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Wiigwaas: An Indigenous Traditional Knowledge Informed Study of Sustainable Roofing Materials

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WIIGWAAS:

AN INDIGENOUS TRADITIONAL KNOWLEDGE INFORMED

STUDY OF SUSTAINABLE ROOFING MATERIALS

by

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Abstract

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The inadequacy of contemporary Indigenous housing has been recognized worldwide from historical problems related to colonization, dispossession, and resettlement. Indigenous housing on reservations is often substandard which meets the minimum regulations for low-income housing, with little regard to the health or cultural values of the people that live there. This study focuses on reincorporating traditional values into tribal housing with the use of wiigwaas, the Anishinaabe Ojibwe word for Paper Birch (*Betula papyrifera*) and a cultural keystone species of the Anishinaabe. The traditional ecological knowledge (TEK) surrounding wiigwaas is utilized to compare it to sustainable roofing materials. The researcher used methodologies which combined autoethnography, Indigenous Research Methodology, and quantitative data collection to analyze the potential of wiigwaas for covering structures. This study concluded that the durability of wiigwaas in terms of flexibility, strength, and energy allow this to be a valid sustainable roofing material for future use on Anishinaabe lands.

Keywords:
Indigenous Housing, Traditional Ecological Knowledge, Natural Building Materials, Paper Birch bark

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Foreword: Anishinaabe Autoethnography

Boozhoo, Biidaaban ndizhinikaaz. Bawating ndonjibaa miinwaa gitchi namebene ziibing ndaading. Aajijaak ndodem, Anishinaabe Ojibwe ndaaw.

Greetings, my name is Biidaaban Moses Reinhardt. I am Anishinaabe Ojibwe, Crane clan, and a citizen of the Sault Ste Marie Tribe of Chippewa Indians. My tribe is from the "Place of the Rapids" (Sault Ste. Marie, Michigan), but I call home "Place of the Sucker Fish River" (Marquette, Michigan).

I began this project as a new graduate student, fresh from my undergraduate work in Physics and Native American studies. "Walking in two worlds" was how I lived my life, preaching about the importance of being interdisciplinary, but never finding quite the right way to connect these two different fields of study. Then I came to Syracuse, New York to study sustainable construction at the State University of New York (SUNY) College of Environmental Science and Forestry (ESF); finding my way with suggestions and support from every direction, yet that disconnect was still there. One person suggested that I do "pure science," which means quantitative, objective, lab work. Another suggestion was to perform an ethnographic study, on my own people. While these suggestions were well intended, they felt more like my Anishinaabe teachings and identity were being undermined.

Indigenous people are the original *scientists* of North America. Although the concept of science being related to the scientific method may originate in a western tradition, the characteristics and functions of scientists have existed within Indigenous cultures since time immemorial. Cajete (1994) provides many examples of how Indigenous knowledge systems and the users of that knowledge existed in a precolonial context and continue to inform Indigenous cultures today. When Western researchers came into our communities to conduct their ethnographic, anthropological studies, these too often were exploitive in nature, preferring to "Other"ize the Indigenous peoples and look at us as primitive societies. According to Smith (2012), "The ethnographic gaze of anthropology has collected, classified and represented other cultures to the extent that anthropologists are often the academics popularly perceived by the indigenous world as the epitome of all that is bad with academics." So, when it was suggested to me to be "objective" and to use ethnography, no, neither of these suggestions sat well with me. However, they brought forth the real reason I was here, to find a new way of conducting research. This is how I was introduced to Indigenous Research Methods.

Initially, I thought it was a single book that I found in my search to find connections, specifically the work of Linda Tuhiwai Smith (2012), *Decolonizing Methodologies: Research and Indigenous Peoples*. Then my friend brought me to the Center for Native Peoples and the Environment and introduced me to what would open my eyes to this section of science that has been shut out from the mainstream. The work of Shawn Wilson (2008), *Research is Ceremony: Indigenous Research Methods*, filled that missing connection. Wilson starts by introducing himself as he would in a letter to his children. He expresses himself as a cultural being, his relationship to his culture, language, and belief system before going into why and how he helped develop this research paradigm.

According to Windchief & Ryan (2019), the summarized components of this methodology are “(1) establishing a relationship (or perhaps more importantly having asked questions because of the relationship), (2) inquiring in a way that continues a larger conversation, (3) leaving space and time for contemplation, and (4) not asking for knowledge sake, rather asking for the sake of community benefit”. The introduction is necessary in order to establish a relationship between myself (the researcher and author) and you (the reader) by telling you who I am, where I come from, and why I am doing this as it relates to my community. While there is a significant long and complicated relationship between ethnographers and Indigenous peoples (Smith, 2012), the acknowledgment of positionality and relationality is an important component of fully formed research, thus I have included a blended approach to this methodology by incorporating autoethnography to reveal the motivations and perspectives I have brought to this work.

According to McIvor (2010), autoethnography as a research methodology “extends beyond the realm of storytelling for entertainment but, not unlike much Indigenous storytelling, it holds a greater purpose of teaching, learning, and at times, creating new knowledge." They go on to explain more in depth that the use of autoethnography and Indigenous Research Methodology are not a full rejection of Western methods, but rather a narrative approach that draws on the experiences of the researcher. "There are two main spaces of synergy between an Indigenous research paradigm and autoethnography. The first is the centrality of the "self" in the work, without a sharp separation between the researcher and the subject (dual meaning intended). The second is the shared modality and intentional use of storytelling as method. It is a fundamental aspect of autoethnographic approaches, as well as a powerful and traditional part of oral societies." This framework of storytelling allows for the “space and time for contemplation” to develop fully formed answers to the research questions and being able to tell the story of them to communicate it to my community; whether it is my family, local community, tribe, or Anishinaabe people living on this Earth.

Identity

This project is rooted at the core in my identity as an Anishinaabe Ojibwe woman and my personal educational experiences in learning about traditional Anishinaabe culture and contemporary issues impacting our communities. A key piece of this cultural identity is locality, both from a sustainable building perspective in relation to climate zones, as well as the place-based focus of TEK from Indigenous peoples, which means my personal relationship with Anishinaabe-aaking, my traditional homelands. This personal place-based identity can best be described by the concentric circle model that starts from the largest being Ngaashe Aki (Mother Earth), Mshike Minis (Turtle Island aka North America), Anishinaabe aaking (Anishinaabe traditional territory), Bawating (where my clan resides, Sault Ste. Marie, Michigan), to the smallest where I currently live at Gitchi namebane ziibing (Marquette, Michigan). Identity and locality are critical components of this study due to the use and practice of the Indigenous Research Methodology.

Wilson's (2008) work resonated through my core by the way he interwove the aspects of his identity as an Indigenous person working with his community and his identity as a student in higher education. The writing shined a light on all my past research and struggles with walking in two worlds. My identity has been as an Indigenous person AND a scientist/researcher, but it was not until reading through this book that I felt I could identify as both; an Indigenous researcher and an Anishinaabekwe (Anishinaabe woman) scientist. This was truly the turning point, where everything I have learned finally came together and I could move forward with the next steps towards developing an Ojibwe Sustainable Housing Framework.

In order to align with this Indigenous Research Methodology, I offer the following introduction; a letter I originally wrote to my niece Luna, but by the end I was writing it as a letter to the future generations to whom this research project is dedicated:

Aanii My Girl,

I am not sure if you will ever read this, but I wanted to write this to collect my thoughts in hopes that someday this project will actually make a difference in the world. I hope this will help to inform and boost change for where we live, for Indigenous people worldwide would be favorable, but at the very least our small rez (reservation) community back home. This letter is a story about my journey to this project, the difficulties I had to overcome, and the eventual end goal of where this is heading to help you, those living on our reservations today, and many generations into the future.

You were there in the beginning, the very beginning. My first week as a "real" researcher. The day when I got my first tour and training in my lab was the day that you decided it was time to come into this world, and for the first time I had a new priority. The work I was doing was no longer just for publication, to present at a conference and move on to the next thing. I decided that it needed to be for future generations, to build a home and a world that you could grow up in, safe. All the components were there, I had already been living the life of two people all the way up to that point.

I grew up much like you, with my mom and dad raising me and my sister, Nim, to be Anishinaabe. Some of my furthest back memories is speaking Ojibwe in school and running around the pow wows with your mom (and my best friend), Rita. I remember the first wigwam I (helped) build with my parents, in my backyard. It was a tiny thing, apparently not up to the standards of Papa, but I loved bringing my friends in there. My family would go in there at night and bring our thermos of hot chocolate and listen and tell stories.

Figure 1: Family photos of our first wigwam (Left) and Nim and I sitting inside the wigwam (Right)

I think I helped build a wigwam almost every summer growing up; from the tribal youth programs, campgrounds, backyards, and sweat lodges. Most of these were with my mom, dad and Nim, but also Earl Otchingwanigan and a few with Wade Wartella. The first structures were not too good, I will not lie, but they got better with time and experience. The gathering of materials was always the hardest part. Everything had to be so particular and done in a good way, with semaa (tobacco) and good thoughts. But there were so many teachers to help guide us; Greg Johnson, Helen Roy, Scott Wyzlic, and all the uncles and aunties. And when I knelt in poison ivy while collecting basswood, oh boy, I learned a valuable lesson from one of our best teachers, Mother Earth.

As I got older and moved all over the country. I noticed quickly that I was the only Native at most of my schools, so in came the introduction to my second world, the alternate Daabii. The one where she is a stellar student, super active and involved in organizations, and extremely humble. During this phase of life, I still went to pow wows, helped my parents, and did ceremony, but I kept it completely separate from my academic side. I had always been good at school, but now I had become a "nerd" as Nim would so endearingly remind me with a sign on my door. Eventually I embraced this designation and went off to become a physicist. I made it into college majoring in physics, went to my labs and math classes before going to eat lunch with my family in the Center for Native American Studies (NAS) at Northern Michigan University (NMU), in Marquette, Michigan. Even then, at a university that offered NAS, I still chose to keep these two worldviews and personas separate.

Then multiple events happened in quick succession. I was awarded a mentorship with the American Indian Science and Engineering Society (AISES) and applied and was awarded an internship at Colorado School of Mines. That summer in 2015, I drove across the country with my sister to become a “scientist” in Golden, Colorado. As Nim flew back to Michigan, I started my first week at my fancy internship and you decided that it was the perfect time to come into this world - three months early.

So, here is where the process began that got me to this point, all the components were present, they just had to combine together. My goal was always to watch out for future generations, but that had always been some abstract thought that my parents repeated to us growing up. It wasn't until I was named godmother to this new tiny human, you Luna, that I realized that the future generations are happening right now. What was I doing to help them?

Then a conversation happened, so brief I am not sure he even remembers. My uncle came up to me as I was working a vendor booth at our university pow wow. I am rushing all around, making sure counts were right, putting wristbands on people when I look up and it is Uncle Bud! I gave him a hug over the counter, pointed to where the drum was setting up and said I would be over to sing a few songs with them when I get a break. But then he turned to me and said, "I heard you were doing some big-name science stuff. So here is a question for you, how is our Ojibwe community being affected by climate change?" Before this point, I never thought about the interconnections between our people and the overarching changing climate. I wrote that question down on a spare sheet of paper we had, but it kept bouncing around in my head all day.

How has our Ojibwe community been impacted by climate change? At first the answer seemed simple; everyone is affected by climate change. But our connection to the land, water, and other beings is part of what makes us Anishinaabe. Our language that has been passed down for generations holds the collective knowledge of how things were in the past, so we can see just how different our world is now; the tree's sap flows at drastically different times of year, the birds are confused by the early spring. This is after we already lived through 500 years of colonization and assimilation. We survived through one massive and ongoing world changing event, and now we are having to prepare for the next. Centuries of assimilation, being forced onto reservations and boarding schools, yet we are still here. A resilient people indeed. We have survived all of this, but the impacts are still extremely apparent. I look around our rez and see the box houses, mold and smoke smell in the air, the lawns, and the Midjim gas station being our only store nearby. I read the statistics of education, poverty, health issues, and wonder where to start. Our communities have already been living with the effects of climate change, our entire lifestyle disrupted, but we are revitalizing. That is what this is about. We are resurging our cultural lifeways.

So, I switched metaphorical directions. Instead of focusing on nanoparticles and novel technologies, I started looking at what we have today, what can I do to help our communities directly and in the present day. I conducted a case study with the Keweenaw Bay Indian Community (KBIC) and their renewable energy systems. That study indicated to me that there are so many barriers to full implementation of these systems that KBIC must look at other aspects in the meantime.

So, I went the direction of education, how to educate the next generation so they can help in this process. In doing so, I helped write multiple grants to provide STEM youth camps, similar to the ones I attended in middle and high school. These programs allowed me to learn about service projects, introduced me to physics and coding, and it is where we built our wigwam to add to the Village. One aspect of these camps is that I got to help develop them by showcasing technology that had been growing and expanding, as well as the interdisciplinary movement of incorporating Indigenous worldviews within the sciences. With researchers from Rensselaer Polytechnic Institute in front of me and the words of Robin Wall Kimmerer literally on the back of my shirt, I learned about wigwametry and culturally-situated design tools. I witnessed the bare bones of this at my youth camps, but to see the progress made and the elaborate patterns we could incorporate by coding while also learning about cultures, specifically my own, was astonishing. This tool set showed me that there were ways to incorporate cultural designs and materials that had been tested and tuned for thousands of years via traditional ecological knowledge (TEK) into modern contemporary systems.

Now I finally found all the pieces necessary to create this project. I have my two worlds background, the catalyst question, the culturally situated design tools, the methodology, and you, the future generation, to incorporate our culture and TEK back into our homes, to build our relationship with Mother Earth, and create healthy, sustainable buildings for Indigenous people. All of which to say, that this is my story. It is a collection of all the knowledge that I have been given and gained through years of learning from and living with Western and Indigenous worldviews. While I share the rest of this project with you, know that I am speaking about my perspective of the lessons from our ancestors and elders, and that this is for us, our community, and all our relations.

Sequencing and Where this Stands

The writing style I follow in this thesis is written in a way that one can follow my thoughts and experiences throughout this process. I am an Anishinaabe woman working to decolonize my own mindset by articulating my values, codes of conduct, knowledge, and worldviews into this academic realm. Geniusz (2009) speaks to this in her book *Our Knowledge Is Not Primitive* as, "Although taking many forms, the decolonization movements are ultimately based on the premise that indigenous people's lives and knowledge systems around the globe have been colonized along with their lands and resources, and it is now time to reverse the colonization process." This decolonization movement is apparent in everything from food and diet, education, language, governance, as well as theories, stories, and methodologies are part of reclaiming our lifeways (Reinhardt, 2015; Eglash et al., 2020; Smith, 2012; Wilson 2008; Battiste, 2000). Genuisz (2009) continues by going on to say "decolonization is about changing, rather than imitating, the European or Western concept of research so that it fits into and can be used in conjunction with indigenous cultures." This thesis aims to contribute to the decolonizing movement with cross-cultural methodologies and a vision for a decolonized Ojibwe Sustainable Housing Framework using Anishinaabe Ojibwe TEK.

I have attempted to sequence the rest of this thesis document according to criteria set out by my university, starting with an introduction to Anishinaabe values and history in Chapter 1 and how that relates to the research questions in relation to using wiigwaas as a sustainable roofing material. From there I take a step back with the literature review in Chapter 2 to draw from the knowledge of previous authors, taking a big picture view of Indigenous housing structures as a whole, before narrowing it down to my focus of Paper birch bark. Chapter 3 explains more in depth the process and approach I took to conducting the fieldwork and data collection and the relationality and collaboration involved with those whom I am held accountable. Chapter 4 uses more of the story approach to chronologically guide you (the reader) through the methods that I used in the two experiments that were set up to test wiigwaas as a material. The results of those two tests are shown in Chapter 5 and the connections between those two are discussed more in depth in Chapter 6. Lastly, Chapter 7 goes into the conclusions drawn from this study, answers the research questions based on the compilation of all the qualitative and quantitative data collected, and address the limitations and future research needed to develop a holistic sustainable Ojibwe house for future generations.

Chapter 1: Introduction

The inadequacy of contemporary Indigenous housing on reservations has been recognized worldwide with the lack of "quality of basic services, materials, facilities and infrastructure, habitability, affordability, accessibility, legal security of tenure, and location and cultural adequacy" (Bailie & Wayte, 2006) as a result of colonization, dispossession, and resettlement. American Indian reservation housing is often substandard, cookie-cutter buildings that meet the minimum regulations for low-income housing, with little regard for the health of the environment or the cultural values of the people that live there (Seltenrich, 2011; Deane & Smoke, 2010). This study focuses on reincorporating traditional values into tribal housing with the use of wiigwaas, the Anishinaabe Ojibwe word for Paper Birch (*Betula papyrifera*) and a cultural keystone species of the Anishinaabe, as a potential sustainable roofing material.

Indigenous Peoples: History and Housing

Indigenous peoples are known as the original or earliest known inhabitants of a region prior to colonization. These inhabitants are described as having distinct culture, language, beliefs, and self-identify as Indigenous peoples at the individual level as well as accepted by their community as such. Indigenous people are living and thriving on every continent despite centuries of ongoing colonial practices. However, it is important to note that there is no such thing as “pan-Indian” culture (Hadjiyanni & Helle, 2009). Smith (2012) goes as far to say that the “term ‘indigenous’ is problematic in that it appears to collectivize many distinct populations whose experiences under imperialism have been vastly different.” As such, this thesis focuses specifically on the Anishinaabe Ojibwe people of the Great Lakes Region.

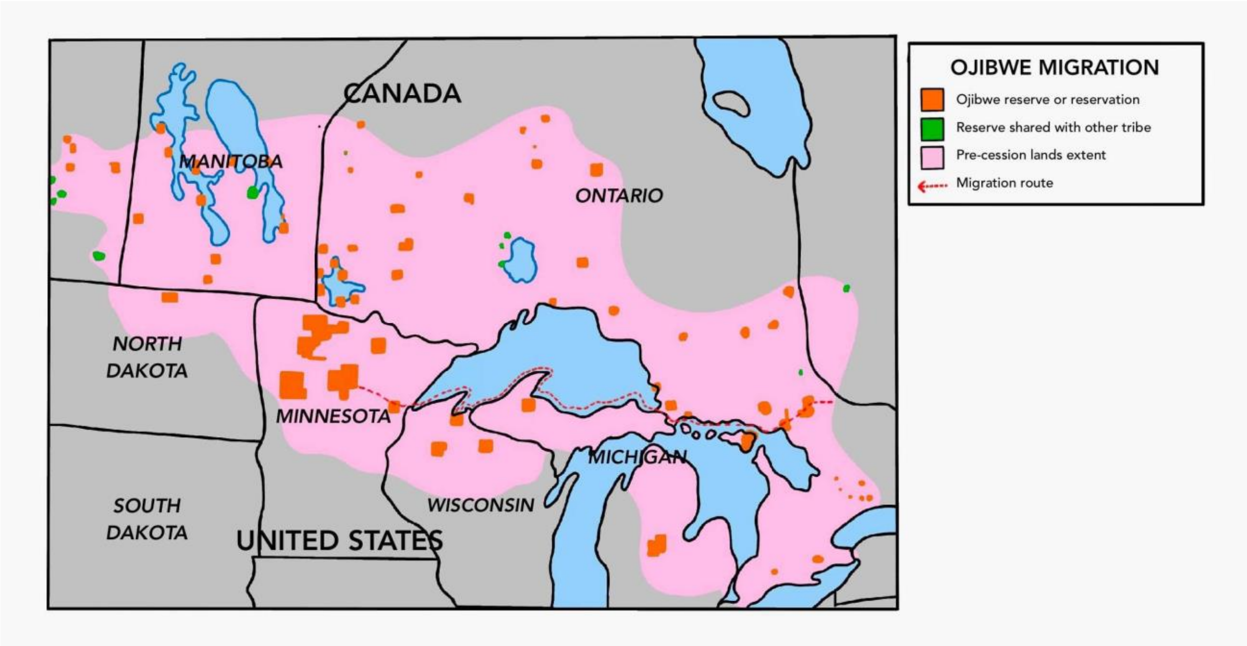


Figure 2: Map of Traditional and Contemporary Ojibwe Lands

Ojibwe people are part of the Anishinaabe Three Fires Confederacy, a group of Algonquian speaking bands that migrated from near what is now considered Maine, along the St. Lawrence Seaway, into the Great Lakes Region. Anishinaabe traditional territory stretches from Ontario, all the way into Minnesota and North Dakota, shown in Figure 2.

Anishinaabe people are guided by our value system which includes the medicine wheel, seven grandfather teachings, and the seven generations philosophy (Benton-Banai & Liles, 1988). The medicine wheel represents, briefly, the four directions, sacred herbs, life cycle, and what most notably pertains to this research; worldview and balance. Each of the four parts of the medicine wheel relate to an aspect of wellbeing: physical, emotional, mental, and spiritual; that relate to how you stay in balance as a person but also looking at the balance with the world around you.

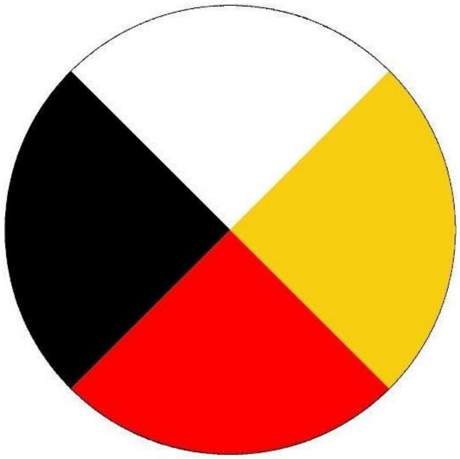


Figure 3: Anishinaabe Ojibwe Medicine Wheel

The seven grandfather teachings are love, wisdom, respect, humility, bravery, honesty, and truth. A form of the seven generations philosophy can be found in many Indigenous nations which states that what we do today has reverberating impacts seven generations into the future. This also means that we are still learning and feeling the effects of what our ancestors went through seven generations in the past. These teachings are the basis of how we interact with the world; all the beings and relations including those which formed this project. According to Hadjiyaani and Helle (2009), the teachings above can be condensed into four cultural anchors; "family and kinship relations, language, spirituality, and the ethos of respect".

Historically, all of these teachings directly relate to how we live, within our housing and community. Prior to colonization, Ojibwe people lived mostly in wigwams and would make seasonal rounds with either their extended family at hunting camps, or in larger villages for fishing and wild-ricing camp, but also may have built wikiups (lean-tos) as temporary shelters. Wigwams are circular dome shaped structures held up by lodge poles and ribbing, covered with wiigwaas (birch bark) and other types of bark on the outer surface. The bark sheets could be rolled up and carried to the next place depending on the season while the lodge poles would stay put until the next round. During winter, there might also be a secondary covering over the first which would help insulate the wigwam during the cold winter months. The trees and roots used for the wigwam are found within the Anishinaabe territory and would be changed depending on the season and region. For example, the top of the wigwam would almost always be covered with wiigwaas, but the sides of the wigwam could be interchanged with cedar bark during winter months, cedar mats, or cattail reeds in order to let air flow through during the warmer summer months. The ribbing and lodge poles would often be maple saplings, but could be changed out with aspen, or other local flexible saplings. The “rope” to tie the ribbing and sew the bark coverings together was often “wiigob” or basswood cordage but could also be jackpine or other pine roots as well.

According to Hadjiyaani and Helle (2009), the wigwam “supported the four cultural foundations [and] ... provided shelter for these extended families and served as the site of activities that helped transfer the culture to the next generations, like cooking, eating, craft making, and storytelling." All of the materials used in the structure would be harvested sustainably, by hand, and with an offering of semaa (tobacco) in order to give back to the Earth.

Colonization and Current Conditions

Around the year 1492, the plague of colonization came to the North American continent. The story of the following 500 years of extermination policies, forced assimilation, and genocidal tactics can be found in every Indigenous nation world-wide, which includes the dislocation from our lands, as well as the loss of language, culture, place-based connection, and enforced dominance of western science over our TEK. The intergenerational trauma from this is still readily apparent in our communities today.

Among the most disruptive of these traumatic events was the era of Federal Indian Law called the Removal and Reservation Era in the 1800’s. This policy forcibly removed entire tribes from their homelands onto reservations with little resources and without the ability to provide for their families. Entire communities of tribal people were forced onto reservations and into an entirely conflicting way of life. Hadjiyaani and Helle (2009) draw on Densmore’s (1974) work, “...large, permanent reservation communities inhibited Ojibwe practices of moving camps in observance of hunting, wild ricing, and maple sugaring seasons; surrounding areas were drained of natural resources, causing severe food shortages and poverty; and contact with Europeans amidst crowded and unsanitary conditions brought deadly diseases that led to the demise of much of the population."

Tribal people were provided housing and provisions in several instances mentioned in multiple treaties in an attempt to support entire communities in a new environment (Kappler, 1972). These homes were stripped of any cultural significance in order to try to assimilate Indigenous people into the "American" way. The language of treaty provisions assumes that the American Indian people will be purchasing housing or housing products to build government approved houses. This is in direct contrast to our traditional housing which is made from materials that are directly harvested from the Earth. The transition from traditional Anishinaabe housing styles to westernized angular housing occurred over multiple decades and happened differently for differing tribal communities. You can see in early historic photographs from the mid 1800's forward that the transition was certainly occurring during the treaty-making period with photos of wigwams incorporating elements such as stove pipes and windows into their wigwams. However, the starkest contrast happened with the development of reservations and advent of government housing on tribal lands. "By the 1870s, some of the first federally funded homes were recognized as substandard by government Indian agents, who noted some were devoid of furniture, in poor condition, decaying rapidly, and in some cases uninhabitable" (Seltenrich, 2012).

Since then, little has changed for those living on American Indian reservations. The problem continued to worsen through the twentieth century with the housing boom funded by Housing and Urban Development (HUD) and the Bureau of Indian Affairs that built thousands of single-family homes to federal codes, rather than state or local codes, without regard for the local climate. Seltenrich cited Daniel Glenn, a Seattle-based architect who specializes in sustainable and affordable housing on tribal lands with saying “If you go from reservation to reservation, you see this same house… People would freeze in them in Montana and overheat in them in Arizona” (Seltenrich, 2012).

The inadequacy of Indigenous housing is not a new phenomenon and is referenced by multiple scholars across the U.S., Australia, and Canada (Cattelino, 2006; Bailie & Wayte, 2006). "Living conditions on the reservations have been cited as comparable to Third World... Despite the Indian Housing Authority's recent efforts, the need [for] adequate housing on reservations remains acute" (Living Conditions, n.d.). Seltenrich (2012) links the extensive problem in tribal housing with asthma and other respiratory illnesses among Alaska Natives/American Indian people which coincides with the commentary Bailie and Wayte (2006) had of the health problems associated through direct and indirect ways of inadequate housing in Aboriginal Australian homes. This comes down to the environmental justice issues explored by Rosier (2008) that states, "almost every environmental issue in Indian country is an environmental justice issue.” Rosier describes that this began with European imperialism and colonial expansion and is still present today with reservations and dispossession of land.

Tobias and Richmond (2014) conducted a qualitative study with Anishinaabe elders in two communities close to the Canadian/U.S. border at Sault Ste. Marie, Ontario which examined the direct and indirect forms of dispossession and its health impact on their resilience and traditional practices. This study found that the “process of environmental dispossession [is] not confined to the historical narrative of Indigenous people’s health; but rather, they continue to shape health in the modern context” (Tobias & Richmond, 2014). This ties together with the idea of “integrated history” coined by van der Leeuw et al. (2011). The idea of integrated history is meant to create a relationship with the past, present, and future. "Knowledge of the past is still essential, perhaps even more essential than ever, but that knowledge must be used in a new way. As a result, many are becoming aware that one cannot understand the present, let alone forecast the future, simply by looking for causality in the past through analogues and then extrapolating toward the future. We wish to unpack different ways of relating the past to the present, and extend that relationship to include the future, as sustainability is, after all, a particular way of looking toward the future" (van der Leeuw et al., 2011). Many times, we speak about the seven generations principle and how we must think ahead to how we are impacting our future generations, but seldom do we say how to do this.

This speaks to the relationship between Anishinaabe people and our traditional housing materials. Indigenous people have been disproportionately impacted by the effects of climate change due to environmental justice issues as well as centuries of assimilation policies that cut us off from our land, food, water, and our way of life. Our connection with the land developed a standard that met the needs of our people, which we learned through centuries of knowledge gained from observation and testing that was then passed on through the generations of Indigenous people. The reservations and boarding school eras led to the severe disruption from our lifeways, while the transition from the traditional wigwam to government housing for Ojibwe people on reservations disrupted our relationship with the past, our traditions, and our materials. The alienation of Ojibwe people with our materials, in government funded housing has undoubtedly left an impact on the material culture and has disrupted and alienated us away from one of our cultural keystone species, wiigwaas.

Contemporary construction materials come from the market economy, but our reliance on them does not have to be so. We are currently in a revitalization movement, where we have the ability to remake it so the materials we use in our housing once again speak to our traditional culture. The revitalization of our traditional materials in the housing system could even impact the relationship we have with economy. That in some ways helps us begin to decolonize our reliance on what Kimmerer (2013) refers to as a windigo economy and exposes us more to a reciprocal, ecological economy where we look to Ngaashe Aki (Mother Earth) for our housing materials.

This is already in development with tribal green building projects happening across the country with thanks to the Native American Housing and Self-Determination Act (NAHASDA) of 1996, which allows tribes to "have the freedom to formalize their new designs by developing codes to replace the less-suitable or ill-adapted codes previously used on their reservations. The outcome, in many cases, has been a hybrid of modern green design elements and indigenous knowledge passed down through the generations" (Seltenrich, 2012).

Research Questions

My initial research question for this project was the following: How can we build a sustainable house using Ojibwe TEK? However, as I continued with the literature review and actual experimentation I realized that this question was much too broad and could simply be answered based on historical evidence, therefore I refined my question to the following: <u>How can (Paper) birch bark be used as a contemporary sustainable roofing material?</u> There are multiple components to this research project. The goal is to eventually develop Ojibwe sustainable housing on reservations and tribal land. However, that is a long way away due to multiple factors such as tribal politics, land use, and financial barriers. As this is a broad topic, I have broken this question into four sub-questions:

1. What is the importance/history behind Ojibwe TEK in regards to housing materials?
2. Where, when, and how do we collect the birch bark we use/used in our wigwams?
3. How do/did we treat and test the materials for resiliency and durability?
4. How do traditional materials compare to contemporary alternative sustainable construction materials?

These questions address the current gap in sustainable housing development in cold climate regions, specifically in relation to Indigenous housing, as well as the need to combine thousands of years of collective knowledge with contemporary tools and equipment to further the alternative sustainable materials field.

Chapter 2: Literature Review

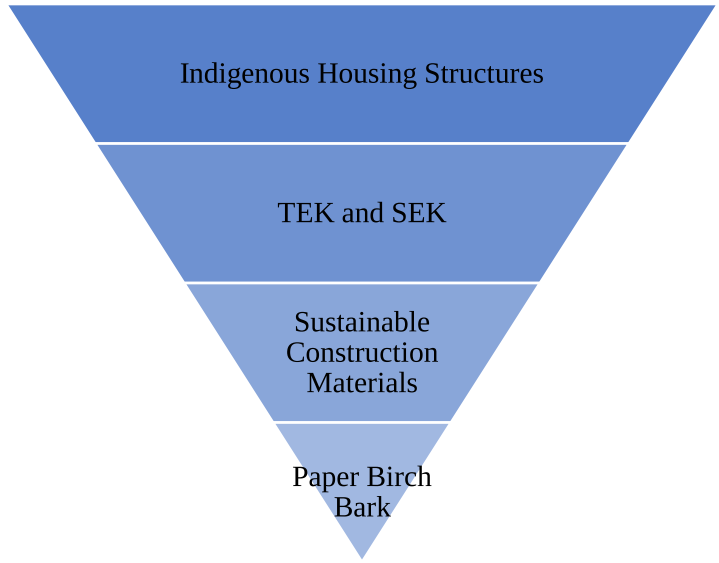


Figure 4: Inverted pyramid depicting scope of literature review

To address the current housing conditions, this research involved understanding and developing a path forward for evaluating the potential for reintroduction of materials that were used for traditional Indigenous housing into contemporary housing. This was done by conducting the following literature review in order to draw from the knowledge and wisdom of those who came before me, as well as to determine where this thesis may be located. Traditional housing was built using millennia of TEK that Indigenous peoples passed down through oral tradition. These structures were built using local, sustainably harvested materials with each component being interconnected with each other. Each of these sections drew from one another in order to narrow down the focus to address the research questions of how might paper birch bark be used as a sustainable roofing material.

Traditional Indigenous Structures

In order to inform professionals and future housing design, we must understand why Indigenous structures were built the way they were for thousands of years. As stated before, each Indigenous nation has their own customs and ideals which are reflected in their housing style, but one thing to consider is that the style of building was region and climate zone specific. In the next sections I provide examples of traditional Indigenous structures, before going into greater detail about the Anishinaabe wigwam.

The varied style of Indigenous housing was heavily dependent on the climate zone, region, and availability of materials. For example, the adobe brick structures of some Southwestern tribes were developed to block wind and sunlight in order to keep the inside cool, whereas the teepee open frame structures of some of the Great Plains tribes were developed both to protect the people from the winds, but also were made to be portable. According to Seltenrich (2012), “We’re looking not just at green technologies but indigenous technologies,” Gough says. “These designs have been developed over millennia.” These technologies, that were generally passed down through oral tradition, held knowledge of passive design, thermodynamics, and ventilation techniques that are still being re-learned and taught today to the next generations of Indigenous peoples and sustainability researchers.

One prime example of the structural technology that was developed to withstand one of the harshest climates is that of the Inupiaq people and their traditional sod igloo. The igloo uses materials available in the Arctic Circle and is bermed into a hillside to retain heat and block wind. "Native technologies incorporated into the home include a passive ventilation system known as a qingok, which uses vents in the ceiling to draw out warm, moist air, and a cold-air trap called a qanitchaq, or ‘Arctic entryway’ in the local Inupiaq language, a sort of foyer that seals off cold air from the main living space" (Seltenrich, 2012). This traditional knowledge has now been integrated into a prototype home built in 2009 in order to address contemporary health issues associated with inefficient housing for their climate region.

This type of integration of our traditional building knowledge into contemporary designs is a growing movement. After centuries of colonization and forcible isolation from our cultural values in our own homes, many tribal communities are partnering with researchers and other groups to create culturally relevant, decolonized design, sustainable buildings. After years of disruption, displacement, and forced assimilation, the authors Hadjiyanni and Helle (2009) conducted a case study in constructing Ojibwe identity with the need for culturally sensitive housing in Minnesota. This case study was conducted via interviews and personal observations with tribal members from an Ojibwe nation living in reservation housing. The authors briefly describe the traditions of the Ojibwe people before exploring current conditions within these homes and discussing the "reconstruction of the past by either supporting or suppressing domestic practices" as well as recognizing the "multiplicity of identities embedded within a cultural group" and how these inform the design and construction process of culturally reimagined homes.

Another case study published by Shelby et al. (2012) took this idea one step further by having researchers from UC Berkeley co-design culturally informed housing with and for the Pinoleville Pomo Nation (PPN) in California. This co-designed workshop included 40 residents from the tribe and 14 participants from the University to "understand the sustainability and environmental needs of the PPN community in order to provide recommendations for housing designs for the community" (Shelby et al., 2012). This workshop needs assessment showed that the top two priorities from the tribal participants are to integrate traditional building techniques and account for energy generation and conservation. Afterwards, the researchers conducted an analysis of climatic features on the PPN land before co-generating Pomo-inspired housing design to incorporate philosophical ideals and historical structure from the tribe. An important conclusion from these researchers is that the effort of tribal members to integrate and adapt our traditional housing is "a possible signal that tribes want to 'return to their old ways'," however the authors understood that the "PPN's pursuit of sustainable buildings and energy systems was about being able to evolve and share their culture and way of life with Natives and non-Natives as an independent, and self-sufficient community that utilizes the latest technological, political, and economic tools available to meet their needs and goals" (Shelby et al., 2012).

Both studies mentioned above focused on the respect for the culture and needs of the tribe when working with outsiders and researchers. This co-designed, participatory research method is also utilized in the article written by Deane and Smoke (2010) titled “Designing Affordable Housing with Cree, Anishinabe, and Metis People.” The word “with” in the title is an important distinction with any researcher working with an underrepresented group of people, but especially when designing places where people live. Deane and Smoke (2010) spent four years in the consultation process between the tribal nations and the researchers which included cultural concepts and design of the buildings that were intended for Indigenous families in urban communities. This input was not just on aesthetics, but on actual conceptual assumptions underlying the framework design of the building. These two examples of co-designed housing between researchers and tribal nations are part of the growing movement to develop sustainable buildings for our tribal lands through sovereignty and best practices found via case studies (US EPA, 2016; Blosser et al., 2014).

Traditional Ecological Knowledge

Traditional Ecological Knowledge does not have a single set definition, due to the changing nature and the components within. However, many Indigenous scholars have written about what TEK means to them and their community, along with the process in gathering/utilizing TEK for the sake of enhancing some aspect of our knowledge base. The most widely accepted working definition is from Berkes (1993) "a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment.” From an ecological engineering standpoint, Martin et al. (2010) defines the field of TEK as "a source of ideas, inspiration and designs for more sustainable methods in ecological engineering, environmental management, restoration, and similar fields.” Lastly, according to Emery et al. (2014), "The essence of Anishinaabe TEK is acknowledgment of relationships between all of creation and behaving in a respectful manner that preserves our resources.”

These definitions of TEK are highly contrasted with the methods behind western science which “emphasize[s] the need to solidify as much as possible the relationship between observations and interpretations. Thus, these interpretations linked the phenomena investigated to what was already in existence at the time they were observed, rather than to what was still to come (and therefore could not be observed)" (van der Leeuw et al., 2011). Western science, sometimes referred to as scientific ecological knowledge (SEK), focuses on objectivity, quantitative materialist knowledge based on what is already in existence. Kimmerer (2018) contrasts TEK with SEK, stating the difference between the two bodies of knowledge and worldview, but emphasizing that “together, they can create a new kind of knowledge that will lead us to true, embodied sustainability.”

These definitions of TEK are indicative of the process behind how TEK is established and passed on to others, and have implications for how it can be used in conjunction with SEK for a more holistic approach to the study of contemporary issues like sustainable housing. The inclusion of TEK, and indeed the attempt to balance TEK and SEK in contemporary studies not only provides more depth to the process and outcomes, but provides me an opportunity to draw on my traditional knowledge and experience as an Indigenous woman while valuing the scientific approach. Both of these knowledges have their own strength, and instead of pitting one against the other, this blended approach allows one to use both to gain a better more robust understanding of the phenomenon that is being studied.

For instance, as indicated by the co-design methodology of Shelby et al. (2012) and the integrated evolutionary adaptive process from van der Leeuw et al. (2011), an important aspect of utilizing TEK in contemporary research is the free, prior, and informed consent (FPIC) when consulting a tribe on any TEK project. This blending of TEK and SEK aligns with Indigenous cultural teachings like the seven grandfathers teachings of the Anishinaabe, one of which is respect. In this case, respect for tribal sovereignty and an appreciation for the origination and collective ownership of knowledge.

This approach is also evident in how Emery et al. (2014) used TEK as a basis for forest inventory, specifically paper birch in the Great Lakes Region. The researchers, non-Native, intentionally sought out expert consultants from the local tribal people in order to find healthy trees and learn about the way Indigenous people classify forests. In consulting with tribal community members, the researchers learned that the vocabularies and identifiers of the bark differed between the gatherers and researchers such as "Value statements such as "good bark" or "desirable bark" were avoided. As the gatherers pointed out, all birch bark is good for something" (Emery et al., 2014).

This is in agreement with the work done by Moser et al. (2015) in which researchers looked directly at bark characteristics in close collaboration with Ojibwe people to develop an inventory of forested lands in the Great Lakes region to see which characteristics traditional gatherers used to evaluate trees for potential uses. "This supplemental protocol was developed in close consultation with Ojibwe gatherers, who identified the paper birch bark characteristics that influenced their evaluation of products that could be created. This protocol is in contrast to traditional wood-grading standards, which emphasize a hierarchy of wood quality, usually based on utilization potential and reflected by price paid. Instead, the paper birch bark grading protocol does not reject any bark features, but rather recognizes the potential for bark characteristics to shape the choice(s) of products that can be made" (Moser et al., 2015). These examples show the essence of appropriate, respectful integration of TEK into Western science methods by combining the strengths of each methodology and knowledge system in order to approach the research questions from multiple viewpoints and expertise areas.

However, not all aspects of using TEK in research follow this protocol. Pengelly (2011) focuses on the development of non-timber forest products in Northwestern Ontario which discusses the controversial interactions between the intellectual property right of the Indigenous peoples who have often been exploited for economic gains. While Pengelly does an excellent job of creating an environment of respect by making a significant effort to incorporate Anishinaabe language into the report, too often in TEK research is there "insufficient mechanisms for maintaining the intellectual property right of Indigenous people and equitable benefit sharing in practice."

Sustainable Construction Materials

From an Indigenous TEK lens, the meaning of the term “sustainable” may carry with it certain nuances not generally found within Western approaches to the idea. For instance, in Anishinaabemowin, the term “gwayahkooshkawin” is a term used for balance, and “ninoododadiwin” is often used for harmony, both of which align with what might be thought of as hallmarks of sustainability in western thought and expression. However, the suffix on the end of both Anishinaabemowin terms indicates that it is a verb that has been made into a noun form. Thus, it requires the speaker to first understand the verb form in order to make sense of the noun form. Therefore, balance is first the act of "balancing" and harmony is first the act of "harmonizing." As mentioned previously, these ideas are often used to describe the Anishinaabe medicine wheel which represents the life cycle, which in the same vein means that it is fluid, evolving, and ever changing. In this tradition, the action precludes the state of being, indicating that the idea of sustainability is intricately tied to life itself. To borrow from Cajete's (1994) work, *Look to the Mountain: An Ecology of Indigenous Education*, it could be said that sustainability for the Anishinaabe is for life's sake.

Sustainability from a Western SEK view is most frequently defined by the Brundtland Commission Report, *Our Common Future* (1987), as "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). This definition is compatible with the Anishinaabe views on looking seven generations ahead, but with focus on development instead. The goal of development has changed with the times as well, with the UN Sustainable Development Goals being the current goals set forth by humanity to "decouple economic growth from climate change, poverty, and inequality" (*Green Building & the Sustainable Development Goals*, n.d.). The current movement towards green buildings has made a significant impact on the health and wellbeing of people and the environment by being held accountable and contributing to many of these goals.

According to the World Green Building Council, a green building is one that "in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life" (*What Is Green Building?*, 2016). This includes retrofitting existing buildings and new construction to use renewable energy, efficient water and lighting fixtures, taking consideration of the climate and surrounding environment, and use of materials that are non-toxic, ethical, and sustainable.

Benefits to using sustainable construction and sustainable materials are numerous. According to Joseph and Tretsiakova-McNally (2010), "Annually, building construction in the world consumes: 25% of the global wood harvest; 40% of stone, sand and gravel; and 16% of water. It generates 50% of global output of GHG and agents of acid rains." This means that new construction plays a large part in the changing global climate, and it is up to current and future generations to account for this when developing new buildings. Currently, our buildings are notably inefficient in terms of how they are constructed and how energy efficient they are. According to the U.S. Green Building Council (n.d.), our buildings use "41 percent of total U.S. energy consumption" thus having a higher ecological footprint than necessary or sustainable. While this can come from various sources of inadequacy, the materials used in the construction process have a large impact on the energy loss and ecological footprint of the house. "To achieve the goals of sustainable development in building construction, a combination of factors must be considered, such as energy saving methodologies and techniques (use of renewable energy resources), improved use of materials, and their further reuse/recycle and emissions control", Joseph and Tretsiakova-McNally (2010) continues, "One of the most important components of sustainable building is the material efficiency."

Morel et al. (2001) conducted a study of using local materials to reduce the environmental impact of construction. The use of local materials drastically decreased the energy usage, but also proved that the use of such materials was climate specific and dependent on availability of the materials. MacDougall (2008) conducted a study on current alternative sustainable construction materials (natural building material products) such as straw-bale paneling, similar to Morel et al. (2001), and determined that “natural building materials can be successfully used in large-scale, mainstream construction projects,” but there is a “need to fund the research needed to develop and understand a natural material so that engineers and architects will have the confidence to use it” (MacDougall, 2008). This thesis research helps to fill this gap by looking at local, traditional materials such as birch bark and determining the viability of using it as a sustainable roofing material through properties testing.

The standards to implement materials into mainstream contemporary building construction are numerous, using methods such as benchmark testing, exposure/weathering, flexibility, and fireproofing. Lewry and Crewdson (1994) developed the testing method to determine the durability of materials used in construction. They stated, "Durability is defined as 'Ability of a building and its parts to perform its required function over a period of time and under influence of agents’" (Lewry & Crewdson, 1994). The authors gave examples of tests such as benchmark, comparative, environmental/stress, and site tests as well as recommendations for pass/fail criteria. An important aspect of these tests is that "traditional materials with a long history of field service can be tested using benchmark tests and reference materials. This can be extended to new materials of the same type, but the environment is limited to that covered by the database of the products history" (Lewry & Crewdson, 1994).

The most commonly accepted standards for construction materials are part of the American Society for Testing and Materials (ASTM) International Standards. These construction standards have specifications of organic and inorganic materials and their properties, durability, and quality levels needed in order to be used in the commercial industry. In relation to this thesis project, the researcher focused on the Roofing and Wood standards from the ASTM Book of Standards; specifically, ASTM D3462 Standard Specification for Asphalt Shingles Made from Glass Felt and Surface with Mineral Granules and ASTM C120 Standard Test Methods for Flexure Testing of Structural and Roofing Slate. Anyone can submit a request that identifies a need for standardization, which then goes to technical committees to research, review, and vote on before approved by the Committee on Standards. This is important to note for the research question of how wiigwaas can be used as a sustainable roofing material, how to compare it to other contemporary materials, as well as future research in determining scalability and development of tribal codes and standards.

Along with those questions, was the question on how to test the materials for durability. An Anishinaabe definition of durability differs from an SEK point of view, but in much the same vein as “sustainability,” there are commonalities between the two as well which relate to the flexibility and strength of a material by developing a holistic understanding of the phenomenon through differing testing methods. The C120 test method is "useful in indicating the difference in flexure (breaking load, modulus of elasticity) between various slates" (ASTM International, 2019a) and is done by preparing and conditioning test specimens and loading them vertically by use of a three-point loading method shown in Figure 5.

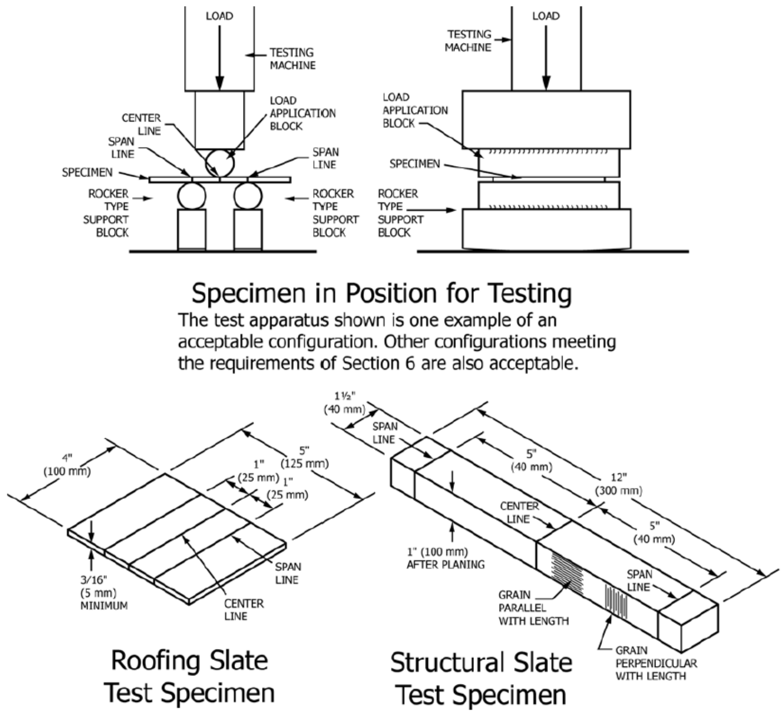


Figure 5: ASTM C120 Three-point Bending Test Apparatus Configuration

In order to test the elasticity of the material as part of what makes wiigwaas durable from an Anishinaabe perspective, the procedure from the C120 test was the focus such as the size and shape of the specimens, and configuration of the apparatus rather than attempting to make a direct comparison between slate and wiigwaas. Due to the stark differences in elastic properties between slate and wiigwaas, the D3462 standard was included as well for a more comparable material. The specification is "designed for the evaluation of products as manufactured" (ASTM International, 2019b) which covers multiple test methods to determine the pass/fail physical requirements for the shingles. For use in this project, the focus was on Section 8.1.7 Pliability, which gives the procedure for measuring the "pliability of specimens of shingle material by bending through an angle of 90 degrees under defined conditions" (ASTM International, 2019b). Both C120 and D3462 were used as baseline procedural methods which were then altered in order to accommodate the difference from slate and asphalt to birch bark.

Keystone Material: Paper Birch

While there are numerous sustainable materials that are in use today in green buildings, many of these are artificial or heavily processed in order to be resistant and resilient in any climate zone. However, the basis of green building and sustainable construction comes from passive design, knowing your environment, and using local and renewable materials. As such, when designing a building and deciding on materials to use for a specific climate zone, many researchers look to the Indigenous peoples of the area to learn how they have created structures through generations of TEK (Shelby et al., 2012; Seltenrich, 2011; Deane & Smoke, 2010).

For the Anishinaabe people, our main traditional housing structure is the wigwam, a dome shaped structure with a paper birch bark roof covering. "Paper birch (*Betula papyrifera*) is a cultural keystone species for the Anishinaabe in the US Great Lakes region. The bark of the paper birch tree has furnished material and cultural resources since time immemorial" (Emery et al., 2014). Garibaldi and Turner (2004) define a cultural keystone species as a "culturally salient species that shape in a major way the cultural identity of a people, as reflected in diet, materials, medicine, and/or spiritual practices." They name six elements that must be considered when identifying cultural keystone species such as:

> "1. intensity, type, and multiplicity of use;
>
> 2. naming and terminology in a language, including the use as seasonal or phenological indicators;
>
> 3. role in narratives, ceremonies, or symbolism;
>
> 4. persistence and memory of use in relationship to cultural change;
>
> 5. level of unique position in culture, e.g., it is difficult to replace with other available native species; and

6. extent to which it provides opportunities for resource acquisition from beyond the territory" (Garibaldi & Turner, 2004).

The paper birch tree is known as wiigwaasi-aatig in Anishinaabemowin, and when harvested, we call the bark wiigwaas. Wiigwaas has been used for our wigwams (houses), jiimaan (canoes), makaks (storage), and arts. It is part of our traditional stories, such as the thunder beings and the birch tree which tells the story of how the birch tree is brother to the thunder beings therefore it will not be struck by lightning (Densmore, 1974) and the story of the Birch Tree, Maple Tree, and Naanabozho (Geniusz et al., 2015). We have used birch bark scrolls to write syllabics that has held parts of our history for hundreds of years due to it being waterproof, rot resistant, and fungal resistant (Birch bark, 2018; Croft & Mathewes, 2014). "Birch is one of the most important resources of the people; it was used for every day survival. Birch bark was essential for making wigwams (dwellings), making containers of all kinds, cooking, gathering water, making canoes, and in burials. The bark of the birch tree is versatile and beautiful. It is still essential to our people today; it is part of who we are" (Harvesting Birch Bark - Our Beautiful Inventory of Birch Bark Baskets Have a Rich History, 2017). The paper birch tree and the wiigwaas we harvest makes the research of re-introducing this material into sustainable contemporary homes even more important from the standpoint of both cultural revitalization as well as combating climate change.

Paper Birch is considered "one of the most geographically widespread species of deciduous tree in North America" (Moser et al., 2015) which spreads from coast to coast in the northern United States and Canada. It is a known "pioneer species," meaning that is often one of the first trees to grow after the land has been disturbed. The lumber and forestry pressure increase which started in the 1800's through late 20th century spurred Ojibwe people to become “concerned about the long-term viability of the paper birch bark resource” (Moser et al., 2015) which led to a multi-decade long inventory from the U.S. Forest Service which examined the basal area of trees in the treaty ceded territories of 1836, 1837, 1842, and 1854 located in Michigan, Wisconsin, and Minnesota.

This inventory, developed in close consultation with Ojibwe wiigwaas gatherers, helped to identify the wiigwaas characteristics, protocol, and harvest mechanism to evaluate the potential use of the bark. After a 30 year inventory of timberland in four major forest types found in the ceded territories, the researchers saw the “total bark supply has decreased substantially on timberland across the region over the past 30 years, ranging from a decline of 30.4 percent in the Upper Peninsula portion of the 1836 treaty area, to a decline of 53.5 percent in the 1842 treaty area” (Moser et al., 2015). While the number of trees is still widespread, this inventory shows that the size of the trees has declined and as such, the amount of harvestable bark.

Harvesting birch bark is a skill that those experienced know how to do without killing the tree, but Geniusz (2009) recommends to only use pieces of bark that had fallen off the tree or with the log rotted out in the woods if you are not experienced. Much like myself, Geniusz was taught by an elder in her community how to peel and gather wiigwaas in a way that will not kill the tree. This is contrary to many who believe that you must cut down the tree before gathering. With this skill of taking the bark without killing the tree, this material can be used as a sustainable construction material as a renewable as well as carbon positive resource. Altogether, “any natural builder looking to use natural or non-industrial materials it is hard if not impossible to find a local, organic material which can withstand moisture for such a long time as birch bark. Most people living in birch-rich locations have historically used birch bark as moisture protection for a variety of different applications when constructing shelters" (Birch bark, n.d.).

Chapter 3: “The Approach”

Relationality

I would like to refer to Wilson’s (2008) work regarding Indigenous Research Methodologies, most notably in terms of relationality and the *process* of conducting Indigenous Research.

> "Indigenous Research is a ceremony and must be respected as such. A ceremony... is not just a period at the end of a sentence. It is the required process and preparation that happens long before the event... It is the knowing and respectful reinforcement that all things are related and connected. It is the voice from our ancestors that tells us when it is right and when it is not. Indigenous research is a life changing ceremony." (Wilson, 2008, p. 61).

Viewing this thesis project from this lens guides us (you, the reader, and myself) to connect the worldviews that have been established in a more procedural way. Incorporating the autoethnographic piece into the realm of “Western science” allowed me to show the required process and preparation that was established long before I developed the proposal for this study.

Also, the importance of incorporating the 3 R’s: respect, reciprocity, and responsibility, with the subject and world around us (Wilson, 2008). The 3 R’s relate to the seven grandfather teachings that Anishinaabe people traditionally live by, which in turn translates to how we conduct our lives, relationships, ceremonies, and of course, research. Relationality is as important to this research project as the quantitative data collected. This is due to the relationships with participants, both human and non-human, the land, and how each of these interconnects with the overarching idea.

The relationship to people is most commonly associated with relationality in research projects. However, with Indigenous research and autoethnography, the participants include anyone from the community associated with the project. For my project specifically, the relationship with people begins with myself, then to my immediate family, extended family, tribe, community, and ancestors. Our community includes the animals, plants, water, sky, and earth around us. Each of these relationships, nurtured and grown over the years, have built the trust required to conduct this research for my community.

The most obvious plant relation is the wiigwaas (birch bark), but we also have to consider the other materials that were gathered such as the roots, cedar, and maple saplings. The protocol of reciprocity and respect is most prominent here, wherein whenever we take from the Earth, we give back in forms of prayer and/or semaa (tobacco) offering. We do not take the first, we do not take the last, we take only what we need. In contemporary times, this is what Kimmerer (2013) has called the Honorable Harvest.

Lastly, albeit the most important, is our connection and relationship with the land. Indigenous tribes and their TEK hinges on a place-based identity. We learn to work with the land, how to grow and move, and live with it. We learned through generations how to survive and thrive within this environment, fierce cold winter, humid summers, and the most beautiful fall and spring months. We recognize Mother Earth, the rocks, soil, and water as their own spirit beings and as such we must respect them.

When the Anishinaabe people migrated to the Great Lakes region we found the prophecy food that grows on the water, built our villages, and moved with the seasons. It is here that we still stand today, revitalizing our languages, building canoes, harvesting our medicines, in the place where our ancestors lived. The land, our Mother Earth, is our greatest teacher, and it remembers the respect and reciprocity that is given.

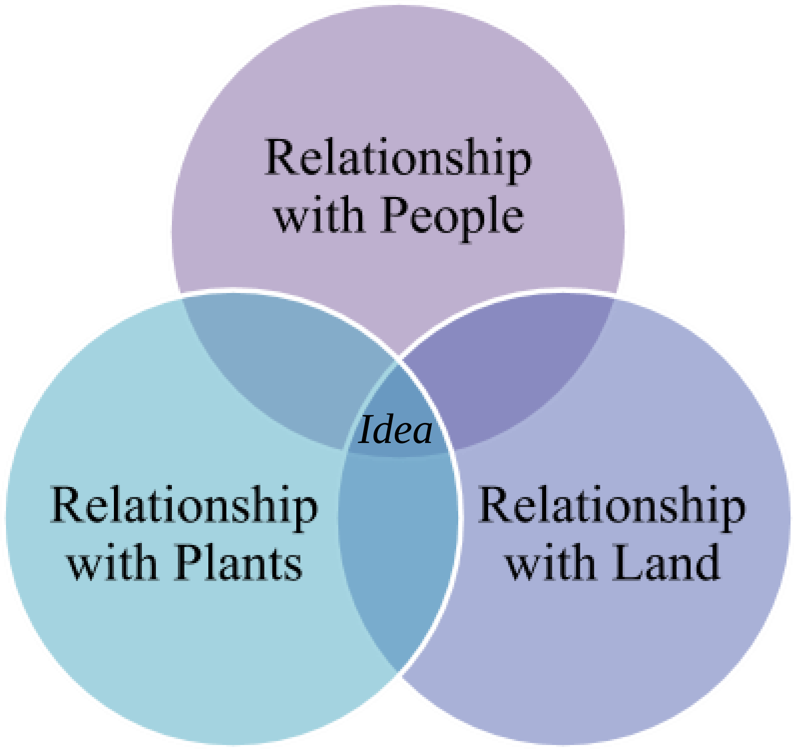


Figure 6: Overlapping Tri-lateral Relations

These three relations, in Figure 6, overlap to define the fourth relation, the relationship to an idea, specifically, how to create sustainable housing for Anishinaabe communities. In order to be accountable to each of our relations, I needed to take guidance and input from each to generate a proposal that would determine the questions, method, and procedure in how to utilize traditional materials in contemporary structures. In doing so, I explored this idea, learning from my elders, harvesting in a good way, and analyzing each success and failure. Relationality is an ongoing process from the very beginning stages and throughout the project in order to stay accountable and respectful to all our relations.

Ongoing Collaborative Analysis

> "In all community approaches *process* - that is, methodology and method - is highly important. In many projects the process is far more important than the outcome. Processes are expected to be respectful, to enable people, to heal, and to educate" (Smith, 2012, p. 130).

> "So you can see that the methods of data collection and the data analysis blended into one. As I was listening I was learning, and as I was learning I was sharing" (Wilson, 2008, p. 131).

When you think of research and scientists, what do you think of? Do you think of lab coats, notepads, the scientific process cut up in well-defined segments? Western science and media have brought about this vision of what science, research, and analysis is supposed to look like. However, Indigenous Research is an entirely separate paradigm, one that is both thousands of years old and new and upcoming. Based on my perspective as an Indigenous person, I am more concerned with using this methodology to inform and guide the process of doing my research, but that does not preclude non-Indigenous people from doing the same while keeping in mind the differences in identity and experience. This decolonized research methodology that Linda Tuhiwai Smith (2012) and Shawn Wilson (2008) are quoted about above is what this paradigm is about. Indigenous research is an ongoing, collaborative process. While in the process of collecting data, I was analyzing it at the same time. Asking my family questions, looking up articles, and finding resources to guide me from my community at every step.

Knowledge can be passed down to the future generations in many ways. Traditionally, Anishinaabe people were oral storytellers. Our stories, traditions, and customs were passed down to subsequent generations through word of mouth, and only recently have been written down. However, in today’s society, knowledge transmission occurs nearly a million times faster through keyboards, electric wires, and invisible waves bouncing around in space. So, while I would love to share all the information I gained from this project in a personal communication while spending a week in the woods, I chose to combine Anishinaabe oral tradition with Western written tradition. I chose this method because I believe there are strengths in both approaches. When the next researcher (maybe Indigenous researchers like my god-daughter Luna) picks up this work, they know exactly how I conducted this project, and hopefully it will guide them in a fruitful and culturally responsive direction.

Chapter 4: Methods

This project was structured by drawing on traditional Anishinaabe techniques of utilizing paper birch bark, such as how to gather, revitalize, and use the bark, along with how to test the bark in terms of its mechanical properties in order to answer the research questions. This project was broken into three overlapping phases to gather data on the bark from multiple angles and worldviews.

The first phase, the literature review, was necessary to develop the framework for which this project will be located within by exploring the importance and history behind our Ojibwe TEK regarding housing. The literature review determined that in order to utilize traditional materials in contemporary structures, a complete Ojibwe housing framework would have to be developed. The initial intention of this project was to create an Ojibwe Sustainable Housing Framework (OSHF), for use by tribes and tribal people across the Anishinaabe territory, which was developed through discussions with family and community members, but also through interactions with faculty and colleagues at my university. The main components were broken down into seven categories, as follows:

Figure 7: Infographic of the Ojibwe Sustainable Housing Framework Components

However, due to the limitations of time and resource availability, I made the decision to focus specifically on what would arguably be considered the key component to creating Ojibwe wigwams (houses): the materials. With the materiality in mind, I narrowed my focus further by looking at the durability, resilience, and characteristics of one of the cultural keystones for Anishinaabe people: wiigwaas. This brought me to the next two phases: site exposure testing and in-lab controlled environmental mechanical properties testing. Both of these tests/phases were used to establish the physical characteristics of the bark, and how it behaves under certain conditions and stresses placed upon it, using adjusted testing methods from Lewry and Crewdson (1994) and ASTM International Standards D3462 and C120 (ASTM International, 2019a; 2019b), as well as participant observation methods from Indigenous Research Methodology.

Site Exposure Test

The Site Exposure test took place during Summer 2019 in Gwinn, Michigan, 20 miles south of the Lake Superior shore. Two structures were built, one using traditional Anishinaabe materials, design, and methods and the other using contemporary methods regarding design and contemporary construction materials while also incorporating wiigwaas as "shingles." These structures were built on the former K.I. Sawyer Air Force Base on my family's property (Figure 8) which is within the boundaries of the ceded territory according to the Treaty with the Ottawa, Etc. of 1836. This test was to determine how durable the material would be when in a fixed structure for a year in the Upper Peninsula weather.

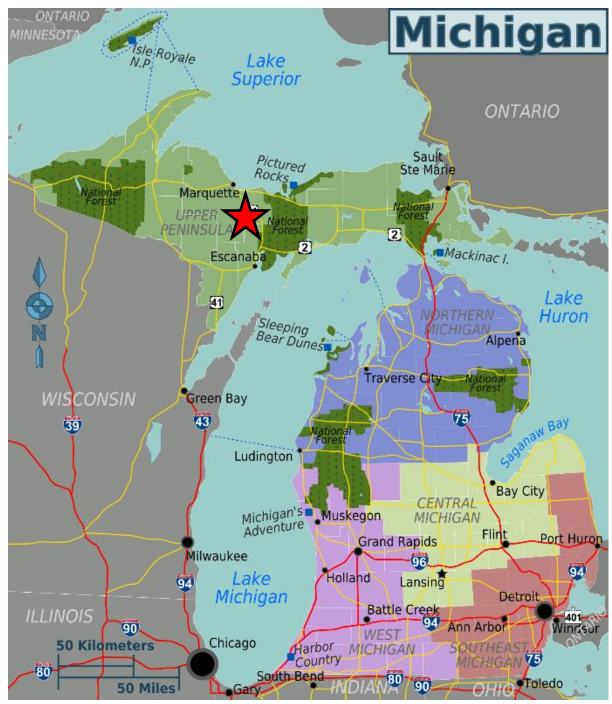


Figure 8: Map of Michigan with star at Exposure Test Site

The first structure built was a wigwam using traditional materials, techniques and design. Throughout the summer months, the materials were harvested including four sheets of birch bark, 17 maple saplings for the lodge poles and ribbing, and four buckets of jack pine roots to tie and sew everything together. All these materials were found on or near the test site within tribal lands. Once the materials were harvested, they were processed for use on the wigwam.

One thing to note is that during an inventory of construction supplies for the second structure, a large pile of dried birch bark sheets was found in a storage room. This bark had been harvested for use in a TEK class taught by Dr. Martin Reinhardt, my dad, but had since been in storage for four years. At this point, four birch bark sheets had been harvested in the summer, but the amount needed for this project would require many more trips to the woods to harvest more sheets. Harvesting the bark does not outright kill the tree, but it does leave it scarred and vulnerable until it can heal, so it is best not to harvest too much bark from one area especially with the decline in harvestable trees (Emery et al., 2014). After speaking with Dr. Reinhardt and other community members, it was determined that it would be in line with the sustainability model to use this bark from storage and repurpose it for use on my structures rather than harvesting all new bark.

Added together with the four sheets previously harvested, there were 23 sheets in total, some of them had already been sewn together using jack pine roots as part of Dr. Reinhardt's class, but the majority of them were standalone sheets. The sheets varied in size and condition, ranging between 50-190 cm in length and 35-100 cm in width. One completed piece used for demonstration purposes was 7 pieces sewn together for a total of 445 cm long and 68 cm wide.

Figure 9: Full bark sheets laid out to flatten and measure

Table 1, listed below, indicates the primary characteristics (surface area, condition, and curl) of the full bark sheets and how each was to be used. The curl rating was judged from 0 (flat) to 5 (the ends fully curled to meet, “scroll-like”), with the inner bark facing outwards. There are several secondary characteristics in describing birch bark that are explained more in depth with Emery et al. (2014), such as smoothness, age, lenticels, color, and blemishes, but these descriptors did not impact the consideration of how to use the full bark sheets for the three set ups in this study.

The bark number refers to the full bark sheet prior to any sorting, cutting, or processing. The area is the total surface area of the full bark sheet and the condition it was in. The bark sheets were used in three applications: the wigwam, shingles, and samples. If used for the wigwam, the full bark sheet was used as is in its entirety and sewn to other sheets to cover the roof of the wigwam. The full bark sheets used for the shingles were cut to size (30 cm x 38 cm) using the flattest part and least number of blemishes. Lastly, the samples used in the ESF lab were cut from the same full-size sheets used to make the shingles. This table is important to see the correlation between the two tests; site exposure and mechanical properties; in order to connect how the bark behaves under multiple conditions.

Bark Number	Area (cm^2)	Condition (intact, slight damage, heavy damage)	Curl, 0-5	Wigwam	Shingles	Samples
1	3100	Intact	3		x	x
2	5000	Slight damage (cracks visible)	2		x	
3	4500	Intact	1		x	x
4	4700	Slight damage	0		x	
5	6000	Slight damage (peeling)	1		x	
6	3100	Intact	1		x	
7	6700	Slight damage (crack on one edge	4	x		
8	5500	Intact	4		x	
9	3900	Intact	3		x	
10	6100	Slight damage (cracked on one edge)	4	x		
11	3900	Intact	3	x		
12	4100	Intact	1		x	x
13	3800	Intact	2		x	x
14	4300	Intact	4	x		
15	2800	Heavy damage (cracks, water damage)	1		x	
16	3400	Intact	3	x		
17	5200	Intact	3		x	x
18	4100	Intact	4		x	
19	30500	Intact	2	x		
20	11200	Intact	1	x		
21	18500	Intact	1	x		
22	10200	Intact	1	x		
23	4500	Intact	5		x	

Table 1: Full bark sheet surface area, condition, and use

Each material had its own timetable for harvesting and processing for use on the wigwam. For instance, the jack pine roots were harvested by hand during the hot summer days by myself and Tina Moses, my mom, and were left to soak in water for two weeks before we were ready to split them to use as "rope." However, the maple saplings that were harvested had to be used immediately while they were still green and pliable enough to be shaped into the dome wigwam structure, referred to as the ribs, see Figure 12. Lastly, cedar splints were made initially from a cedar log, but after testing and struggling with the irregularities in the log, the splints were made from graded lumber. See Figure 11 for a sample of how the cedar splints were tied to the end of the bark sheets.

The repurposed birch bark took the most processing because it had been dried and in storage for many years, and as such the edges of the sheets had curled into a scroll-like shape. There has been evidence that Anishinaabe people had been able to rehydrate bark for use in our crafts and storage (Geniusz et al., 2015), but not so much for housing. After discussing with multiple TEK holders that had experience with birch bark, my parents and I determined a few methods that might re-hydrate the bark to be pliable and flat enough to process further for the structures. The re-hydration methods that we used were as follows: flattening with added weight, steaming, soaking with hot water, sun drenching (laying the bark out in direct sunlight on damp ground while gently pressing flat), and steam ironing. Each of these methods was tested for proof of concept, but the ironing method was chosen in order to make it as flat and pliable as needed to move on to the next steps in processing.

Figure 10: Example of curled birch bark

After the ribs were formed and held together with jack pine roots, the birch bark sheets were ready to go onto the structure. Individual birch bark sheets were sewn together with splints on each end to make long sheets to be draped over the ribbing to create a dome, see Figure 11. Altogether, five long sheets were sewn and placed onto the wigwam, see Figure 12. In most traditional wigwams, the bottom half of the dome would be covered with another type of material, sometimes cedar or reed mats, and was dependent on climate and regional availability of materials. For this reason, only the top half of the structure was covered for the purposes of this project.

Figure 11: Sewn birch bark sheet for wigwam

Figure 12: Wigwam structure for site exposure test

A second structure was built using contemporary construction methods and materials aside from the birch bark itself. The process here was to create a flat, sloped roof similar to those on contemporary housing but using the birch bark to create "shingles." Based on the amount of bark and materials available, we decided to build one 120 cm x 244 cm plywood sheet roof and cover it with the wiigwaas shingles.

After building the frame and covering it with tar paper using a slap stapler, we still needed to make the shingles. We needed 28 shingles in order to cover the entire plywood sheet, so we made a template and cut the shingles out of the repurposed bark. As part of the experimental design to connect the site exposure test bark with the mechanical properties test, the bark number was documented and an inverse matching system was done to make sure all the shingles were not next to another from the same sheet of bark. Once the shingles were adhered with screws and construction adhesive to the board and left overnight to make sure they would lay flat, the last piece of the project came into play.

Figure 13: Shingles laid out to determine layout on the roof

In order to simulate the chemical processing done to industry standard shingles to test for further treatments or finishes on the bark, the shingles were covered in three different coatings to see what the differences would be with the exposure testing. The roof was split into four categories, see Figure 14: control, sunflower oil, pine resin, and Thompson's Water Seal. The control group represented the traditional way we used birch bark as a roofing material, all natural with only the inherent properties to protect it and us from the elements. The sunflower oil and pine resin were used as a natural finish, both of which have been used in other traditional

Anishinaabe products. Lastly, the Thompson's Water Seal was used as an industry standard sealant against the elements.

Figure 14: Sloped roof with finishes. Left to Right: Control, Sunflower Oil, Pine Resin, Thompson's Water Seal

Once the finishes were dry and the sloped roof was leveled off at 15 degrees, the two structures were deemed finished, see Figure 15. Two trail cameras were placed opposite each other facing the structures in order to track the appearance of the structures and to note if any people or animals disrupted the structures during the year-long exposure study. Along with this, various family members were asked to periodically check on the structures which helped keep track of what impacts the weather had on the condition of the birch bark structures.

Figure 15: Finished structures for Site Exposure Test

Mechanical Properties Test

This mechanical properties testing was performed to measure and collect quantitative data of the properties, durability, and resilience of the birch bark within a controlled environment to further develop the viability of using birch bark as a sustainable roofing material and how to compare it to contemporary sustainable materials. The wiigwaas samples used in this test were cut from the same large sheets that were used in the site exposure test and were recorded in order to match characteristics between the different bark sheets. This test was designed to determine the physical and mechanical properties of the repurposed birch bark under controlled conditions by using ASTM Standard testing that was adjusted for use with the bark. The ASTM standards to be used were C120 Flexure Testing of Structural and Roofing Slate and D3462 Asphalt Shingles Made from Glass felt and Surfaced with Mineral Granules which are used to test slate and asphalt shingles. The mechanical properties testing took place in Syracuse, New York at the State University of New York (SUNY) College of Environmental Science and Forestry (ESF) during the Fall 2019 semester and Spring 2020 semester. However, due to the Coronavirus pandemic in the Spring of 2020, only the C120 three-point bending test was able to be tested in-lab before total shut down of SUNY ESF and other universities nationwide.

In order to make the bark pliable for testing and processing, I continued with the rehydration testing methods in order to attempt to mimic the moisture content that the bark would have if it had just been harvested off the tree. In the site exposure test, a steam iron was used for the large bark sheets. However, the samples for the mechanical properties test were much smaller, so after discussing with family and community members back home, we determined a few more methods to rehydrate the bark; steaming and submerging.

The first of these conditioning methods was tested in the Fall 2019 semester with steaming the bark in a homemade 30 cm x 30 cm x 89 cm pine box with a Rockler Steam Generator attachment, see Figure 16. Four wiigwaas sample specimens were tested in the steam box at a time, for a total of two hours and with the dimensions and weight being checked at half hour intervals. The pliability of the samples was checked before and after the steam test both visually and manually using a 0.001” AMES dial indicator. It was immediately apparent in the first check, however, that the 30 minute interval was too long for the bark due to the curling of the samples shown on the right in Figure 17, so two additional tests were done with similar methods with shorter time intervals. While the steam rehydrated the bark very efficiently, each of the bark pieces went from 1-2 curl to 5 curl in under ten minutes. As such, it was determined that the steam box was not a viable method, so the submersion method was the chosen rehydration method for the remaining mechanical properties testing.

Figure 16: Pine Box and Rockler Steam Generator set up

Figure 17: Comparison of birch bark samples at start and 30-minute check during steam test

With the steam test no longer viable, I had to go back to the drawing board with my family and community back home, talking with knowledge holders to see what other rehydration methods I had not tried yet that would make the bark usable and pliable enough for the ASTM testing. With this, however, I stepped back to remember why I was trying to rehydrate it. Traditionally whenever Ojibwe people built our wigwams, we would get the bark from the tree and use it soon after on the wigwam structure, while it still holds moisture and before it firms and the edges curl as seen in the repurposed bark I have been using in this project. In order to make the bark pliable and usable for construction purposes, we were trying to infuse the bark with moisture to mimic the way it would be when coming off the tree. With this in mind, it became obvious why the rehydration methods didn't seem to be working; we were adding too much heat. As such, with the last pieces of the repurposed bark at the ready, we determined our last rehydration method before the final ASTM C120 testing.

After a discussion with a knowledge holder back home, he mentioned that while it would be best to use the bark directly off a tree, it would also be possible to use the bark if it was submerged in running water for two weeks. Given that it was now February in Upstate New York, there were no readily available lakes or streams to submerge the bark that were not frozen over. It was decided that the bark would be placed in a cleaned, sanitized sink in Baker Lab, and submerged with running tap water for two full weeks before going forward with the three-point bending test.

To prepare for the bending test, the specimens were all cut down to uniform size according to the ASTM C120 standard. From the bark sheets used in making the shingles, the smaller pieces that were brought to ESF were cut to 10.0 cm x 12.0 cm +/- 0.4 cm according to the ASTM C120 guidelines. These bark pieces were chosen from the flattest parts with the least number of “defects” on them (knots, peeling, damage, etc.). Along with this, an equal number of specimens were chosen for each orientation. The orientation refers to the direction of the lenticels on the bark which goes back to how the tree grows naturally. The lenticels are the dark horizontal markings on the trunk of the tree “through which gases are exchanged between the atmosphere and underlying tissues” (Merriam-Webster, n.d.) which can be seen in Figure 18. The bark samples were labelled with reference to the long side of the bark and whether the lenticels were horizontal or vertical in that facing direction (Figure 19).

Figure 18: Image of paper birch tree showing horizontal lenticels around trunk

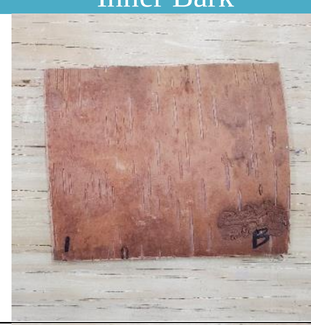
Orientation	Outer Bark	Inner Bark
Vertical		
Horizontal		

Figure 19: Orientation examples with wiigwaas samples

These samples were labelled with an ink marker on the specimens to differentiate them during the testing process, but each correlate to a larger section of the full bark sheets. These samples were then split into two groups of eight samples with four from both orientations before being placed into their conditioning environment: either in a 65% relative humidity climate-controlled chamber (Control) or submerged in running tap water (Submerge) for the duration of the conditioning.

Sample	Number	Bark Sheet Number	Orientation	Conditioning Environment	Curl (0-5)
A	1	12	Vertical	Control	1
A	2	12	Vertical	Submerge	1
A	3	12	Vertical	Submerge	2
B	1	3	Vertical	Control	1
B	2	3	Horizontal	Control	1
C	1	13	Vertical	Control	3
C	2	13	Vertical	Submerge	2
D	1	1	Horizontal	Control	2
D	2	1	Horizontal	Submerge	3
D	3	1	Vertical	Control	2
E	1	3	Horizontal	Submerge	0
E	2	3	Horizontal	Control	0
F	1	3	Vertical	Submerge	3
F	2	3	Horizontal	Submerge	2
G	1	17	Horizontal	Control	1
G	2	17	Horizontal	Submerge	1

Table 2: List of 16 Samples with which bark sheet they were cut from, batch, and curl

A total of 16 specimens were prepared for the C120 test, and 8 smaller pieces were set aside for use in the D3462 test, which ultimately were used either to test the Shimadzu machine parameters, or as extra pieces for future research. These sample pieces were split into two groups with an even amount from both orientations to be placed in their conditioning environments, Submerge and Control, for 10-14 days.

Figure 20: Front and back of samples for C120 and D3462 tests

Figure 21: Samples in both conditioning environments, submerge and climate control chamber

In order to conduct the bending test to determine the Modulus of Elasticity (MoE) and Modulus of Rupture (MoR), I was trained in using the testing machine. The Wood Science Lab in Baker Lab has several Young's Testing Machines, but from working with the bark I already knew that the MoE would be much smaller than most construction materials such as lumber and slate. As such, the Shimadzu Testing Machine, model AG-X, was chosen due to the small chamber size and precision for small measurements. After learning how to run the machine, with help from various colleagues and the administrator's manual, I then determined the parameters in which to run the tests, which were max force, max displacement, stress, strain, and elastic range. While some comparative data was available, most of the parameters were found through trial and error with multiple tests runs with extra samples prior to the full-scale testing with the submerged and control bark.

Figure 22: Shimadzu Testing Machine, model AG-X, prepped for three-point bending test

It was previously stated that the bark was to be submerged for two full weeks followed by the D3462 testing. However, after only six days in the running water, the Coronavirus pandemic had spread rapidly in the US such that the SUNY system determined that it would be moving to online platforms. Based on the exponential growth of the virus, I determined that I had a week at most before the campus was locked down and I would be unable to continue using the testing equipment. In hindsight, this was spot on. With the greatly accelerated timetable in front of me and the virus in the back of my mind, I moved forward with my project.

Two days were dedicated solely to learning to run the Shimadzu fluidly as well as setting up the methods and determining the parameters such as the beam length (L), the crosshead velocity, and the outputs from each test. Extra bark samples were used to determine the proper parameters and orientation of the samples in the machine.

The samples were placed in the machine concave down (outer bark facing up to the crosshead, shown in Table 6) and the crosshead descended at 2mm/min. The vertical orientated samples had the lenticels running parallel with the crosshead, while the horizontal orientated samples had the lenticels perpendicular to the crosshead as shown in Figure 23.

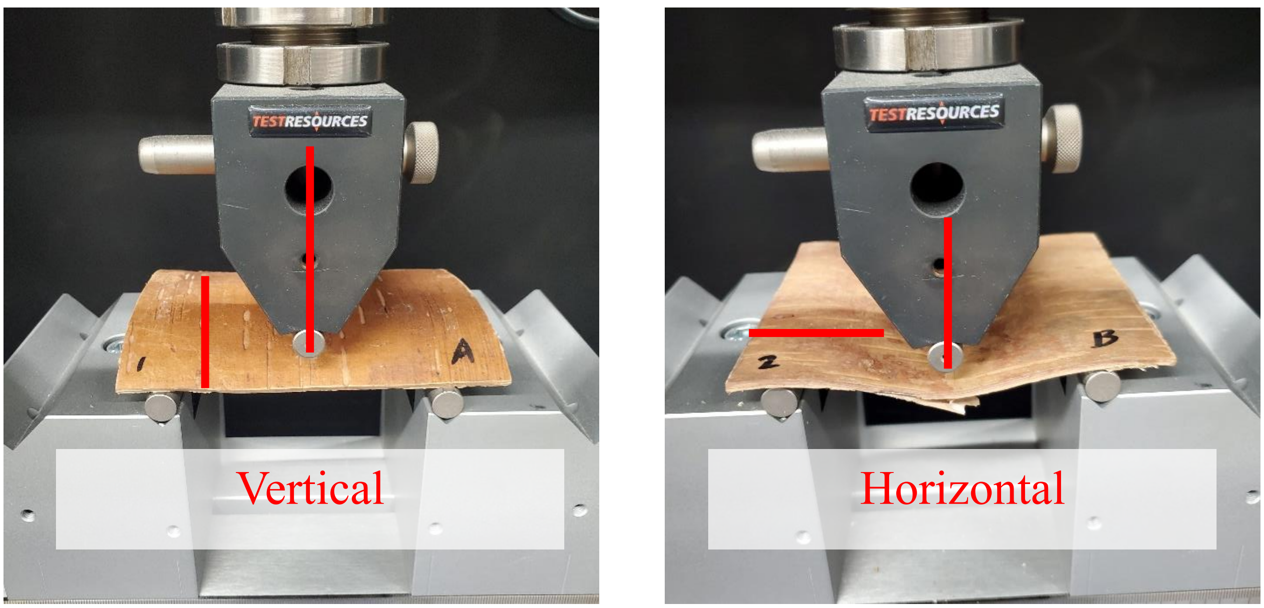


Figure 23: Diagrams of vertical and horizontal orientations in the Shimadzu testing machine

Once the method and procedure for this test was finalized, the full testing began for the C120 three-point bending test. The control samples were tested first, in a batch of four with the others of the same grain. Once all eight samples passed the point of failure and the data had been recorded, all of the specimens were placed in a drying oven in order to determine the moisture content of the samples.

The submerged samples were tested next, at 10 days submerged in running water instead of the 14 days that was suggested. Each of the specimens were taken from the water, one at a time, measured, and then put through the Shimadzu test so that each would be out of the water for less than 30 minutes before the start of its individual test. Again, these were tested in batches of four with others of the same orientation, and immediately following the last failure, the specimens were placed in a drying oven to determine the moisture content. Optimally, all of these samples would have stayed in the drying oven until they were at a consistent dry weight, but the lab and university shut down precluded further testing.

Figure 24: Final image of dried samples at end of testing

Chapter 5: Results

The results below are split into two sub sections with results from the site exposure test and the mechanical properties test. These were determined using the autoethnographic and Indigenous Research Methodology analysis methods relating to observation and documentation with pictures, videos, notes, and logs throughout both processes. The mechanical properties test results include quantitative data analysis while also applying the qualitative methods as well.

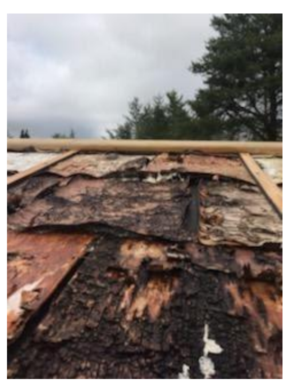
Site Exposure Testing Results

The bark used in the site exposure field test was monitored with trail cams and in person checkups for light maintenance and documentation. Figure 25 shows the wigwam and flat roofed structures during each of the four seasons over the year exposure test. As shown here, the structures themselves start to succumb to the UP weather, but the bark itself was the part that I was observing. It was immediately apparent during the Fall checkup that the bark edges had started to curl up which was not favorable going into the Winter. Surprisingly, despite the curling, the bark withstood a UP winter (+200 inches of snow total) and completed the year-long site exposure test in Spring 2020 mostly intact.

Test	Start – Summer 2019	Fall	Winter	End – Spring 2020
Wigwam				
Shingles				

Figure 25: Wigwam and Sloped Roof conditions during year-long site exposure test

The sloped roof structure had visible wear of the birch bark shingles which could be seen in the trail cameras and up close in the images below in Figure 26. This shows the four finishes (control, sunflower oil, pine resin, Thompson's Water Seal) on the flat roof structure and the progression of the bark through the year-long site exposure test. Originally, I hypothesized that the pine resin or Thompson's Water Seal would perform the best, but overall, the bark that was in the best condition by the end of the study was the control group. Both the pine resin and Thompson's Water Seal finishes crumbled off the shingle exposing the bark underneath to be intact, indicating that although the finishes themselves could not withstand the year exposure, the bark shingles could on their own. Lastly, the sunflower oil section performed the worst, with the bark looking and feeling like it had "baked" in the sunlight with visible cracking to expose the tar paper underneath.

Finish	Start – Summer 2019	Mid – Fall 2019	End – Spring 2020
Control			
Sunflower Oil			

Pine Resin			
Thompson's Water Seal			

Figure 26: Condition of each of the four sections of finishes on the sloped roof during site exposure test

Mechanical Properties Testing Results

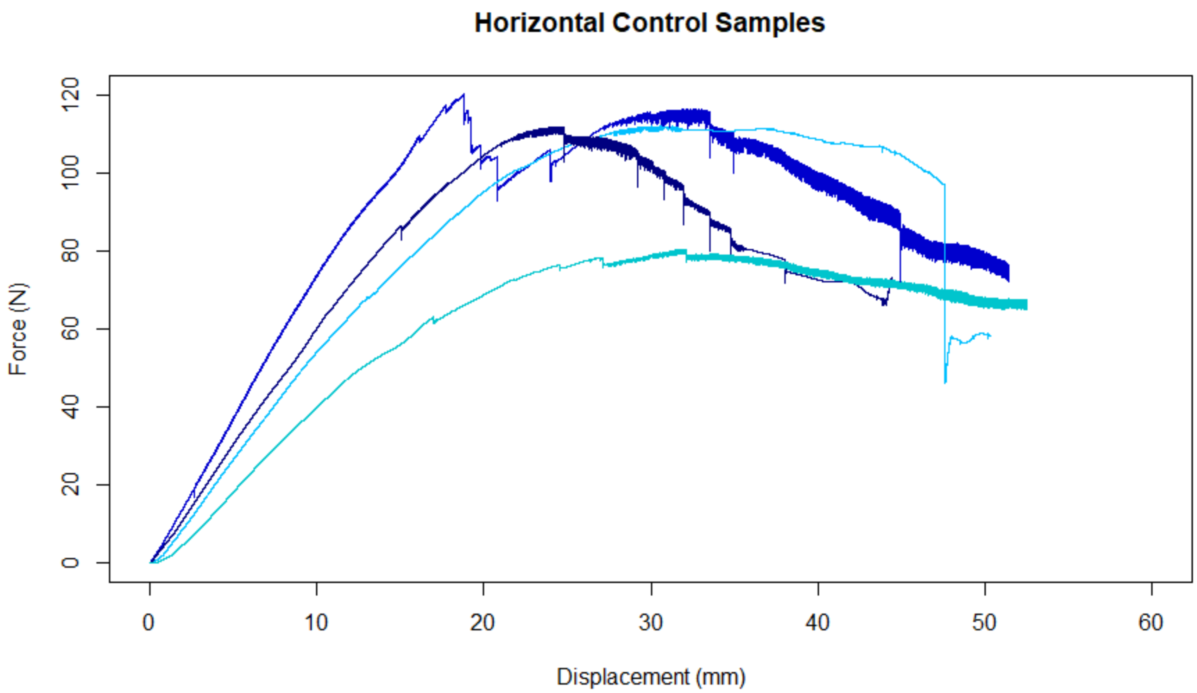
The experimental procedure for this experiment was to bend the samples to the point of failure which in this case of substituting birch bark for slate shingles meant that the point of failure and the bending strength was much different in comparison to the slate samples specified with ASTM C120. As such, multiple tests were done with extra bark pieces to determine a suitable speed as well as to determine the orientation and what defined "failure" in this case. With contemporary construction materials, the point of full failure is when the specimen breaks to the point of no longer being able to carry any load. However, given the nature of birch bark and knowing that it is highly elastic just based on observation, the criteria of a "full failure" (i.e. brittle failure) in the bark specimen was defined as breaking through all layers of the bark, as opposed to only a few layers (i.e. elastic tearing) as shown in Figure 27.

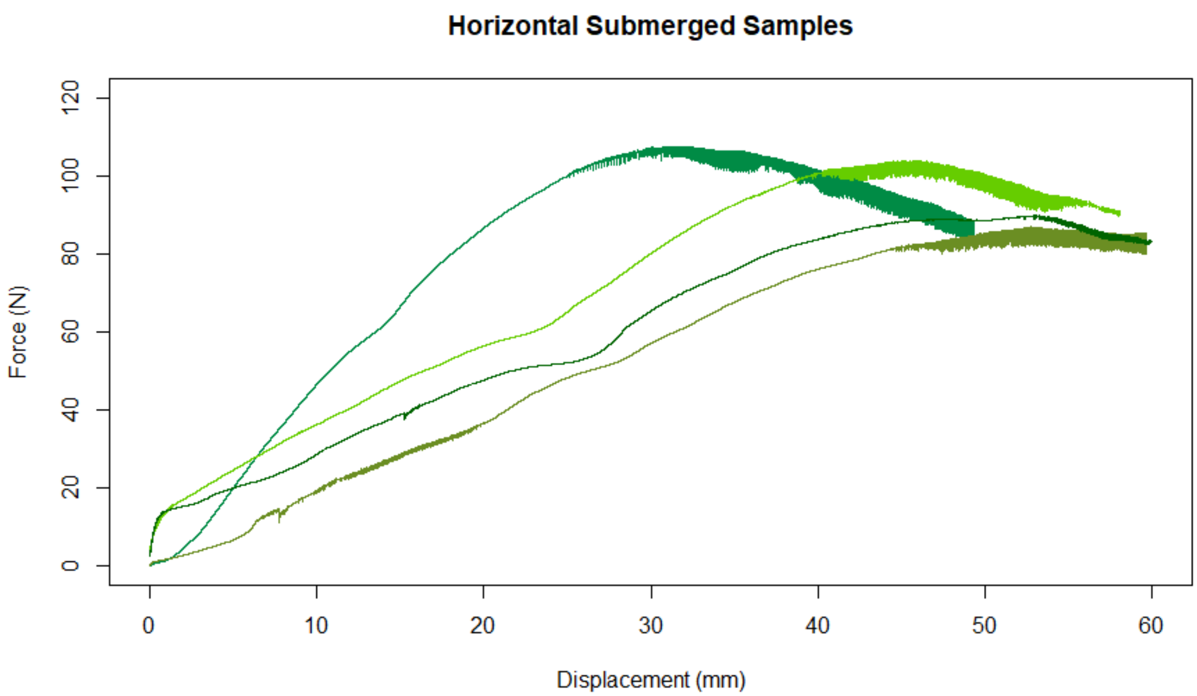
Figure 27: Breakage examples on a horizontal and vertical sample

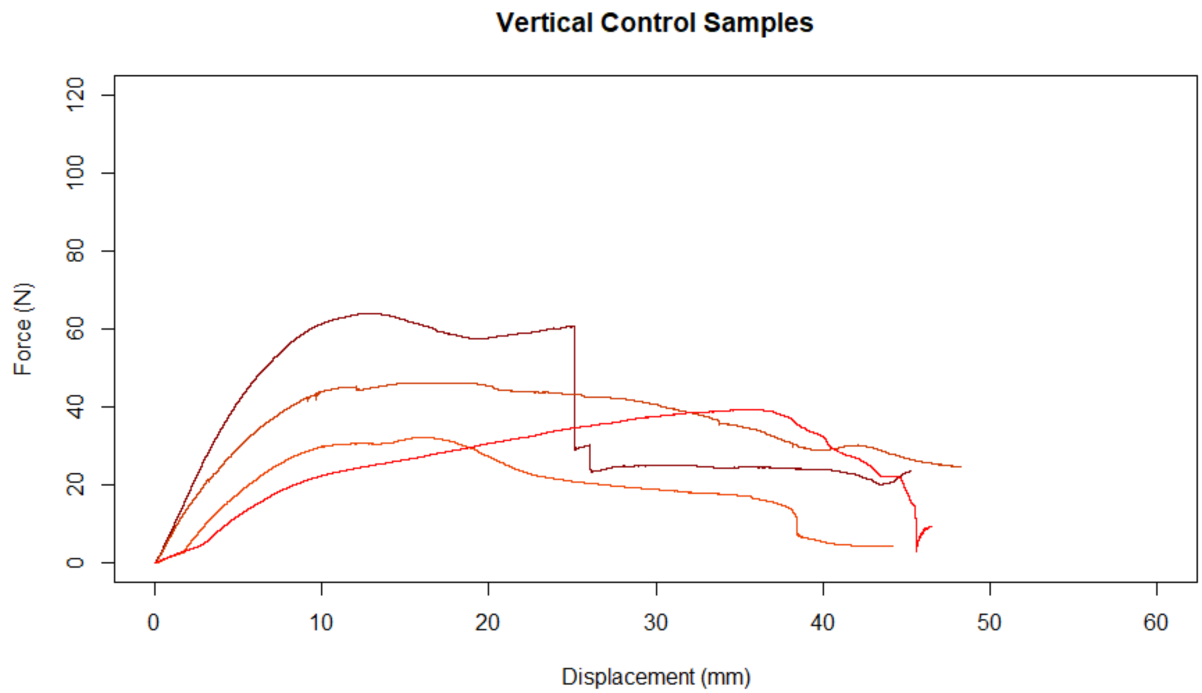
The point of ultimate load (Max Force) was recorded on software and the correlating displacement at that point. Along with this, multiple other breaking points were observed, documented with notes and video, and were calculated immediately after the test was completed. The Modulus of Elasticity was calculated using RStudio for the elastic range for each individual sample, based on the visible and observed elastic range of the material during the bending test. The plots for each individual sample specimen can be found in Appendix A. The individual sample plots were then overlaid with each other in their test batch in Figure 28 and the average max force and average MoE for each of the four batches was further calculated seen in Table 3. For consistency purposes, each batch is color coordinated, but represents four samples per batch.

Batch	Statistics	Average Max Force (N)	Average MoE (GPa)
Horizontal Control	Average:	106.091	0.267
	Range:	39.948	0.176
	Std Dev:	17.626	0.079
Horizontal Submerged	Average:	97.029	0.129
	Range:	20.557	0.129
	Std Dev:	10.131	0.056
Vertical Control	Average:	45.446	0.220
	Range:	31.796	0.238
	Std Dev:	13.614	0.101
Vertical Submerged	Average:	40.250	0.449
	Range:	27.580	0.583
	Std Dev:	13.573	0.265

Table 3: Average Max Force and MoE of each of the four test batches


Horizontal Control Samples
Force (N)
Displacement (mm)
0
20
40
60
80
100
120
0
10
20
30
40
50
60


Horizontal Submerged Samples
Force (N)
Displacement (mm)
0
20
40
60
80
100
120
0
10
20
30
40
50
60



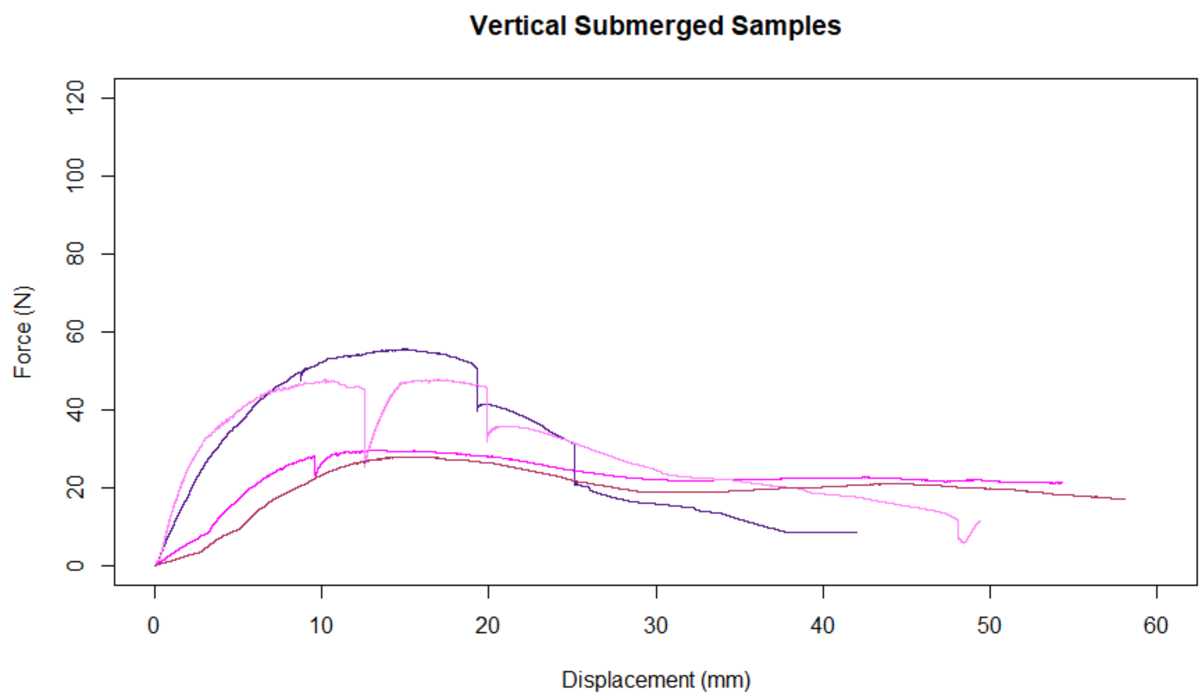


Figure 28: Four RStudio Plots for each of the test batches for orientation and conditioning

Both visually and with the numerical data, you can see that the horizontal orientated samples could withstand on average more than double the amount of force applied to the sample. The average max force for the horizontal control batch was 106.1 N of force and the horizontal submerged batch average to be 97.0 N of force, in comparison to both of the vertical batches averaging in the 40-45 N range. Along with this, the shape of the graphs themselves reflect the amount of breakage between the two orientations as well. The horizontal batch graphs were more parabolic in that they extend high before having a long, pronounced curve. Whereas the vertical batch graphs had shorter ranges and more distinct breaking points.

This difference in the graphs is significant because it shows that in the vertical orientation the samples have more definite breaking points, which by observation and documentation show that these were full, brittle failures at the places where the graphs spikes downwards. When the vertical sample pieces broke, it was very apparent both in sound and visuals. Along with this, the vertical samples also were more likely to have multiple breaking points, where there was the first major one, followed by multiple minor breaks. The horizontal orientation was more prone to "elastic tearing" which can be seen by the thicker, oscillating lines in the graphs, but which by observation showed that the tearing was only happening with the outer layer of the bark sample. Of the eight samples in the horizontal orientation, only one had a full brittle failure due to a knot being broken (Sample G1, Appendix A, p. 109).

While the orientation of the sample batches correlated with the ultimate strength of the material, the conditioning environment had a significant impact on the flexibility or elasticity of the birch bark. The average MoE of each batch can be seen in Table 3, and Figure 29 shows the MoE in a box plot format. From this plot, the difference in moisture content is apparent. The two control batches had a consistent MoE despite the difference in orientation. However, the two batches that were submerged in running water for 10 days had vastly different elastic properties. This is significant because it shows that there is a distinct difference in how the material behaves when moisture is reintroduced into the bark via rehydration methods.

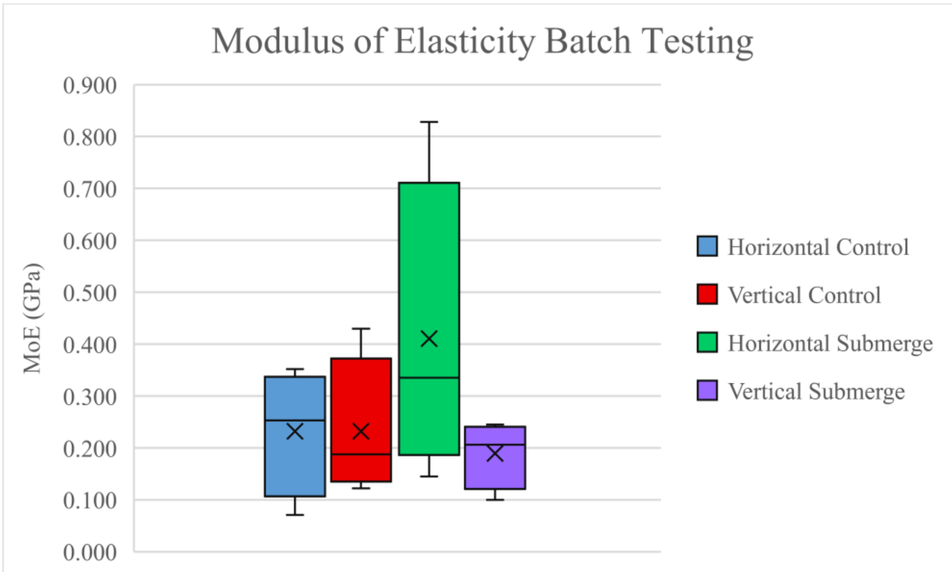


Figure 29: Box plot of MoE for four test batches

Chapter 6: Connections

After two years of intensive observation while conducting this research project, I had a tremendous amount of data to draw from and no idea how to connect the pieces. The stories and wisdom from the TEK side felt so disconnected from the results that I found in the lab experiments. This disconnect was so prevalent that I did not know where to begin these final sections for over a month. After reading many books from Indigenous and non-Indigenous authors, hiking through the woods to be with my plant relations, holding the sample pieces one by one individually memorizing what each one looks like, then matching each to the field work structures, it still didn't click. What was missing? What was I missing?

Everything was there, I had all the pieces of the puzzle, but for some reason I could not figure out the right way to put them together. Until it hit me.

I set up for the thesis writing day just like I had every day, but this time I got out my whiteboard, absolutely determined to figure out what that missing piece was. I held in my hand two of my sample pieces from the Shimadzu testing, bending them slightly to see where they had broken and see how far they could still go. I noticed that one was much more intact than the other. “Interesting,” I thought to myself, “that must be the way that we put it on our wigwams.” I drew it out, and then decided to double check with the previous structures.

Figure 30: Directionality differences in wigwam from museum and wigwam for project

I opened up the two pictures shown in Figure 30, the one on the left is a picture I took when I visited the Marquette Regional History Center that shows a wigwam made by a local Anishinaabe elder while the one on the right is a picture of the wigwam that was made for this study in the site exposure test. I looked at these two images, side by side and it finally hit me; the direction was wrong! The lenticels were going in the wrong direction! I sat back and thought about it and it seemed so intuitive that of course the lenticels should flow into one another, because that is how they would be on the tree. The lenticels grow horizontally on the tree and as the tree grows and expands, the bark does too connecting lenticels to the other lenticels just like it should if you sew the birch sheets together. If the direction is correct, you would be making one large birch bark sheet that would wrap around the trunk of the biggest tree in the world. But the one that we made, that had the lenticels in the opposite direction would be as if we had stacked multiple birch trees on top of one another, creating a very tall tree, but one that is unstable. In the horizontal orientation you are creating stability in the bark itself, for a larger "tree" (i.e. wigwam) that is durable and strong while still remaining flexible, whereas the vertical orientation makes a very tall "tree" that is prone to breaking and cracking.

After confirming this with my parents, I found my connection; direction is what connects each of these pieces together, through the four directions of the medicine wheel, the direction of the lenticels on the bark, the directions from our elders, spirits, and all our relations.

Once I realized that direction was the key to connecting all the pieces, I realized that I had known this all along. Growing up, the medicine wheel was taught to me as a guide, as a teacher, as a way of viewing the world. Through the four directions came the four aspects of well-being: physical, emotional, mental, and spiritual. Starting in the Eastern direction, each of these build off one another to create a whole, spiritual being. As a researcher, this worldview and symbol of balance translates to a process, a methodology through the steps to reflect on the project as a whole. While Western science focuses heavily on the physical ideas, the quantitative numbers and graphs, the Anishinaabe method goes beyond that to incorporate in the emotions of the researcher, the connections and energy between the spirit beings involved in every step, the process and overlaps, the accountability, the intellectualization, and finally reflecting on it all as we look to the future.

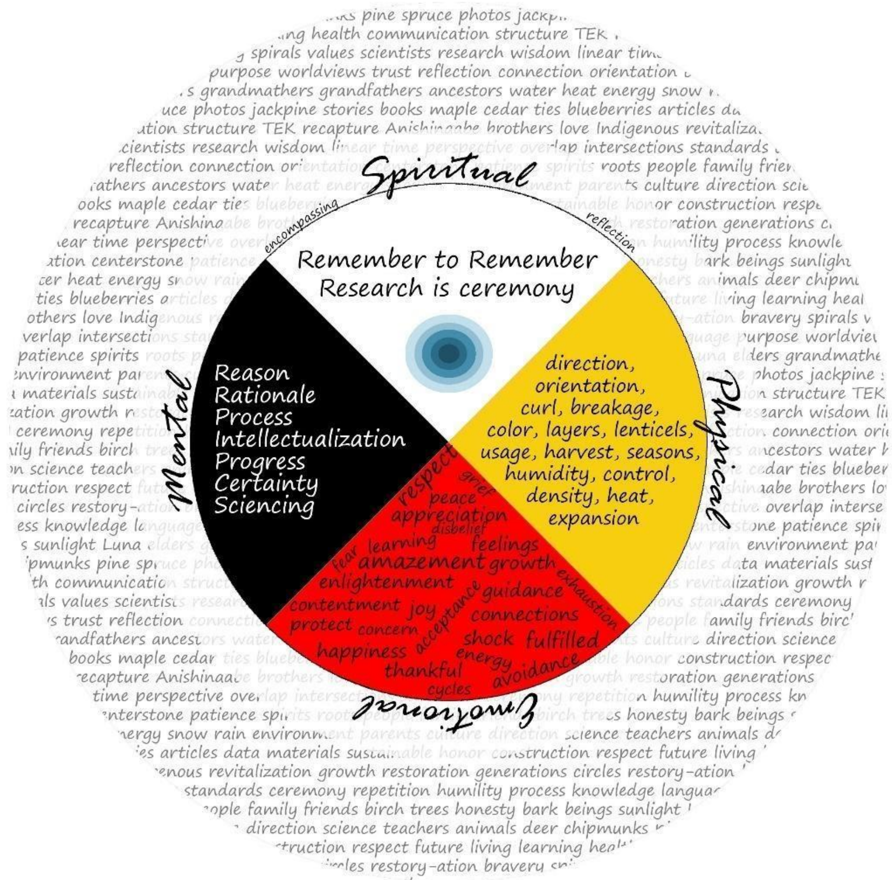


Figure 31: Stylistic representation of "mind map"

I am including the picture above as a guide to the mind mapping that led to the resulting discussion section below. Each "direction" relates to an aspect of well-being, which I correlated with an aspect of this research project; physical, emotional, mental, and spiritual. As much as I tried to keep the "sections" separated, I kept coming back to the idea that everything is related, we are all related, and research is indeed a ceremony. These directions build off one another, one result led to another, the emotions involved were guided by the framework, and most of all I remembered to remember the teachings of my elders and all our relations.

Direction

Each of the pieces came from one of 23 full bark sheets that were harvested traditionally in a class four years prior to the start of this thesis project. The bark was then cut, sewn, and otherwise processed for the two structures as well as the sample pieces that were tested in the lab in Syracuse, New York as explained in the Methods section. The wigwam was made traditionally according to instructions that were taught to my parents from their aunts and uncles as well as other knowledge holders in the Ojibwe community. However, after analyzing the results from two tests and comparing it to historical evidence, it has been determined that a vital piece of TEK failed to pass down in order to ensure that the bark on the wigwam would not curl or break after exposure to the harsh Upper Peninsula elements. The direction of the lenticels on the bark plays a key role in the longevity of the bark and in turn its use as a sustainable construction material.

As seen in the picture below, the birch bark sheets when sewn together should have the lenticels flowing into one another from sheet to sheet, or in the context of this project should be in the "horizontal" orientation. The historical and contemporary use of birch bark shows that when the birch bark is sewn together in this orientation, the edges are firmly clamped down by being tied to one another and the end tied to a cedar splint.

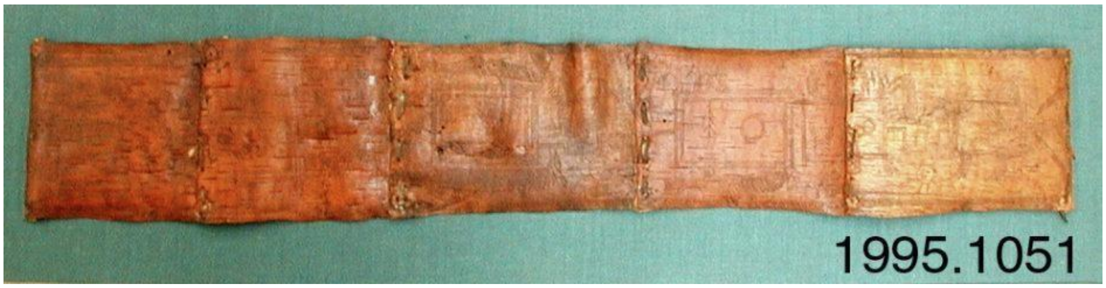


Figure 32: Midewiwin Scroll, ca. 1860 [Birch bark] showing direction of lenticels

The wigwam made with the TEK that was passed to my parents was made with birch sheets that were tied together in the vertical direction which meant the edges were allowed to curl and were more likely to break. This curling and breakage was not immediately recognized as we used many rehydration methods to make the bark pliable enough to be sewn and secured to the roof of the structure. However, after drying and being exposed to the elements, this curling and cracking was very apparent through the seasons, culminating in the final check where the curled edges after being exposed to sunlight for a year were bleached and cracked through with a full failure. This was further confirmed by looking back at the results from the Shimadzu testing results. Table 3 shows the results from the quantitative data collected by the machine, but this breakthrough came about because of observation, recorded pictures and video, and written notes taken during each sample bending test.

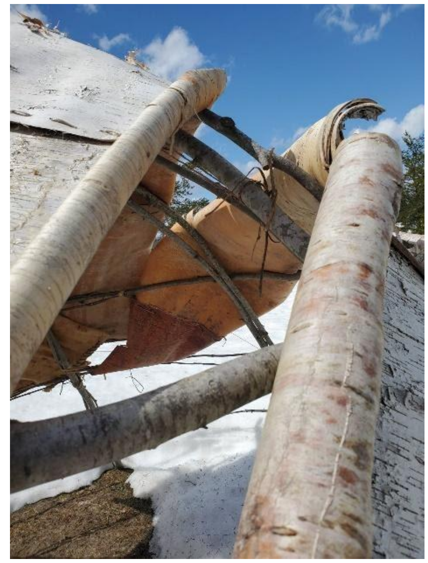


Figure 33: Bark from wigwam at end of site exposure test, curled and bleached

Each of the samples had a distinct Modulus of Elasticity that was calculated first by the machine, then by RStudio, then again by hand to verify the information. However, the breakage of these samples was starkly contrasted between the two orientations. The two batches set in the vertical direction, eight samples total, all had a brittle failure of the sample specimen through all layers, along with 1-4 more smaller tears. The two batches set in the horizontal direction had elastic tearing through the outer most 1-2 layers, or no breakage at all in the case of two of the submerged samples. One might think that these samples in the horizontal orientation did not get to full breakage simply due to the machine or the knob getting in the way (Figure 34), but I went one step further after all the testing was done and bent two of these dried samples in half, a full 180 degrees in the horizontal orientation, and they refused to break any further. An important note here is that this bending from 0-90 degrees would have been investigated if the D3462 testing were able to take place, but due to the university being shut down, this was found by a happy accident and curious mind.

Figure 34: Example of Sample running into knob during Shimadzu testing

This directionality and orientation of the bark is a piece of vital TEK that is imperative to the strength and resiliency of this material in relation to buildings, canoes, crafts, and anything we use birch bark for as Ojibwe people. Which made me realize that it was something that was so integral to us prior to colonization that it was assumed that we would continue knowing exactly what to do.

After coming to this conclusion, I went back through my articles and books that had brought me here and I found the video "Earl's Wigwam," a video from the Center for Native American Studies at NMU where an Ojibwe elder, Earl Otchingwanigan, takes us on a step-by-step journey to build a traditional wigwam. My family was there learning from him, and my sister and I can even be heard in the background when we are gathering materials. Even in this step-by-step guide, the direction of the bark is never brought up, but it is shown that you must attach each piece together as they would naturally fit together. With fresh bark this is easy, the sheets mold and bend to the will of the person preparing it, so even when my parents made our wigwam as children using this fresh bark in the vertical direction, the bark shaped to the wigwam as it was guided to. This directionality may never have been brought to light if the conditions of this project hadn't been in just the right place, where we happened to have a stockpile of re-purposed birch with an Ojibwe graduate student that wanted to integrate Ojibwe TEK into sustainable buildings.

Orientation and Expansion

The direction of the lenticels and orientation on the structure is one of the most important aspects of ensuring the longevity of the bark. This is due to the elasticity in relation to these two when dried. The lenticels are the markings that go around the circumference of the tree which are the weakest point on the outer layer of the bark. As such, bending parallel along the lenticels is what caused full failure breakage in the bending test. Although there was breakage when the bark orientation was horizontal (perpendicular to the crosshead) there were no brittle failures in the bark. The direction that the bark is placed on a traditional wigwam dome structure has the lenticels horizontal, connecting to one another and flowing away from the Eastern doorway. This was done opposite in the wigwam created for this project which caused the breakage, curling, and sun bleaching of the bark.

The curling on the edges of the bark goes in the opposite direction it would be curled around when still attached to the tree which is perpendicular to the lenticels. After observing this for years and discussing with other TEK knowledge holders, it was determined that the curling has to do with the outward expanding direction as the tree swells and grows and how this seasonal shift in moisture transport affects the structural integrity of the transitioning outer bark.

As the bark grows layer by paper layer on the tree, it transitions from the inner bark to the outer bark. This split from the cambium is where nutrients flow through the tree while still being protected by the outer layer of bark that is waterproof and disease resistant. The lack of structural integrity of the outer bark is what makes the bark curl "outward" once it is cut off the tree and let dry. The outer bark peels and tears as the inner bark expands, similar to the outer layer of our skin. In the spring, when the rains come and moisture levels are high, the inner bark transports water and nutrients and puts pressure on the outer layer of the bark. Therefore, the time and season is extremely important when harvesting the bark. When on the tree, the outer layer of bark is attached to itself in a tube around the entire tree, but when a couple of Anishinaabe people come along and create that long T shaped slit the pressure gives way and the whole outer layer comes off with a loud "POP", see Figure 35.

Figure 35: T-shaped slit and example of bark popping off tree when cut

However, with the re-purposed birch bark, we had to rehydrate the entire bark sheet in order to make it pliable to work with. When we rehydrated the bark, it was better able to be flattened out and worked with such as with sewing. While the bark remained wet, it remained much more pliable, but as soon as it began to dry, it began to curl and became rigid. The major difference is that when the bark is still attached to the tree, the inner bark does not curl because it remains uncut and intact. Whereas the outer bark tears and actually does begin to curl. This is obvious in how the tree sheds its bark.

Figure 36: Example of peeling outer layers when still on tree

Moisture Content

The moisture content of the bark has a direct relation to the elasticity and resiliency on a structure. For instance, green bark or recently harvested bark can be easily rolled up, flattened, sewn together, and molded to the shape of the project needs, such as canoes, makaks (storage containers), or wigwam structure. Prior to this study, I had only worked with fresh bark for use in structures, and only used re-purposed bark in small scale crafts such as earrings or small baskets. If we had used fresh bark instead of the re-purposed bark, the sheets would have molded to the shape of the wigwam structure easily such as they had with the wigwams my family made when I was younger. However, once the bark is dried, it is much harder to bend without due care. Therefore, a large portion of the prep work to use re-purposed birch bark was spent on determining a suitable rehydration method to mimic the moisture content that bark has when first traditionally harvested from the tree.

Of the two methods that worked the best, ironing and soaking, the soaking method is one that was told by an Ojibwe knowledge holder as well as in the book by Geniusz et al. (2015), whereas the ironing method was brought about in a brainstorming session with my family and other community members.

The steam ironing method worked to an extent on the semi-curled pieces of bark, but the soaking in running water method would have been the best solution to rehydrate and make all the bark sheets pliable enough to flatten and work with. The specimens that were part of the ESF experiment were able to regain some of their pliability when placed in a 65% relative humidity climate-controlled chamber, but given the results from the MoE, the difference in moisture content was negligible compared to the orientation. However, each of these are qualitative results that were observed by myself and those that were helping with the experiment. This is due to the moisture content sensor being unable to obtain any moisture reading on the inner part of the bark even shortly after taking it out of the water. The sensor was able to determine a moisture reading on the outer (white) part of the bark, but not the inner bark.

Further testing was done by splitting a few test pieces during the steaming process layer by layer, approximately the thickness of a piece of paper, to see the difference in humidity readings from each one. The longer the samples were in the steam box, each inner layer "grew" 2 mm with every check in the horizontal direction but did not expand in the vertical direction, see Figure 37. At the end of the two hour testing the

Figure 37: Picture of growth by layer during steam test

bark sample layers were almost 2 cm difference in length when flattened, and the humidity sensor was only able to get a reading greater than 5% on the first three outer layers even directly after steaming.

The separation between the inner and outer bark can easily be seen not only with the bark popping off, but also in fallen birch trees where the core has rotted away and all that is left is the bark. The bark generally remains intact retaining its circular shape. Inner bark and outer bark have obvious color features that seem to follow a gradient based on the bleached white outer bark, to a salmon/pinkish color, and then to a creamy orange-ish color, and finally to a deep red of the inner bark. The exact coloring on the inner bark seems to vary depending on where the tree was harvested from, the season, and age of the tree, as well as the length and environment from storage. The birch sheets used in this project were generally in great condition, but some had a dark brown inner bark color where they had been damaged.

Chapter 7: Conclusions

Prior to colonization, the main style of Anishinaabe housing was a structure known as a wigwam which included a dome shaped structure covered on top, and sometimes on the sides, by wiigwaas (birch bark). The transition from wigwams to non-Anishinaabe western style houses occurred at different times at different locations throughout the land of the Anishinaabe, but by the time this thesis was being written, it was rare to encounter anyone that had actually built a wigwam, and even more unusual to have met someone who actually lived in one.

As the author of this thesis, my experience with building wigwams as a child both influenced and informed my research on the use of wiigwaas as a contemporary roofing material. Having met people who actually lived in wigwams, and having my own personal experiences with building them and using them for education and entertainment, I knew from my firsthand experience that wiigwaas still played a major role in shaping and/or reinforcing my identity as an Anishinaabe person. I am also keenly aware that my generation may be the one that determines if we as Anishinaabe people are going to revitalize our relationship with wiigwaas as part of our homes or not.

The seventh-generation philosophy is partially meant to keep in mind our future generations, but also that we are currently part of the seventh generation from the past to the present. According to the grand chief of the Anishinaabe Three Fires Confederacy, Eddie Benton-Banai (1988), we are currently living in the "seventh fire" meaning that we are at the end of the prophecy where there are two paths in front of us. One path leads to mino-bimaadiziwin (the good life), "a rebirth of the Anishinaabe nation and a rekindling of old flames" which if this path is chosen will light the 8th and final fire - an eternal fire of peace. However, there is another path, the wrong path that if we choose that path then all of Earth's people are sure to be destroyed.

Winona LaDuke quoted the words of an Anishinaabe elder in her book *All Our Relations* (1999) with where we are today in this prophecy, "[T]he reality we live within is totally different from anything we ever knew. It is just a different environment, a different context. Not a very good one, not a very harmonious or balanced one, not a very healthy one, but this is the environment that we live in today. The lifeway that spoke to our people before, and gave our people life in all the generations before us, is still the way of life that will give us life today." Prior to colonization, Anishinaabe people lived according to a value system that centered on respect and reciprocity with nature. We were aware that the things we received from our Mother Earth provided us with the ability to live a good life. This relationship included the homes we lived in. The materials we needed to build our homes came from our Mother Earth, and the way we used them were based on traditions handed down from one generation to the next for thousands of years. Not only was wiigwaas used as a material for roofing, but also for canoes, baskets, and recording keeping by way of scrolls. As such, wiigwaas was and continues to be a cultural keystone species for the Anishinaabe.

Although the forces of colonization have disenfranchised the Anishinaabe and other Indigenous peoples from their lands and traditions in many ways, there are also many people who kept this special knowledge intact, or are at least trying to piece it back together through decolonizing methodologies. This thesis is focused on decolonizing housing by way of drawing on wiigwaas as a contemporary sustainable roofing material. Despite the centuries of colonization and forced assimilation practices, we have survived. We are resilient, and we are revitalizing our traditional knowledge to decolonize our lifeways.

Importance of Ojibwe TEK

This knowledge of wiigwaas as a sustainable construction material is just one step towards decolonizing our lifestyle and our homes. The importance of our history and Ojibwe TEK goes beyond simply slapping birch bark shingles onto a roof, but rather listening to the stories and oral tradition and then taking the time to see for yourself what these stories are trying to tell you. When I was conducting this project with my family, as we used chainsaws to cut down saplings, an iron to rehydrate our bark. When I was on campus in Syracuse, New York, I used a Shimadzu bending machine to help me test the bark in an experimental way. There was a question that kept popping up in my head as I conducted my experiments using modern technology: what would our ancestors think? Of course our ancestors used the technology available to them in their day, and I was using what was available to me, but as I worked through my research I felt disconnected from my traditions even while attempting to revitalize them.

It was near the end of my research, while writing up the results, that I had a moment of epiphany by way of our ancestors speaking to me through the wiigwaas. As I was looking at the way I had oriented the bark on my wigwam, I realized it was the opposite of the way it was oriented on other wigwams in historical photos. I looked at several examples and there it was, a piece of TEK that had not found its way into my life until that very moment. Again, I asked: What would our ancestors think? This time I felt like I knew the answer, they would wonder why we were not orienting the bark the way they did. From the stories I have heard, I believe they would have been shaking their heads while laughing to each other while we figured out new techniques for the traditional ways. They would probably be frustrated that they could not share what they knew, but also relieved to see we are living and learning from them still.

Our stories and language hold so much knowledge in them, but we still must learn from experience. The major disruption of colonization and assimilation cut us off from many of the teachings from our elders such that we are relearning what would have been obvious to our ancestors. The use of the contemporary tools and methods in gathering and building the wigwam would make our ancestors shake their heads, but they would understand and laugh along with us. However, the directionality of the lenticels on the bark would have been something that was extremely obvious to them or any elder that still works with and builds wigwams today. This was very apparent as soon as I noticed the difference and went back to look at Earl's Wigwam. Along with this is the TEK that says that you should use fresh bark when building a wigwam or canoe, bark that is taken during the beginning of summer and done a certain way. The difference in using fresh bark as opposed to the repurposed bark that we needed to rehydrate was as different as eating a grape versus a rehydrated raisin. It worked to an extent, but there was an obvious difference. Fresh bark is much more moldable, and flexible, such that when we made our wigwams when I was a kid the birch sheets would mold to the shape of the wigwam regardless of orientation. This meant that during the years that my parents and I made wigwams together, we never noticed the difference in direction of the lenticels because the fresh bark dried in place. This aspect of TEK is one that I had to learn with this project, but I am now able to share it with the rest of my family and relations.

Harvesting Experience

The importance of how, when, and where we collect the wiigwaas was answered with multiple sources; my own experience in the woods with family, listening to our elders speak, and in books and articles from researchers both Native and non-Native. The work by Geniusz et al. (2015), *Plants have so much to give us, all we have to do is ask*, holds the collective knowledge of generations of Anishinaabekwe finally in written format that uses a culmination of story and "scientific writing" to explain where and how to collect plants from all over the Great Lakes Region.

The most important teacher of them all, however, is experience. We learned to collect birch bark for use in our wigwams by going out with gatherers and watching, listening to the woods around us. There is no set date when it is time to collect bark for wigwams, but I was taught that it is best to go out in the days just after the springtime, when the rains are here and the ground is wet. When it is hot and humid, and you see the ferns covering the ground. Then when you get to the tree and feel the cool touch of the bark, guide your knife in a long slit through the outer bark, and here the "POP", then you know it is time. The best way to collect birch bark is this way, making sure to not cut too deep to harm the tree, laying the bark down flat and rolling it up with ferns in between each sheet to keep the moisture inside while we transport it home.

Durability

The question of how do/did we treat and test the materials for resiliency and durability took quite a few turns during this thesis work. It was not until I was nearly at the end of my time with this project that I was directly challenged about this by one of my mentors, Dr. Robin Wall Kimmerer. Where does this idea of durability come from? What does it mean for a material to be durable? And why was that the first thing I thought of when I decided to study birch bark, to look at how durable it could be in relation to other contemporary sustainable roofing materials? The idea of durability from a Western framing may come from the need to own something, to have property and rights to a place and have a sense of permanency.

The average US home is angular, multi-level, with an expectation that once that home is built it will be there for generations. The people living there will stay put, own the house and live out their lives in that one place. While there are obvious exceptions to this, people move all the time, but the buildings stay put.

Traditionally, Anishinaabe people moved with the seasons, taking our belongings with us including the rolls of bark that were attached to the ribbing of our wigwams. Our idea of "durable" had to do with being able to withstand the climate, strong and water proof enough to hold against the multiple feet of snow, but flexible enough to roll up and pack it up to move to the next camp. Resin deposits within the bark make it waterproof on its own, but if a completely waterproof roof/container/canoe was desired, the exposed edges could be covered in pine pitch or similar sap from a coniferous tree (Geniusz et al., 2015).

The two differing viewpoints on what makes a roofing material "durable" made for interesting experimentation and defining conclusions from this study. The four treatments/finishes in the site exposure test revealed that the bark lasted well enough on its own and based on historical evidence this is true unless you want to create an absolutely waterproof container using pine pitch. The testing with the site exposure test and the mechanical properties test inadvertently set out to test the "durability" of this material from a western framing, but ended up looking at the aspects of durability that are important from a traditional Anishinaabe perspective. The site exposure test showed how the wiigwaas itself behaves when exposed to the Upper Peninsula weather and the mechanical properties testing tested the strength and elastic range of wiigwaas as well having definitively looked at why we as Anishinaabe people chose this material for our roofing thousands of years ago.

Comparing Exposure, Elasticity, and Energy

At this point we have now answered all but one of the original four questions. We know the importance of the TEK, harvest techniques, and how to process the bark, so how does birch bark compare to contemporary natural sustainable building materials? With that we must look at the results of the two experiments as well as a broad viewpoint of this project as a whole.

The benchmark testing for birch bark comes from hundreds of years of use in Indigenous structures, scrolls, transportation, and storage. However, in contemporary times, birch bark has long been overlooked as a construction material, as such the testing done for this project used contemporary standards testing focused on site testing (exposure) as well as comparative tests (three-point bending test) to compare it to currently used natural and industrially processed construction materials.

The site exposure test was designed to measure how the bark reacts within the climate zone of the Great Lakes Region, specifically climate zone 6 according to the Department of Energy, along the south shore of Lake Superior. The weather conditions for this area have very harsh, cold, snowy conditions for up to seven months of the year, along with wind, rain, and sun exposure. The one-year site exposure test showed that the bark does hold up to moisture and UV radiation, but due to the directionality of the bark discussed previously, there was large amounts of cracking in both the dome and flat roof structure. However, based on historical evidence as well as contemporary educational wigwams made by TEK holders in lower Michigan, Northern Wisconsin, and Minnesota, there is a potential for birch bark to durable enough to last hundreds of years under the right conditions. Archeological records show that baskets, canoes, and birch bark scrolls have lasted up to hundreds of years remaining intact (Green, 2017; Croft & Mathewes, 2014), which indicates that as a roofing material, birch bark could potentially outlast many of the currently used natural roofing materials such as wooden shakes and shingles and green roofs.

The three-point bending test was just the beginning of comparing birch bark to other contemporary roofing materials via ASTM international standards. The procedure for this test was adopted from the C120 test for slate shingles and the results found the Modulus of Elasticity (MoE) for the samples at a controlled relative humidity as well as after being submerged in running water for 10 days. The MoE for the control samples averaged out to be 0.243 GPa for both directions, and the submerged samples averaged to 0.289 GPa. However, the range for the submerged samples varied widely between the two directions indicating that more research must be done before finalizing that value. Nevertheless, the MoE for birch bark proved to be much more flexible than nearly all lumber/timber products and behaved similar to that of semi-rigid plastic. As a reference, the closest man-made product with a similar elastic range is that of polyethylene LDPE between 0.1-0.4 GPa, and the lowest MoE for any wood is cedar between 5.5-11.7 GPa.

The elasticity and pliability of materials is part of the standards to determine the breaking point and elastic range of materials. To compare the birch bark to current contemporary materials, more research would need to be done to find a definitive answer. However, the testing done in lab and via observation shows that the bark has a large elastic range indicated by the low MoE value and is not prone to failure in the horizontal orientation.

While these two tests were able to determine answers about birch bark and how it behaves under certain conditions, much of the research done has brought about more questions for future research instead of a defining answer to the question posed. So how does all this come together to answer, how can we compare birch bark to alternative construction materials? How can Ojibwe TEK be incorporated into developing sustainable construction materials? The answer to that is what connects us all: energy. Energy is all around us, part of us and every being in the universe. It connects us all, it drives our economy, and has a direct impact on our future.

I started out this project trying to find the connections between climate change and how it affects Indigenous nations, specifically the Anishinaabe people of the Great Lakes Region, which brought me to green buildings and reincorporating our TEK into our homes with this project here. As Anishinaabe people, our value system is about keeping things in balance, and doing so in a respectful way. The honorable harvest is a guide to sustainably harvesting local materials, using them in a good way, and giving back to the Earth. The life cycle of our traditional materials is a closed cycle, meaning that the energy lost by taking the bark is replenished by the tree continuing to grow and eventually by the bark going back into the ground at the end of its life. This is an important aspect of comparing birch bark to contemporary sustainable roofing materials because of the extensive energy loss from taking raw materials from the ground, processing, transporting, using, and eventually going into waste. While some materials can be recycled into other products, the overall life cycle of roofing materials like asphalt, slate, or metal takes far more energy than it gives back into the world.

When you take from the Earth to create a solar panel or asphalt shingle, the raw materials are processed beyond natural comprehension, but when you take birch bark off a tree in a good way, the tree still lives. Naturally, one would want to see this for themselves, so despite being told this all my life, I decided to take a walk when writing this final section of my paper. I went into the woods, one year later almost to the date to visit my tree relatives to see how they were doing. I walked through the woods, with my parents once again and there in the distance we could see it, unlike I had ever seen a birch tree before.

The scar on the tree shown a deep reddish brown in a perfect cylinder around the trunk where we had harvested our birch sheet a year ago. I was overwhelmed with emotion, in awe as I felt the roughness of the tree that transitioned into still healthy living bark on both the top and bottom edges. I looked up the trunk and saw the leaves shining brightly, a meadow green against the blue sky and saw just how much more living this tree still had to go. I shed happy tears which I left on the trunk of my friend before we continued on to visit our other three that we had traded our semaa for their outer bark, all in the same condition. This is the true difference which separates birch bark to all other natural building materials. We can calculate the energy gains and losses, the carbon footprint, and conduct an entire life cycle analysis of each material to quantify the difference in these sustainable materials. Or, we can look up and see the leaves growing and know that this is the way, this is why our ancestors learned and used the bark of this tree to house us, to transport, to store our most precious resources.

Figure 38: One year later of the tree harvested from for project

While this may seem obvious to some, I set out with all the testing and experiments involved in this project in order to develop a holistic understanding of this material, wiigwaas, to show from multiple worldviews that this can and should be used as a sustainable roofing material. We knew for thousands of years that under the right conditions, wiigwaas is an ultimate roofing material, but in order to use it in modern society today there are standards and codes that need to be accounted for before it can be scaled up to use in and on our homes. Validating wiigwaas as a sustainable roofing material for use in contemporary homes on reservations is a multi-step project, that is one part of combating unnecessary energy usage by using locally sustainably harvested materials while also reintegrating one of our cultural keystone species back into our homes. This keystone species of the Anishinaabe people has been a sustainable construction material for thousands of years, and as we move forward into the future, we can utilize and decolonize our materials in order to create a healthy world for all of our future generations.

Future Research and Recommendations

There are a number of limitations and barriers in place right now to implement this material into our tribal housing in Anishinaabe aaking (the lands of the Anishinaabe). First is the knowledge of the bark itself from both TEK and SEK perspectives. The bark itself is a cultural keystone species for the Anishinaabe, but the process to utilize it within the context of people's homes is a long term commitment to quantifying the bark from an SEK perspective "so that engineers and architects will have the confidence to use it" (MacDougall, 2008). This can be done by continuing the blending of the two worldviews by being respectful of the trees when harvesting while also going forward with adjusting ASTM or similar standards and researching the cellular structure of the outer birch bark to determine characteristics in relation the moisture content. In performing the experiments for this study, I observed and speculated about the structural integrity of the bark, but due to limitations of this study from timing and labs closing nationwide, this is the next step for future researchers who may pick up this study.

Next, in order to actually implement wiigwaas into our tribal housing, a complete multi-disciplinary study needs to be conducted to address all seven aspects of the Ojibwe Sustainable

Housing Framework (OSHF), such as other traditional and non-traditional materials, and any additional components that community input deems necessary. Within this OSHF is the need for community input and design such as that seen in the Pinoleville Pomo Nation co-designed study (Shelby et al., 2012), or any of the other 16 case studies as seen in the report by the Sustainable Native Communities Collaborative (Blosser et al., 2014) that look at the best practices of reintegrating cultural and historic design elements into tribal housing. "Most of the projects that incorporated culturally based design strategies did so through a strong community-engagement process, meeting with various user groups, including potential residents, community members, elders, youth, and cultural leaders" (Blosser et al., 2014). Part of this community engagement would be the knowledge transmission from TEK holders and elders in the community to the younger generations, especially in regards to how to locate, gather, and process wiigwaas.

This relates to the third limitation for implementation; scalability. According to Emery et al. (2014), the total birch bark supply has decreased substantially across the ceded territories in the past 30 years. Although there is a decrease in the amount of harvestable trees, this material may still be scalable for a limited population. The intended application is for tribal reservation housing in the near future once the OSHF is more fully developed.

A gradual integration into reservation housing would also provide more time for growth of trees, and for establishing trade with other communities that have greater access to wiigwaas. Realizing that not all Anishinaabe people are likely to be concerned about the reintegration of wiigwaas into their homes for cultural reasons, the potential marketability of the idea may hinge more on other aspects like aesthetics, insulation value, cost, etc. As such, there may be some resistance to integrating it en masse on every reservation, even if it were not in short supply. Nonetheless, given that there is a limited supply in the amount of total trees in this region, part of the future work would be to plant and grow more birch trees where they would flourish as well as working with lumber companies to establish a precedent for gathering bark off of the birch trees before the logs are taken for lumber processing.

Indigenous housing worldwide has issues relating to the materials used and health of the people and the environment. However, there are multiple groups of researchers across Mshike Minis that are working towards reintegrating our cultural values into our homes with a hybrid of contemporary sustainable green building and our Indigenous knowledge and technologies (Bailie & Wayte, 2006; Blosser et al., 2014; Cattelino, 2006; Deane & Smoke, 2010; Hadjiyanni & Helle, 2009; Seltenrich, 2012; Shelby et al., 2012) through establishing tribal building codes, design elements, and integration of local culturally relevant materials. There are challenges to implementing these onto our reservations such as funding and politics, as well as research that must be done, but as part of the seventh generation, overcoming these barriers to reintegrate our cultural values and materials into our housing and lifeways is imperative for future generations.

Reflections

At the beginning of this thesis, I introduced myself and my path here by following Wilson's lead in his letter to his sons by writing a letter to my goddaughter, Luna. At that point, it was necessary as a way to conceptualize how to do this thesis, how to combine the Western science and my Anishinaabe teachings and values by talking to someone that I love about what brought me here. I write this letter now, not as a need, but as a closing, a way to say "baamaapii" to you the reader who has gone on this journey with me. "The research that we do as Indigenous people is a ceremony that allows us a raised level of consciousness and insight into our world. Through going forward with open minds and good hearts, we have uncovered the nature of this ceremony." (Wilson, 2008)

Aanii Luna,

We did it, we made it to the end of this academic journey. So much has changed in the world since I set out to fulfill this project and develop an Ojibwe Sustainable Housing Framework for our little rez in Upper Michigan. We have changed as people; you are no longer the tiny binoogiis that you were when I started thinking about these ideas. You are now a full human, with thoughts and opinions and a spitfire personality that rivals your mothers at that age. I have grown up too, this process of conducting an entire thesis using Indigenous Research Methodology has made it so I am finally whole. I am no longer split between my academics and my culture; I am fully an Anishinaabekwe scientist.

This process has not been easy, but remembering the broader impacts and reverberating conclusions this project will have for our community is what kept me going, for you, for our family, for our entire community. This may not matter to you for a long time, but I did this for you and the future Anishinaabe people. I know there are pressing issues in our community, I have seen them myself; poverty, drugs, alcoholism, violence, all the environmental injustices that we have faced for hundreds of years still so prevalent in our community. Whenever I talk to tribal leaders, that is what they are focused on; survival. While obviously that is what we need to do first and foremost, I am hoping by the time you are old enough to have these conversations with me, we will be past the need to simply survive and begin to live and dream together; to incorporate green buildings, clean energy, community gardens, and focus on the health of our people not as a survival technique, but of growth.

Looking back, our community has come a long way in the past decades, from forceful assimilation to the revitalization movement we are part of today. We are well on the path to decolonizing our lifeways, looking to our seven grandfather and medicine wheel teachings. It may not be your generation, but maybe your kids or grandkids will one day live in a house that incorporates our designs with the circular architecture and central fire, a house that is sustainable and green with multiple generations under a birch bark roof. I hope that by that time, TEK is taught and valued in school, at all levels, that we will have revamped the education system to focus less on tests and more on experience. I can see our tribe winning against the pipelines that cross our land, and continue fighting for all our relations, human and non-human. And I hope that we will have recognized the importance of an ecological economy, a reciprocal economy, over the consumption driven economy we live in today.

This knowledge, conclusions, and methodology embedded in this thesis is for us all as Indigenous peoples to incorporate our cultural values, keystone species, and TEK into our lifeways. In order to be in balance in all four directions, we not only need to be in balance for ourselves, but the world around us as well. We are part of our family, our tribe, and all living on Turtle Island together. By decolonizing our housing, and our lifestyle with small steps, we are on the path towards a sustainable, healthy future for seven generations and more.

Chi-miigwech, baamaapii giigawaabimin,

Biidaaban M. Reinhardt

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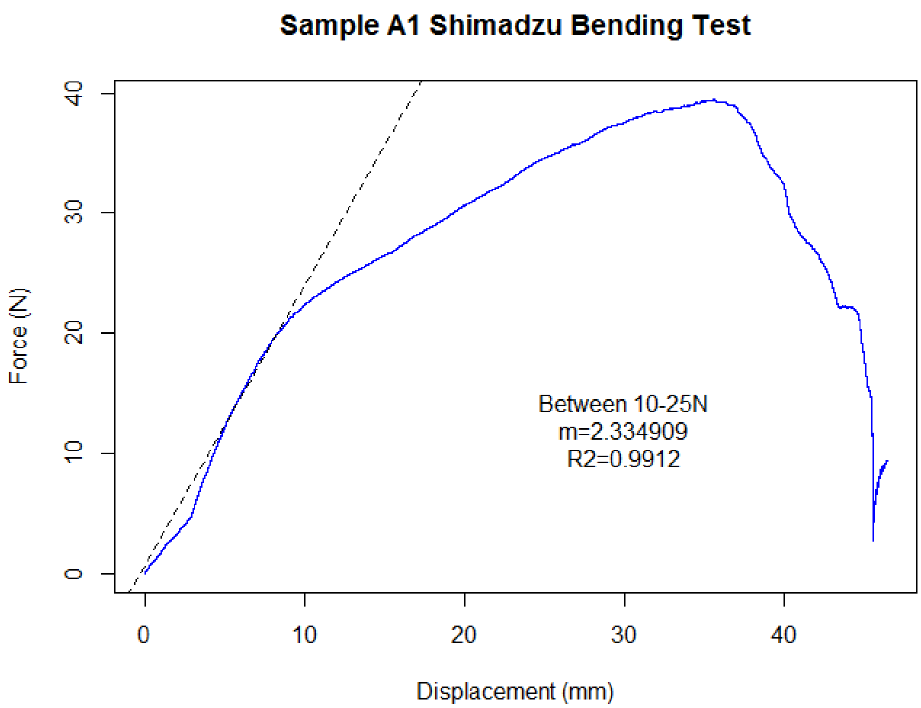
Appendix A

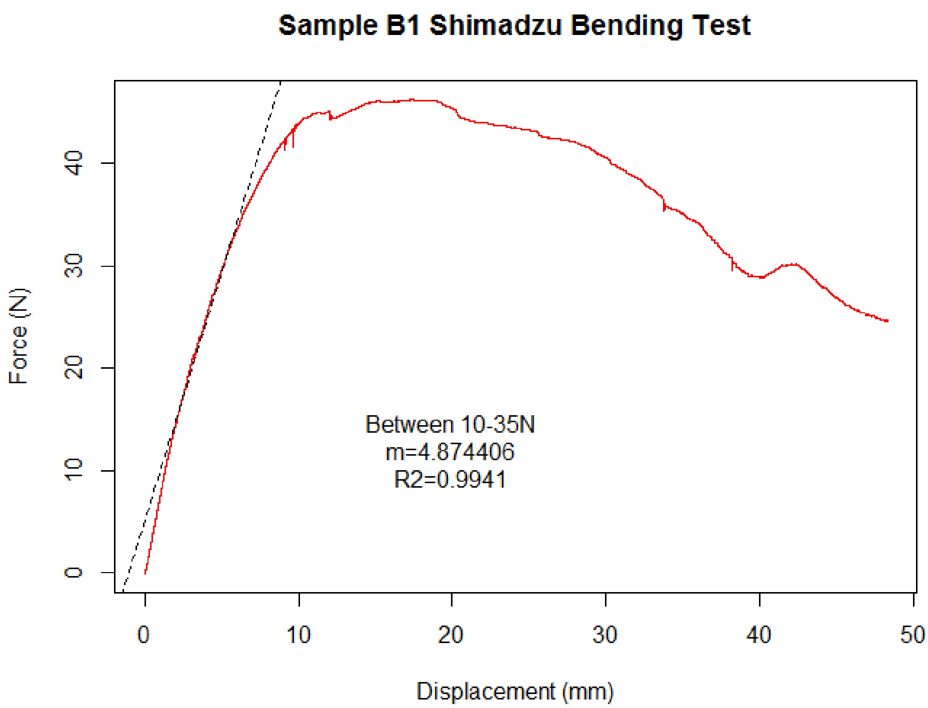
Below are the plots for each individual sample for the three-point bending test. The summary of the MoE for each group can be found on page 63, Table 3.

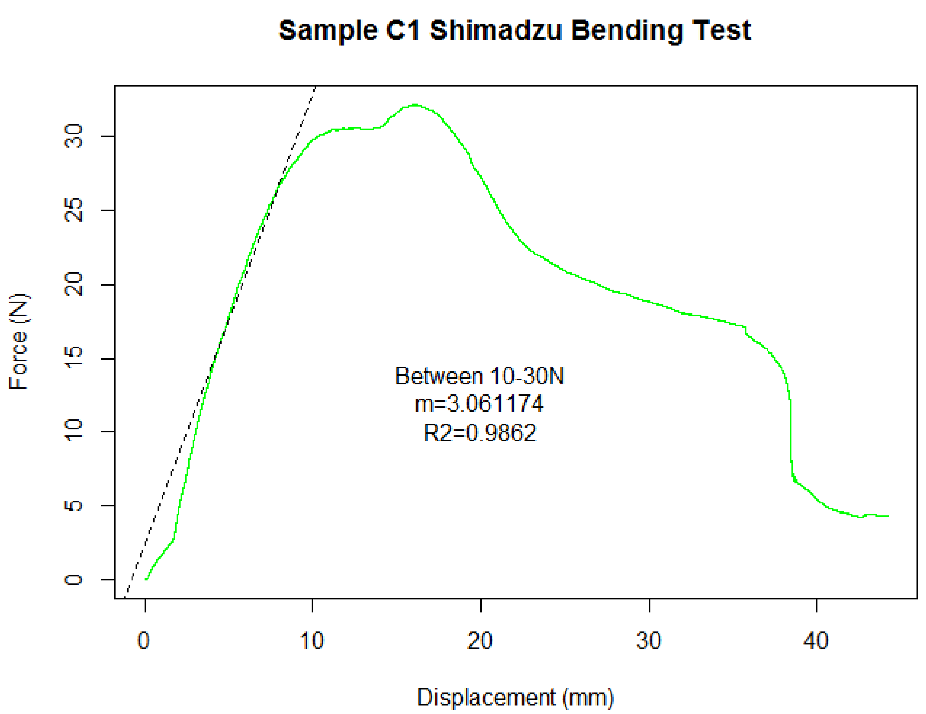
They are grouped as follows:

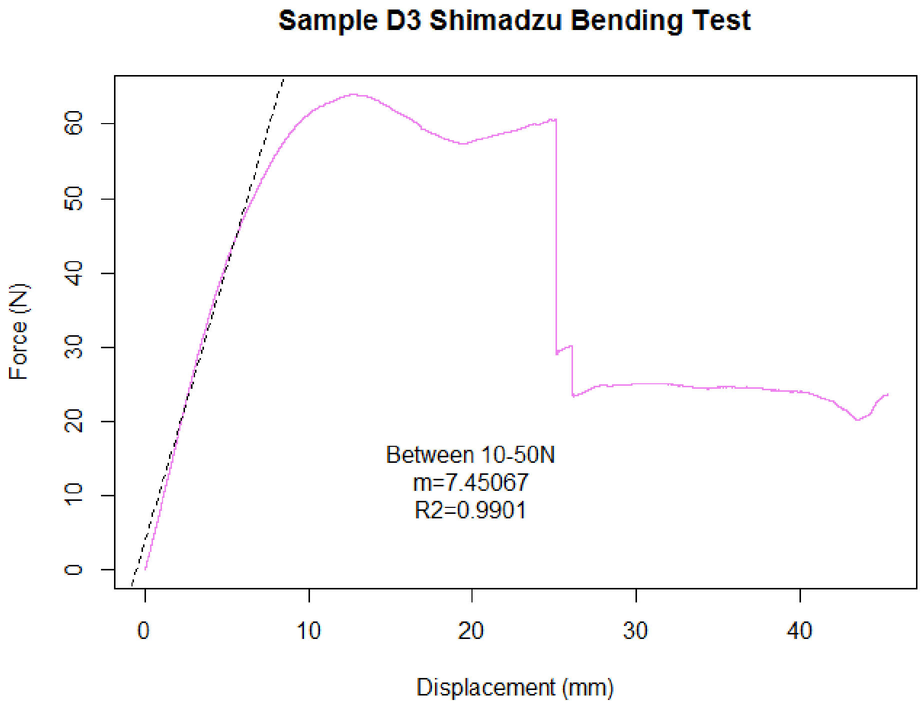
- Vertical Control group
- Horizontal Control group
- Vertical Submerged group
- Horizontal Submerged group

Vertical Control Group: Samples A1, B1, C1, and D3

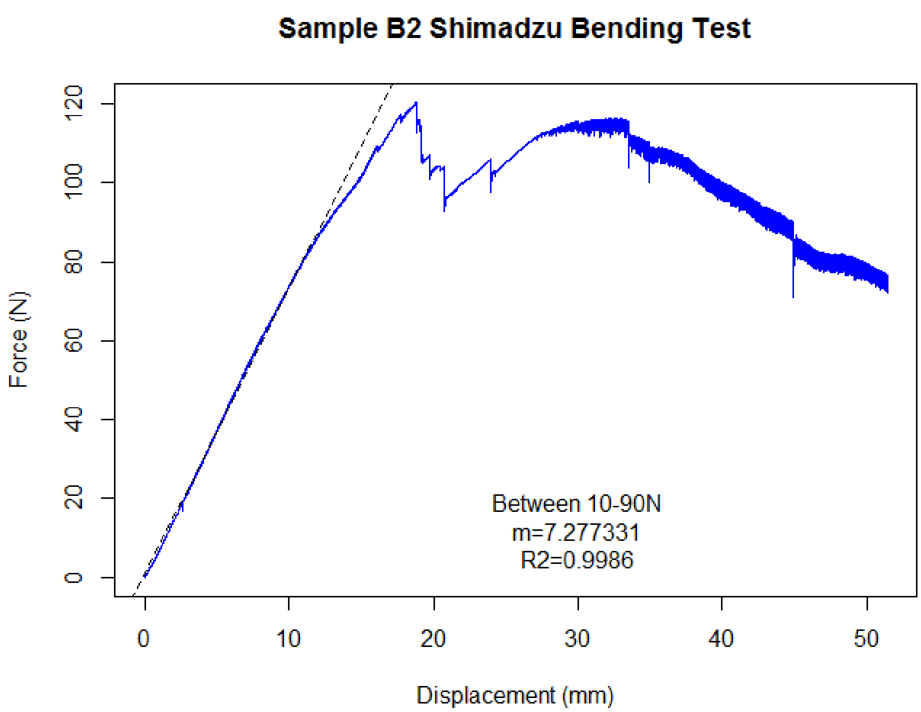


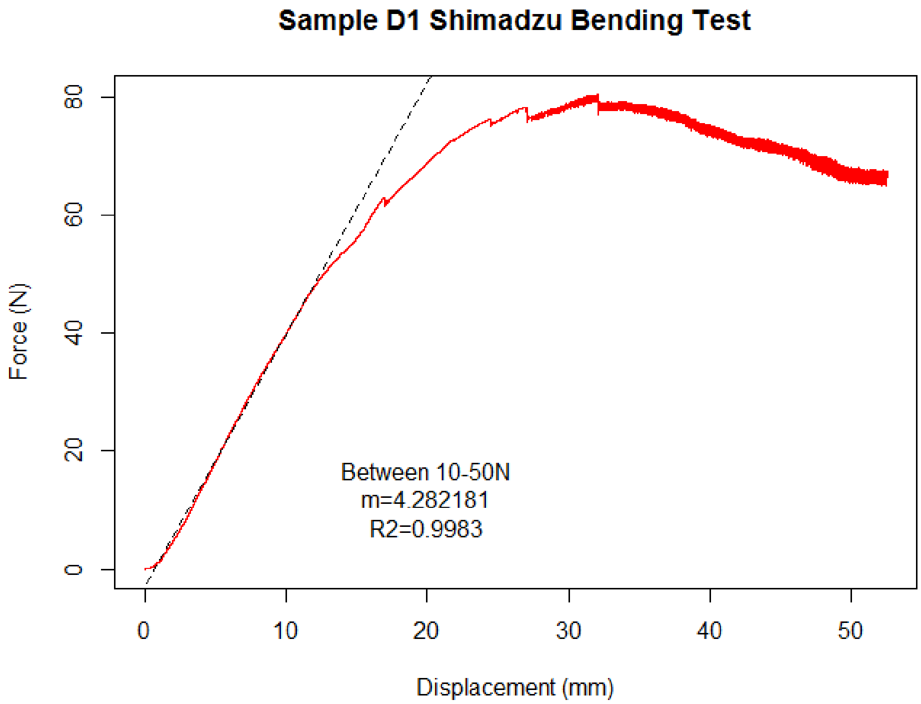

Sample B1 Shimadzu Bending Test
Force (N)
Displacement (mm)
0
10
20
30
40
50
Between 10-35N
m=4.874406
R2=0.9941

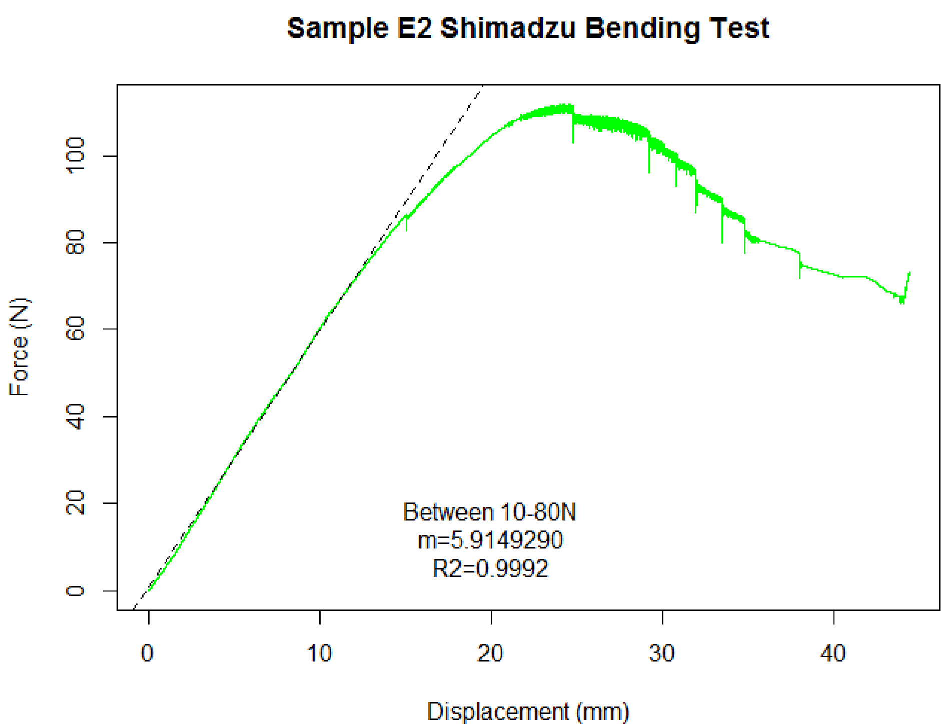

Sample C1 Shimadzu Bending Test
Force (N)
Displacement (mm)
0
5
10
15
20
25
30
40
Between 10-30N
m=3.061174
R2=0.9862

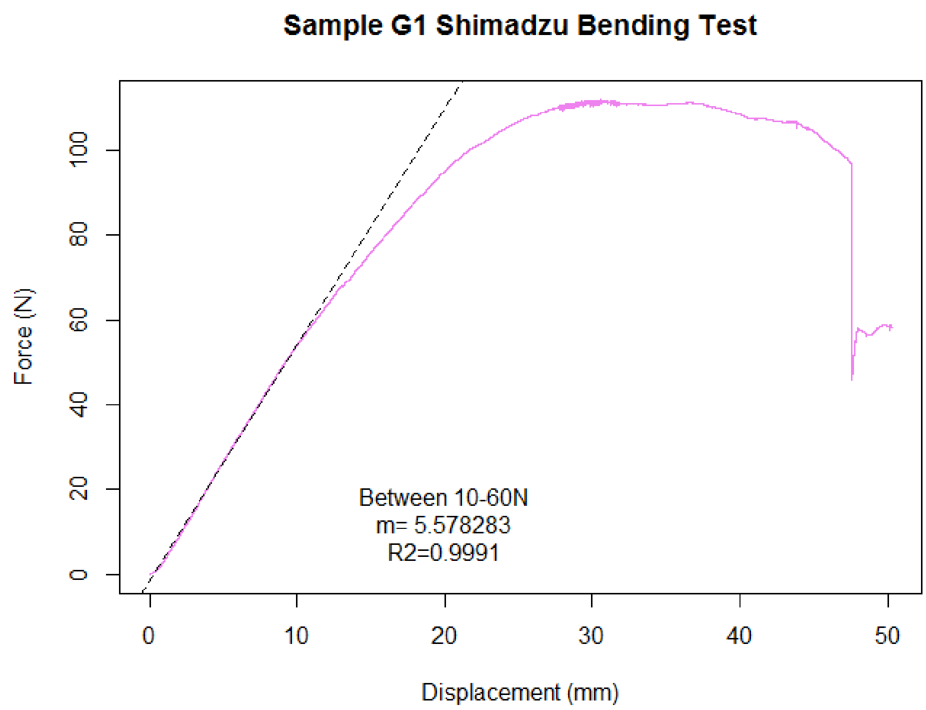


Horizontal Control Group: Samples B2, D1, E2, G1

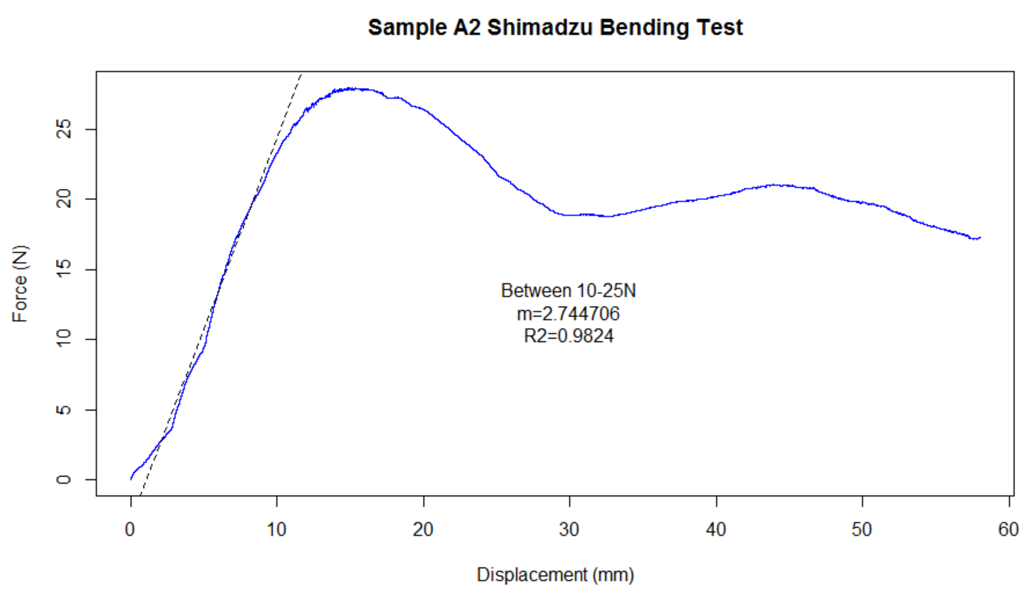


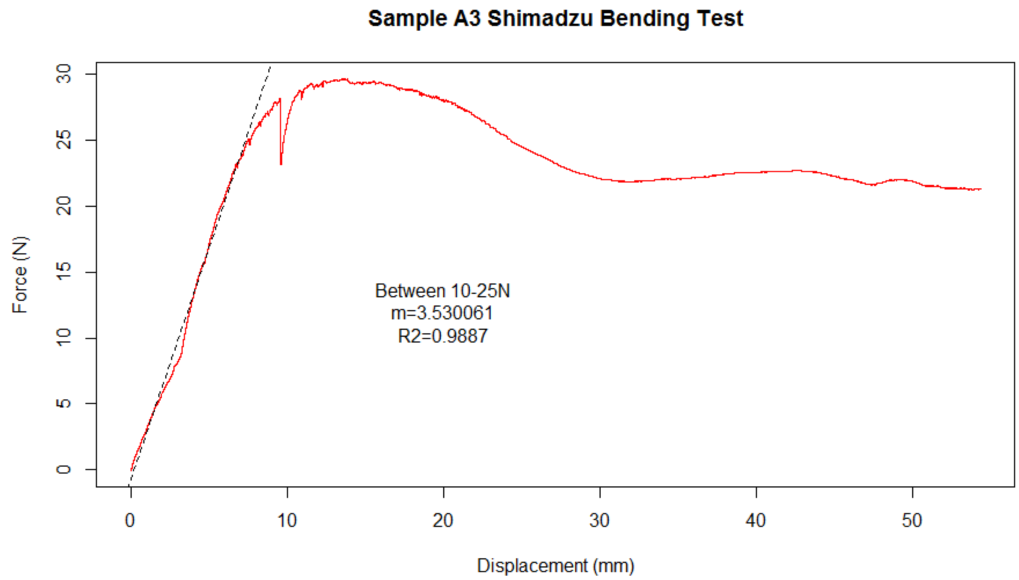

Sample D1 Shimadzu Bending Test
Force (N)
0
20
40
60
80
Between 10-50N
m=4.282181
R2=0.9983
0
10
20
30
40
50
Displacement (mm)

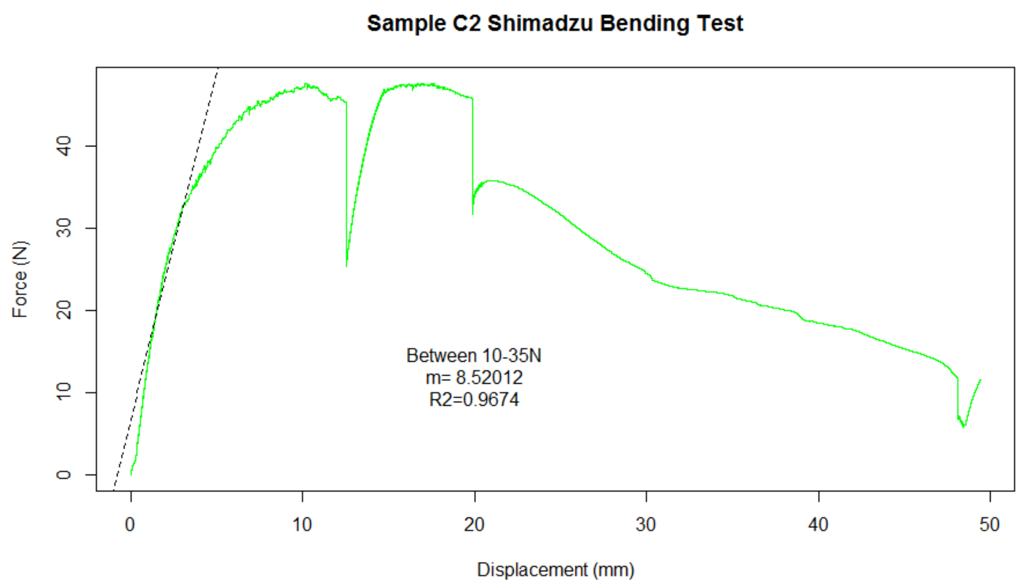

Sample E2 Shimadzu Bending Test
Force (N)
0
20
40
60
80
100
Between 10-80N
m=5.9149290
R2=0.9992
0
10
20
30
40
Displacement (mm)

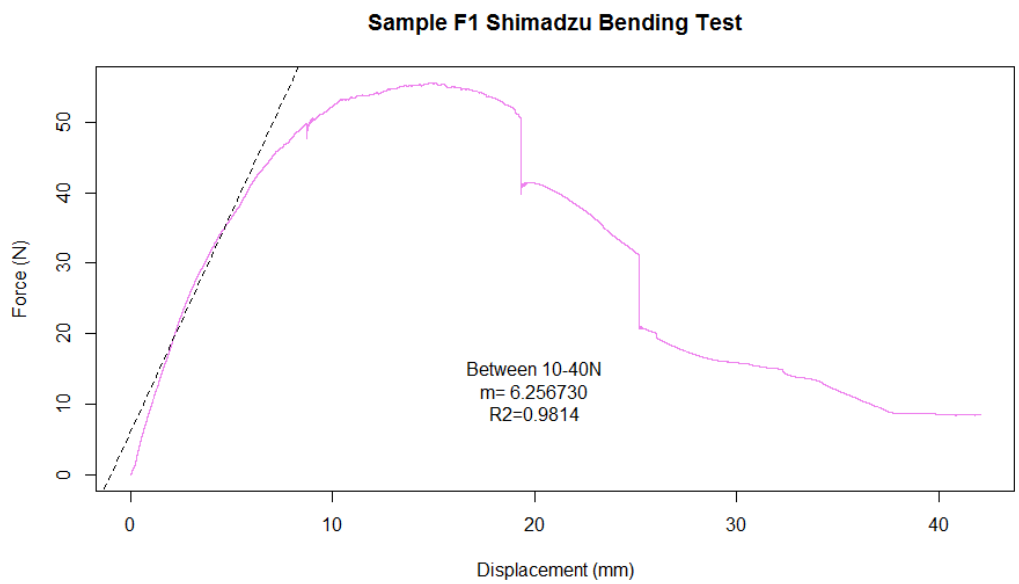


Vertical Submerged Group: Samples A2, A3, C2, F1

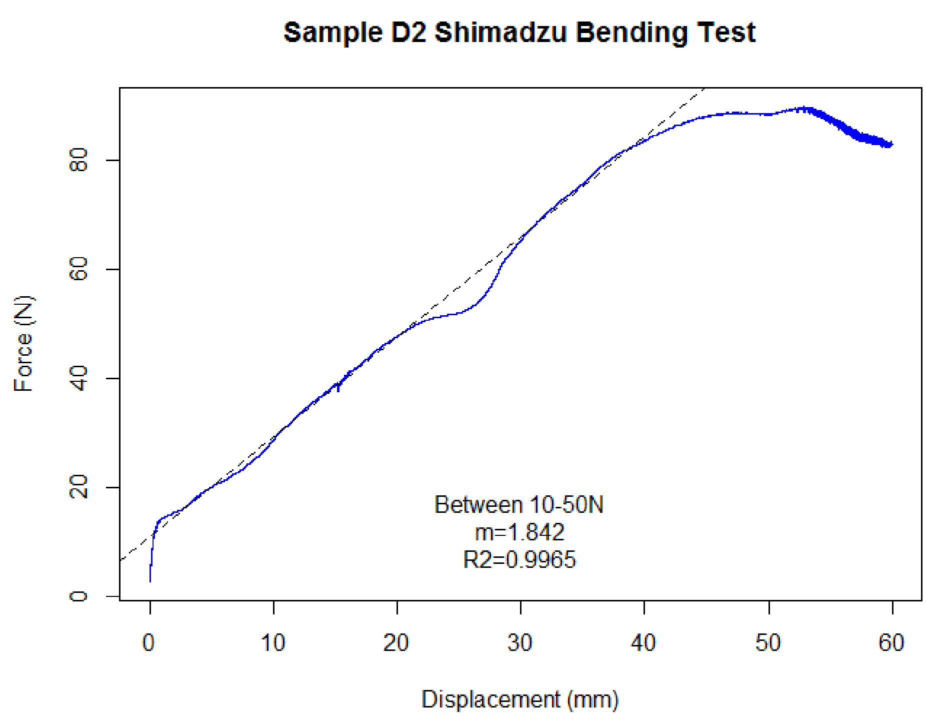


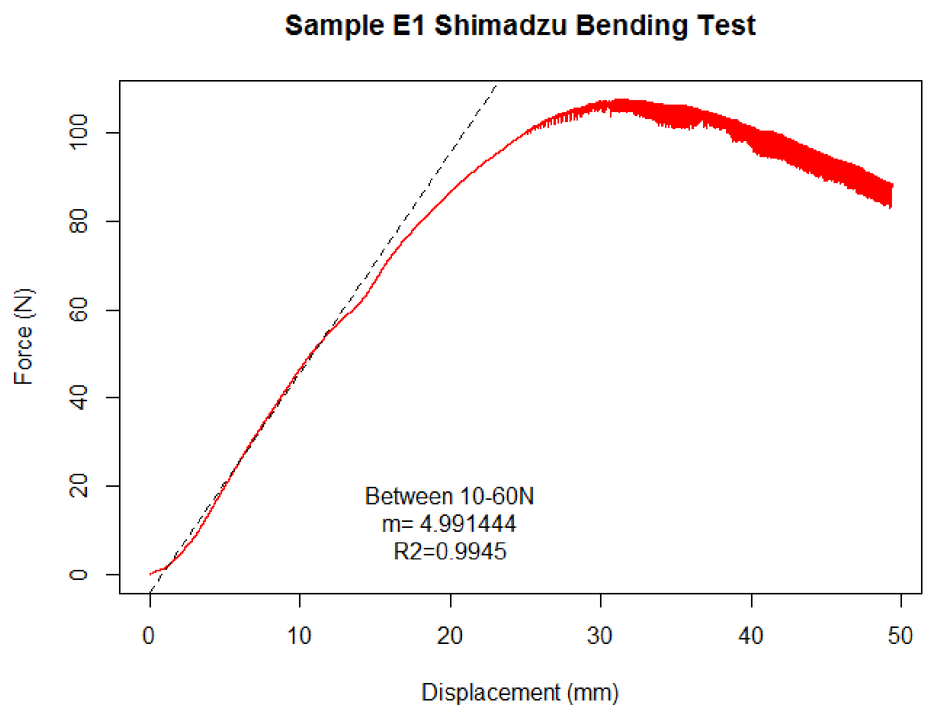

Sample A3 Shimadzu Bending Test
Force (N)
0
5
10
15
20
25
30
Displacement (mm)
0
10
20
30
40
50
Between 10-25N
m=3.530061
R2=0.9887

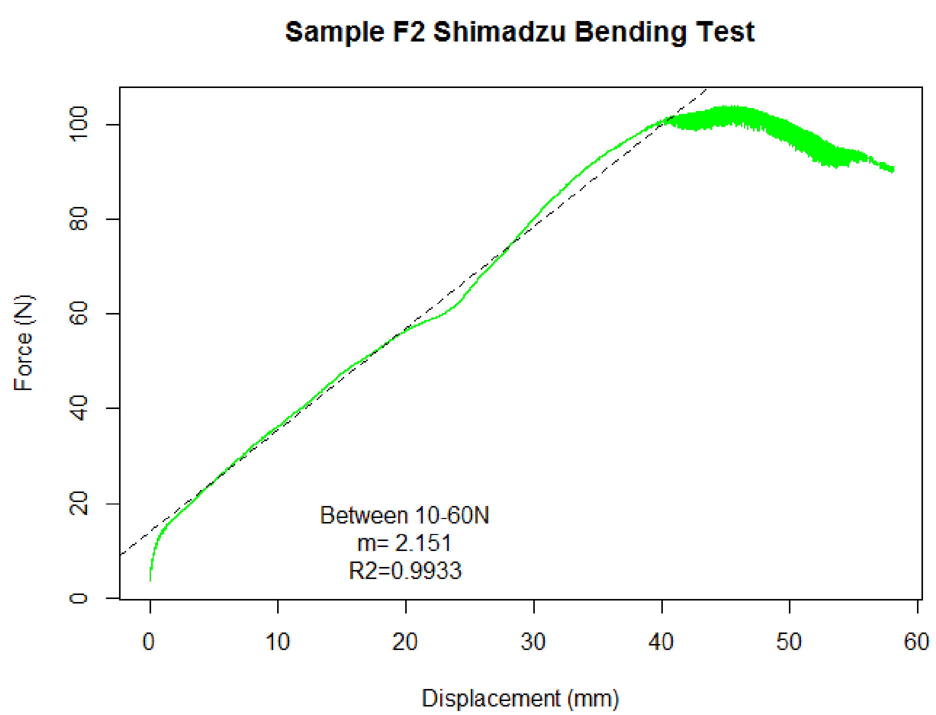

Sample C2 Shimadzu Bending Test
Force (N)
0
10
20
30
40
Displacement (mm)
0
10
20
30
40
50
Between 10-35N
m= 8.52012
R2=0.9674

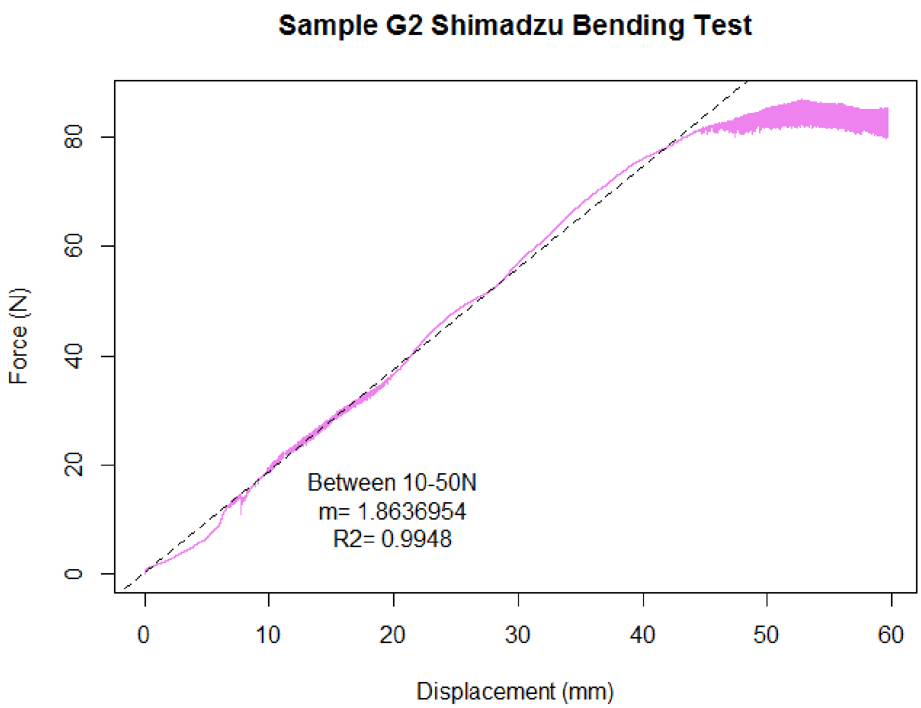


Horizontal Submerged Group: Samples D2, E1, F2, G2




Sample E1 Shimadzu Bending Test
Force (N)
0
20
40
60
80
100
0
10
20
30
40
50
Displacement (mm)
Between 10-60N
m= 4.991444
R2=0.9945


Sample F2 Shimadzu Bending Test
Force (N)
0
20
40
60
80
100
0
10
20
30
40
50
60
Displacement (mm)
Between 10-60N
m= 2.151
R2=0.9933


Sample G2 Shimadzu Bending Test
Force (N)
0
20
40
60
80
0
10
20
30
40
50
60
Displacement (mm)
Between 10-50N
m= 1.8636954
R2= 0.9948

Reinhardt CV

Biidaaban M. Reinhardt
720-810-4982 | biidaaban.reinhardt@gmail.com

EDUCATION

State University of New York College of Environmental Science and Forestry (SUNY ESF)
Syracuse, New York
Master of Science in Sustainable Construction, Expected Graduation August 2020
Thesis Title:
Wiigwaas: An Indigenous Traditional Knowledge Informed Study of Sustainable Roofing Materials
Keywords: Indigenous Housing, Traditional Ecological Knowledge, Natural Building Materials, Paper Birch Bark
GPA: 3.68 on a 4.0 scale

Northern Michigan University (NMU)
Marquette, Michigan
Bachelor of Science in Physics and Native American Studies, Cum Laude, December 2017
Physics, Senior Seminar Titles

> "Gashkaabika-igaade biisi: Bound State Particle (AKA Quantum Dots and how to use the variational principle)"
> "Silicon Quantum Dots: Deposition, Functionalization, Characterization, and Application"

Native American Studies, Theoretical Capstone

> "The Seventh Generation" Grant Project Proposal

Mathematics - Minor
GPA: 3.53 on a 4.0 scale

Gwinn High School
Gwinn, Michigan
Diploma received May 2013
National Honor Society Member
GPA: 3.83 on a 4.0 scale

PROFESSIONAL EXPERIENCE

SUNY ESF Office of Diversity, Equity, and Inclusion, Syracuse, NY
Diversity Fellow (August 2019- May 2020)

- Develop grant proposals and assisting in outreach and retention of underrepresented minorities and women in STEM

SUNY ESF Forest and Natural Resources Management Department, Syracuse, NY
Graduate Assistant (2018-2019)

- Assisted in course logistics and assignments for multiple courses in Sustainable Construction Management as a Teaching Assistant

NMU Center for Native American Studies, Marquette, MI
STEM Outreach Coordinator (2018)

- Assisted in outreach and compilation of commitments for the National Science Foundation INCLUDES ALLIANCE: Reimagine Indigenous Earth Education grant proposal

NMU Office of Diversity and Inclusion, Marquette, MI
Student Worker (2017)

- Planned and implemented multiple activities for diverse student populations including the Reimagine STEM programs, youth campus visits, and enrollment fairs
- Developed website for Office of Diversity and Inclusion and Reimagine STEM pages

NMU Center for Native American Studies, Marquette, MI
Reimagine STEM Summer Academy Mentor (2017)

- Assisted in implementation of two-week, culturally inclusive, residential academy for 47 high school students

Barbiere's Villa Capri Italian Restaurant, Marquette, MI
Server (2017)

- Aided customers in restaurant with any needs while thriving in fast-paced, multi-tasking, work environment

University of Massachusetts Amherst, Amherst, MA
Undergraduate Researcher (2016)

- Completed and presented 10-week research project involving mass spectrometry

Colorado School of Mines, Golden, CO
Undergraduate Researcher (2015)

- Completed and presented 10-week research project involving quantum dots

NMU Registrar's Office, Marquette, MI
Transcript Clerk (2013-2015)

- Oversaw the daily mailing of official transcripts requested by students
- Supported students and administrators with printing and mailing confidential documents

Great Lakes Indian Fish and Wildlife Commission, National Indian Youth Leadership Camp
Camp Counselor (2014)

- Organized and led small and large group cultural activities for middle and high school aged students for one week at Camp Nesbit in the Ottawa National Forest

RESEARCH EXPERIENCE

Department of Forest and Natural Resources Management, SUNY ESF, Syracuse, NY
August 2018-August 2020
Research Advisor: Dr. Paul Crovella
Thesis Committee: Dr. Robin Wall Kimmerer and Neil Patterson

- Designed and implemented interdisciplinary Master's thesis research using a mixed methods approach from autoethnography, Indigenous methodology and quantitative data collection
- Studied wiigwaas (paper birch bark) from a traditional ecological knowledge (TEK) lens to research the validity of using it as a contemporary sustainable roofing material for use on Anishinaabe tribal lands and reservations

McNair Scholars Program, NMU, Marquette, MI
December 2015-December 2017
Research Advisors: Dr. Sarah Mittlefehldt and Dr. Martin Reinhardt

- Planned and developed Summer 2017 research project with McNair Scholars Program staff and the Keweenaw Bay Indian Community (KBIC)
- Conducted literature review, a review of strategic plans, interviews of tribal representatives, and provided recommendations to KBIC to potentially overcome the barriers to renewable energy systems on tribal lands

Department of Chemistry, University of Massachusetts Amherst, Amherst, MA
May 2016-August 2016
Research Advisor: Dr. Richard Vachet and Ph.D. Candidate Kristen Sikora

- Research Experience for Undergraduates (REU) student in Collaborative Undergraduate Research in Energy program
- Analyzed and interpreted data regarding gold nanoparticles and various pure lipids
- Learned operating procedures of the Autoflex (MALDI-MS)

Department of Physics, Colorado School of Mines, Golden, CO
May 2015-August 2015
Research Advisor: Dr. Reuben Collins and Ph.D. Candidate Grant Klafehn

- REU student in Renewable Energy Material Research Science and Engineering Center
- Developed and implemented a functionalization and deposition process involving Silicon Quantum Dots and Silicon nanowires
- Instructed users on the operation of the Scanning Election Microscope

PUBLICATIONS

Dual Mass Spectrometric Tissue Imaging of Nanocarrier Distributions and Their Biochemical Effects
Kristen N. Sikora, Joseph M. Hardie, Laura J. Castellanos-García, Yuanchang Liu, Biidaaban M. Reinhardt, Michelle E. Farkas, Vincent M. Rotello, and Richard W. Vachet
Analytical Chemistry **Article ASAP**
DOI: 10.1021/acs.analchem.9b04398

PRESENTATIONS

Reinhardt, B. (November 16, 2019). *Indigenous Thinking: Learning from our ancestors for a sustainable future*. Oral Presentation. Central New York Youth Climate Summit, Keynote Speaker. Homer, NY.

Reinhardt, B. (October 11, 2019). *Anishinaabe Ojibwe Traditional Ecological Knowledge (TEK) Sourced Sustainable Construction Materials.* Oral Presentation. American Indian Science and Engineering Society 2019 National Conference, Graduate Research Session. Milwaukee, WI.

Reinhardt, B. (April 17, 2019). *Solar Decathlon Design Challenge*. Oral Presentation. 17th Annual New York State Green Building Conference, Green Solutions Track. Syracuse, NY.

Reinhardt, B. (December 4, 2017). *Seventh Generation Project*. Oral Presentation. Northern Michigan University, Center for Native American Studies Theoretical Capstone, Grant Proposal Presentation. Marquette, MI.

Reinhardt, B. (November 10, 2017). *Gashkaabika-igaade biisi: Bound State Particle (AKA Quantum Dots and how to use the variational principle).* Oral Presentation. Northern Michigan University, Physics Department Senior Seminar Presentation 2. Marquette, MI.

Reinhardt, B. (October 5, 2017). *Barriers to Developing Renewable Energy Systems within Tribal Communities: A Case Study of the Keweenaw Bay Indian Community*. Poster Presentation. National Indian Education Association 2017 National Convention, Poster Session. Orlando, FL.

Reinhardt, B. (September 27, 2017). *Silicon Quantum Dots: Deposition, Functionalization, Characterization, and Application*. Oral Presentation. Northern Michigan University, Physics Department Senior Seminar Presentation 1. Marquette, MI.

Reinhardt, B. (September 22, 2017). *Barriers to Developing Renewable Energy Systems within Tribal Communities: A Case Study of the Keweenaw Bay Indian Community*. Oral Presentation. American Indian Science and Engineering Society 2017 National Conference, Undergraduate Research Session. Denver, CO.

Reinhardt, B. (September 1, 2017). *Barriers to Developing Renewable Energy Systems within Tribal Communities: A Case Study of the Keweenaw Bay Indian Community*. Oral Presentation. Northern Michigan University, McNair Scholars Program Summer Research Presentations. Marquette, MI.

Reinhardt, B. (April 13, 2017). *Evaluating the Effect of Gold Nanoparticles on MALDI-MS Analysis of Biological Molecules*. Poster Presentation. Northern Michigan University, Celebration of Student Scholarship. Marquette, MI.

Reinhardt, B. (August 5, 2016). *Nanomaterials in Biological Systems: Improving Sensing of Gold Nanoparticles in Biological Samples using MALDI Mass Spectrometry*. Collaborative Poster Presentation. University of Massachusetts Amherst, Collaborative Undergraduate Research in Energy, Undergraduate Research Symposium. Amherst, MA.

Reinhardt, B. (November 27, 2015). *Functionalization of Silicon Quantum Dots and Deposition into Silicon Nanowire Arrays*. Poster Presentation. American Indian Science and Engineering Society 2015 National Conference, Undergraduate Poster Session. Phoenix, AZ.

Reinhardt, B. (July 31, 2015). *Functionalization of Silicon Quantum Dots and Deposition into Silicon Nanowire Arrays*. Poster Presentation. Colorado School of Mines, Renewable Energy Materials Research Science and Engineering Center, Undergraduate Research Symposium. Golden, CO.

LEADERSHIP EXPERIENCE

Syracuse Energy Efficient Design
Presentation Lead (October 2018-May 2019)

- Created and designed reports and presentations for the Mixed-use Multifamily division winners for the US DOE 2019 Solar Decathlon Design Challenge competition
- Wrote letters and a grant for fundraising to bring twelve members of team to Golden, Colorado to compete in international competition

Indigenous Women Working within the Sciences
Committee Member (2016-2018)

- Two-year grant program (Reimagine STEM) awarded to the Center for Native American Studies and Office of Diversity and Inclusion
- Funded by the National Science Foundation (NSF) Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) grant (#1649082)
- Acted as student coordinator and mentee input for the three activities in 2017; Summer Academy, Educators Institute, and Fall Summit

American Indian Science and Engineering Society (AISES) Sequoyah Fellowship
Member (October 2015-present)

- Lifetime membership in AISES
- Sponsored by Marcellus Proctor, Assistant Division Chief at NASA/GSFC

NMU AISES Student Chapter
President (October 2014-December 2017)

- Planned and obtained travel funds for members to attend two National Conferences
- Planned community events for organization
- Lead organizer for 2017 March for Science Marquette, MI satellite march
- Designed multiple posters, flyers and other promotional material for events

NMU Native American Student Association
Co-President (September 2016-December 2017)
Volunteer Committee Head (September 2013-April 2016)

- Planned and implemented cultural events such as the Learning to Walk Together Pow-wow, Indigenous Peoples' Day events, and the First Nations Food Taster
- Designed multiple posters, flyers and other promotional material for events
- Worked with NMU departments and local tribes for funding, promotion, and support

NMU Physics Club
Member (September 2014-December 2017)

- Provided physics demonstrations to elementary-aged students
- Volunteered for multiple outreach events related to science communication such as Science Olympiad, Kaleidoscope, and Spooky Science Night

NMU Mortar Board Honor Society–Telion Chapter
Membership Chair (March 2016-April 2017)

- Worked closely with Mortar Board President to set standards of eligibility for membership admission
- Planned and implemented new membership selection process including the timeline, number of new members, tapping, initiation, and transitions
- Wrote official membership report of selected candidates with the President to be sent to the National Office

HONORS AND AWARDS

SUNY ESF Diversity Fellowship
Awarded August 2019-May 2020

SUNY ESF Graduate Teaching Assistantship
Awarded August 2018-July 2019

Cum Laude
NMU Institutional Honors
Awarded upon graduation, December 2017

NMU Dean's List
Awarded Fall 2013, Winter 2014, Fall 2014, Fall 2017

NMU Excellence Award
Awarded for academic achievement up to 8 consecutive semesters, Fall 2013-Winter 2017

AISES National Conference Travel Scholarship
Awarded travel scholarship to attend AISES 2016 National Conference in Minneapolis, MN

NMU Honors Program, Lower Division
Completed Fall 2015

AISES Lighting the Pathway to Faculty Careers for Natives in STEM Program
Accepted into Cohort 1 Mentorship program in Fall 2014

AISES A.T. Anderson Memorial Scholarship
Awarded scholarship two consecutive years, 2014, 2015

Society of American Indian Government Employees (SAIGE) Travel Scholarship
Awarded travel scholarship to attend SAIGE 2014 National Conference in Albuquerque, NM