Exploring the potential of strong wool base biomaterials to produce regionally sustainable bio-composite materials in Aotearoa for the built environment

Exploring the potential of strong wool base biomaterials to produce regionally sustainable bio-composite materials in Aotearoa for the built environment

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Attestation of Authorship:

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning

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Abstract:

This research investigated the potential of strong wool in a bio-composite building material for architectural use. Considering the historical significance of strong wool in New Zealand and its unique qualities, I chose to make this material a key part of the project. My goal was to contribute to the reduction of the negative impact the construction industry has on the environment. Various biomaterials were combined and tested to develop a final 'recipe' for a locally sourced, low-tech bio-brick.

Through experimentation and multiple iterations, I developed a biomaterial composite containing strong wool, seaweed, recycled clay and cornstarch. This was the most promising composite and the resulting bio-brick was lightweight and had notable compressive and tensile strength. A key aspect of my research was to ensure that any composite I developed could be fabricated using low-tech methods. Therefore, I underwent a trial-and-error process to create a 'fool-proof' recipe for the bio-brick, which does not require precise measurement and can be made on-site.

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Chapter One: Introduction

Background and context:

New Zealand's economy has always been reliant on exports. In the primary industries sector, strong wool was a leading export from the 1850's to 1970. Following this, the value of strong wool declined rapidly. This was largely due to the creation of synthetic fibres, which were cheaper and faster to produce. As synthetic fibres gained popularity in the construction industry, carbon emissions rose(Abedin Khan et al., 2024). Currently, the construction industry accounts for the largest share of greenhouse gas (GHG) emissions, representing 37% (Li et al., 2025). A large proportion of these emissions comes from the ongoing production of materials (Li et al., 2025). My research aims to contribute positively to the environment within the material construction space.

Figure 1: Emissions of greenhouse gases in the manufacturing sector (Ganapati et al., 2020)

Local biomaterials have two major benefits: they are inherently more sustainable because they biodegrade, their production often emits lower levels of greenhouse gases than that of traditional building materials, and, owing to the local fabrication chain, transport-related emissions are lower.

Strong wool has many beneficial properties. This fibre is naturally flame-resistant, offers excellent moisture control, is biodegradable and provides strong thermal insulation and acoustic performance (Zhou et al., 2025). This suggests that strong wool could be incorporated into a composite material. The successful utilisation of New Zealand's strong wool could also restore some value to the once-loved fibre.

Given the construction industry’s heavy reliance on carbon-intensive materials, there is an urgent need to reduce the embodied carbon of materials. We need to reconsider how we design and engage with materials. This study aims to advance the current understanding of how biomaterials can potentially be used in architecture.

By reimagining strong wool, I created a composite biomaterial that could reduce carbon emissions in the construction industry and thereby mitigate environmental harm.

Issues and questions:

The context of this study is to provide a deeper understanding of what biomaterials are and how they can be used to create locally produced products. Biomaterials, such as strong wool, have been underestimated to date. However, my project intends to bring light to the possible ways in which biomaterials can interact and create new composite materials suitable for construction. An indirect benefit of the use of biomaterials may be an increase in value of these products which would contribute positively to the local economy.

A key issue in the construction industry is the ongoing development of materials and the abundance of synthetic materials. These materials most often end up in landfills, where they cannot biodegrade. By focusing on biomaterials that are available locally, we could reduce waste and carbon emissions as well as improve resilience in the systems surrounding construction. Move the need to import materials and rely on other systems. The use of local biomaterials could also help foster a deeper connection to the local ecosystem.

Research questions:

The project set out to address the following questions:

1. How can we use strong wool along with other locally sourced biomaterials to develop a composite material suitable for building purposes?
2. How could the use of biomaterials change the ways we construct and manufacture locally?
3. What are the key principles for biomaterials to be successful?

Aims and Objectives

The project aims to:

- Investigate the material properties and architectural potential of strong wool as a bio-based building material.
- Develop a strong wool composite that can be produced using low-tech, accessible fabrication methods.
- Contribute to sustainable and regenerative design practices that support both users and local ecosystems.

Objectives

This project seeks to deepen our understanding of the physical, structural, and environmental properties of strong wool and to subsequently evaluate its viability as a building material. It focuses on developing a composite system that can be fabricated in low-tech environments, increasing accessibility and practical application across diverse contexts. By prioritising biodegradable and locally sourced materials, this research aims to support design approaches that minimise harm to the environment and support local resilience.

Limitations:

Several limitations affected the scope of this study. The choice of a low-tech approach to the development and testing of composite biomaterials meant that accurate measurements and key datapoints were unable to be obtained. In part, this was due to limited facilities for testing and poor interfaculty coordination.

Time constraints on material development forced me to work with only a few biomaterials. There were 20 materials initially selected that could show promises for suitable building. Therefore, the key materials were to be chosen prior to any composite creation or testing, which meant they had to perform across many different categories. Not just one area.

If time and resources had permitted, I believe I could have attained a better understanding of all 20 materials, which would have informed the biomaterials for the composite and consequently the ingredients of the bio-brick.

Contribution:

This research contributes to sustainable construction by exploring the development and application of strong wool-based bio-composite materials for the building sector. It advances biomaterial experimentation, low-tech building, and accessible construction practices, with a particular focus on bio-based bricks.

By investigating wool as a primary bio-based resource, the study repositions wool beyond insulation, examining how it can combine with other biomaterials to create a composite with the structure and strength that an otherwise soft material lacks. This approach addresses environmental concerns regarding material sourcing, waste reduction and renewability, while also highlighting the underutilised potential of wool.

Secondly, this research contributes methodologically through prototyping and low-tech testing of bio-based composites. Rather than prioritising highly technical or industrial testing processes, this study adopts an exploratory, iterative approach that emphasises material behaviour, constructability and practical usability. The prototypes developed in this research serve as proof of concept, suggesting directions for future research and development rather than presenting finalised building products.

Finally, this research holds the potential to contribute to the community by proposing strategies for non-expert construction methods using bio-based bricks. By prioritising simplicity, accessibility, and low-tech assembly, the study challenges conventional construction practices that rely heavily on specialised labour and complex technologies, thereby making them more accessible to community-led and small-scale projects. In doing so, this research broadens the potential application of sustainable biomaterials beyond professionalised building environments and supports more inclusive approaches to construction.

Overall, this biomaterial-led, exploratory research focuses on localism, low-tech construction and sustainable material development. Further research will be required into the technical data of these materials however, this represents a step towards more sustainable construction methods.

Chapter Two: Methodology and Theoretical Framework

Materials play a vital role in any architectural project. The materials chosen for a project ultimately shape the narrative of a space visually, tactually, functionally and ethically. By focusing on the use of biomaterials, my research challenges the status quo of building materials and intents to shift perspectives on these materials.

To guide this material research and ensure the most meaningful outcomes, I have adopted a hands-on, experimental methodology. This approach is informed by Elvin Karana's framework of Material Driven Design (MDD) (Karana et al., 2015). MDD emphasises the importance of understanding a material's technical and experiential properties before determining the scope of a material's application. By following the four stages of MDD, I gained a deeper understanding of the full potential of each material's characteristics and properties, which informed the application. The four stages of MDD are:

1. Understanding the Material
2. Creating a Material Experience Vision
3. Manifesting Material Experience Patterns
4. Designing Material/Product Concepts

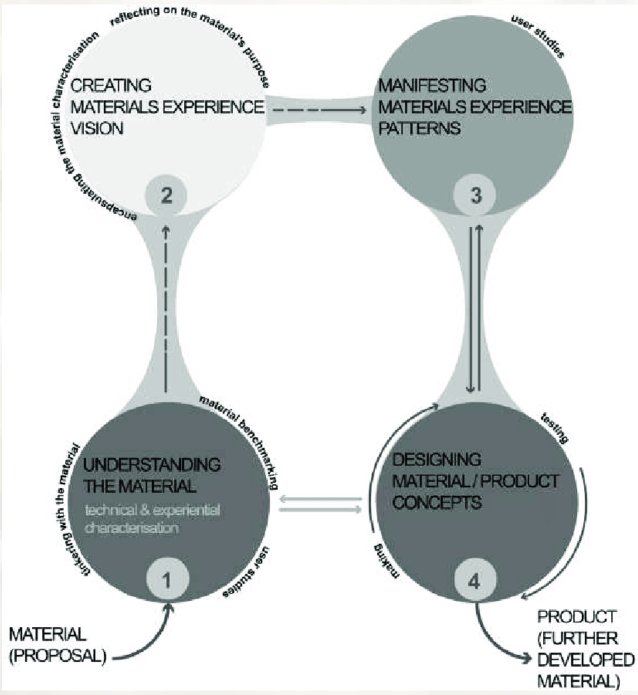


Figure 2: Material Driven Design (MDD) method (Karana et al., 2015)

Stage One: Understanding the Material

This stage involves engaging deeply with the chosen material to uncover its characteristics and behaviours. Through tactile experimentation and testing with different ratios, this stage helps reveal how a material might perform, respond, and interact with the local environment. Only by fully understanding a material in isolation can we begin to explore its true potential before it is combined with other materials and exposed to various environments.

This approach was used in the project to initially investigate a variety of materials and binders. Insights were gained into each material's properties and characteristics and the selection of a single binding agent was made. This stage of MDD enabled observation and exploration of how each material performed both independently and under the influence of the binder.

Stage Two: Creating a Material Experience Vision

In stage two, MDD involves the creation of a vision of how a material might be perceived or experienced within its potential application. This includes examining how the material interacts with other materials and whether it fulfils its intended function. If the material does not meet its intended purpose, the user should revisit stage one to reassess its suitability or consider alternative materials.

Stage two of my project involved combining two or more materials. Building on the deeper understanding of each material gained through individual testing, this stage allowed for further experimentation and exploration of how the selected materials interacted and performed when used together. This process helped me develop a material adapted to its intended purpose.

Stage Three: Manifesting Material Experience Patterns

At this stage, the material's performance is formally analysed and documented. The focus shifts to how the material communicates its story and whether this aligns with the intended narrative and sensory experience. The designer formulates a vision statement that articulates the material's role and identifies whether further iteration is needed to refine its expression or functionality.

In my research, stage three was slightly adjusted to align with the context. Rather than undertaking technical analysis of the material, the focus shifted towards refining the material recipe through low-tech testing methods. This process resulted in an improved material, which was then advanced to the final stage of MDD.

Stage Four: Designing Material/Product Concepts

Once a material meets the desired outcome, it can then be developed into a product or architectural concept. It is common to work with multiple materials at this stage, testing their integration into manufacturing processes and their ability to achieve the desired outcome. This final stage often involves further refinement, which may lead to the discovery of new material combinations that may require returning to earlier stages of MDD for deeper exploration of their performance.

Stage four involved further refinement of the material recipe, with the primary goal of keeping the manufacturing process as low-tech as possible. Multiple tests were conducted to develop a recipe that could be followed with minimal to no prior knowledge of composite development. This stage also included experiments for forming and application, leading to the development of an interlocking mould system, designed to support and enhance a low-tech building approach.

MDD summary:

By slightly refining MDD, we can better align this experiment with the vision of a biomaterial. By being informed by the literature review and precedents. We then move on to how the materials are collected and processed. Once these two areas have been completed. Then the four-step process starts with understanding the material as an individual before interacting as a composite.

MDD encourages a cyclical, non-linear design process that discourages the designer from reaching premature conclusions about materials or their potential purpose. Instead, MDD creates a space for exploration, iteration, and reflection. Throughout this process, designers can better understand both the technical and experiential aspects of a material before committing to their use. This minimises the risk of a suboptimal outcomes and improves the sustainability of material design.

By embracing this methodology, materials can be developed that not only perform effectively but also connect with both human and non-human entities. This approach facilitates a deeper engagement with the material and supports regenerative, responsive and meaningful design.

I followed the four stages of MDD in my research and adapted stage three to suit my design process better. Stage three of MDD requires an understanding of how the material performs and is perceived. I used this stage to deepen my understanding of the material and to examine how a low-tech approach to building can be implemented in the context of a composite biomaterial.

My version of Material Driven Design:

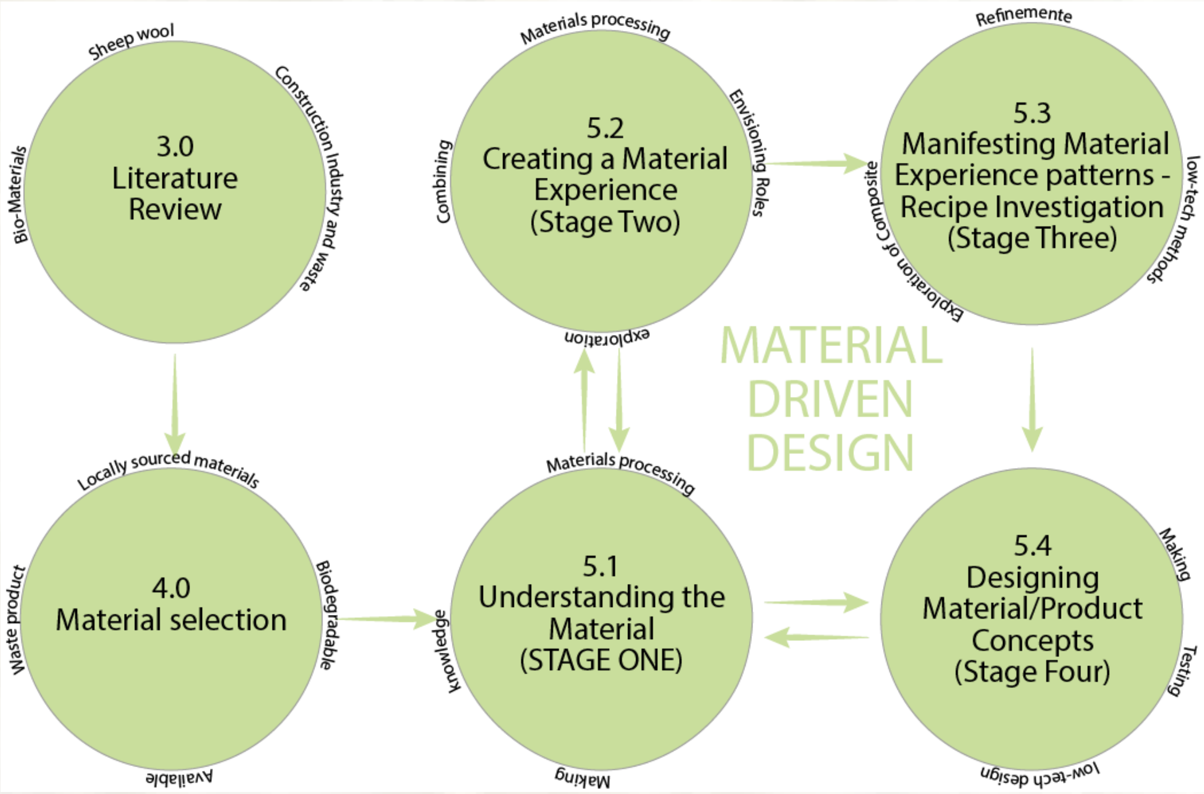


Figure 3: My version of Material Driven design

Theoretical Framework: Entanglement and New Materialism

New Materialism and the concept of entanglement have formed the framework guiding my research. Donna Haraway (2016) and Karen Barad (2007, 2012) question the relationship between human and non-human worlds – including the material world. Entanglement is the idea that all things are interconnected and interdependent, rather than separate entities with fixed boundaries. Entanglement outlines that all entities, human, non-human, environmental and technological, are connected. This implies that if one area changes, it will have an impact on other areas.

Emerging in the 1990s, new materialism is an interdisciplinary framework that bridges philosophy, cultural theory, social sciences, and natural sciences. The main concept is that human and non-human entities do not pre-exist but are entangled through their relationships with one another (Puzio, 2024). This challenges our view of materials as it portrays that a materials' properties are not inherent but rather, they emerge through interaction with other entities.

As humans, we tend to categorise and contain ideas, effectively putting them into metaphorical boxes. Barad challenges this notion by introducing the concept of intra-action, which emphasises that entities do not possess pre-existing characteristics rather, their identities and properties are formed through ongoing entanglement with other entities. Barad suggests that human and non-human bodies “are not objects with inherent boundaries and properties; they are material–discursive phenomena” (Puzio, 2025) which acquire their boundaries and properties through intra-action (Puzio, 2025).

We as humans, often place ourselves at the centre of the world. However, the concept of entanglement states that we are simply interacting and reconfiguring the world to our preferred state for example, creating roads to enable transport.

Barad (Puzio, 2025) shows that, through specific agential intra-actions, humans and materials alike do not have fixed characteristics or boundaries; rather, these are developed through ongoing intra-actions with one another (Puzio, 2025). Humans are not separate from the world instead, they are in constant interaction with it, continually reconfiguring and reshaping their relationships with different entities (Puzio, 2025)

Based on the concept of entanglement and theories of new materialism, it is apparent that humans are in constant relationship with other entities including ecosystems within the natural environment. However, the way in which humans interact can be modified. By developing bio-based materials, the interaction between humans and the environment can become more positive for both parties, moving toward a mutually beneficial relationship rather than a parasitic one. For example, by working with the local environment, we may discover more environmentally friendly solutions to the current issues we face in construction.

Chapter 3 Literature review:

Reviving Strong Wool: A Sustainable Solution for New Zealand's Construction Industry

Globally, the construction and demolition of materials contribute significantly to carbon emissions, with the building industry accounting for approximately 40% of total global emissions (Too et al., 2022). These emissions have detrimental effects on the natural environment affecting forests, oceans, waterways, green spaces and all living things, including humans. To address this significant problem, we must rethink conventional construction materials (Chen et al., 2024). Many synthetic materials are selected for their affordability, speed, and ease of maintenance, yet they also generate negative environmental impacts and pose challenges for end-of-life sustainability. The widespread use of synthetic fibres has led to the rapid production of materials but consequently, increased the amount of waste and emissions produced by the construction industry (Przybek, 2025).

As our climate and economy evolve rapidly, the question arises: how can we better support our ecosystem and local industries? The development of low-tech biomaterials offers a compelling solution. Typically sourced locally, biomaterials often undergo low-impact processing, possess a zero to minimal carbon footprint, and are biodegradable. The use of biomaterials in the building industry facilitates a shift towards a cradle-to-cradle approach. In some cases, these materials may even contribute to ecological regeneration.

Since colonisation, New Zealand has been supported by a range of primary export industries to drive its economy. In the 1950's, New Zealand's leading export was wool (Stringleman & Peden, 2009) which generated over 30% of New Zealand's export income (Statistics New Zealand, 2012). However, the rise of synthetic fibres reduced the demand for New Zealand wool (Wool Industry Project Action Group, 2020) Furthermore, in 2023 - wool accounted for just 0.567% of New Zealand's total exports. (Nicol & Saunders, 2025).

The use of wool in low-tech biomaterials could enhance the value of New Zealand wool while reducing reliance on carbon-intensive materials in the building industry. Simultaneously, utilising a local material improves sustainability and enhances resilience in the face of a changing climate.

By harnessing natural resources such as strong wool, we can begin to address the complex challenge of GHG emissions while revitalising the demand for strong wool. This strategy not only supports local agriculture but also aligns with efforts to create a more sustainable and resilient built environment.

Environmental burden of the construction industry

The construction industry is inherently wasteful. In 2021, it was estimated that the New Zealand construction industry contributed 347,000 tonnes of waste, of which 267,000 tonnes were expected to end up in landfill (Nelson et al., 2022). The principal materials comprising this waste were concrete, plasterboard, and timber (Nelson et al., 2022).

Synthetic fibres and plastics, used for purposes such as insulation, cladding, sealants and building wrap, also contribute to microplastic pollution in both landfills and marine environments (Periyasamy & Tehrani-Bagha, 2022).

Another major issue in the built environment is the demolition of homes, which generates substantial volumes of waste. An estimated 126,000 tonnes of waste was produced in New Zealand 2021 from the demolition of residential structures (Nelson et al., 2022). The significant amount of waste is due to multiple factors, such as widespread use of non-biodegradable materials and the difficulty of separating components during deconstruction (Tong et al., 2026).

EMISSIONS

The construction industry has a significant impact on global greenhouse gas (GHG) emissions, particularly through rising CO_2 outputs (Transition to a Low-Carbon Economy for New Zealand, 2016). This is a complex, multifaceted issue that we, as architects, must address. Currently, the construction sector accounts for approximately 40% of global carbon emissions (Too et al., 2022). A recent publication in Nature found that if emissions from all other industries' carbon outputs were reduced to zero, the construction industry would still use up carbon budgets and increase global warming by 1.5 degrees Celsius (Li et al., 2025). The global construction industry has doubled its carbon footprint over the past three decades and is projected to double again by 2050 (Li et al., 2025). The main sources of emissions in the industry are from cementitious materials, bricks and metals (Li et al., 2025). Transportation, machinery, and on-site activities account for approximately 37% of emissions, with the remainder from glass, plastics, and bio-based materials (Li et al., 2025).

BIOMATERIALS IN CONSTRUCTION

Biomaterials are organic substances derived from nature, encompassing matter, surfaces, or constructs that interact with biological systems (Pavlovic, 2015). They are increasingly being applied across a diverse range of industries, including medicine, fashion, packaging, agriculture and more recently, construction. Biomaterials offer a wide range of benefits as the global and New Zealand communities work to reduce emissions, with projections suggesting a potential 40% reduction by 2060. By developing and implementing biomaterials with lower environmental impact, we can reduce this figure by 45% (Zuiderveen et al., 2023), moving towards net zero emissions in New Zealand. The Royal Society of New Zealand had previously outlined a vision for achieving net-zero emissions by the end of the 21st century (*Transition to a Low-Carbon Economy for New Zealand*, 2016). To meet this goal, we must begin incorporating new design approaches and consciously selecting carbon-sensitive materials, specifically using carbon-neutral biomaterials that enhance local ecosystems and reduce long-term emissions.

Another factor that would contribute to lowering carbon emissions is reducing the need for heating and cooling residential spaces. Currently, heating and cooling homes account for an average of 32% of total energy consumption per home globally. (*Transition to a Low-Carbon Economy for New Zealand*, 2016). In New Zealand, however, heating and cooling homes account for 34% of total energy output (*Transition to a Low-Carbon Economy for New Zealand*, 2016). Certain biomaterials exhibit properties that enhance thermal regulation and therefore, could be used in construction to reduce the energy required to heat or cool homes. For example, clay naturally regulates temperature and humidity (Petcu et al., 2023) and strong wool improves the thermal performance of a home, which could reduce the energy required for heating (Hetimy et al., 2025).

In the construction sector, biomaterials are primarily used in interior fitouts, serving as insulation, acoustic panels, and furniture components (Dr Emina Kristina Petrović et al., 2025). While these applications are valuable, they address only a fraction of the industry's carbon-intensive processes. Significant CO_2 emissions stem from the production of structural materials such as exterior cladding, plasterboard, and bricks (IEA, 2023; UNEP GlobalABC, 2022).

The benefits of biomaterials are twofold. Using biomaterials in construction reduces carbon emissions meanwhile regenerating the surrounding ecosystem as the material biodegrades and returns to the soil. A compelling example is Redhouse Studio Architecture's creation of the world's first self-supporting mycelium structure (Marc Violo, 2024). These bricks were made from waste generated by local mushroom farming and using biomass from the invasive Namibian bush, which must be cleared to combat desertification (Marc Violo, 2024). This approach not only produced a functional structure but also improved the local ecosystem by removing -1 kg of CO_2 for every kilogram of material produced(Marc Violo, 2024). In comparison, traditional brick emits +0.5 kg of CO_2 per kilogram manufactured (Wang & Abuel-Naga, 2025a)

Biomaterials are beginning to outperform conventional materials (Zuiderveen et al., 2023) across various sectors. Inrcrmycelium leather mimics the look and feel of traditional leather. Rice-based clay offers an alternative to cement for tile coatings (*5 Examples of Innovative Biomaterials*, n.d.). Agar Agar is used to produce bioplastics that surpass traditional plastics (Henn et al., 2021). Lignin, a bio-based compound, shows promise in sustainably treating timber, although it remains in the testing stage before commercial viability (Henn et al., 2021).

Despite advances in biomaterials, challenges remain including the lack of natural waterproofing options. Beeswax, pine resin, and carnauba wax provide some water resistance but fall short of synthetic alternatives.

While biomaterials are increasingly integrated into many architectural applications, their potential in structural components remains underexplored (Henn et al., 2021). Figure 4 shows that biomaterials are scarcely used and if so, only for internal applications. This is due to many factors such as the rigorous standards required for building materials which requires waterproofing properties which biomaterials often lack. However, the development of biomaterials is accelerating globally, and there is growing interest in New Zealand in this area, by hands-on exhibitions and experiential learning.

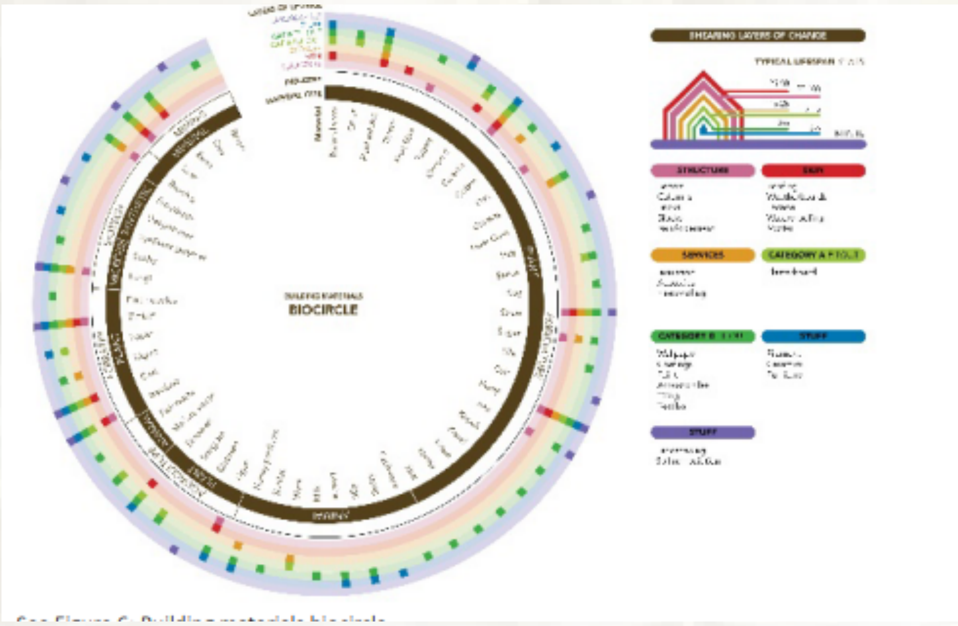


Figure 4: Material BioCircle – showing what materials are used where in a construction (Dr Emina Kristina Petrović et al., 2025)

Exploring the potential of Strong wool as a Biomaterial

Strong wool has long been a vital part of New Zealand's identity and economy; however, its value and use have significantly declined since the 1990s.

In 1966, the wool market collapsed with prices dropping 40% overnight (Bartlett, 2021). This sharp decline was largely due to the emergence of synthetic fibres.

These new materials, although lacking some of wool's properties, were easier to produce and significantly cheaper. As a result, wool became less desirable, and New Zealand farmers suffered the consequences.

What is strong wool?

Strong wool accounts for approximately 80% of New Zealand's wool production, with merino wool making up the remainder (McIsaac, 2024). Strong wool is a thicker fibre, traditionally used in carpets, rugs, and blankets, whereas merino is highly valued and used for garments. Today, strong wool is valued at just NZD $3 per kilogram. (Bartlett, 2021) compared to its former peak of NZD $55kg (Wisewool, n.d.). At the current market price, this value does not even cover the cost of shearing, leaving farmers at a financial loss every time a sheep is shorn. The wool is dumped or burnt. (Camilli et al., 2025a) which negatively impacts the environment; otherwise, wool can be buried. While burying wool is not harmful to the environment, it is a waste of a potentially useful resource. (Camilli et al., 2025b)In 2024, New Zealand generated NZD $54.3 billion in revenue, yet wool and carpet exports accounted for only 9% of export value (NZD $4.8 million). This is a huge shift from when wool exports dominated the market from the mid-1880s to the late 1980s (Stringleman & Peden, 2009)

Properties of Wool

Wool is regarded as a super fibre due to its inherent qualities. Its complex protein structure enables temperature regulation, moisture control, odour resistance and long-lasting durability. (Zhou et al., 2025). Strong wool is naturally water-resistant, making it suitable for exterior building applications. Strong wool also has non-melting and flame-resistant properties, increasing the case for a composite material. (International Wool & Textile Organisation, n.d.).

These combined properties confer strong wool with super fibre performance and significant potential for sustainable construction. For example, strong wool has the potential to increase thermal resistance (R-value), thereby significantly reducing energy consumption in the housing sector.

Unlike synthetic fibres, strong wool is biodegradable and carbon-positive (Hodgson et al., 2023a). This means that when it enters waterways or local ecosystems through the disposal or destruction of materials, the strong wool naturally breaks down and enhances the environment in which it decomposes. Strong wool has been successfully used in filtration systems to clean oil spills and riverways (Sun et al., 2022) and studies have demonstrated its ability to absorb contaminants and even filter dyes from water (Sun et al., 2022). Furthermore, when wool is integrated into the land, it contributes positively to the ecosystem by creating healthier, more diverse soil. As a natural product, wool inherently supports a cradle-to-cradle lifecycle. When it biodegrades, returning to the earth, enhancing the growth of grass (Hodgson et al., 2023b) and begins to grow the next flock for the next biomaterial.

Currently, in architecture, strong wool is used for insulation and acoustic panelling; for example, Wool Insulation NZ offers 100% strong wool insulation. (Richard, n.d.). Along with floc ding acoustic panelling (*Why Specific Floc? | Wool Acoustic Panels | Floc*, n.d.). Yet many of these applications have to compete with cheaper synthetic alternatives. Given wool's properties, its use should not be limited to insulation. It holds promise for structural applications, interior and exterior finishes, wall panels, and more. When combined with other biomaterials, wool can form high-performance bio-composites that enhance its natural properties.

If we begin to replace some of the synthetic fibres used in construction with biomaterials such as wool, we can expect a reduction in pollution in both landfills and marine environments. (Hodgson et al., 2023b) and also create new market opportunities, thereby increasing wool's value for farmers and benefitting the New Zealand economy.

Exploring the Architectural Potential of Strong Wool

Wool exhibits multiple properties that are useful for various architectural applications. The outer cuticle acts as a waxy, scale-like barrier, providing water resistance. Beneath the outer cuticle is the cortex, which makes up 90% of the fibre and provides sound absorption and thermal regulation. Within the cortex, macro- and microfibrils reinforce the fibre, like steel rods in concrete, providing strength and flexibility. The matrix attracts moisture, allowing wool to absorb up to 30% of its weight in water without feeling wet. Finally, the keratin helix prevents overstretching and breakage. Together, these layers make up this amazing super fibre.

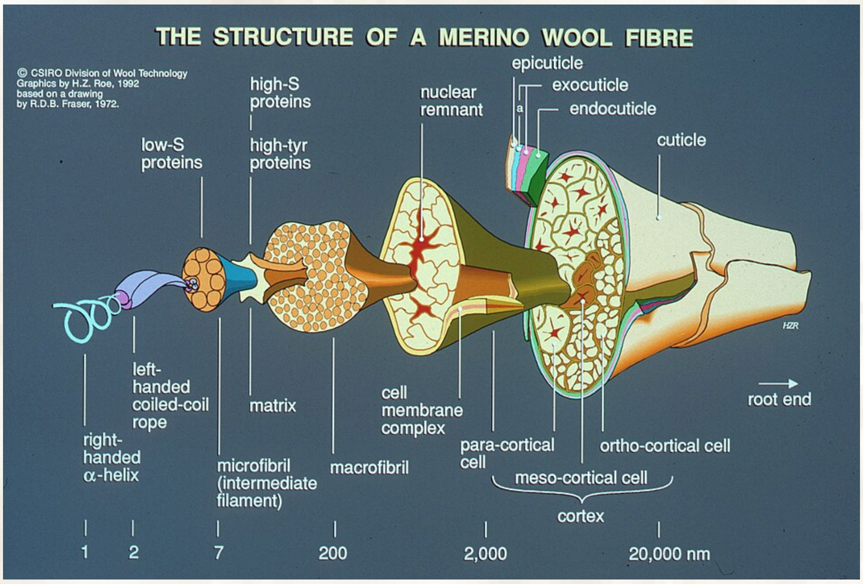


Figure 5: The structure of Wool Fibre shows us the complexity of it structure and how diverse is it for construction (File:CSIRO ScienceImage 2489 Diagram of Wool Fibre Structure.Jpg - Wikimedia Commons, n.d.) Showcase the different layers of Strong wool.

One particularly compelling synergy is between wool and timber. Wool has been shown to draw moisture from surrounding materials, thereby reducing the moisture content of timber and extending its service life. (Matua, 2019). While some studies suggest that sheep farming contributes to environmental degradation, the full life cycle of wool production tells a different story. (Matua, 2019). For every kilogram of strong wool, approximately 1.8 kilograms of CO_2 are stored within its fibres. When incorporated into a biomaterial, this carbon is locked in the structure. At the end of its life, the biomaterial will gradually release CO_2 during biodegradation. This slow release allows natural ecosystems to absorb and utilise the CO_2. Hence, biomaterials function as temporary carbon sinks and support regenerative cycles through biodegradable construction materials.

Reflection

The negative environmental impacts of the building industry have been largely driven by high waste generation and CO_2 emissions, as well as increased use of synthetic fibres. Addressing this issue by utilising sustainable and regenerative materials, such as strong wool, offers a promising path forward to grow local economies, which can provide more affordable housing and building alternatives, and regulate local environmental and ecosystem conditions.

This research aimed to address the gap in locally sourced, low-tech, and low-carbon composite materials. It focused on moving biomaterials beyond their predominant use in interior fit-outs and exploring their potential for structural applications as we explore the potential structural use. The idea behind a bio brick will be investigated. Suppose the traditional red brick produces substantial carbon emissions. In this case, an alternative material could be developed. This will help to combat the significant waste in the construction industry.

The project begins to explore the unique characteristics and material capabilities of strong wool and to demonstrate its potential in architectural applications. An underlying driver for my work was the desire to develop a bio-brick using materials sourced directly from New Zealand's local ecosystem. Through this project, I intended to contribute to the limited research on biomaterials for structural applications. In my opinion, it is no longer sufficient to aim for net-zero products. Instead, we must work to enhance and rejuvenate the environments in which we develop and build.

The concept of 'localism', which is the move of power away from bigger organisations and brings a focus back to local councils, communities and local sources. This has inspired me to seek 100% local materials that I can gather or source within a 100km radius of my home. There is no defined radius for localism. But I have just set the task of 100km for this research. This approach was not only more efficient for me, but could also be applied in other circumstances. For example, locally sourced materials would help build resilience amid global disruptions, material shortages, and extreme weather events that have been experienced around the world in recent years.

New Zealand has a unique opportunity to lead the innovation in this space. By reducing reliance on carbon-intensive materials, sourcing locally, and enhancing the value of strong wool, we could help regenerate New Zealand's ecosystems, reduce the environmental footprint of construction, and contribute to the national economy. This transition would not only support local systems and agriculture but also focus efforts on achieving net-zero emissions in the construction industry and on creating more resilient communities.

Precedent Study of Bio Materials

New Zealand has a rich history of building with locally sourced materials, dating back to early Māori settlement. Between the 13th century and the 1700s, Māori villages were constructed using local resources such as timber, rushes, harakeke (NZ flax), bark, toetoe, and other native materials (*Early Houses | Te Ara Encyclopedia of New Zealand*, n.d.). These materials enabled simple, rapid construction methods that allowed communities to build huts efficiently. Because the materials were locally sourced and natural, they decomposed at the end of their lifecycle. Creating minimal carbon emissions and bringing the entire community along with it.

Figure 6 : Part buried whare (New Zealand: Rotorua, n.d.)

With the arrival of European settlers in the late 1700s, Māori began to adopt European building practices. This shift moved away from traditional materials, beginning with the whitewashing of timber, which became a rudimentary form of treatment that extended the material's durability and slowed its natural decomposition. By the 1800s, New Zealand was importing fully prefabricated houses from Britain and Australia. Moving away from local materials (*Building Materials | Te Ara Encyclopedia of New Zealand*, n.d.)

Figure 7: State housing (Pascoe, 1945)

This transition from locally sourced materials to imported materials was a pivotal moment. This move began to increase embodied carbon in supposedly sustainable materials. While materials like these may reduce upfront costs, they entail significant environmental consequences.

This project explores how we might return to using local and biogenic materials to counter the carbon intensity of modern construction. By embracing low-tech, DIY building methods and locally sourced resources, we can reduce reliance on commercial supply chains. Communities can engage directly in design and fabrication, fostering deeper connections with both materials and one another. Homes become personal expressions, extensions of identity and place.

The following examples showcase innovative approaches to sustainable construction, reimagining waste as a resource and empowering local communities to build more responsibly, and illustrate the use of strong wool as a biomaterial.

Sargablock - (Omar Vazquez)

Sargablock is a building material made from sargassum seaweed washed ashore on Caribbean beaches. As rising sea temperatures accelerate seaweed growth, Mexico has become one of the first regions to confront this ecological challenge. In 2018, Omar proposed combining sargassum with clay waste from a construction site to create Sargablock (Vazquez, n.d.). While the exact recipe remains proprietary, it is estimated to contain around 40% sargassum.(Vazquez, n.d.)

By paying residents to collect seaweed, Omar can produce housing at minimal cost. Providing shelter for low-income families. These homes are said to last up to 120 years, and the blocks can be broken down and reused. Sargablock exemplifies how local waste can be transformed into durable, regenerative building materials. Also, bring the community together to create bricks for local homes.

Figure 8 : Sargablock(Vazquez, n.d.)

Figure 9: Sargablock*(Vazquez, n.d.)*

Mycelium Brick

Red House Studio Architecture completed the world's first self-supporting mycelium structure using waste from mushroom farming and biomass from the Namibian bush. Oyster mushrooms were cultivated on bush waste; after harvest, the remaining substrate was converted into bricks. These mycelium bricks achieved a compressive strength of 6 MPa, comparable to that of Namibian concrete blocks (7 MPa). (Marc Violo, 2024).

These myco-bricks are suitable for non-load-bearing walls; they sequester 1 kg of CO_2 for every kilogram produced. Concrete emits approximately 1 kg of CO_2 per kilogram. This process also supports bush thinning, a conservation strategy to combat desertification, and contributes to local food security. Red House Studio has not only created a sustainable material but a regenerative one that enhances buildings, communities, and ecosystems. (Marc Violo, 2024).

Figure 10: Mycelium Red House Architecture (Marc Violo, 2024)

HY-FI Brick

HY-FI, a mycelium brick project recognised by the Holcim Awards in 2014, demonstrated the environmental potential of biodegradable architecture. The bricks were made from mycelium and locally sourced corn stalk waste, offering a cost-effective and efficient construction method. After standing for three months, the structure was disassembled and composted to enrich the community garden soil. (Hy-Fi – Biodegradable Tower Built from Mushroom Bricks | Holcim Foundation, n.d.).

Figure 11: Hy-Fi Bick (Hy-Fi, New York - The Living Architecture Lab | Arquitectura Viva, n.d.)

Strong wool Applications:

Here are three examples that have inspired me to explore strong wool's potential further:

- Barron Surfboards: A local New Zealand shaper, Barron uses strong wool and bio-resin to create carbon-negative surfboards. Traditional surfboards rely on toxic materials like fibreglass, carbon fibre, and plastic. All of which contribute to landfill waste. Barron's innovation replaces these materials with sustainable alternatives, proving that wool can outperform synthetics in both function and environmental impact (*Woolflex – Barron Surfboards*, n.d.).

Figure 12: Surfboard made out of wool and resin. (Woolflex – Barron Surfboards, n.d.)

- Solidwool: is a UK-based company that produces a composite material made from 50% strong wool and 50% bio-resin. The result is a durable, aesthetically pleasing material used for furniture, including chairs, placemats, and tabletops. The visible wool fibres impart a unique texture and pattern to each piece (Full Circle | The Recycled Hembury Side Table — Solidwool, n.d.).This raises interesting questions for further consideration. Could increasing the wool content enhance its natural benefits? Could this material be adapted into a 3D-printable filament to enable broader accessibility and design flexibility?

Figure 13: Solid Wool - (Full Circle | The Recycled Hembury Side Table — Solidwool, n.d.)

- (*SOM Foundation | MycoKnit: Cultivating Mycelium-Based Composites On…*, n.d.)(*SOM Foundation | MycoKnit: Cultivating Mycelium-Based Composites On…*, n.d.)(*SOM Foundation | MycoKnit: Cultivating Mycelium-Based Composites On…*, n.d.)(*SOM Foundation | MycoKnit: Cultivating Mycelium-Based Composites On…*, n.d.)(*SOM Foundation | MycoKnit: Cultivating Mycelium-Based Composites On…*, n.d.)MycoKnit: Developed by researchers at Pennsylvania State University, MycoKnit uses wool netting as a scaffold for growing mycelium. Under the right environmental conditions, the mycelium consumes the wool, forming a lightweight, fire-resistant, and water-resistant wall structure (*SOM Foundation | MycoKnit: Cultivating Mycelium-Based Composites On…*, n.d.). These walls are built on-site with minimal energy input, showcasing the potential of combining wool with other biomaterials to create efficient, low-impact construction systems. This also allowed the creator to write on the wall how they see fit. It makes each wall distinct from the others.

Figure 14:: Wool Knite strucutre for the mycelium to grow through. (SOM Foundation | MycoKnit: Cultivating Mycelium-Based Composites On…, n.d.)

Figure 15: Mycelium growing through wool structure. (SOM Foundation | MycoKnit: Cultivating Mycelium-Based Composites On..., n.d.)

Reflection:

These examples demonstrate the potential to develop strong wool as a building material. Being a regenerative, high-performing natural resource. This might provide the potential to reshape how we build. As we move toward a more sustainable future, we must reimagine wool not merely as insulation but as a foundational element in construction. This shift extends beyond wool. Biomaterials has to become a key focus in the future of building. Moving away from a focus on machinery for material production, which results in a sustainable material becoming carbon-intensive. By shifting sustainable materials into low-tech processes, we can begin to reduce their carbon footprint. For instance, Baron Surfboards rely on CNC machines to shape materials. Furnaces are used to produce rigid components. Biomaterials encourage simpler, locally driven methods. This transition emphasises simplicity, local engagement, and ecological responsibility. Positioning biomaterials as both practical and regenerative alternatives for the built environment. In this low-tech biomaterial study, the primary focus is on how a bio-block might be fabricated. By developing a low-tech bio block, the material assumes familiar, accessible dimensions that people can readily connect with. Brick forms are straightforward to produce and can be physically handled. Enabling construction without reliance on heavy machinery. Additionally, block form promotes uniform drying, a critical factor in the success of biomaterials.

There is something surreal about crafting your own material and connecting with its origin and understanding what comprises the ecosystem that surrounds us. Across the projects that engage with biomaterials, there is a consistent emphasis on regeneration, community involvement, and local sourcing. By embracing low-tech, DIY building methods and locally available resources, we can reduce dependence on commercial supply chains. Communities can participate directly in design and fabrication, fostering deeper relationships with both the materials and one another. Homes and installations can become personal expressions and extensions of identity and place.

In the next stages of my work, I aim to advance this low-tech approach to building. So simple and accessible that communities can begin constructing with these materials themselves. Whether through objects, buildings, or installations, this hands-on engagement invites a rethinking of how we build and how we gather. These systems have the power to drive local growth and begin to rejuvenate ecosystems and social structures.

Chapter 4.0 Material selection

Material selection plays a critical role in shaping the outcome of any architectural project. This section outlines the rationale behind the materials chosen for experimentation. These materials are all ‘regenerative’, meaning they must benefit ecological systems and can be renewed or repurposed over time.

By using regenerative materials, the goal was to not only develop a sustainable brick but also to promote a different approach to building. This process enables structures to thrive within their designed environments while enhancing the local ecosystem. The emphasis was shifted from reducing the carbon footprint of a build to creating buildings that facilitate ecological regeneration.

Throughout this research, a diverse range of materials was explored, with each material undergoing a series of low-fidelity tests to understand its properties, performance, and potential for integration into architectural applications. The hands-on testing process was essential for understanding how each material behaved under varying conditions and for optimising it for specific applications.

The chart below outlines the selection criteria that materials were required to meet to be selected for stage one of the experiment. These criteria ensured that only materials with strong potential and architectural viability were carried forward for further development.

	**Local Availability**: Material to be local to the area. Easy to collect and process. This will reduce transportation impact and take the strain off mass production.
	**Material Type**: Material has to be biodegradable and sourced from a renewable source or waste product.
	**Performance properties**: Materials are evaluated on what their properties are and categorized into each section. These sections could be fillers, structural materials, binders or preservatives.
	**Environmental impact:** the materials selected must not impact negatively on the environment. This also includes when sourcing from the environment, as well as the end of life must not impact or change the environment for the negative.

Figure 16: Material selection process

Material categories:

This section outlines the materials included in the experimental stage. Each material met the selection criteria (Figure 6) and were carefully categorised based on their key properties and intended role within the process.

The materials were organised into six essential categories: binding agents, structural materials, insulation, fillers, preservatives, and water-resistant components. These categories represent the core functional areas identified as critical to the development of a sustainable, eco-friendly bio brick.

Material Investigation

	Material	Characteristics / properties	Binding Agent	Structural Material	Insulation	Fillers	Preservatives	Water-resistant
1	Sheep Wool	Insulation - filler, absorbing, moisture control						
2	Bio Resin	Fast-setting binder						
3	Beeswax	Waterproofing						
4	Mycelium	Binder with waste products, lightweight						
5	Pine Resin	Waterproofing and binder, thermal						
6	Corn Starch	Natural thickner, rapid hardener, lightweight						
7	Recycled Clay	Strength and bulk						
8	Agar Agar	Natural hardener, transparent						
9	Gelatine	Elastic binder, odourless						
10	Glycerol	Preservative						
11	Calcium Carbonate	Strength and bulk						
12	Coffee grounds	Filler - can increase strength						
13	Eggshells	Increases strength, improves thermal insulation						
14	Seaweed	Natural hardener						
15	Sand (NZ)	Reduces gaps						
16	Sawdust	Lightweight filler - acoustic and thermal						
17	Harakeke (NZ)	Fibre structure						
18	Alginate	Fast bio-friendly binder						

Figure 17: Material Investigation chart

This table shows the breakdown of materials by category and indicates where each material overlaps with others. By categorising materials, we could readily replace one material type with another with similar properties, enabling efficient testing and prototyping. Most of the time, a successful material has properties that fit multiple categories.

4.6 Materials selected

These materials were selected to focus on characterising each material's properties individually, prior to any combination or composite testing. This foundational step was essential for identifying which materials held the most promise for architectural applications before entangling them with other materials. Section 5.0 will begin stage one of Material Driven design (MDD) to understand how each material responds under specific conditions.

Key Materials Investigated:
Strong wool
Recycled clay
Seaweed
Eggshell
Beeswax
Harakeke

Figure 18: List of materials

Each material was studied in isolation to assess its natural behaviour, performance, and potential contribution to sustainable construction. Low-tech testing and literature informed the following insights:

Strong wool

Strong wool demonstrates exceptional qualities including fire retardancy, water resistance and thermal insulation (Zhou et al., 2025). It is locally available and renewable, making it a highly accessible material for community-based construction. Its hygroscopic nature supports moisture regulation, further enhancing its suitability for architectural applications.

Figure 19: Washed and prepared Strong Wool

Recycled Clay

Sourced from surplus construction-site materials, recycled clay offers strong structural potential while addressing industrial waste. Notably, it sets naturally without the need for chemical hardeners, simplifying low-tech fabrication. Its inherent water resistance and compressive strength make it ideal for load-bearing applications. A rammed-earth wall provides a promising application for unfired clay. (*Rammed Earth – Earth Studio*, n.d.).

Figure 20: Recycled Clay

Beach-Cast Seaweed

Beach-cast seaweed is becoming an environmental issue. (Xhaxhiu et al., 2024) as it accumulates on shorelines and disrupts coastal ecosystems. Rich in biopolymers such as agarose and agaropectin, seaweed can be heated to produce a natural bio-resin. This resin enhances material hardness and, when combined with other components, can improve insulation. (Xhaxhiu et al., 2024). Overall, it is a valuable additive in bio-brick development.

Figure 21: Washed and dried beach cast seaweed

Eggshell

Though traditionally used in compost or as a cleaning abrasive, eggshells show potential for use in construction. When ground and blended with a natural hardener. Eggshell provides significant strength to composite materials. The availability of eggshells, particularly from domestic sources, supports local sourcing and circular material flows.

Figure 22: Ground Eggshells

Beeswax

Beeswax addresses a common limitation of biomaterials: their lack of waterproofing. As a natural hydrophobic agent, it may serve as an exterior coating to enhance water resistance in biomaterials. Its local availability further supports sustainable sourcing and ecological integration. The only drawback is that beeswax must be reapplied to maintain its waterproofing properties.

Inset photo

Figure 23: Double boiled wax

Harakeke (New Zealand Flax)

Harakeke is renowned for its durable fibres, which are difficult to break or mulch. The fibres have a high tensile strength and, when incorporated into a natural binder, can reinforce structural integrity and improve insulation. Harakeke also contributes to temperature regulation, making it a valuable component in passive design strategies.

Figure 24: Collected flax

Mapping/sourcing:

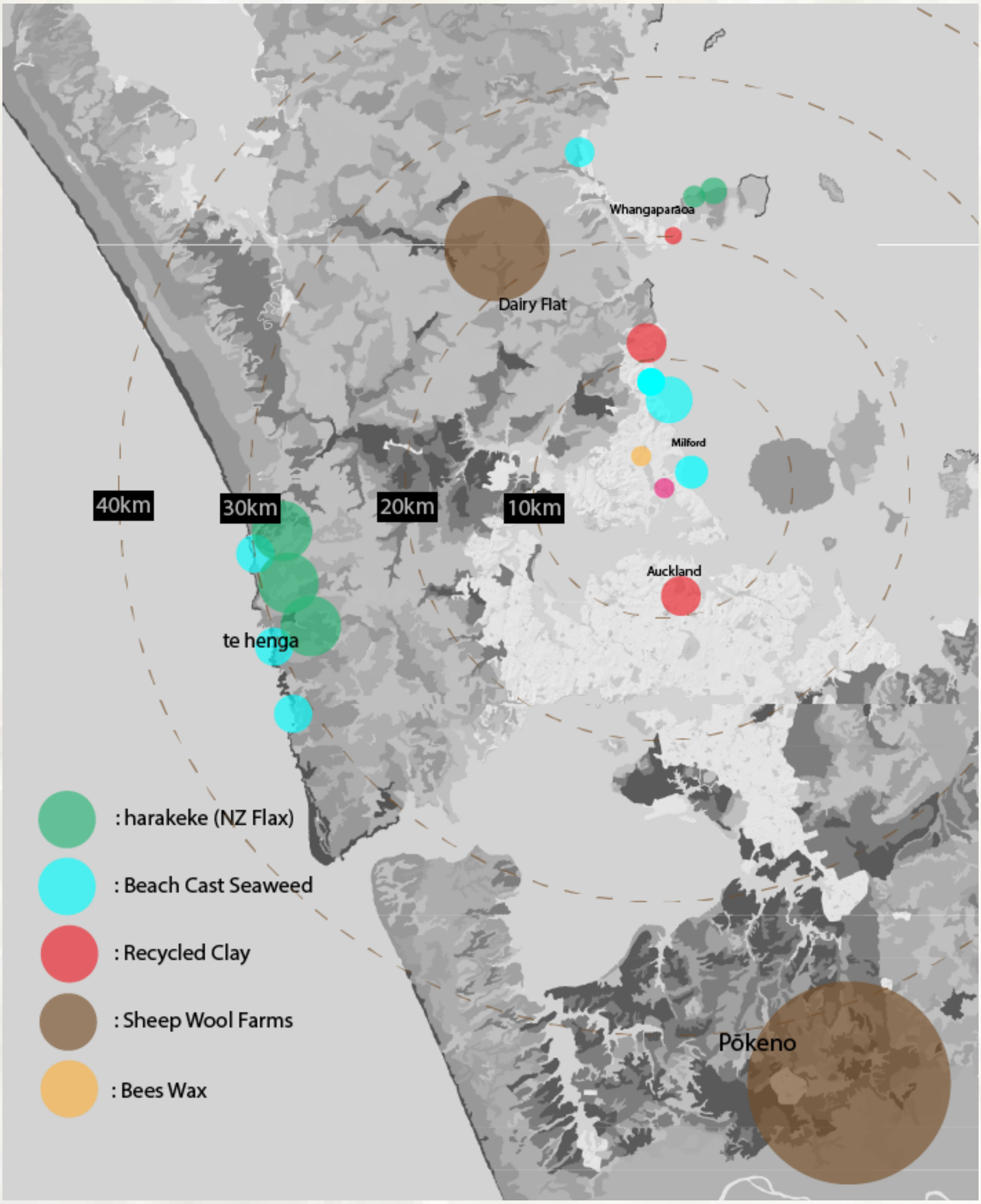


Figure 25: Local materials sourced

This map identifies the main raw materials, all of which were sourced locally. These materials were used in my experimental process to produce a bio-composite.

The strong wool was obtained from a local farmer just outside Pokeno, while beach-cast seaweed and sand were collected from beaches along both the west and east coasts of Auckland. Sawdust was sourced from offcuts provided by a local boatbuilder in Whangaparaoa. Bee's wax was sourced from a local farmer in Milford, and harakeke from the local forest around Milford.

All these materials can be farmed or harvested across New Zealand. Individuals can readily collect and prepare these resources to develop a regenerative bio-brick.

4.7 Collection and Processing of Materials

This next section will begin to unpack the materials investigated with the collection and processing of each material. Each material will be examined further, possibly with some changes to how it is processed. These will be discussed later if there are any adjustments. The materials include beach-cast seaweed, strong wool, beeswax, eggshell, harakeke (flax), and recycled clay.

Beach Cast seaweed:

Beach-cast seaweed was collected from local beaches along the east and west coasts of Auckland following storm events, which resulted in large accumulations of seaweed. It didn't matter what seaweed was selected. But the mix is better if we just use brown kelp. Once collected the seaweed was thoroughly cleaned using a two-bucket system of fresh water:

Wash 1: removed sand, salt, insects, and debris.

Wash 2: provided a final rinse to eliminate residual contaminants.

Figure 26: Unwashed Beach-cast Seaweed

Figure 27: Washed and dried beach cast seaweed

After cleaning, the seaweed was air-dried out of direct sunlight for approximately one week to preserve its structural integrity and optimise its potential as a bio-resin base. (Sarbatly et al., 2010). Once dried, the seaweed was shredded by a food processor into fine strands. Once heated it will release a natural hardner that will potentially been the only setting agent required to the experiment.

Figure 28: Ground / cut seaweed ready to be either mixed or heated

Strong wool

Strong wool was sourced from local farms, primarily from Wise Wool, located approximately 100 km from Auckland, which I have defined as the local radius. Ideally, future iterations would benefit from on-site farming and harvesting.

Post-shearing, the wool was cleaned to remove dags and washed with soap to eliminate odour. Once the wool was dried, you can either pull it apart with your hands, breaking the fibre, or start hand felting. This action begins to break up the strands and makes it easier to use, but it is not essential. Doing this last process also helps make the wool more consistent. This prepared the wool sufficiently for experimentation.

Figure 29: Strong wool

Beeswax

Beeswax was harvested from local hives in the North Shore region of Auckland. The collection occurred naturally when a queen bee died, and the colony vacated the hive. The wax was scraped from the hive and purified using a double-boiler system, which separated dirt and grit. This process was repeated until the wax reached its purest form. Beeswax was selected for initial waterproofing trials on newly developed bio-based materials.

Figure 30: Beeswax

Eggshell

Eggshells were sourced from a small domestic chicken run in Gulf Harbour. Their accessibility makes them the ideal candidate for a locally sourced material. After collection, the shells were boiled to eliminate bacteria and finely ground to a consistency similar to coffee grounds. This powder was incorporated into various material blends to enhance its strength.

Figure 31: Ground Eggshells

Harakeke (New Zealand Flax)

Harakeke has a rich cultural and material history. Following Māori tradition, harvesting was conducted respectfully by reciting a karakia (prayer) and cutting only the outer tīpuna (grandparent) leaves, allowing younger shoots to thrive and ensuring plant regeneration.

Once harvested according to tikanga, the flax was washed to remove soil and contaminants, then air-dried for approximately a week until no moisture remained. It was then shredded into fine strands, ready for use as a natural hardener.

Figure 32: Cut Harakeke

Recycled clay

Recycled clay has been used in numerous composite materials for structural applications. New Zealand has large amounts of clay. However, one of the biggest drawbacks is the machinery they must use to excavate the clay. However, by using only clay from construction sites, or, in this case, from a local plumber who has leftover clay. We have either reduced the water content by drying or added water to the material to prepare it for the experiment. We will not fully understand the required water content until we conduct appropriate testing.

Figure 33: Dry Clay collected from local construction site

Summary of materials, source location and preparation methods

Material	Source Location	Preparation Method	Processing Technique	Intended Use
Beach cast Seaweed	Local coastline	Washed, dried	Shredded, air-dried	Binder/hardener in composite
Flax (Harakeke)	Regional forests	Cleaned, stripped of fibres	Shredded into pulp	Reinforcement in panels
Recycled Clay (waste)	Construction sites	Filtered, decontaminated	Added water for the right viscosity	Base filler for composite
Sand	Local beaches	Sieved, dried	Dried in the sun	Filler for structural density
Strong Wool	Local farms	Washed, carded	Washing containments out	Insulative layer in panels

Figure 34: Summary of materials

Conclusion/reflection:

Chapter four has introduced the materials to be investigated across the four stages of Material-Driven Design. There are 20 materials in the materials table. However, the key materials we will investigate across the four stages are strong wool, beach-cast seaweed, recycled clay, and sand. The remaining material will be added to improve performance where needed. For example, I will not use pine resin at each stage. However, pine resin may be incorporated into the composite if additional waterproofing is required. This will be discussed and developed in the upcoming stages.

The materials process may change during stage one of the MDD if the outcome requires refinement or adaptation. This will be discussed in the next chapter.

Chapter 5 Application of MDD

In this section, I employed the MDD framework to thoroughly understand the selected materials, determine their functionality and interactions, explore potential combinations and develop product concepts. This was an experimental and iterative process, which meant that if the results at any given stage did not meet expectations, I could return to the former stages and adjust the inputs to better align with the desired outcome. By the end of this stage, I had a better understanding of each material individually and of the potential combinations that could yield a composite biomaterial.

5.1 - Stage One: Understanding the Material

Stage one of testing focuses on understanding the materials. Guided by the principles of Material-Driven Design (MDD), this stage involved identifying the unique characteristics of each material and assessing its performance after manipulation. Through continuous interaction among the material, human input, and technology, I was able to understand how each material behaved under standardised experimental conditions.

Twenty materials were initially tested; however, only four key materials were selected to undergo the entire MDD process due to their greater potential as bio materials for architectural applications. These key materials identified in the material selection 4.6 were beach-cast seaweed, harakeke, strong wool, and recycled clay. Eggshell and beeswax were also considered but were not taken all the way through the process. The four selected materials showed initial promise, with a quick analysis from figure 17 indicating that they spanned multiple categories, suggesting a potential for a wide range of applications. As we explore how to build a bio brick, this process may help us identify other applications for biomaterials through investigation.

Initial testing involved exploring how each material's properties changed when combined with a natural binder. For this experiment, I created a simple gelatin and corn starch mixture. This formed a binder with a 50% corn starch-to-water ratio that solidified upon gentle heating. The benefit of this binder was that it was simple to make and easy to replicate. A corn starch resin aligns with a low-tech, accessible approach to material fabrication.

Stage One of testing used a cornstarch binder for the first experiment with each material. The benefit of a cornstarch binder was that it produced a highly flexible paste, which set over time. This enabled me to observe how each material interacted with the cornstarch binder.

5.1.1 Recycled Clay

- Created a fast-curing, strong material
- Difficult to mix thoroughly due to its thick consistency
- Took longer to dry compared to other materials
- After approximately one month, the sample began to crumble

Introduction: Recycled clay serves as an effective filler and strengthening agent in building materials. When combined with the corn starch paste, the clay became very thick, making it difficult to mix evenly throughout the sample. One way to address this is to add more water to the clay, which could also help the material absorb and integrate more effectively with the corn starch binder. However, this may increase the drying time.

Outcome: The sample took longer than expected to dry. This delay may be acceptable if the user is not building immediately or if bricks are being prepared well in advance. However, it limits the material's usability for time-sensitive construction.

Reflection: The clay dried unevenly across the brick sample; some areas hardened quickly, whereas others remained soft. This inconsistency likely resulted from incomplete mixing of the cornstarch and clay and from the clay's requirement for a stable drying environment. The moulds I used only dried from the top down, rather than from all angles. A controlled drying room with indirect light and balanced airflow would likely improve consistency.

Category	Details
Material	Recycled clay
Binder Used	Gelatine and corn starch paste
Mixing Notes	The thick consistency made it difficult to mix evenly.
Drying Time	Took approximately one month to dry; drying was uneven across the sample.
Outcome	Initially strong, but it began to crumble after full drying.
Reflection	Uneven drying likely due to poor mixing and top-down mould exposure; stable drying conditions recommended

Figure 35: Notes of the recycled clay

Figure 36: Clay + Cornstarch mix – This material has shown considerable crack, but high compressive strength

5.1.2 Beach-Cast Seaweed

Process Summary:

- When heated with gelatin and cornstarch, the seaweed released natural polymers that reinforced the gelatin.
- The mixture set very quickly.
- Initially hardened for about a week, but did not retain structural integrity in wet conditions.
- As water content decreased, the final product became significantly harder.

Introduction: The process of working with beach-cast seaweed proved to be particularly intriguing. Finely chopped seaweed was added to a pot and brought to a boil, which activated its natural polymers. This reaction produced a bio-resin-like paste with promising material properties.

Outcome: Combined with cornstarch and gelatin, the seaweed produced a fast-setting material with high potential. However, despite its initial rigidity, the material became increasingly flexible and softened over the following weeks. After approximately six weeks, the seaweed composite hardened again, suggesting that reduced water content and adjusted gelatin ratios could enhance its strength and shorten drying time.

Reflection:

On first glance the seaweed didn’t provide a competitive material compared to the other. The seaweed material was flexible and not that hard. But once I left it to dry for over a month this material became very ridged. The biggest downside was the cracking through the material. This might be because it dried to quickly or it simple doesn’t really have a filler to integrate into the crack. Something to explore in the upcoming experiments

Category	Details
Material	Beach cast seaweed
Binder Used	Gelatine and corn starch paste
Processing Notes	Finely chopped and boiled to release natural hardening polymers
Setting Time	Very fast initial set
Short-Term Strength	Very flexible short term
Long-Term Behaviour	Became significantly harder after 1 month as water content decreased
Reflection	High potential as a bio-resin; reducing water and gelatin may improve strength and drying time

Figure 37: Reflection of seaweed and cornstarch

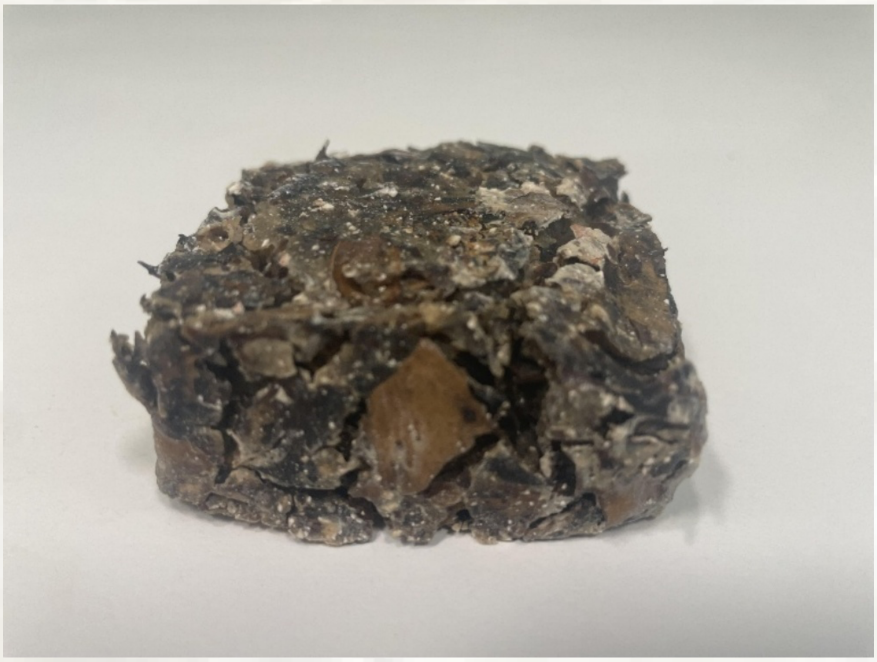


Figure 38: Beach-Cast Seaweed and cornstarch. Once fully dry it was very hard. But did show cracking

5.1.2 Eggshell

Process Summary:

- Eggshells were ground up
- Eggshells produced an unexpectedly stiff material.
- Initially underestimated, but after one month, the sample had hardened to a stone-like consistency.

Introduction: Inspired by theories suggesting that eggshells can enhance material strength, I incorporated crushed eggshells into a cornstarch-based paste and cast a flat sheet. The result was a remarkably stiff material that required minimal drying time.

Outcome: The material set quickly and exhibited impressive rigidity from the outset. Although its performance was initially overlooked, revisiting the sample after a month revealed a dramatic transformation. The product had become extremely hard and durable, resembling stone.

Reflection: This experiment highlights the untapped potential of eggshells as a structural additive. Their contribution to long-term hardness in composite materials suggests promising applications in bio-composite development, particularly where low-cost, waste-derived reinforcement is desirable.

Category	Details
Material	Crushed eggshells
Binder Used	Corn starch paste
Processing Notes	Cast as a flat sheet; minimal drying time required
Setting Time	Fast initial set with early rigidity
Long-Term Behaviour	Hardened significantly over one month; stone-like consistency.
Reflection	Strong potential as a low-cost, waste-derived structural additive for bio-composites

Figure 39: Reflection of Eggshell and Cornstarch

Figure 40: Eggshell and Cornstarch

5.1.3 Harakeke (New Zealand Flax)

Process Summary:

- Harakeke produced a material comparable in hardness to beach-cast seaweed.
- Its fibrous structure created a cohesive piece that was difficult to break apart.
- Despite its integrity, it lacked sufficient compressive strength for brick-like applications.

Introduction: Harakeke was used to form a sample brick, and its fibrous structure facilitated the binding of the cornstarch matrix. This resulted in a material that was difficult to separate, offering benefits similar to those of seaweed. However, seaweed proved more effective than harakeke due to its natural polymer content, which contributed to greater structural performance.

An important consideration is that harakeke is not food-safe. In low-tech or DIY contexts, where individuals may prepare these materials using household cookware, this raises concerns about contamination and safe handling.

Outcome: The harakeke composite demonstrated strong internal cohesion but limited compressive strength. While its fibrous network enhanced durability, it did not perform well under load-bearing conditions, making it less suitable for structural applications without further modification.

Reflection: Harakeke shows promise as a filler due to its natural fibre matrix. However, its lack of inherent polymers and food safety limitations present challenges. Future iterations could explore combining harakeke with other bio-based additives to improve strength.

Category	Details
Material	Harakeke (New Zealand flax)
Binder Used	Corn starch paste
Processing Notes	The fibrous structure creates strong internal cohesion; it is difficult to separate once set.
Short-Term Behaviour	Comparable hardness to beach-cast seaweed
Structural Performance	Limited compressive strength; not suitable for load-bearing applications without modification
Food Safety Concern	Not food-safe; raises concerns for DIY users using household cookware
Reflection	Promising as a binder due to its fibre matrix, the material warrants further testing of polymer-enhanced blends to improve strength and safety.

Figure 41: Reflection of Harakeke and Cornstarch

Figure 42: Harakeke and Cornstarch

5.1.4 Strong wool

Process Summary:

- Strong wool produced a surprisingly dense and solid brick.
- Despite its softness, the material has tensile strength.
- Likely to possess high insulation value.
- Soft to the touch and fast setting.

Introduction: Strong wool was used to form a lightweight yet dense brick, with its fibrous structure serving as a matrix for cornstarch. Preliminary low-tech testing indicated strong tensile performance, suggesting that wool's natural cohesion contributes meaningfully to material integrity.

Outcome: The wool composite set rapidly and maintained a soft surface texture while exhibiting notable internal density. Its tactile softness contrasted with its structural solidity, yet it formed a rigid composite. Given wool's well-known thermal properties, the material is likely to provide high thermal insulation.

Reflection: This experiment reinforces the potential of strong wool as a bio-based construction material, particularly for applications requiring thermal performance and lightweight strength. The fast-setting nature of the composite and tactile appeal are benefits for low-tech creation. Further testing could quantify its insulation capacity and explore its role in composite blends aimed at enhancing both structural and environmental performance.

Category	Details
Material	Strong wool
Binder Used	Corn starch paste
Processing Notes	Fibrous structure effectively bound the matrix, forming a lightweight yet dense brick.
Setting Time	Fast-setting
Tactile Properties	Soft surface texture with notable internal density
Performance Notes	Structurally robust despite softness; likely high insulation value
Reflection	Promising for thermal and lightweight applications; further testing recommended to quantify insulation and explore composite blends.

Figure 43: Reflection of Sheep wool and Cornstarch

Figure 44: Sheep wool and Cornstarch

5.1.5 Reflection on Stage One

Stage one testing enabled me to explore how various biomaterials interacted with a simple binder agent. This process revealed the distinct characteristics of each biomaterial that emerged through combination with a cornstarch binder.

Of the 20 biomaterials tested, several demonstrated notable potential for further refinement. As discussed above, beach cast seaweed retained a high level of moisture. Increasing the cornstarch ratio and reducing water content could enhance the structural integrity. Increasing the percentage of seaweed in the composite could also mitigate the high water content and may yield a harder brick upon drying. However, this may also increase the product's shrinkage upon full drying. I found that after 1 month, the seaweed mixture had fully dried and was as strong as the eggshell-cornstarch composite.

Recycled clay proved difficult to mix evenly. By increasing the seaweed content and the viscosity of the clay, integration with cornstarch and other biomaterials may be improved. This would assist in controlling the overall consistency of the mixture and, consequently, the uniformity of the brick.

I hypothesised that my proposed adjustments would improve performance and reproducibility and make the recipes more accessible for low-tech fabrication and scalable experimentation.

To increase the product's scalability, I introduced a second binder, 'bio resin'. This Bio resin is derived from food waste, specifically corn waste, and uses a two-part mixing system. This binder is fast-setting and more robust than the cornstarch binder; however, it is more complex to prepare and has a shorter working time. I suspected that this might increase the product's workability, but it could also reduce its usability, making it less accessible and more technologically advanced. This also shows the potential to reduce costs, as it is locally available and made from cheap materials that are mostly considered waste product. In stage two, we looked into how these materials might be integrated. We also introduced a chemical bio resin. It allows the materials to set within a couple of hours, making them ready for construction.

5.2 - Stage Two of MDD: Creating a Material Experience

Stage Two marks the second step in the MDD process, which required me to ‘create a material experience’. In this second stage, the material experience was explored by combining two or more biomaterials to create new bio-composites.

Building on the insights gained in Stage One, where each material was tested in isolation, this stage investigated how the characteristics of each material evolved when integrated with others. When the materials were combined, I assessed whether each material’s characteristics were enhanced or compromised.

All stage two tests continued to use cornstarch resin as the primary natural hardener. However, I also investigated whether biodegradable bio-resin derived from food waste could serve as an additive or a replacement for cornstarch as a binder. Unlike petroleum-based epoxy resins, this bio-resin offers a sustainable alternative that aligns with cradle-to-grave principles. Recipes were tested using a full bio-resin formulation or 50/50 cornstarch blend.

Material Combinations Investigated

The following 9 Composite Formulations were developed and tested:

	Materials used	Ratios	Images
1A	Strong wool / Recycled Clay / Cornstarch	30%/50%/20%	
1B	Strong wool / Recycled Clay / Bio-Resin	30%/50%/20%	
2A	Strong wool / Recycled Clay / Seaweed / Cornstarch	15% / 30% / 30% / 25%	

2B	Strong wool / Recycled Clay / Seaweed / Bio-Resin	15% / 30% / 30% / 25%	
3A	Strong wool / Eggshell / Seaweed / Cornstarch	20% / 10% / 60% / 10%	
3B	Strong wool / Eggshell / Recycled clay / Cornstarch	20% / 10% / 60% / 10%	
4A	Strong wool / Harakeke / Cornstarch	20% / 40% / 10%	
5A	Strong wool / Seaweed / Cornstarch	20% / 70% / 10%	
5B	Strong wool / Clay / Bio-Resin	20% / 70% / 10%	

Figure 45: Nine different Materials tested throughout stage two

Key Findings:

The primary focus of this stage was to evaluate the structural integrity of each biomaterial composite and its functional potential in architectural applications.

I found that composites with a high clay content exhibited higher compressive strength and could be extruded from the mould more quickly.

When bio-resin was introduced into a composite, similar results were obtained. The bio-resin improved the composite's compressive strength and cohesion. After curing for over 2 hours in bio-resin, these bricks were firm to the touch and workable, suggesting they could be used on-site the following day without requiring extended drying periods. In comparison, composite materials that used only cornstarch as a binder/resin typically took 2-3 weeks to fully dry.

To assess long-term performance, all materials were left to dry outdoors for one month. Over time, they became increasingly rigid, and the strong wool composites continued to dry out, supporting the idea that the insulation capacity of strong wool may improve with extended curing. Initially, I predicted that the wet mixture would leave the wool damp, reducing its insulating value. However, this was disproven when the bricks were broken; the strong wool was actually dry. I assumed that the complex structure of wool, especially the scale fibres, helped the wool adhere to the material it was combined with, thereby boosting the product's structural integrity. Upon inspecting the composites after the one-month drying period, all showed similar compressive strengths compared to the bio resin. The bio resin materials couldn't be broken, whereas the cornstarch-based products could. Nonetheless, they showed very similar performance in compressive strength, with the cornstarch not reducing in height while being compressed. Overall, the composites using bio-resin as the binder were slightly stronger than those using cornstarch.

Yes, the bio-resin binder materials exhibited greater structural integrity. However, the corn starch exhibited relatively similar strength. I did take longer to dry. But maybe that is okay. Maybe we have to rethink how we build. In this day and age, we are all about building with speed and quantity. However, it may be about slowing down. Understanding what we are doing and begin to foster a deep connection with the process, community and place.

Reflection

Future iterations can focus on showcasing strong wool, seaweed, and recycled clay using a cornstarch binder. Bio-resin may still be necessary as a component of the bio-brick. Bio-resin is used as an agent to hold it all together, not as the true setting agent? Further investigation is required to determine whether the drying time of bio-resin can be reduced from 3-4 weeks to a more practical time frame, such as one week.

If bio-resin is used in a composite, I have found that the material increases in strength and thermal performance as it cures over subsequent months. This is useful in the context of construction; however, the use of bio-resin will shift the process away from low-tech due to the more complex preparation procedure required to produce it.

A key observation from stage two was that many bricks remained damp after 2–4 days of drying within their moulds. Once fully dried, however, they exhibited considerable strength. The surfaces exposed to sunlight hardened and dried more quickly, while the faces encased in the mould retained moisture. This was not an issue for the composites, which included a bio-resin, as they could chemically harden. In contrast, the cornstarch-based materials might benefit from being extruded straight away to allow the material to dry more evenly.

Materials containing small amounts of recycled clay exhibited shorter drying times and higher extraction efficiency. However, materials with high clay content may be more prone to cracking. This was largely due to uneven drying, resulting from being left in moulds or left out in the sun and drying too quickly.

Overall, Stage Two marked a significant advance in understanding how biomaterials interact with other materials when incorporated into composite bricks. Several composite bricks showed promising results, moving biomaterials closer to structural application. These have been assessed using low-tech methods, including visual inspection, tactile evaluation, and manual break tests. These approaches provided practical insights into the material's performance and potential for architectural application.

Steps Forward

To improve material performance and usability, the next stage of experimentation focused on reducing the water content of each recipe. Lower moisture levels help to shorten drying times and may enable composites to be formed without the support of a constant mould. I proposed that this could be achieved by increasing the cornstarch content in the resin mix and reducing the water content in the seaweed blend. Creating a firmer paste with enhanced workability. This recipe adjustment can be tested by iteratively looping back to stage one to reassess how each recipe performs individually before incorporating them into composite materials. This will be further refined in the following stage.

Additionally, I revisited the resin formula for the overall binding agent. Which had a goal to minimise bio-resin content while maintaining sufficient structural setting. Ideally, the bricks would not require bio-resin and would use only cornstarch as the binder, thereby keeping the process low-tech.

5.3 Stage Three - Manifesting Material Experience patterns - Recipe Investigation

Stage three involves "Manifesting Material Experience Patterns" as defined in MDD. This stage focused on refinement and how the material was communicated. A key focus of this stage was to ensure that anyone could create this material using low-tech methods with little to no background knowledge.

While the construction methods remain consistent with stages one and two, adjustments were made to the recipes to try reduce the water content and increase the seaweed percentage in each composite. This may increase hardness, which may positively or negatively affect the outcome.

Each test aimed to refine the material's strength, drying time, and mixability.

For the following recipes, I primarily used cornstarch as the binder. To enable comparison, I created a bio-resin control composite in which bio-resin served as the hardener/binder. This enabled a bio brick to determine whether a cornstarch-only binder was a viable option. Confirm how long it takes to dry out before it reaches the same compressive strength as a bio-resin.

5.3.1 Strong wool – Clay (high) – Seaweed – Starch

This composite material looks into combining strong wool, clay, an updated seaweed paste, and cornstarch resin. I anticipated this material not to work from the initial cornstarch materials. It was only because I came back to some older materials that had, in fact, hardened. Initially, I was very sceptical about the outcome, given past challenges with cornstarch alone; however, with new insights into cornstarch and seaweed and how they dry, I realised that cornstarch acts as an initial binder, followed by seaweed, ultimately becoming the active hardener.

Recipe: Weight 130g

- Strong wool: 10g
- Clay: 80g
- Seaweed paste: 20g

- Cornstarch paste: 10g water + 10g cornstarch

Outcome: Developing this brick was among the most engaging processes because of its high clay content, which required thorough manual mixing to incorporate wool and seaweed. Once pressed into the mould, the brick could be removed within 3–4 hours for air-drying. Its ability to dry evenly on all sides was key to its success. However, rapid drying led to surface cracking, warranting further investigation into how to prevent this in future iterations.

Figure 46: Strong wool drying through the brick

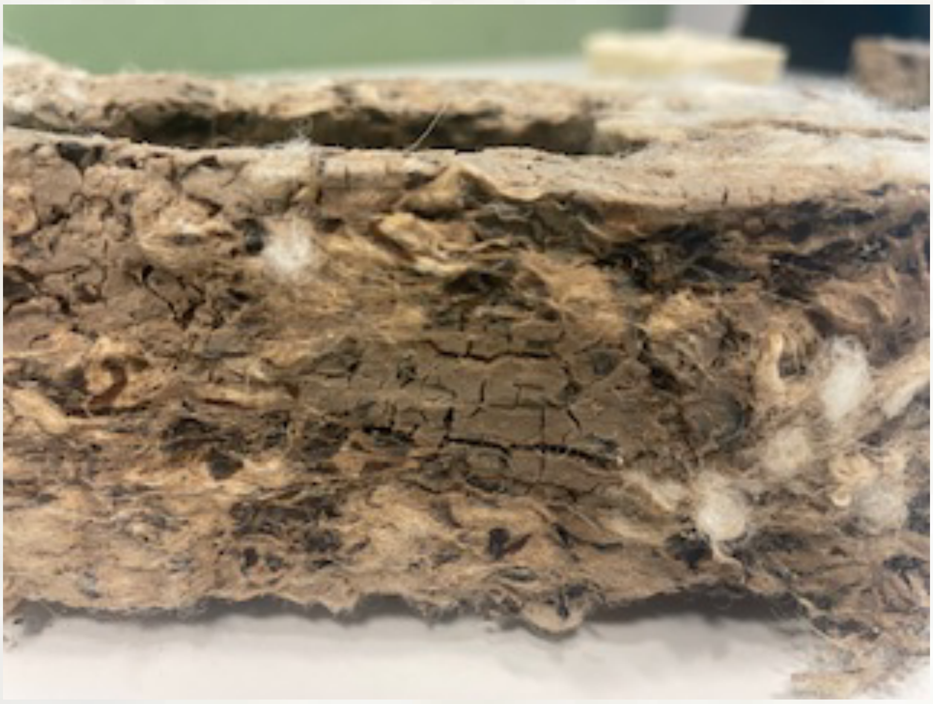


Figure 47: Clay has began to crack with the high levels in this biomaterial. Not enough filler

5.3.2 Strong wool – Clay (Low %) – Seaweed – Starch

This variation reduced the clay content and increased the seaweed content to examine how these changes might affect mould release and cracking. I hypothesised that using less clay and more seaweed would reduce cracking and improve stiffness, owing to seaweed's natural hardening properties.

Recipe: weight 130g

- Strong wool: 10g
- Clay: 40g
- Seaweed paste: 60g
- Cornstarch paste: 10g water + 10g cornstarch

Outcome: The brick met expectations for form and stiffness; however, slight cracking remained. The increased seaweed content made the mixture more viscous, requiring a full day to remove the material from the mould. This recipe is less suitable for rapid production using a single mould. Although this recipe was more successful in the long term, it had a negative short-term impact. A potential solution would be to create a mould that can be separated, allowing the brick to begin drying on all sides.

Figure 48: Strong wool / Clay / Seaweed mixed and place into first brick form

5.3.3 Strong wool – Seaweed – Starch

Introduction:

This test aimed to eliminate clay by investigating whether seaweed and starch alone could sufficiently bind strong wool into a viable brick. While the clay used in my research was recycled from construction sites, its excavation in general remains carbon-intensive. The goal was to assess whether a clay-free, low-fyi recipe could perform adequately.

Recipe: Weight 130g

- Strong wool: 10g
- Seaweed paste: 90g
- Cornstarch paste: 10g water + 20g cornstarch

Outcome: Without clay, the brick was initially very wet and difficult to remove from the mould. It required several additional days to retain its shape compared with other clay-based materials. However, it showed no signs of cracking and became stiff once cured. Although less robust than clay-based bricks, this brick demonstrated potential for low-tech applications.

After I broke the brick in half, I observed the fibres of seaweed and wool that held it together. This brick showed great potential as a non-load-bearing wall, though it was not as strong as the other clay bricks. Being a wetter product, it could be applied to a panel mould to create a jib-like wall. This could lead to future research.

Figure 49: Seaweed pressed into sheep wool

Figure 50: Seaweed pressed into sheep wool

5.3.4 Strong wool – Seaweed – Bio Resin

Introduction: Building on the previous test, this recipe introduced bio-resin to address the strength and drying-time limitations of the strong wool/seaweed/starch brick. The aim was to accelerate mould formation and enhance structural integrity.

Recipe: Weight 130g

- Strong wool: 10g
- Seaweed paste: 90g
- Bio resin: 30g

Outcome: This brick had an impressive form time and could be removed from the mould within less than an hour. However, it remained wet and soft to the touch for up to two weeks. I presumed this was due to the seaweed making the strong wool damp and the bio-resin setting the form before the strong wool could properly dry. The bio-resin enabled rapid production, enabling the creation of multiple bricks per day.

Figure 51: Bio-Resin encasing the sheep wool and seaweed

Reflection

The investigation into four bio-based recipes further developed my understanding of how the two binders could be used to form strong, resilient composite bricks for architectural use. Both binders ultimately produced materials of comparable hardness after 3 to 4 weeks of curing. However, bio-resin offered a key advantage by enabling bricks to set within 1–2 hours. This would allow for rapid demoulding and more continuous production. In contrast, the cornstarch-based brick required 12–24 hours to be removed from the mould. With further recipe refinement, I believed the cornstarch-based composite materials could reach a stage where they were ready for demoulding more quickly.

Two of the tested bricks incorporated clay, while two did not. The clay-free bricks were more compressively resistant than those without clay. Further drying and testing would be needed to determine whether a clay-free brick can achieve comparable performance. One idea was to further reduce the water content of the seaweed paste, which would ideally enhance the brick's strength without relying on clay.

Overall, this stage of my research focused on developing a sustainable, locally sourced, biomaterial-based brick that reflects New Zealand's ecological environment. The use of inexpensive local materials, such as beach-cast seaweed, strong wool, and recycled clay, was essential to creating a low-tech alternative to conventional construction materials.

The final stage of testing, stage four of MDD, employed low-tech methods to assess the viability of the bio-bricks in a real-world construction scenario.

5.4 Stage Four: Designing Material/Product Concepts

Stage four of the MDD focused on refining and optimising the most promising composite bio-brick ratio identified in stage three. No new materials were introduced. Instead, the emphasis was on improving the existing formulas through targeted testing and on examining how a mould would help improve the bio-material and low-tech construction.

Up until this stage, there have been strict, measured ratios to understand each material's characteristics and how they changed through interaction with other materials. This final stage investigated how an individual with limited background knowledge could develop a composite material. For example, I assumed that some people may not have access to precise scales or measuring equipment. The same recipe uses strong wool, seaweed paste, clay, and cornstarch. The clay ratio has been investigated, as clay levels are crucial to the success of the bio brick. With low clay levels, the brick becomes too wet and must stay in the mould overnight. In comparison, high clay levels increase the risk of cracking during drying.

Key Findings from Previous Stages:

- Strong wool acts as a natural binder, with its fibrous structure interlocking effectively with seaweed and filler materials.
- Clay contributes significantly to compressive strength and structural integrity.
- Seaweed functions as a natural hardener, continuing to cure and strengthen over time.

With the key findings and beginnings of exploring a low-tech application. These next tests will investigate a high-clay-volume test and a low-clay-volume test. In previous tests, we observed that the clay sometimes cracks, typically due to shrinkage or rapid drying. Each material will still be measured when mixing. Throughout this next process, I will assess how it might be built with a low-tech approach with little to no measuring. I will also include a simple box mould. Allow the bricks to be pressed and extruded straight away.

Clay Testing:

5.4.1 High volume brick (50%)

The key to this brick lies in understanding how to manage clay cracking, and I have a few ideas. One possibility is that it is due to a high percentage of clay, like in this example, or it is that the clay wasn't mixed thoroughly with the other ingredients. To better understand the outcome of this brick, if it cracks, I will increase the water content in the next tests.

Bio-Recipe: 300g total wet weight

- Sheep wool: 20%
- Recycled clay: 50%
- Seaweed Paste: 30%

Figure 52: High Clay volume bio brick

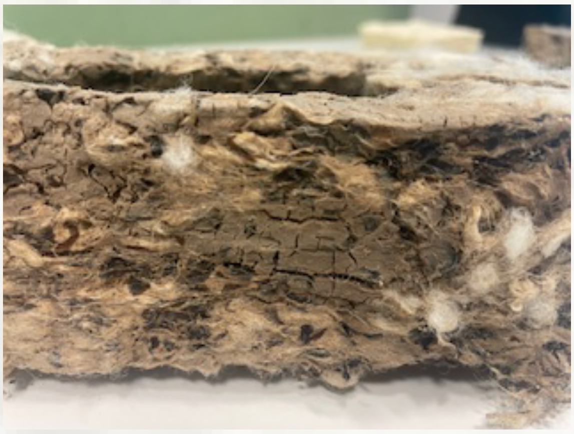


Figure 53: High clay volume bio brick showing it cracking in parts

Reflection:

There is still a clear cracking issue within this mixing process. We observe that only one area of the brick has cracked, while the rest remains intact. Figure 51 shows the same ratio, but with higher water content than Figure 52. The additional water will be tested in the low-clay mix to determine whether the outcome is successful for the build. This will need to be developed into a simple method for measuring the clay.

5.4.2 Low clay volume brick (20%)

The high-volume brick has cracking in parts of the bio material. This experiment will test a low-volume mix containing only 20% clay. However, a key difference is adding extra water to the clay mix during integration. Once again, we used the same square mould as before, with the same 300g wet weight.

Bio-Recipe: 300g wet weight

- 20% recycled clay
- 30% Strong Wool
- 50% seaweed paste

Figure 54: 20% Clay in this sample

Figure 55: Visibly no crack in this bio brick

Reflection:

The low-level clay recipe proved to be the most successful among the high-level clay recipes tested. This was mainly due to the addition of more water before mixing the clay with the strong wool and seaweed. The increased water content did extend the dry time, but this needs to be accounted for when working with this new biomaterial.

5.5 Final brick investigations

The final recipe was selected after extensive controlled and uncontrolled testing. Uncontrolled tests were designed to assess whether the material could be reliably produced with minimal or no measurement. This required only a visual assessment of the materials and mixing. Essentially, this could be deemed 'low-tech' construction of building materials. A few of the low-tech tests will be shown within the assembly guide.

Final Bio-Brick Recipe (300g):

- Strong wool: 60g (20%)
- Seaweed Paste: 120g (40%)
- Clay: 120g (40%)

Figure 56: Final recipe of bio brick

This formula proved to be the most reliable, both in terms of measured proportions and intuitive, visual mixing. The recipe is forgiving and allows for up to 10% variation in ingredient quantities without compromising the structural performance. This 40% ratio of clay and seaweed allowed the material to be measured in equal parts. It could have been done with less clay, and the performance would be slightly better. But to enhance its low-tech build, 40% seaweed and 40% clay is just a handful of this and a handful of that, making it very easy for someone to measure visually.

A key step was the development of the simple square mould, which allowed the material to be extruded immediately, taking around 2-3 minutes to form one brick. Developing an interlocking brick will reduce the actual construction time of a wall, as it allows the bricks to be placed and interlock. This eliminates the need for experienced builders and mortar in each layer, similar to conventional red brick.

5.6 Interlocking Brick investigation

To further progress this research on low-tech applications, an interlocking mould will be investigated. Interlocking bricks are not a novel innovation in construction. There are many established examples across the industry. I will briefly review which ones have been successful and which design type would help unlock the bio-material.

The key advantage of interlocking systems is their ability to reduce construction time, minimise the need for technical expertise, and promote more sustainable building practices by reducing motor use. This system would also accelerate build times

6.1 Examples of Interlocking Systems:

6.1.1 System 3E (Poland): (SYSTEM 3E, n.d.) Utilises perlite to create lightweight blocks. Each element interlocks through precise geometry, eliminating all degrees of movement. This system eliminates the need for cement or mortar, reducing water use and construction time by approximately 35% relative to traditional methods. Its simplified design requires no specialised labour.

This interlocking design appears promising but requires a very precise jig to achieve it. Making it not suitable for a low-tech build.

Figure 57: System 3E interlocking brick (SYSTEM 3E, n.d.)

6.1.2 *Soil Blocks (South Africa):* (Mwangi, 2025) Constructed on site using soil from the building site, these blocks employ a dry-stacking method and do not require plaster/motor. The process involves compacting soil, followed by a 14-day curing period before use. With two operators and a machine, up to 500 blocks can be produced per day, providing both efficiency and environmental benefits.

This project is closely related to the BioBrick I have created: it involves collecting and constructing onsite and using a simple machine to compress and push out these soil blocks. I see this mould being very simple for someone to construct and replicate.

Figure 58: Soil Blocks from South Africa (Mwangi, 2025)

6.1.3 Interblock (Bowers & Son Ltd, New Zealand) (*Interbloc - Envirocon*, n.d.)Designed for retaining walls and heavy construction, these blocks range in length from 0.6m to 2.4m. Simple divots on the top and bottom allow tractors or cranes to stack them securely, creating an interlocking system suitable for large-scale applications. These can be investigated at an earlier stage. Allowing low-tech buildings to take place.

The interblock is another example of an interlocking design, featuring simple divots at the top and bottom of the mould, enabling rapid, effective construction. Research will be needed to determine whether it works with a smaller-scale build. This interlocking design may be more difficult to replicate than the other designs explored.

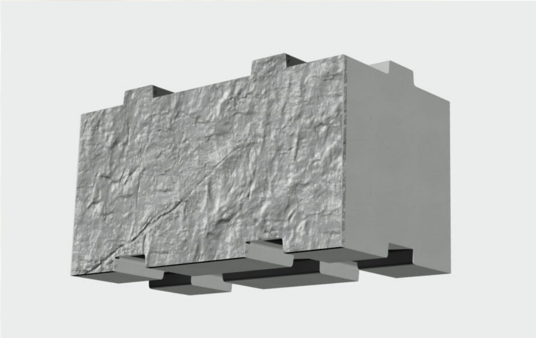


Figure 59: Interblock is used mainly in heavy construction (Interblock - Envirocon, n.d.)

5.7 Reflection

Investigating the optimal interlocking mould design will enhance the project's low-tech nature and enable on-site construction of bio-bricks without heavy machinery.

From research and understanding the interlocking systems, we see significant advantages. Interlocking systems offer significant advantages, as they can reduce construction time by up to 35% (Mwangi, 2025), eliminate the need for mortar in construction (STAR INTERLOCKING BRICKS, 2023), and minimise reliance on professional expertise. In addition, they support on-site production, which helps reduce carbon emissions and supports more sustainable building practices. This interlocking building method further increases each brick's strength, transferring 35% of the load to it and making it suitable for low-rise buildings and homes. (STAR INTERLOCKING BRICKS, n.d.)

Interlocking systems present several drawbacks, including the difficulty of replacing individual bricks once they are set, the risk of failure if bricks are poorly designed and do not interlock properly and the restriction of creative freedom since the mould system fixes dimensions.

In this research on interlocking moulds, I have chosen to develop a mould similar to the South African soil block. This simple mould allows users to receive it and modify the brick once set quickly and effectively. Shaving off slightly raised bits to make a brick fit around the corners of the construction. Shown in the assembly book.

5.8 Chosen interlocking mould:

I have chosen to investigate the development of a mould for a soil block similar to those used in South Africa. This Soil block has a very simple mould, unlike the other case studies. This mould relapses closer to the build's low-tech nature, allowing the material to be slightly out of dimensions without hindering the construction's outcome.

The mould created for the design will be an open-source file. Allowing anyone to download and 3D-print this file makes it accessible to a large number of users.

Construction Drawings of interlocking mould:

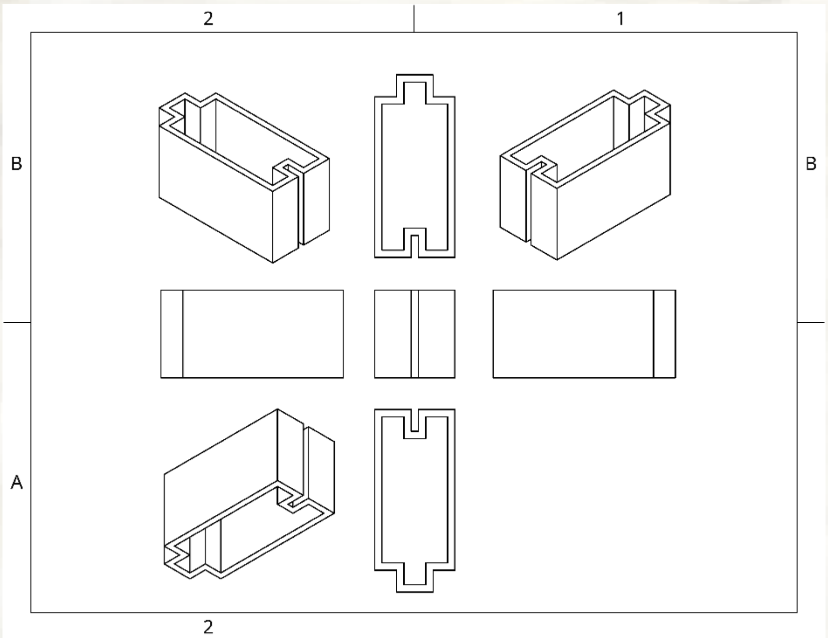


Figure 61: Interlocking Mould wall construction

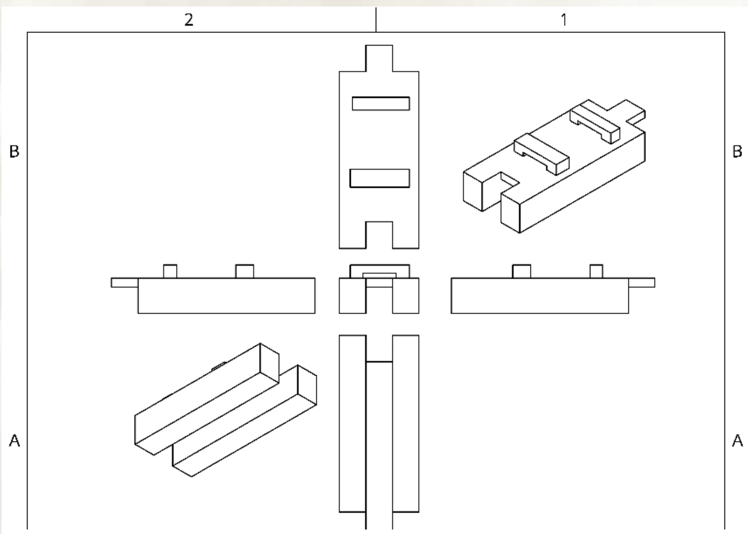


Figure 60: Interlocking Top side of mould

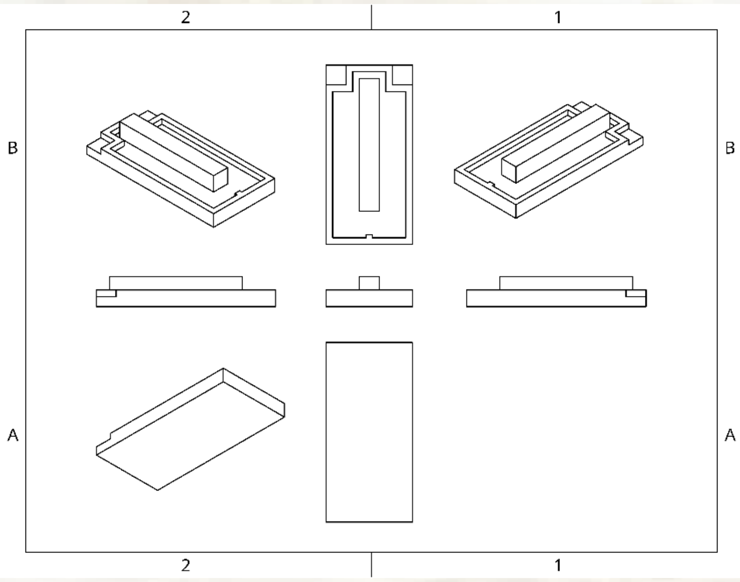


Figure 62: Interlocking bottom of the mould

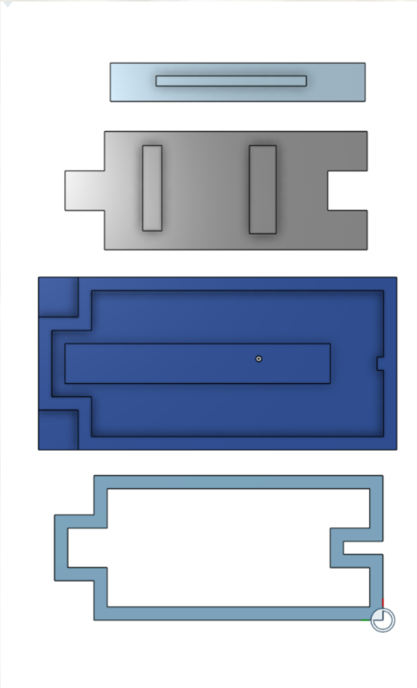


Figure 63 : Top View of mould pieces

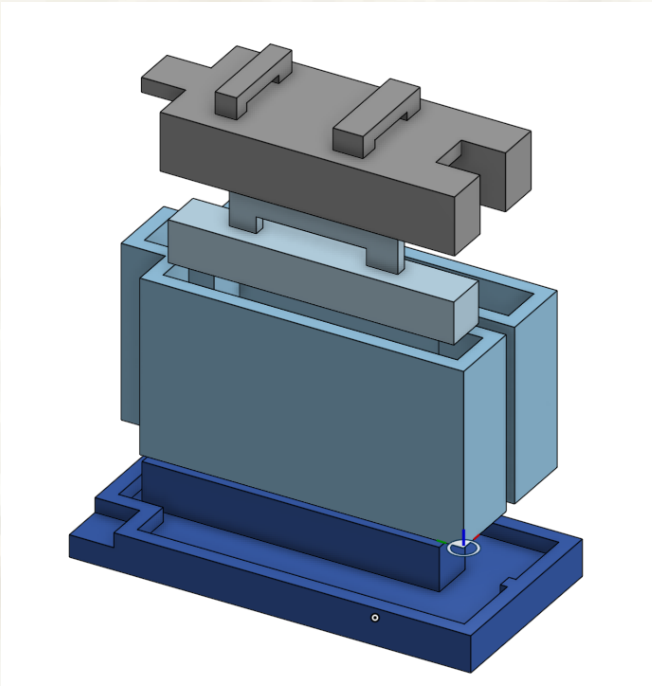


Figure 64: Exploded view of mould

6.0 Analysis and Findings (Carbon Calculations)

While this bio-brick requires extensive testing before it can be formally approved for widespread use, initial low-tech evaluations of manual strength indicated that the material is progressing in the right direction.

A key finding was the comparative carbon performance of the bio-brick versus traditional red bricks. A standard red brick weighing approximately 2–2.5 kg emits around 0.3 kg of CO_2 during production. (Wang & Abuel-Naga, 2025b). In contrast, the bio-brick could have a carbon-negative footprint by actively sequestering 0.4 kg of CO_2 per unit, around 2kg. The breakdown of carbon sequestration per material is as follows:

- Strong wool (carded): 1.94 kg CO_2 sequestered per kg (Wiedemann et al., 2015)
- Dry Weight Seaweed: 0.96kg CO_2 sequestered per kg (Farghali et al., 2022)
- Recycled clay: Carbon neutral (as a waste-derived material)

Based on the final recipe selected for production, which features high levels of seaweed, the total carbon impact per brick is approximately 0.0058 CO_2. This means each brick removes more carbon from the atmosphere than it emits. This may change slightly depending on how the materials are collected.

6.1 Whole-Build Impact:

For a house measuring approximately 124.4 square meters, an estimated 14,928 bricks would be required. A conventional build using red bricks would result in 3,358.8 kg of CO_2 emissions produced. This also does not account for end-of-life disposal. In contrast, the bio-brick construction would sequester approximately 44.03 kg of CO_2, providing a substantial carbon offset and slowly releasing the stored carbon through biodegradation.

6.1.2 Biodegradation Consideration:

While these bio-bricks capture significant carbon during production, a valid concern is the eventual release of CO_2 during biodegradation. Notably, the use of a cornstarch-based binder and strong wool would likely ensure a gradual breakdown. This means that the CO_2 trapped within the bio-brick would be released over an extended period. Allowing the surrounding vegetation to act as a natural carbon sink, absorbing CO_2 emissions over time and mitigating negative environmental impact. The actual rate of biodegradation is an unknown variable and would require further testing.

7.0 Assembly Guide:

This Assembly guide provides practical guidance on what an end user can expect to receive and how to begin creating this bio brick. This will include the low-tech testing of each stage. It contains little to no measurement data. Creating a strong case for anyone to be able to create these materials. From small-scale projects to large-scale projects. The assembly guide will take you through a step-by-step guide to designing and building the sea wool block. Please note that the next few pages will be provided as a separate handbook.

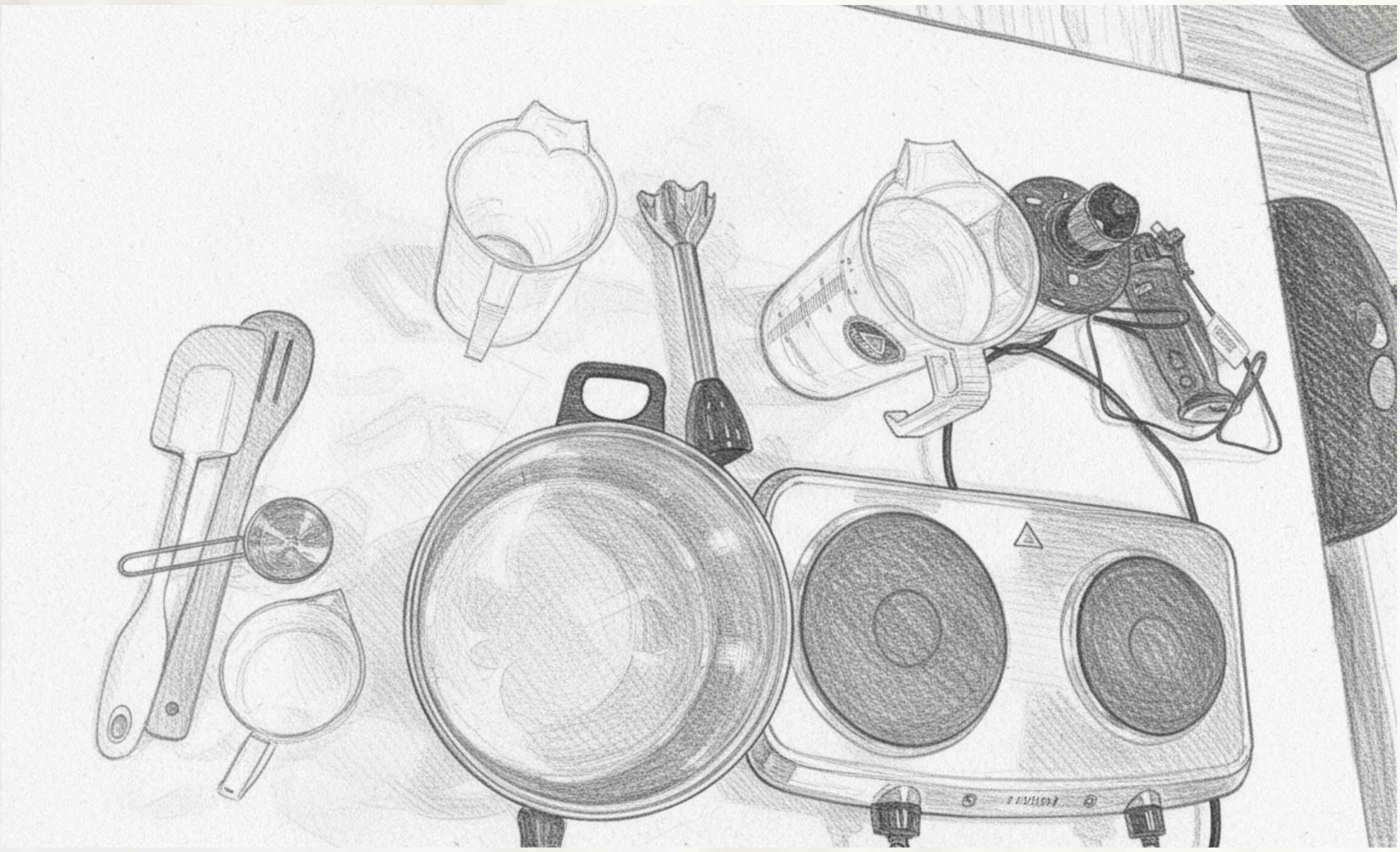
Assembly Guide: A step by step guide to making a SeaWool Block

This guide outlines a clear and practical process for producing SeaWool blocks, beginning with material collection, followed by mixing, and concluding with block formation. It demonstrates how individual components are transformed and integrated into a composite material, resulting in a bio-material suitable for structural applications.

Contents:

Tools Needed:

- Bucket x 4
- scissors
- Scales for weight material
- Pots for heating seaweed
- Source of heat
- Gloves
- Spoons
- Food processor / way of blitzing seaweed
- Moulds ready
- Hand carder (strong wool)
- Mixing cups
- Space to hang / dry material
- Coconut Oil / spray



Timeline of Collec

Timeline of Events:

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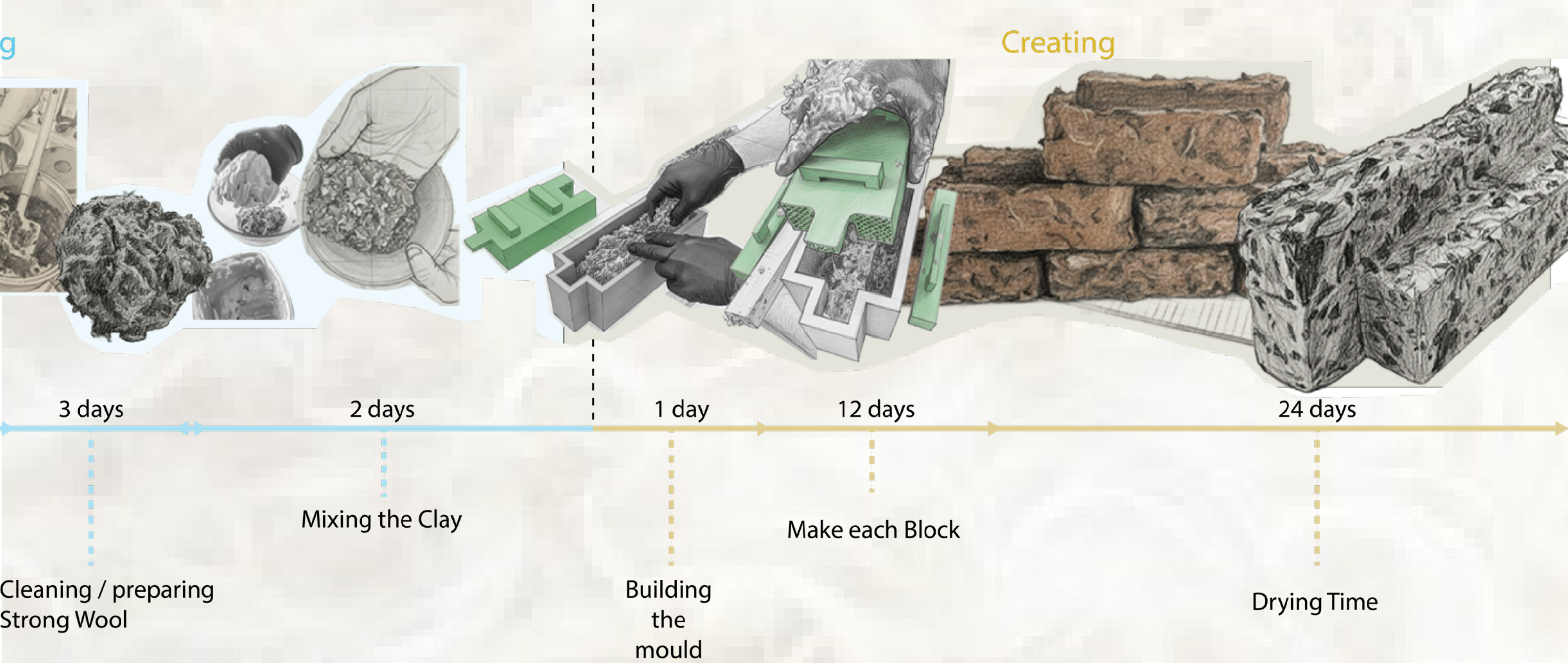
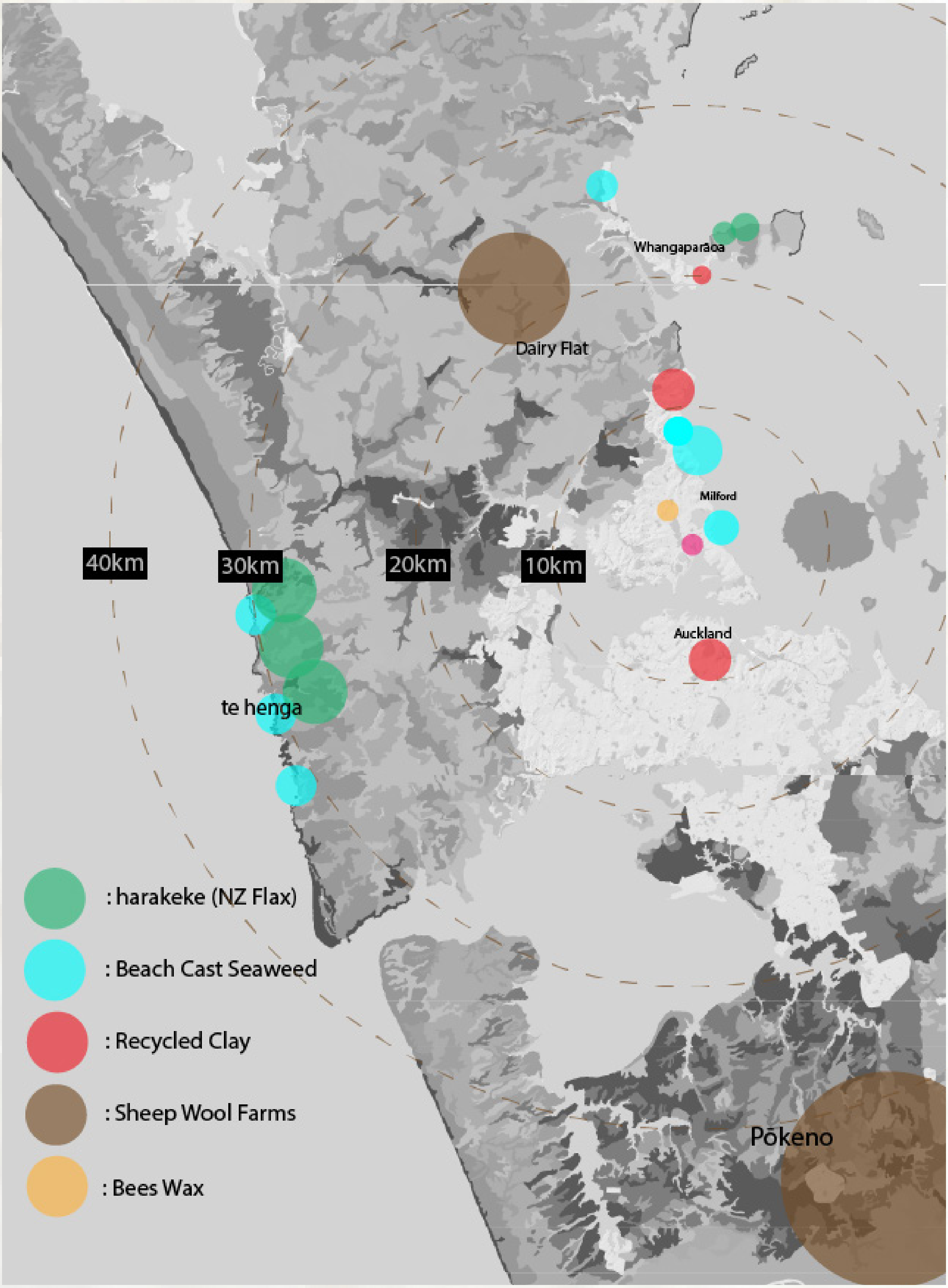


Material Collection:



Material Preparation:

Beach-cast seaweed must be collected, shredded, and properly prepared. Refer to pages 8 - 10 for the full preparation procedure required to produce the Seaweed Paste.

Strong wool must be arranged in advance, as local farmers require sufficient time to prepare and supply the material. Refer to pages 11–12 for the full process to ensure the strong wool is ready for mixing.

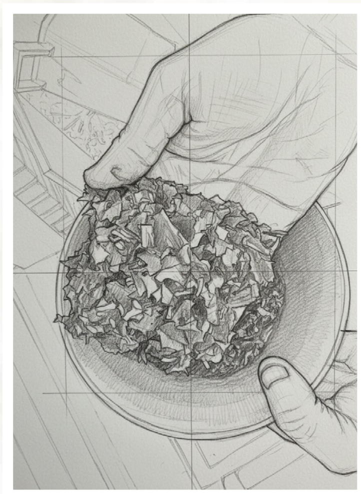
Recycled or unwanted clay can be sourced from a variety of companies, including builders, plumbers, and electricians, essentially anyone excavating clay that will not be reused. This process helps divert the material from becoming waste. Please refer to page 14

Seaweed Preparation:

1. Collecting the Seaweed
Begin by gathering seaweed from a local beach. The best time to collect is after a storm or when strong onshore winds have been blowing for two or more days. Any beach-cast seaweed will work, though brown kelp is ideal for this process.

2. Washing and Drying the Seaweed
After collecting the amount you need, rinse the seaweed to remove insects, debris, and excess contaminants. A little sand left behind is fine and can even help during drying. Once washed, hang the seaweed to dry completely. Drying strengthens its natural hardness and makes it far easier to transport, as dried seaweed weighs significantly less than when wet.

3. Preparing the Seaweed for Processing
When fully dried, chop the seaweed into strands. The size of the pieces depends on how smooth you want the final product to be. Finer chopping generally results in a smoother mixture later on.



4. Finely Chopping the Seaweed
Start by hand-cutting the seaweed with scissors, then transfer it to a food processor or similar chopping device. Process it until you achieve a very fine texture. If the mixture becomes too dry and the processor struggles, add a small amount of water to help it blend evenly.

5. Heating the Seaweed Mixture
Next, heat the chopped seaweed to release its natural thickening properties. Add the seaweed to a pot in measured handfuls, keeping track of how many you add—this will be important for the next step. Stir gently as it heats. Once the mixture begins to boil and simmer, you're ready to move forward.

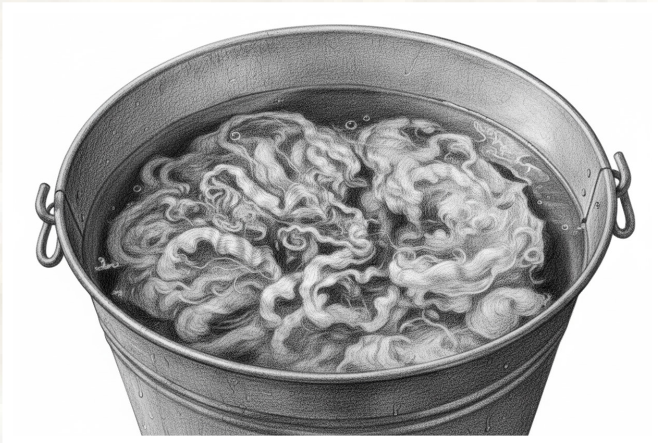
6. Creating the Seaweed Paste
When the seaweed is boiling, prepare the thickening mixture. For each handful of seaweed added earlier, mix one heaped tablespoon of cornstarch with a small amount of water. Pour this into the pot while stirring. For example, if you added five handfuls of seaweed, you'll need five tablespoons of cornstarch.

Final look of Seaweed :

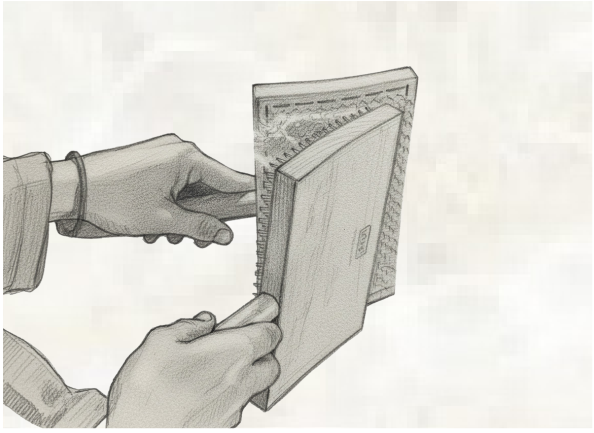
Sheep Wool Preparation

1. Collecting the Sheep Wool
Gather the wool from a local farm. Wool can come in many forms depending on how it was removed or stored, but in most cases you'll follow the four steps outlined below to prepare it properly.

2. Washing the Wool
Begin by washing the wool in warm, soapy water. This removes contaminants such as dirt, oils, and any debris attached to the fibers. Gently agitate the wool without over-handling it to avoid felting.



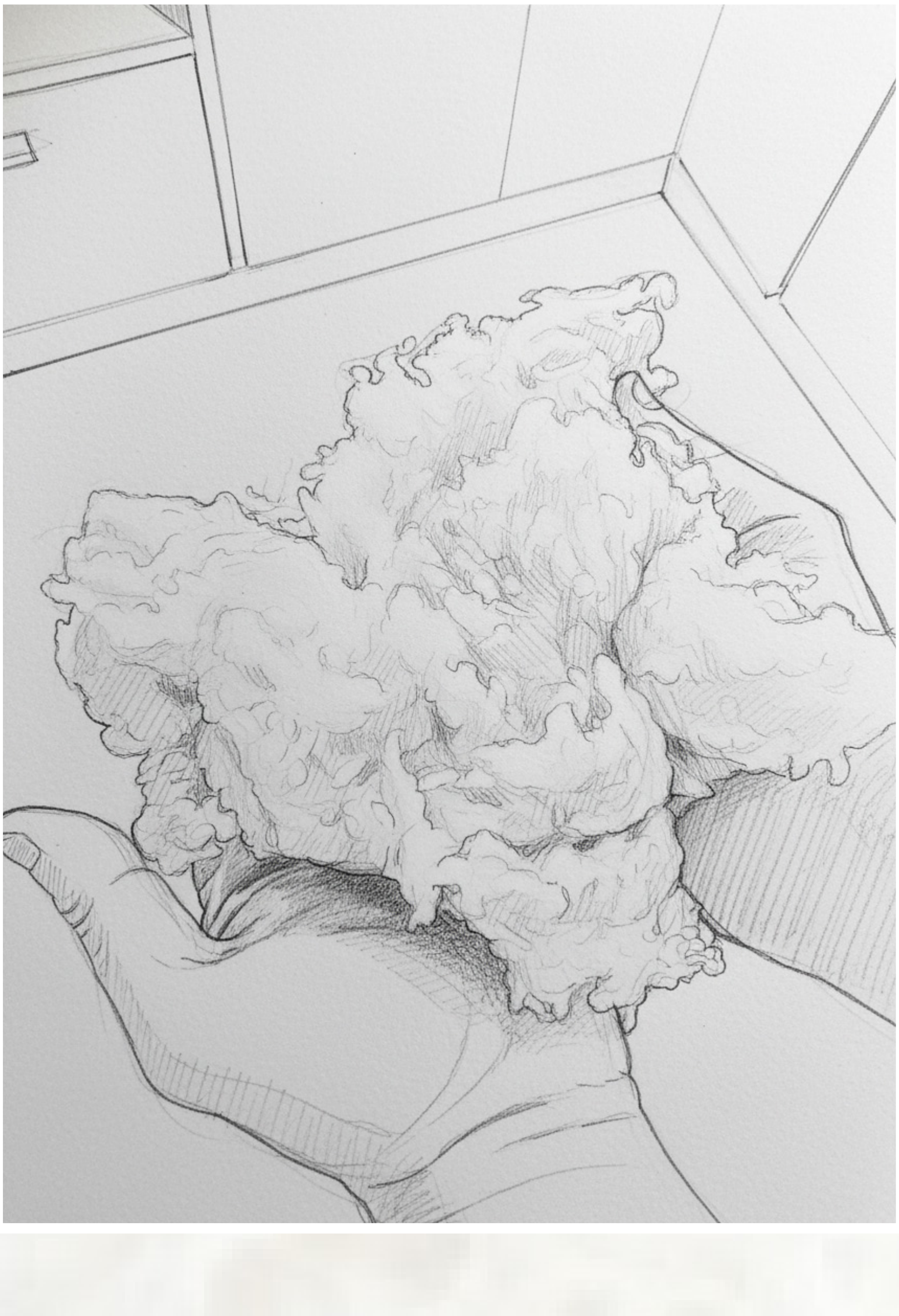
3. Drying the Wool
After washing, spread the wool out to dry. This process can take a couple of days depending on airflow and weather conditions. Ensure it is fully dry before moving on to the next step.



4. Carding the Wool

Once the wool is completely dry, process it through a hand carder. Carding separates and aligns the fibers, making them lighter, fluffier, and much easier to mix into the seaweed blend later on.

Final Sheep Wool



Clay Preparation

1. Collecting Recycled Clay

Source recycled clay from a local company that is discarding excess material. Contact them in advance to arrange collection and confirm how the clay will be provided. Depending on the quantity you need, you may need to organise buckets, containers, or a trailer for transport.

2. Adding Water to Form a Clay Paste

Once you receive the clay, begin by adding water to soften it into a workable paste. The amount of water required will vary depending on how dry the clay is. Aim for a consistency that is moist and pliable—slightly wetter than a typical clay body, but still able to hold shape.

3. Mixing the Clay

After adding water, mix the clay thoroughly. This can be done by hand or with an electric mixer, depending on the volume you're working with. Continue mixing until the clay is smooth and evenly hydrated.

Clay test:

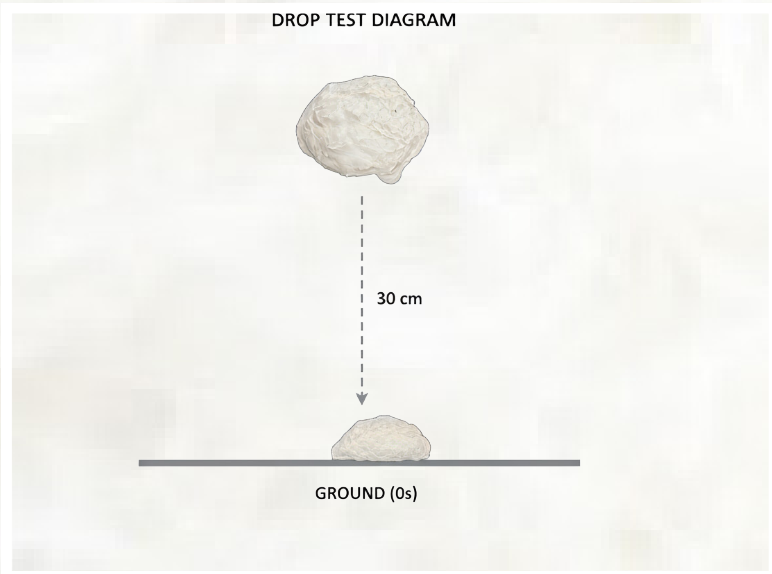
There are two very simple tests. These tests will determine whether your clay is too wet or too dry.

- Performing the Sun Test

To carry out the sun test, roll a ball of clay roughly the size of your palm (about a fist). Place it in direct sunlight and leave it to dry for 48 hours.
If the ball cracks: the clay mixture is too dry and needs more water.
If the ball collapses or loses its shape: the mixture contains too much water and needs more clay added.

- Performing the Drop Test

Using the same fist-sized clay ball, drop it from a height of approximately 30 cm and observe the result.
If the ball compresses more than half its original height: the mixture is too wet; add more clay.
If the ball breaks apart into many pieces: the mixture is too dry; add more water.

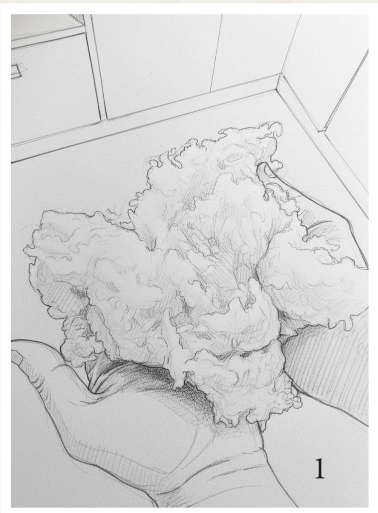


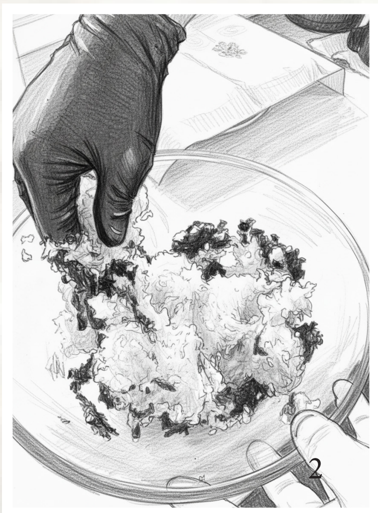
Mixing Process

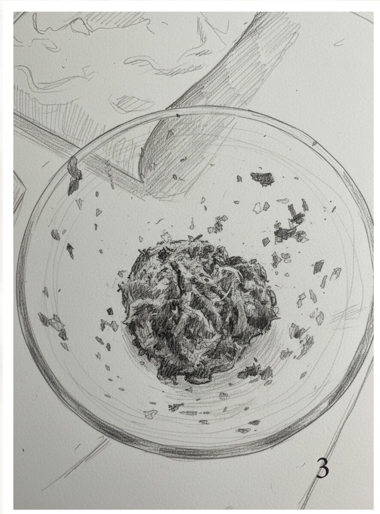
The mixing process is very simple. This low-tech method allows for around 10% variation in material volumes, making the process accessible to almost anyone.

Measuring Volumes of Materials

For this mixture, the measurements are intentionally simple and flexible, making the process accessible to almost anyone.
For every cup or handful of seaweed paste, use one cup or handful of recycled clay.
The ratio is roughly 1:1, regardless of whether you measure by volume or by hand. Its okay to use slightly less clay as well.
Use as much strong wool as possible.
The wool acts as the main structural fibre, so continue adding it until the seaweed paste can no longer absorb any more.





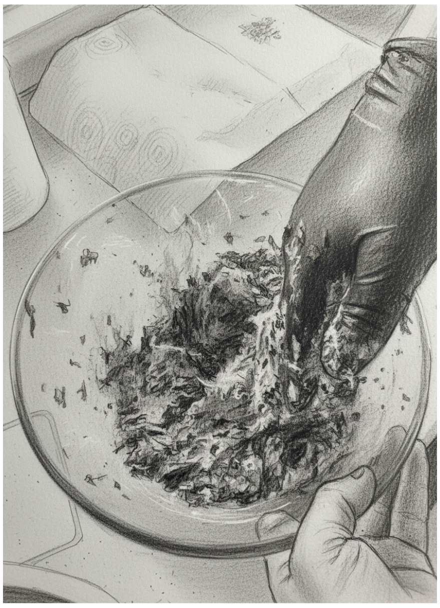


1. Combining the Seaweed Paste and Strong Wool

Following your measuring guidelines, begin mixing as much strong wool into the seaweed paste as possible. The seaweed will start with a thick, glue-like texture, but as you gradually add wool, the mixture will begin to bind together and form a cohesive ball. Continue adding wool until the seaweed paste can no longer absorb any more—this indicates the mixture is fully saturated and ready for the next step.

2. Incorporating the Clay

Once the wool is fully integrated, begin combining the materials. Add one handful of clay and one handful of the seaweed-and-wool mixture into a separate bucket or mixing container. Blend the two materials thoroughly until there are no large clay clumps remaining. The mixture should be uniform and able to form a solid, stable ball when pressed together.



3. Preparing for Testing or Final Production

After the materials are fully combined, you can proceed to sample testing or, if the mixture meets your requirements, move directly into creating the final product. At this stage, the texture should resemble the reference image you mentioned—firm, cohesive, and evenly blended.

Sample test:

1. Preparing the Sample Block

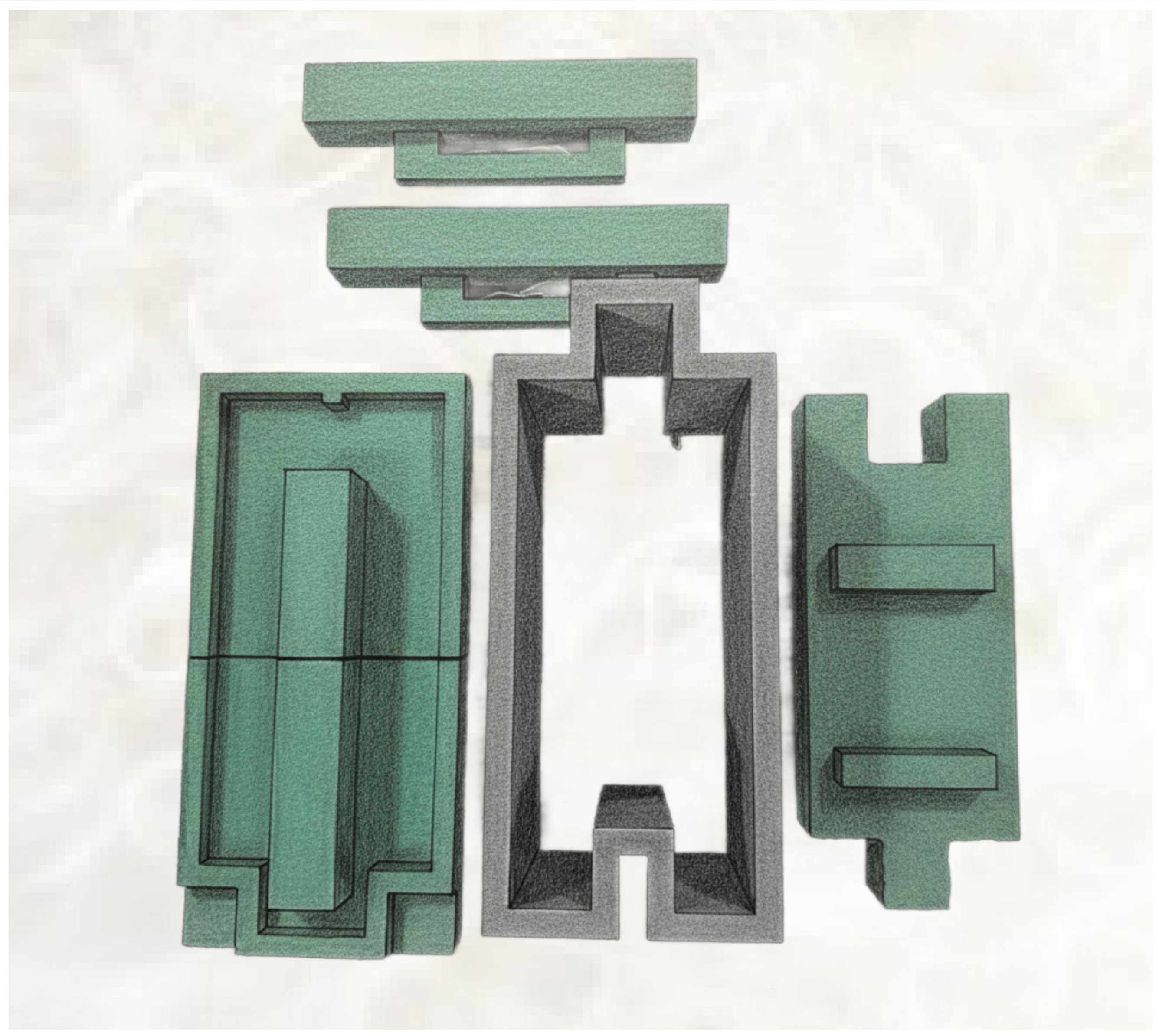
A sample test is an essential step for understanding how your material behaves before committing to larger-scale production. Using a small 10 × 10 cm cube, press together a test brick using the pre-mixed ingredients you've already prepared. This allows you to evaluate the material quickly and make adjustments early in the process.

Mould Setup:

Using 3D-Printed Moulds

All moulds used in this process are 3D-printed from an open-source file, allowing anyone to produce a precise and consistent mould no matter where they are located. The design features an interlocking brick system, which is more complex than a standard mould, but this guide will walk you through the most effective method to achieve clean, accurate results.

As you repeat the brick-making process, you'll naturally become more familiar with the material and the mould. Over time, the workflow becomes smoother, and when it comes to construction, the interlocking bricks will simply lock into place, creating a stable and intuitive building system.



Ramming of material

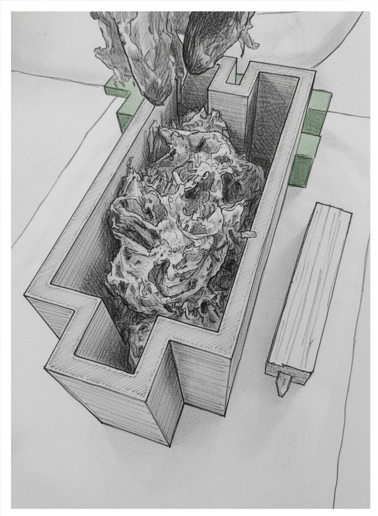
Now that the biomaterial is complete, the next step is to place it into the mould. This will create a solid brick, ready for construction.

1. Setting Up the Workbench

Prepare your workspace before you begin. Have your 3D-printed mould, compacting stick, and paper towels within easy reach. This helps maintain a smooth workflow and consistent results between each brick. It is also very helpful to have an extra pair of hands during this stage, especially when compacting or extruding the material.

Tools requied:

- Mould
- Compacting stick
- paper towels
- Oil or lubbricte / or sand
- gloves
- place to dry bricks
- paper towels for cleaning mould

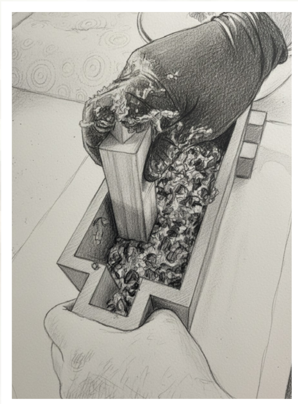


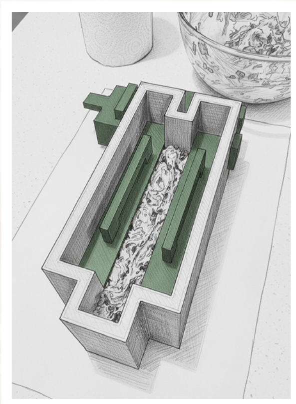
2. Creating the First Layer

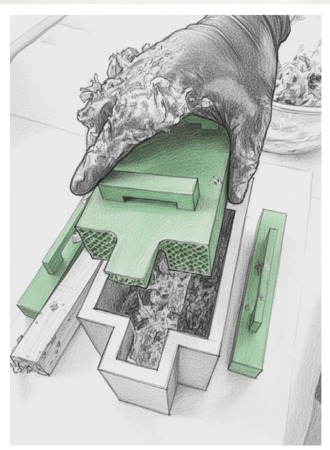
Start by spraying a light coat of oil around the inside of the mould. This prevents the material from sticking later on. Begin adding your material mixture in thin layers. Make sure the mixture is pressed firmly into the corners and edges of the mould. The first layer should be especially thin to ensure it fits neatly around the bottom section of the interlocking shape. After each layer, use the compacting stick to press the mixture down, removing trapped air and ensuring a strong bond between the clay, strong wool, and seaweed compo-nents.

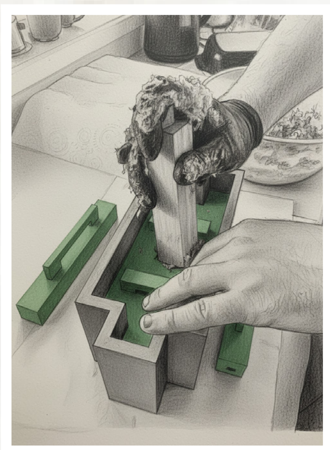
3. Using the Green Spacers

When the mould is about halfway full, insert the green spacers. These help form the top section of the interlocking brick. Continue filling the mould until the material reaches the same height as the spacers. Once level, carefully remove both spacers before moving on.









4. Final Layer and Extrusion

Spray a small amount of oil onto the lid of the mould to prevent sticking during extrusion. Place the lid on top and press the material firmly to give it a final compaction.
When you're satisfied with the compression, begin pressing the material from the lid side so it extrudes through the opposite opening. This step may require some force, so having another person assist can make the process easier and ensure an even, controlled extrusion.

Drying time:

Drying the Brick

Once the brick has been fully extruded, place it in a well-ventilated area to dry. This stage typically takes 2–4 weeks, depending on the surrounding humidity and temperature. During the drying process, the brick will gradually lose moisture and become significantly lighter, usually shedding around half of its original weight.

When fully dried, the brick should weigh approximately 1–1.2 kg, indicating that it has cured properly and is ready for testing or use.

8.0 Discussion:

This thesis explored the creation of, and potential application for, regenerative bio-bricks made from locally sourced biomaterials, particularly strong wool. In this material study, I investigated how to combine strong wool, beach-cast seaweed, and recycled clay to form a biomaterial composite for the fabrication of a bio-brick.

For this research, I drew on the Material Driven Design (MDD) framework (Karana et al., 2015). This informed my experimental process and required me to first understand the characteristics of each material individually before developing composites for bio-brick production.

While MDD was a useful framework, I needed to adapt it to my specific work, as it requires extensive consideration of sensory and visual information about a material that is less relevant to my work. The project primarily focused on the strength and workability of each composite material. Shifting the focus away from visual and sensory application, into adjusting the 3rd stage of MDD to examine the characteristics of each composite biomaterial in greater detail and understanding of its low-tech application.

8.1 Materials & Methods

The process of experimenting with biomaterials to produce a composite bio-brick was highly iterative. The exploratory nature of this project and the MDD framework were highly suitable for the study I was undertaking, as I was able to refine my vision of the outcome as I interacted more with the materials.

While I gained key insights into the materials and their interactions and behaviours, the process was not seamless; I encountered multiple issues in the experiments, namely drying time, water content, and the required accuracy to produce a successful composite. Therefore, creating a low-tech version of the bio-brick seemed infeasible. However, through persistence and multiple rounds of trial and error, I developed a low-tech, locally sourced bio-brick. This was guided by a few key principles throughout the design process. Each material used in the experiment had to have multiple advantages, having characteristics and properties in two or more categories. Shown on the material chart categories (Figure 6). The second key principle was that it had to be local to Auckland or to the building site where the user is located. Thus, largely reduces material transport emissions. Lastly, the third principle is that it must be sufficiently basic that anyone can perform it. If a product is easy to use, people will be motivated to use it. This is being referred to as low-tech design.

Initially, 20 locally sourced biomaterials were identified as potential materials for experimentation. While the characteristics of many of these materials were promising, due to time constraints, I chose to conduct a thorough experiment on only four key materials. I selected these materials based on their use in previous studies, such as the Sargablock. (*Home - Sargablock.Com.Mx*, n.d.)and their properties, spanning multiple categories of requirements for composite materials.

Strong wool had many beneficial properties; however, some of these also made the material difficult to work with, particularly at the stage when I began integrating the materials to make a composite. Hence, I had to undergo a trial-and-error process, adjusting material ratios to create a viable bio-composite.

Originally, I theorised that adding the strong wool in the final stage of material production would be more effective, as this would make the strong wool the driest component of the composite. However, I found that soaking the strong wool in water allowed me to incorporate it into the composite at the start of mixing, ensuring full integration with the other constituents. This also results in the gradual release of moisture throughout the drying process.

The incorporation of strong wool provided robust binding and insulation. Using strong wool mitigated the need to fire the clay, reducing the energy required to produce the bio-brick.

Beach-cast seaweed acted primarily as a natural biopolymer binder in the bio-brick. When heated, the seaweed releases its biopolymer, which increases the brick's stiffness as it dries. A key discovery was that seaweed could be incorporated into the cornstarch-water mixture to produce a seaweed paste, thereby increasing the bio-brick's drying time to approximately 1 week. In this combination, the cornstarch served as a short-term hardener, enabling immediate workability. The seaweed served as a long-term hardener, hardening the composite during drying.

Initially, I was hesitant to use recycled clay because I believed a more sustainable filler was available. The benefits of recycled clay were its ready availability, increased strength, reduced water content, and shorter drying time for the bio-brick.

One challenge with using the clay was that if the brick hardened too quickly, the clay would crack. On the one hand, I was pleased to have reduced the drying time, making the creation process more efficient; on the other hand, I faced a new challenge. To overcome this issue, I found that increasing the amount of seaweed increased the bio-brick's flexibility, so that when the clay hardened, it did not crack. This illustrates how constant interaction between the materials and the user facilitated the identification of each material's roles and characteristics within the composite.

Another challenge of making the bio-brick was understanding and controlling the moisture levels. While this was achieved through precise measurements, iterative experimentation enabled me to develop a visual guide to the quantities of each material required to produce a successful bio-brick.

I found this part of the experiment highly engaging because it required constant interaction with the materials. In this manner, I was able to define and redefine the roles of each material within the composite. I now appreciate what is required to produce a successful material and how material interactions can influence the outcome.

The final recipe was determined based on multiple criteria:

- How easy the brick was to make (low-tech)
- The strength of the brick (compressive & tensile)
- The margin of error for measuring without precise scales

Final recipe:

20% wool

40% seaweed paste

40% recycled clay

Figure 65: SeaWool Brick

The interaction of the above materials resulted in a strong, solid, light, and fibrous bio-brick. The strong wool's inherent fibrous nature facilitated interlocking of the materials, while the seaweed supplied a natural polymer hardener. The cornstarch enabled the composite material to be workable immediately after all ingredients were integrated. Overall, the composite material stayed intact throughout the drying process and formed a rigid bio-brick. I was unable to compress, tear or break the bio-brick using my own force.

The final recipe for the bio-brick achieved its design with a low-tech approach. This enabled the bio-brick to be produced on-site, eliminating the need for precise measurements. In this case, the materials could be measured using approximations of a cup size and visual cues to produce a successful brick still.

Overall, the combination of strong wool, beach-cast seaweed, and recycled clay created a composite biomaterial that could be moulded into a bio-brick for low-tech structural applications. The applications of this bio-brick in its current state could include non-load-bearing walls, flooring panels, and a biodegradable plant-a-box or a similar structure.

With further refinement, the bio-brick can be used in construction for load-bearing walls and single- and two-story dwellings, provided it meets applicable building standards.

8.3 Comparison to precedents

Numerous key precedents informed my decision to investigate the use of biomaterials in structural applications. For example, the Sargablock is made from seaweed and clay. Red House Studio is creating mycelium bricks from Namibian bush waste. These two key precedents show what is possible in a structural manner. By looking at what each product did, I see success. I was able to use these ideas and begin to incorporate their knowledge into my own bio-brick.

These key ideas include:

Saragblock:

- seaweed creating a hardener/filler
- low-tech building approach
- creating a structural application
- locally available

Mycelium brick (Red House studio)

- using waste product to build with

- creating a structural application
- locally available

My bio-brick incorporates all these key attributes into the build. Most importantly, the locally available materials are sourced from New Zealand. This bio brick has shown promise for structural applications, including those listed above. Being created with little to no measurements makes it accessible to anyone. In addition, waste materials such as strong wool and clay from local work sites are used. Making this bio-composite material has potential for structural applications. Moving the line away from biomaterials used primarily in interior applications.

8.4 Environmental and economic implications:

This bio-brick could help address the significant waste and emissions generated by the construction industry. The bio-brick is inherently sustainable due to its ability to biodegrade and the fact that some of the materials are 'recycled', namely the clay and strong wool. Furthermore, each bio-brick unit sequesters almost the same amount of carbon that a standard red brick emits during its production.

A full carbon exercise would be required to be 100% certain that the bio-brick has a net zero output. Regardless, the process of collecting local materials, using a low-tech approach, and reducing reliance on professional builders or heating and drying tools is far more sustainable than current building practices.

Utilising cradle-to-cradle materials increases the likelihood of achieving an overall carbon-neutral result. For example, seaweed in its early life sequesters carbon from the atmosphere, while strong wool also acts as a carbon store. When combined into a composite bio-brick, the carbon is contained for the remainder of the material's period of use. Following this, the bio-brick will begin biodegrading, likely occurring over months to years. The slow release of carbon from decomposing keratin will make the surrounding ecosystem a carbon sink.

Overall, the utilisation of biomaterials supports a cradle-to-cradle approach that complements the principles of sourcing materials locally and using low-tech construction processes. Furthermore, repurposing strong wool could affect the material's value and, consequently, its profit margin, thereby benefiting New Zealand farmers.

8.5 Limitations :

8.5.1 Testing:

The testing I conducted was qualitative and low-tech. Unfortunately, the resources for structural testing could not be reallocated to a low-tech approach.

While I determined the basic properties of the bio-brick, formal testing is required to fully understand its performance and how it compares with other traditional building materials.

The individual materials used in the bio-brick exhibit inherent properties that suggest the bio-brick may be partially fire-resistant and contribute to thermal insulation when used in a building application. Future testing should ideally measure the bio-brick's compressive and tensile strengths, durability, R-value, fire and water resistance, and true biodegradability. Unfortunately, due to time and monetary constraints, I was unable to perform such testing during my project.

8.5.2 NZ building code of compliance:

To comply with the New Zealand Building Code, the bio-brick would require rigorous testing. Testing of the structural integrity, durability, moisture content, and potential hazards of the bio-brick would be required for it to be considered a mainstream building material. If this bio-brick met building standards, it would be the first of its kind to be created in New Zealand.

8.5.3 Scale:

The experimentation was conducted on a small scale; however, upscaling the production of this bio-brick is plausible. However, the current drying time remains a limiting factor. The bio-brick must be left to dry for 1-2 weeks before it can be removed from the mould and used in construction. Future research could investigate ways to reduce drying time.

8.5.4 Life cycle:

Complete life-cycle assessment (LCA) data are unavailable. The estimated carbon sequestration and emissions calculations have been performed for this bio-brick; however, further analysis would be necessary to determine the material's true life-cycle.

8.8 Future Research Opportunities

- Complete standardised testing for the bio-brick to achieve the building code of compliance
- Waterproofing of the bio-brick
- LCA and carbon accounting of the bio-brick
- Explore other possible combinations of biomaterials to create a bio-brick

- Live trials and demonstrations for communities. E.g. a plant-a-box for a community garden
- Mapping of the potential value of the bio-brick for local businesses, e.g., the cost of strong wool and the jobs created by sourcing biomaterials, etc.
- Community and cultural engagement: Explore how biomaterials can bring communities together and provide an incentive to live more sustainably in their local environment.
- Further seaweed applications in the construction world.

8.9 Final remarks

Research has shown that biomaterials are a key to reducing carbon emissions in the construction industry. By using locally sourced biomaterials, I have demonstrated that it is possible to create cradle-to-cradle material composites. Furthermore, these biomaterials were constructed using low-tech methods which promotes us to rethink the development of mainstream construction materials.

Other implications of this work were not discussed in depth in this thesis. However, employing a low-tech approach to biobricks demands more consideration of how we interact with our surroundings, how we gain knowledge and understanding of materials, where a material can be sourced from and when, as well as increasing awareness and accessibility of construction for the community.

To shift the paradigm of material construction, we need to engage more deeply with materials, from sourcing through to end-of-life. The low-tech approach to bio-brick prompts us to consider when and where a material might need to be sourced from, what and who do we need to approach to achieve this, and how long it takes to construct, mix or dry a material for the project. This promotes the reconsideration of our relationship with the built environment through community, materiality and gathering. It is not as simple as pay now, import and throw out later. This shift in how we think will ultimately shape how we interact within the built environment and move us to a more sustainable world for human and non-human entities.

Significant work remains to get the bio-brick up to standard for commercial use. However, this research has demonstrated proof of concept for a locally sourced biomaterial-based composite brick which contributes to the advancement of strong wool as a structural material.

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Appendix:

1a: Picture of the presentation

1b: Picture of presentation 1.2

2a: Picture of finished wall.