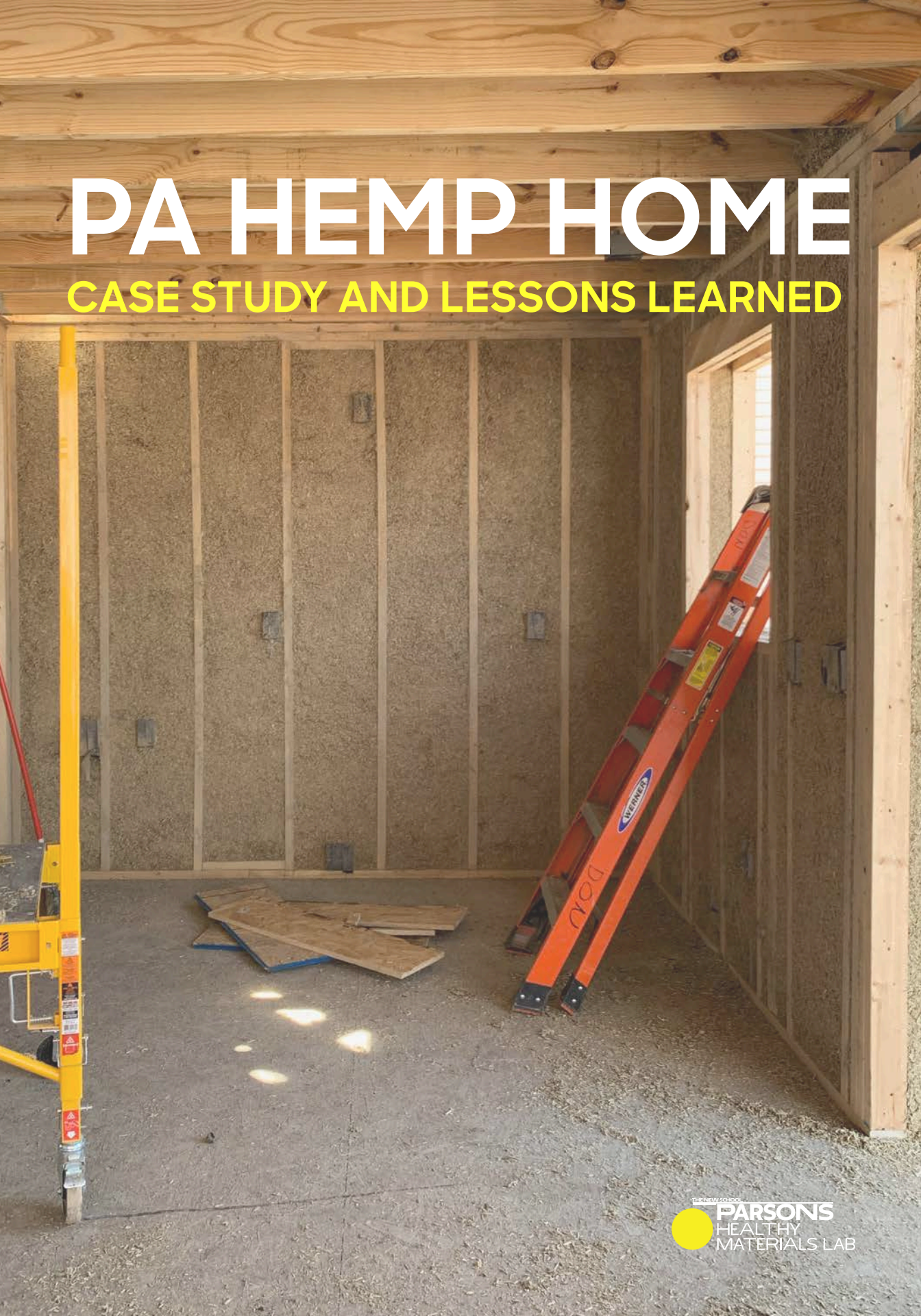

PA HEMP HOME

CASE STUDY AND LESSONS LEARNED

THE NEW SCHOOL
PARSONS
HEALTHY
MATERIALS LAB

Acknowledgments

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Floyd

Project Design–Construction 2021–2022

Fig 1.1 Hemp Hurd Ready for Mixing

Content

1. Introduction

Background

The construction industry is one of the largest carbon emitters contributing to the climate crisis. Additionally, the tens of thousands of tons of hazardous chemicals used to make building products are linked to large-scale and local environmental disasters. These chemicals also harm people's health, particularly in our homes. Today, in the midst of multiple environmental and health crises, there is an increasing demand for innovative building solutions, including regenerative, environmentally sustainable, and benign construction materials, to ultimately decarbonize the industry and make healthier places for people to live.

In the last 50-60 years, there has been a dramatic increase in the number of plastics used in typical building materials.

The reliance on petroleum-based ingredients has increased demand within the petrochemical industry, increasing carbon emissions and exacerbating climate change. The United Nations reports that the construction industry is responsible for 40% of global CO2 emissions, and carbon emissions from the production of building materials are rising. With increased production and use, people are increasingly exposed to these substances, and most petrochemicals harm human health. People living near chemical manufacturing plants are exposed to these emissions in the air and water they depend upon, in addition to chemicals in their homes. With more extreme weather events, there is an increase in environmental chemical contamination from large chemical and manufacturing facilities located near historically low-income residential neighborhoods.

Reduction of Toxics + Carbon Emissions

Many manufacturers of building products have ignored the impact of their products on people's health and on the environment. A new demand for materials transparency from architects, designers, organizations, and consumers is persuading manufacturers to declare the chemical content of their building products. By identifying the substances which are most harmful, we can look for better alternatives.

The 2022 UN Climate Report states without immediate and radical emissions reductions across all sectors, limiting global warming to 1.5°C will be beyond reach. Using products that sequester rather than emit carbon dioxide can reduce carbon impacts and work towards carbon neutral and carbon negative goals.

What can we do now?

Healthy Materials Lab (HML) works to improve the health of residents living in affordable housing through the use of healthier building materials in renovation and new construction. Prioritizing the renovation of existing

Fig 1.2 The rear of PA Hemp Home prior to construction

buildings dramatically reduces carbon emissions while reducing building waste. The PA Hemp Home project began with a plan to use hemplime, a carbon-sequestering, healthy, plant + mineral based insulation, to renovate a vacant, wood frame house in New Castle, Pennsylvania.

This pilot project proposes a systemic approach to change typically carbon-intensive, unhealthy construction practices. It begins with farmers planting industrial hemp fields and establishing hemp processing facilities to create healthier plant-based building products. The hemp plant sequesters carbon as it grows regenerates the soil, does not need much water, and is strong, making it an ideal ingredient for building products. Hemp is used to develop products such as insulation and flooring. As these processes become established, increased demand for these products is anticipated, creating new jobs and workforce training in hemp agriculture and construction.

Hemplime, in particular, is a very effective insulation material. It is made from hemp stalks that are broken down into small pieces and mixed with lime and a small amount of water. Hemplime holds many promising qualities, including excellent energy efficiency, regulation of indoor humidity, resistance to mold and pests, and it is naturally fire retardant. It is also recyclable and biodegradable. Walls made with hemplime provide a healthier, breathable interior living environment. This project is an opportunity to test construction processes and create a baseline to which local building codes can adapt. Documentation and testing protocols were established at the project's onset to evaluate the material's viability and to analyze building processes and overall performance.

Over months of collaboration, experimentation, and dedication, DON Enterprise and several partners of varied expertise brought this project to fruition. PA Hemp Home proves that vacant houses can become habitable, well designed, healthy homes using hemplime insulation and other healthier building products. After the pioneering renovation was completed, DON Enterprise sold the home at an affordable price to a local community member. This new climate resilient, affordable home serves as an innovative prototype for future housing.

This case study summarizes the team's process, lessons learned, and the final product of the PA Hemp Home. The report is meant to serve as a reference for others looking to renovate homes with hemplime and other healthy materials.

Fig 1.3 DON Processing's Test Acres Program, an experimental crop of Industrial Hemp which was used in PA Hemp Home

Hemp Agriculture

DON is an organization with a broad vision. They want to develop new beneficial systems for their local community and economy. One of their main focuses is the cultivation of hemp. They worked with local farmers to grow hemp in western PA in 2019. Their first harvest produced one bale from four acres, but they did not give up. Beginning any new venture is challenging and requires trial and error, which they anticipated.

Summer 2020 was a better year for the hemp farms. A grant supporting education for hemp farming assisted six farmers in planting hemp in four counties. The participants were chosen from a list of 59 interested farmers. They planted 14 acres, experimented with two seed varieties, and tested planting methods with grain drills and broadcasting. The 2020 harvest yielded 77 small square bales, seven large square bales, and 16 large round bales. Some of their harvests were made into flooring through a collaboration between DON and HempWood, a new flooring manufacturer. The hemp flooring was installed in the PA Hemp Home in 2022.

Since then, there has been a dramatic change in this nascent industry. Plans for hemp processing facilities are underway in New Castle, PA, and across the US, while new hemp building products are developing in many states.

Fig 1.4 DON Services Harvest Bailing

Fig 1.5 DON Services Harvest Yeild

The Team

DON Enterprise aims to encourage people with disabilities to fully integrate into society by becoming employed and utilizing their talents and abilities to create wealth and quality of life for themselves and their families. They encourage people with disabilities to become homeowners and to become self-employed. DON Enterprise assists people in learning, finding resources and developing plans to achieve the goals they set. DON is a family of corporations that empower individuals with disabilities to live as independently as they choose. DON is the second largest employer in Lawrence County, Pennsylvania, and has provided support and services to individuals with disabilities for over 20 years. Collaborating with other agencies, DON is creating accessible, affordable housing options for individuals with disabilities while creating a diverse, inclusive integrated community. DON renovates blighted homes and builds new homes in New Castle, an Act 47-designated city. They administer several home repair grant programs that improve the accessibility and quality of homes across the city and surrounding counties. DON is testing the use of hemplime to renovate a blighted wooden home as part of its revitalization program.

Healthy Materials Lab (HML) is a design research lab at Parsons School of Design founded with a mission to place people's health and environmental health at the center of every design decision. They are committed to improving the future of the built environment by creating resources for designers, architects, teachers, and students to make healthier places for all people to live. HML's ultimate goal is to empower the creation of healthier spaces, reduce people's exposure to toxics, and support healthier, thriving lives for all people.

Americhanvre is a full service hemp building material installer with a mission to actively store carbon in the walls of homes while dramatically improving energy efficiency. Americhanvre is dedicated to developing applications for hemp and lime materials that reach beyond their capacity for thermal and fire resistance. Americhanvre envisions a future where hemp begins to bridge the gap between sustainability and affordability in the choice of building materials. Americhanvre is committed to being mindful of environmental impacts, supporting the local economy whenever possible, and promoting the growth and well-being of clients and employees.

UK HEMPCRETE

UK Hempcrete specializes in the use of Hempcrete (or 'hemp-lime') alongside other natural materials. They use these low impact materials in both new build construction projects and the repair and upgrading of traditional and historic buildings. With a wealth of in-house expertise and knowledge, UK Hempcrete offers a range of services to suit people's needs, whether a project is a new build 'future-proofed' natural home or a repair and upgrading of a listed building. Their team has a passion for low impact building methods and upgrading of traditional, historic buildings using eco-friendly, sustainable materials.

Building on the success of their specialist construction contractor services, UK Hempcrete extended their services to include specialist hempcrete design, material supply, consultancy, and training. UK Hempcrete Director Alex Sparrow is recognized as one of the UK's leading advisers in the use of Hempcrete, regularly speaking at conferences and events, writing articles, and hosting training days. Alex was an advisor on PA Hemp Home and its construction details.

PHRC
PENNSYLVANIA HOUSING RESEARCH CENTER

Pennsylvania Housing Research Center is a research group within Pennsylvania State University that collaboratively engages with the residential construction industry to catalyze advancements in homebuilding through education, training, innovation, research, and dissemination. They provide and facilitate education, training, innovation, research, and dissemination to the residential construction industry for the purpose of improving the quality and affordability of housing. Educational programs and publications by the PHRC address a wide range of topics relevant to the home building industry and are designed to reach a diverse audience of builders, code officials, remodelers, architects, developers, engineers, planners, landscape architects, local government officials, educators, etc. to provide professional development and continuing education. The PHRC is administered through the Department of Civil & Environmental Engineering at Penn State University.

Pennsylvania Housing Research Center (PHRC) analyzed the thermal, insulative properties, and performance of hemplime as well as the resulting impact on utility costs in this residential renovation. A comparison between thermal, insulative properties of hemplime and residences using typical insulation and construction is forthcoming.

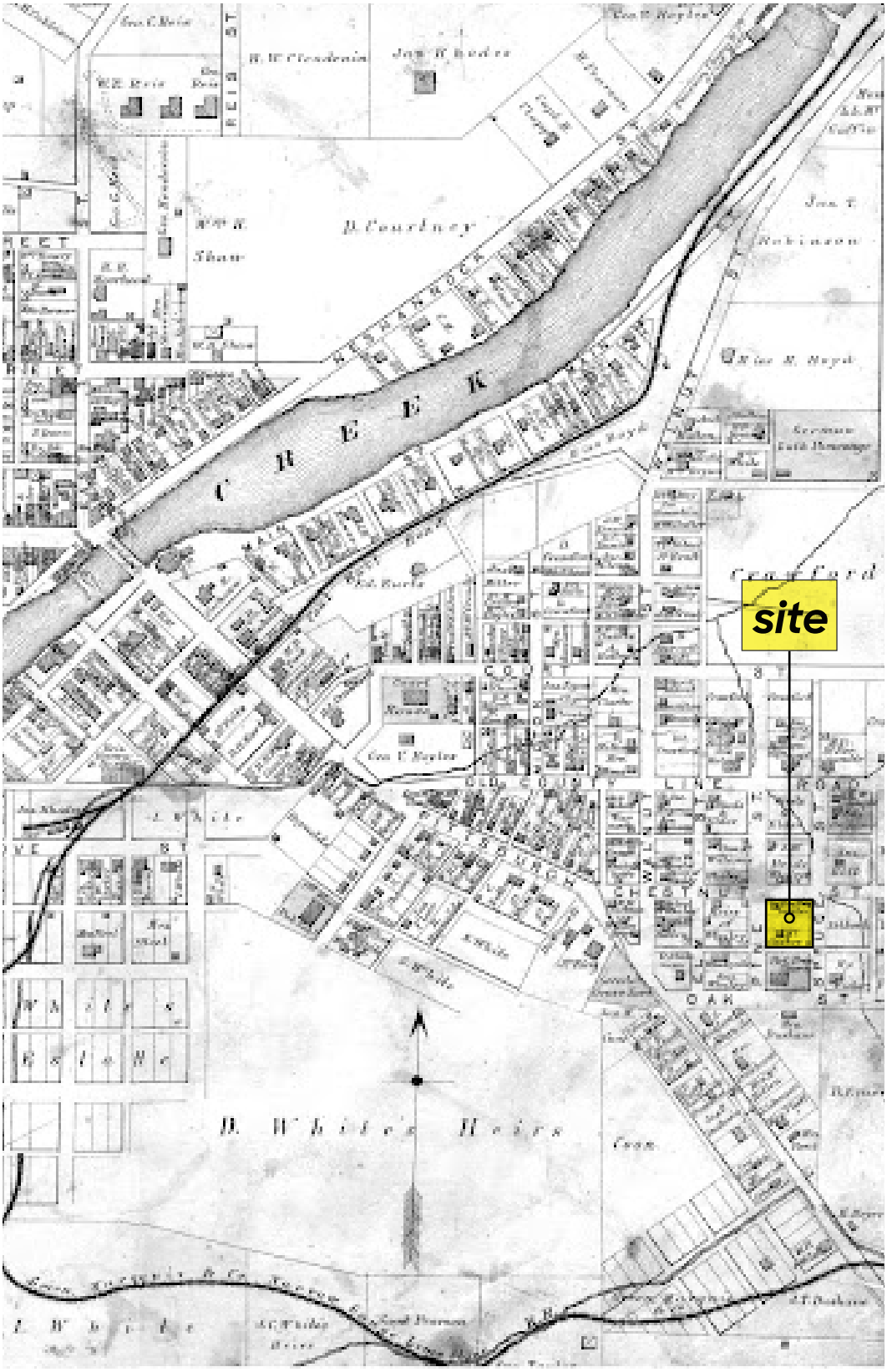


Fig 2.1 1872 map of New Castle, PA from USG Archives

2. Site

New Castle, PA

New Castle is a formerly robust industrial town in Western Pennsylvania that has seen much of its housing stock deteriorate over the last several decades. It is located 50 miles northwest of Pittsburgh and 18 miles southeast of Youngstown, Ohio. What used to be a booming steel and tin manufacturing town now faces the same issues as many post-industrial cities. A place that used to be home to innovation and industry is now filled with blight and a severe lack of affordable housing.

Like many other Rust Belt cities, New Castle faces economic hardship and social disruptions because of the reduction of lucrative industries like steel production. The loss of job prospects has led to a dramatic reduction in the local population. Cities like New Castle face the challenge of creating new, viable, healthy futures for their residents. They also have a unique opportunity to transition to new, innovative sustainable industries. DON Enterprise has a vision for a city that incorporates agriculture and workforce development to create healthy, affordable housing.

DON Enterprises is revolutionizing how they build and renovate affordable and accessible housing. They work tirelessly to bring industries back to the city by producing agricultural hemp. New Castle has the capacity to support an industry that will create jobs and help improve the systems in place. What is most exciting about the production of industrial hemp is its use in Affordable Housing. Through this project, PA Hemp Home will be a prototypical home for the city of New Castle. It then can be replicated, increasing the need for hemp production and providing healthier homes for the citizens of New Castle.

In Spring 2020, students of Parsons Master of Architecture Studio researched the city of New Castle to better understand the current state of housing through the dissection of demographics, materials, energy, zoning, financing, and construction practices. This research was used at the start of PA Hemp Home. For more research, please see our “Affordable Housing with HempLime” publication.

Fig 2.2 PA Hemp Home prior to construction

506 Spruce Street

In the fall of 2020, DON Enterprise purchased an 800 square foot, two story home located at 506 Spruce Street in New Castle. This single-family home, built in 1900, was originally designed as a one bedroom dwelling. The house was left empty for quite some time, and demolition processes revealed that there had been a fire in the attic as well as rot and termite damage in much of the timber.

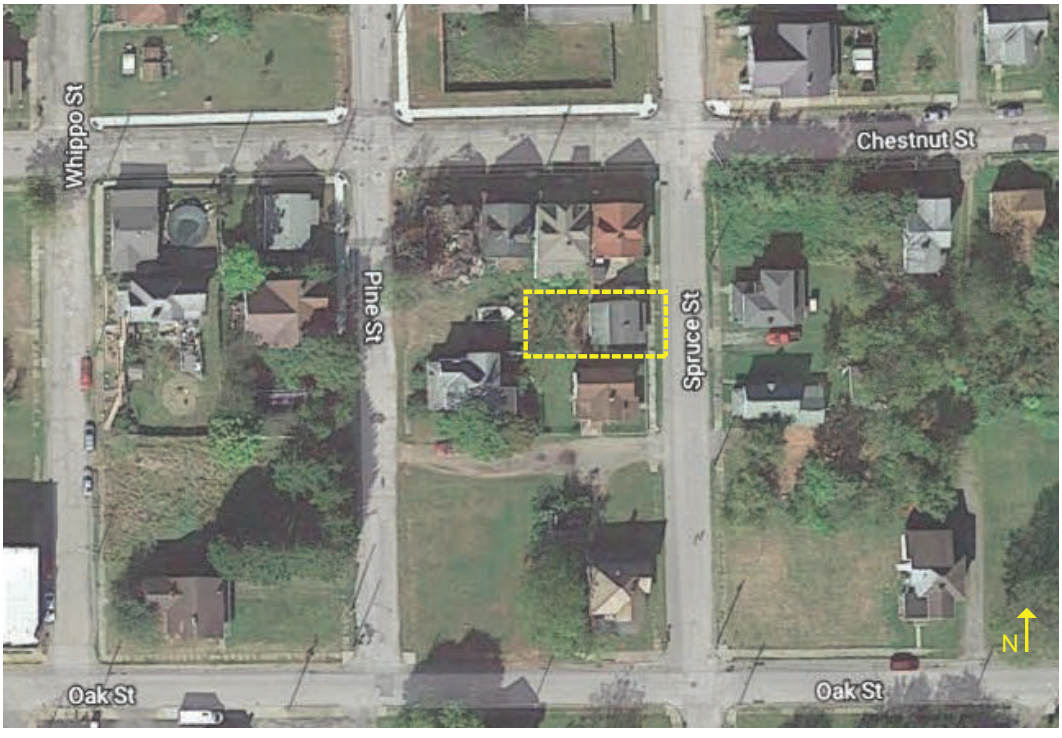


Fig 2.3 PA Hemp Home location from Google Earth

3. Design

Design Approach

At HML, we began sketching and envisioning how to renovate this modest house to maximize the use of the space. It was initially intended to be fully accessible. After studying the existing floor plan and arrangement of spaces, we identified that a simple addition at the back corner of the home, to square it off as highlighted below in yellow, would be a worthwhile endeavor in order to achieve a small yet accessible bedroom on the first floor and a more spacious living area. We developed three schemes that were presented to the team at DON Enterprises. The chosen scheme allowed the ground floor to be opened up by removing part of the structural wall and replacing it with a beam. It has a straight line of circulation from the front door to the back door to allow the accessible door to be just as welcoming as the front door. A small accessible bedroom and a full bath with a washer/dryer unit occupied the first floor. The bedroom met the minimum square footage requirement for a non-master bedroom. On the second floor, accessed by a switchback stair, is the master suite with a full bathroom and two closets. However, the design changed further along in the process due to budgetary and code constraints.

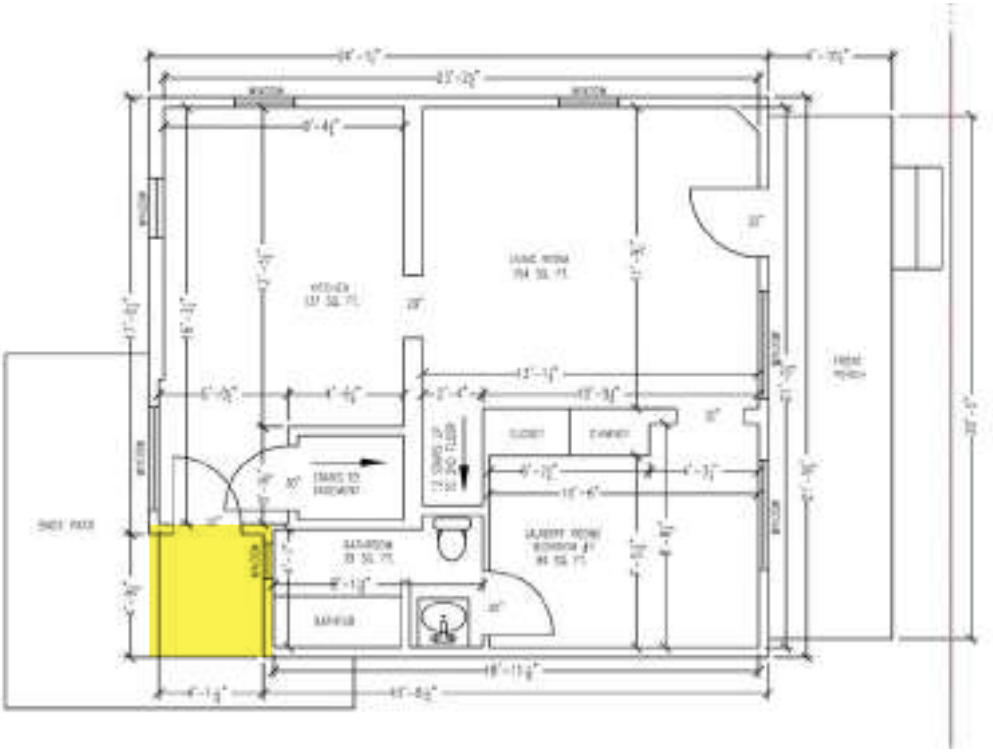


Fig 3.1 PA Hemp Home Existing Floor Plan

Fig 3.2 PA Hemp Home Proposed First Floor Plans by Meryl Smith

Fig 3.3 Exterior Render of PA Hemp Home by Anthony Vespirini

Fig 3.4 Interior Render of PA Hemp Home by Myles Arkins

Final Design

Ultimately, the bedroom on the first floor was eliminated because there was no room for a closet without pushing up against the code minimum requirements. Budget constraints eliminated the skylights above the kitchen and some of the windows. The shower was eliminated from the first floor bathroom, and its placement shifted. The small space that remained on the first floor became the dining room, as shown in the interior rendering.

The rendered images of the interior and exterior were created as promotional images when the project was featured on the television show America By Design, Season 1. Later, the exterior and interior finishes changed dramatically due to issues that came up during demolition, construction, and procurement of healthier materials.

The exterior stucco, shown above, was replaced with a local wood rainscreen due to detailing of the wall assembly. The roof, shown as metal panels, also changed due to tight budgets. The kitchen and furniture layout shown in the interior image was changed due to further exploration of kitchen fabrication opportunities and furniture donations.

Shown on the next few pages are the as-built plans, sections, and elevations of the final design.

The design and materiality of the renovation evolved as conditions of the house were revealed during the demolition phase.

LESSON 01

Plans

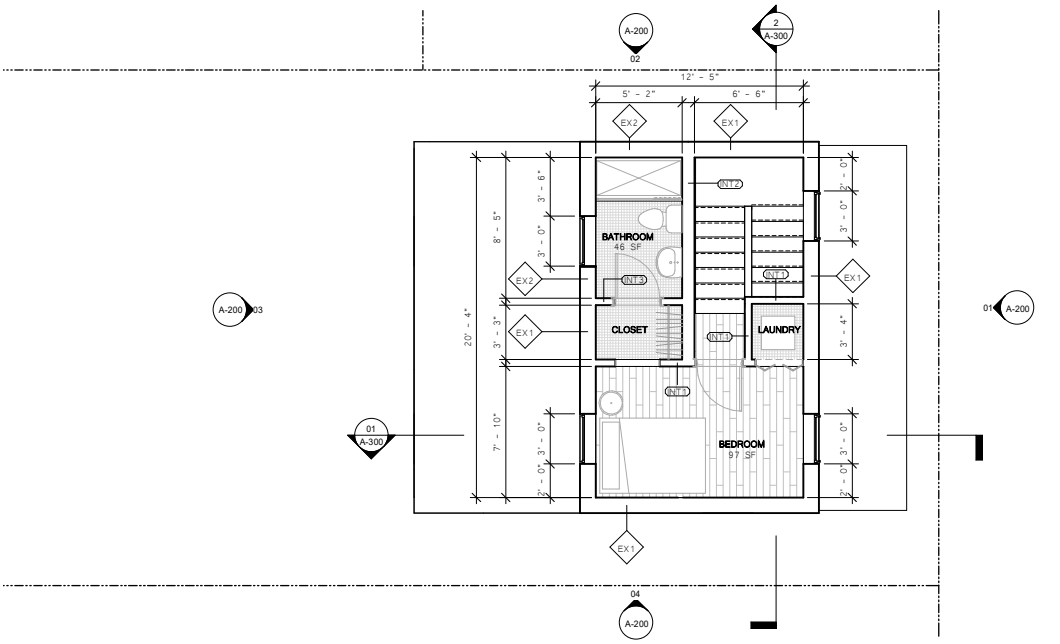


Fig 3.5 Second Floor Plan As-Built

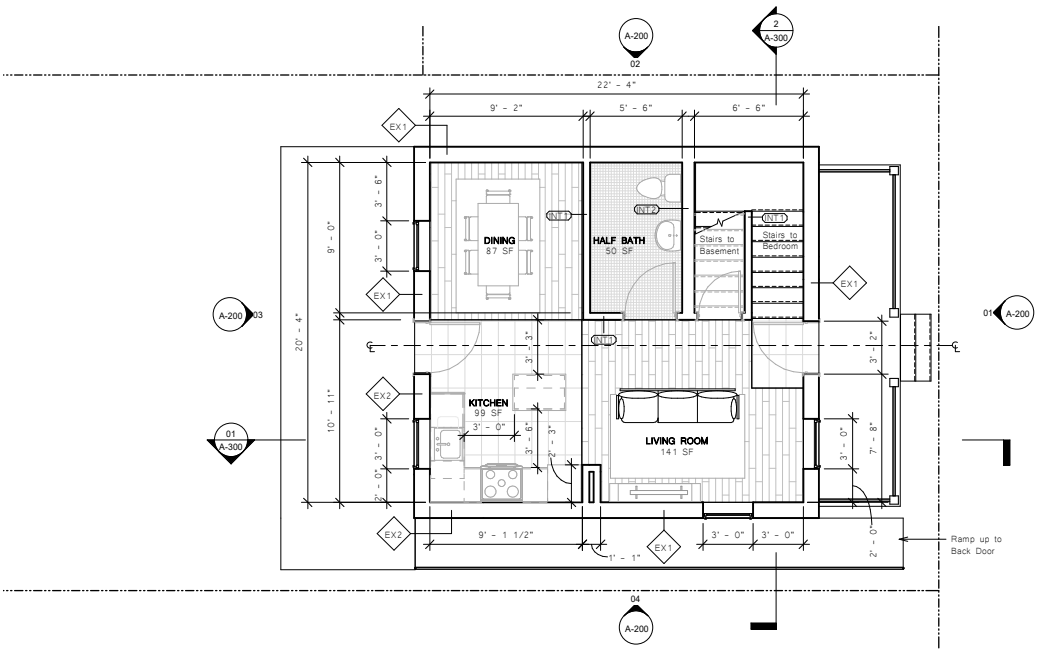


Fig 3.6 First Floor Plan As-Built

Elevations

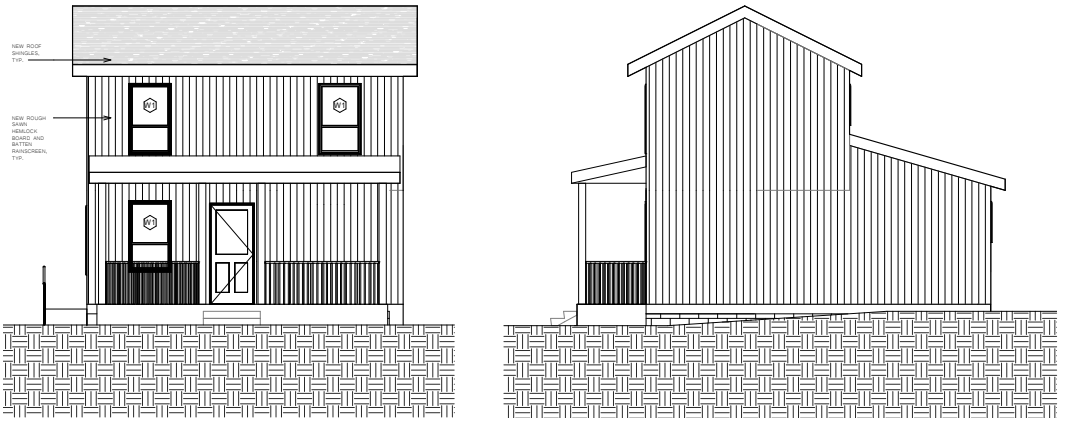


Fig 3.7 East and North Elevation, As-Built

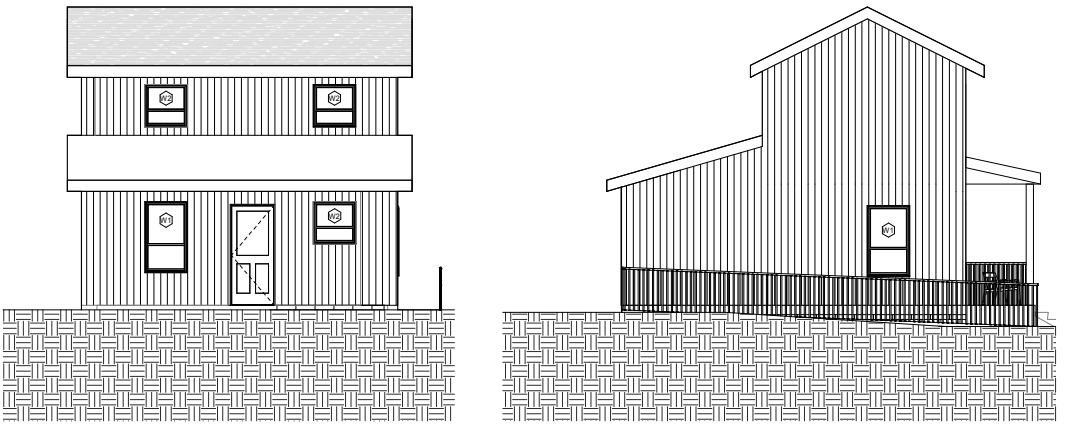


Fig 3.8 West and South Elevation, As-Built

Sections

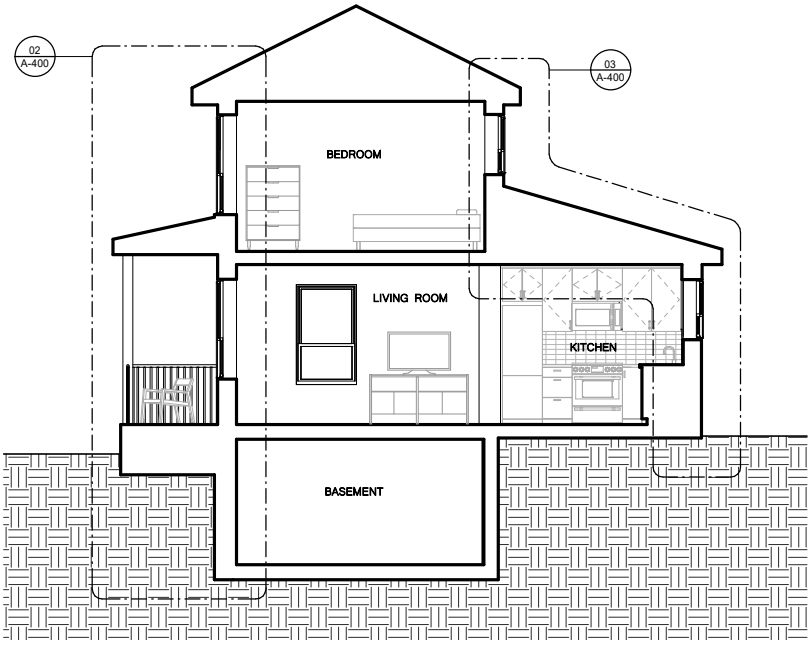


Fig 3.9 East/West Section As-Built

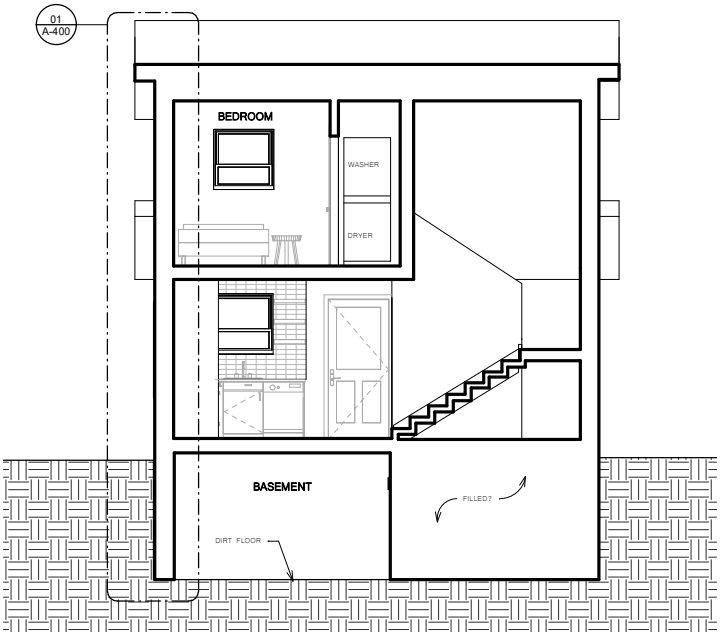


Fig 3.10 North/South Section As-Built

Fig 3.11 Interior View of Upstairs Bedroom after Hemp Installation

4. Demolition

Before Photos

The two-story home at 506 Spruce Street was left vacant for quite some time. Its interior finishes were peeling away, the windows were failing, and the exterior materials showed significant damage. When analyzing the materials and finishes used in the home, we found many plastic products. The kitchen had MDF counters and cabinets laminated in plastic. Its floors were covered in vinyl tiles adhered to the subfloor. Polyester carpets lined the stairs and old bedrooms. Plastic wood-like wall panels were glued to the walls in many rooms.

Plastic blinds were covering the windows. The exterior was clad with vinyl siding and imitation stone veneer. Almost all of the materials used to finish the interior and exterior of the home were plastic-based and unhealthy for the occupants.

When demolition began, the original materials used to frame the home and its structural components were revealed.

Fig 4.1 Existing exterior with vinyl siding

Fig 4.2 Existing Kitchen with vinyl tiles, laminate counter tops and cabinets, and plastic window fixtures

Fig 4.3 Existing upstairs bathroom with polyester carpets and plastic wall paneling

LESSON 02

When the petroleum based products were stripped away, all that was left were natural, healthy materials used to build this house in the early 1900s.

Fig 4.4 Wood rafters and structural studs

Fig 4.5 Orgininal wood stair, strucutre and sheathing exposed

Fig 4.6 Front of PA Hemp Home with the exterior siding stripped off and windows removed

Fig 4.7 The rear of PA Hemp Home in the midst of demolition

Demolition Process

Demolition began in December 2020 and continued into the spring. Work began on the interior, removing the interior finishes, stripping the interior walls, and eventually moving on to the exterior walls and roof. The construction team encountered more damage than expected. During the process of removing the exterior siding, they uncovered structural damage from termites and had to replace much of the wood structure. When removing the floors, they found structural damage, leading to replacing many floor joists. They discovered that there had been a fire in the small attic above the kitchen. Because of this, they replaced the entire roof above the first floor.

Overall, a lot of the old lumber had to be replaced. This extended the duration of demolition, pushed against the project timeline, and put pressure on the overall budget.

Fig 4.8 First floor interior during demolition

Fig 4.9 Damaged wood and structure at the foundation
Fig 4.10 Existing walls at existing foundation

Much more lumber was replaced in the walls and floors than originally anticipated due to unexpected damage from fires and termites. This affected the available budget for other items, such as windows and skylights.

LESSON 03

5. Construction

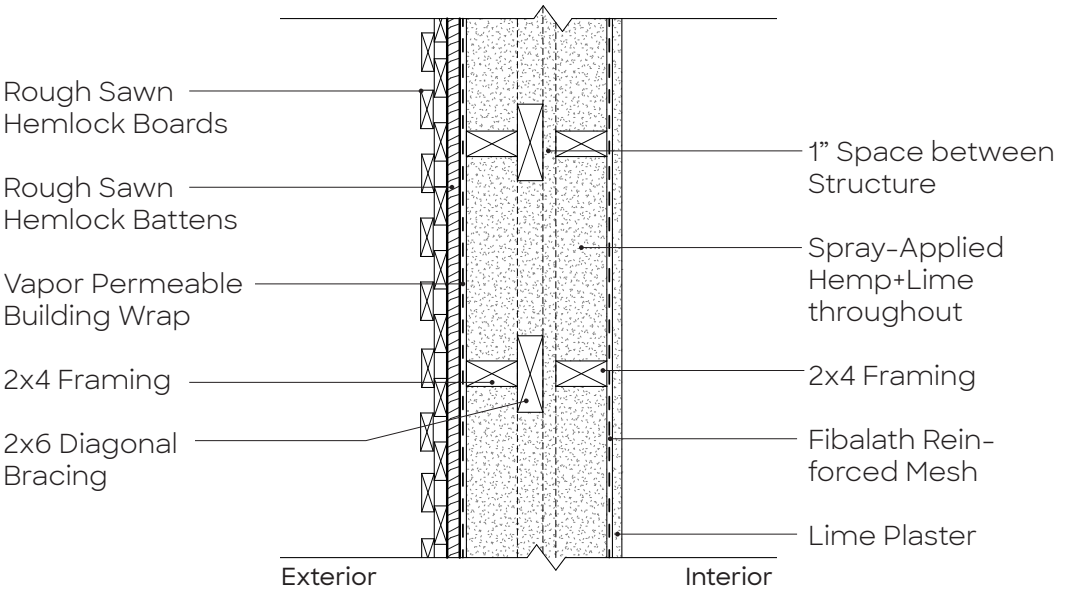
Approach

Once demolition was complete in the Spring of 2021, the team prepped the home to install new hemplime insulation. The process began with framing the home with a double stud wall on the exterior and a single stud for interior partitions. The framing was constructed to allow for the installation of sprayed hemplime using the Ereasy hempcrete system.

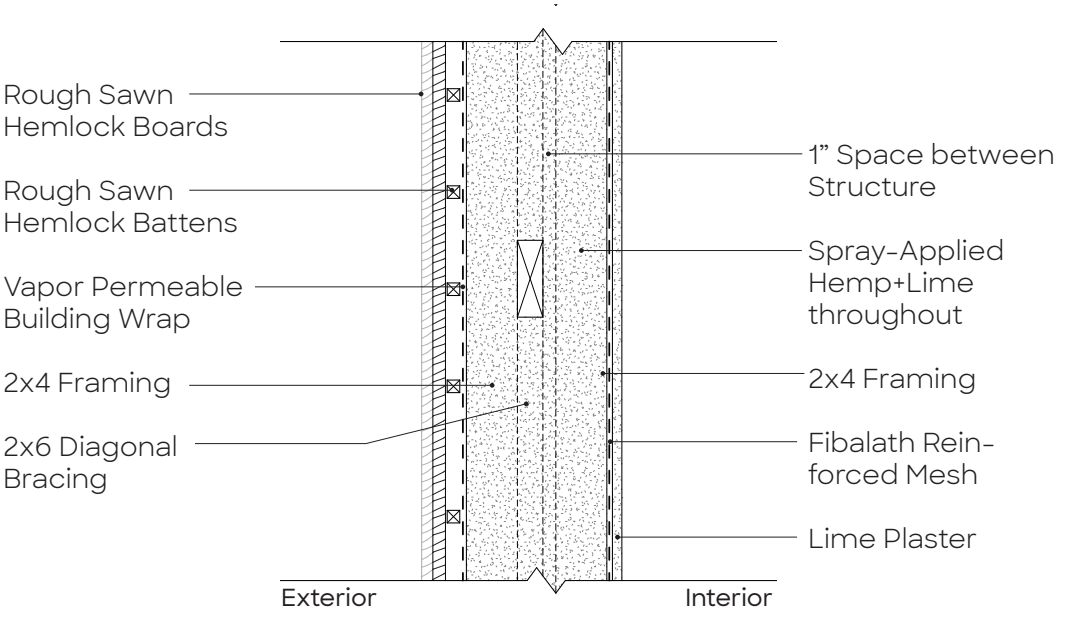
This chapter details the various stages, installation methods, and decisions encountered during each step of construction.

Fig 5.1 Cameron from Americhanvre packing Hemp into the corner of PA Hemp Home

Exterior Wall Assembly | Spray Applied Hemp+Lime

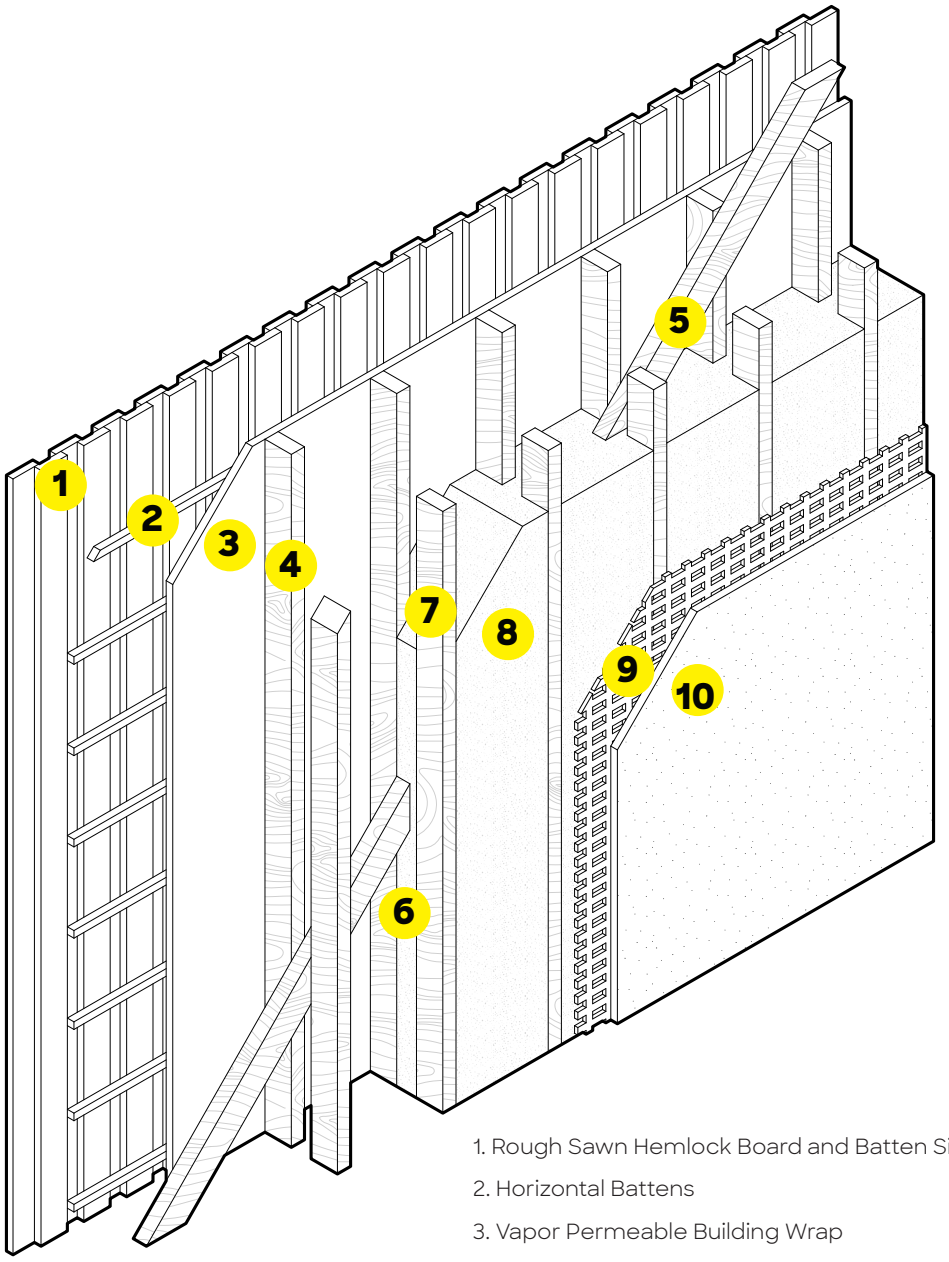


PLAN



SECTION

Exterior Wall Axonometric | Spray Applied Hemp+Lime



1. Rough Sawn Hemlock Board and Batten Siding
2. Horizontal Battens
3. Vapor Permeable Building Wrap
4. 2x4 Framing
5. 2x6 Diagonal Bracing
6. 1” Space between Structure
7. 2x4 Framing
8. Spray-Applied Hemp+Lime throughout
9. Fibalath Reinforced Mesh
10. Lime Plaster

Framing

Fig 5.2 (Left) Framing of the interior and exterior walls upstairs

Fig 5.3 Exterior wall framing at the first floor

Installing a second layer of structural lumber was necessary to allow for a thick enough wall assembly to meet the required R-value of the hemplime insulation.

HempLime Installation

With the framing complete, the house was prepared for the hemplime installation. Plywood boards and reused plastic lined the home's exterior to capture the spray-applied hemp lime. The process of mixing was relatively simple. Hemp hurd and powdered lime are poured into the "Mud Hog" where a machine valve carefully measures the amount of added water. Once sufficiently combined, the mixture is shoveled into a trough and pushed through a long tube with compressed air. The experienced installer, Cameron McIntosh, uses a tube apparatus to spray the mixture into the wall cavity, in and around all of the structural studs. A fascinating aspect of this process is that the waste and overspray mixture that does not make it into the wall gets collected back into buckets. It then returns to the Mug Hog, making the waste completely recyclable. The actual hemplime installation took 3 days, although a few rainy days stretched the process over a week. The spray-applied hemplime must fully cure before plaster or stucco can be applied to its surface. The curing process can take up to three months, so after installation, the waiting game began.

Fig 5.6 The home fully framed and prepped for the spray-applied hemplime install

Fig 5.4 Bags of Lime imported from France to mix with the Hemp hurd

Fig 5.5 KanaBat is building grade Hemp hurd that will be mixed with Lime and Water

Fig 5.7 The install starts with the Mud Hog, which mixes the hemp hurd, lime and water

Fig 5.8 Hemp hurd is added to the Mud Hog

Fig 5.9 The team then shovels the mixture from the Mud Hog, into the sprayer

Fig 5.11 Cameron from Americhanvre installing the hemplime mixture

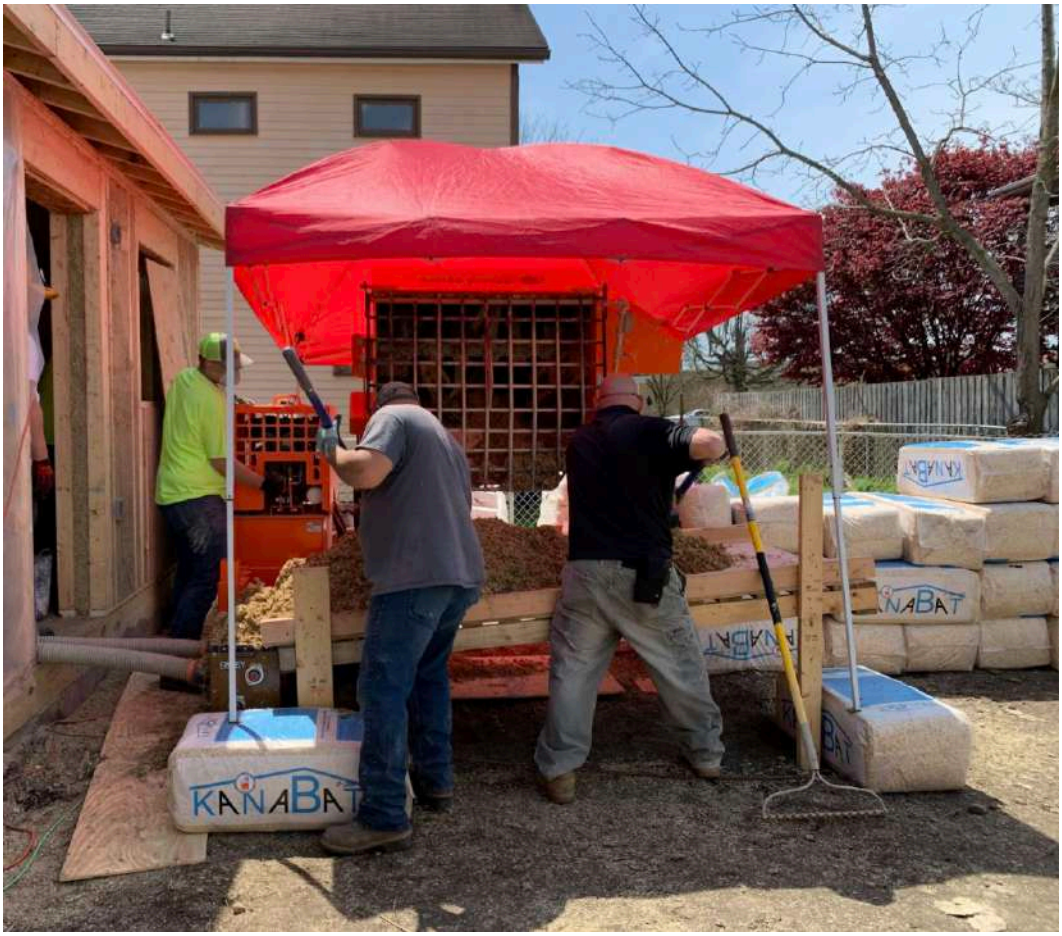


Fig 5.12 The mixture comes out of the Mud-Hod onto a platform, where the team takes shovels to feed it into the sprayer

Fig 5.13 On the inside, as the mixture is being installed, a team of two sweeps up the excess and shovels it into a buckets

Fig 5.14 The excess mixture can be re-added to the Mud Hog, leaving no waste behind

Fig 5.15 PA Hemp Home after the hemp installation was completed

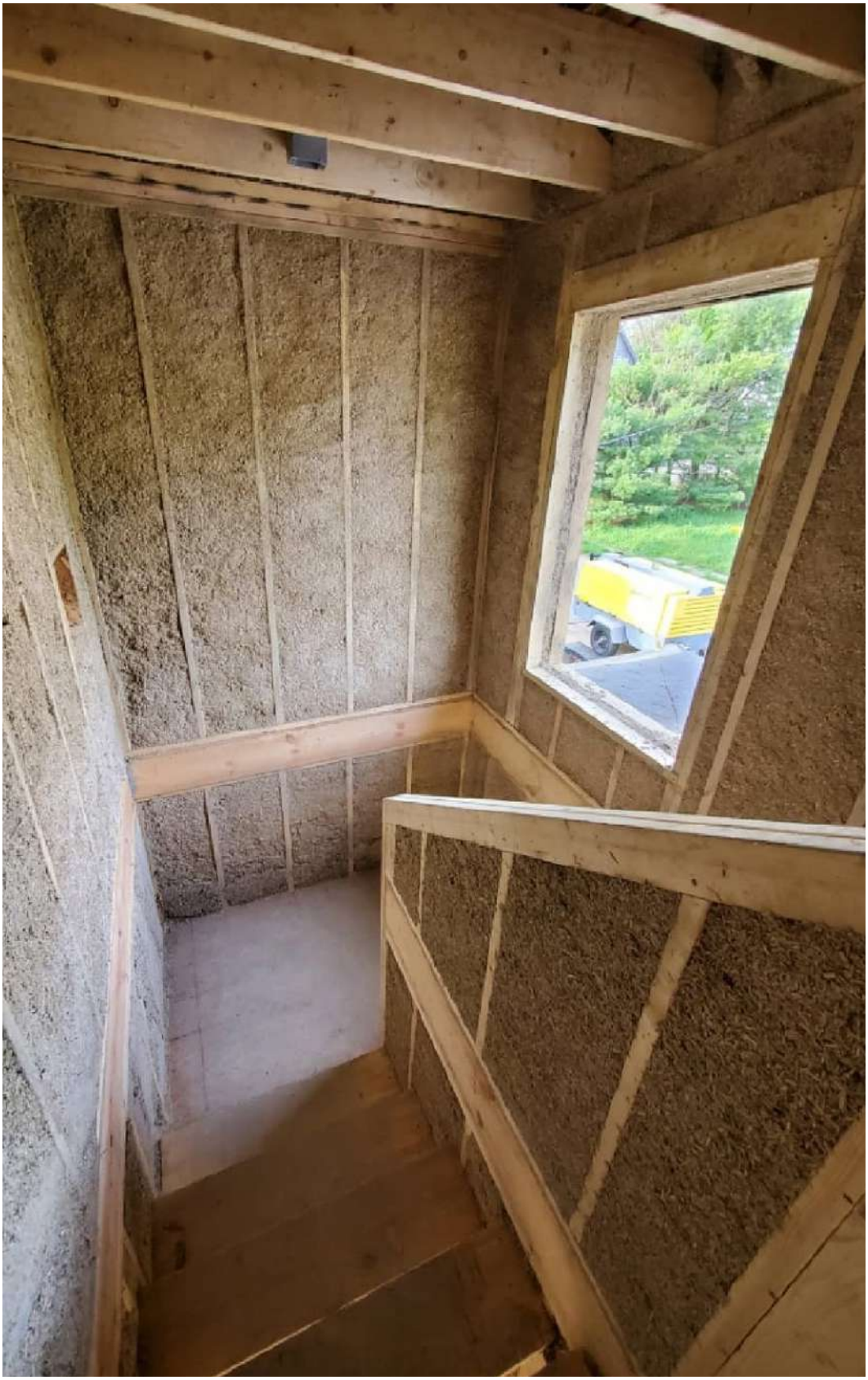


Fig 5.16 The stairwell of PA Hemp Home with fully installed hemp

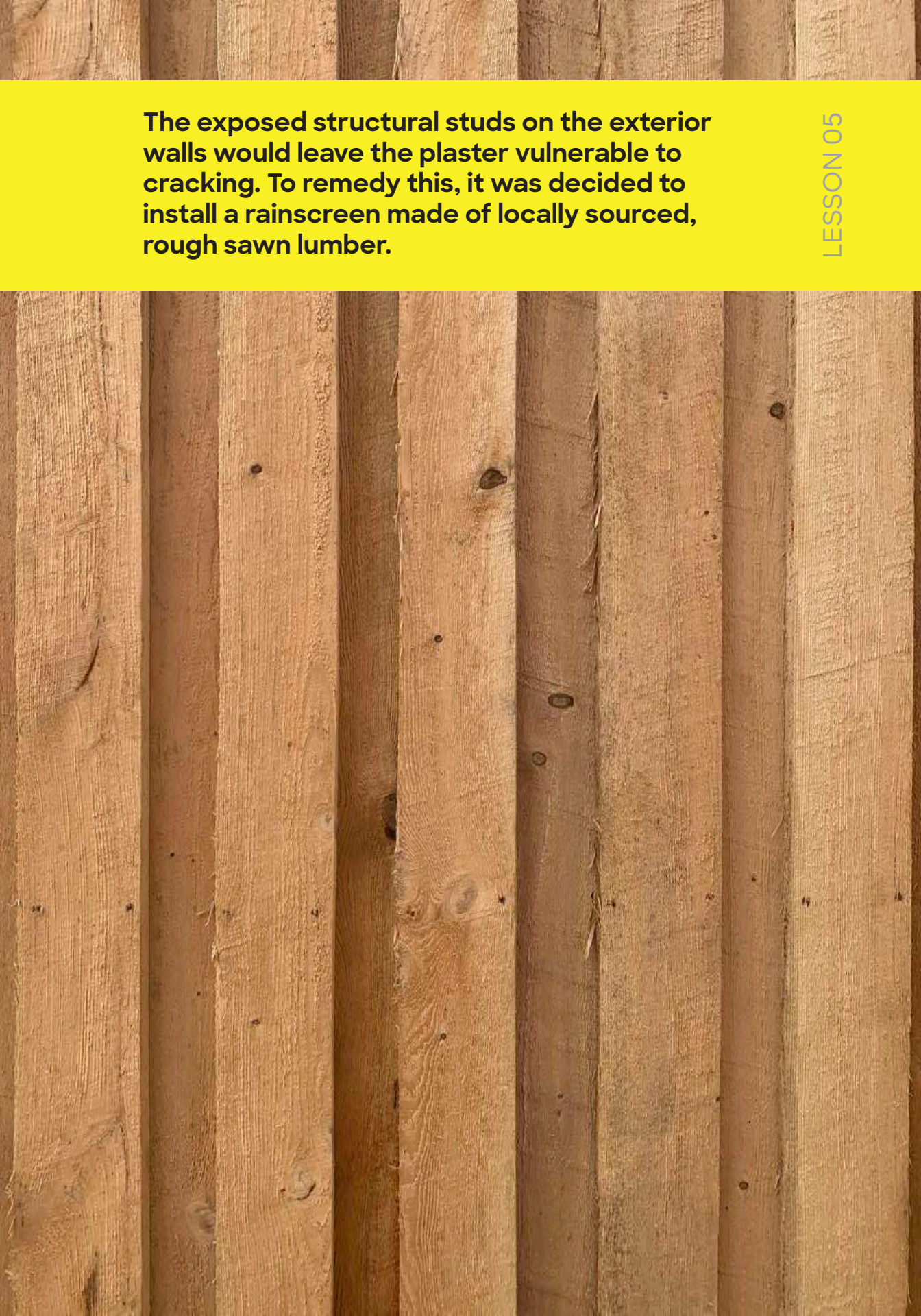
Wood Rainscreen Installation

During construction, the decision was made to forgo the exterior plaster and use locally sourced, rough-sawn Hemlock boards instead. The wooden boards act as a rainscreen, protecting the hemplime walls from weather. A rainscreen like this allows for the walls to remain vapor permeable or breathable. Hemlock boards are a local material in Pennsylvania. Rough sawn boards generally need time to dry before they are treated. After the wood finishes drying out, it can be painted or stained to the desired finish.

The construction team was able to begin the exterior installation while the hemplime walls continued to dry and cure. This decision sped up the construction timeline. They were able to fully complete the exterior before the winter freeze, which allowed for the work to continue on the interior.

Fig 5.17 PA Hemp Home's exterior with newly installed, locally sourced, hemlock rainscreen

Fig 5.18 (Right) Close up image of the rough sawn hemlock board and batten rainscreen



The exposed structural studs on the exterior walls would leave the plaster vulnerable to cracking. To remedy this, it was decided to install a rainscreen made of locally sourced, rough sawn lumber.

LESSON 05

Plastering

After the spray-applied hemplime walls were completely cured and dry, they were ready to accept plastering. A lime-heavy hemplime mix which included hemp hurd, locally sourced lime, and sand, was used to finish the interior surface of the walls. The mix is left overnight to mature before application. The next day it is applied by hand, smoothed with a wooden float and burnished with a wooden trowel. This mix and application method is a one-coat process. Due to climate inconsistencies and unforeseen circumstances, this plaster mixture and application technique was not best suited for the job. Some of the surfaces ended up cracking, perhaps because of the aggregate used in the mix or because the lath was placed over the studs rather than being continuous. It is hard to say what exactly caused these issues. After all, much of this building was an experiment.

A new mix and technique were quickly implemented through consultation with LimeWorks.us, a leading local manufacturer and distributor of lime products, and Alex Sparrow from UK Hempcrete. With some trial, error, and testing, the walls were successfully plastered.

LESSON 06

The use of Metakaolin as an aggregate in this plaster mix was problematic. Metakaolin is a clay, which is fast acting but rapidly shrinks and often causes problems. Sand should always be used as an aggregate in plaster mixes.

Always test the plaster mix in a small area to determine how it behaves on a particular site before installing it entirely.

Fig 5.19 Plaster mixture being installed by hand

Fig 5.20 Plaster mixture being smooth with a metal trowel

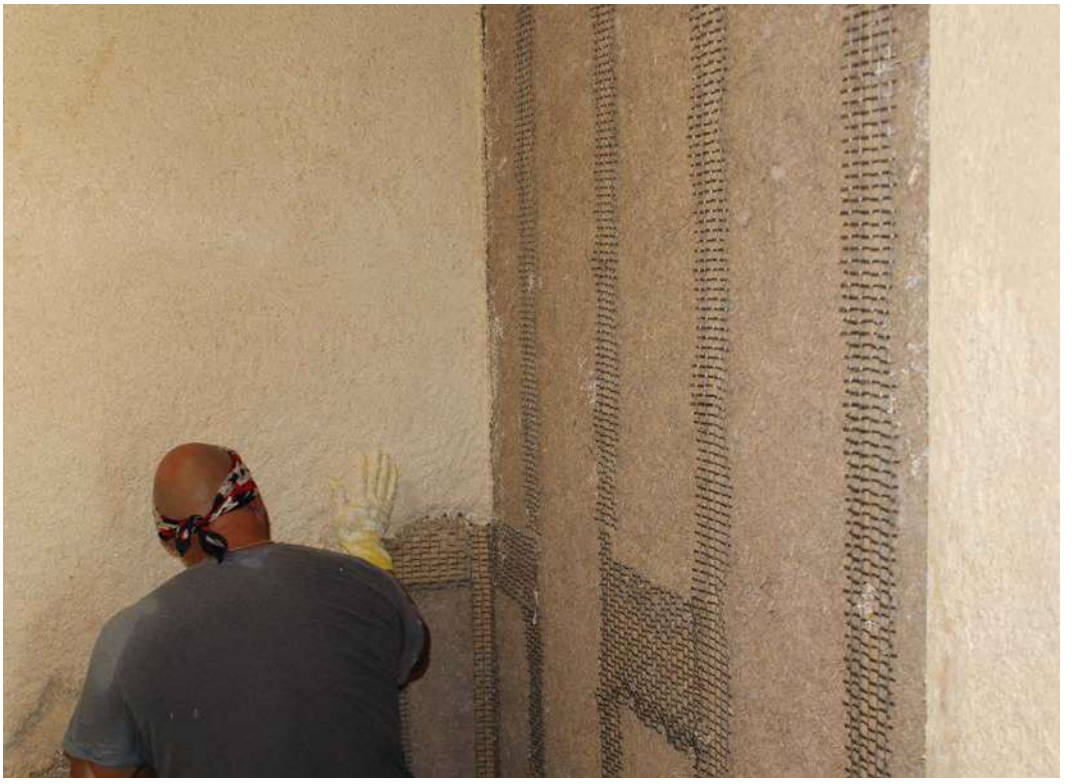


Fig 5.21 Plaster mixture being installed in the downstairs bathroom

Fig 5.22 Close up of hemplime, Exposed wood studs covered with lath and Plaster

Lath was placed only over the exposed wooden studs and the plaster began to crack at the spaces between the stud and the hemplime. It is likely that lath should have been placed over the entirety of the surfaces.

LESSON 08

6. Healthier Interior Finishes

Wall Finishes

Ultimately, Ecologic™ PLASTER TAKCOAT™ Platinum from LimeWorks.us was used to cover the original layer of plaster. Once fully dry, a white lime wash was applied in a beautiful matte finish. For the final layer a clear coat of Ecologic™ Waterglass, made from potassium silicate, was brushed on the walls to fortify and protect the surfaces. This product works well to prevent limewashes from dusting while maintaining the vapor permeability of the entire system.

LESSON 09

A hardener was used as the final coat on the interior walls to prevent dusting. Check the ingredients and properties to ensure it is healthy and vapor permeable, because it is important to allow the hemplime walls to breathe and achieve their full potential.

Fig 6.1 Stair well during the plaster and limewash process

Kitchen Cabinetry

Most prefabricated cabinets are built using a combination of three or more wood composites and veneers. Unfortunately, these materials typically contain toxic glues containing formaldehyde, a known human carcinogen. Currently, prefabricated cabinets are composed of only 5%-30% healthier materials. Designers can increase this percentage by requesting that manufacturers build with NAF (no added formaldehyde) composite woods.

For the PA Hemp Home, it was crucial that we found a way to design and fabricate a healthier kitchen. In Lawrence County, PA, where the city of New Castle is located, there is a large Amish population that maintains many traditional skills. We partnered with a local woodworker, JS Woodworking, to ensure that the kitchen was designed and built with thoughtful craftsmanship in the healthiest way possible. In this case, with formaldehyde free plywood, metal fasteners instead of glue, plant-based paint, and reclaimed hardware.

Formaldehyde Free Plywood

Columbia Forest Products generously donated PureBond plywood for the kitchen cabinet boxes and fronts. PureBond is Columbia Forest Products' formaldehyde-free plywood, which comes with standard veneer core and composite hardwood. They use soy-based adhesives, replacing traditional urea formaldehyde (UF) adhesives typically used in composite wood. This healthier material choice not only benefits the future residents of the home and also makes the cabinetry fabrication shops safer and healthier.

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PureBond® HARDWOOD PLYWOOD

Fig 6.2 Kitchen Design using PureBond Plywood and a small moveable island

Fig 6.3 Metal fasteners are being used rather than harmful adhesives

Fig 6.4 Wall and Base Cabinets ready and waiting to be finished with healthier paint

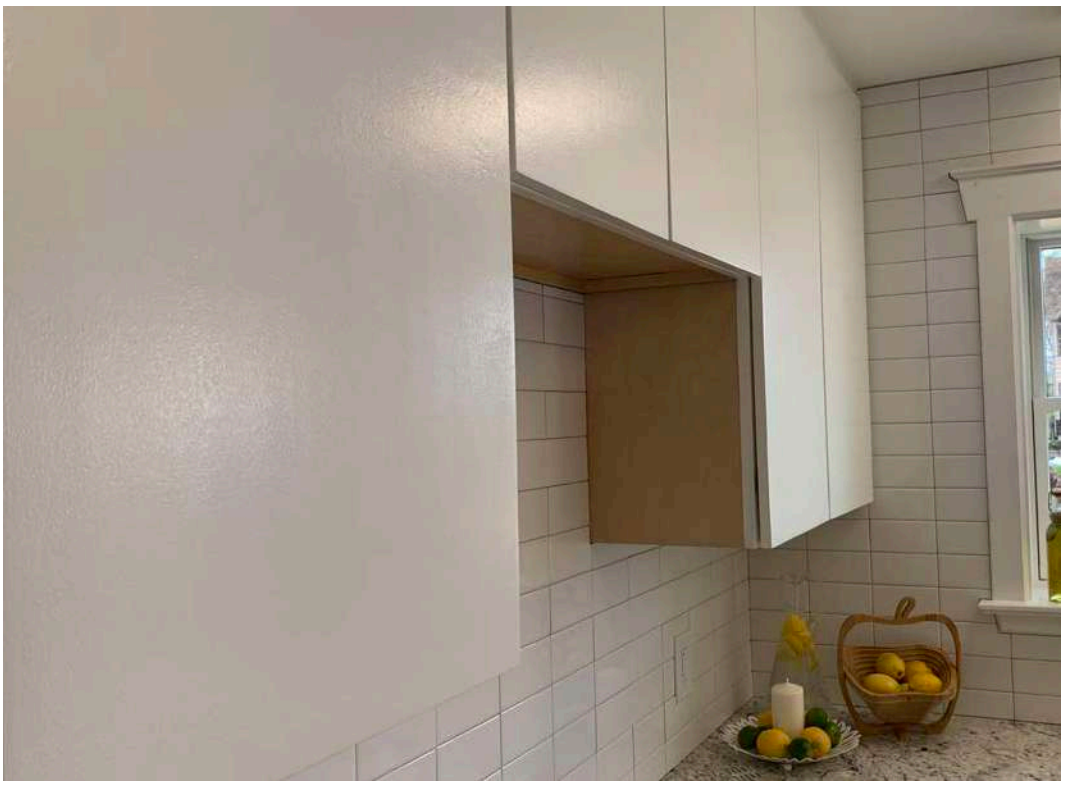

Fig 6.5 The kitchen cabinets finished and installed in PA Hemp Home

Natural Paint on Cabinet Fronts

The kitchen cabinets were finished with Ottosson Linseed Oil paint purchased from Earth + Flax in eastern PA. Linseed Oil Paint is free of solvents and petrochemicals, making it safer to work with and healthier to live with. It is manufactured in Sweden with two main ingredients: cold-pressed, raw linseed oil with impurities removed and tinted with natural pigments. It is designed for both interior and exterior wood surfaces.

For the cabinets, a “primer” of 70% pure Linseed Oil to 30% Linseed Oil Paint was used as the first coat. After the primer coat was applied and left to dry, Linseed Oil Paint in White Titanium Zinc was slightly diluted with Linseed Oil for easier application. Two coats were applied to achieve a smooth, durable finish.

When experimenting with natural paints for the first time, it is important to leave ample time to make samples, troubleshoot and determine the best application technique for the surface. Allowing for extra dry time is necessary.

LESSON 10

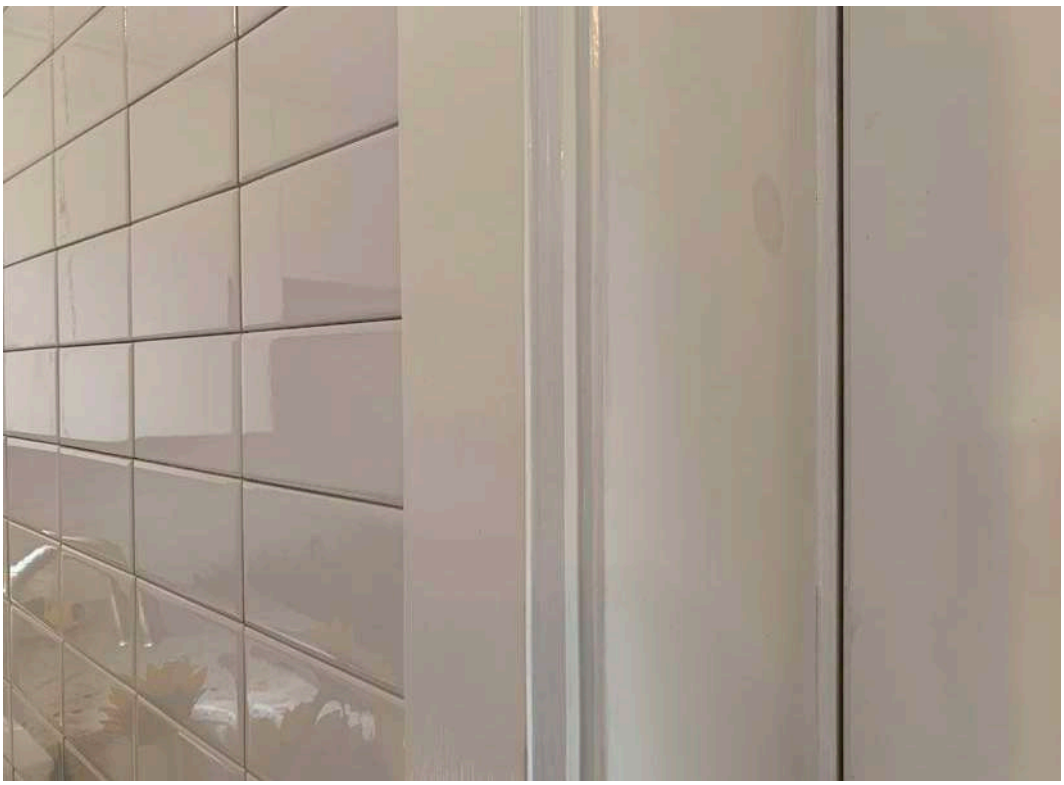

Fig 6.6 The kitchen cabinets finished and installed in PA Hemp Home

Fig 6.7 View into downstairs bathroom with Daltile Keystones in Waterfall used for the floor

Tile and Flooring

Before the radical renovation of this home, its floors were covered with vinyl products and synthetic carpets.

It is hugely important to consider alternatives to vinyl flooring for many reasons. Firstly, during the manufacturing, burning, and landfilling of vinyl, highly toxic chemicals known as dioxins are released. Dioxins not only persist in the body for years after exposure but are linked to cancer, reproductive disorders, and hormone disruption in humans. Secondly, vinyl production is carbon intensive and contributes to greenhouse gasses which cause climate change.

When finding a ceramic replacement for vinyl tiles in the kitchen or bathroom, it is important to look for tiles that do not contain toxic additives in their pigments, frits and glazes. Historically, heavy metals such as lead in glazes have been a major health concern.

With our focus on a healthier renovation, we needed to find healthier, affordable alternatives for the floors. Materials such as Hempwood made from locally sourced hemp and unglazed porcelain tile were used.

Daltile Colorbody Porcelain

Colorbody Porcelain is a type of tile in which the color or pigment exists throughout the body of the tile instead of only on the surface glaze. The local Daltile supplier in Cranberry Township, just outside of Pittsburgh, PA, generously donated two types of Colorbody Porcelain to this project: unglazed and free of toxic additives. “Astronomy” is a large tile with a natural, matte limestone look. We used this in the kitchen and entry areas. “Keystones” are mosaic tiles that come in a variety of colors and are manufactured locally in Gettysburg, PA. These small, colorful tiles were used on the floors of both bathrooms. Both of these products are made in the U.S. and contain both post-consumer and pre-consumer recycled material.

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Fig 6.8 Daltile Colorbody Porcelain in Waterfall used in the downstairs half-bathroom

Fig 6.9 Daltile Colorbody Porcelain in Arctic White used in the upstairs bathroom

Fig 6.10 HempWood finished with a whitewash showen in the upstairs bedroom

HempWood Flooring

HempWood is an engineered flooring product composed of hemp, soy flour, and binders (free of isocyanates). The base is Columbia Forest Purebond plywood, the same formaldehyde-free plywood used for the kitchen cabinets. HempWood is harder than oak and a durable wood option that promotes the carbon-sequestering hemp-growing industry. The boards used in this project were made from Hemp locally grown in New Castle, PA, by DON's Test Acres program. HempWood products are available either with a factory finish or unfinished. In this case, we used Bona NordicSeal in White over brown hemp wood to create a modern and dynamic look while achieving the material health goals for this project.

Fig 6.11 View of PA Hemp Home's living space, complete with a lightly used sofa from Floyd

Furnishings

Beyond the finish and material selection process, looking at healthier ways to furnish the home is important. We partnered with Floyd Furniture and Aronson's Floor Covering to procure healthier and sustainable furnishings, including tables, media consoles, seating, and area rugs. These pieces were generously donated by Floyd and Aronson's and were left in the home for the future resident to enjoy.

Floyd

In the US alone, furniture waste has grown 2.5x the rate of household growth since 1960. Floyd believes that the most sustainable thing they can do is design products that people will keep and to build furniture that won't deteriorate when moved. They design pieces to be repairable, making it easy for customers to replace parts over time if necessary. And they manufacture in the US, closer to customers, to reduce emissions caused by excess transportation. Through their Floyd Full Cycle center, they could donate lightly used pieces of furniture that had been returned. Full Cycle is Floyd's center for extending the lifecycle of its products, and imperfect pieces can be purchased and kept out of landfill. By creating a circular market for their products, they can ensure that less furniture waste reaches landfills. The table, media console, and sofa fit perfectly in this compact home.

FLOYD

Aronson's Floor Coverings

Aronson's Floor Coverings provides flooring solutions for everything from private residences, hotels, and apartment buildings to retail environments and corporate office interiors. Their focus is on environmental sustainability, a fact that is reflected in their flooring collections featuring natural fibers and other sustainable materials, beautiful designs, and quality workmanship. We worked with them to select area rugs made from undyed wool for the living and dining rooms.

Synthetic carpets are complex in their composition and chemistry. Their complexity presents a variety of hazards in their backing, pile, and surface treatments. The litany of additives used for resistance to mildew, stains, and fire makes it important to examine the contents of a carpet product before accepting claims that it is "healthy." Our selections from Design Materials Inc. and Ulster Carpets contain no synthetic materials or additives.

ARONSON'S
FLOOR COVERING

Fig 6.12 A natural, undyed, woven wool rug from Aronson's Floor coverings with the HempWood floors

Fig 6.13 Reclaimined Chairs from DON Reclaim and second-used dining table from Floyd

7. Press

America By Design

America by Design is a television show about inspiration, disruption, and changing the world through the power of design. America by Design has reviewed work nationwide and features everything from a smart sprinkler system to a contraceptive counseling tool to our very own PA Hemp Home. Twenty-nine innovations from around the country were chosen to be highlighted for Season 1 of the show, and our PA Hemp Home collaboration in New Castle, PA, made it to the top 10 innovations for the People's Choice Award.

Watch America by Design Season 1 Episode 2 to check out our segment.

In the episode, HML co-Director Jonsara Ruth and Masters of Architecture student Meryl Smith take host Will Hall through the PA Hemp Home project and give him details about what makes it so different from the typical affordable housing built in the US.

Currently, our homes are built primarily from petroleum-based materials that harm our bodies and the environment. In particular, affordable housing construction has been chronically underfunded and regulated by racist housing policies. Products like vinyl siding and foam insulation line the walls, and after years of widespread use, these low-cost, substandard, and toxic building materials are now directly linked to more serious health risks for low-income families. Indoor air pollution within homes has resulted in an alarming rise in childhood asthma, among other health concerns.

The PA Hemp Home is built differently. A hemp-lime mix creates breathable, highly insulated walls, producing a durable house that offers increased comfort compared with currently available housing. The plant and mineral-based material is naturally flame retardant and anti-microbial, eliminating the need for any added toxic chemicals. Hemplime walls continuously absorb odors, toxics, and carbon dioxide from the air making the indoor air cleaner than the air in buildings made from typical petrochemical-based building materials.

Fig 7.1 Chris Lloyd, from DON, on set with America By Design

Fig 7.2 Cameron MacIntosh, from Americhanvre, on set with America By Design

Fast Company Innovation by Design Awards

PA Hemp Home received an honorable mention in the materials category alongside designers and businesses who are solving the problems of today and tomorrow.

Entries were judged on the following innovation criteria: functionality, originality, beauty, sustainability, user insight, cultural impact, and business impact. The Materials category looked for material innovations that lead to greener, better products.

PA Hemp Home was honored not only because hemplime is a healthier product but because it shows that hemplime can transform affordable housing. It will also revitalize local agriculture and create jobs for plant-based industries. With new incentives to grow hemp in the US, there is a potential to create an agriculturally based system for producing healthy building materials. This will create new opportunities for farmers and provide training opportunities for both industrial and construction workers. Not only will we be able to design and construct healthier, affordable houses, but we will also create jobs and new value chains for rural and small urban communities.

Fig 7.3 Fast Company Innovation by Design, Honorable Mention Announcement

Fig 7.4 Hemp Install at PA Hemp Home

Pittsburgh Action News Segments

Historic Hemp House built in Lawrence County

Fig 7.5 Pittsburgh Action News team on site with DON Enterprises, filming a news segment

National Hemp Tour ends journey at hemp house in New Castle

Fig 7.6 Pittsburgh Action News team on site with DON Enterprises, filming a news segment

News Articles

Project PA Hemp Home Becomes A Regional Showpiece

letstalkhemp.com, June 2021

Hemp Home Builds a Bright Future for Farmers

420intel.com, October 2021

Pennsylvania's Project

thehia.org, June 2021

DON demonstrates hemp use in local home rehab

ncnewsonline.com, June 2021

Hemp Home Builds a Bright Future for Farmers

hempbuildmag.com, October 2021

Touring journalists visit New Castle hemp house

ncnewsonline.com, August 2021

8. Conclusion

Overall, the design, demolition, and construction of PA Hemp Home took about a year and a half to complete. On Friday, April 22, 2022, a ribbon-cutting ceremony was held in New Castle to celebrate the completion of the home. Appropriately unveiled on Earth Day, the house is Pennsylvania's first total renovation of a residential structure using hemp-based building materials, utilizing breathable spray-applied hemplime on its walls and hempwood on its floors. During the event, we heard from representatives from Parsons' Healthy Materials Lab, the Pennsylvania Department of Agriculture, the Pennsylvania Housing Research Center, Americhanvre, and DON Enterprises. Each team member talked about the potential of hemp-based building, including the economic potential for farmers and the hemp industry and the impact on health from eliminating toxics in the building industry. After the program of speakers, members from the community were invited to tour the home.

Fig 8.1 The completed exterior of PA Hemp Home on ribbon cutting day

Indoor Air Quality Testing

Once the construction was complete, we began to test the advantages of using hemplime and other healthier materials. With a team of Industrial hygienists and engineers, we were able to execute testing of both the home's indoor air quality and energy efficiency.

HML coordinated Cardno ChemRisk (now Stantec) to test the indoor air quality of the newly completed PA Hemp Home, designed and constructed with hemplime and other healthier materials, compared to a home developed with conventional building materials. The two homes are similar in size and were constructed in a relatively similar timeframe in the same neighborhood in New Castle, Pennsylvania. At the time of testing, both homes were new and never occupied. Testing commenced following the completion of construction and three weeks of ventilation.

HML provided a "Priority Pollutant Wishlist" of chemicals and toxics generated based upon substances most commonly found in common building products used to build affordable homes. The list includes volatile organic

Fig 8.2 Industrial Hygenists from Cardno ChemRisk (now Stantec) setting up for sampling in PA Hemp Home

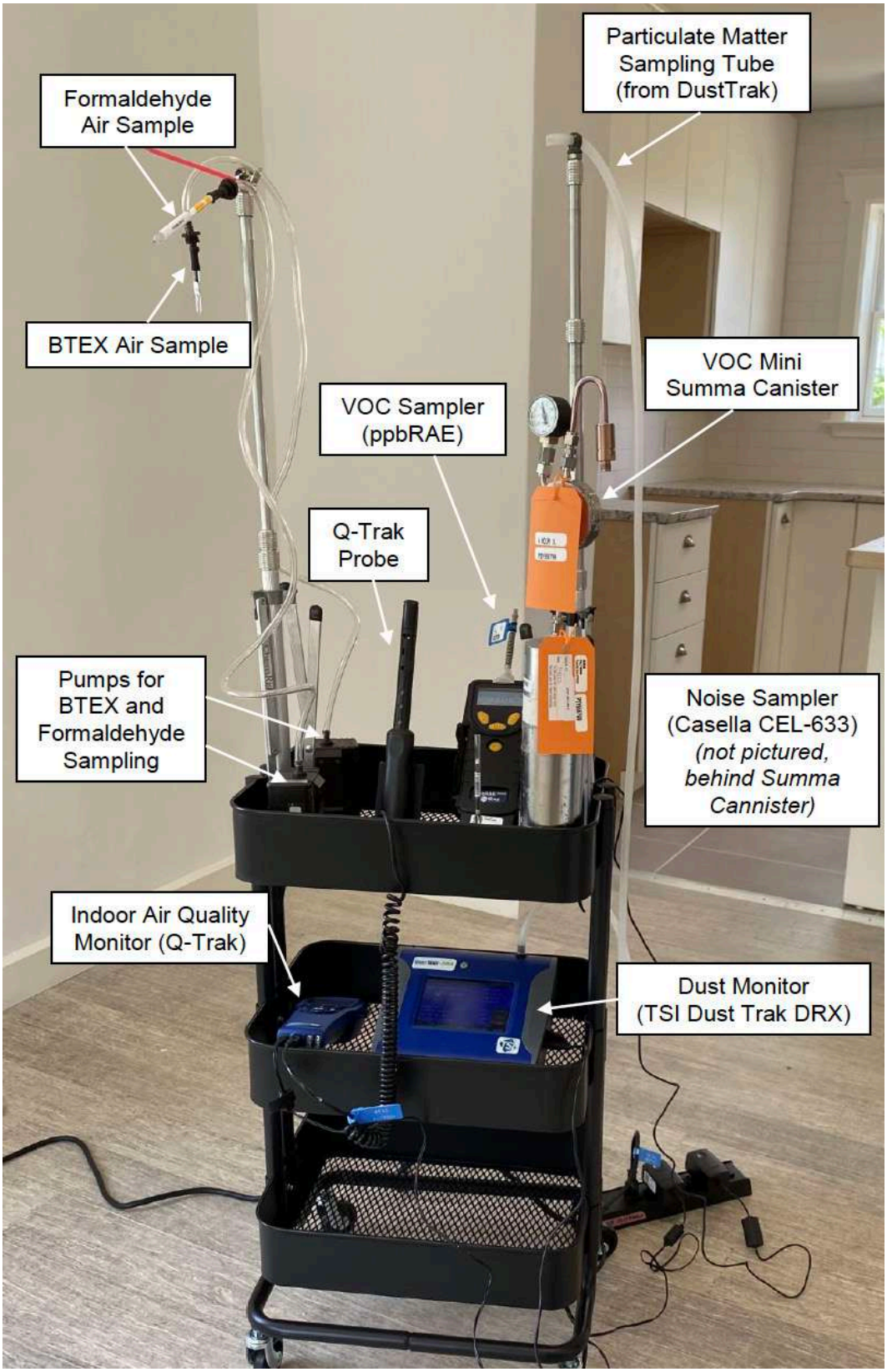

Fig 8.3 The sampling station all set up

compounds (VOCs) & alkylphenol ethoxylates (APE) found in common paints; flame retardants found in common insulation, upholstery, and other products in the home; urea-formaldehyde found in common cabinetry, wood flooring, and other wood furnishings; (ortho) phthalates (e.g., DEHP & DINP) found in PVC products such as vinyl flooring; solvents (e.g., benzene, toluene) typically found in adhesives, sealants, and coatings; isocyanates commonly found in foam insulation, wood coatings, carpet padding, caulk, adhesives, and more; heavy metals (e.g., lead, arsenic, cadmium, chromium VI, mercury) commonly found in gypsum wallboard, carpet backing, spray insulation; PFAs (highly fluorinated chemicals) often found in resilient flooring, carpeting, upholstery; and total dust.

After months of planning, a 24 hour sample collection period and a few weeks of laboratory testing, we received a report of the testing results. The most significant difference between the two homes was that formaldehyde concentrations in the PA Hemp Home were reduced by 420% compared to the conventional home.

Room conditions in PA Hemp Home were tested (temperature, relative humidity, carbon dioxide and carbon monoxide, total VOCs, ambient light, and sound), and all of the results fell below or within the recommended ranges.

Significantly, when the home was tested for flame retardants, none were detected.

Thermal and Energy Testing

Pennsylvania Housing Research Center is a research group within Pennsylvania State University that collaboratively engages with the residential construction industry to catalyze advancements in homebuilding through education, training, innovation, research, and dissemination. Their goals and mission are aligned with that of DON and HML. They aim for a residential construction industry equipped with the knowledge, skills, and technology to build better homes.

The study and testing that they conducted were to determine the thermal resistance of hemplime walls and evaluate the energy performance and utility cost of PA Hemp Home compared to its initial condition. Sensors were installed within the walls to monitor the heat exchange between the interior and exterior of the walls. After monitoring the sensors for a few months, they determined that the R-Value (the capacity of an insulating material to resist heat flow) of the hemplime walls is 16.93. Compared to the R-value of a conventionally built wall, which is 13.42. Concluding that, indeed, hemplime walls are better at insulating and resisting heat flow.

Fig 8.4 Heat flux monitor in the upstairs bathroom that was installed by PHRC

Special Thanks

We would like to extend deep thanks to the folks at DON Enterprise for inviting us to collaborate on this groundbreaking experimental house. A special thanks to Lori Daytner for leading the project with determination, tenacity, kindness, and generosity and to Patrick Mcguire for his detailed supervision of construction.

And special thanks to everyone involved in making this project come to life. Especially:

Cameron McIntosh of Americhanvre
Alex Sparrow of UK Hempcrete
Pennsylvania Department of Agriculture
Pennsylvania Housing Research Center

The interior furnishings were supported by our partners and collaborators. Thanks to their generous donations and insights, we were able to achieve the material health goals for PA Hemp Home.

Aronson's Floor Covering
Columbia Forest Products
Daltile
DON ReClaim!
Earth + Flax
Floyd Home
HempWood
Limeworks.us
Lowes
Precision Countertops and Stone
Pella

Fig 8.5 The completed exterior of PA Hemp Home from the backyard

Fig 8.6 This project was made possible by generous donations and discounts from our collaborators

9. Appendix

Lessons Learned Matrix

LESSON 01	The design and materiality of the renovation evolved as conditions of the house were revealed during the demolition phase.
LESSON 02	When the petroleum based products were stripped away, all that was left were natural, healthy materials used to build this house in the early 1900s.
LESSON 03	Much more lumber was replaced in the walls and floors than originally anticipated due to unexpected damage from fires and termites. This affected the available budget for other items, such as windows and skylights.
LESSON 04	Installing a second layer of structural lumber was necessary to allow for a thick enough wall assembly to meet the required R-value of the hemplime insulation.
LESSON 05	The exposed structural studs on the exterior walls would leave the plaster vulnerable to cracking. To remedy this, it was decided to install a rainscreen made of locally sourced, rough sawn lumber.

LESSON 06

The use of Metakaolin as an aggregate in this plaster mix was problematic. Metakaolin is a clay, which is fast acting but rapidly shrinks and often causes problems. Sand should always be used as an aggregate in plaster mixes.

LESSON 07

Always test the plaster mix in a small area to determine how it behaves on a particular site before installing it entirely.

LESSON 08

Lath was placed only over the exposed wooden studs and the plaster began to crack at the spaces between the stud and the hemplime. It is likely that lath should have been placed over the entirety of the surfaces.

LESSON 09

A hardener was used as the final coat on the interior walls to prevent dusting. Check the ingredients and properties to ensure it is healthy and vapor permeable, because it is important to allow the hemplime walls to breathe and achieve their full potential.

LESSON 10

When experimenting with natural paints for the first time, it is important to leave ample time to make samples, troubleshoot and determine the best application technique for the surface. Allowing for extra dry time is necessary.


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