currently not being a high value product, there is a lot of it available to develop and use in many applications.

Bark is the boundary layer of a tree and protects it from physical and biological exterior attacks. Therefore it has ideal properties, such as a low density, a high concentration of extracts, very good thermal insulation properties, and relatively low flammability [6]. The properties that make bark a great material for use in insulation board is its thermal conductivity, heat storage capacity, and mechanical characteristics. All these properties can be affected by panel density, resin content, and particle size of the boards [7]. These properties harnessed together can create a product that reduces energy consumption, is more environmentally friendly, and adds value to the current bark industry.

I plan to look at ways of improving the qualities of bark-based insulation boards to get the best properties out of the least use of material. I will be looking at the thermal conductivity, heat storage capacity, and mechanical characteristics of bark-based boards compared to those

on the market today. Looking as bark qualities such as its low density, high concentration of extracts, good thermal insulation, and comparatively low flammability will be important to find out effective and efficient ways to use bark in insulation boards. The project aims to show ways that bark-based insulation boards can be improved on, and qualities that make it ideal for application.

6.2 Research

The bark-based insulation boards were made out of pine (*Pinus sylvestris)* bark and spruce (*Picea spp*.) for this research project. This bark was chosen because of how readily available it was in Austria as well as its properties. The properties of this pine and spruce bark seemed to be very promising in regards to heat storage capacity, mechanical properties, and thermal conductivity that was tested in this research [8].

Topics in this research studied include the resin content of the pine in addition to the density of the panel and bark particle size. These topics proved to be extremely important to analyzing the bark-based insulation boards as a whole after the research was concluded for this trial.

The glue mixture combining with the bark was extremely difficult to get to stick together, but once completed it turned into being a very effective material that also visually looks very nice compared to the current insulation material on the market today. We worked with a few different types of glue through the testing process, including a natural based hexamine glue and tannin based glue.

The bark was mixed and it was insured that the individual bark pieces were approximately the same size which is important for glue application. If the pieces are uniform it makes the glue apply much better and creates a more homogenous mixture. This mixture was extremely difficult to achieve as bark has a much higher surface area than comparable natural materials like straw.

The board was formed in a 45 cm by 45 cm box so that it could be pressed mechanically at a temperature of 120 degrees Celsius. The board was pressed for approximately 25 minutes to make sure the glue properly bonded with the bark pieces in the mixture. This ensured that the glue was able to hold together these bark pieces which therefore would make the insulation board easy to install in real applications.

6.3 Research Results

The results of using the particular pine species, *Pinus sylvestris,* was very promising for application as a bark-based insulation board. The pine species performed better overall than the spruce bark did however. The results were quite expected for the research and nothing really stood out during analyzation. The results concluded showed that the bark has a low density, a high concentration of many extracts, relatively low flammability compared to other naturally occurring products, and makes a good thermal insulation for cold temperatures. Particle size of the bark had a great effect on the mechanical characteristics boards in addition to the panel density and resin content through the testing completed during the project.
The boards showed a very low thermal conductivity which makes them more fire resistant than even I expected. This in addition to the heat storage capacity of bark is important for its use as an insulation board. The boards performed much better than even I expected as the surface area of the bark is much higher than many other materials such as straw.
All the great properties that make bark unique can create a valuable product in the future that is much more environmentally friend and reduces consumption of precious energy sources. More testing and research must be completed to determine adequate ratios of glue to bark, particle size of the bark, and characteristics of the bark-based insulation boards. Research and development of the bark-based insulation boards is important to understand, therefore is kept confidential as progress is made.

7 Summary

The Marshall Plan Scholarship trip to Austria was very successful in regards to achieving my set goals and research events. Due to time constraints and being there during summer holiday it made it more challenging and I didn't get as much time as needed for an extremely in depth study of bark-based insulation board. I was able to look at a wide variety of research studies which proved to be very interesting and I learned a lot along the way. Being both organized and flexible in my research project was very important so that all task were met, which is a crucial life skill.

The bark-based insulation board research was as expected, and nothing was really out of the ordinary from what I expected to happen. If anything I think it behaved even better in testing than I thought that it would. The other events and research I was able to be a part of was unexpected and was a bonus to my educational growth while I was in Austria.

The Marshall Plan Scholarship provided not only the opportunity for me to complete research in Austria but to experience the culture as well. I was able to work with a wide variety of students and people throughout the summer, which I will treasure as I continue in gaining towards my educational experience and personal growth. The diversity of the people I worked with throughout the summer was important to my overall experience in Austria through being a Marshall Plan Scholar. This experience is a crucial part of my college education and life experience thus far in my life.

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