

Embracing the Air:

The Sensory Experience of Hemp-Lime Architecture

by

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EMBRACING THE AIR
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HEMP-LIME ARCHITECTURE



ABSTRACT

Through this research, I explore the multi-sensory properties of hemp-lime construction as an antidote to the overly visual experience of contemporary architecture. I begin design from the material and elaborate on the senses involved with the dynamics of hemp walls: the airy trio of humidity, thermal and sound. I dissolve the complexity of a conventional wall, where the layers act separately, and compare this to a hemp-lime composition which acts in unison. Throughout, my research strives to be environmentally responsible with methods of construction that consider the lifecycle of the material; from the conception of a carbon-negative product to the built experience, and to its afterlife of being recycled or fully decomposed. Alongside the historical significance of hemp and lime, the project works at crafting a space of reverence, located in the sacred site of St Raphael's Cemetery (Ontario), that cleanses the occupant's senses through materiality.



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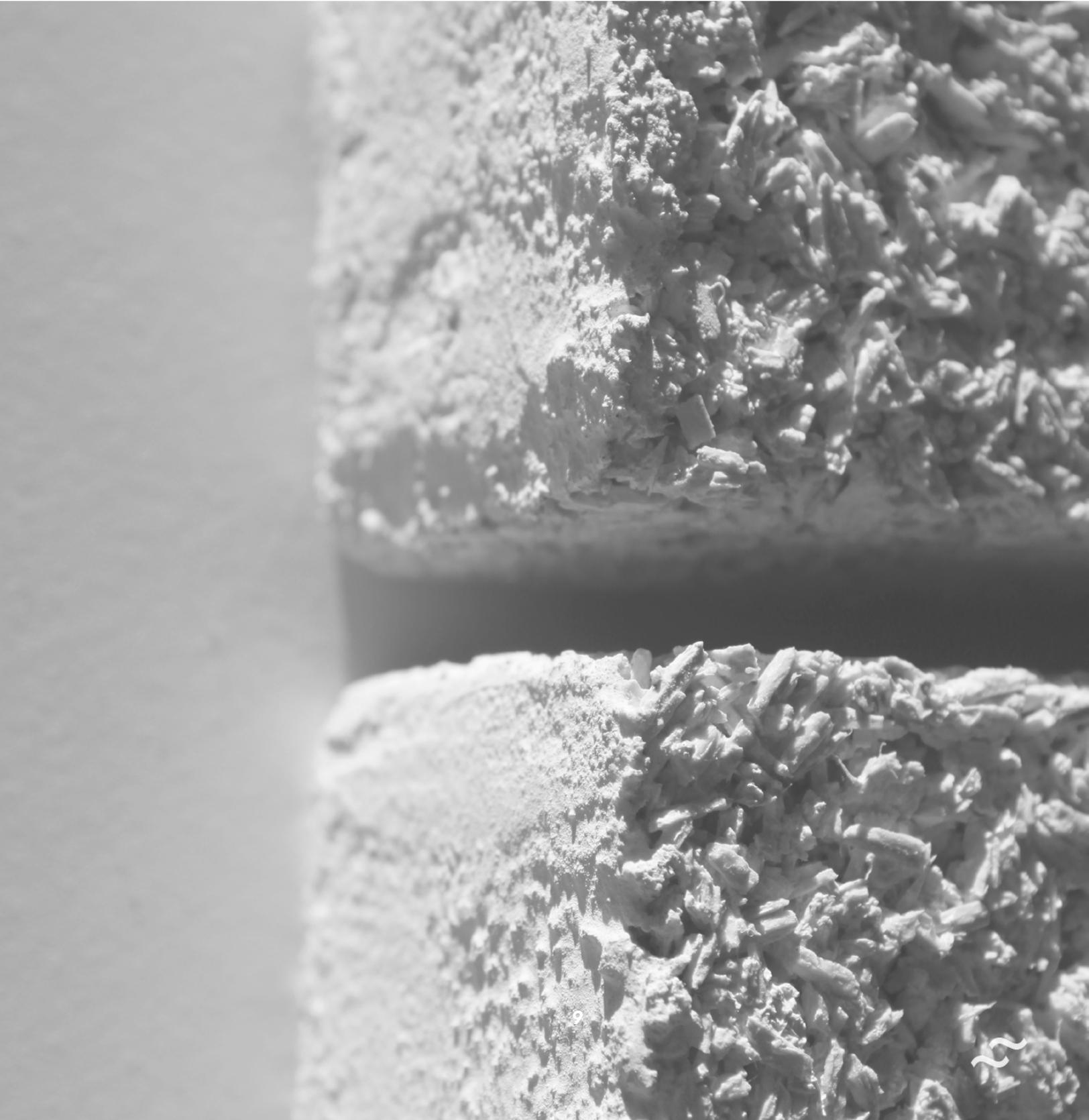
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CH.1

INTRODUCTION



1.1 MATERIALS AND THE GLOBE

Construction materials today can release volatile organic compounds, carry extensive embodied energy, generate unnecessary waste, and involve significant transportation emissions. These manufactured products can be harmful; from the workers in the facilities where they are made, to the builders on site and even the individuals who live within these spaces. All these factors are detrimental to the air, the soil, and the individual. Unfortunately, the construction methods that exist today do not show signs of ceasing this cycle. The manufacturing of building materials continues to use excessive fossil fuels which are becoming increasingly scarce, overly costly and where the impact of using non-renewable resources is unsustainable.¹

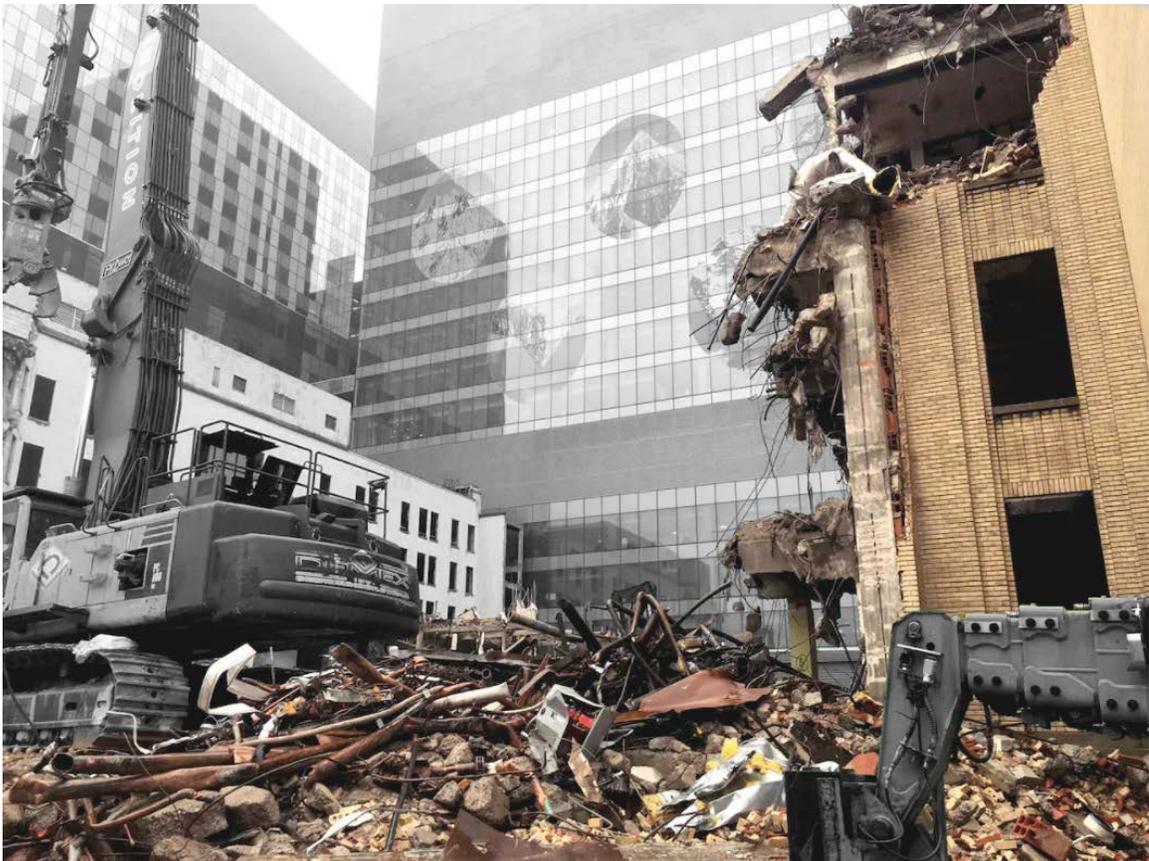


Figure 1 – Debris from Montreal’s Saint-Luc Hospital demolition, 2018

Source: CBC News, <https://www.cbc.ca/news/canada/montreal/montreal-construction-farmland-enquete-1.5057076>

1 Bevan and Woolley, *Hemp Lime Construction: A Guide to Building with Hemp Lime Composites*, 1.



Evidently, greenhouse gases are rising, and global building emissions are largely responsible and are increasing yearly. In the International Energy Agency (IEA) Global Status Report of 2019, the building and construction sector was responsible for 39% of energy and process-related carbon dioxide (CO₂) emissions, which rose 2% from 2017-2018 to reach a record high of 9.7 gigatons.² And where 11% of these emissions ensued from the creation of building materials; the leaders being steel, cement and glass.³ Unlike operational emissions, which can be lowered progressively with the use of renewable energy and better energy efficiency renovations, embodied carbon emissions are enduring once a building is built or a material is constructed.⁴ As influential as building materials are for the air they are equally impactful for the earth. In Canada, the amount of construction, renovation, and demolition waste (CR&D) [see figure 2] was 3.8 million tons in 2016; of that amount, 3.2 million tons were disposed of with less than 16% being diverted through material recovery or recycling and composting.⁵

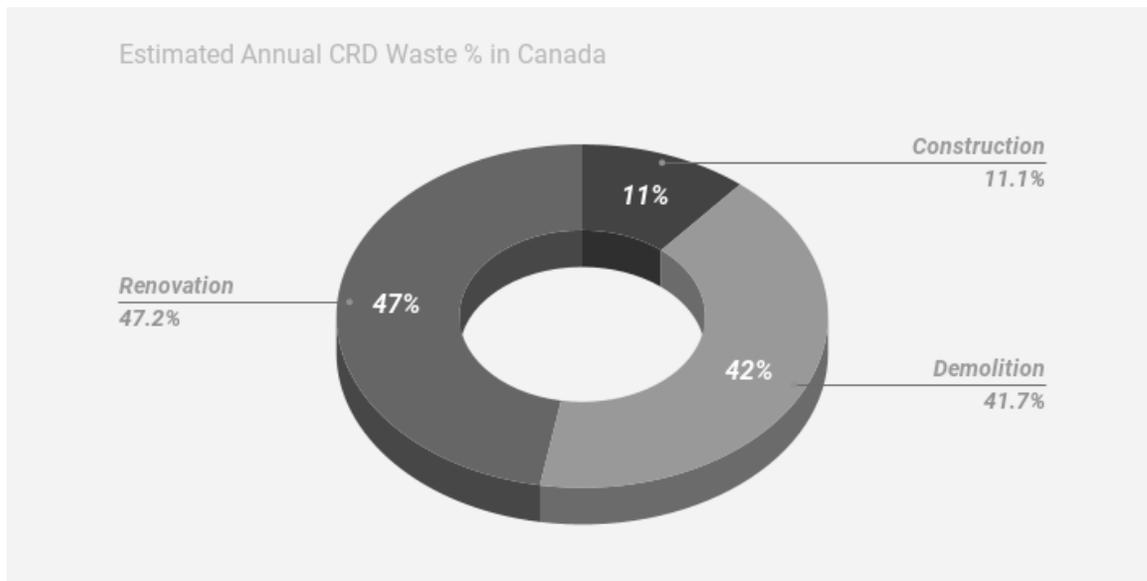


Figure 2 – Construction, Renovation and Demolition waste Canada 2016

Data source: Environment and Climate Change Canada, <http://publications.gc.ca/site/eng/9.884760/publication.html>

² Global Alliance for Buildings and Construction, International Energy Agency, and United Nations Environment Programme, "2019 Global Status Report for Buildings and Construction Sector," 9.

³ Global Alliance for Buildings and Construction, International Energy Agency, and United Nations Environment Programme, 9.

⁴ 2030, Inc., "New Buildings."

⁵ Environment and Climate Change Canada, "National Waste Characterization Report: The Composition of Canadian Residual Municipal Solid Waste," 13.



With the changing climatic conditions and economic crises, many organizations have begun to apply natural building methods around the world.⁶ Academic and government interest in hemp building construction has created a proficient market in Europe in just over a decade.⁷ Yet, Canada and the U.S. are decades behind Europe in sustainable building practices. The prime cause for the detachment between these continents was due to the ban on industrial hemp cultivation in North America. The prohibition was active in Canada until 1998 with the passing of the *Industrial Hemp Regulations*⁸ and recently in America with the *Hemp Farming Act of 2018*.⁹ The development of hemp construction is increasingly coming to fruition for many reasons. At the forefront, the motivation is its simplicity of only three biodegradable elements - water, hemp, and lime [see figure 3, 4].

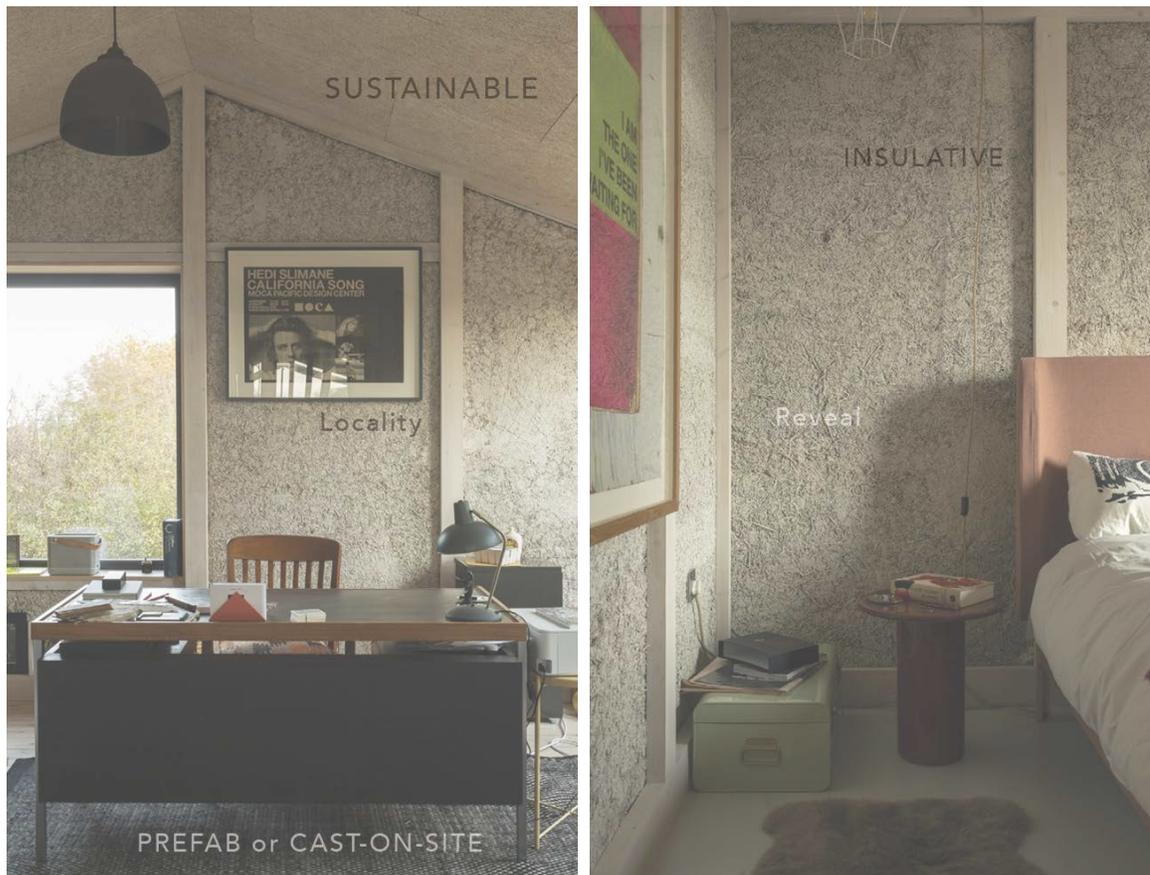


Figure 3 – Flat House constructed of hemp-lime with exposed walls, UK, 2019

Source: Practice Architecture, <https://practicearchitecture.co.uk/project/flat-house/>

6 Kennedy, Wanek, and Smith, *The Art of Natural Building*, 6.

7 Magwood, *Essential Hempcrete Construction*, 2.

8 Health Canada, "Hemp and the Hemp Industry Frequently Asked Questions."

9 "H.R.5485 - 115th Congress (2017-2018)."





Figure 4 - Flat House constructed of hemp-lime with exposed walls, UK, 2019

Source: Practice Architecture, <https://practicearchitecture.co.uk/project/flat-house/>

The use of hemp and lime as a building product has benefits at the scale of the natural environment, the built environment and to the health and experience of the inhabitant. Initially, hemp is reverted from the waste of industrial production currently dumped in landfills, composted, or used as animal bedding. Locally sourced, hemp construction can help remove the environmental impacts that come with typical materials. These factors undoubtedly call for builders, clients, and architects to make responsible decisions for selecting building products. Construction should be based on more than aesthetics and price, but led by life cycle thinking - creation, inhabitation, and degradation. Plus, a material can even be sacred. In my research, I investigate “walls” and “materials” that are more than solely a division of space. Through these constructs I highlight the word *reverence* to express their relationship to the site, to the inhabitant (both present and past) and most importantly to the future of the earth.



2.1 THE INVISIBLE GAS

Authors Rania Ghosn and El Hadi Jazairy offer insight for why environmental issues seem un-graspable. They state, “people observe daily weather changes, but they do not perceive climate... Climate change may be hard to grasp because it’s geographic representation is overly abstracted and unapproachable”.¹⁰ The systems we use today to tell the story of climate change present a deficient scale of reference. And when it comes to understanding the rising levels of atmospheric CO₂, it is difficult to comprehend for two reasons. First, the gas is invisible to the human eye. Second, the atmosphere overwhelmingly stretches as far as 10,000km above the earth’s surface (avg. human figure to the scale of atmosphere = 1:5882353).



Figure 5 – One tonne of CO₂ at pwc office, London

Source: pwc UK, <https://www.pwc.co.uk/who-we-are/our-purpose/low-carbon-circular-business/carbon-emissions.html>

Recently, a few companies have taken the task to visualize CO₂. A UK based business pwc have scaled a single ton of carbon dioxide at atmospheric pressure, into the form of a 32ft inflatable sphere, to bring an awareness to carbon emissions [see figure 5]. A second company, Carbon Visuals, capably assembles the magnitude of the invisible gas while still

¹⁰ Ghosn and Jazairy, *Geostories*, 11.

being computer generated. In one representation, they model the mass amount of CO₂ released daily (39 billion metric tons), and it can be felt at a gargantuan scale when placed over New York city measuring 3.7km high by 7.4km across [see figure 6]. Both projects introduce an impactful and necessary designer stream that makes climate change tangible.

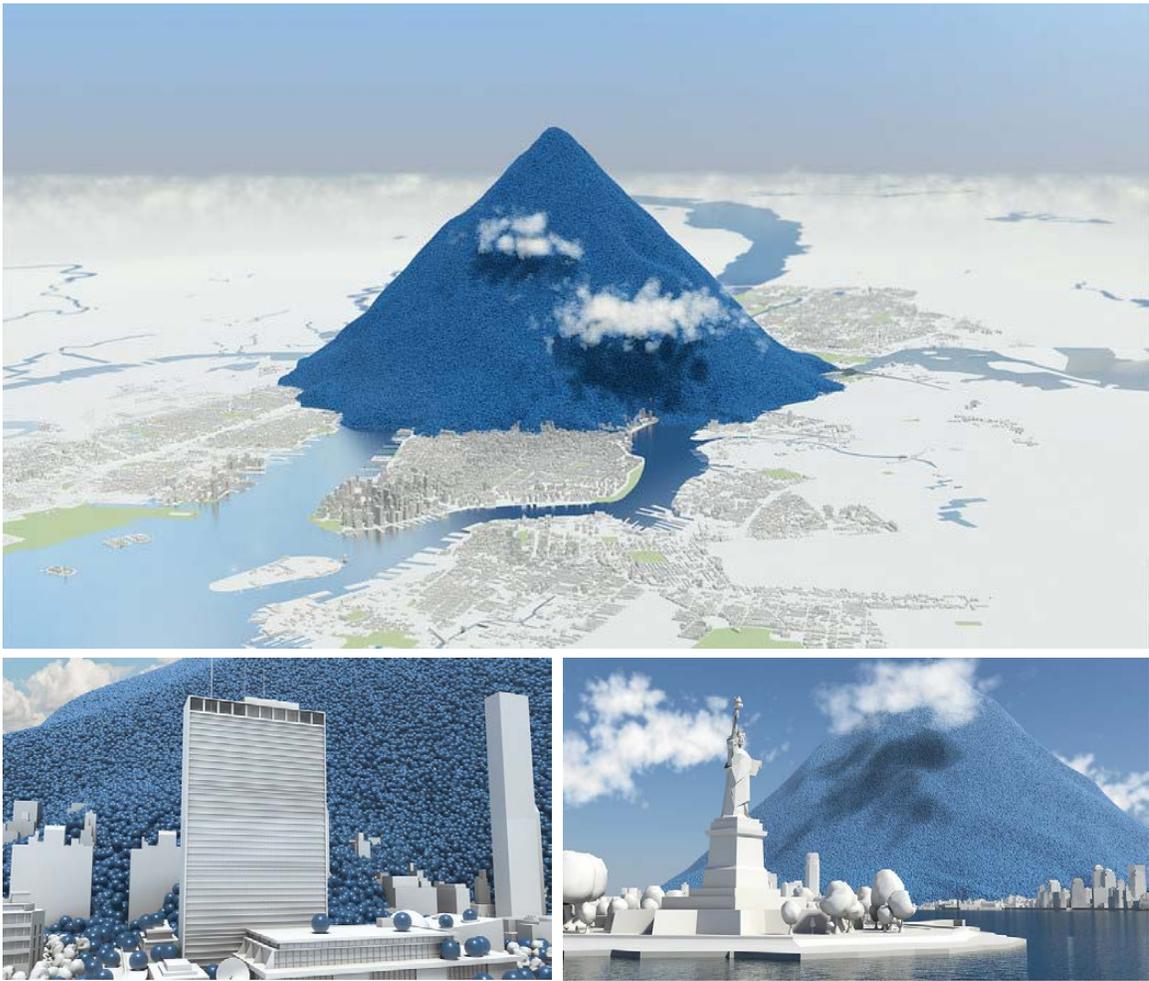


Figure 6 – Daily CO₂ emissions over NY city

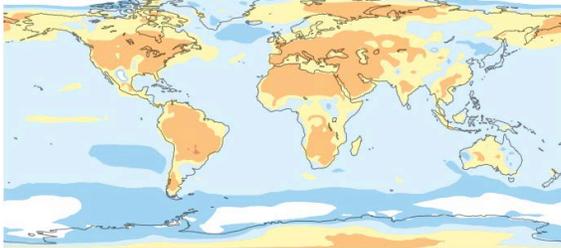
Source: Carbon Visuals, <http://www.carbonvisuals.com/projects/wbcsd>

Understanding the accumulation of emissions that pollute the air today should also consider the effects on humanity in the future. In NASA's recent Global Climate Change report, they suggest that even a minor rise in temperature from +1.5-2°C worldwide would result in daunting climate risks for humans (not including implications on natural systems) [see figure 7]. A list of these threats include increased heat related illness and mortality,

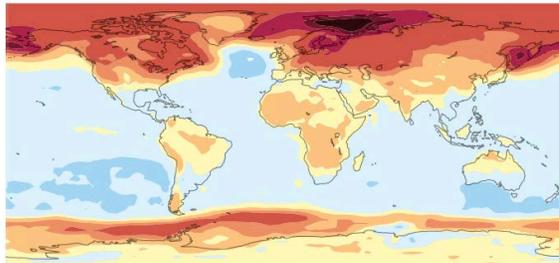


reduced food security and lower crop yields, greater vector-borne diseases, and change in salinity of coastal groundwater that will stress freshwater supply.¹¹ Seen in a new perspective, NASA's CO₂ axonometric mapping visualizes the vertical scale of atmospheric carbon dioxide. Significantly, vegetation plays a large role in sequestering the invisible gas [see figure 8].

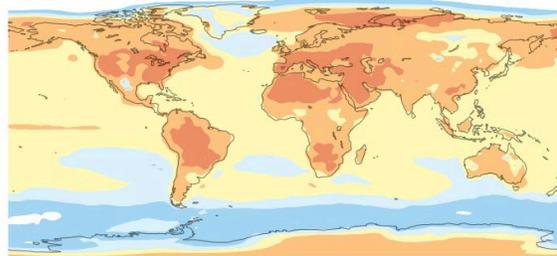
+ 1.5°C: Change in average temperature of hottest days



+ 1.5°C: Change in average temperature of coldest nights



+ 2.0°C: Change in average temperature of hottest days



+ 2.0°C: Change in average temperature of coldest nights

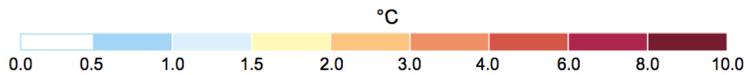
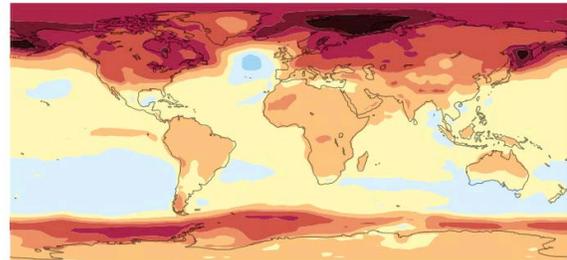


Figure 7 – Temperature rise around the globe

Source: NASA, <https://climate.nasa.gov/news/2865/a-degree-of-concern-why-global-temperatures-matter/>

11 Buis, "A Degree of Concern: Why Global Temperatures Matter - Part 2."



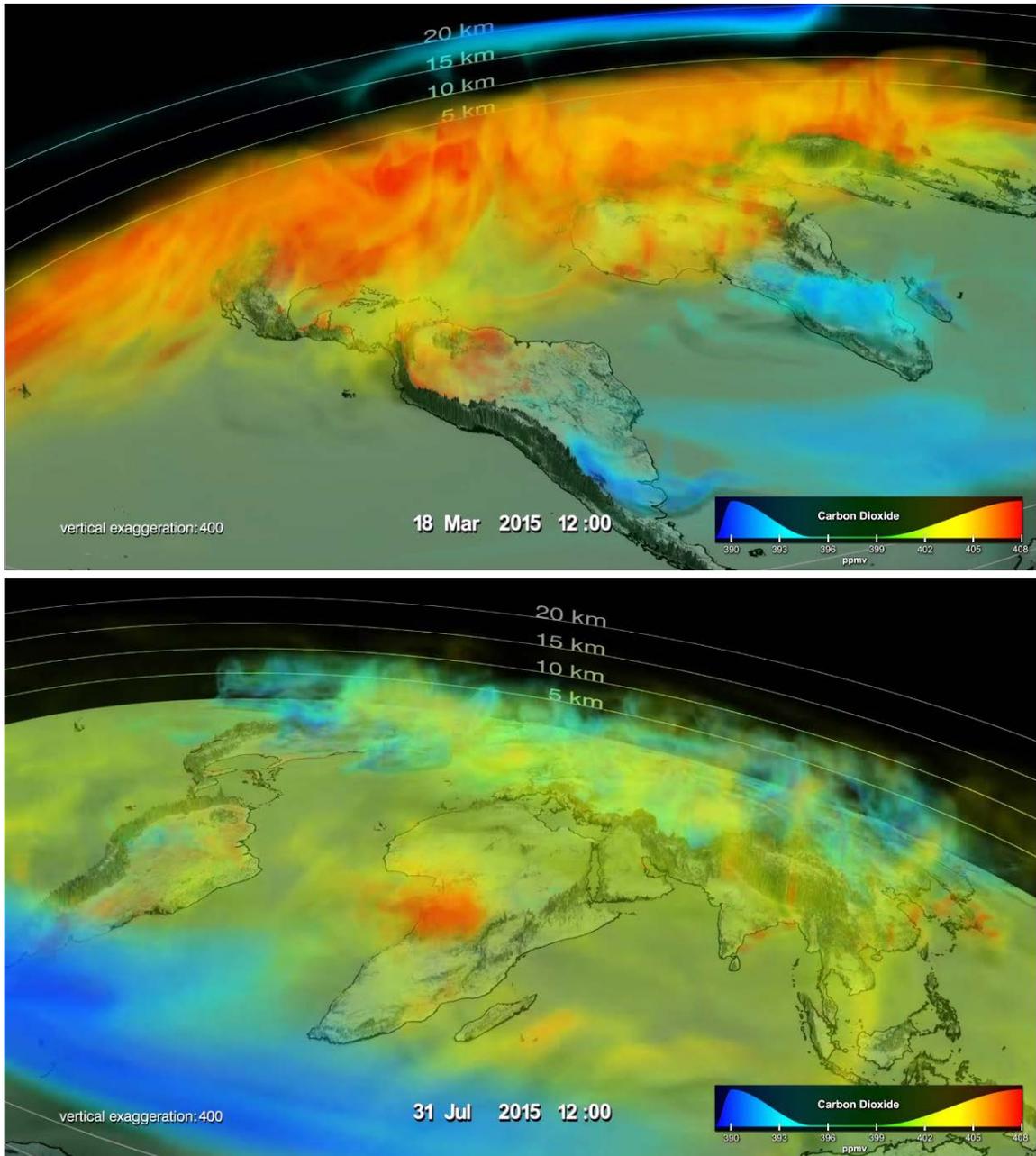


Figure 8 - Winter vs Summer concentration of atmospheric CO₂

The height of the earth's atmosphere and surface are exaggerated vertically to exemplify the flow of gas. These calculations were taken by NASA's second Orbiting Carbon Observatory (OCO-2). The results are influenced highly by fossil fuel emissions and seasonal change.

Source: NASA, https://climate.nasa.gov/climate_resources/152/video-seasonal-changes-in-carbon-dioxide/

2.2 WHERE BUILDING MATERIALS GO TO REST

Where do materials go to perish? In Canada, construction, renovation, and demolition waste (CR&D) has four outcomes. One: it is “diverted through material recovery facilities or centralized organics processing operations” such as composting and recycling. Two: waste is sent for “disposal in landfills”. Three: it is directed to “incineration facilities” for gasification which generates energy from gas, or “residual waste processing” which converts it to an alternate fuel source.¹² Fourth and last: waste is removed and “exported to the United States”.¹³ Of the 3.2 million tons of CR&D waste disposed of in 2016, over 90% generated is composed of four main categories – wood (40%), non-wood building material (34%), other (12%) and plastics (5%) [see figure 10, 11].



Figure 9 – Demolition of condo in Pointe Gatineau 2020

Source: CBC News, <https://www.cbc.ca/player/play/1658120259563>

¹² Environment and Climate Change Canada, “National Waste Characterization Report: The Composition of Canadian Residual Municipal Solid Waste,” i.

¹³ Environment and Climate Change Canada, 13.

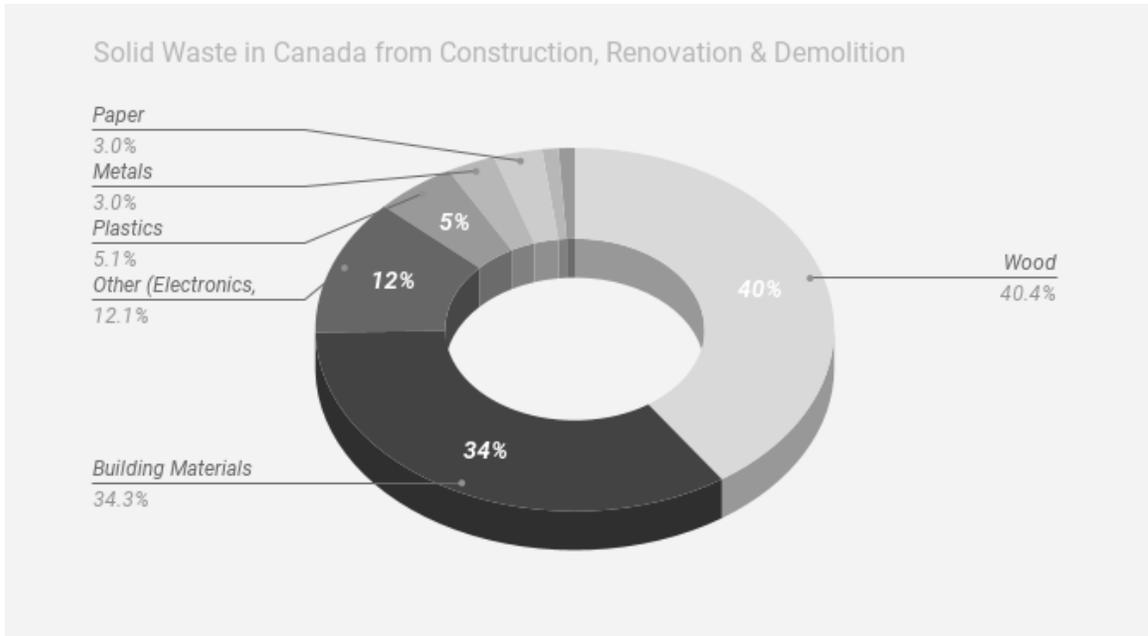


Figure 10 – Estimated CR&D waste composition, Canada 2016

Data source: Environment and Climate Change Canada, <http://publications.gc.ca/site/eng/9.884760/publication.html>

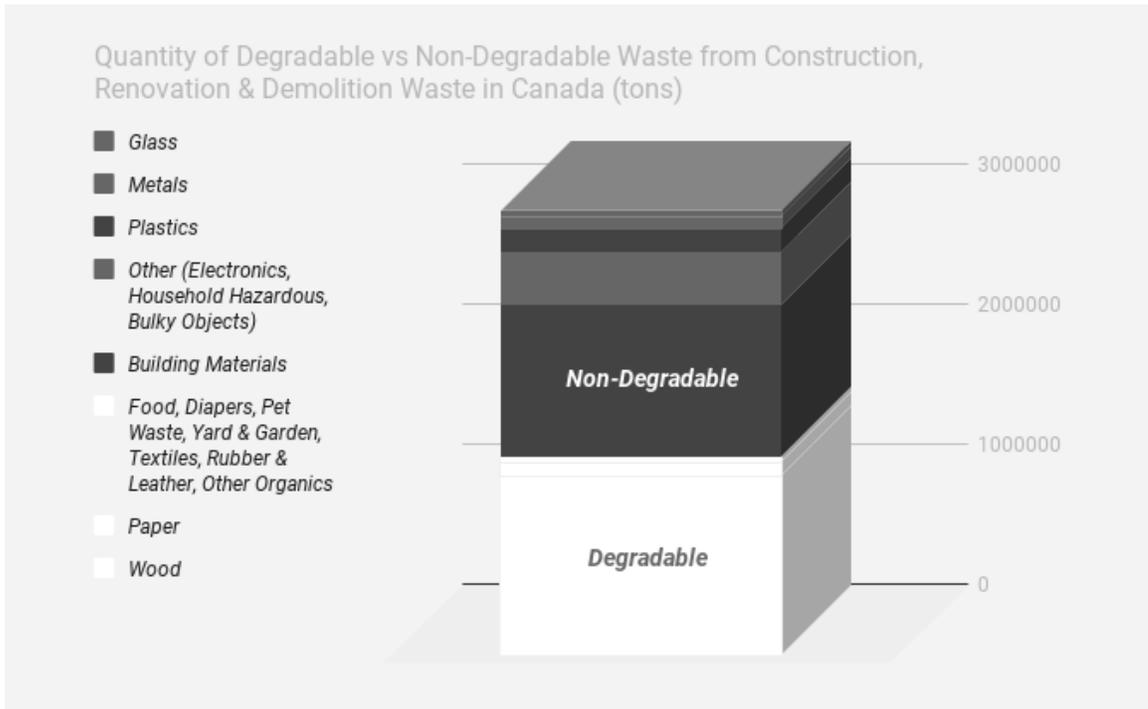


Figure 11 – Degradable vs Non-degradable CR&D waste, Canada 2016

Data Source: Environment and Climate Change Canada, <http://publications.gc.ca/site/eng/9.884760/publication.html>



Openly wood and paper are the only major bio-degradable items (which are renewable) versus the non-degradable man-made products [see figure 9, 10].¹⁴ The “building material” category is difficult to sub-divide because it encompasses residual municipal solid waste which consists of asphalts shingles, drywall, plaster, masonry, bricks, flooring, and carpeting.¹⁵ Ultimately, the CR&D waste that does end up in the landfill (84%) is mixed on site and slowly releases potentially harmful substances into the surrounding soil and water [see figure 12].

Uses	Bulding Material	Sample Chemical/Group
Solvents & Thinners	Wood Preservatives, Paints & Coatings & Insulation Foams	Formaldehyde, Naphthalene (polycyclic aromatic hydrocarbons)
Plasticisers & Dispersants	Vinyl & Rubber Materials, Piping, Cable Housing, Concrete, Wallboard	Phthalates
Anti-corrosive coatings	-	Chromates
Flame Retardants	Textiles, Adhesives, Coatings, Plastic Resin & Building Materials	Organic & Halogenated FR, Boron, Asbestos
Fungicide & Pesticides	Wood, Adhesives, Caulking	CCA, ACA, AZQ, Creosote, Pentachlorophenol, Coric Acid
Waterproofing	-	Phthalates
Pigments & Colouring	Textiles, Paint & Coatings, Plastics	Cobalt salts, Chromates, Lead Cadmium, Azo-dyes
Decolouring	Glass, Ceramics	Selenium Acids
Soldering Flux	-	Boron Sodium Oxide
Curing & Drying Agents	Paints, Adhesives, Caulking	Phthalates, Cobalt Salts
Electric Insulators & Coolants	-	PCB

Figure 12 – Confirmed and likely uses found in CR&D waste in Canada

Source: Recycling Council of Alberta, https://recycle.ab.ca/wp-content/uploads/2014/10/VanderPol_Perry.pdf

¹⁴ Environment and Climate Change Canada, 12.

¹⁵ Environment and Climate Change Canada, 21.



2.3 BUILDING WASTE: THE UNACCOUNTED-FOR

The known implications related to a building material can negatively affect humans, the air, the soil, and our wildlife. Still, there are objects beyond what are identified in landfills as quantified data. When we take the time to stop and look around us, we can easily find items inadvertently transported away from their original site into other parts of our ecosystem. The information in this section opens a door into the unaccounted-for places where waste is improperly disposed-of and irresponsibly polluting.

This spring, at a local river beside my home, I went out in search of building waste. Electing this location was a suitable beginning because in seasons past trash has surfaced due to fluctuating water levels. Upon my pursuit, I was astounded that my arms were encumbered with 37 synthetic items which forced my return. These findings were majorly various forms of mand-made plastics (containers, electronics, bottles, ect) and of particular interest expanded polystyrene insulation (EPS). When I discovered this non-degradable white substance, it was not defined to a single location (like the other items), but it was haphazardly displaced [see figure 13 & 14]. The insulation had fragmented into smaller and



Figure 13 – Waste Walk: Imagery of Local River

Imagery indicating location of fragmented EPS insulation 1-7, with unknown beginning or end. [Personal image].



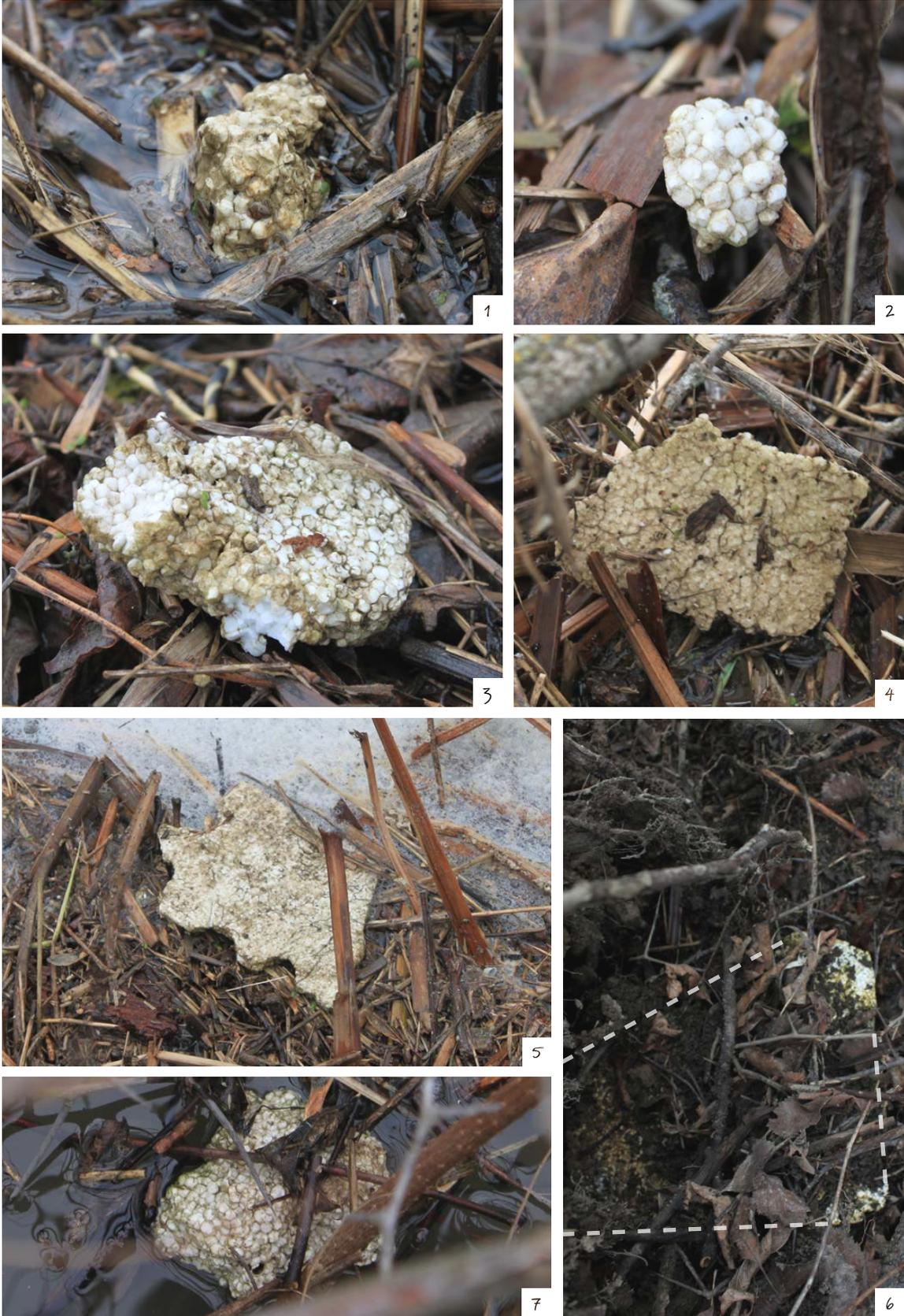


Figure 14 – Collage of EPS from Waste Walk [Personal images].

lesser portions, often trapped floating between a submerged branch, or washed up in the mudded grass. The unplanned path it traveled by the river totalled 1500+ feet, dispersed over seven locations. Something that once provided warmth and protection as an insulation, now lay bare in the river - for an indefinite amount of time with unknown effects on the future ecosystem, wildlife, or humanity. Returning with these forgotten and inappropriately durable products, I was overcome with questions: asking about their origins, production, and what other locations they will inevitably transpire? Certainly, they did not belong here, in this river.



Figure 15 – Assemblage of salvaged waste items

The separate items did not include fragmented or lost pieces and was mainly comprised of plastics. [Personal image].

2.4 AN ISSUE OF DURABILITY?

From a major North American city, a demolition survey was taken that focused on building age, building type, structural material, and reason for deconstruction of 227 sample buildings. The results suggested that there was no major correlation between a failure of the structural system and the service life of the building. Rather the purpose for demolition were primarily associated to area redevelopment (35%), the building being unsuitable for the current needs (22%), and a lack of maintenance of non-structural components (24%).¹⁶ When the reason being physical condition (only 3.5% were structural issues), 65% of buildings were in the 76-to-100-year range. Resulting in the intended lifetime for buildings being outspoken by pre-mature demolition decisions. Discarded materials then become relegated to landfills long before their designed shelf life. Thus, rather than infinite durability, we should design for flexibility that allows future changes and de-constructability.¹⁷

Valuable insight can be lent from Steven J. Jackson's article, *Rethinking Repair*, anchored on the concept of "broken world thinking". His viewpoint, which is from a media and technology perspective, can be beneficial when applied to the world of architecture. Jackson asks, "what happens when we take erosion, breakdown, and decay, rather than novelty, growth, and progress, as our starting points in thinking through the nature, use, and effects...".¹⁸ The separation between the themes of innovation and repair are near opposites in our world today. Innovation comes first with the new and pristine, and repair comes last as a fix to the failure.¹⁹ Knowingly, buildings are demolished pre-maturely without consideration of how these *durable* products impact the environment. Should the ever-present procedures of creating imperishable materials be reversed, just as Jackson suggests, with designing for inevitable repair and alteration [see figure 16]?

¹⁶ O'Connor, "Survey on Actual Service Lives for North American Buildings," 8.

¹⁷ O'Connor, 1.

¹⁸ Steven J. Jackson, "Rethinking Repair," 221.

¹⁹ Steven J. Jackson, 226.





Figure 16 – Study on Discarded Hemp-Lime Sample Re-use

The material can be recycled an infinite number of times and is easily deconstructed without machinery. [Personal images].

Without due diligence of knowing the pathway from formation to degradation of a product (influenced by price, aesthetic, or availability) our decisions about building materials can have a detrimental influence on our planet. Architect Michael E. Reynolds explains, “Our rules and regulations are about things that aren’t pertinent anymore – stick frame houses that you pump heat into, endless of amounts of energy and water – wasteful methods of living. Those days are over due to climate change, population explosion and dwindling resources. If you project them into the future we’ve got a problem.”²⁰ Since air and soil are collectively shared, can local ecological materials be used to reconstruct the earth in a respecting and accountable way?

20 Stubbs, “Michael Reynolds Quotes.”





3.1 HEMP – OUT OF THE WEAVE

A versatile agricultural crop, before 1000 BC until the late 1800s, hemp was used to produce numerous necessities including cordage, cloth, food, lighting oil and medicine.²¹ Being the strongest and most durable of natural fibers attests to its importance in earlier agricultural economies. The plant originated in central Asia, and moved into Europe, Africa, and later into the New World. Eventually this led to the first hemp crop grown in Canada by botanist Louis Herbert in 1606.²² By the turn of the 17th century hemp textiles were significant and widespread in naval ships and merchant fleets.²³ Primarily the fibres were used for sails and rope because of its strength and good moisture handling properties [see figure 17].



Figure 17 – Industrial Hemp Stalk, Hemp Hurd and Hemp Fibers

Hemp fiber is widely used in manufacturing. Hemp hurd (or shiv) is considered to be a byproduct. [Personal images].

²¹ Ranalli, *Advances in Hemp Research*, 8.

²² Larsen, "Canada's First Marijuana Farmers."

²³ Larsen.

The eventual demise of the plant resulted from the popularization of cotton, acid-process pulp paper, kerosene for lighting oil, and the invention of petrol-chemical fibers for nylon rope (1938). A short resurgence of the agricultural crop arose in North America and was labelled the “billion-dollar crop” in a *Popular Mechanics Magazine* published in 1938 [see figure 18]. An onslaught of propaganda followed in the late 1930s, labelling industrial hemp as a narcotic, which ultimately led to its prohibition (though hemp is separate from high THC cannabis).²⁴ With the lift of the ban in 1998, industrial hemp under Canadian regulations could be grown with 0.3% THC (tetrahydrocannabinol) or less in their leaves or flowering heads and strictly for manufacturing purposes.²⁵



Figure 18 – Popular Mechanics February 1938 issue

Source: <https://www.popularmechanics.com/science/environment/a19876318/popular-mechanics-billion-dollar-hemp/>

24 Ranalli, *Advances in Hemp Research*, 8.

25 Health Canada, "Hemp and the Hemp Industry Frequently Asked Questions."

3.2 LIME IN CONSTRUCTION – OUT OF THE LIMELIGHT

Lime derives from limestone and chalk, which are both forms of calcium carbonate geologically produced under water from the deposits of shells and the skeletons of marine organisms²⁶ [see figure 19]. The use of lime in building has ancient roots that trace back to 1800 BC, in Crete, Greece in the formation of a mortar. And the earliest excavated lime kiln is dated to around 2450 BC at Khafaje, Mesopotamia.²⁷ Still, the material's longevity is quite remarkable. Lime plaster that was used in the chambers of Egyptian pyramids and temples, dating back to 2000 BC, are still solid and intact. The extent of lime in their composition included a three-coat lime stucco, a fill in joints and levelling cavities in masonry, and over sculpture for surface colouring.²⁸ In the classical period, Greeks used lime mortar in pavements, aqueducts, and temples. Some of the greatest engineering was done by the Romans who extensively used a concrete-type mixture or artificial stone (consisting of sand



Figure 19 – Hydrated lime in powdered form

Hydrated lime is often mixed with hydraulic lime or pozzolans for faster drying time and stronger mortar / plaster. Additional water is added to the white powder and hemp hurd to form hemp-lime. [Personal image]

²⁶ Williams, *Limekilns and Limeburning*, 8.

²⁷ Williams, 3.

²⁸ Cowper, *Lime and Lime Mortars*, 3.

or small rocks and lime) to build vaults and structures ²⁹.

The decline of lime in construction is attributed to the creation of Portland cement starting in England in the 1800s. The cement replaced lime as a binder in concrete, and the popularity continued to rise in modern building for structures and cement stucco finishes (the precursor to synthetic stucco consisting of latex and other chemical components).³⁰ Aside from building, lime had a specific use on the stage. It was termed the *magic lantern*, “a precursor to the spotlight in the theater, in the days before electricity. When heated, the lime gives off an intensely white light, which spotlighted the person on stage. This gave rise to the term, “in the limelight,” which we still use today.”³¹ Unfortunately, today lime plastering is now out of the spotlight and is primarily an artisan trade.



Figure 20 – Lime, hemp hurd and water mixture

When first mixing lime into the hemp and water to begin creation of the building material, the mixture takes on a beige-grey tone and gradually become whiter as it dries and cures. [Personal image].

²⁹ Williams, *Limekilns and Limeburning*, 3.

³⁰ Guelberth and Chiras, *The Natural Plaster Book*, 16.

³¹ MacLachlan, Hoch, and Merriam, *Rockland Area Lime Industries*, 7.

3.3 PERSONAL ENCOUNTERS: MASADA

My first interaction with lime construction was the ancient fortress of Masada, Israel in February of last year. Although the national heritage site went through the turmoil of a major earthquake, various raids throughout centuries and erosion from wind and rain, many ruins in Masada remain – including their specialized uses of lime mortar and plaster. The walls and foundations of the Herodian era (37-73 AD) were made of raw stones from local dolomite and non-local soft limestone which is found in the private Northern Palace of King Herod³² (both sedimentary rocks, dolomite is believed to be produced by recrystallized limestone³³). I remember coming to a standstill passing through one of the covered bath houses. Stopped in awe of the enduring lime plaster and restored frescoes (done by Centro di Conservazione Archeologica in 1996) in their geometric style [see figure 21]. The choice to use a lime-



Figure 21 – Lime plaster wall with fresco finish, Masada

Photos taken as part of the Extreme Landscapes options studio traveling through Tel Aviv, Jerusalem, Ein Gedi, the Negev desert, and Petra in Jordan - February of 2020. [Personal image].

³² UNESCO and ICOMOS, "WHC Nomination Documentation: Masada (Israel) No. 1040," 139.

³³ Frederick L. Schwab, "Sedimentary Rock - Limestones and Dolomites."

plaster base, versus the local earth-reinforced-straw mix that was found on many of Masada's walls, was for function more than aesthetic. A special hydraulic lime-based plaster (composed of ash and lime) was used in rooms that were exposed to high humidity. Such as the bathhouses, cisterns, and water channels ³⁴ [see figure 22]. Knowingly built in moisture prominent areas, testifies to why the water responsive lime plaster lasted for so many years.



Figure 22 – Mikveh (ritual bath) finished in lime plaster, Masada

Photos taken as part of the Extreme Landscapes options studio traveling through Tel Aviv, Jerusalem, Ein Gedi, the Negev desert, and Petra in Jordan - February of 2020. [Personal image].

34 UNESCO and ICOMOS, "WHC Nomination Documentation: Masada (Israel) No. 1040," 139.



3.4 REVIVAL OF MATERIAL – HEMP-LIME AND THE SOIL

Today, the farming processes used for hemp involve far fewer pesticides and herbicides, than any other grain or crop fibers, limiting environmental damage.³⁵ Typically grown for either seed or fiber, the interior woody core (called *hurd* or *shiv*) is not often used and is considered a by-product that can be repurposed as compressed fuel pellets, mulch or animal bedding.³⁶ In Europe, the bedding is the most valuable market for hemp hurd (at 62% of its use) for horses and other animals because the woody core can absorb up to four times its dry weight in moisture.³⁷ When it comes to hemp-lime building - hurd is the key component due to its moisture handling abilities in addition to its porous, airy structure which is key for its insulation value.³⁸ With the inclusion of lime, its properties increase. Uniquely, the final build of hemp-lime is not the end of its life. The old wall can easily be de-constructed, recycled and added into new hemp-lime mixtures or reclaimed by the soil.

Today, lime is to be found in many applications. The uses range from employment in manufacturing, agriculture, papermaking, steel refining, soil stabilization for sizeable construction projects, environmental cleanup, and as an ingredient in cement, plaster, and mortar in the building trades.³⁹ Up until the 19th century, much of the lime produced was used for agricultural purposes, known as *liming*, and today is readily available for that purpose. The practice of applying lime (an alkaline substance) to the soil is for neutralizing soil acidity which can be a result of fertilizers and manure [see figure 23 & 24]. Calcium is also essential for plant growth and can break down heavy clay soils for better drainage and workability.⁴⁰ Still, the construction uses are scarce. Fortunately, a resurgence in earthen plaster is arising, often in conjunction with natural building such as straw bale, cob, adobe, rammed earth⁴¹ and hemp-lime.

35 Magwood, *Essential Hempcrete Construction*, 7.

36 Magwood, 6.

37 Michael Carus et al., "The European Hemp Industry: Cultivation, Processing and Applications for Fibres, Shivs and Seeds," 6.

38 Magwood, *Essential Hempcrete Construction*, 6.

39 MacLachlan, Hoch, and Merriam, *Rockland Area Lime Industries*, 7.

40 Williams, *Limekilns and Limeburning*, 9.

41 Guelberth and Chiras, *The Natural Plaster Book*, 17.



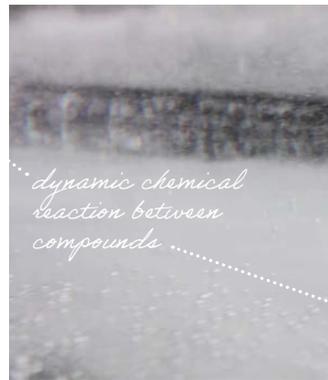


Figure 23 – Study on lime’s impact on water

I first tested water acidity with sodium bicarbonate (baking soda) and acetic acid (vinegar). Any visible reaction will result in the water being too acidic or alkaline. I then added powdered lime to raise the pH level. No visible reaction results in a neutral pH and confirms that the lime has raised the pH and lowered the acidic level. [Personal images].





Figure 24 – Study on hemp-lime’s impact on water

Most plants do not grow well in high acidic soil.. Lastly I used the same test and methodology in soil with additional recycled hemp-lime block. No reaction = neutral pH and safe for crop growth. [Personal images].



3.5 REVIVAL OF MATERIAL: HEMP-LIME AND THE AIR

Just as hemp can rebuild the soil, it also cleanses the air. In the short growing season, of 85-120 days in Canada,⁴² the tall 16ft stalks can store 716lbs of CO₂ per one ton of dried hemp⁴³ [see figure 25]. The plant also provides an enduring environmental benefit as it is formed into a building material. With the addition of lime and water the composite initiates CO₂ sequestering, known as the lime cycle [see figure 26]. When limestone (calcium carbonate) is heated to a temperature of 900-1100 Celsius, carbon dioxide escapes as a gas resulting in quicklime (calcium oxide [$\text{CaCO}_3 - \text{CO}_2 = \text{CaO}$]). With the addition of water, quicklime reacts to form slaked lime also known as hydrated lime (calcium hydroxide [$\text{CaO} + \text{H}_2\text{O} = \text{Ca(OH)}_2$]). Hydrated lime then gradually responds to carbon dioxide in the atmosphere as its water evaporates - reverting to limestone and thus completing the cycle.⁴⁴ Over its lifetime, this sequence will continue to absorb CO₂ and become stronger with age. With the carbon sequestration of the crop combined with the lime cycle; the hemp-lime resolves as a carbon negative building component [see figure 27].

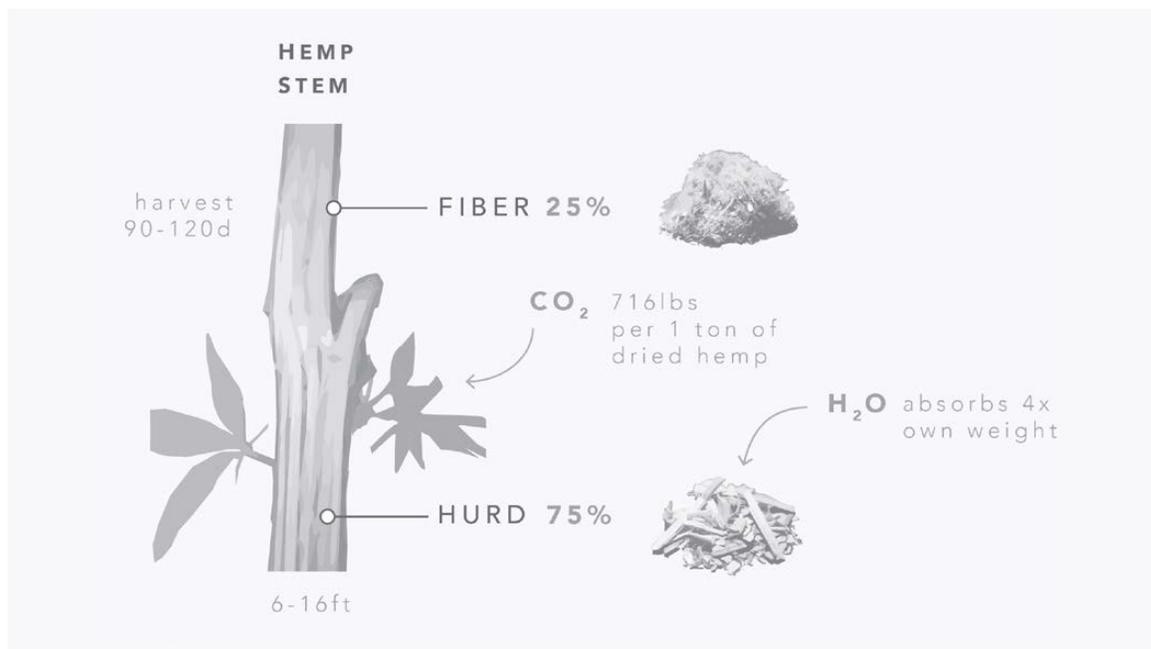


Figure 25 - Cross Section of industrial hemp stalk [Personal diagram].

42 Health Canada, "Hemp and the Hemp Industry Frequently Asked Questions."

43 Pervaiz and Sain, "Carbon Storage Potential in Natural Fiber Composites," 331.

44 Williams, *Limekilns and Limeburning*, 8.



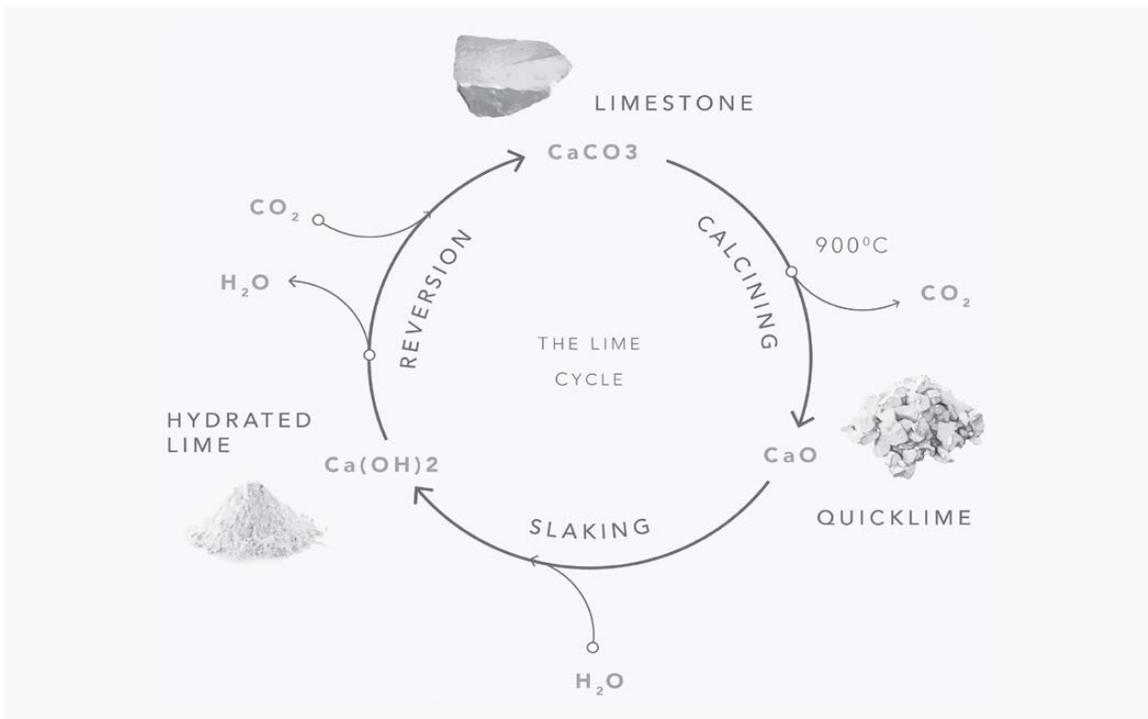


Figure 26 – The Lime Cycle

[Personal diagram].

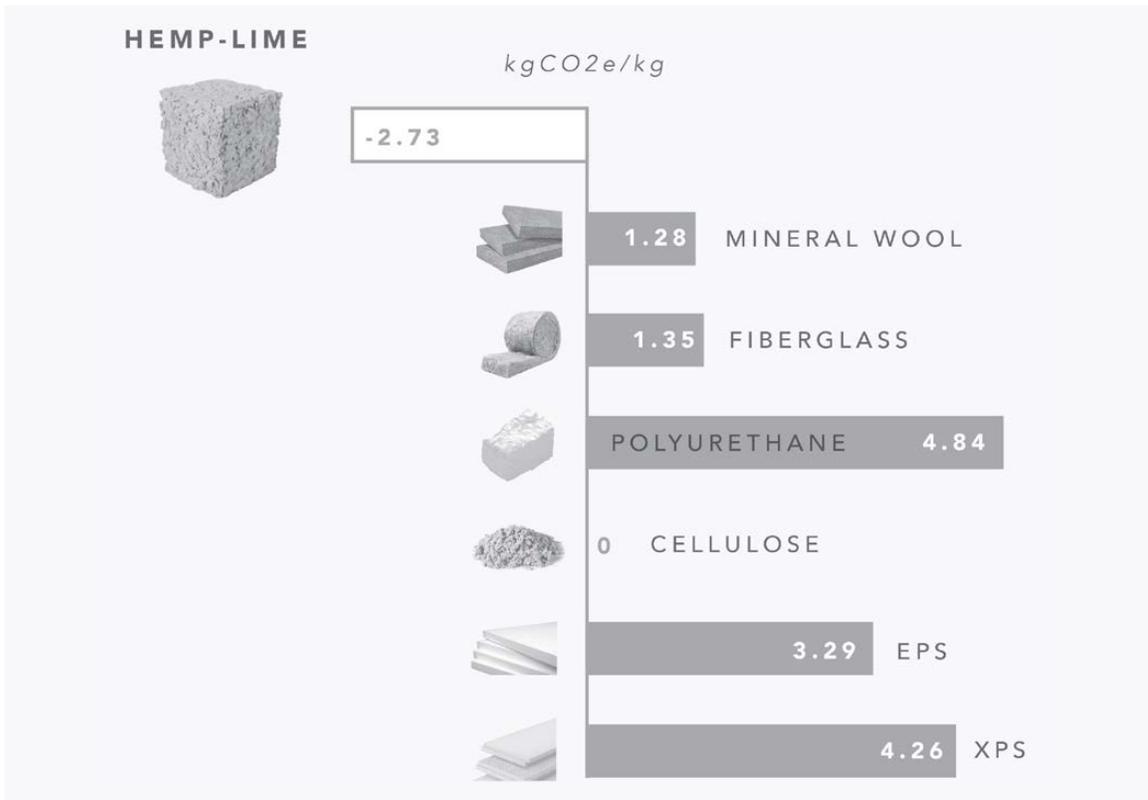


Figure 27 – Embodied Carbon of Insulations

Information sourced on hemp-lime from: *Essential Hempcrete Construction* by Chris Magwood. Other insulations sourced from ICE DB 3.0.. [Personal diagrams].



Certainly, typical building processes and materials do not consider nourishing the air. Specialist on Hemp construction Chris Magwood rationalizes, "In Canada, about 200,000 new homes are built each year, with an average footprint of 2,000 square feet. If they were all insulated to code minimum requirements with hemp[lime], a total of 990,718 tons of carbon could be sequestered annually. If the same homes had walls with fiberglass insulation, 207,345 tons of carbon would be emitted to create that insulation"⁴⁵ [see figure 28]. If the process of creation is integral to the recycled biomass, it was then essential for me to know the material *by making* and understanding its properties firsthand.

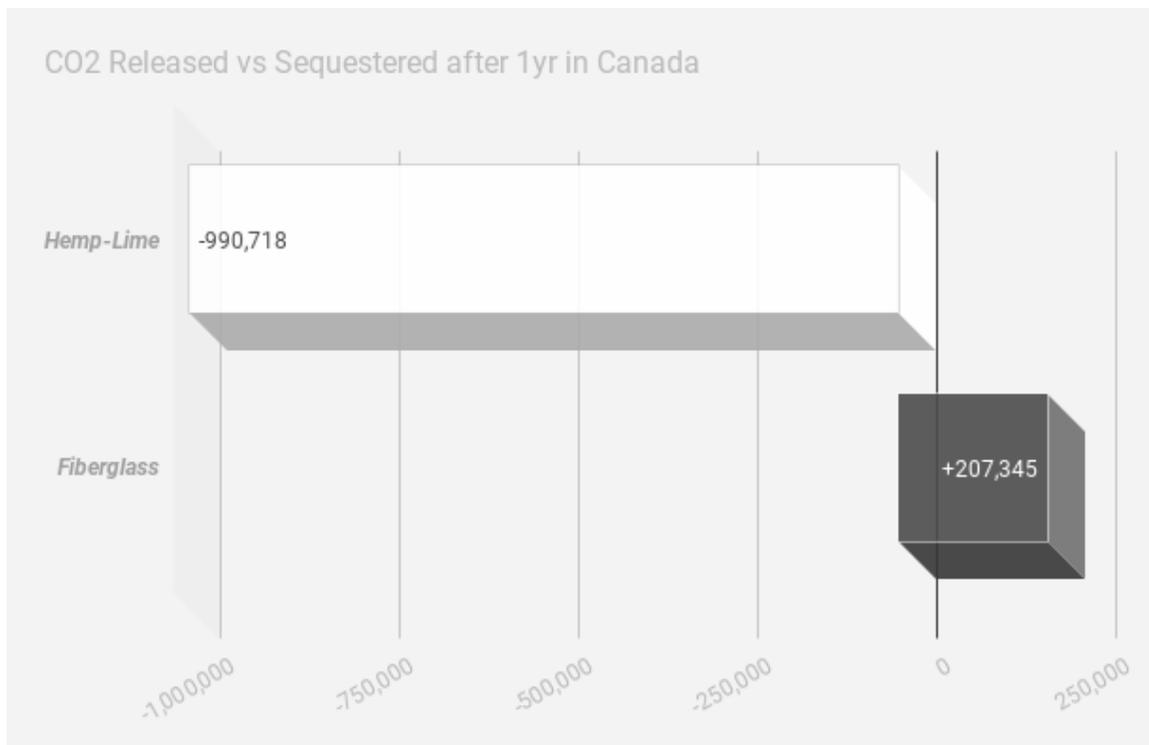


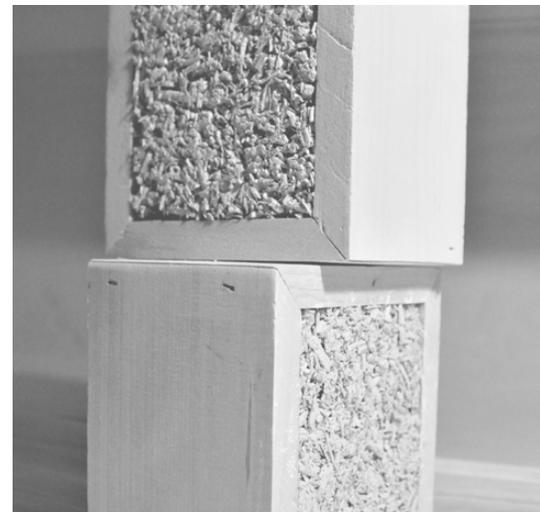
Figure 28 – CO₂ generated, by ton, over 1 year of homes built in Canada
Source data from: *Essential Hempcrete Construction* by Chris Magwood.

45 Magwood, *Essential Hempcrete Construction*, 7.



CH. 4

KNOW BY MAKING



4.1 EXPERIENCE AND EXPERIMENT

In modern use, the connection between *experience* and *experiment* is basically non-existent, as described by Raymond Williams in his book *Keywords: A Vocabulary of Culture and Society*. The disconnect occurred in the late 18th century when *experience* became defined into two main senses. First, “[as] knowledge gathered from past events, whether by conscious observation or by consideration and reflection”. And secondly, “a [present] particular kind of consciousness”.⁴⁶ Today, the term *experiment* has evolved into a scientific archive of specific data points annulled of any influence from experiential *qualities*. Data, both qualitative and quantitative, are narrowed down to facts. The etymology of the word *experientia* is of Latin *ex* – “out of” and *peritus* – “experience, tested”. Thus, the two words must be in symbiosis to have a full understanding of the subject being analysed.



Figure 29 – Hemp-Lime Formula
[Personal diagram].

4.2 MATERIAL EXPLORATIONS

The creation of hemp-lime is an immersive process. It does not require an expert builder⁴⁷ and strives on its simplicity of materials and methods. Still, the resources are hard to find, and the building method is still in its infancy. With supplies of hemp (sourced in Ontario from partnership with Hurd Solutions), I began to explore different mixtures to create a wall made of natural materials free of VOCs (volatile organic compounds). My initial studies used a hands-on approach to learn from the material and record its physical properties [figures 30-33 & 35]. In collaboration with the civil and mechanical engineering departments at Carleton, the various samples underwent testing for their performance metrics: thermal value and structural compression capabilities [see figure 34 & 36]. These material analyses will serve as the basis for tangible design development for future hemp connections and assemblies.

⁴⁶ Williams, *Keywords*, 83.

⁴⁷ Magwood, *Essential Hempcrete Construction*, 10.





Figure 30 – First Hemp-Lime Process Photos [Personal images].



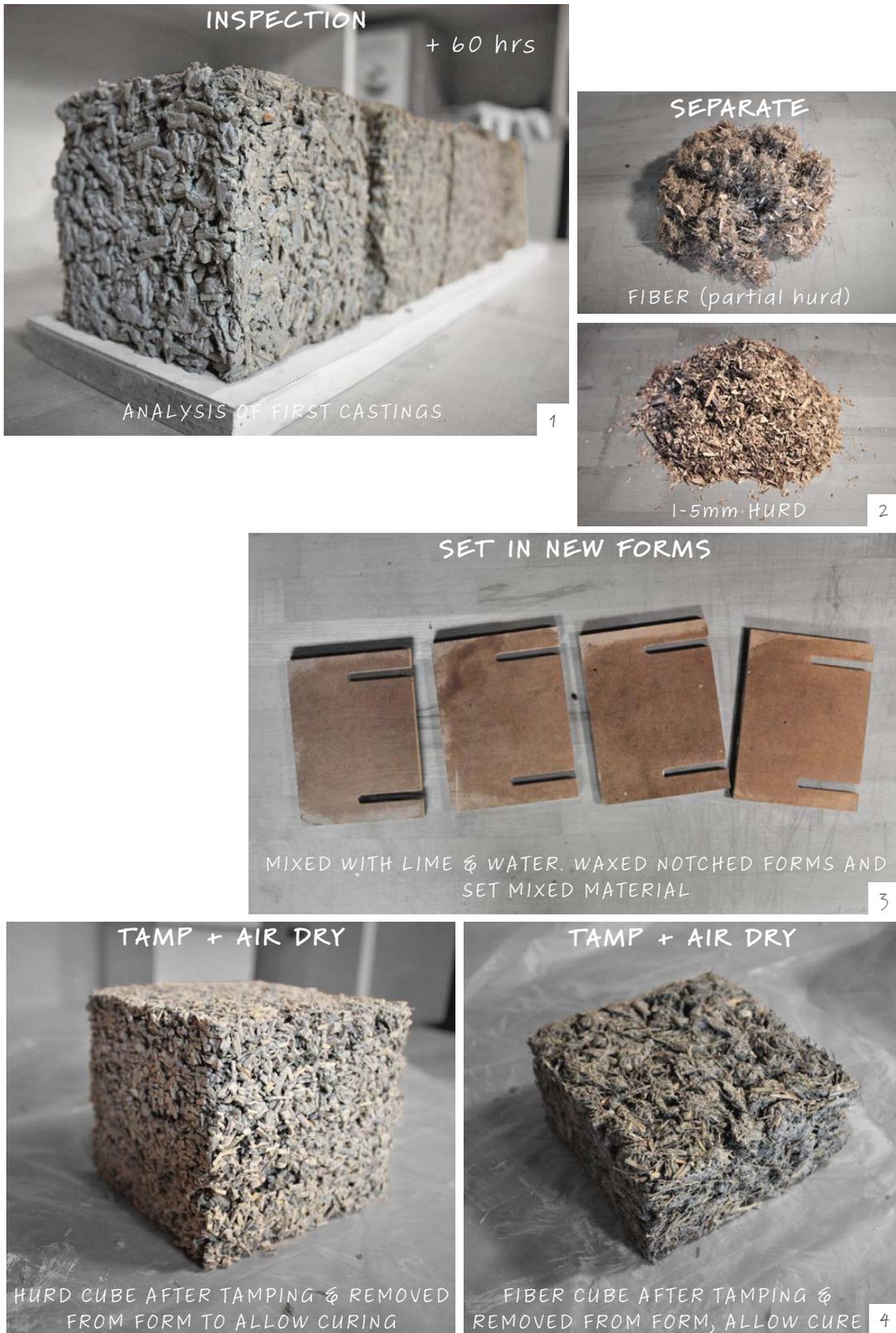


Figure 31 – Following up First Process & Forming of Second Mix

[Personal images].



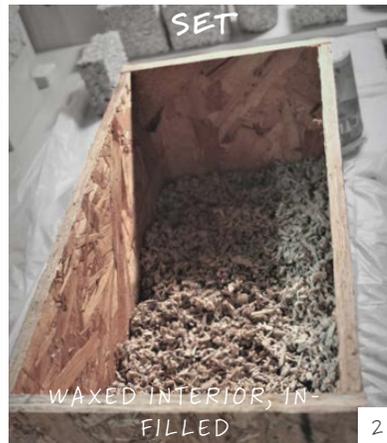
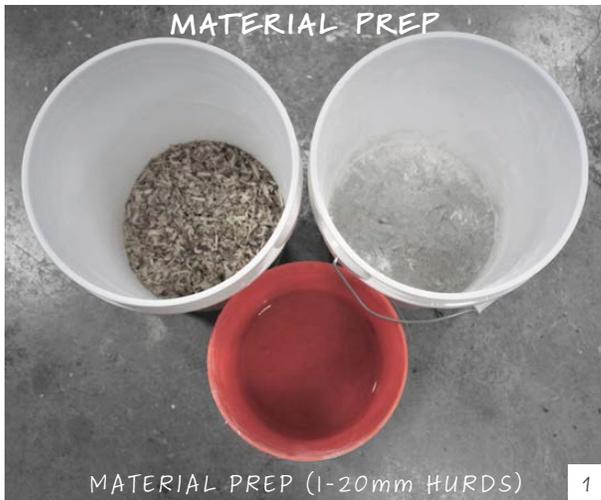


Figure 32 – Scaling up Hemp-Lime Samples and Alternative Mixtures
[Personal images].

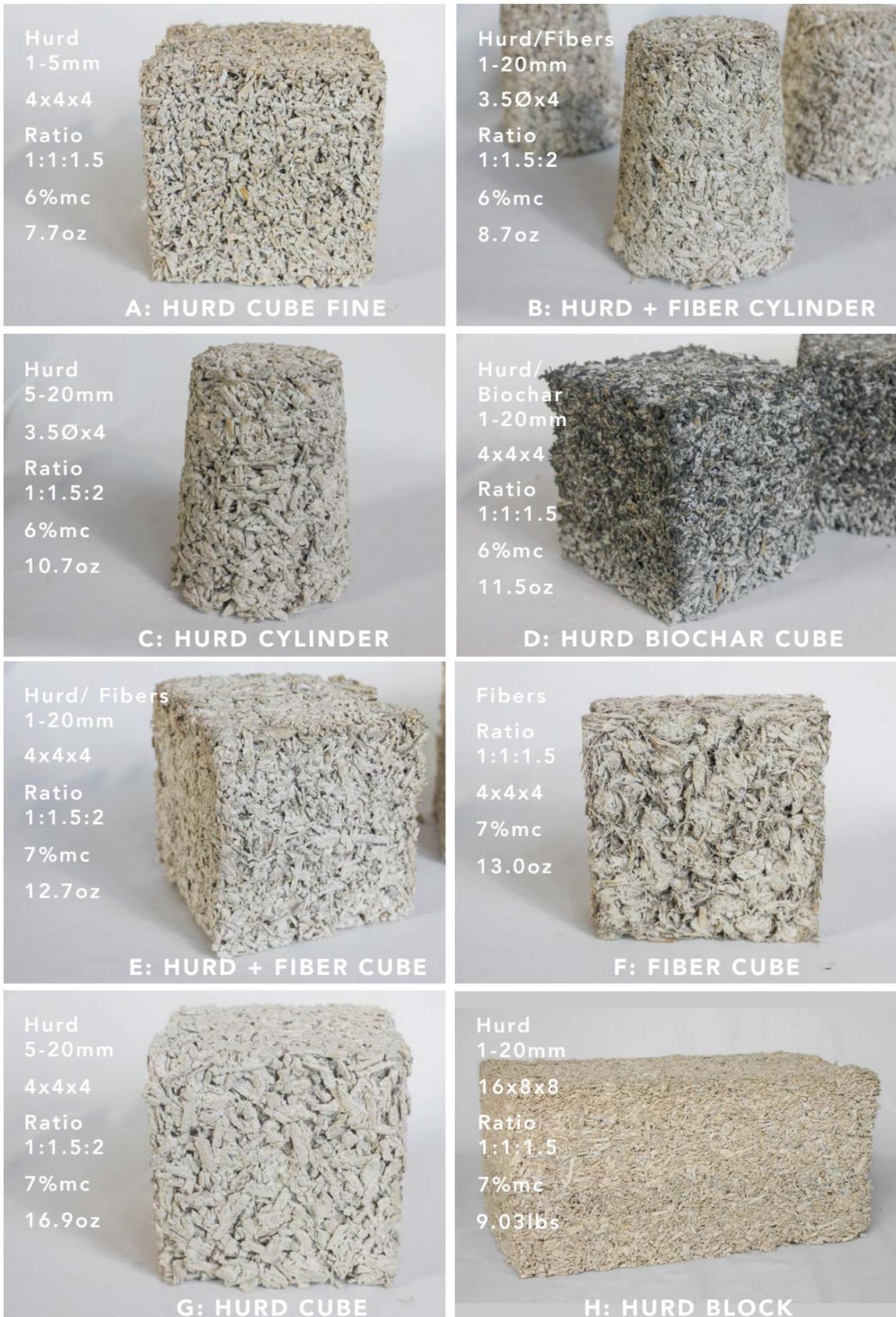


Figure 33 – Catalog: initial mixtures of various hurd to fiber ratios [Personal images].



The triad of hemp hurd, hemp bast fiber and hydrated lime (apart from water) were all extremely light substances. As I continued to explore the mix proportions, the aspect of lightness continued to express itself. The heaviest of the 64 cubic-in samples I made (fully dried) weighed just over 1 lbs (16.9 oz) [sample G of figure 26a]. The wet mixes contained an earthy aroma, with a pale greyish-beige tint and a structural delicateness. It was thus extremely important to design proper removable forms - pressure fit and easily slide-able.

Uniquely, once the mixture was properly tamped down or hydraulically pressed, the forms could be removed right away. And indeed, hemp-lime works most effectively when the forms are removed - as it requires exposure to the atmosphere for the release of moisture and the absorption of CO_2 to cure. This allows the hemp to properly dry and strengthen. This fabrication methodology also informs the constructed wall assembly - that plastic vapour or air barriers will hinder its effectiveness for curing and buildup moisture.

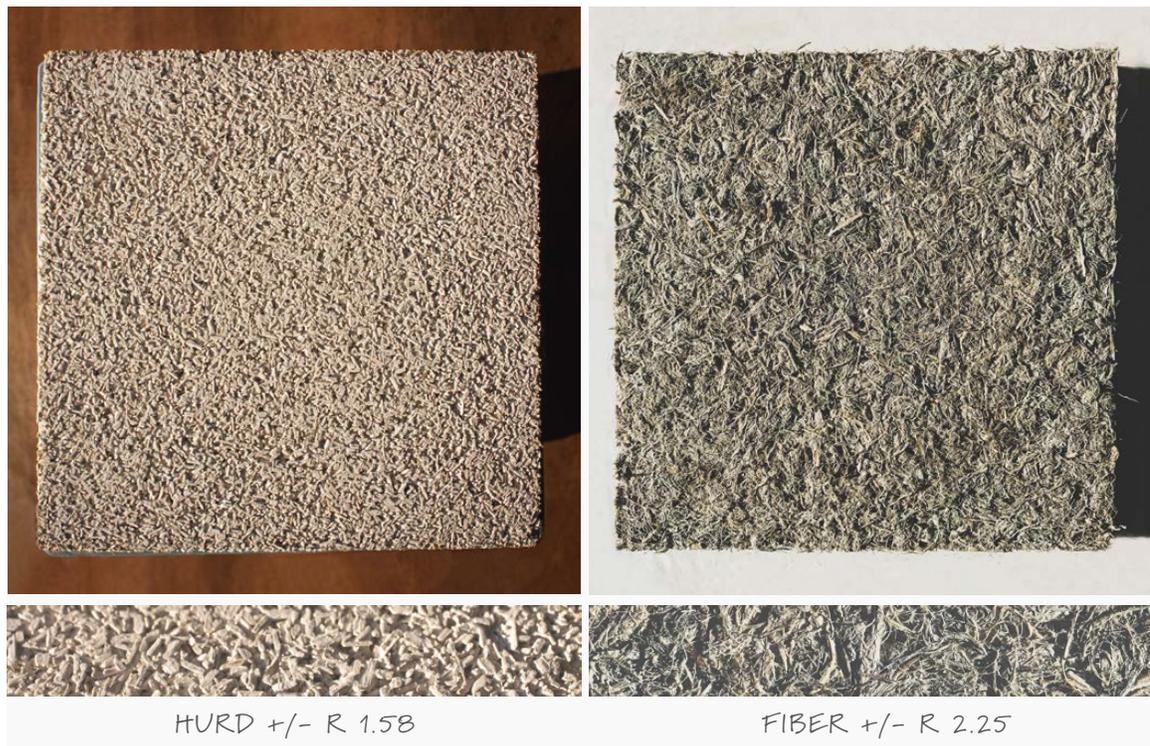


Figure 34 - Hemp samples for thermal testing

The goal of this exercise, in collaboration with the Mechanical lab at Carleton University, was to provide thermal calculations for the two separate parts of the industrial hemp stem - fiber and hurd. Thermal conductivity was measured using a Guarded Hot Plate Apparatus on four 12"x12"x1" samples. The study showed that hemp fiber resulted in a higher thermal resistance (r-value) than its respective hurd counterpart. [Personal images].



Figure 35 - Catalog: progress of pressed hemp-lime samples [Personal images].





Figure 36 – Pressed hemp-lime board

The hemp samples reached their fracture point early on during the Universal Testing Machine which continued to crumble under pressure. The compressive stress averaged 1.0625MPa with Compression Parallel to Surface test. [Personal images].

4.3 REFLECTION & POTENTIAL

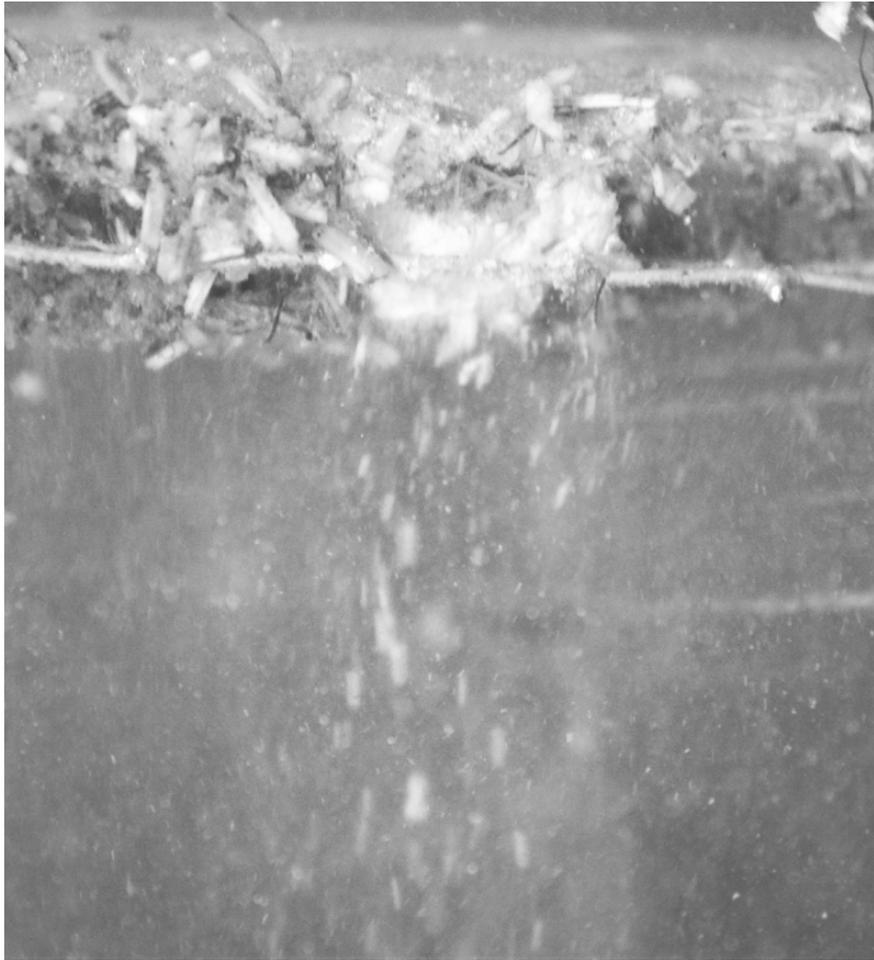
To summarize, the making processes for the hemp-lime samples helped to better inform the ideal ratios for mixing the final specimens (later tested for their performance metrics). The design of easily removable forms was also significant to safely mold them without damage. For large scale construction, prefabricated blocks would be most suitable to expediate the time for drying on site (which ranged from 1-2 weeks depending on sample size). Though, fans and dehumidifiers can accelerate the process. It is important to note; proper protective equipment must be worn when mixing the components as lime is a caustic substance and therefore requires a well ventilated or outdoor space. When it comes to building, hemp-lime does require a thicker wall to achieve a standard insulative value. Overall, the making process was straightforward and easy to learn.

The pursuit of compressing industrial hemp was significant for discovering its potential as a structural pressed board. For these samples, the focus was also on using a natural lime binder versus the formaldehyde-based adhesives which are common in manufactured wood products. For the study, a Universal Testing Machine was used to measure the strength of the boards. Ensuing, the hemp samples retained a minor compression strength and would require further research and development before being considered a structural option or moving onto other hybrid building components such as SIPS (Structurally Insulated Panels). Though, the products revealed a promising quality as an aesthetic hemp-based board. In all, recycled hemp and locally sourced lime are environmentally conscious materials versus the widespread use of non-degradable synthetics today.



CH. 5

DISSOLVING THE WALL



5.1 LIGHTNESS

The Greek word for breath and vapour that refines the mood or character of an architectural setting, which architects describe as atmosphere, first derived from *atmos*.⁴⁸ Currently, walls are void without *atmos*. Typical homes are constructed into tight boxes of air for a desired thermal comfort. As Lisa Heschong describes in her book *Thermal Delight in Architecture*, "fascination with this potential for control of our environment has prompted the invention of mechanical systems that have made natural thermal strategies seem obsolete by comparison."⁴⁹ The need to dwell is now in unison with keeping air isolated. Primarily, this has resulted in concentrating architecture as an inert body, rather than providing a fluidity of *atmos*. Furthermore, it has removed an appreciation of walls.

It is then essential, as Italo Calvino says, "...we must remind ourselves that the idea that the world is made up of weightless atoms surprises us because we have experienced the weight of things."⁵⁰ The heaviness and inertia around us, as Calvino describes is, "...the opacity of the world."⁵¹ Denseness that divides the exterior from interior. Properly, "...knowledge of the world entails dissolving the solidity of the world."⁵² The solid element which separates inhabitants from laterally experiencing the environment is - the wall. Thus, to design with breath at the forefront bears a stronghold of weightlessness. So, let us dissolve the wall.

In my study of lightness [see figure 37], I strove to dissolve the weight of materials. I began by submersing frozen lime, hemp, and sand into warm water and recording my thoughts. The hemp hurd, representing lightness, breaks away from the ice and the conventional – sand. It gently floats to the top, in transcendence, as the sand quickly falls to the bottom. The lime, embodying *atmos*, slowly blends into the water - blurring the boundaries between light and dense. Finally, the layers settle, and the water is clear. Hemp remains buoyant, and lime separates the weight of sand, the world.

48 Leatherbarrow, *Architecture Oriented Otherwise*, 24.

49 Heschong, *Thermal Delight in Architecture*, 11.

50 Calvino and Brock, *Six Memos for the Next Millennium*, 18.

51 Calvino and Brock, 4.

52 Calvino and Brock, 10.





Hemp fibers,
hurd, sand and
lime powder
- solidified in
an ice block
then allowed
to thaw in
the medium
of water,
to visualize
lightness of
material.
Ephemeral and
dynamic.

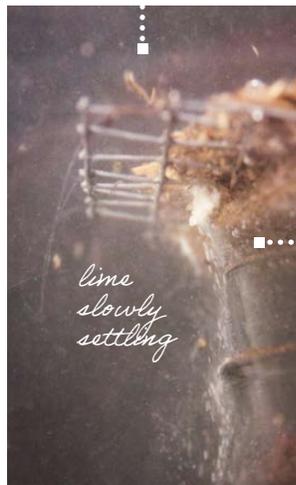


Figure 37a – Study of Lightness

Hemp fibers, hurd, sand and lime powder - solidified in an ice block then allowed to thaw in the medium of water, to visualize lightness of material. [Personal images].

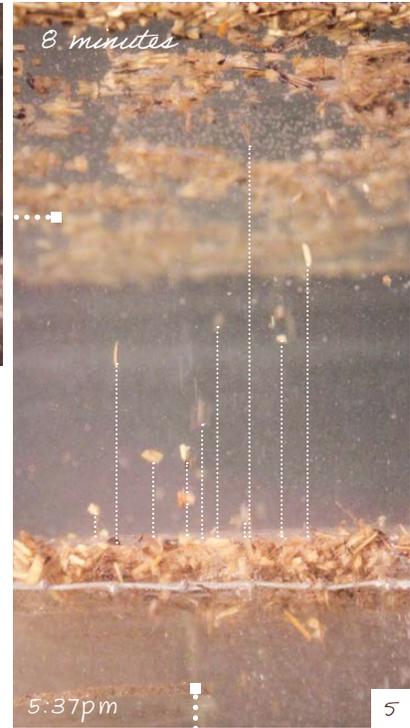


Figure 37b – Study of Lightness

Hemp fibers, hurd, sand and lime powder - solidified in an ice block then allowed to thaw in the medium of water, to visualize lightness of material. [Personal images].



5.2 BEGINNING WITH MATERIAL

Truly, how does one dissolve a wall? By starting from the beginning - the material. Today, there is an increasing number of homes that are constructed from synthetic and highly processed materials.⁵³ The animation of the senses and the nearness to our walls has been replaced by synthetics. How can an inhabitant connect with something artificial? There is a lack of understanding for how the material was made, where it came from or where it is going to end up at the end of its life. As architect Juhani Pallasmaa describes, “natural materials express their age and history, as well as the story of their origin and their history of human use.”⁵⁴ The machine-made has contributed to the demise of the physical and sensual essence of architecture.⁵⁵ Unfortunately, modern homes have become dislodged from natural building strategies, resulting in homes that are only *occupied* rather than *experienced*.

Starting design from material first places it in the context of site and of climate. And this method, in fact, is not new. Lisa Heschong describes four scenarios where, “[Early] builders consistently used forms and materials that effectively moderated prevailing climate conditions”.⁵⁶ These ancient cultures understood the wall and material very well. First, in the desert - a thermal mass of clay and stone retained heat from the sun during the day and release it at night when it was cool. In the hot humid climate of the tropics, light materials made of bamboo and reeds were used for shading, airflow, and protection from the rain. A similar approach was employed in the Japanese House allowing for lightness and ventilation with their removable paper walls. Lastly, the fourth climate was the winter igloo - where the domed shape was intended for maximum protection from the chilling winds and was intimately sized for preserving inside heat [see figure 38].

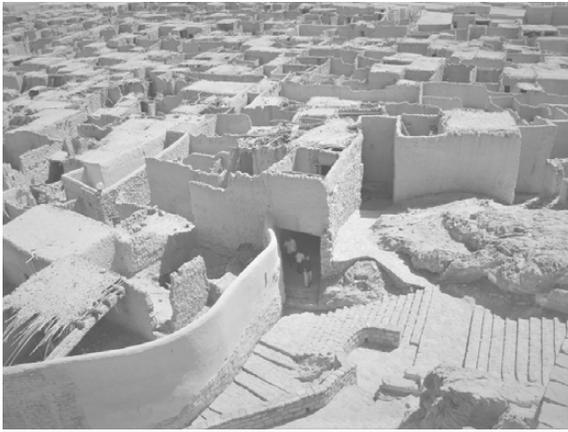
53 Guelberth and Chiras, *The Natural Plaster Book*, 1.

54 Pallasmaa, *The Eyes of the Skin: Architecture and the Senses*, 31.

55 Pallasmaa, 32.

56 Heschong, *Thermal Delight in Architecture*, 8.





DESERT



TROPICS



JAPANESE HOUSE



IGLOO

Figure 38 – Four climatic strategies for utilizing material

Desert - ameinfo.com/industry/tech-and-mobility/travel-and-tourism-in-saudi-arabia-by-the-numbers

Tropics - i.pinimg.com/originals/21/c0/f2/21c0f2190391c049be7f7852108f4e4c.jpg

Japanese House - interactiongreen.com/wp-content/uploads/2016/10/engawa-small.jpg

Igloo: mnmcapedorsetnewbies.blogspot.com/2010/03/igloo_26.html

5.3 TO LAYER OR NOT TO LAYER

So, what is our modern wall system? It is a multi-layered wall that is unnecessarily complicated: with façade, gaps, barriers, structure, insulation, more barrier, finishes, and paint [see figure 39]. Now, “buildings have become intricate systems composed of hundreds or thousands of materials, many of them produced from complex, resource-intensive manufacturing processes.”⁵⁷ The wall is also informed by the management of temperature. The obsession for controlling indoor environments has negated the natural fluctuation of

57 White, “Better Building Materials: Understanding Human Health and Environmental Attributes,” 13.



humidity in the air. As Lisa Heschong states, “such uniformity is extremely unnatural and therefore requires a great deal of effort, and energy, to maintain. Engineers must use extremely sophisticated methods to ensure that every location within an enormous office tower can be maintained at a constant temperature and humidity.”⁵⁸ Consequently, to accommodate for the lack of moisture in the interior air, the solution is yet another mechanical device – a humidifier.



Figure 39 – Typical wall (left) vs Hemp-lime wall (right)

Typical wall: personal photo Source for hemp-lime wall: practicearchitecture.co.uk/project/flat-house/

This conventional layered wall system has become the standard in North America. Occurring so gradually (over the past 50 years) that we missed its significance.⁵⁹ One of the largest issues of the typical wall construction is its reduction in water vapour transmission due to: plastic vapour barriers, vinyl wall coverings, foiled faced fiber glass batts, airtight OSB, and impermeable foams. Together these layers impede a walls ability to allow moisture to pass through it. The prolonged exposure of stagnant moisture in materials can result in harmful mold.⁶⁰ A substantial example of this pitfall, is evident in the Cat Lake community of Northern Ontario [see figure 40].

The housing units of Cat Lake have been susceptible to mold and moisture issues that has spread into their interior living spaces. The community claims it has left many members, included children and elders, with rashes and health concerns.⁶¹ The First Nations

58 Heschong, *Thermal Delight in Architecture*, 20.

59 Joseph Lstiburek, “BSI-039,” 1.

60 Joseph Lstiburek, 3.

61 Fiddler, “Chief of Cat Lake Says Indigenous Services Minister O’Regan Needs to See Crisis First Hand.”



community declared a state of emergency in January 2019 and evacuated 1 month later, as the inhabitants continued to seek assistance. An advocate and MP of the NDP Charlie Angus alleged, "the problem is... that Cat Lake is the tip of the iceberg. Because there are communities across this country that are suffering from the mold crisis."⁶² With the eventual response, the Canadian government intervened with \$3.5 million for 15 new homes, \$1.5 million to demolish unlivable structures, and \$2.1 million to repair and renovate 21 homes.⁶³ Unfortunately, the new work was to be done using the same moisture susceptible construction and ventilation.



Figure 40 – Collage of Cat Lake homes affected by mold, 2019

Sources: <https://www.cbc.ca/news/indigenous/cat-lake-first-nation-mould-1.5009079>

<https://globalnews.ca/news/4965990/cat-lake-first-nation-considers-evacuation/>

<https://www.aptnnews.ca/national-news/chief-of-cat-lake-says-indigenous-services-minister-oregan-needs-to-see-crisis-first-hand/>

62 Maham Abedi, "When Is Help Coming?"

63 By Staff, The Canadian Press, "Federal Government Promises \$10M for Cat Lake First Nation amid Housing, Mould Crisis."



5.4 INDOOR IMPACTS

Many manufactured products are not only detrimental for the soil and the atmosphere but can also be harmful in indoor environments. Some past materials (that were once widely used) have been identified and removed from markets, including lead paint and asbestos. Consciously, “Each of these substances had a well-intended functional purpose, yet information about the product’s human health and environmental harms came to light only after widespread use.”⁶⁴ Hence, what other synthetic building products exist in our buildings today that might be inadvertently and adversely affecting our health? [see figure 41].

Today, artificial products often carry harmful volatile organic compounds (VOCs) to enhance their resistance to moisture, mold, fire, and insects. The release of VOCs indoors can expose occupants to potential cancer-causing substances.⁶⁵ These compounds are created during the manufacturing, installation, operation, and disposal of materials. The unseen

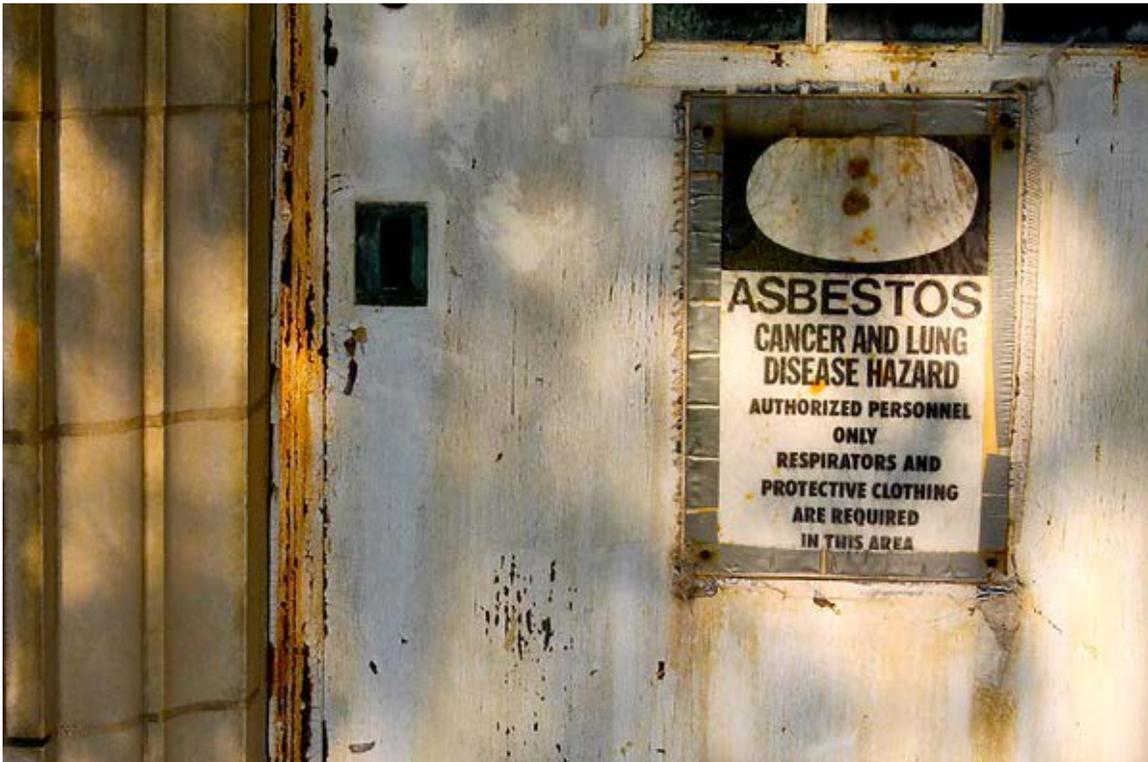


Figure 41 – Sign warning the dangers of asbestos in existing building

Source: Michael Jett, July 30 2009 - https://www.flickr.com/photos/mike_jett/3783420877/

⁶⁴ White, “Better Building Materials: Understanding Human Health and Environmental Attributes,” 14.

⁶⁵ White, 31.

VOCs become part of the atmosphere, both inside and outside. In response, individuals like Born and Elinor Barikor have created Britain's first hypoallergenic home.⁶⁶ They learnt that many building products such as paints, furniture polish, carpeting and treated woods, can intensify allergies because they off-gas chemicals which can easily be inhaled⁶⁷ [see figure 42]. The goal was to create a haven for their children, that was as allergen-free as possible. When measuring the number of toxic VOCs released into their house, Born praised that their home performs over 70% better in indoor air quality than against a new build.⁶⁸

Stepping away from natural building has depreciated materials to be non-sensory. It has also imparted issues of air toxins and trapped moisture causing mold. As a modern building culture, we no longer *experience* indoor environments. On the other hand, hemp-lime is a multi-faceted experiential material that is both sustainable and safe. In the next chapter, I begin to further explore the senses the biomass engages at a personal level.



Figure 42 – Manufactured wood products

OSB, plywood, particle board openly use glue formulated with formaldehyde. [Personal photo].

⁶⁶ Jayne Dowle, "Grand Designs TV Houses - TV House: Look inside Britain's First Hypoallergenic Home."

⁶⁷ Cook, "Meet the Parents Who Built an Allergy-Free House."

⁶⁸ Episode 3 *Grand Design*, 43:29-43:35.



6.1 THE FORGOTTEN

The cool robust feeling of concrete. The warm textured qualities of wood. The cold strong capabilities of steel. So then, we have an extensive knowledge of concrete, of wood, and of metal. But what do we know of hemp-lime? What experience is in a wall of biomass? What can this wall material provide for the inhabitant? Our current known materials may only serve solitary purposes - for strength or protection. They are not used for the airy categories of thermal insulation, breathable humidity, or sound absorption. I understand these to be the *forgotten experiences* in our current walls. Juhani Pallasmaa explains, "The inhumanity of contemporary architecture and cities can be understood as the consequence of the negligence of the body and the senses and an imbalance in our sensory system."⁶⁹ Conventional airtight wall systems are responsible for this imbalance. Lisa Heschong affirms, "I doubt anyone would put forth an argument for a monochromatic world. And yet a steady-state thermal environment is the prevailing standard for office buildings, schools, and homes... Such uniformity is extremely unnatural and therefore requires a great deal of effort, and energy, to maintain."⁷⁰ Inhabiting space should be more than programming for activity, constructing walls to divide those activities, then filling it with a steady-state environment - more human senses should be involved.

The three unique sensory qualities I discovered in experiencing hemp-lime are thermal, humidity and sound. The material engages these senses simultaneously. In the following experiments, I attempt to sub-divide the qualities to better understand each part. As I immerse myself into the process - I ask, 'what does this material want to be?' and record my findings. I did not seek specific results but was open to the unpredictability of the events experienced through my senses.

⁶⁹ Pallasmaa, *The Eyes of the Skin: Architecture and the Senses*, 17–19.

⁷⁰ Heschong, *Thermal Delight in Architecture*, 20.



6.2 THERMAL



Figure 43 – Thermal Study by Conduction

From left to right: a hemp-lime board made of fine fibers and hurd, a cedar board, and a sheet of aluminum. All 4"x4" samples. Aluminum melted the ice the fastest, under 3 minutes. Hemp and cedar at +1hr. [Personal photo].

When revealing the thermal phenomena, I was amazed by the sense of touch. Simply by holding the hemp sample, I was informed about the warmth of the material by the gentle rate it retained heat from my hand. Lisa Heschong implies, "Thermal information is never neutral; it always reflects what is directly happening to the body. This is because thermal nerve endings are heat-flow sensors, not temperatures sensors... they monitor how quickly our bodies are losing or gaining heat."⁷¹ In this way, the material was instructing me of its virtues. I then began to explore the full extremes of the thermal scale in relation to hemp. From the piercing chill of ice to the burning touch of flame.

Initially, scaling down the hemp-lime into 3 similar forms, I cast them into ice. The three mixtures consisted of granulated hemp-lime, a fine fiber, and a fine hurd mix. The 64 cubic inches of ice were embedded with hemp-lime, which survived a rapid outdoor freeze [see figure 44]. The cubes were then placed in a controlled glass tank. First, I recorded an ambient freeze-thaw at room temperature. The second cube was semi-submersed in water at the same room temperature. Lastly, the third cube was fully submersion in water in the same area [see figure 45-47]. Through contact, I discovered that the ice melted quicker from

⁷¹ Heschong, 19.



Figure 44 – Scaling hemp samples & freeze cycle analysis [Personal photos].



ice representing yearly release of CO2 into the atmosphere by building material manufacturing + construction

no water representing low concentration of CO2 in the atmosphere in the past

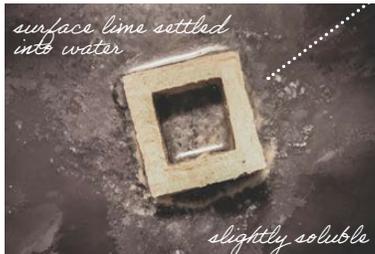
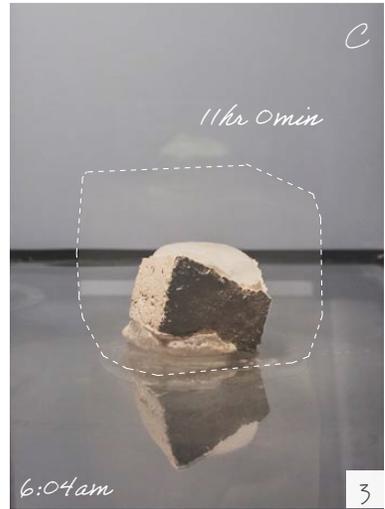


Figure 45 – Ambient thaw of hemp-lime

The full thaw cycle lasted over 12 hours and small amount of lime and hurd can be seen whirling in the thawed water. [Personal photos].





Figure 46 – Semi submersed thaw of hemp-lime

The full thaw cycle lasted over 6 hours and small amounts of lime and hurd can be seen settled in the bottom.

[Personal photos].



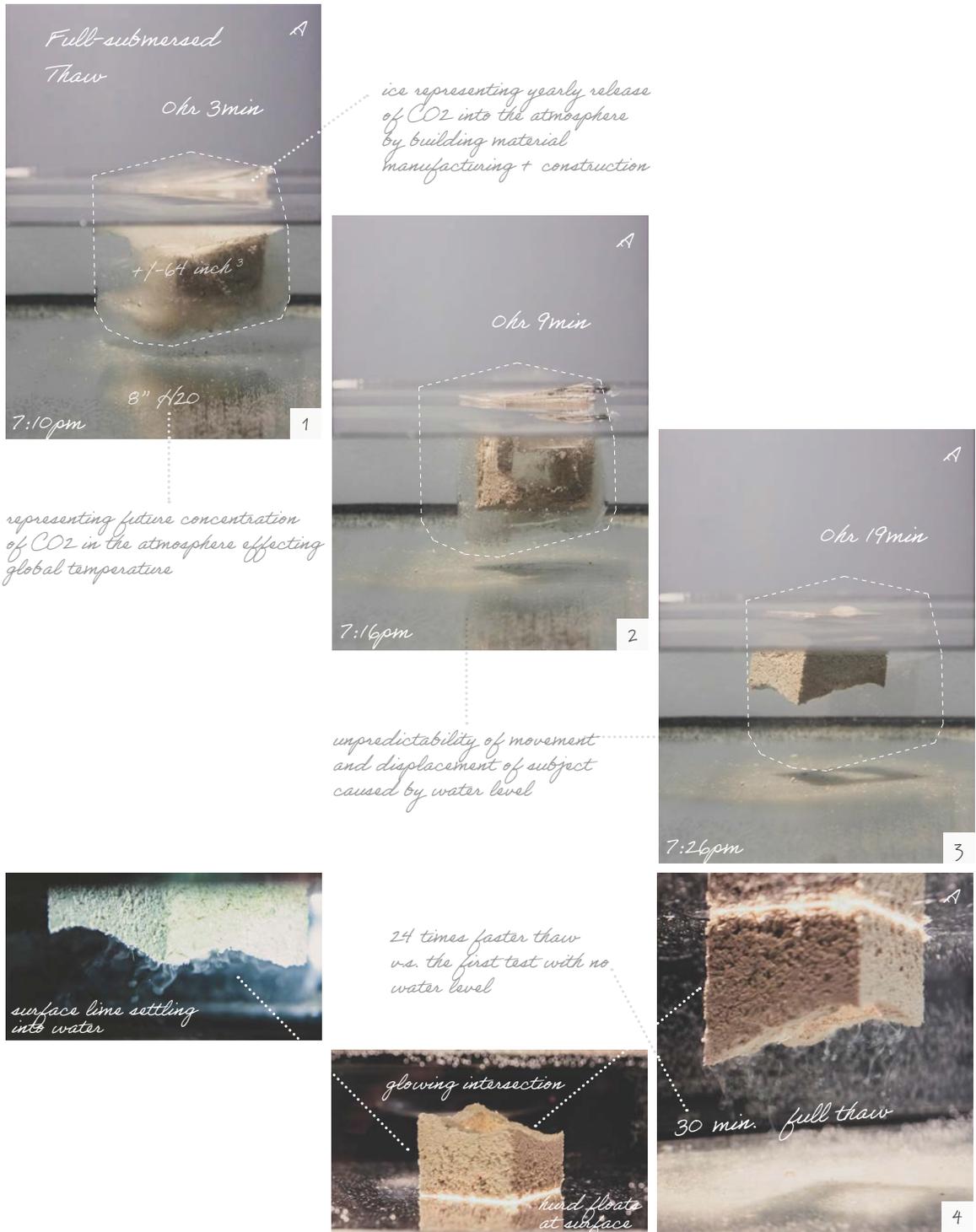


Figure 47 – Full submersion thaw of hemp-lime

The full thaw cycle lasted under 30 minutes and small amount of lime and hurd can be seen settling in the tank.

[Personal photos].



conduction than from convection. Thus, the ambient test took the longest to thaw at 12 hours. In the semi-submersed scenario, the water had melted the ice in direct contact until the hemp-lime sample had reached the floor of the tank, which then served as an insulation layer. From there it began to melt *convectively*. The thaw lasted 6 hours, total. The final test, of full submersion in water, created a melting unevenness which propelled the ice cube into motion until it was completely thawed at 30 minutes. In these experiments, I aspired to see how the hemp-lime would endure when sited in the context of our seasonal Canadian climate. In all three scenarios, the structures remained fully intact with minute amounts of surface lime and hemp mixing into the water.

Shifting from the extreme cold on the thermal scale to high combustion. And intently, classifying this exploration as a “study” - I was not looking for specific results but was open to the unpredictability of the findings. Located in a large open space outdoors, the exploration began with three insulations: pink fiberglass batt, blue extruded polystyrene (XPS), and a beige hemp-lime cube. Purposely, to examine how the insulations would interact when exposed to a direct flame. With an active torch centered at the front face of each sample, my



Figure 48 – Combustion study of various insulations

From left to right: fiberglass insulation, extruded polystyrene, hemp-lime block [Personal photos].



results recorded the length of time the fire was able to penetrate or conversely resist ignition [see figure 48]. The 3.5" fiberglass batt lasted 15.7 seconds before there was an evident hole through the center and where the burnt remains had incinerated into grey smoke. The 1.5" XPS withstood for 9.5 seconds before a clear opening could be seen and melted into a hard plastic and black smoke. Finally, the 4" hemp-lime specimen endured for an entire 5 minutes and 23 seconds with the torch positioned at it's center. The cube displayed a 1cm depression and a charred midsection but did not burn through. The hemp sample also retained the heat within its core, as it radiated a bright orange colour which glowed for 32 seconds after the flame was removed. For this exploration, hemp-lime proved dominant, over the synthetic insulations, with its resistance to combustion.

6.3 HUMIDITY

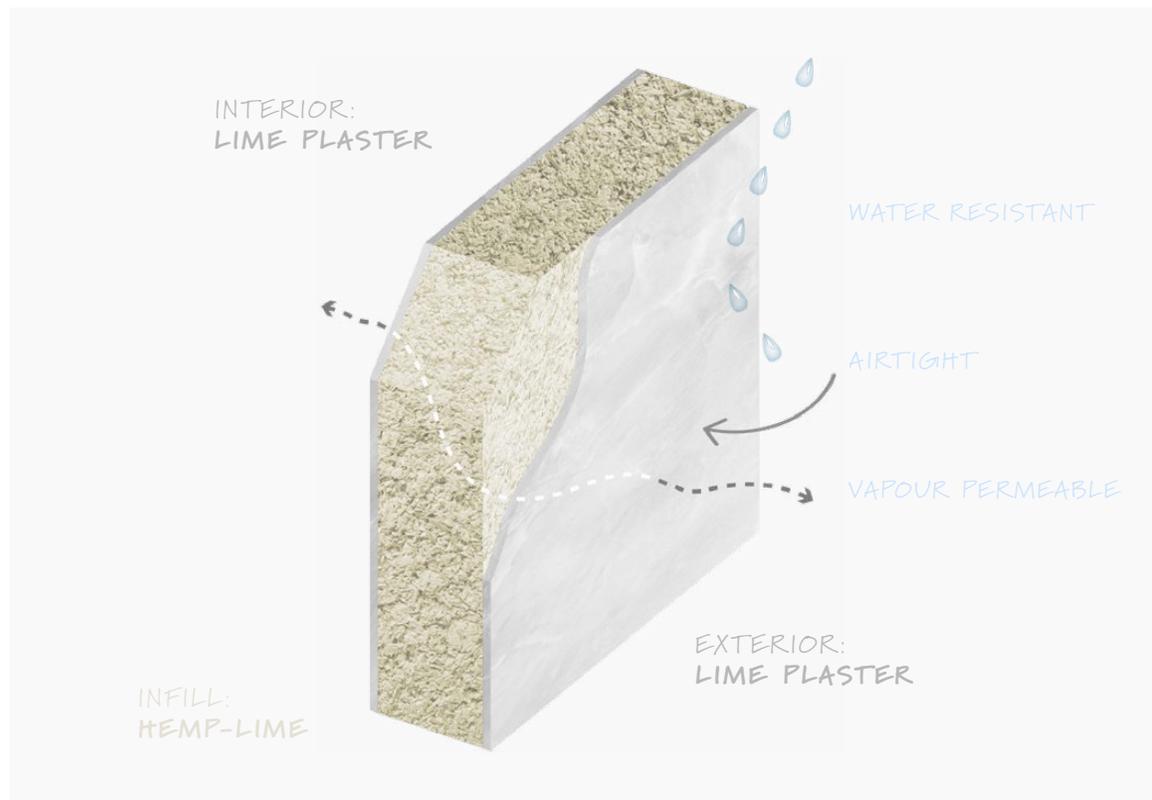
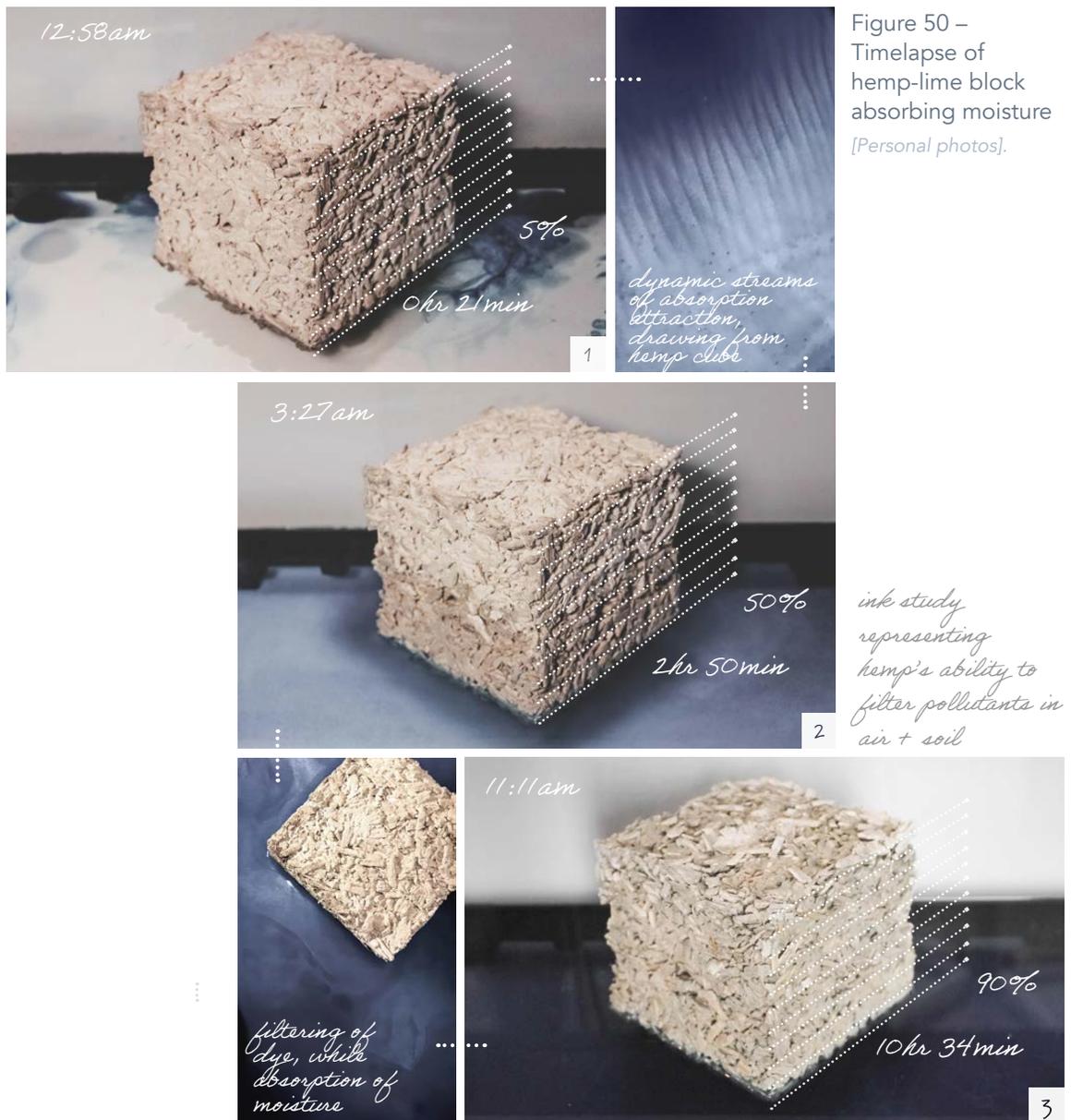


Figure 49 – Hemp-lime wall diagram with lime plaster finish

Contains self-healing properties, Both interior and exterior wall to be finished in lime plaster increases airtightness, performance, Moisture vapour drawn into wall will be released back into environment when conditions become drier. [Personal diagram].



Understanding moisture as an aspect of a building material was foreign to me at first. But the relationship of hemp-lime is dynamic because of its ability to regulate humidity in excessively moist or dry air conditions.⁷² Finished with a lime plaster on the interior and exterior, the hemp-lime wall system is still capable of vapour permeability [see figure 49]. Distinctively, this affiliation is symbiotic. As the occupant breathes, so too does the wall. The inherent *absorb-ability* of the hurd with the addition of a lime coating (which is anti-fungal and anti-microbial) creates a high mold resistant surface ⁷³ (see mold study in appendix A).



72 Magwood, *Essential Hempcrete Construction*, 8.

73 Magwood, 6.



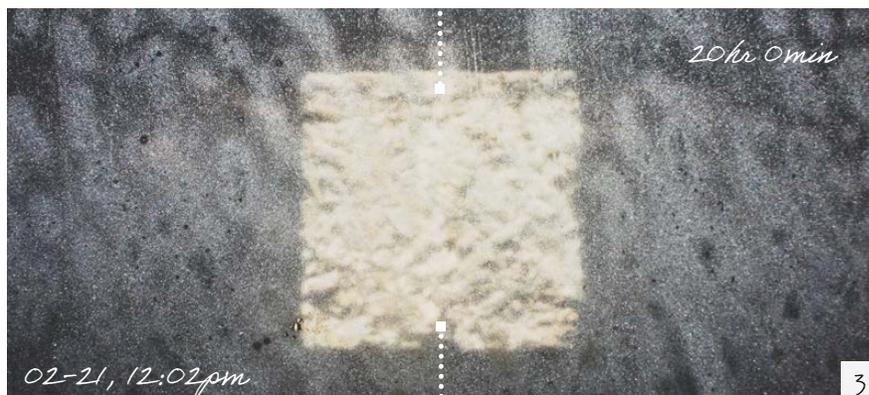
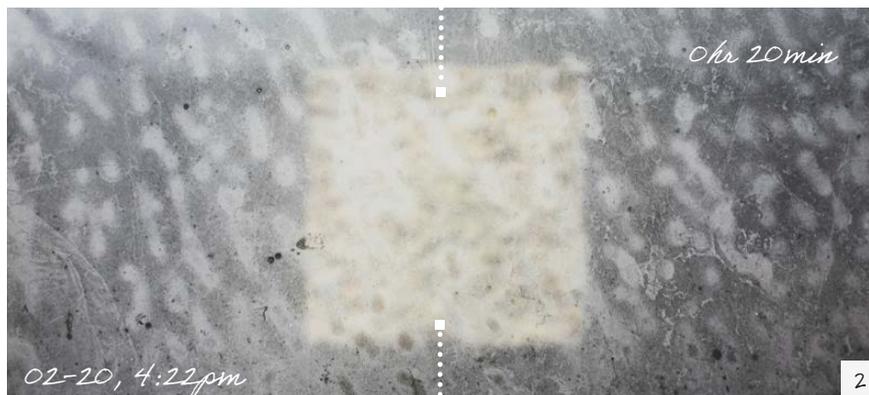
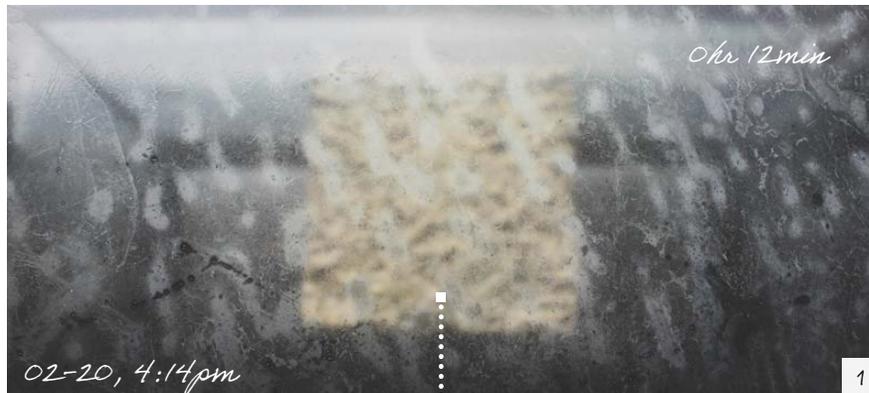


Figure 51 – Timelapse of hemp-lime block regulating humidity
[Personal photos].

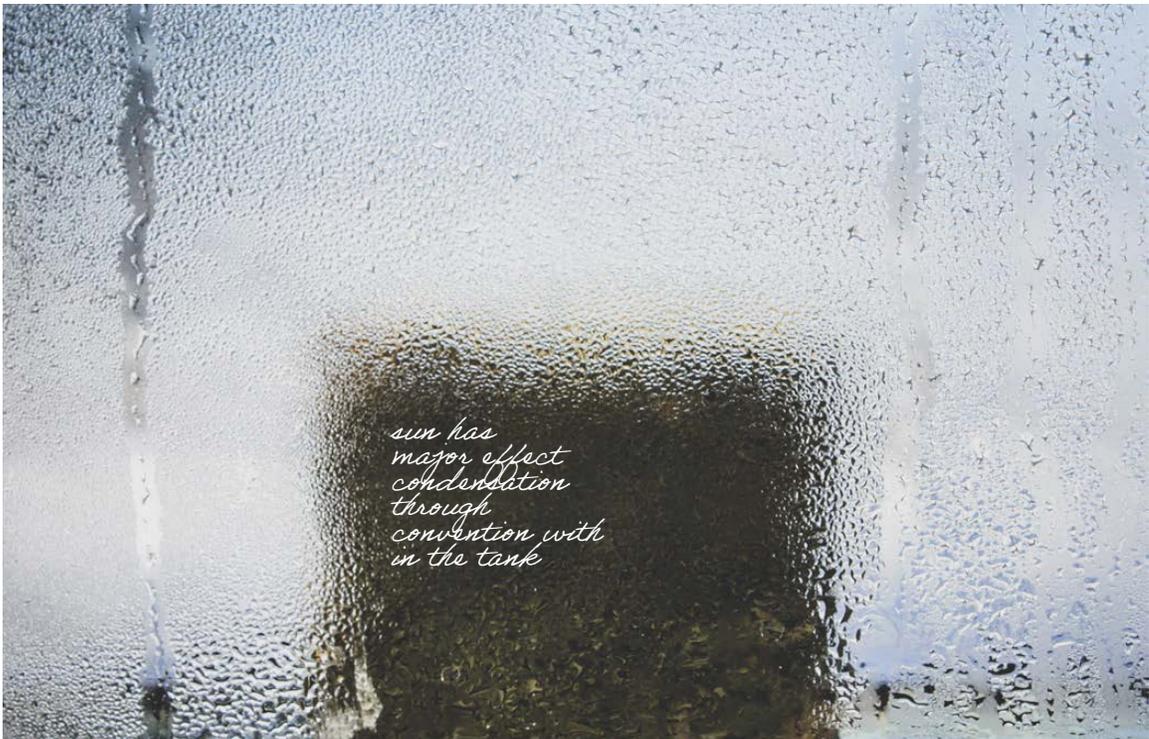
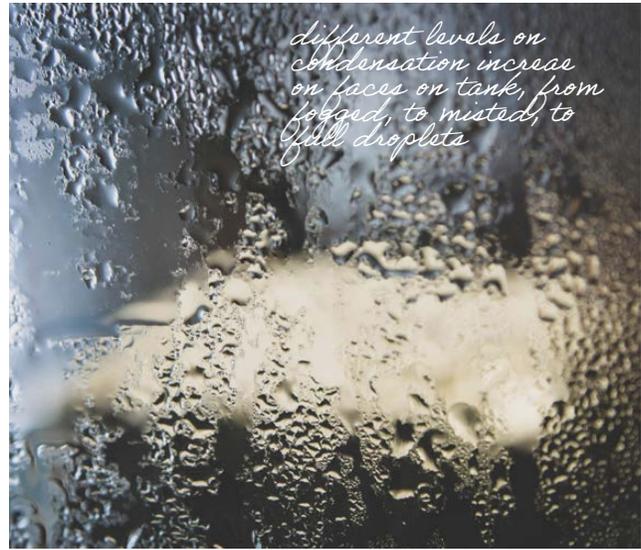
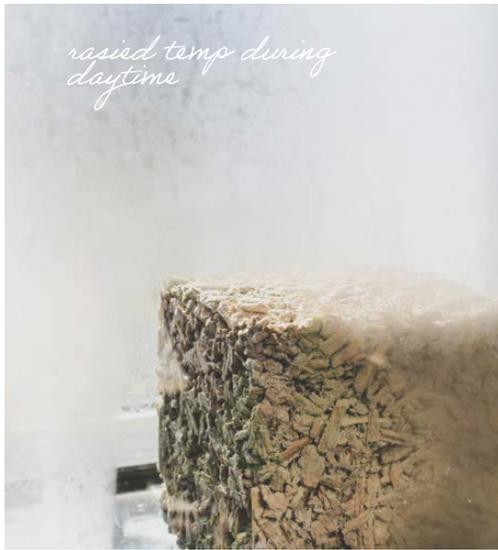


Figure 52 – Hemp-lime block regulating humidity
[Personal photos].

Interested in the biomass' capabilities of holding and releasing moisture, I returned to the tank. Placing a 64-cubic inch hemp sample into a shallow layer of water, I then added a few drops of dye. I was initially expecting the dye to seep up along the sides of the cube so I could visualize its absorbing rate. Yet rather than the stain leaching into the block, it was left in the tank. The hemp filtered past the dye, only to absorb the water. The rate of absorption was relatively slow. 12 hours later, the cube was about 90% saturated [see figure 50]. No visual detriments to the sample could be observed.

I then shifted to the opposite - the ability to release moisture. Covering the top with a plastic film, I positioned the saturated hemp cube into the empty glass tank. Within minutes, the humidity levels of the tank rose, and moisture had accumulated on the sides. In over a few hours in direct sunlight, enough water had built up on the faces of the tank that droplets began forming [see figures 51 & 52]. Since the glass box was fully enclosed on all sides, the moisture had nowhere to escape. I removed the top film and allowed the sample to fully dry as it offered the humidity to my home.

6.4 SOUND

The knowledge one may have of a sound absorbing building material, may only extend to soundproofing a room with foam panels, aluminum baffles and insulation. There is also the uncanny phenomena one may get from cleaning a room, or preparing to move, where the subsequent room lies empty. Now, the voice of the occupant resonates off the blank surfaces continually uninterrupted. The objects and possessions that once stood their place are said to be "missing". Things that helped the room feel homey and inviting. It is as if the management of sound is integral for a person to dwell and feel safe.

Contrasting, the excess of noise and the lack of the silence in our culture today provokes me with the question - can we handle silence? In his book, *In Pursuit of Silence*, George Prochnik arrives at a chapel reserved for monks beneath the church of New Melleray Abbey in Iowa. As his guide led him, he warned, "the silence in the room was so intense



*hemp-lime is inherently light, porous and textured
- this airy structure provides good acoustical
properties*



*sound reduction of 58 dB (pair of 6" walls with
a 3" cavity space... Code minimum is 53 dB)
stat source: Essential Hempcrete Construction - Magwood 2016
(pg. 9)*

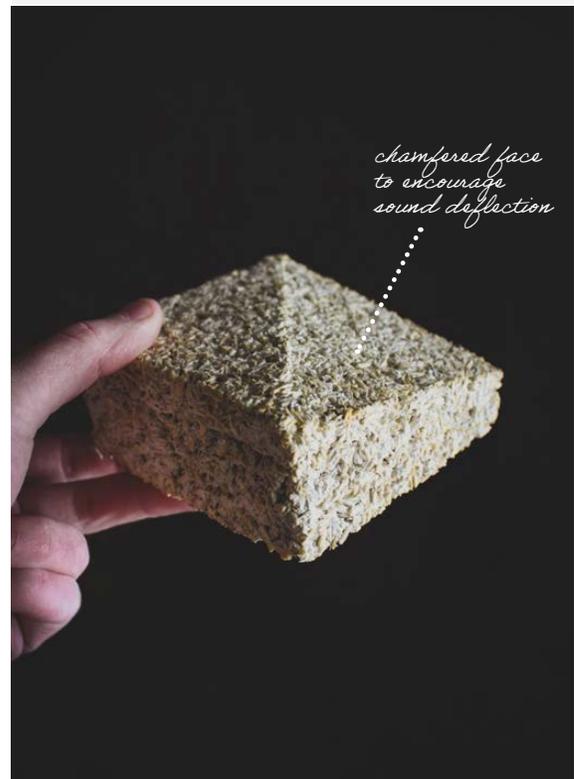


Figure 53 – Close up of the light and porous structure hemp hurd [Personal photos].

that it was likely to, “take me out of my comfort zone”. He knew of cases where people from the big city had found themselves physically unable to remain in the chapel for even five minutes.”⁷⁴ Have we become so attuned to sound that the absence of it makes us sick?

As I focus in on the third sense, the relationship of sound to hemp-lime, I come back to the process of making. Since noise handling is difficult to visualize without involving technology, I approached from a design standpoint. Hemp is inherently sound absorbing due to its porous and airy composition. I thus began to angle surfaces to deflect sound and create channels in the center to capture noise [see figures 53 & 54]. As I look back, I am reminded that noise is another change in air density. Hot air expanded by heat. All three experiences exemplify ideas of lightness – thermally insulating, hold and release of humidity, and sound absorption. An airy trio unique to this material. Together they give purpose back to walls through revitalizing experience.



Figure 54 – Hemp-lime block design for increased sound proofing [Personal photos].

74 Prochnik, *In Pursuit of Silence*, 47.



6.5 REFLECTION ON ARCHITECTURAL POTENTIAL



Figure 55 – Hemp-lime block with lime plaster finish *[Personal photos]*.

It was vital that the studies on the senses were novel and not associated to standardized trials seeking strict quantified data. In this way it allowed me to immerse in experience alongside experiment without hindering exploration. When returning to analyse the dynamic experiences of hemp-lime, it became clear that its use would work in harmony in a dwelling. The qualities of humidity, thermal, and sound are continually active in the material and occur in tandem. Thus, they are most advantageous in homes and may become lost or under-appreciated in other spaces which are occupied for intermittent timeframes.

First, reflecting on the thermal explorations, the way in which the material reserved heat from the flame stood out the most. This inspired me to re-imagine insulation – to be a middle ground between a mass wall and a lightweight product. Rather than seeking to fully restrict temperature flow (as it is with airy synthetic insulations) perhaps it could also be storage. For example, heat from the sun or indoor activity, could be collected in a hemp mass wall during the day for potential release at night as it became cooler. Therefore, the

occupant would not only have to rely on a mechanical system for heat but could trust in (and design) the architecture for warmth. Additionally, the remarkable fire resistance of hemp-lime alone is enough sustenance to be a material worth pursuing.

Second, acknowledging the presence of humidity and moisture in buildings, then using it as an advantage is unique to hemp-lime. Although, manufacturers typically desire moisture resistant materials and tight wall assemblies because the existence of moisture can be detrimental. Homes also accumulate stale and stagnant indoor air - only remediated by a percentage of fresh air through a mechanical air exchanger, which unfortunately also removes humidity. Therefore, humidifiers are required to recreate a healthy and humid indoor environment. Using the moisture studies to see hemp-lime actively store and release moisture has shown great potential as a vapour permeable wall system. For one, this creates air that is both healthier and contains a more pleasant level of humidity for occupants. wo, it reduces cost incurred from mechanical systems.

Third, if building for fire-resistance and instinctive moisture handling, sound-management comes as an involuntary benefactor due to the supple character of hemp. The capability of walls to absorb sound is absent in conventional walls. A typical gypsum board finish bounces sound back, and hollow walls allow noise to travel through. Indiscreetly, we have learned to live the noises we hear daily. Dwelling in a home where every wall is capable of absorbing sound would be a peaceful and quiet space – ideal for studies and bedrooms. Also, the material's final shaped is defined by the forms; allowing a greater freedom in design whether to control noise or for aesthetic purposes. Wholly, the relationship between the three experiences becomes greater as the wall becomes larger. The more material added equals enhanced sound proofing, higher insulative value, and better moisture distribution.



CH. 7

SACRED MATERIAL, SACRED SITE



7.1 SACRED LIME

Knowing our disconnection to materials and the continuous renovation of buildings to keep up with trends; have the material our walls are composed of lost all value? Can material still have meaning? Can material be sacred? For these questions, I return to a few ancient lime practices. Besides early lime-construction, which was predominantly of monumental nature,⁷⁵ there were also sacred burial uses. Dating back to 1500 B.C., a fibrous lime-gypsum plaster was used for ornamenting coffins.⁷⁶ Material adoration in ancient cultures was also expressed in the preparing and embalming of those who past-away. Expert on limekilns and limeburning Richard Williams eerily explains, “[in parts of the far East] bodies were buried in lime and when the flesh disintegrated the bones would be washed and placed in pots on the hillsides. In the Canary Islands and no doubt elsewhere, bodies were limed at burial for hygienic reasons.”⁷⁷ Importantly, the materials connection to life and death was also a purposeful one – for sanitary intentions and preservation.



Figure 56 – Lime plaster finish at sunset

Plaster consists of 1 part lime to 3 parts fine sand and water until putty type consistency. [Personal photo].

75 Cowper, *Lime and Lime Mortars*, 3.

76 Cowper, 3.

77 Williams, *Limekilns and Limeburning*, 3.

7.2 PRECEDENT: RE-FORMED

Built in 2000, the *Chapel of Reconciliation* designed by Reitermann & Sassenroth Architects, has a deep history in the sacred. Though a relatively small footprint, the project has diverse themes including: the silence of site, reconciling the past, connection to the earth, and the regeneration of material. The project was constructed as the successor to the demolished church of 1985 because of its location on the former death strip of the Berlin Wall.⁷⁸ The interior rammed-earth core serves as a place for reflection and prayer - representing the vigor of the community. The outer wooden shell used for circulation represents the delicacy and vulnerability of harmony and reconciliation. Leaving the old foundation in place, the 390 tons of earth used in the new walls and floors, were composed of soil mixed with brick remnants from the former church.⁷⁹ Quite literally building up from the past [see figure 57].

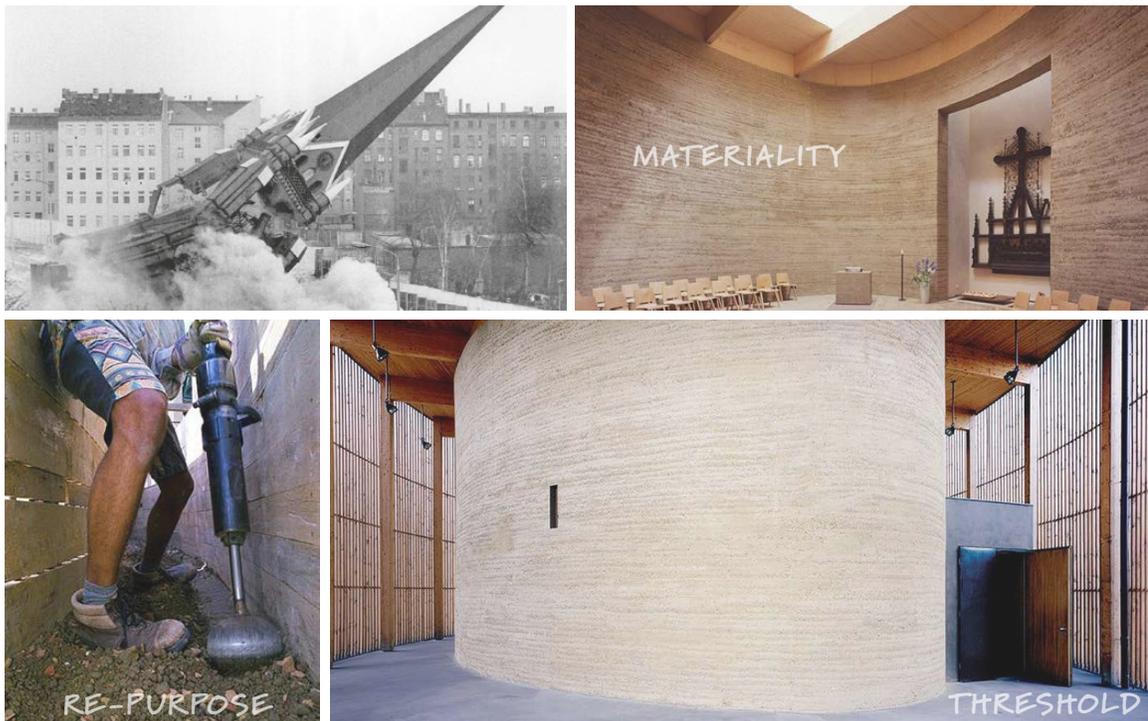


Figure 57 – Chapel of Reconciliation, Berlin 2000

Designed by Peter Sassenroth and Rudolf Reitermann. Sources; Image demo: tagesspiegel.de/images/kirche/11262278/5-format43.jpg | Image source 2, 4: <https://thisispaper.com/mag/chapel-of-reconciliation-by-reitermann-sassenroth> | Image sources 3: dachverband-lehm.de/bauwerke/kapelle-der-versoehnung

⁷⁸ "Kapelle Der Versoehnung."

⁷⁹ "Kapelle Der Versoehnung."

7.3 PRECEDENT: REVERED

Built in the Herodian era by Herod the Great, the Western Wall in Jerusalem marks a significant place for faith and contemplation. The location is described as the “holiest site where Jews are allowed to pray”.⁸⁰ This ancient structure is all that remains standing from the Romans destruction in 70 CE of the second temple complex (the second destruction of the two Jewish temples built in Jerusalem). Carved boulders still lay tossed along the ground from the wreckage 2000 years ago.⁸¹ The edifice that stands 60 feet tall and nearly 160 feet long was constructed of thick limestone blocks.⁸² The cracks are filled from the tradition of setting notes of written prayers within. Today, the lasting remains of the limestone wall continue to be the focal point of religious ritual and pilgrimage⁸³ [see figure 58].



Figure 58 – The Western Wall, Jerusalem

Photos taken as part of the Extreme Landscapes options studio traveling through Tel Aviv, Jerusalem, Ein Gedi, the Negev desert, and Petra in Jordan - February of 2020 [Personal Image].

80 Tobin, “Is Jerusalem’s Western Wall Falling down?”

81 Newman and Borschel-Dan, “Ancient Boulder Dislodges from Western Wall...”

82 Tristram, “What You Need to Know About the Wailing Wall or Western Wall.”

83 Duignan, “Temple of Jerusalem | Description, History, & Significance.”



7.4 PRECEDENT: COMMEMORATIVE

In an aspiring World War 1 war memorial, Constantin Brancusi set three various pieces (in 1937-38) spanning just over a mile. Alongside the river in Tirgu-Jui, Romania, the plan was to honor the Romanians who stood against the German offense in October 1916. Brancusi located his first installment near the bridge where a crucial part of the battle took place. In all his pieces, especially this one, he opted for a simple and tranquil work rather than anything triumphal.⁸⁴ The *Table of Silence*, he titled it, composed of twelve round stools positioned around a circular slab of bampotoc limestone. As Brancusi calmly explained, “I carved this Table and stools in stone for people to dine and rest”.⁸⁵ The use of limestone was significant for the sculptor to craft a commemorative work that was visually humble, peaceful, and sacred in its muted but warm colour. Where those seated, alive, or past, would come together in silence [see figure 59].



Figure 59 – Constantin Brancusi, *Table of Silence*, Tirgu-Jui, 1937-8

Built of bampotoc limestone table 90 cm tall and 215 cm wide. Stools stand at 45 cm in height and 55cm wide. Image source: *A Bitter Truth* by Richard Cork - page 311.

⁸⁴ Cork, *A Bitter Truth*, 310.

⁸⁵ Cork, 310.

7.5 SITE - ST. RAPHAEL'S

The duality of experiencing the *silence* and the *sacred* (that are so closely-knit) led me to the site of St. Raphael's, Ontario. In reflection after my first visit to the location, I was pleasantly surprised to discover that a key material, I had been working with in my research, was throughout the former church's character. The Scottish pioneers who first constructed the church in 1815-1821 [see figure 60], used local Glengarry limestone for the walls that supported a timber roof structure.⁸⁶ The exterior was constructed in ashlar masonry - dressed stone (happenstance the same method used in Masada's Northern Palace [chapter 3.2]). The interior church walls used a roughly squared stone covered with a lime plaster. In 1970, a fire destroyed the roof and interior only leaving the masonry walls remaining.⁸⁷ Years later, a stabilization project would restore what had endured. Today, a more modest church extends from its back and the passageways to the *inside* of the ruins are gated closed - only to be opened for ceremonial purposes such as weddings. The cemetery stayed untouched from the fire and new gravestones run parallel along the rear.



Figure 60 – St Raphael's Church, erected in 1818

Source: <https://saintraphaelsruins.com/stabilization-project/>

⁸⁶ "The Stabilization Project."

⁸⁷ "The Stabilization Project."





Figure 61 – St Raphael's Ruins and Cemetery, Site Visit

Photos taken on February 1st, 2021 at 4:30pm. Temperature -8C, wind 23km/h. [Personal images].

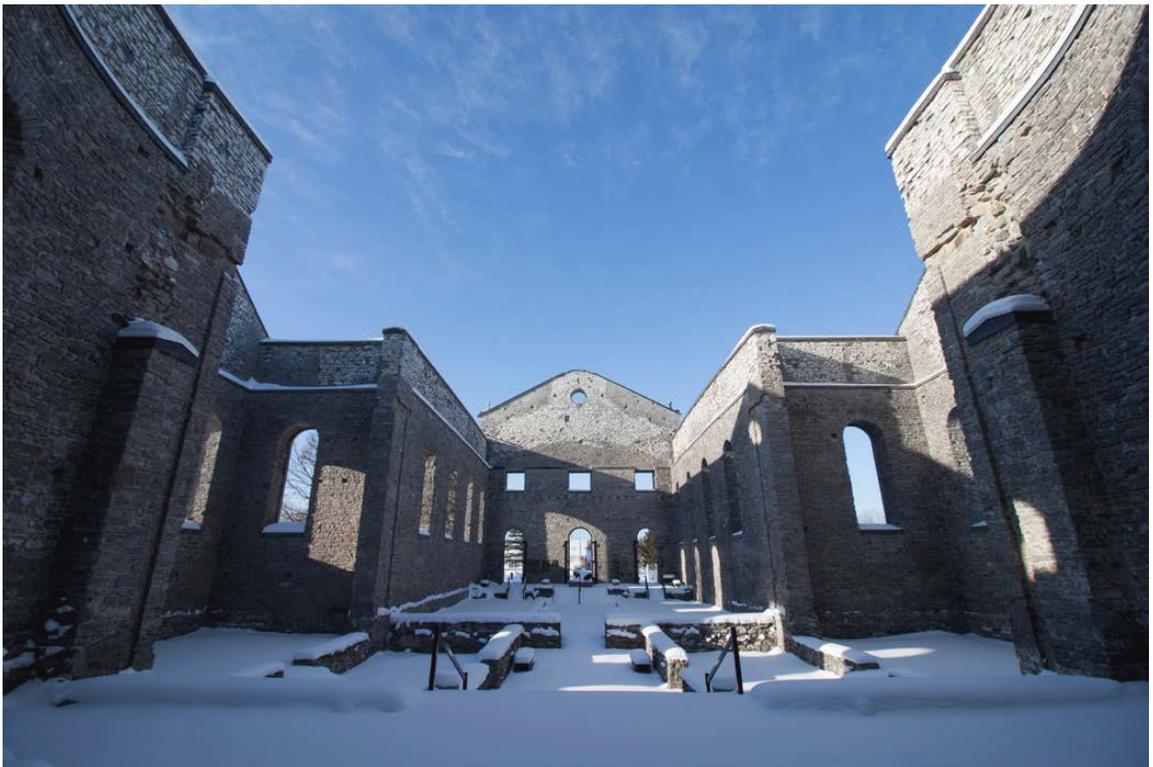
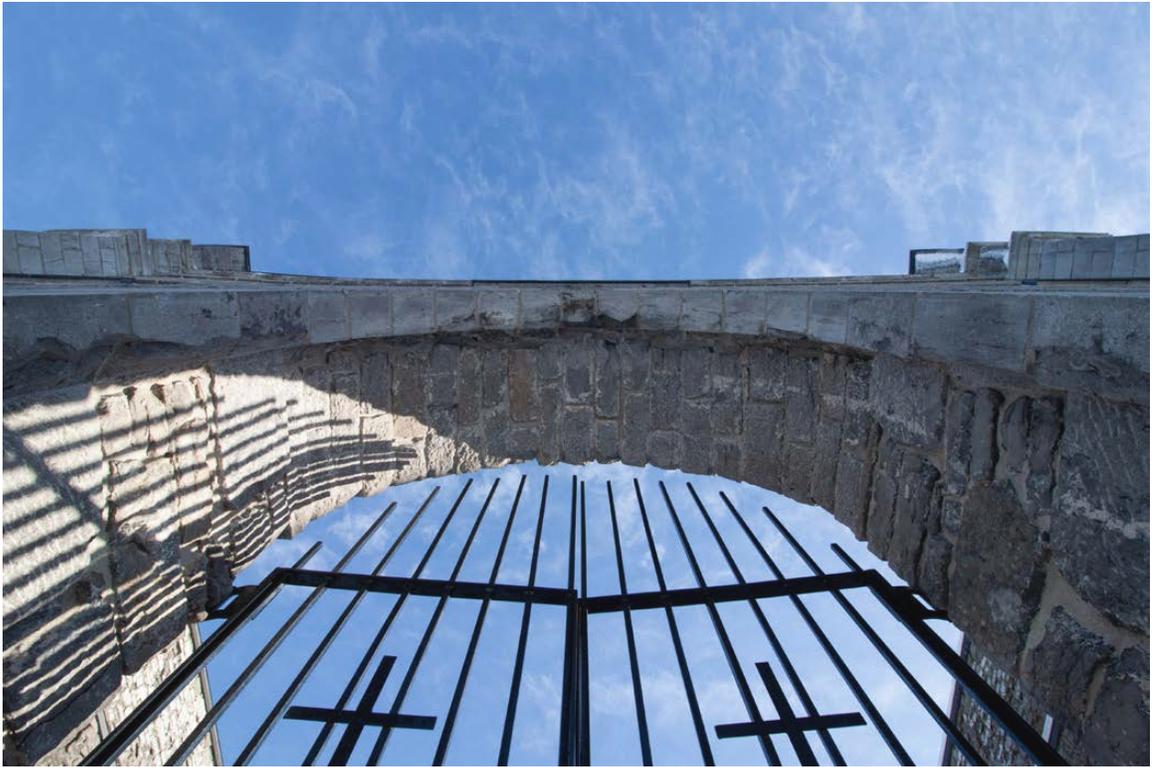


Figure 62 – St Raphael's Ruins, Site Visit

Photos taken on February 1st, 2021 at 4:30pm. Temperature -8C, wind 23km/h. [Personal images].



7.6 THOUGHTS ON CEMETERY

A site rarely visited and, in some cases, avoided. The evolution of the cemetery is significant and deserves more attention. The interconnectedness, the revered, and the quietness all make this place unique from all other parts of the city. In the book *Of Other Spaces* Michel Foucault provides a captivating overview on the story of the cemetery:

"It is a space that is however connected with all the sites of the citystate or society or village, etc., since each individual, each family has relatives in the cemetery. In western culture the cemetery has practically always existed. But it has undergone important changes. Until the end of the eighteenth century, the cemetery was placed at the heart of the city, next to the church... Basically it was quite natural that, in a time of real belief in the resurrection of bodies and the immortality of the soul, overriding importance was not accorded to the body's remains. On the contrary, from the moment when people are no longer sure that they have a soul or that the body will regain life, it is perhaps necessary to give much more attention to the dead body, which is ultimately the only trace of our existence in the world and in language... In correlation with the individualization of death and the bourgeois appropriation of the cemetery, there arises an obsession with death as an "illness." The dead, it is supposed, bring illnesses to the living, and it is the presence and proximity of the dead right beside the houses, next to the church, almost in the middle of the street, it is this proximity that propagates death itself... during the nineteenth century, the shift of cemeteries toward the suburbs was initiated. The cemeteries then came to constitute, no longer the sacred and immortal heart of the city, but "the other city," where each family possesses its dark resting place."⁸⁸

88 Michel, Foucault, *Of Other Spaces*, Vol. 16:25.



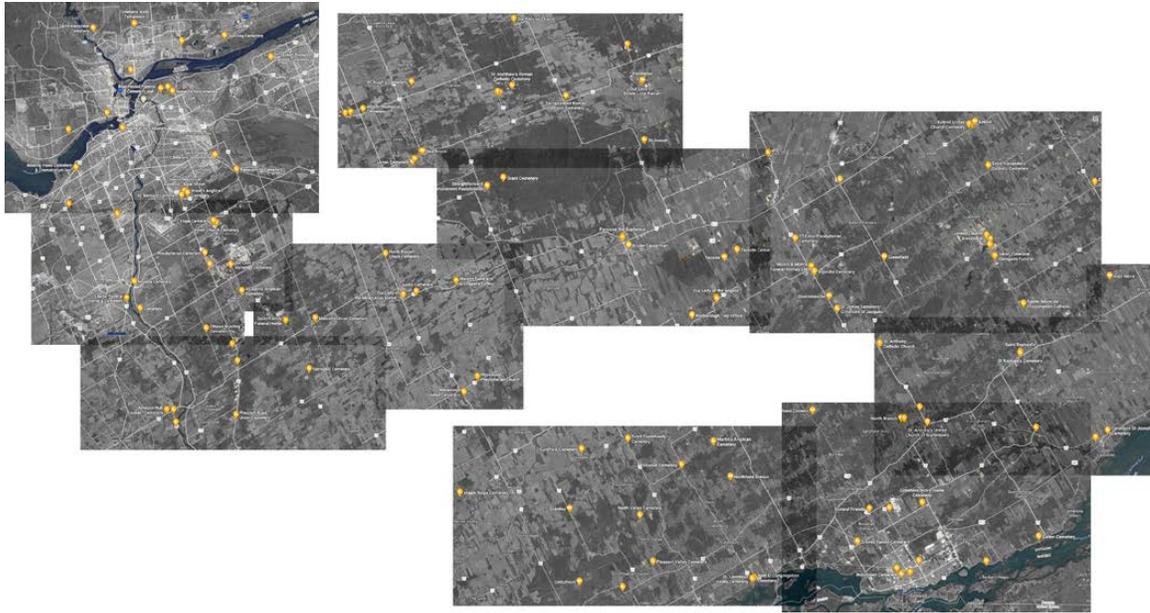


Figure 63 – Locations of cemeteries in Ottawa, Cornwall, and surrounding area

A large majority of cemeteries, identified in orange, are located outside of the city core and beside small towns, greenspace, and agricultural land. The aerial imagery spans from Ottawa (on the left) to Cornwall (at the bottom right). [Personal diagram].

Initially, I am captivated by Foucault’s description of the cemetery being intertwined to every part of the city and society [see figure 63]. And the connection is a humble 2.5ft x 8ft piece of allocated soil that extends through time. While pushed to the outside of the urban life, the cemetery is many tangible parts of history in one place.

Furthermore, as Foucault concludes, he highlights that the cemetery has lost its core sacred element. Plus, individuality has taken its place. As I reflect many years after his initial insights (published in 1986) I ask - have we continued to lose the significance of these sites? Do they no longer hold relevance to our culture? Compared to ancient cultures, a tomb was a resting place of high regard and was made to last theoretically an eternity. Mortality and the afterlife were celebrated in the ornamentation of these constructs and caskets, many on a base of lime plaster. As Lisa Hescong advocates, “In religious societies sacredness is a way to communicate extreme importance of a symbol to society. When a symbol represents something considered essential to human experience, its preservation is of paramount importance. By deeming it sacred, a symbol becomes inviolable, ensuring



its survival through time.”⁸⁹ Today, “in a time when civilization has become “atheistic,””⁹⁰ as Foucault describes, will cemeteries continue to devolve with the thought that death is an *illness*? Eventually, de-constructing itself; from tomb - to cemetery - to what?

7.7 THE RUINS AND THE CEMETERY

Still, being very aware of the multi-sensory experience of hemp lime I explored in the previous chapter - it was crucial for me understand how these experiences currently existed on the site (or lack thereof) and record these observations. This is my account...



Figure 64 – Aerial shot of St Raphael's Ruins and Cemetery

Personal drone footage. Facing SW, shot on February 28th, 2021 at 12:30pm - temperature 4C, wind 13km/h.

[Personal image].

89 Heschong, *Thermal Delight in Architecture*, 51.

90 Michel, Foucault, *Of Other Spaces*, Vol. 16:25.



Alas, the former church is left open and exposed. There is no division between interior and exterior. One could travel beyond the walls and yet still be connected to the entire site. Always touching the atmosphere... I step out of my heated car. I feel the wind, the cold, and the bright sun on my face. I approach the front facade of the ruins, making my way through the high snow. By the ruin wall, I raise my head to the sky and feel uplifted, transcendent. No barrier separates me from the sky. Free of bodily enclosure and free of spirit. I am instantly reminded of the famous Pantheon in Rome – with oculus open to the heavens presenting the eye of God. I then recall the beautiful ceiling paintings in the Palace of Versailles, France. The art depicting heavenly figures floating through space and time. Here at the ruins, the walls frame the sky, and the clouds paint a scene, ever-changing. Undoubtedly not designed to be this way, but perhaps more alive than it was before... I then walk to the shadowed side of the stone ruins. Suddenly, I am protected by the ruins from the prevailing winter winds. I continue forward and turn to my left to notice the grey and white tombstones of the cemetery, piercing through the snow. I continue onward. Following the footsteps of someone who already conquered the snow before me. I reach the back of the ruins and see the footsteps disappear into drifts reclaimed by the wind. I stand still and absorb the serenity of the golden sun shining off the glistening snow. The contrasting tombstones standing in unison, some leaning from age. As I look back to see the site in its entirety, I listen... I hear the road. The constant traffic driving past the front of the site. The rumbling of fueled engines under steel bodies and the friction of rubber on cold asphalt. The hurried, fast paced, anxiety of humanity – the vehicle. The few trees that may have muffled the noise in the warmer months now lay bare. In the sacred site, I anticipated to be silent, I am now distracted by noise.

CH. 8 **RETURN TO MATERIAL, RETURN TO EXPERIENCE**



8.1 STILLNESS

The angst of movement which occurs at the adjacent road is noticeably absent within St Raphael's cemetery. As Manfredo Tafuri understands, "to live in the world of today is to live in a state of constant anxiety".⁹¹ This outer circulation of the living does enter the cemetery for a short time with a visitor. It then ceases with silence and pause. Greeted unwritten respects. Unfortunately, the lack of threshold at St Raphael's allows the distraction of the persistent urgency of our society to enter the site. The noise is reflected off the cold ruins and tombstones and strikes the subject. The rare arrival of the guest is brief, and this time of silence cut short, only to return to the rush of the street. And back to the anxiety of thought and of body.

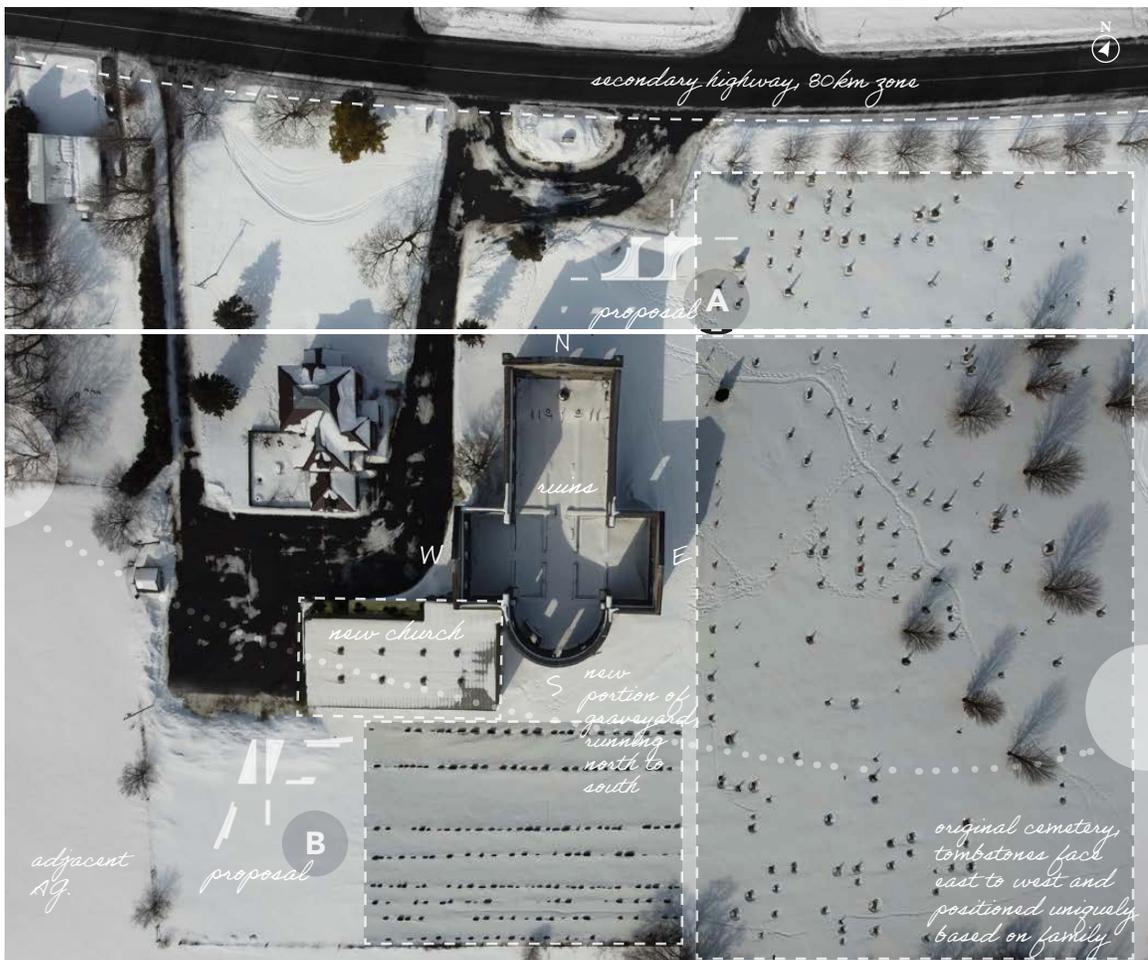


Figure 65 – Site Plan of St Raphael's with proposal locations [Personal image].

91 Manfredo, Tafuri, *There Is No Criticism, Only History*, 11.



8.2 EXPERIENTIAL

How does one construct in an existing graveyard? Thus, by being as light as possible - without excavation. Foremost, choosing a lightness of material and form to respect the fragility of the soil. For creation: In the warm months, the hemp building material is grown and harvested from the neighboring fields (being as local a material as possible) and native lime is acquired. Mixed and cast on site, extra material is scatter over the ground. The “new walls” will be built as a threshold for the site and will respect the materiality of the ruins by means of the lime-cycle. Beginning as powdered lime, with the addition of hemp and water, the walls will revert overtime to be limestone once again. For degradation: time will also reveal that the construct in the cemetery dissolves. Knowingly, this process of weathering will allow lime to run into the adjacent fields from which it grew, helping the neutralize the acidic earth and provide calcium vital for plant growth. For inhabitation: I afford the opportunity to celebrate the multi-sensory experience of hemp-lime.



Figure 66 – A glowing hemp-lime block resonating warmth and muffling noise
[Personal photo].





Figure 67 – Plans of Proposed Thresholds [Personal diagram].



Once constructed, rather than echoing sound throughout the site, the intervention aims at resonating lightness. As it muffles the sound from the road, the welcoming colour of hemp-lime radiates a warm golden glow from the sun - inviting the visitor's burdens to be lightened [see figure 66]. They are encouraged to forget any anxious noise as they begin to travel through one of two thresholds (one at the entrance and another at the back). Reaching the humble construction, steam rises from the hemp-lime walls. The architecture fogs the guest's vision as they pass through the steam. Here they are provided with a clarity of mind by the temporal touch of warmth. The feeling of warmness is alive and central to all things.⁹² Creating an appreciation for the fleeting moments of life. The designs intent prepares the visitor as they reach the inner cemetery and ruin. Intentionally "cleansing" the senses through the airiness of humidity, heat, and silence. This multi-sensory experience achieves similar effects of a sauna [see figures 68 & 69].



Figure 68 – Steam rising from a hemp-lime cube to express thresholds

A study combining all three experiences discovered in the previous chapter (thermal, humidity, sound) into one intervention. [Personal images].

⁹² Heschong, *Thermal Delight in Architecture*, 26.





Figure 69 – Steam rising from a hemp-lime cube to express thresholds. *[Personal images].*

Originating in Finland, the sauna was a place for ritual, family, a cleansing before ceremonies, and a celebration of both life and death.⁹³ Lisa Heschong quotes H.J. Viherjuri, “The sauna was a place for the worship of the dead, who were supposed to return gladly, even after death, to so pleasant a place.... some people believed that the throwing of water over the stones was a form of sacrificial ceremony. The Finnish word *loyly*, meaning the “steam which rises from the stones” originally signified spirit, or even life... “In the Sauna one must conduct oneself as one would in a church,” according to an old Finnish saying. It was forbidden to make a noise or to whistle, or to speak indecently in a sauna, because all evil influences had been driven out”.⁹⁴ Thus, the celebration of life through a multi-sensory experience is core to the site of the cemetery. Heschong continues, “Fire and steam were

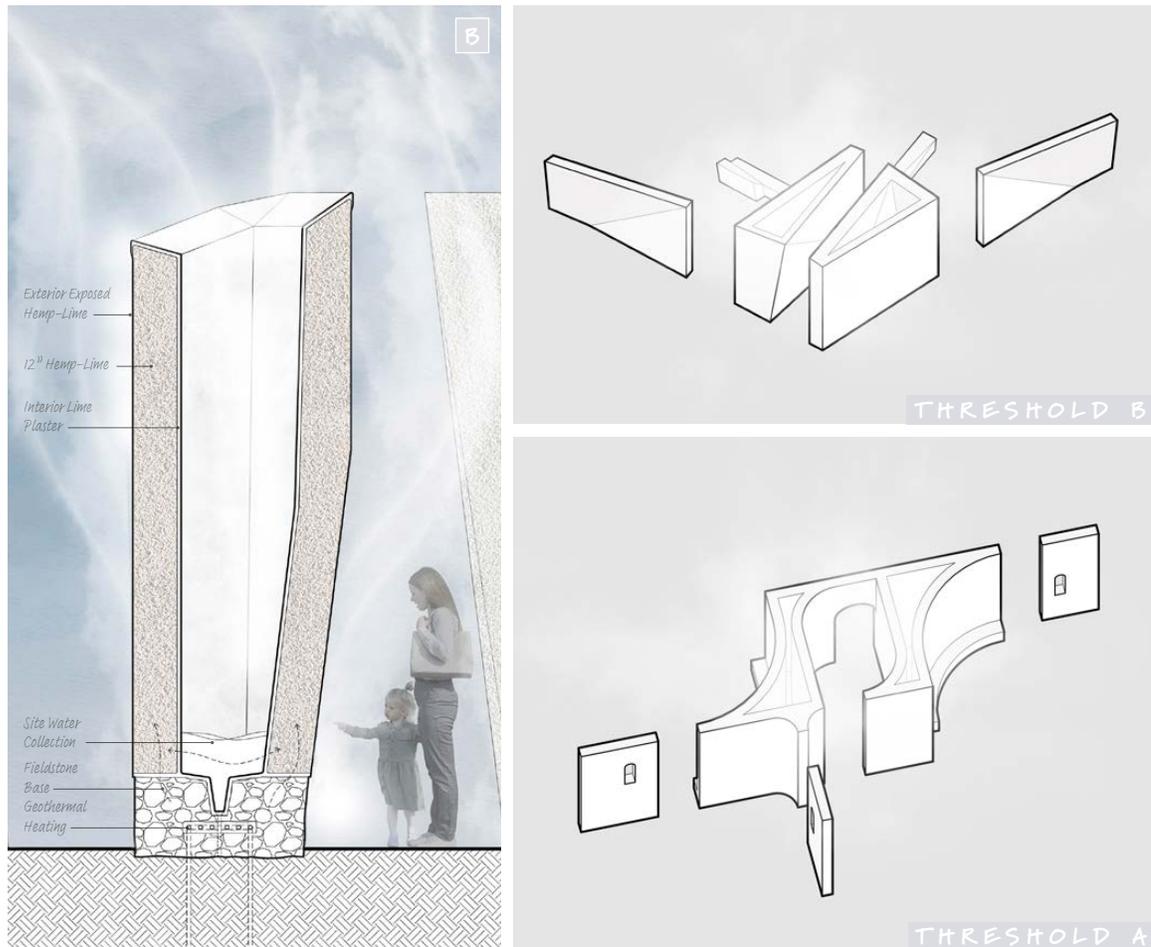


Figure 70 – Thresholds Section and Design

93 Heschong, 53.
 94 Heschong, 54.



valued because they were elemental. They offered an experience of the purity associated with the spiritual realm, and thus provided a link between the physical world of human beings and our ancestors' conception of the principles of the universe".¹

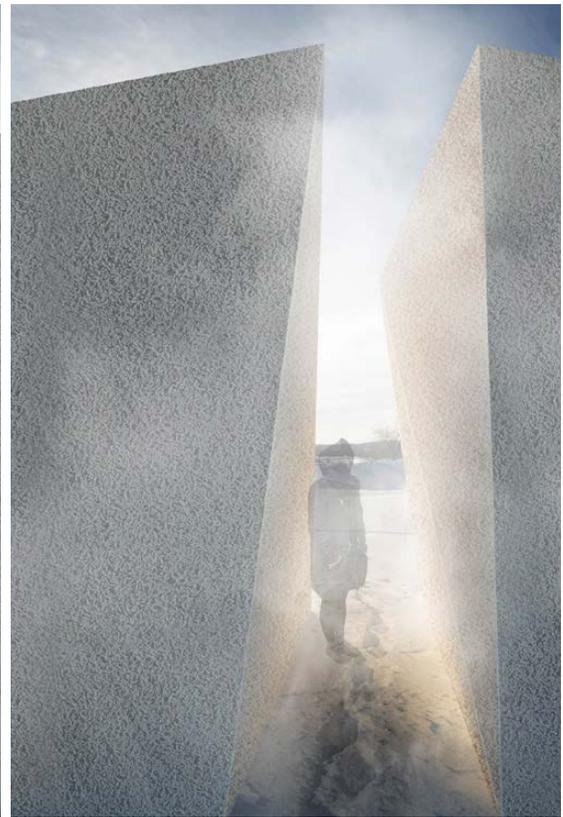


Figure 71 – Vignettes: Approach and journey through thresholds

¹ Heschong, 55.



8.3 CLOSING THOUGHTS

In retrospect, looking at the entirety of my research enabled me to derive supplementary significance. Within *Chapter 1: Introduction* and *Chapter 2: Understanding Climate*, the goal was to recognize the environment from a new perspective - making it perceptible by scale and statistics. Going through the explanation phase helped me to make the overwhelming realities of climate change tangible. Uncovering how wasteful a building society we can be, and often for reasons unrelated to condition or repairability but by demolition coined for progress or for the brand new. Therefore, as building designer my influence has a vital impact on the planet, simply by the materials chosen.

Syphoning *Chapter 3: Hemp & Lime; Origins, Uses, Encounters*, the investigation of natural building strategies led me to hemp and lime. I discovered that both materials have a long history of use but have been forgotten, often replaced by synthetic materials. However, their formation and benefits are respectful for the occupants, the earth, and the air. Both materials, once natural substances originating from the earth, may willingly degrade and be returned to the soil. Thus, reviving these materials and properly educating the public about them is the first step in creating a healthier and safer environment.

Reflecting on *Chapter 4: Know by Making*, molding analysis and data into application, I sought an additional layer of understanding through working with my hands - utilizing touch, smell, and sight. Discerning that hemp-lime requires patience and keen motivation but is exceptionally simple to learn and teach. Through reviewing guidebooks, existing projects, and tutorials, the process of making was not something done in seclusion but often a procedure that involved eager homeowners and even members of the local community. As a result, there was an overall appreciation for the final construction, complemented by feelings of environmental responsibility and accomplishment.

Looking back at *Chapter 5: Dissolving the Wall*, the focus was on analyzing a conventional system in comparison to a hemp-lime wall. Revealing that the traditional multi-



layered construction functions to negate the elements and is informed by the mechanical control of temperature. Although, to properly design for a specific climate, one must understand how the materials will interact in that location. Historically, early builders used local materials and the climate to their advantage, yet today there is a disconnect to these natural building strategies. Additionally, we will only fully understand the consequences of using today's synthetic materials (used in building) decades after their conception.

In *Chapter 6: Multi-Sensory Experience*, I transitioned from a technological viewpoint into a new poetic posture. Realizing that this material had more to offer than pursuing strict data. The multi-sensory experience that hemp and lime create, when combined into a building product, are unique and valuable to explore. Revealing, through my various studies, that occupants can depend less on a mechanical system and instead rely on hemp walls for experience – be it thermal, humidity and sound. Where this natural building material actively works to create a healthy atmosphere, indoors and out.

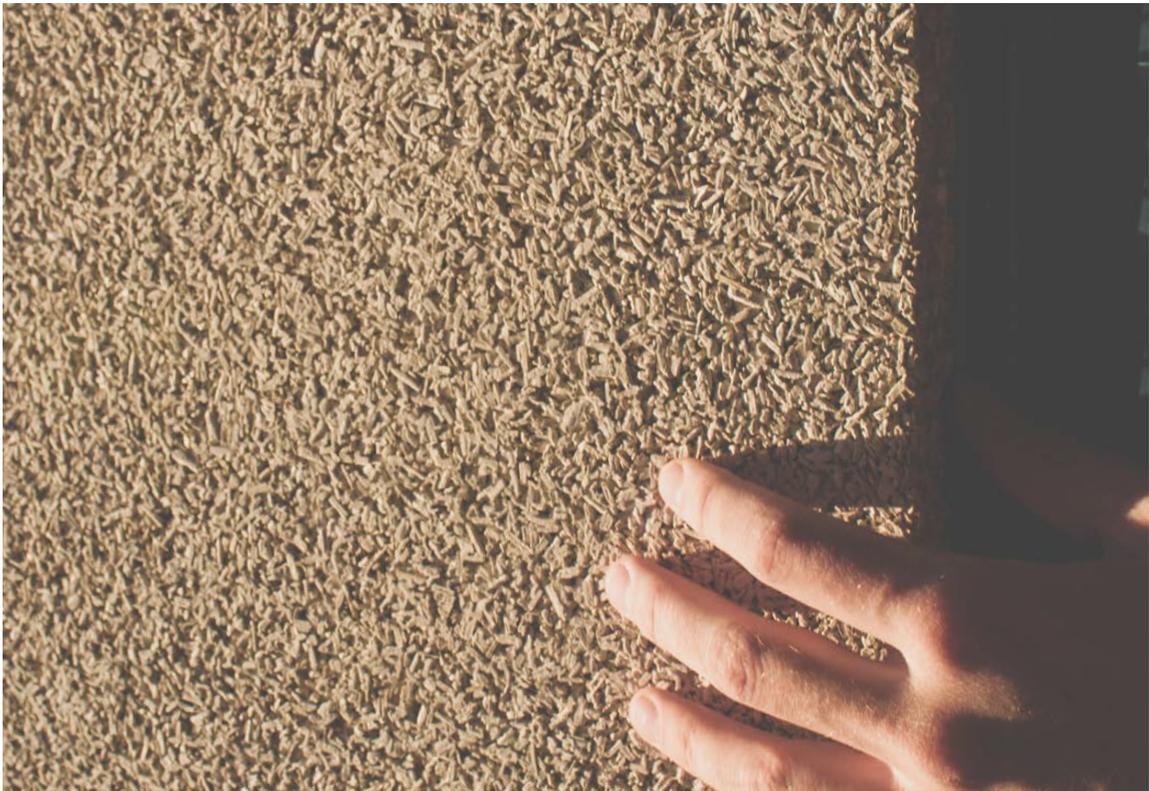


Figure 72 - Interaction with Hemp-Lime Insulation [Personal photo].

Upon reaching *Chapter 7: Sacred Material, Sacred Site*, the research grew to existing precedents (aged and contemporary) where material was used with purpose and identity. In these projects, materiality was found to be sacred. This appreciation is not instantaneous after formation but rather it develops over time. For this reason, synthetic materials and plastics cannot be sacred because they are outside of time (being non-degradable), and without source, ownership, or personality. Alternatively, though hemp-lime is a new product, it may grow to become sacred through its historical uses; where lime was once destined for monumental construction and ornamentation, and hemp previously held a vigorous diversity of functions.

In the final *Chapter 8: Return to Material, Return to Experience*, I sought to merge my research discoveries into one project. Since humanity moves at an ever accelerating pace (via traffic, technology, and work) we often miss out on admiration - whether it be a location, a material, a program, or a memory. Hence, we deeply need spaces that refresh our senses as reverence for others and ourselves. Regrettably, any value of dynamic experience is absent within our current buildings. Lisa Heschong confirms, "We are not now inclined to regard the modern heating and cooling systems as representative of a spiritual realm. The physical principles involved in their operation are thoroughly understood; there is no mystery about them."⁹⁵

Building with plant matter may seem to be a niche and not a necessity. But when weighing the state of our climate we need to reconsider the life cycle of building. Non-degradable plastic insulations (xps, eps, iso, ect.) are far from vernacular because they cannot be traced once disposed. In the *History on Ecological Design*, Lydia Kallipoliti states, "[plastics] will outlive us, but most important, they will inevitably alter and redefine the complex interrelationships between subjects and their environment...".⁹⁶ Looking forward, I am reminded of hemp-limes *traceability* and *degradability* - a raw material where its origins and resting place are clearly defined.

⁹⁵ Heschong, 55.

⁹⁶ Kallipoliti, *History of Ecological Design: Dark Naturalism*.



In conclusion, the moisture handling capabilities, the heat storing capacity and the sound absorbing qualities of hemp-lime bring an appreciation back to walls. And it was by knowing the material through the process of making that I was able to discover these senses. It inspires questions of what a wall composition can be and what a wall can do for us. Pressing for walls to be more than just an inert separation to the outdoors, but for an environmentally conscious and experiential architecture.

8.4 REVERENCE IN THE SILENCE

*Snow and soil at my feet, soul and body come to meet.
The walls do not speak, but humbly listen to my plea.
Where may I be still? Where may I find brief quiet?
The past no longer aid me, though I pay my respects.
The living only echo confusion, indirect.
Here in the temporal, may I think free of trial.
Here in the temporal, do my thoughts reconcile.
Connected through time, a dedicated solemn space.
My mind hopes for peace, as the silence soothes in pace.*

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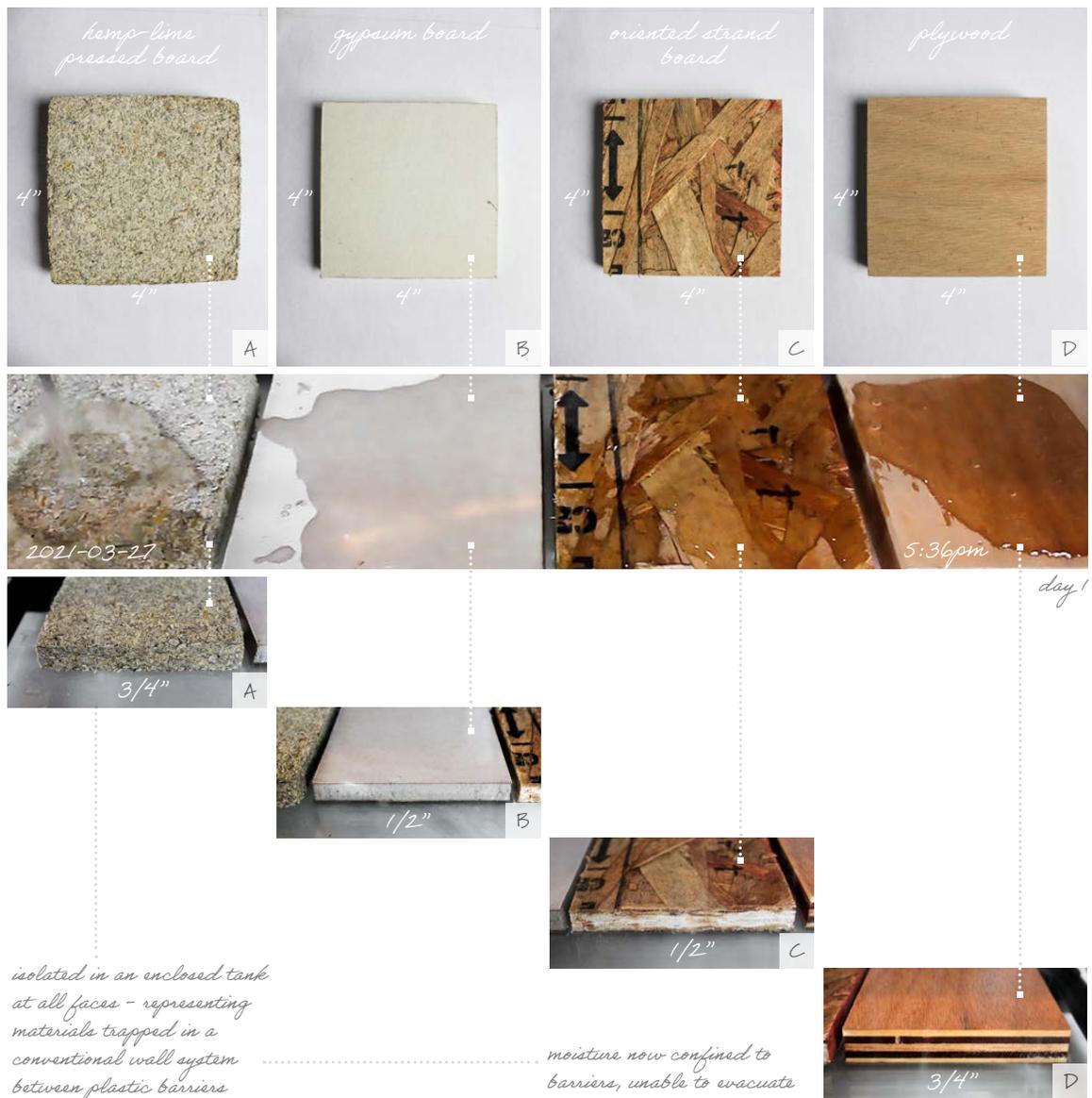


APPENDICES

APPENDIX A: MOLD STUDY

Curiously, I began to explore the less attractive side of moisture. To encourage the development and understand the growth rate of mold, I enclosed a clear tank on all sides - generating a warm and moist environment. I then placed hemp-lime (which resulted in a higher resistance to mold), gypsum board, OSB and plywood within the chamber and recorded my findings for 9 days.

1. Dampen Specimens: Mold analysis for conventional materials v.s. hemp-lime

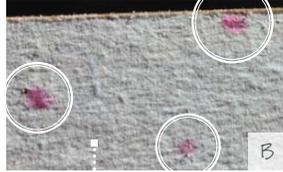


Inspection at 3.5 days: ..Mold analysis for conventional materials v.s. hemp-lime



no visible mold growing on the hemp sample.

hemp-lime pressed board

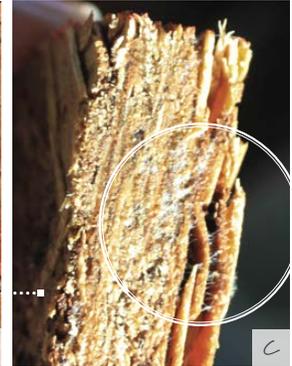


gypsum board

warm + moist environments are susceptible to mold if moisture is unable to be released

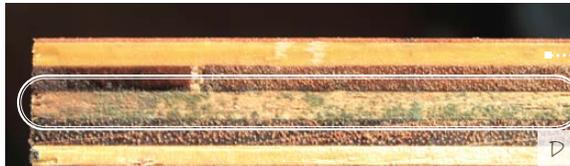


oriented strand board



84hrs (3.5 days)...

Different colored mold growing on the 3 manufactured subjects



plywood



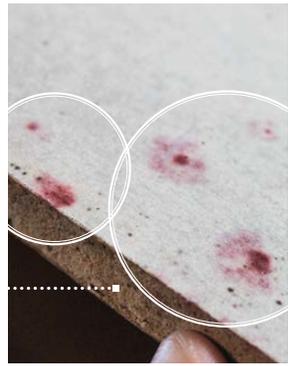
Inspection at 7.6 days: ..Mold analysis for conventional materials v.s. hemp-lime



182hrs (7.6 days)...
Significant amounts of different colored mold growing on the 3 manufactured subjects, first sign of potential mold on hemp edge at 7.5 days (will follow up).



7 full resistant days to mold



4 different types of mold now present on edge of plywood sample



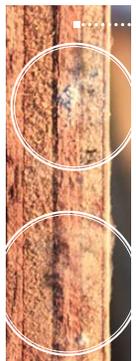
Inspection at 9.6 days: ..Mold analysis for conventional materials v.s. hemp-lime



230hrs (9.6 days)...
 Different colored mold growing on all subjects. (Evidently, prolonged exposure to moisture in trapped condition produces mold growth (common in conventional plastic barrier wall assemblies.)



Some materials are seen to be more mold resistant than others. (Hemp - 7 days, Gypsum - 3 days, OSB + Plywood 2 days)



Post-Reflection

If continuing the mold testing further, it would be advisable to create separate tanks to house the specimens, but retain the same conditions of temperature and heat. Mold may have potentially traveled within the tank on to other samples and increased the growth which may not have occurred if isolated.





THANK YOU.

