Reforming Grounds

Building with the Earth’s Forgotten Resources

A guide for making homes from crop residue and geological surplus: hemp, straw, stone and earth.

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Case Study Booklet

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How to Repurpose Industrial Surplus and Agricultural By-products for Construction

This booket examines a range of case studies looking at how we can build with surplus of biological and geological materials. It seeks to find techniques with optimal aspects for circular construction by studying exemplary low-carbon buildings. It showcases both the building construction scale, as well as on the individual component level, to see how these are made and assembled, as well as how they sit within the bigger picture. Through taking cross-sections of key nodes, a understaning of the construction is illustrated, along with step-by-step assembly photos for each construction technique.

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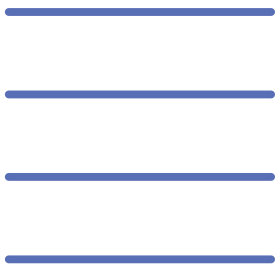
TECTONIC ALPHABET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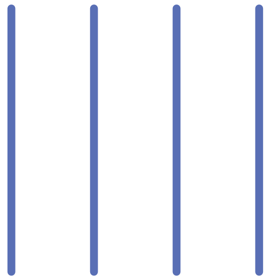
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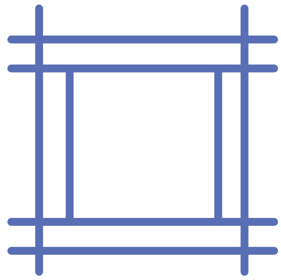
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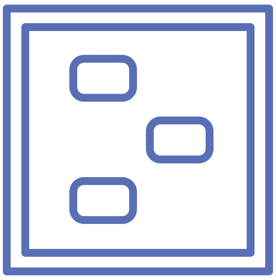
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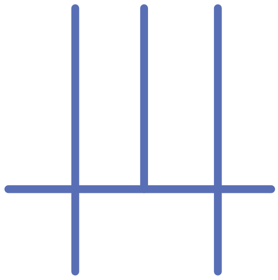
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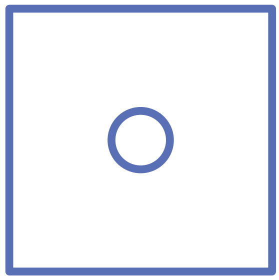
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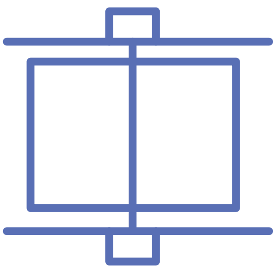
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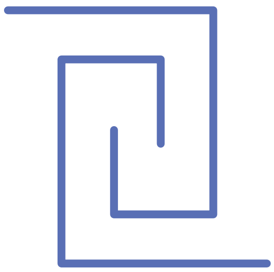
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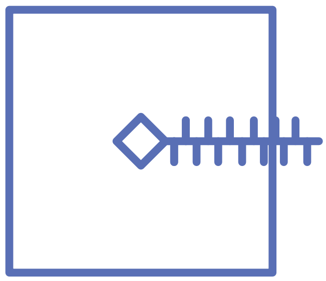
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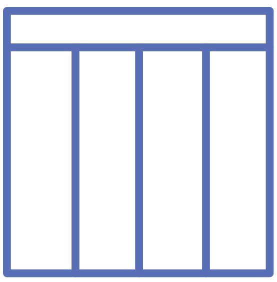
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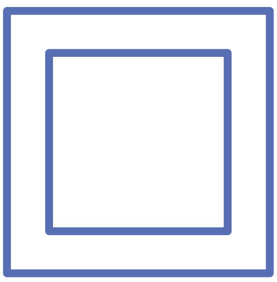
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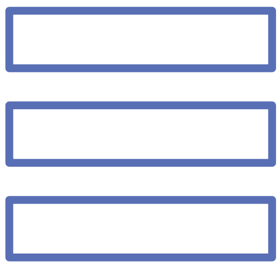
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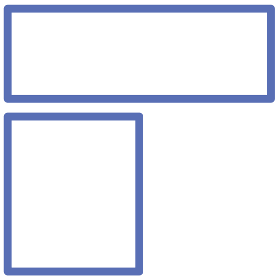
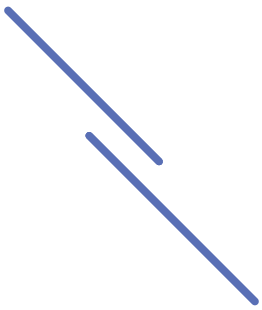
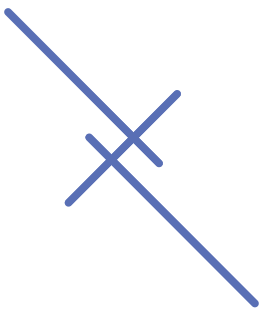


Resting

Pitching



Overlapping



Stapling

Introduction

Tectonics and design for assembly

In architecture and construction, tectonics refers to the art and science of how buildings and structures are put together. It focuses on the design, assembly, and expression of materials, techniques, and construction processes. Tectonics highlights the relationship between form, structure, and materiality, emphasising how these elements work together both functionally and aesthetically. It often explores the craftsmanship and expressive potential of construction methods.

Tectonics is valuable for designing simple assembly systems because it emphasises the clear relationship between materials, structure, and connections. By focusing on the logic of how components come together, it simplifies construction processes, reduces assembly errors, and enhances efficiency. Tectonic thinking encourages modular and intuitive connections, making assembly and potential disassembly straightforward while supporting material reuse and adaptability. This approach not only ensures efficient construction but also aligns with sustainable principles by enabling durable, flexible, and reversible systems.

Selected Cases
Criteria

Each material section is suppored by a case study for each technique that will eventually aid in understanding how geo-/bio- surplus and by-products could be re-purousped for building beautiful architecture. Since there are few examples of such architecture built projects using specifically surplus/by-products, (or not as biocomposites which are still very experimental), I turn to contemporary built examples that focus on hemp, straw, stone and earth. Built sources also provide the detail and information needed to understand how we can adapt building methods for forgotten material resources of quarries and crop farms, in a clear and logical way. The criteria for each of the case studies was outlined as follows:

1) Prevalent use of natural materials as much as possible throughout the construction

2) Modernsation or adaptation of traditional building techniques to suit contemporary industrial standards

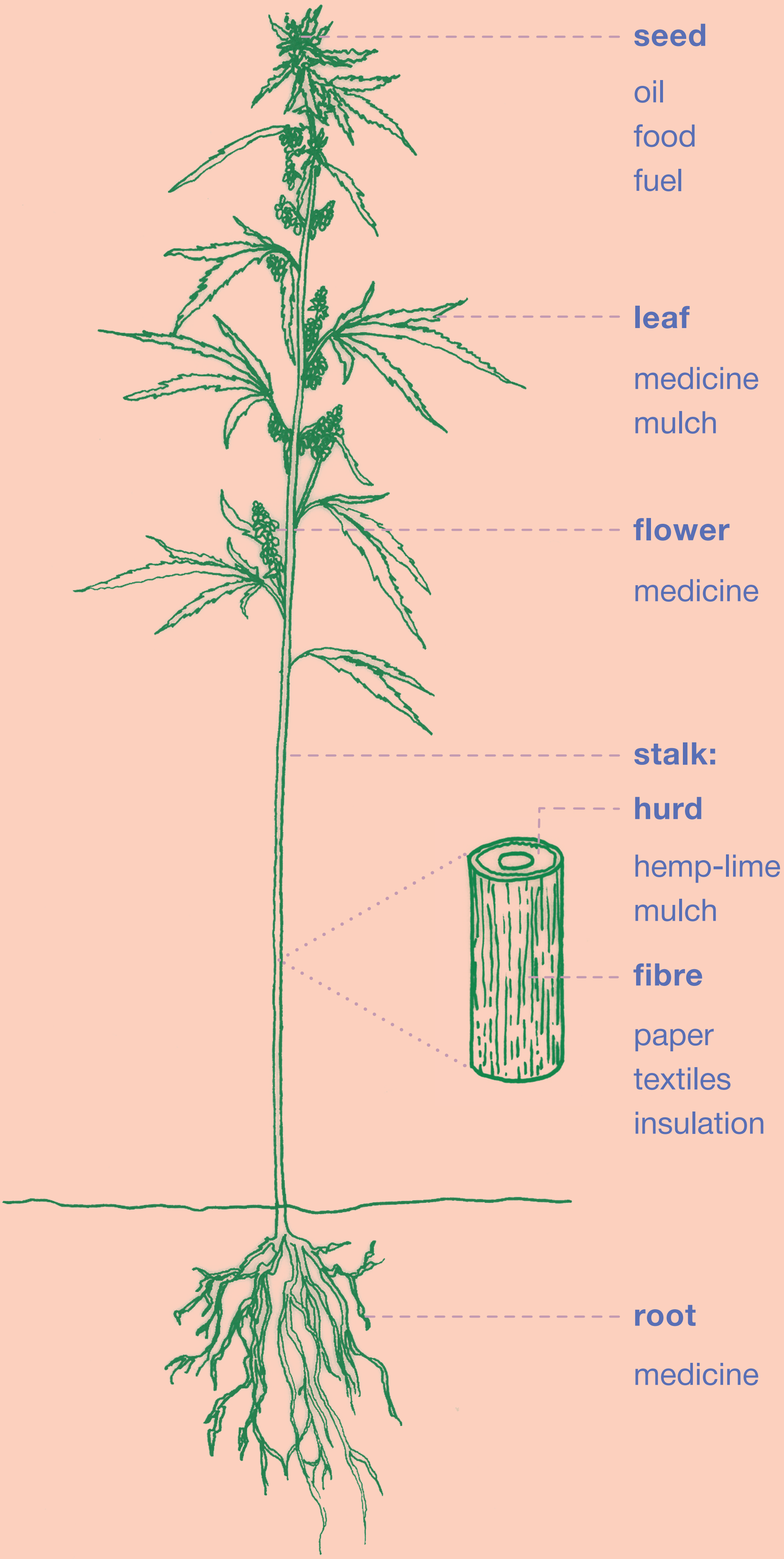
3) Exemplary low to negative co2 footprint

4) Simple assembly of components based on low-tech methods where possible

5) Reversible joints (connections) which can be (dis)assembled with ease

SECTION 1: BI

IO MATERIALS


seed
oil
food
fuel
leaf
medicine
mulch
flower
medicine
stalk:
hurd
hemp-lime
mulch
fibre
paper
textiles
insulation
root
medicine

HEMP

Hemp is a natural fibre source that is rich in cellulose and lignin and can be processed into durable materials for construction, textiles, and bioplastics. Hemp has been cultivated for over 10,000 years, originating in ancient China and spreading globally due to its adaptability and versatility.[1] Over centuries, hemp varieties were selectively bred to enhance fibre quality and seed production. The plant grows rapidly, reaching harvest within just four months, making it an ideal renewable resource.

Hemp has long been used for construction, for example in the production of hempcrete, a bio-composite material made from hemp hurds, lime, and water. The lignin and cellulose fibres in hemp create a structural matrix that provides thermal insulation and moisture regulation.[2] Once processed, hempcrete is lightweight, fire-resistant, and durable, making it a popular material for sustainable building projects.

Hemp is also an excellent thermal and acoustic insulator, with its performance varying depending on density and the composition of the construction elements. Its embodied energy is 87 times lower than that of concrete, and hemp products contribute to significant carbon sequestration during growth.[3] With proper management, hemp is an ecological and renewable solution for modern sustainable construction.

Common Name	Hemp
LatinName	*Cannabis sativa*
Age at Harvest	100 - 120 days*
Height at Harvest	1.5 - 4.5 metres
Soil Preferance	Well-drained, loamy soil
PH	6.0 - 7.5 pH
Climatic Conditions	Warm or temperate climate (prefers abundant sunlight and moderate rainfall)
Appearance	Tall, slender stems with palmate leaves, fibrous stalks, and seed-bearing flowers in female plants.
Method of Regeneration	By seeds (annual plant)
Supported Biodiversity	Provides habitat for beneficial insects and supports soil health through deep roots.
Fungal Networks	Forms associations with arbuscular mycorrhizal fungi, enhancing nutrient uptake.

* depending on variety and growing conditions

1. Small, Ernest, and David Marcus. "Hemp: A New Crop with New Uses for North America." In Trends in New Crops and New Uses, edited by J. Janick and A. Whipkey, 284-326. Alexandria, VA: ASHS Press, 2002.

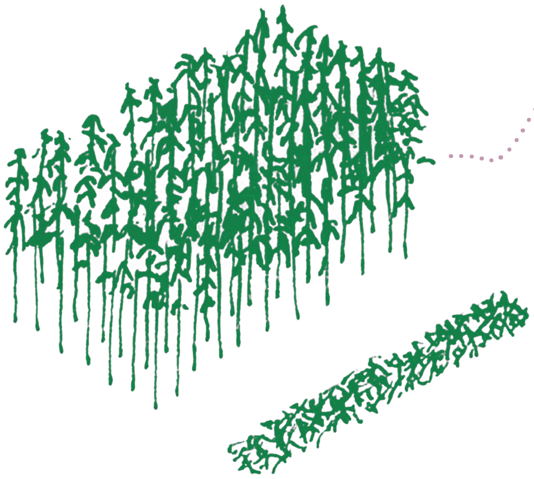
2. Lawrence, M., et al. "Hempcrete as a Sustainable Material for Construction: Thermal and Environmental Analysis." Advances in Materials Science and Engineering 2017, Article ID 1968539.

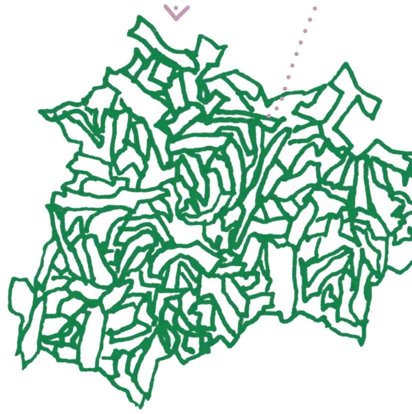
3. Cherrett, N., Barrett, J., Clemett, A., Chadwick, M., and Chadwick, M. Ecological Footprint and Water Analysis of Cotton, Hemp, and Polyester. Stockholm Environment Institute, 2005.

hemp harvesting + construc

HARVESTING

Hurd is cut before turning to seed, then left to dry for about a month (retting), to seperate the fibres from the hurd.



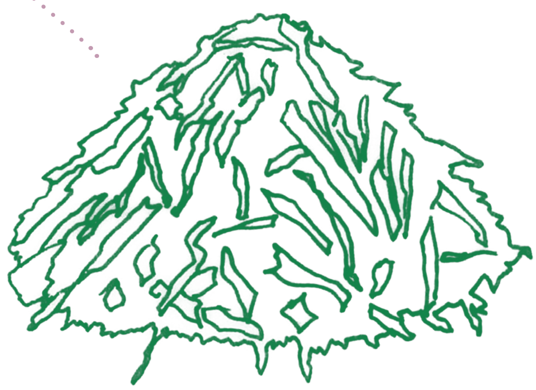


PROCESSING

Baled, stored before and fibre is seperatec decorticating machin

GROWING

Hemp reaches maturity in ~100 days. Deep root systems stabilise and regenerate soil.



PLANTING

Industrial hemp is grown from seed, compact planting prevents weeds and promotes tall central stalks.

MULCH

Hemp can be turned into biofuel or mulch for landscaping and soil enrichment.

DISA

Can b repur or co

ction

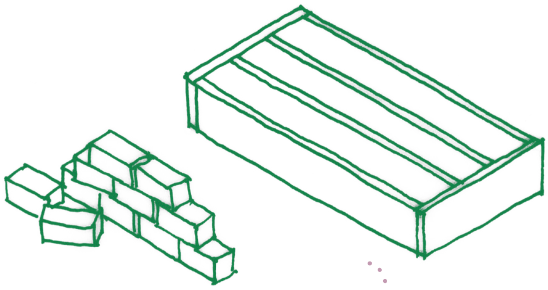
lifecycle

MIXING

Hemp hurd is mixed with lime and water to create hemp-lime.

MANUFACTURING

Hemp-lime can be prefabricated into panels or blocks for controlled drying.



LIME PRODUCTION

Lime comes from heating limestone ($CaCO_3$) into quicklime (CaO). Hydraulic lime, containing clay, is often used with hemp.

hurd
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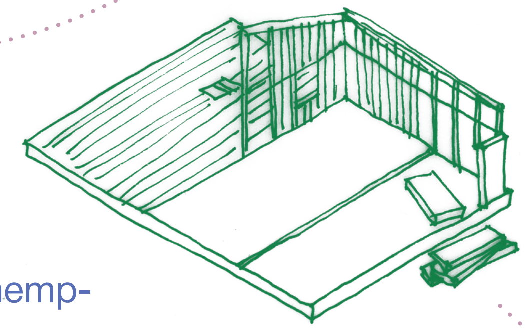
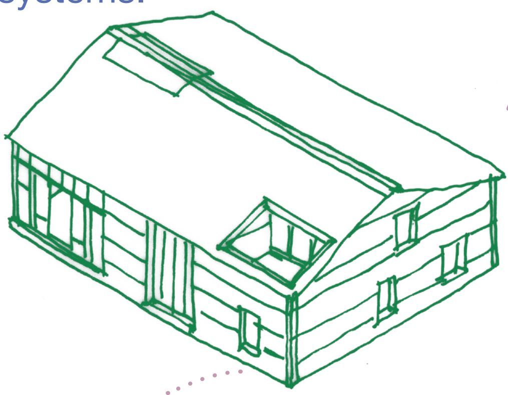
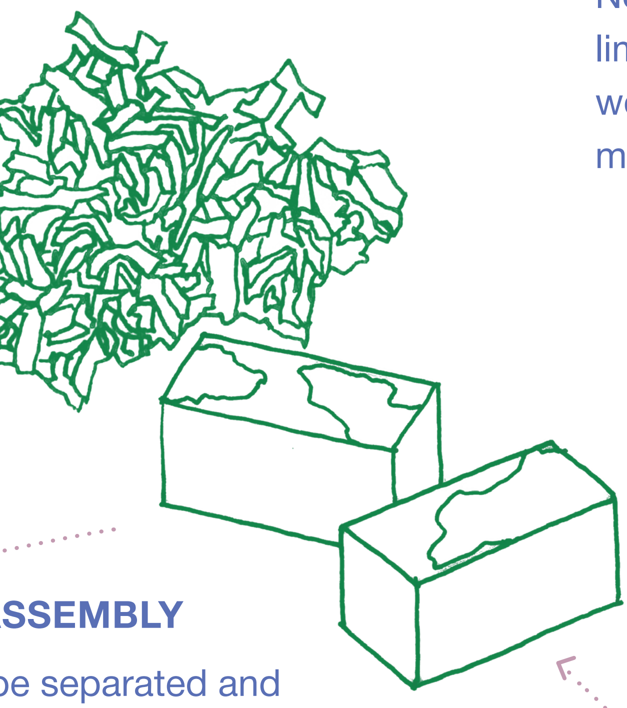


ASSEMBLY

Non-load bearing hemp-lime is combined with wood frames to create mass wall systems.





SSEMBLY

be separated and
posed, downcycled,
mposted.

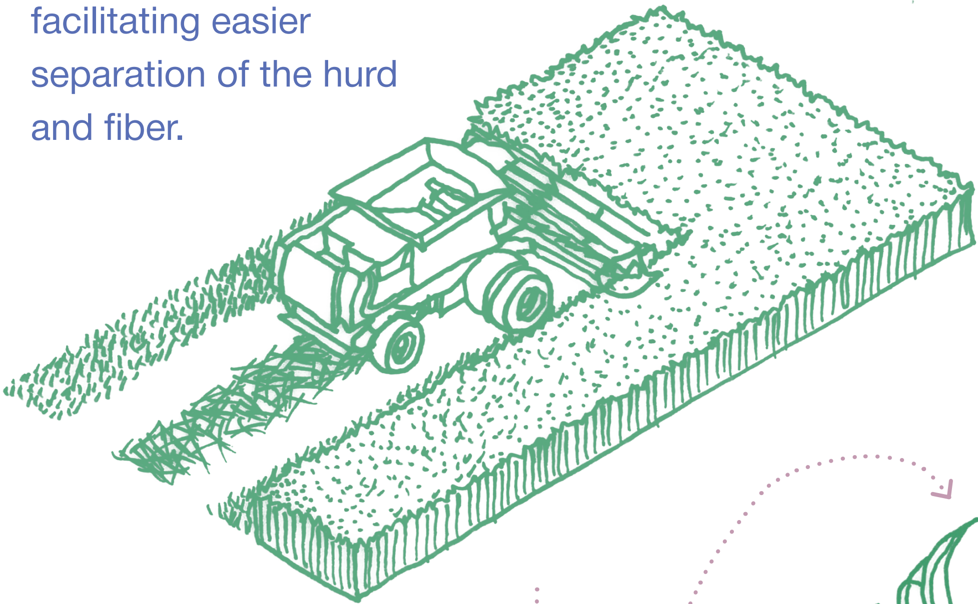
IN-USE

Naturally mould, rot, and insect resistant, vapour open and breathable with little maintenance required.

hemp processing + constru

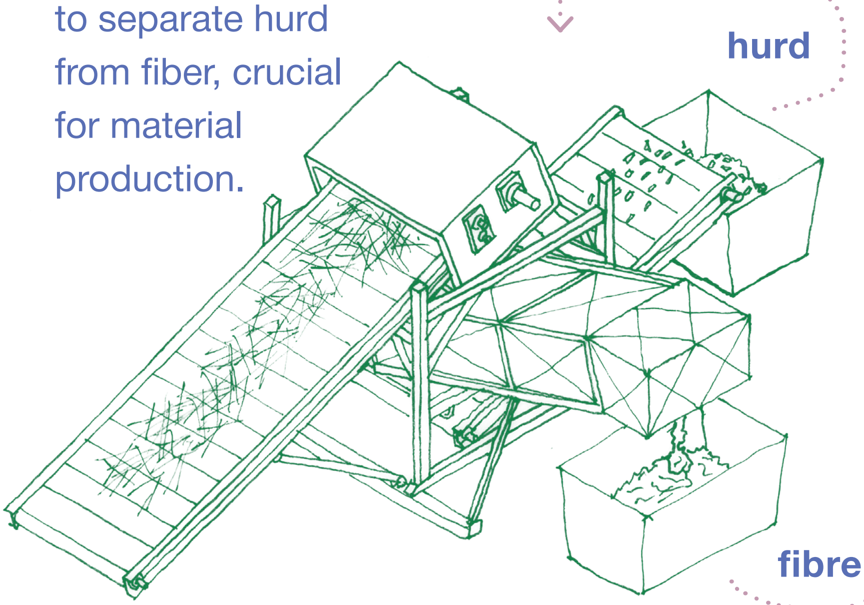
HARVESTING

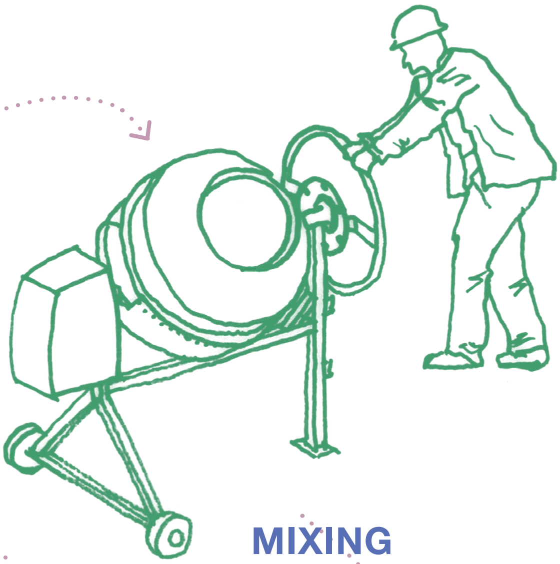
Hemp stalks are cut and left to ret or dry, facilitating easier separation of the hurd and fiber.



DECORTICATING

Stalks are processed through a decorticator to separate hurd from fiber, crucial for material production.



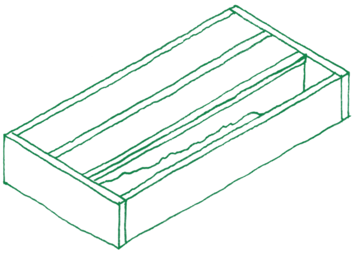


MIXING

hemp hurd
+ lime
+ water
= hemplime

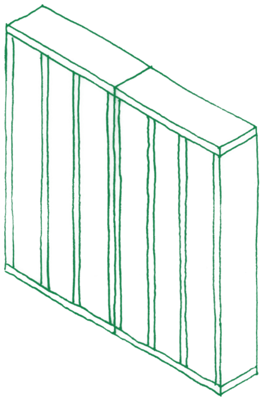
ction

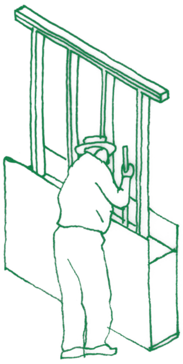
techniques



COMPACTING

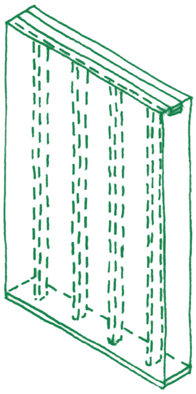
prefabricated panels

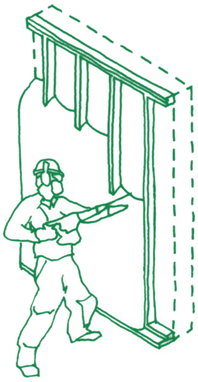




COMPACTING

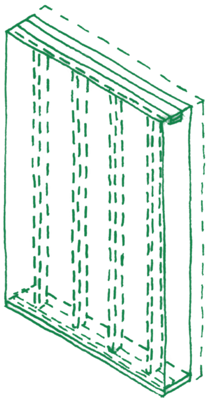
between formwork

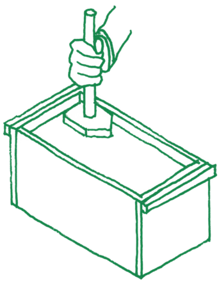




SPRAYING

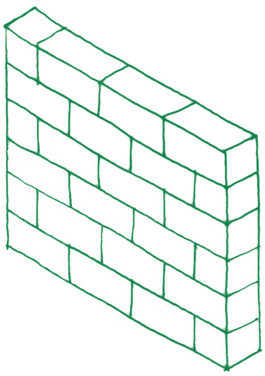
over wood framing

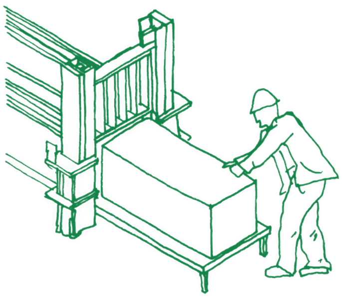




PRESSING

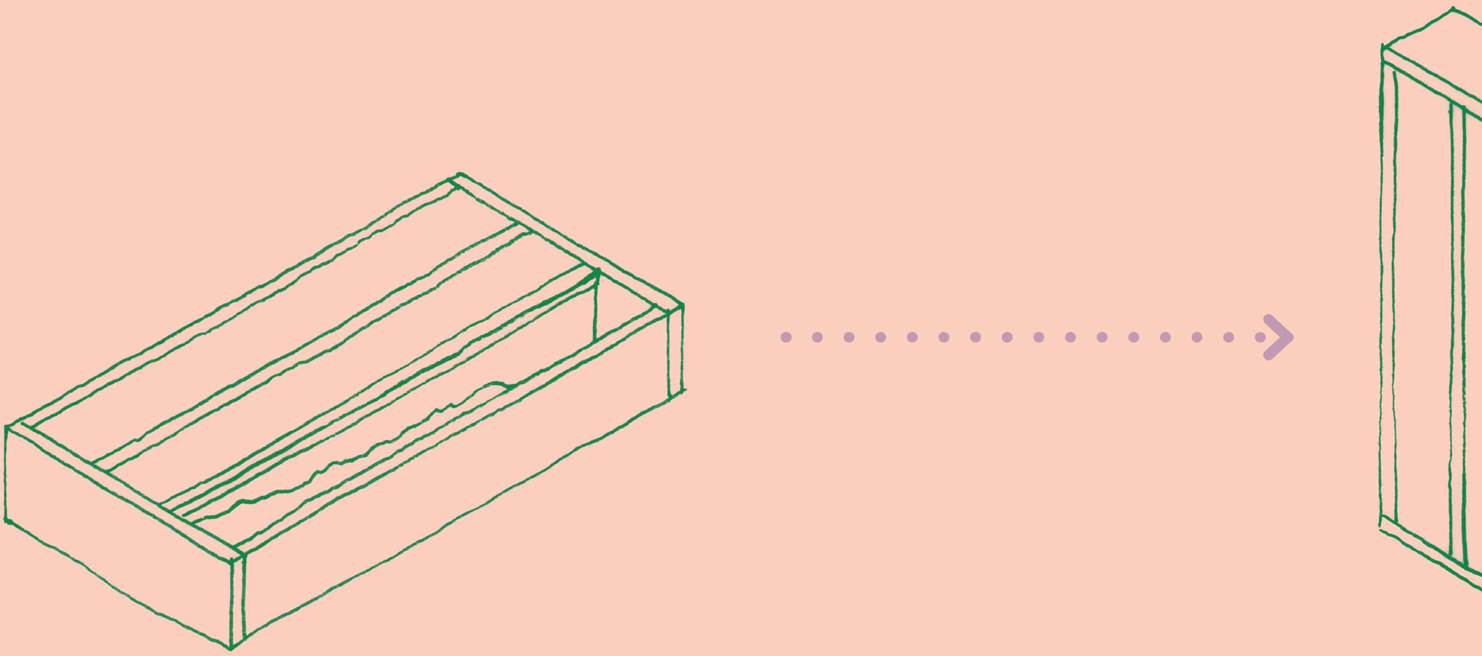
block forming



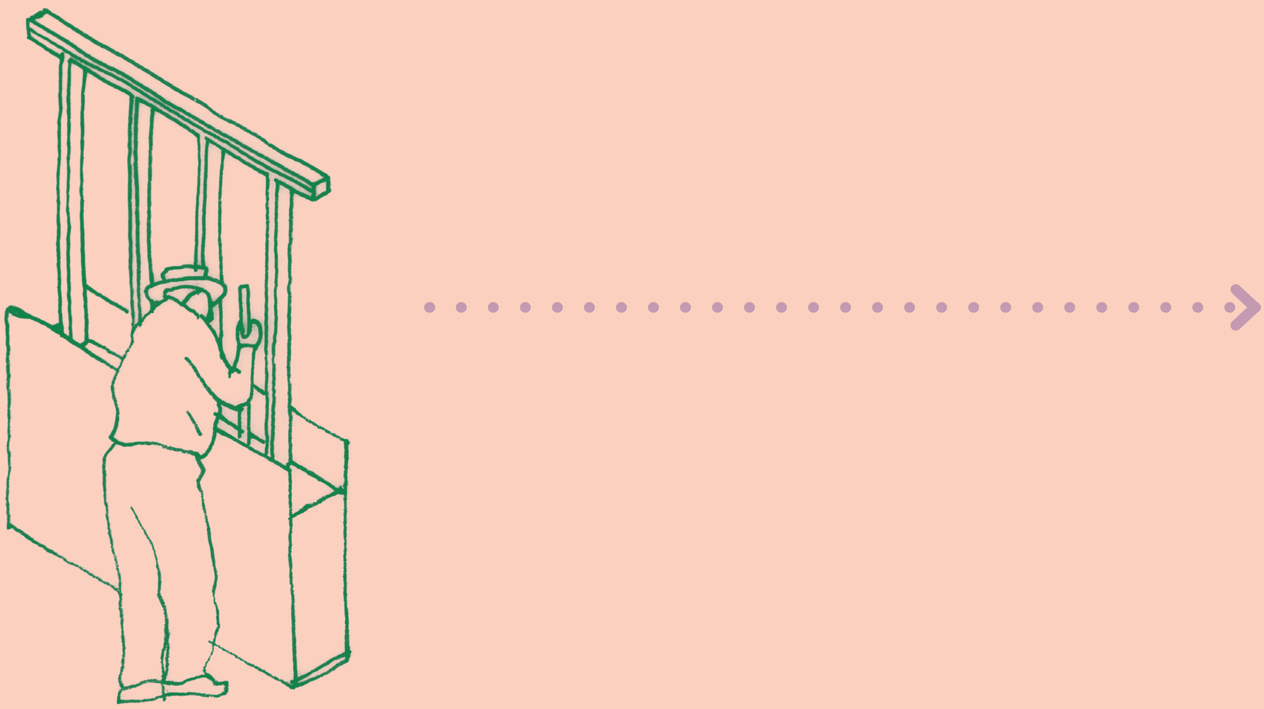


COMPRESSING

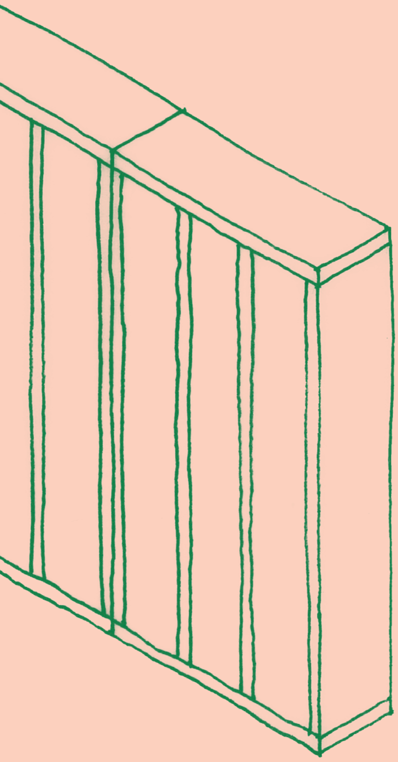
mechanically



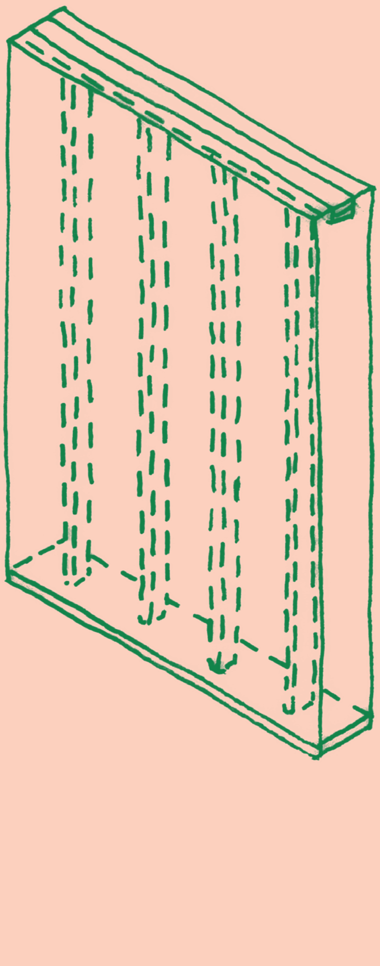
PANELS (OFF-SITE)



FORMWORK (ON-SITE)



TECHNIQUE: COMPACTING



Compacting - prefabricated panels

Case Study: Flat House

Construction: April 2018-March 2019

Gross internal foor area: 97m^2 (house), 60m^2 (hot house)

Construction cost: £250,000 - £1,600 per m^2 (including hot house), £2,200 (house only)

Architect: Practice Architecture

Client: Margent Farm

Structural engineer: Fordham Consulting

Hemp construction: Will Stanwix

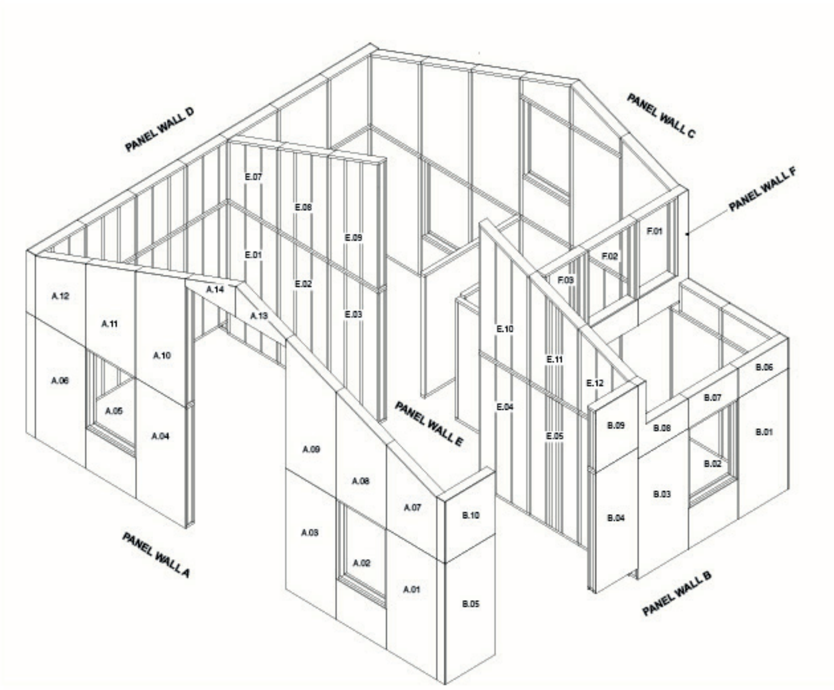
Hot house: Henry Stringer

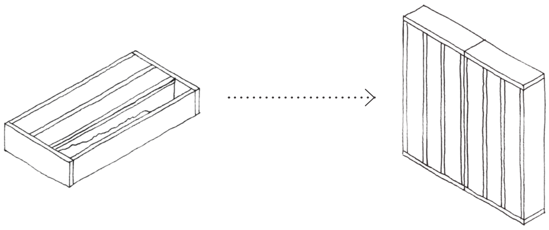
Prefabrication: Material Cultures

Annual CO2 emissions: –2.32 kgCO2/m^2

Embodied CO2: -8,268 kgCO_2

Flat House (2020) by Material Cultures is a groundbreaking residential project at Margent Farm, an R&D facility exploring bio-plastics with hemp and flax. Designed by Practice Architecture, it integrates low-tech, bio-based materials—hempcrete cassettes, hemp fibre cladding, and timber—with prefabricated construction. Using hemp grown on 20 acres of the farm, the timber and hempcrete panels were installed in just two days, showcasing scalability for various building types. The house employs natural material technologies to regulate humidity, temperature, and air quality without mechanical systems, achieving outstanding sustainability metrics: -5.1 tonnes of embodied carbon (with sequestration), -2.2 tonnes of annual CO_2 emissions, and near-perfect environmental ratings. This innovative approach reimagines traditional techniques for contemporary low-carbon construction.





1. *World Atlas.* "Loess Soil and Ground Fertility." Accessed November 12, 2024. https://www.worldatlas.com/articles/loess-soil-and-ground-fertility.html.

2. Burrough, Peter A., Rianne Finke, and Bert Heuvelink. "Map of Southern Limburg, the Netherlands, and Contiguous Areas Showing Locations of Soil Sampling Sites and Landforms." In *Spatial Aspects of Soil Properties in the Netherlands,* ResearchGate, accessed November 12, 2024. https://www.researchgate.net/figure/Map-of-southern-Limburg-the-Netherlands-and-contiguous-areas-showing-locations-of_fig1_270105660.

3. *Project Contracts2.0.* "CIL Limburg & Groningen." Accessed November 12, 2024. https://www.project-contracts20.eu/cils/cil-limburg-groningen/.

Compacting - prefabricated panels

Case Study: Flat House

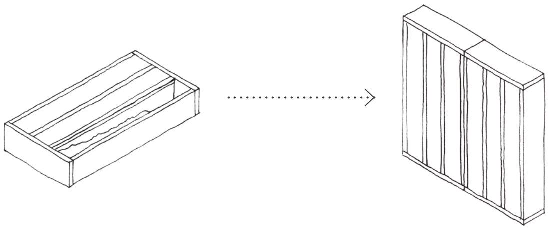
1) Hemp was harvested on-site from 20 acres of Margret farm and procssed. The stalk was seperated into fibre for the composite cladding, and shiv, the woody core for the hempcrete panels.

2) Then, the Lime was mixed with the hemp shiv to create hempcrete and conveyer poured into the mix into timber frames, filling the panels.

3) Panels wer
vertical studs
just 10 days b
electrical con
hempcrete, w

5) A forklift moves the panels in the off-site production facility to be transported to the truck.

6) The hempcrete panels are wrapped up to be protected from the elements and transported to the siteusing a flatbed truck with a crane



e constructed using timber I-joists as the
within a structural cassette system, built in
by Oscar Cooper. Will Stanwix fitted all the
duit and HGMatthew's helped to cast the
hich only took 4 days.

4) These were left to cure and dry. In 20 days of work the structural frame, 35 cubic metres of hempcrete, all electrical first fix and the finish surface were complete, constructed and dry.

7) A crane lifts and positions the panels, guided by a construction worker for precise placement.

8) These modular components were raised into place in just two days.

1. *https://www.margentfarm.com/about-us/the-farm*

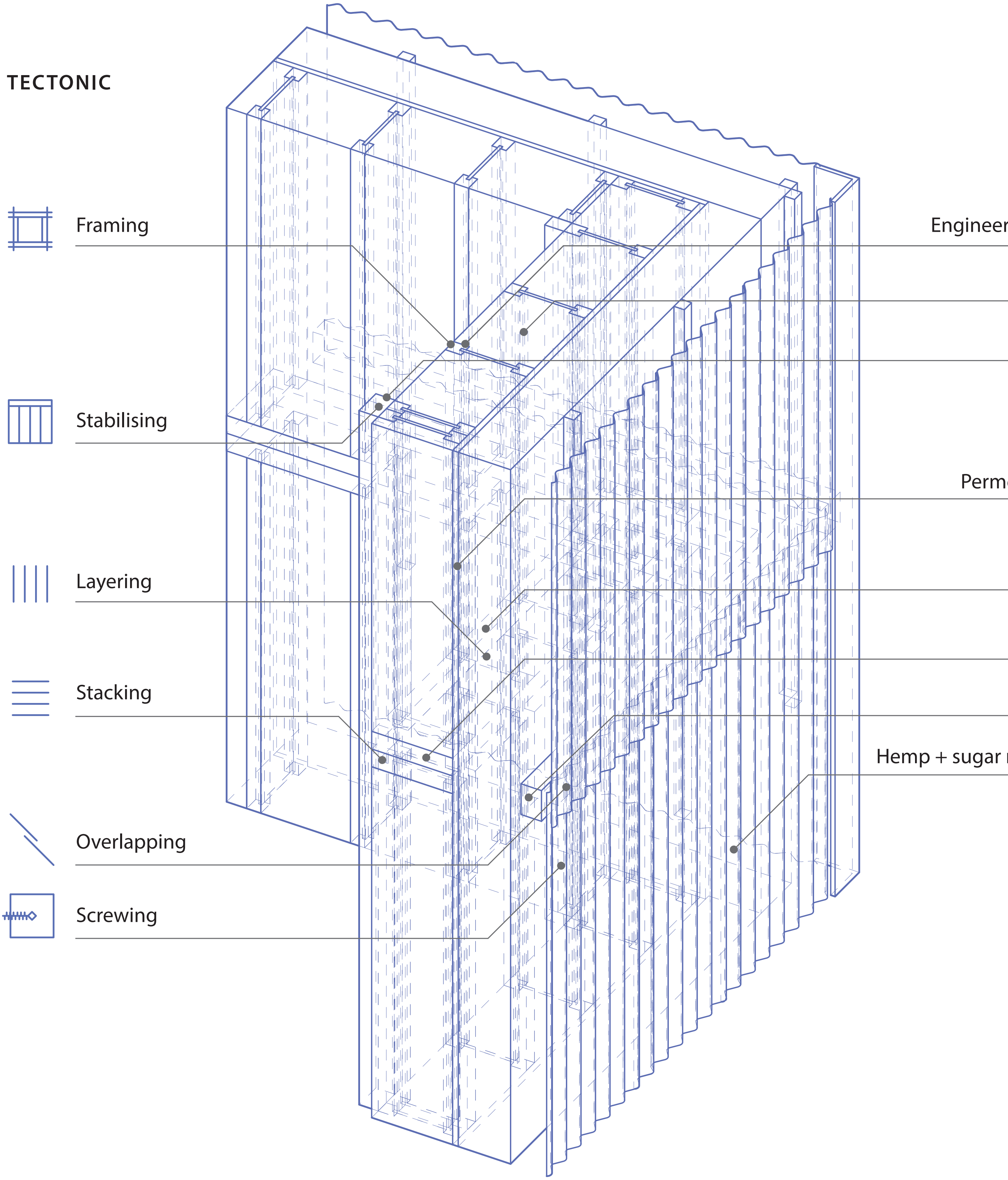
2. *https://thathempcreteguy.com/work/hempcrete-panel-house*

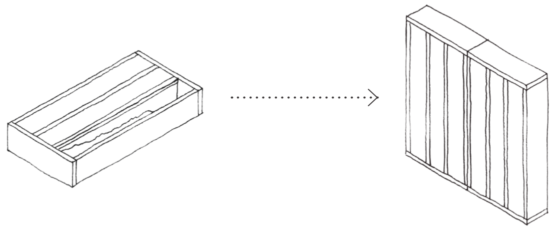

EIVISSA

1. https://divisare.com/projects/427542-practice-architecture-oskar-proctor-flat-house#lg=1&slide=10

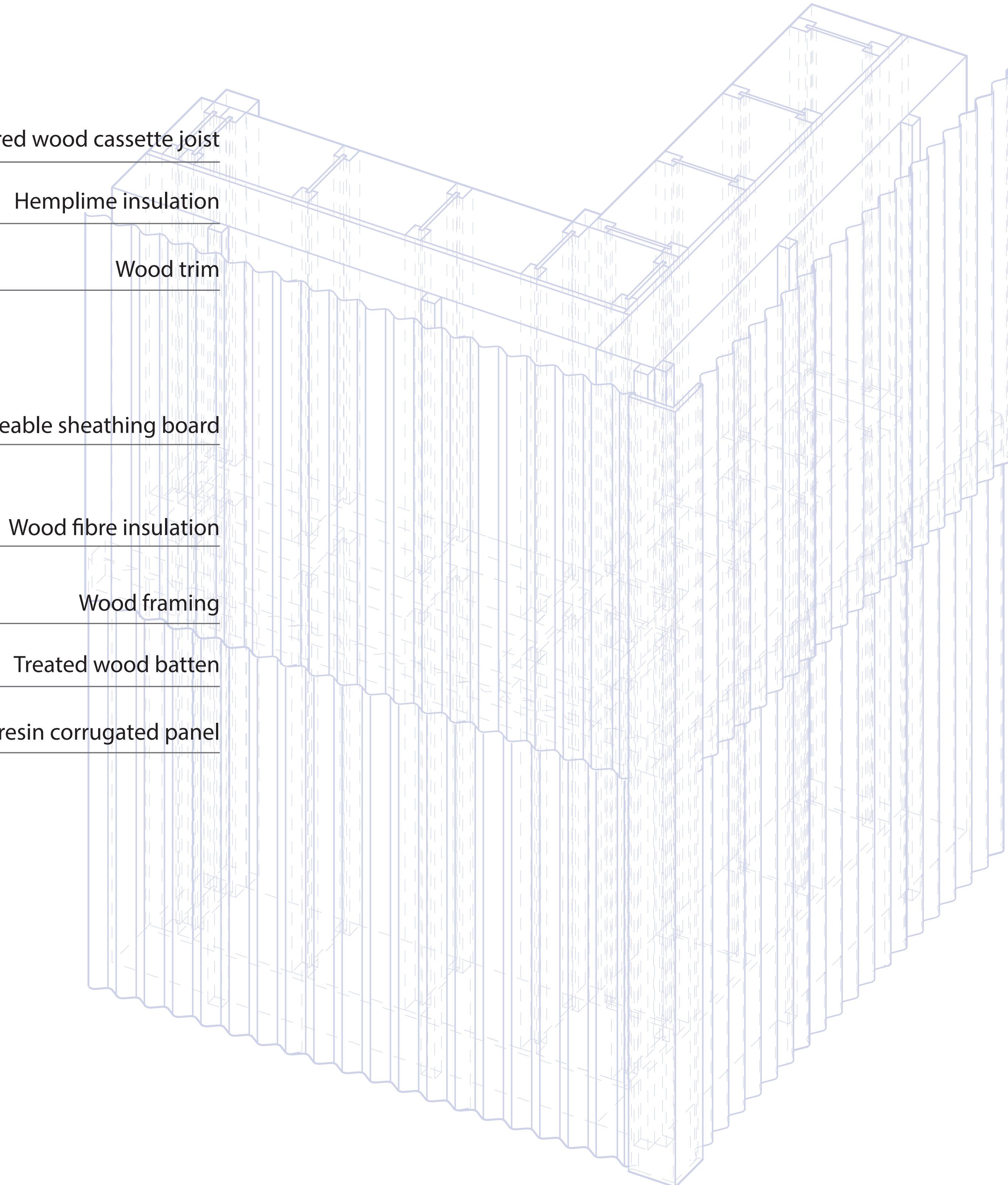
Tectonic Analysis

TECTONIC

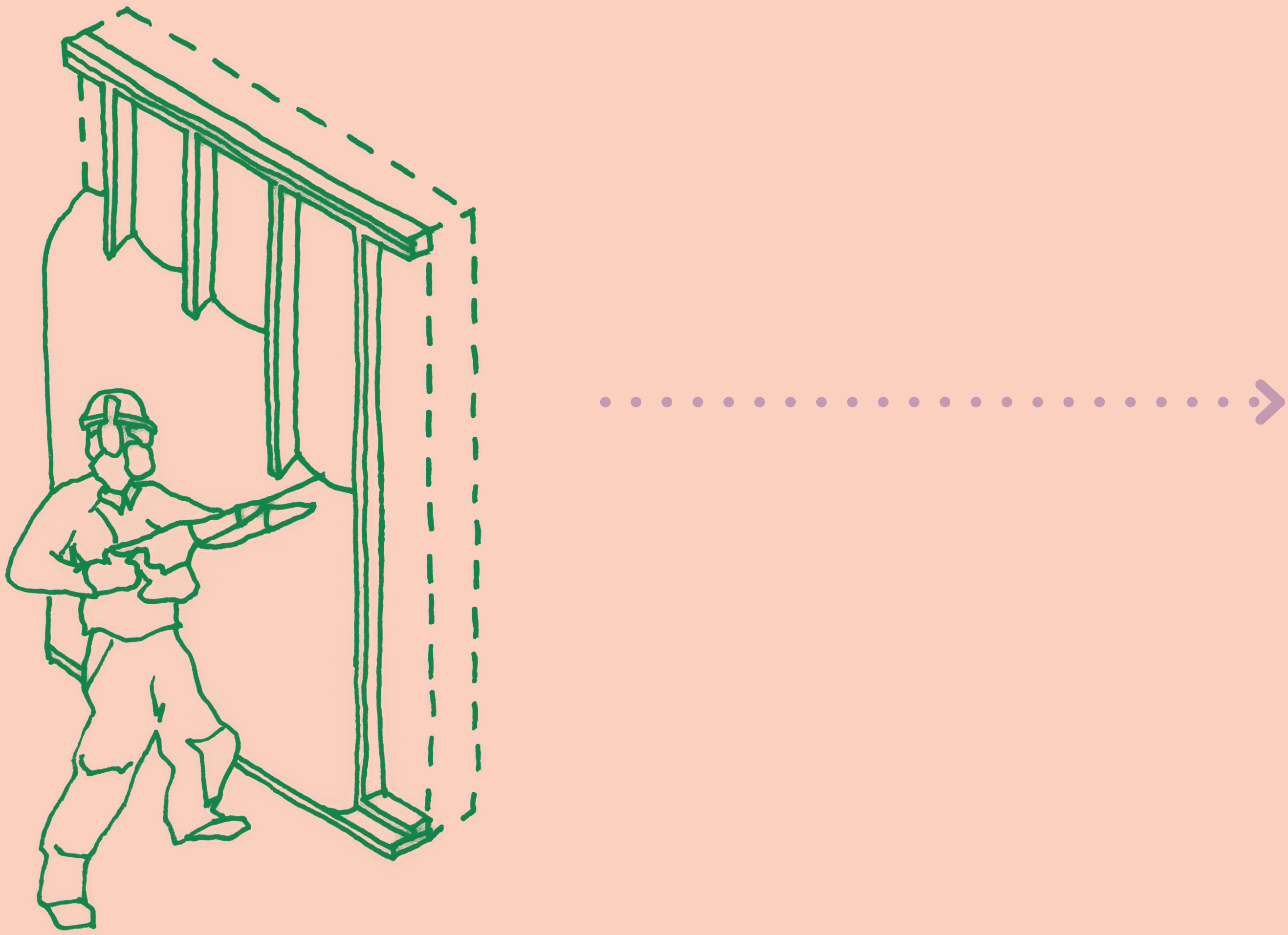




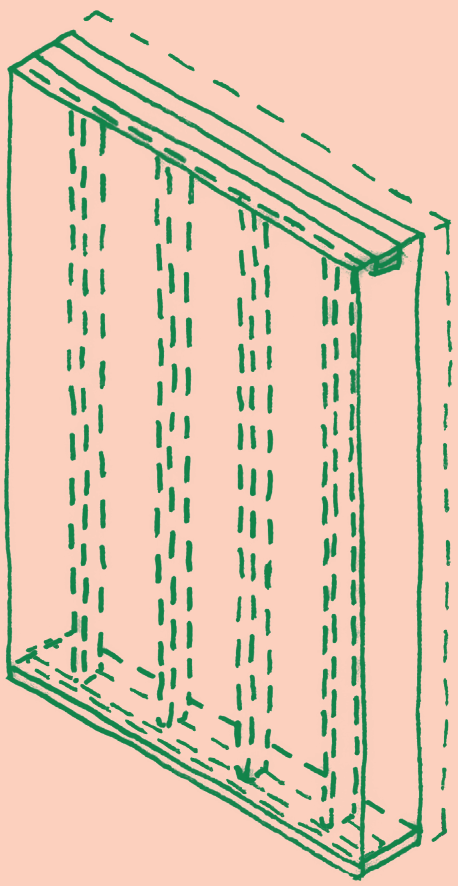
TECHNOLOGY



Own drawng adapted from Manual from Biogenic House Sections (page 327)



ON WOOD FRAME



TECHNIQUE: SPRAYING

Spraying - on wood frame

Case Study: Cape Cod

Construction: Spring 2021-March 2022

Gross internal foor area: aprox. 557m²

Construction cost: Undisclosed

Architect: Estes Twombly + Titrington Architects

Client: Michael Monteiro

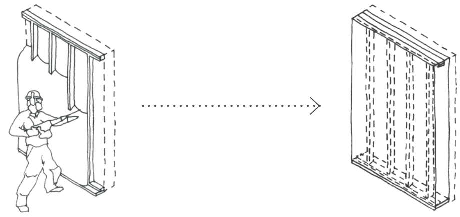
Structural engineer: Structures Workshop

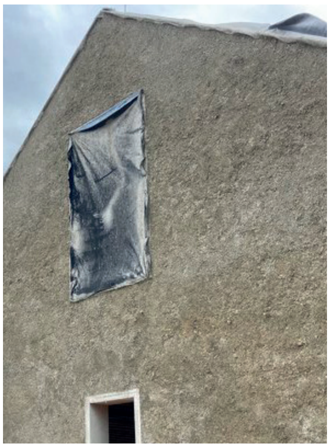
Hemp construction: HempStone, LLC

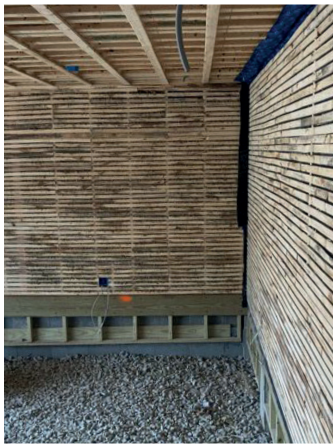
Mechanical + energy engineer: ZeroEnergy Design

The Cape Cod Hemp House is an innovative net-zero energy home in Harwich Port, Massachusetts, designed by Estes Twombly + Titrington Architects. The house features 12-inch hempcrete walls, triple-pane windows, air source heat pumps, and a 15kW solar array that offsets 120% of its energy needs, making it a net-positive energy home. For construction, hemplime, reed and timber replace traditional petroleum-based materials. The hemplime sequestering over 21,000kg of CO_2 and cutting embodied carbon by 50% compared to conventional builds. Featuring sustainable alternatives like recycled glass aggregate insulation, vapor-open assemblies, and locally sourced materials, the house integrates seamlessly with its Cape-style surroundings while pioneering a high-production, spray-applied European hempcrete system, marking its first use in North America.

1. https://www.capecodhemphouse.com/photos







1. https://www.structuresworkshop.com/complete-works/2022/12/20/harwich-port-house

2. https://globaldesignnews.com/cape-cod-hemp-house/

Spraying - on wood frame

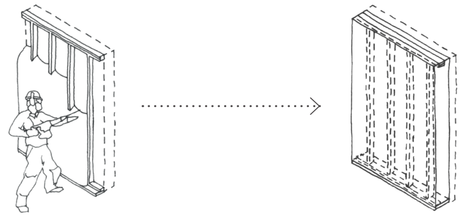
Case Study: Cape Cod

1) Timber wood structural frame goes up

2) Reed matting is secured to the timber (inner side) for captuing the spray applied mixture

5) Hemplime mix is sprayed onto the roof

...and the walls



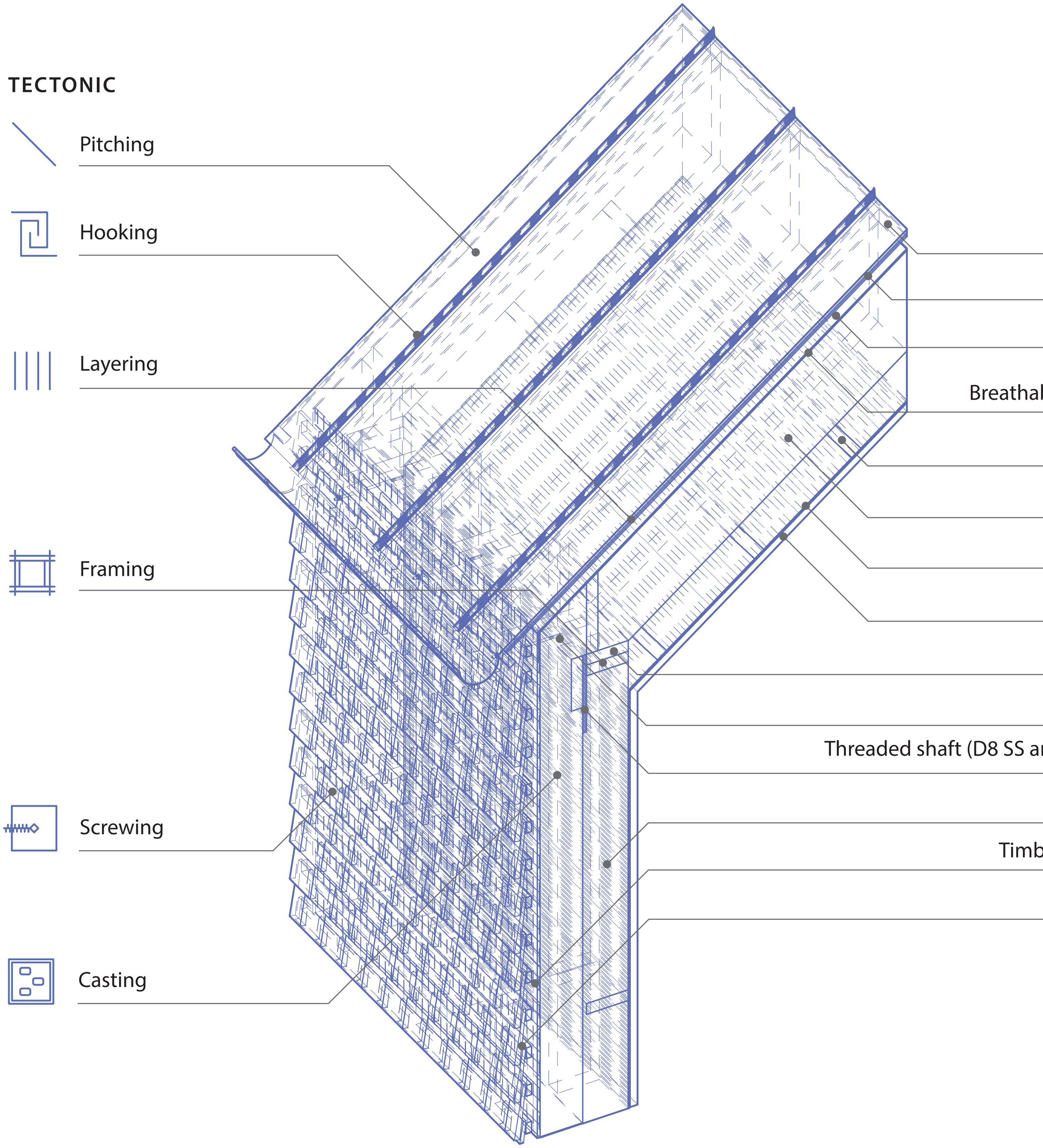
3) The hemp from Agro Chanvre (hemp producer and processer in France) arrives

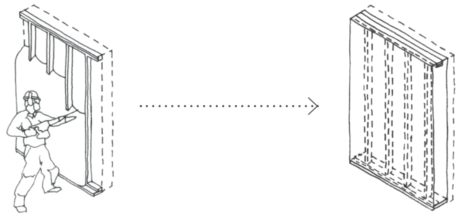
4) In the Valkyrie, a French Hempcrete Spray Machine, hemp shivs are mixed with lime and water

6) After drying, plaster is spray-applied to walls, using the JLG boom lift

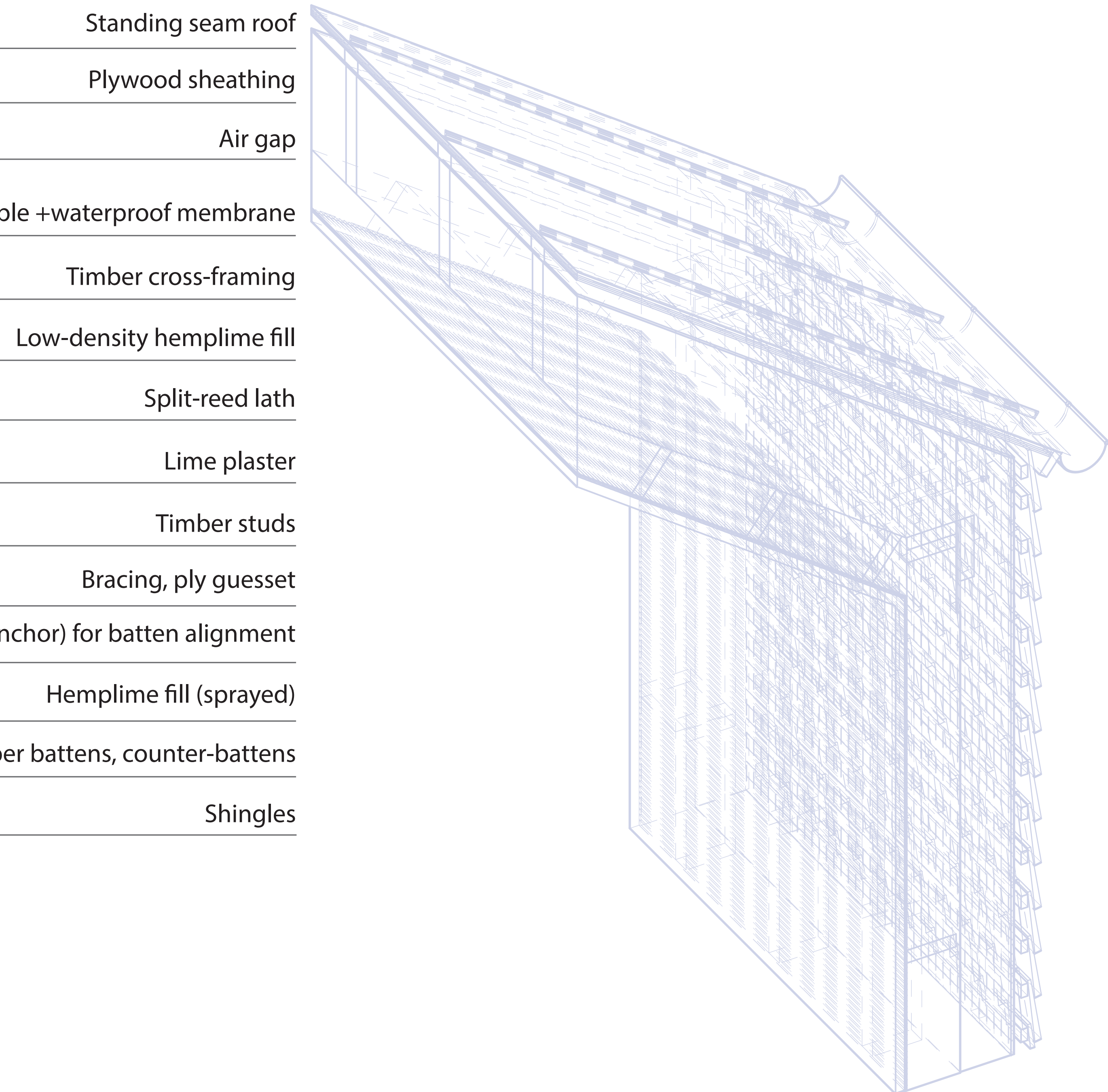
7) Square timber spacers are added in intervals to get the alignmnet right and then wooden vertical and horizontal battens are screwed on, ready for shingles to be nailed on.

Tectonic Analysis

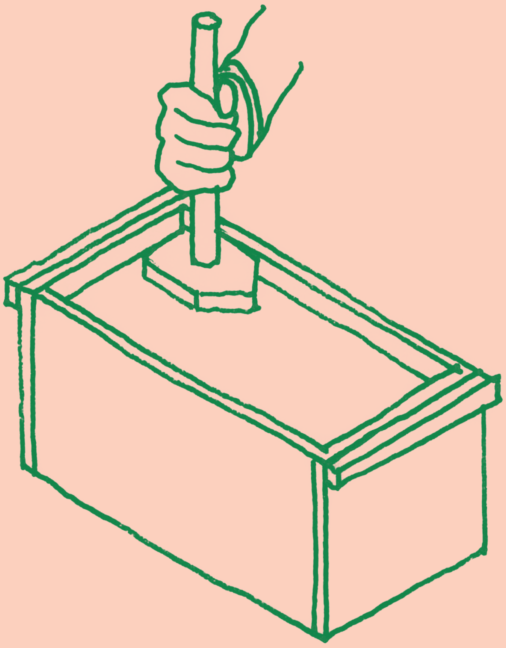




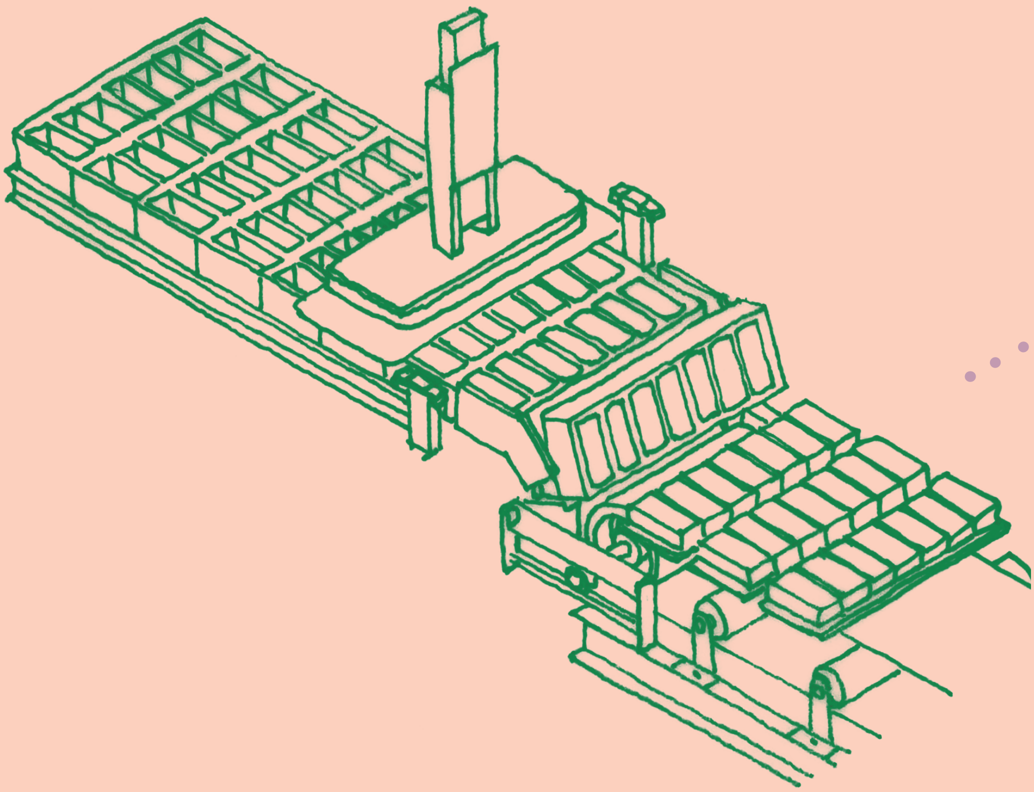
TECHNOLOGY



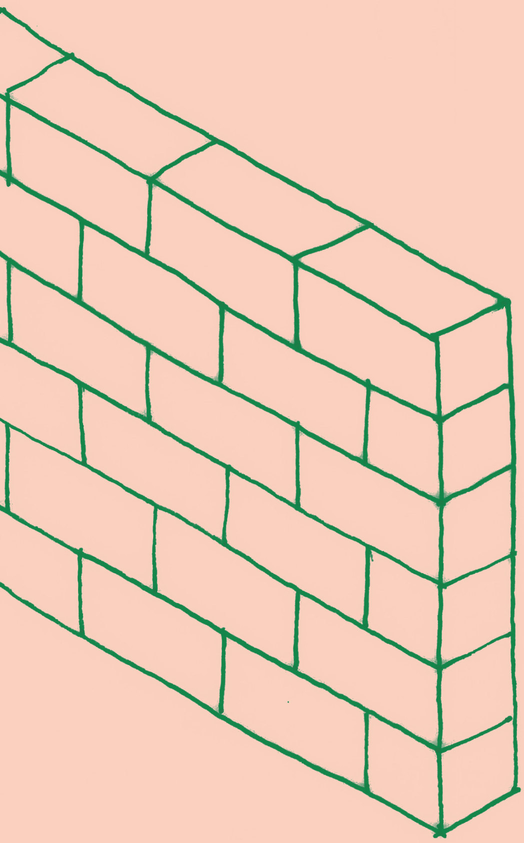
Detail information shared by Adam Titrington via email correspondence on February 3, 2025



BLOCK FORMING (BY HAND)



BLOCK FORMING (MACHINE)



TECHNIQUE: PRESSING

Pressing - block forming

Case Study: Woonhuis Balk

Construction: Completed in 2020

Gross internal foor area: Unknown

Construction cost: Undisclosed

Architect: TWA Architecten

Clients: G. Hiemstra and J. van Beek

Structural engineer: Undisclosed

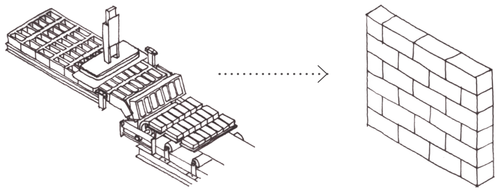
Hemp manufacturer: IsoHemp

Contractor: Agricola Bouw

Energy consultants: Plushuis

Annual CO2 emissions: ?

Woonhuis is in Balk, the Netherlands and was completed in 2020 by TWA Architecten. This energy-neutral home, built to passive house standards, incorporates bio-based materials like hemp and wood for sustainable construction. IsoHemp hemplime blocks, known for their insulating and moisture-regulating properties, were used on the exterior side of a post-and-beam structure. Heating is powered by an aqua-thermal system that draws energy from nearby water, while the interior features IsoHemp's natural PCS plaster. The house is located on the historic site of the former 'De Volharding' factory in Balk, beside the De Luts waterway.



1. *https://www.twa-architecten.nl/projecten/woonhuis-balk/*

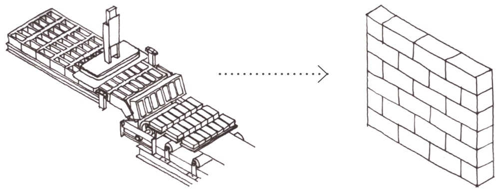
2. *https://www.isohemp.com/en/references/new-construction-single-family-home-frise*

Pressing - block forming

Case Study: Woonhuis Balk

The Isohemp blocks (from Belgium) were pre-fabricated using Quadra's machinery (from France), where a concrete batching plant, vibrating press, and handling equipment have been specifically designed to be able to produce with recipes based on bio-sourced materials. The manufacturing process begins with mixing hemp hurds, lime, and water into a uniform mixture, which is then molded into blocks using a specialised press with a patented vibration system for compaction. The blocks are air-dried naturally without baking, requiring 6 to 10 weeks to cure fully. Once cured, they are palettized and shipped for use in construction.

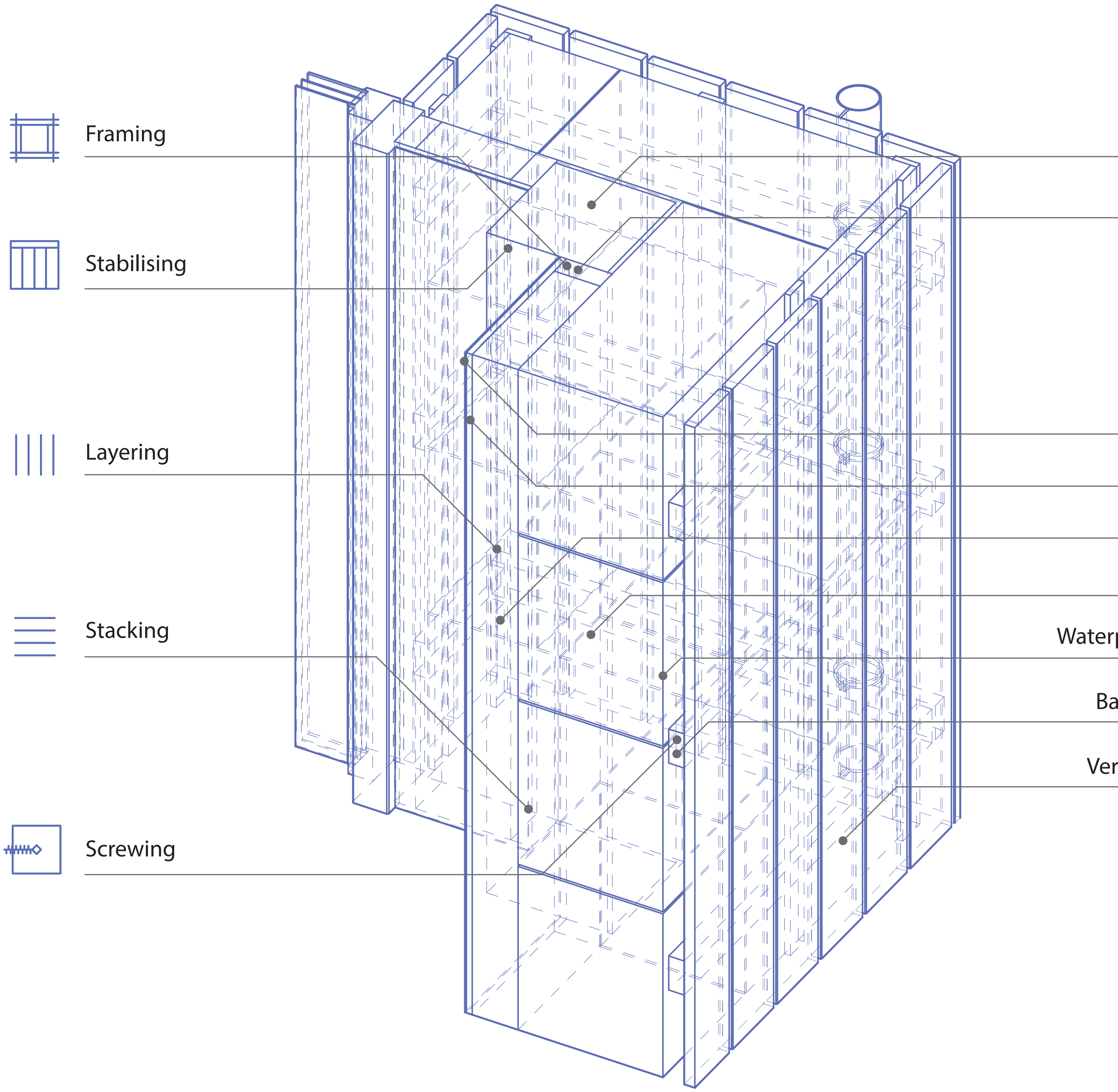
Building with IsoHemp blocks starts with preparing a dry, level foundation, protected with sealing tape to prevent capillary rise. The first row of blocks is laid on a mortar bed, ensuring perfect alignment and leveling. Subsequent courses are bonded using IsoHemp adhesive mortar, applied with a notched trowel for slim joints, and adjusted as necessary. The final course is cut to fit beneath ceilings, leaving minimal gaps filled with flexible insulation or bonding foam. Finishing options include breathable renders or interior coatings that preserve the blocks' vapor permeability.

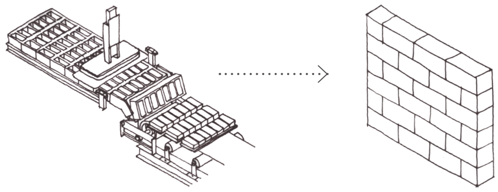


https://www.isohemp.com/en/references/new-construction-single-family-home-frise

Tectonic Analysis

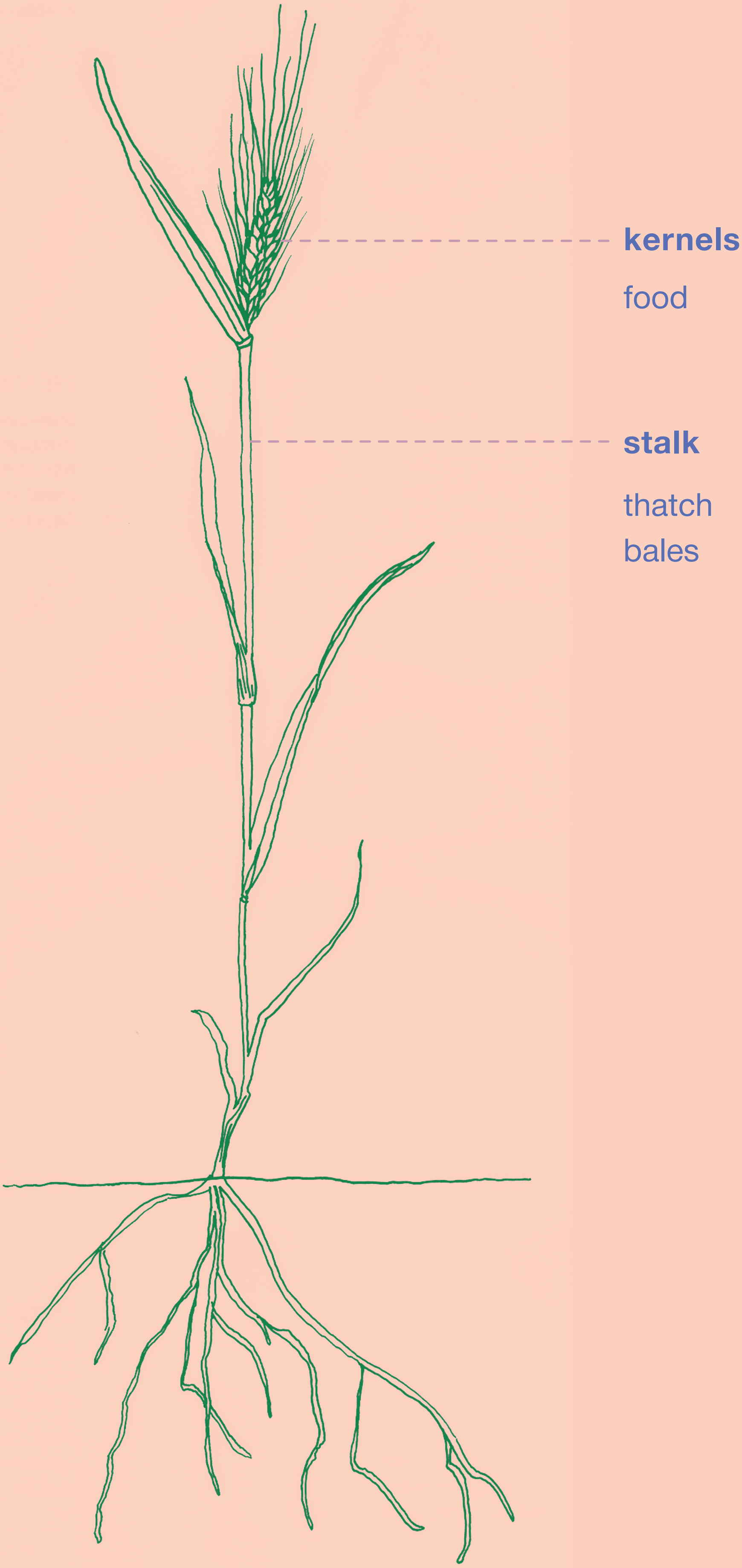
TECTONIC





TECHNOLOGY

Thanks to detail information shared by Alex van der Meulen (TWA Architecten)
via email correspondence on January 30, 2025


kernels
food
stalk
thatch
bales

STRAW

Straw is a natural fibre by-product of cereal crops such as wheat, barley, oats, and rice, consisting of the dried stalks remaining after grain harvesting. It is composed mainly of cellulose, hemicellulose, and lignin, and can be processed into construction materials. Straw has been used in building for thousands of years across Europe, Asia, and the Americas.[1] As an agricultural residue from annually grown crops, harvested between 4-8 months, straw is abundantly available each season, making it a renewable and low-impact material.

The construction applications of straw vary depending on the cereal source. Wheat and barley straw are most commonly used for **straw bale construction** due to their longer, more uniform fibres, which compress well into dense, load-bearing or insulating bales. Rice straw, being finer and more brittle, is better suited to **compressed panels or chopped insulation** in climates where it is more readily available.[2] Straw is also widely used for **thatching**, especially in regions of Northern and Western Europe. In the UK, combed wheat reed (a type of wheat straw prepared by removing leaves and nodes) and water reed (*Phragmites australis*, technically not a cereal straw) are commonly used for more long-lasting thatch roofs. Rye straw (*Secale cereale*) is also used in some regions for its water-shedding characteristics and durability in harsh climates.[3] When finished with lime or earth plasters, straw bale walls can be highly fire-resistant, moisture-regulating, and extra durable.[4] Depending on the type of straw and finishing, properties and appearance can vary, but all contribute to a highly energy-efficient building design.

Common Name	Straw
Source Plants	Wheat, barley, oats, rice, rye, and other cereals
Latin Name	*Triticum aestivum* (wheat), *Hordeum vulgare* (barley), *Avena sativa* (oats), *Oryza sativa* (rice), etc.
Age at Harvest	90 - 120 days*
Height at Harvest	0.5 – 1.5 metres (varies by cereal crop)
Soil Preferance	Well-drained, loamy soil
PH	6.0 - 7.5 pH
Climatic Conditions	Grows in temperate to continental climates
Appearance	Golden-yellow, tubular stalks with a hollow structure
Method of Regeneration	By seeds (annual plant)
Supported Biodiversity	Can be used in permaculture and regenerative agriculture to support habitats when used as mulch
Fungal Networks	Can host decomposer fungi when left in soil or used as mulch, aiding organic matter cycling.

* depending on variety and growing conditions

1. Minke, G., 2009. Building with Earth: Design and Technology of a Sustainable Architecture. Birkhäuser.

2. Chiras, D.D., 2000. The Natural House: A Complete Guide to Healthy, Energy-Efficient, Environmental Homes. Chelsea Green Publishing.

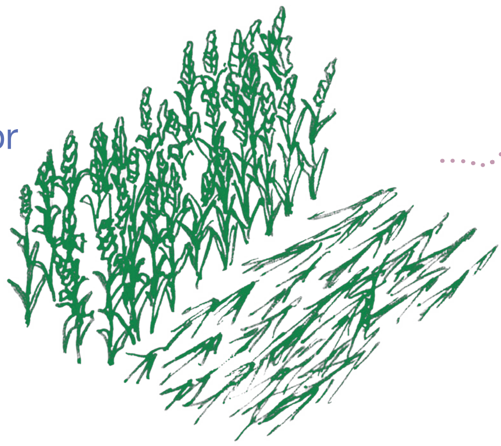
3. Veerman, C., 1997. Rieten Daken in Nederland: Geschiedenis en Techniek van het Rieten Dak. Stichting Bouwresearch.

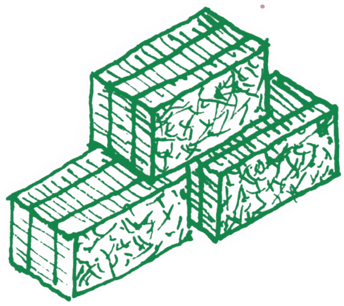
4. Jones, B., 2002. Designing with Straw Bales. Green Building Press.

straw harvesting + construc

HARVESTING

After grain seeds are removed, straw is left as a remnant. Mechanical balers compress and strap them into bales for transport.





BALING

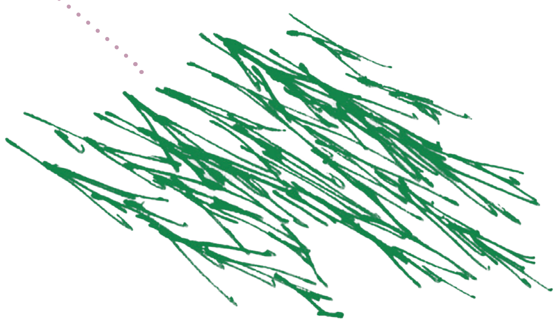
Range of sizes from t
string rectangles ~22
round bales weighing
a ton.

GROWING

Straw is an agricultural by-product from cereal crops like wheat, rice, oats, barley, and rye. Typically harvested between 4-8 months.

PLANTING

The industrial farming of wheat and other cereal grains often involves the use of fertilisers, herbicides, and pesticides.



MULCH

Straw can be ground into mulch and used for biofuel, for landscaping or put back to soil to biodegrade.

DISA

Straw
or pre
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reuse

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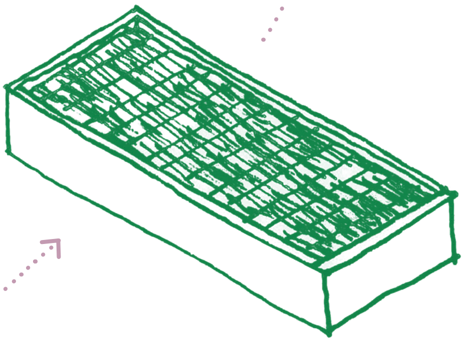
lifecycle

two-
kg to
g over

MANUFACTURING

Porefabricated units can be made from straw packed into wood casettes.

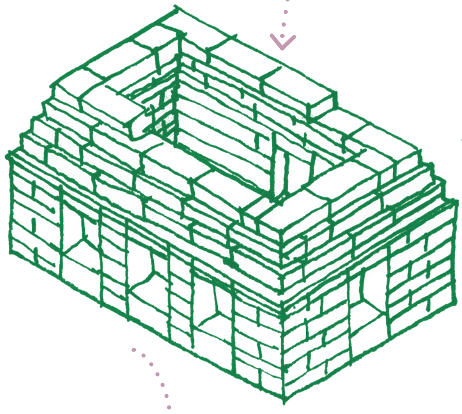


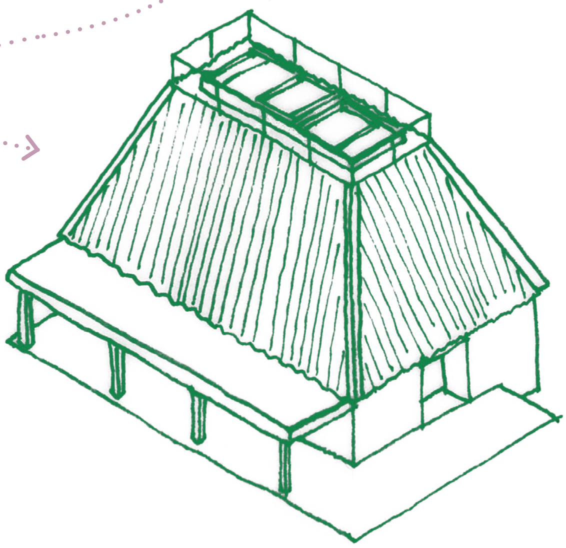
PLASTER PRODUCTION

Clay, lime and/or cement are often used as a finish to protect from water and moisture.

ASSEMBLY

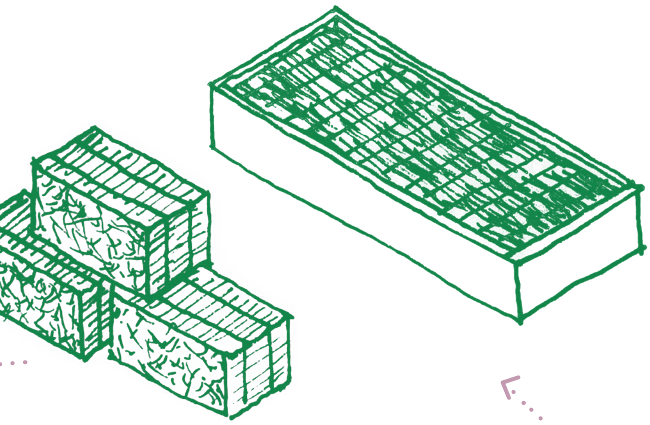
Bales are stacked to create load-bearing structure or elements are integrated with structure.





IN-USE

The excellent thermal values and hygroscopic properties of straw support healthier indoor environments.

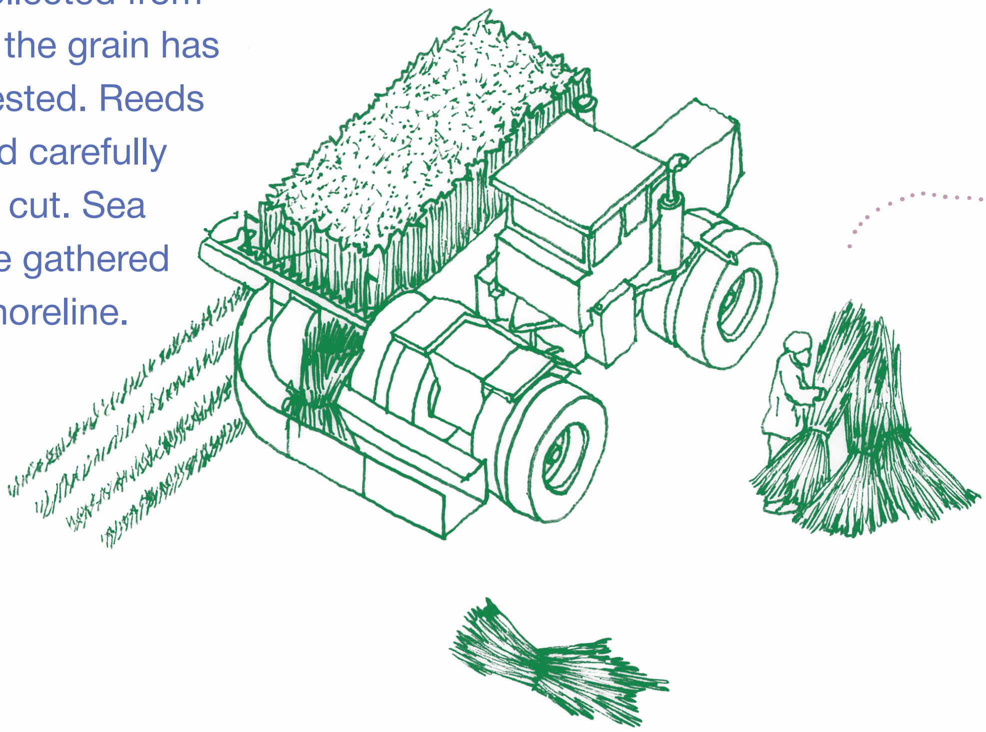


SSEMBLY

/ walls can decompose,
efab elements can
sily taken apart and
d.

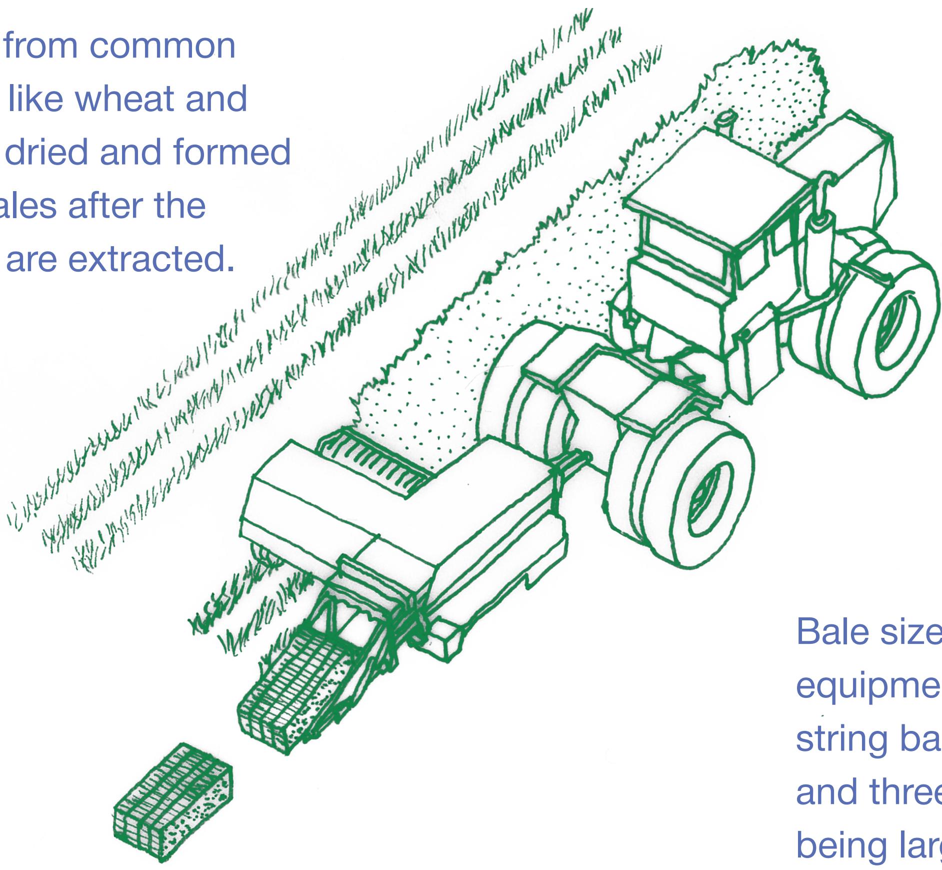
HARVESTING BUNDLES

Straw is collected from fields after the grain has been harvested. Reeds are bundled carefully after being cut. Sea grasses are gathered from the shoreline.



HARVESTING BALES

Straw from common grains like wheat and rice is dried and formed into bales after the seeds are extracted.



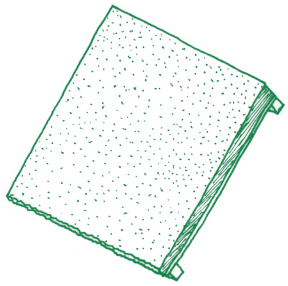
Bale sizes depend on the equipment used, with two-string bales being smaller and three-string bales being larger.

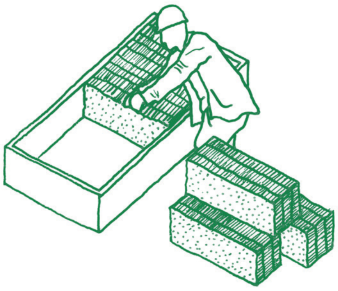
ction

techniques

THATCHING

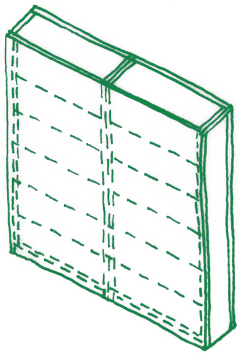
overlapping bundles





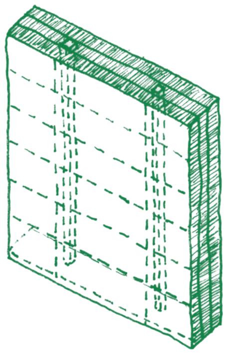
PACKING

prefabricated panels



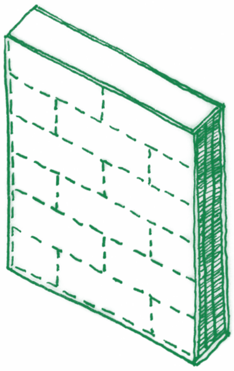
STACKING

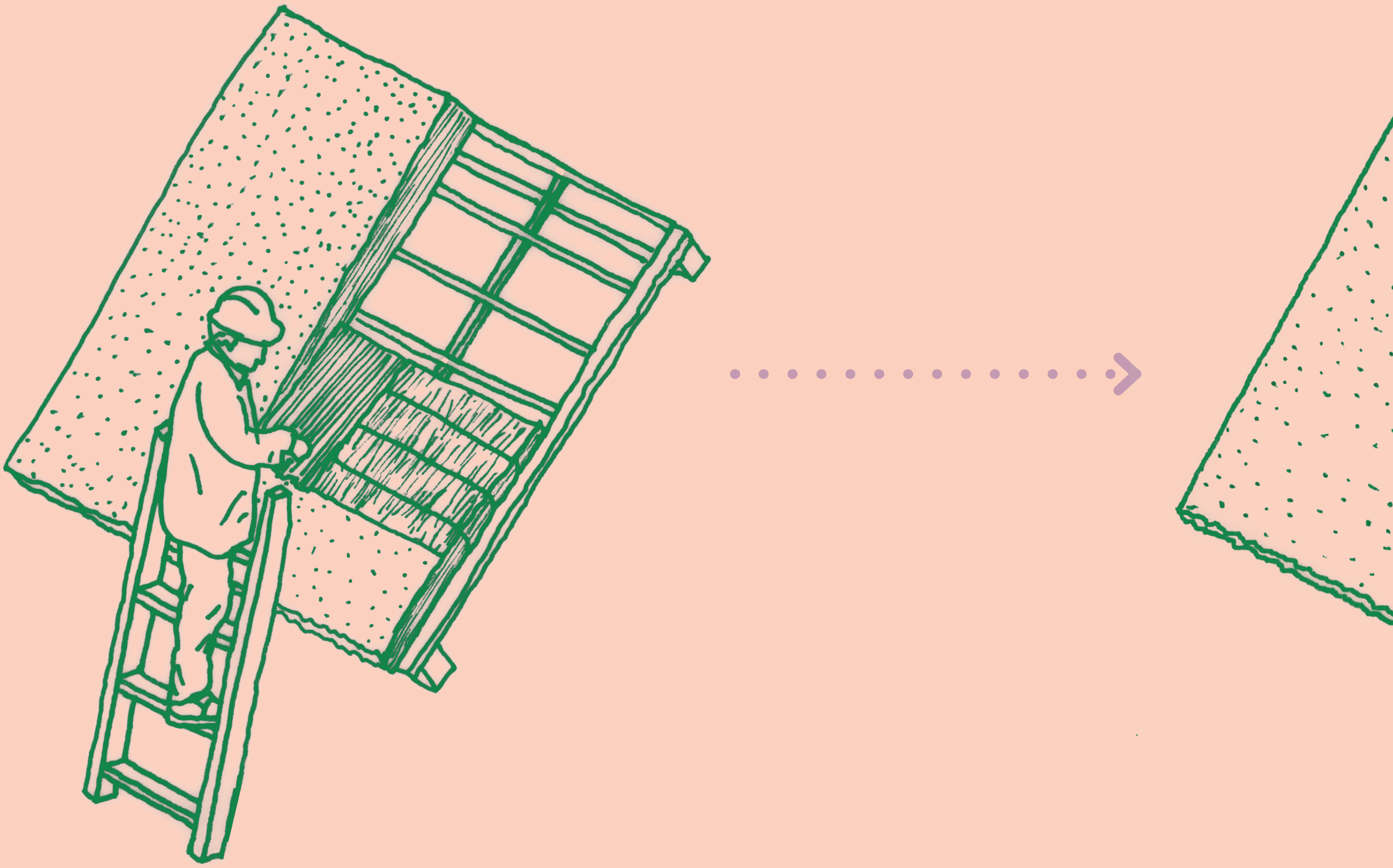
bales around/within wood framing



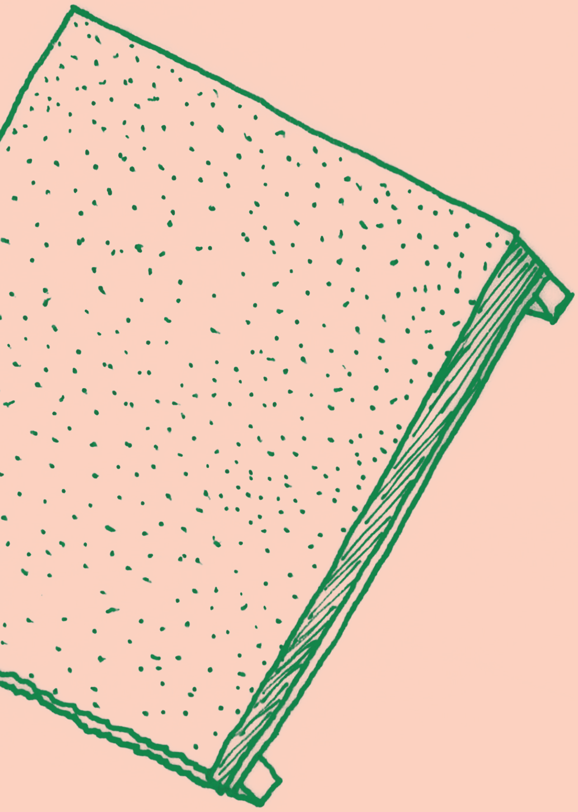
STACKING

load-bearing bales





OVERLAPPING BUNDLES



TECHNIQUE: THATCHING

Thatching

Case Study: Dune House

Location: Pape, Latvia

Construction: Completed in 2016

Gross internal foor area: 175m^2

Construction cost: Undisclosed

Architect: ARCHISPEKTRAS

Client: Private

Structural engineer: Undisclosed

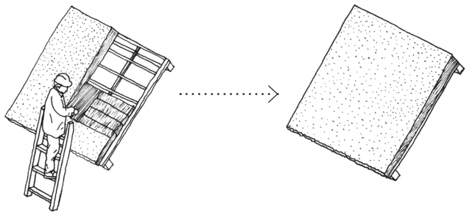
Manufacturers: Arcwood, Damava, Durų sistemos

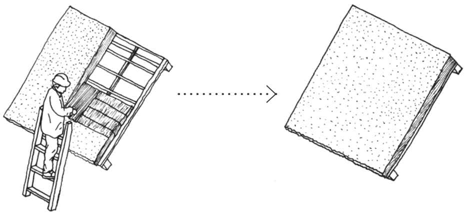
Annual CO2 emissions: ?

The Dune House by Archispektras is a compelling example of modern architecture that harmonizes with its natural surroundings. Located in Lithuania, this seaside retreat draws inspiration from traditional regional building techniques, particularly the use of thatched roofing crafted from locally sourced reeds. The design masterfully integrates contemporary minimalism with the organic textures of the surrounding dune landscape, creating a home that is innovative while remaining deeply rooted in local culture.

Rather than appearing as a distinct roof placed atop the house, the thatch forms a unified structural skin, wrapping seamlessly from roof to wall along the building's laminated wood framework. The structural design is centered around 16 glulam ribs, each uniquely shaped to accommodate the house's dynamic, tapering geometry while maintaining a uniform height of seven meters. These ribs anchor the laminated wood structural skin, which both defines and supports the roof and walls. The thatch, applied in a 300 mm layer, further accentuates the form, extending beyond the interior volume over the carport and floating above portions of the house, revealing wood framing, glazing, or open-air slots. Internally, pine boards line the walls, their vertical alignment echoing the ribs to emphasise the building's height.

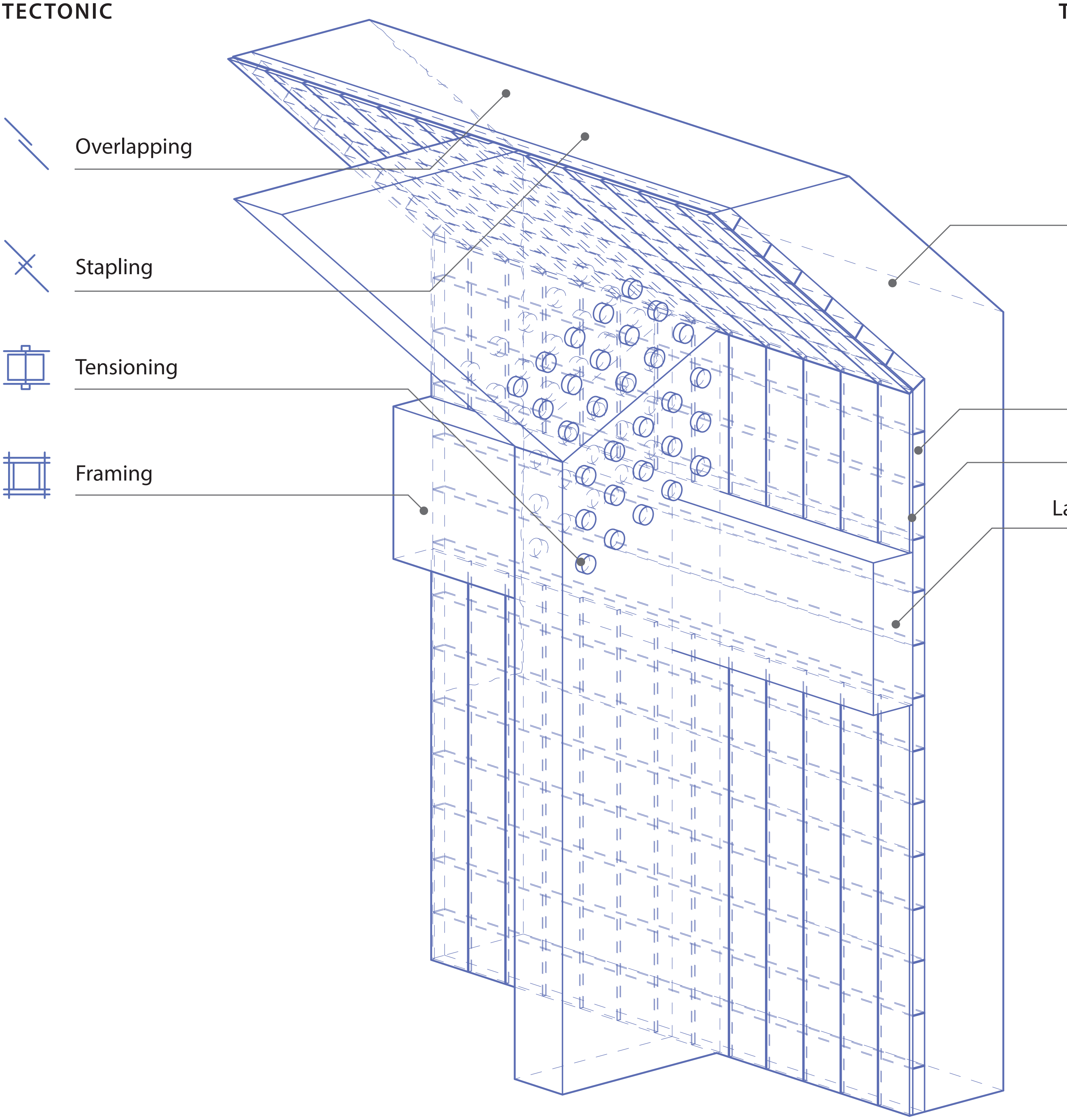
The house's geometry is as dynamic as its setting, with its width tapering consistently from one end to the other. The widest portion accommodates a carport, storage, a billiard room, and a bedroom, while the narrowest end houses intimate bedrooms. Between these extremes lies an open-plan living, dining, and kitchen area, emphasizing spatial fluidity and connection to the environment. The crispness of the geometry contrasts sharply with the textured density of the reed thatch, which blends harmoniously with the surrounding grasses and dunes. By employing local biogenic materials and techniques, the Dune House situates itself firmly within the ecology and culture of its site, offering a sophisticated reinterpretation of contextual architecture that balances sustainability, functionality, and bold design.



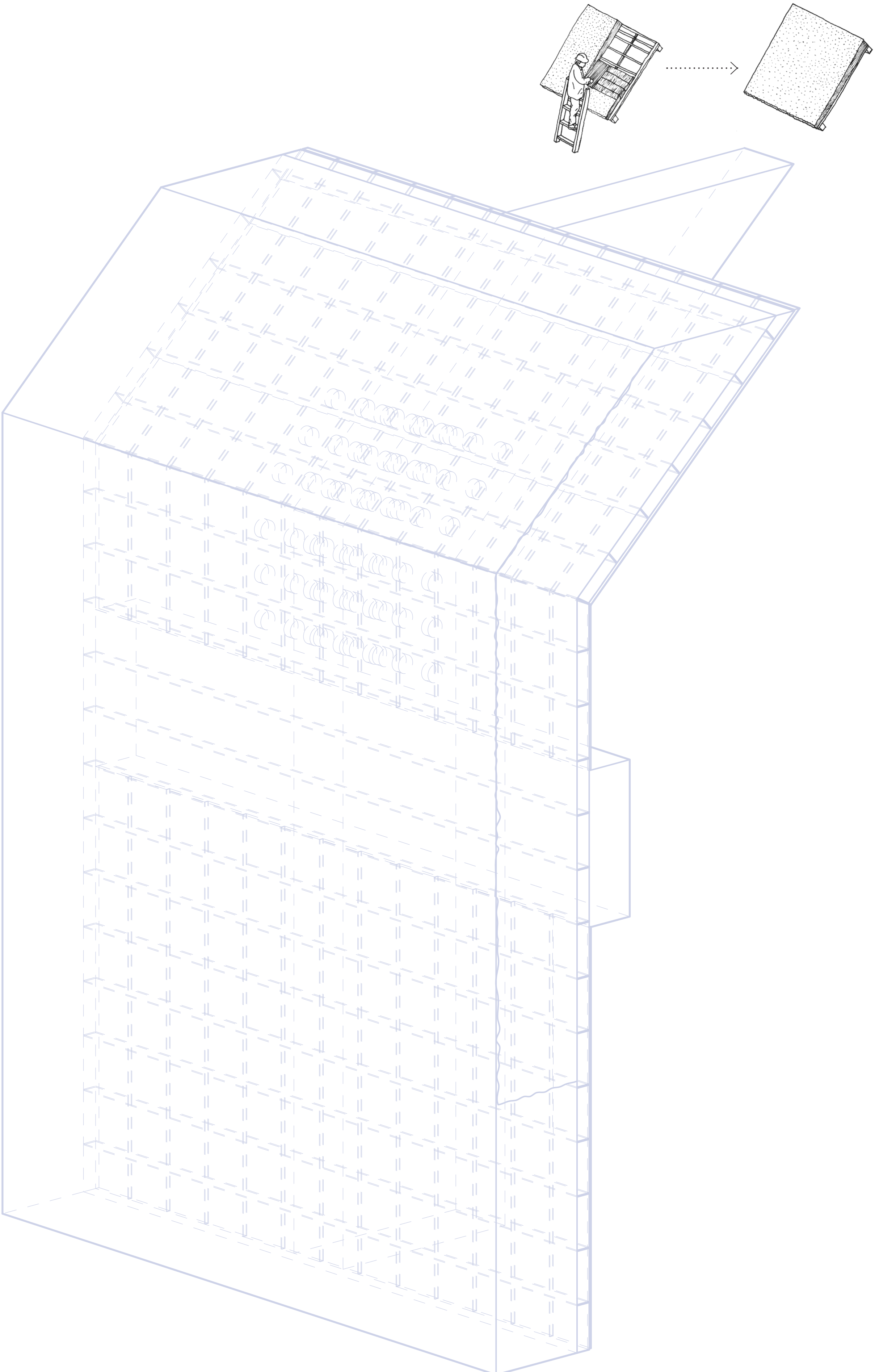


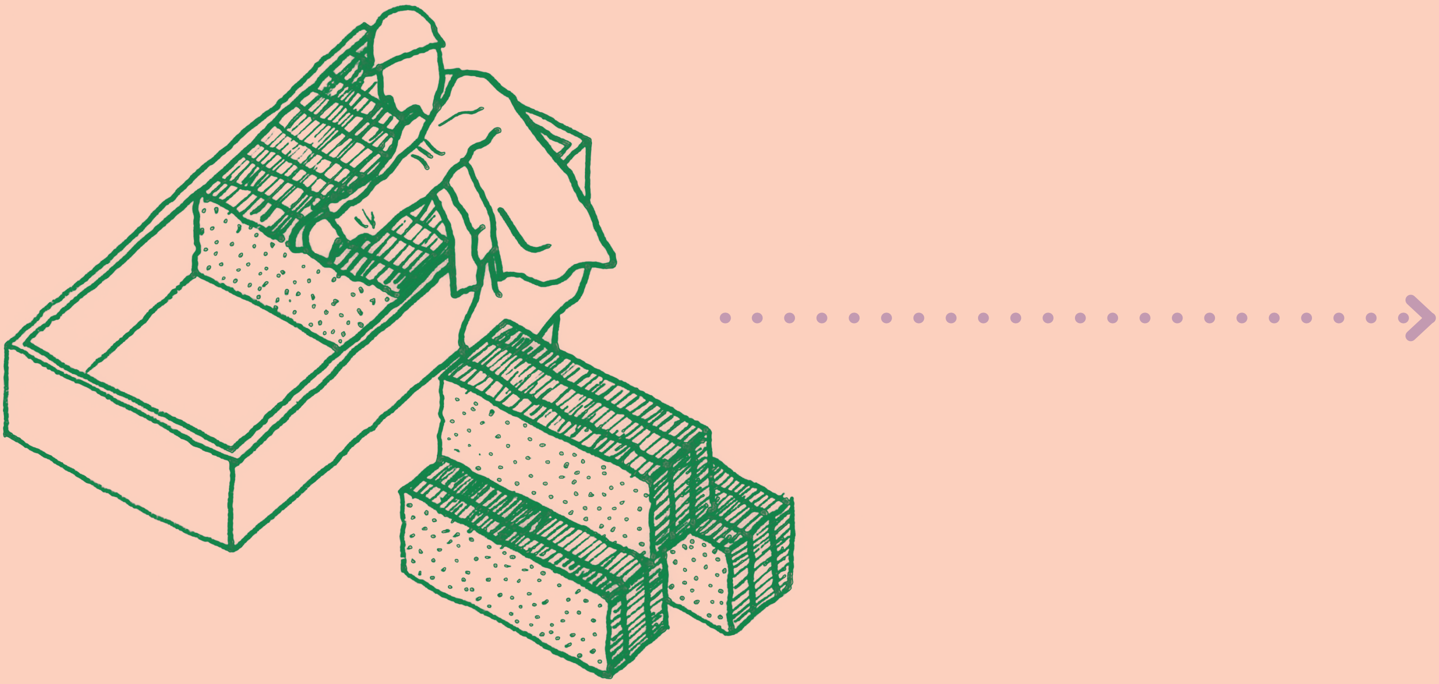
Tectonic Analysis

TECTONIC

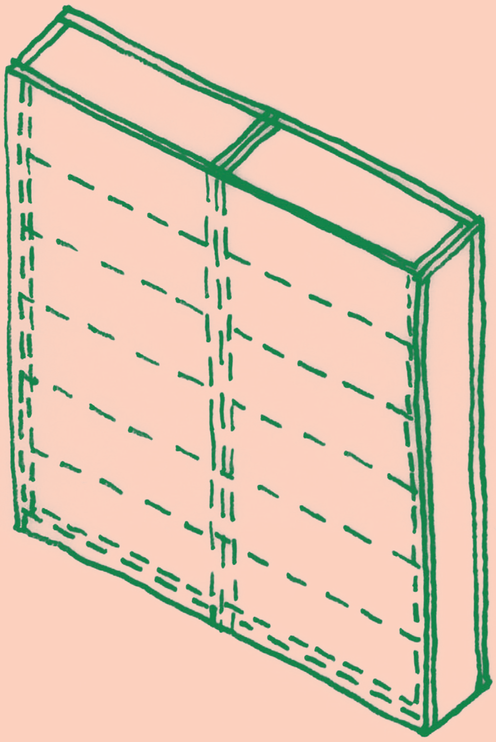


TECHNOLOGY





PREFABRICATED PANELS



TECHNIQUE: PACKING

Packing - prefabricated panels

Case Study: Straw Bale Social Housing

Location: Nogent-le-Rotrou, France

Construction: Completed in 2019

Gross internal foor area: 1,100 m²

Construction cost: 1,620,000 € / 1218.05 €/m²

Architect: NZI Archiitects

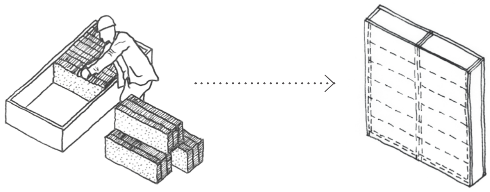
Client: Nogent Perche Habitat

Structural engineer: I + A

Manufacturers: Bacacier, Cruard Charpente

Annual CO2 emissions: ?

This social housing development, located in Nogent-le-Rotrou roughly 150 km west of Paris in France, comprises 13 individual houses constructed using large panels from regional wood and straw. The lightweight nature of the materials facilitated the prefabrication of entire wall sections in a factory setting. These panels were then easily transported and assembled on-site without the need for heavy machinery, reducing both construction time and costs. The houses are arranged in three clusters (Blocks A, B, and C), with staggered placements to avoid monotonous alignments and to create private green spaces for residents. The varying roof heights and variation of natural, charred, and white-stained wood façade finishes add visual interest. The project exemplifies how biogenic materials and prefabrication techniques can be effectively utilised in social housing, providing ecological and cost-effective solutions whilst allowing for versatile sleek design forms and finishes.



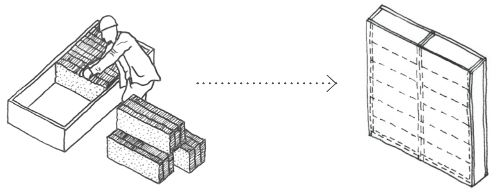
https://www.juane-sepulveda.com/gallery/album/13-maisons-en-paille-nzi-architectes

https://www.archdaily.com/918820/wood-and-straw-housing-nzi-architectes

Packing - prefabricated panels

Case Study: Straw Bale Social Housing

At a local workshop, Cruard Charpente, a company specialising in timber construction fabricated the wood spruce frame walls and filled them with bundles of 36 cm thick compressed straw. The materials were sourced locally from the region. On site, only a simple mobile crane was needed for lifting and assembling the components. The intermediate floors are constructed using traditional wood and for the roof, industrial wooden 'fermette' trusses are installed and insulated with wood wool. The pine cladding features three distinct finishes, adding variety to the design: brown autoclave-treated pine that will naturally weather to a gray tone over time, facades treated with a whitewash film-forming paint, and darker structures finished with saturated black-painted pine.

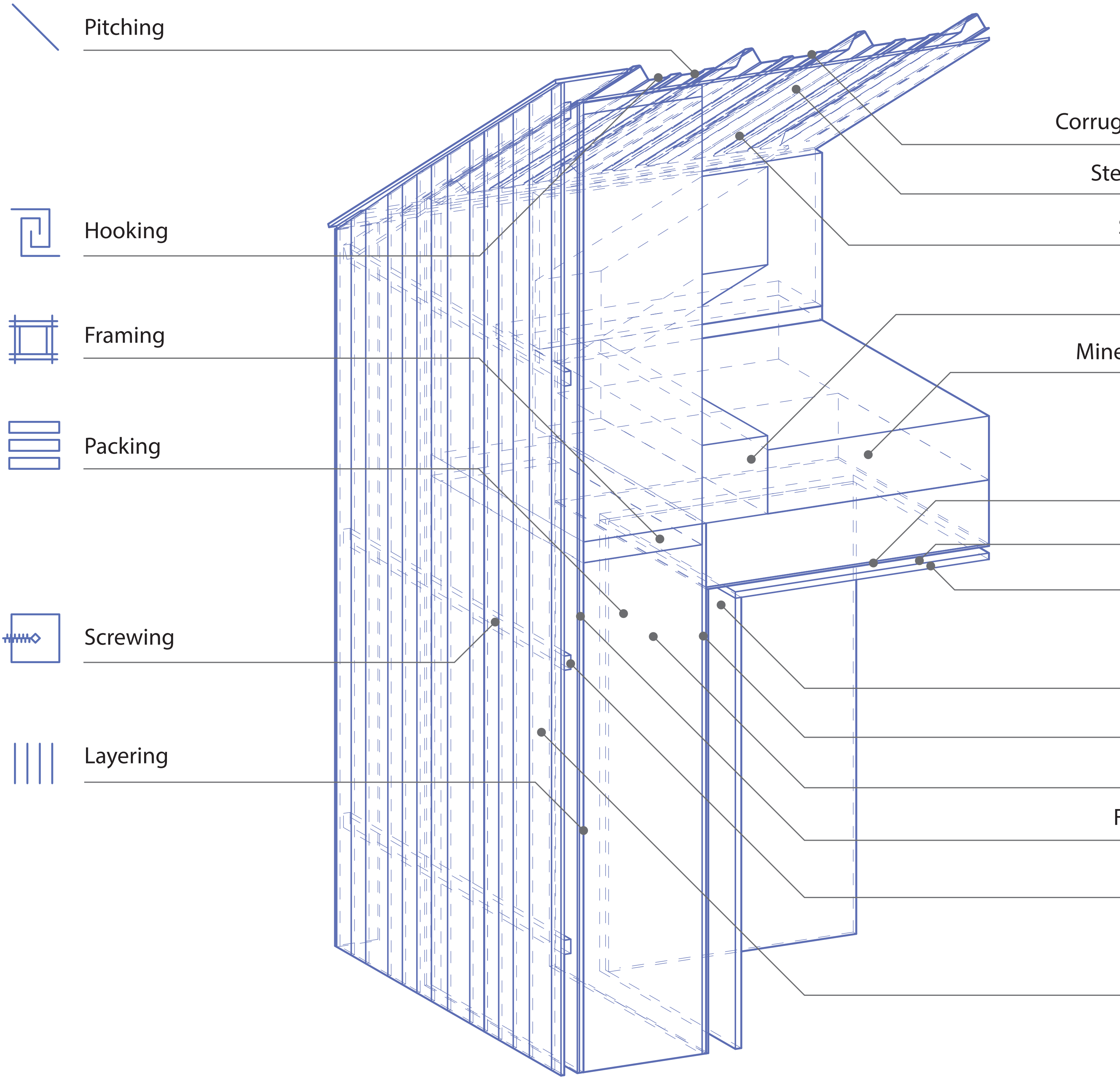


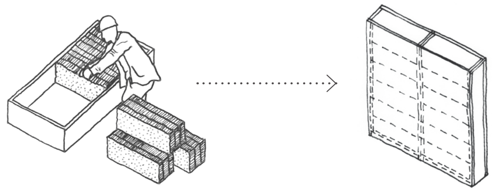
https://www.archdaily.com/794461/the-dune-house-archispektras

https://www.nzi.fr/logements-nogent

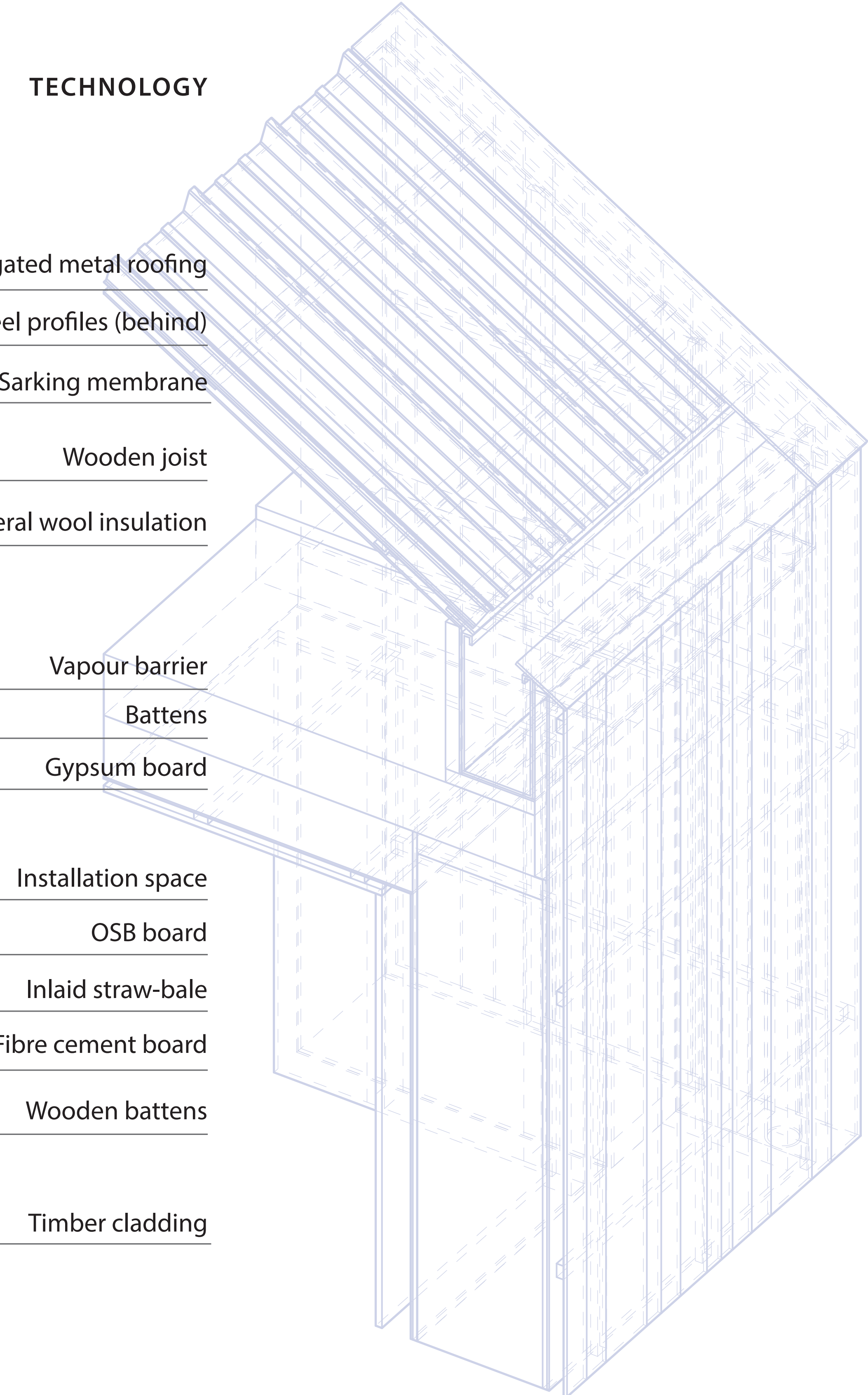
Tectonic Analysis

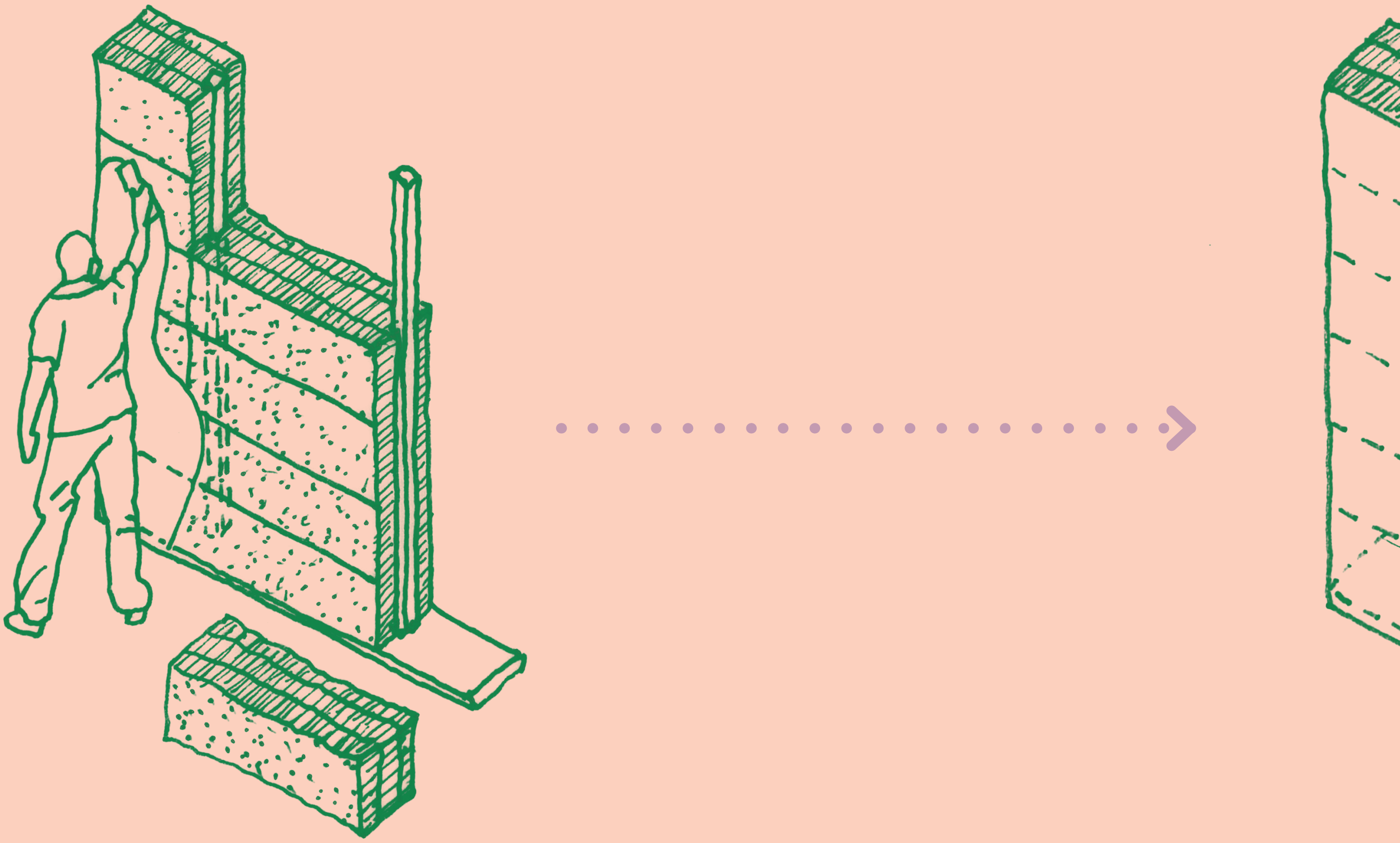
TECTONIC



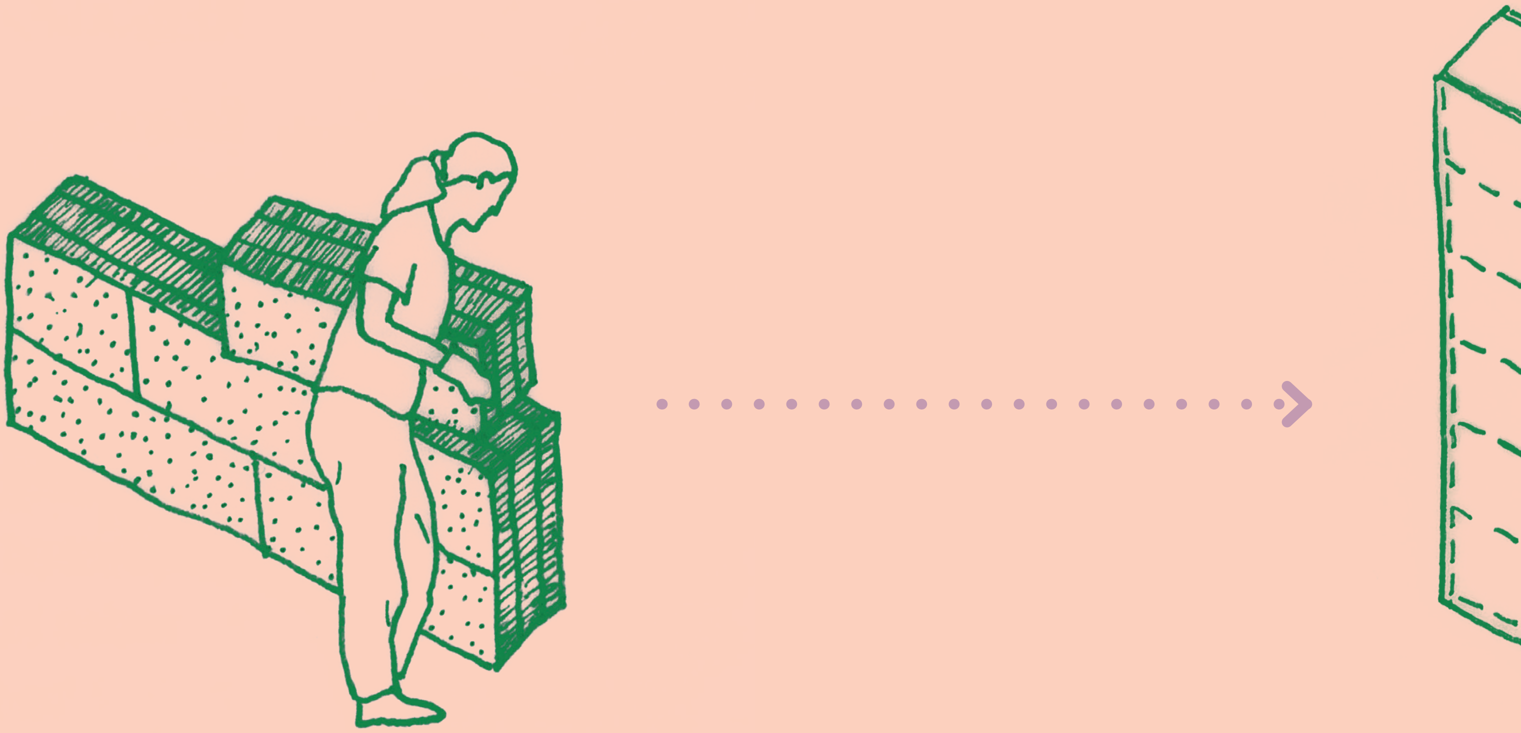


TECHNOLOGY

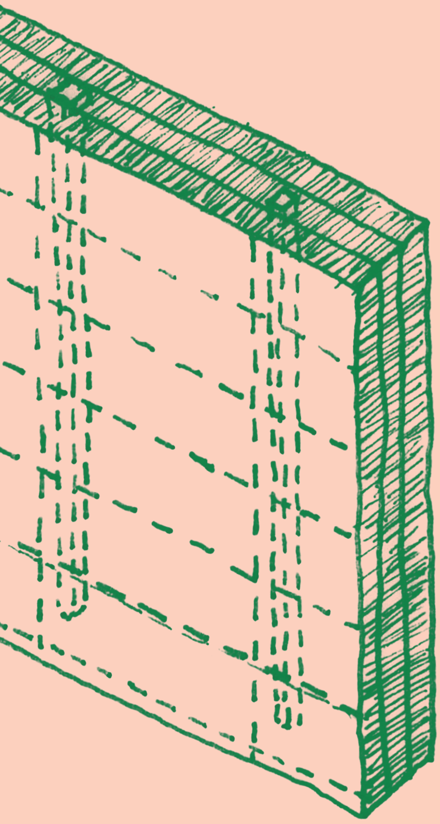

gated metal roofing
el profiles (behind)
Sarking membrane
Wooden joist
eral wool insulation
Vapour barrier
Battens
Gypsum board
Installation space
OSB board
Inlaid straw-bale
Fibre cement board
Wooden battens
Timber cladding



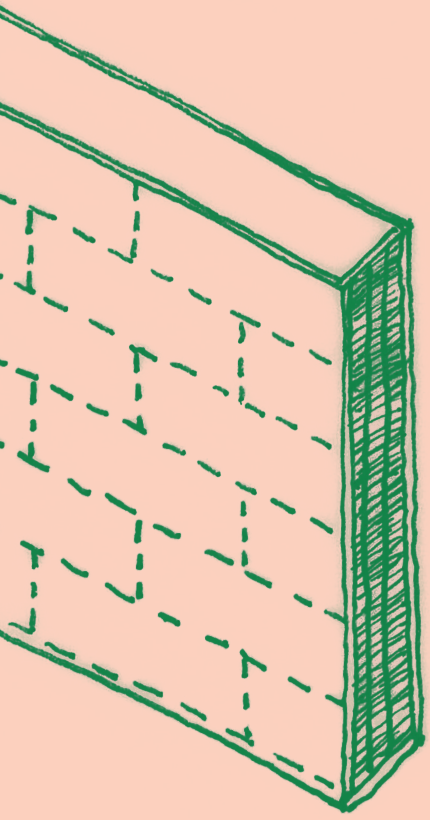
BALES IN/AROUND WOOD-FRAME



LOAD-BEARING BALES



TECHNIQUE: STACKING



Framing - Infill Walls

Case Study: Haus Hoinka

Location: Pfaffenhofen, Germany

Construction: Completed in 2023

Gross internal foor area: 521 m^2

Construction cost: Undisclosed

Architects: Atelier Kaiser Shen

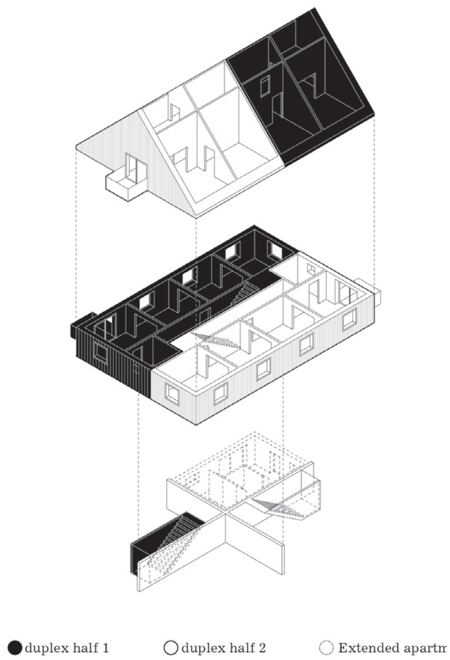
Client: Private

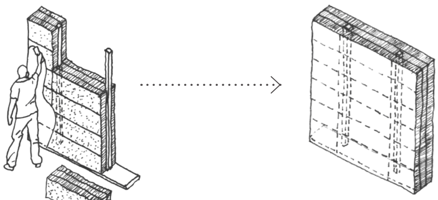
Structural engineer: F2K Ingenieure GmbH, Stuttgart

Timberwork: Heyd GmbH Zimmerei - Holzbau

Annual CO2 emissions: KfW 40 Plus Efficiency, House and the Efficiency House Plus Standard

Haus Hoinka, designed by Atelier Kaiser Shen, is a distinctive residential building located in Pfaffenhofen, Germany. Completed in 2023, this project exemplifies sustainable architecture through its innovative use of natural, renewable materials and adaptable design. The house employs straw bales combined with clay plaster as thermal insulation for its floors, ceilings, roofs, and walls. The bales are pressed between a wooden framework to a thickness of 365 mm, with any excess trimmed off with hedge cutters. To protect the straw bales in the floor slab from soil humidity and spray water, the house is elevated by an entire floor, resting on a concrete cross and four supports. The interior is lined with CLT boards and the roof is integrated with solar-tiles and a band of skylights. Care was taken to ensure that all materials used for the construction could be recycled and separated appropriately end-of-use so glued connections were avoided. All materials, and their sourcing, was recorded in a database for sustainable building products, developed by the client.



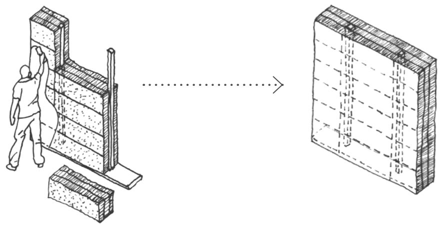


https://www.archdaily.com/998574/house-hoinka-atelier-kaiser-shen

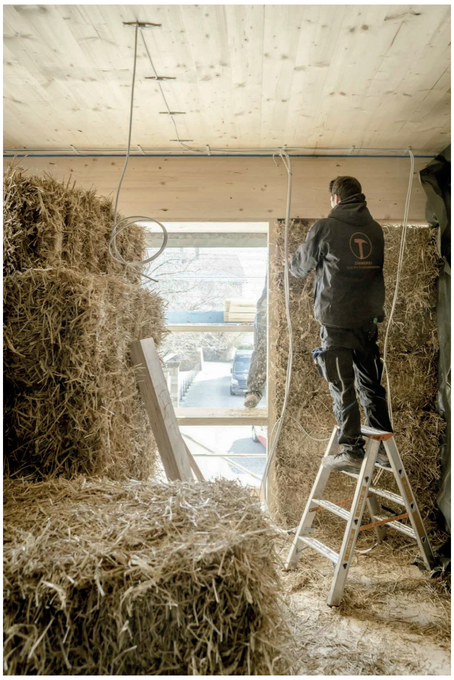
https://www.baunetzwissen.de/daemmstoffe/objekte/wohnen/haus-hoinka-in-pfaffenhofen-8469192

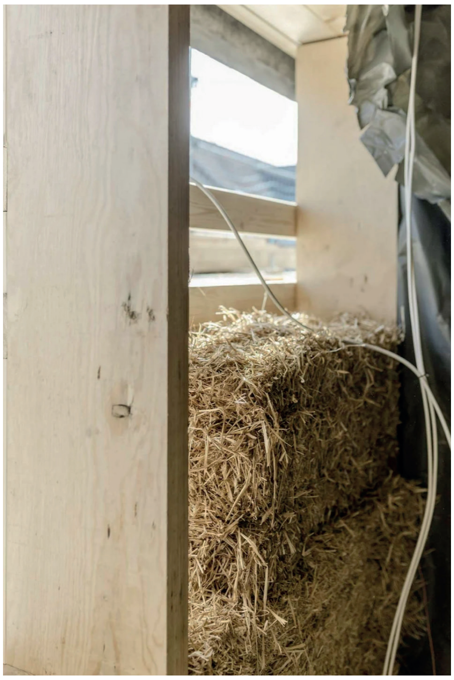
Framing - Infill Walls

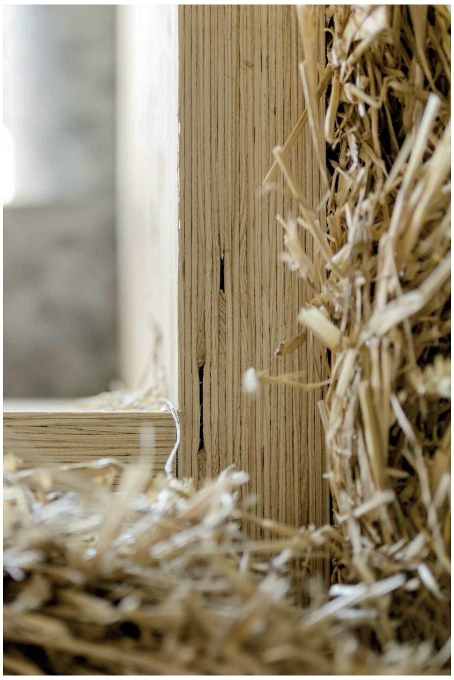
Case Study: Haus Hoinka



The straw bales were supplied by local producers. On-site they are compactly inserted into a plywood frame. Any straw extending beyond the frame was trimmed using a hedge trimmer. The interior walls were coated with a 5 cm thick layer of clay plaster, which also functions as a fire-resistant barrier, providing 90 minutes of fire protection (F 90 rating). The structure sequesters approximately 100 tons of CO_2. Compared to a conventionally insulated semi-detached house of the same size, this construction reduces CO_2 emissions by 95%.



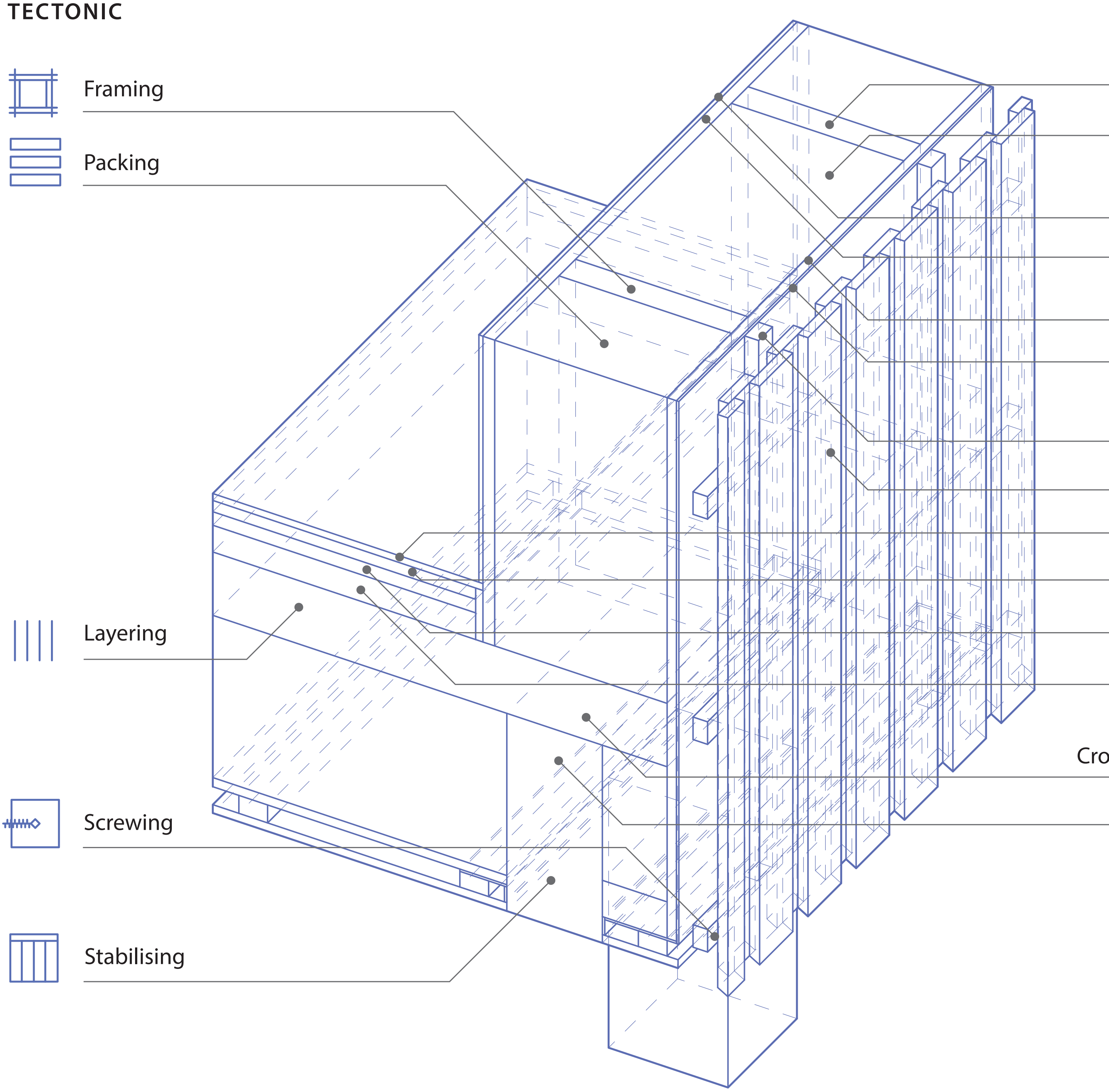


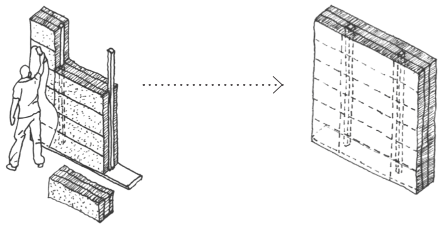


https://divisare.com/projects/476906-atelier-kaiser-shen-brigida-gonzalez-stuttgart-haus-hoinka

Tectonic Analysis

TECTONIC





TECHNOLOGY

Laminated veneer studs

Strawbale insulation

Clay plaster

Clay building board

Fibre-board

Underlayment

Battens/counter-battens

Silver fir wooden cladding

Parquet

Screed

Woodfibre board

Honeycomb fill

ss-laminated timber ceiling

Glulam beam

Thanks to detail information shared by Maya Isenberg (atelier kaiser shen) via email correspondence on January 30, 2025

Stacking - Load-Bearing

Case Study: Gartist GmbH House

Location: Bubikon, Switzerland

Construction: Completed in 2017

Gross internal foor area: 113 m^2

Construction cost: Undisclosed

Architect: Atelier Schmidt GmbH

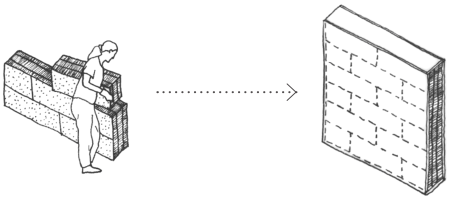
Client: Gartist GmbH

Structural engineer: ?

Manufacturers: ?

Annual CO2 emissions: ?

This innovative building serves as the office and showroom for Gartist GmbH, a landscaping company. Designed by architect Werner Schmidt, it is notable for its load-bearing straw bale construction with a cantilevered vaulted roof—the first of its kind in Switzerland. The structure is elevated on stilts to ensure proper ventilation and protection from moisture and pests, a method reminiscent of ancient pile dwellings. The walls are composed of densely compacted straw bales and the cantilevered vaulted roof is constructed by stacking the straw bales in a progressively offset manner until they meet at the apex, eliminating the need for additional support structures. The building's design ensures that heating is virtually unnecessary, though a small wood stove is installed for exceptionally cold conditions. Solar collectors provide hot water, and rainwater is harvested beneath the building to irrigate the surrounding experiential garden.



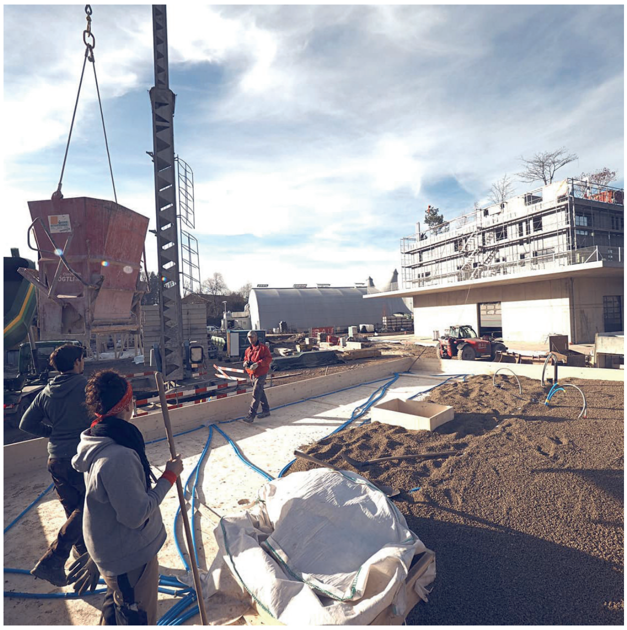
https://gartist.ch/portfolio/bubikon/neubau/

https://www.atelierschmidt.ch/gartist-bubikon

Stacking - Load-Bearing

Case Study: Gartist GmbH House

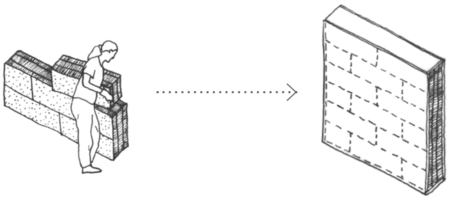
1) The building is elevated on piles, ensuring protection against ground moisture and pests. A timber base frame is installed on the piles, creating a level and stable foundation for inserting the straw bales.



2) A layer of gravel is added

5) Wooden window and door frames are pre-installed within the wall sections. The building is given stability by these wooden boxes measuring around 7-12 x 1.3 x 0.8 metres around which the bales are stacked.

6) As the stacking progresses, the bales are compressed slightly using timber plates and straps to ensure uniformity and stability. Wooden dowels or stakes may be used to interlock layers, particularly in areas requiring additional reinforcement.



3) Underfloor heating pipes are laid out on the prepared gravel ground layer with a renforcement grid to hold the pipes in place, before screed is poured.

4) The straw bales are stacked in rows to create load-bearing walls. The stacking process begins at the corners for alignment and structural stability. The walls are made of 2.50 x 1.20 x 0.75 metre straw bales weighing about 300 kilograms and very heavily compacted.

7) To create the roof the bales are staggered (offset inwards) by about 30 cm at each level, to form a 67 degree steep and 6 metre high roof. Due to the stacking the vault reaches its peak without requiring internal structural supports.

8) At the roof's apex, a skylight is installed, secured with timber framing to allow natural light to enter the building. The ridge is capped with additional layers of straw bales or a protective material for weatherproofing.

https://gartist.ch/portfolio/bubikon/neubau/

https://www.atelierschmidt.ch/gartist-bubikon

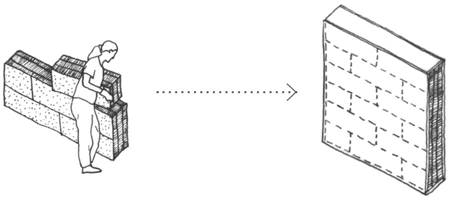
https://strawbuilding.eu/ausstellungsgebaude-gartist-gmbh/

Stacking - Load-Bearing

Case Study: Gartist GmbH House

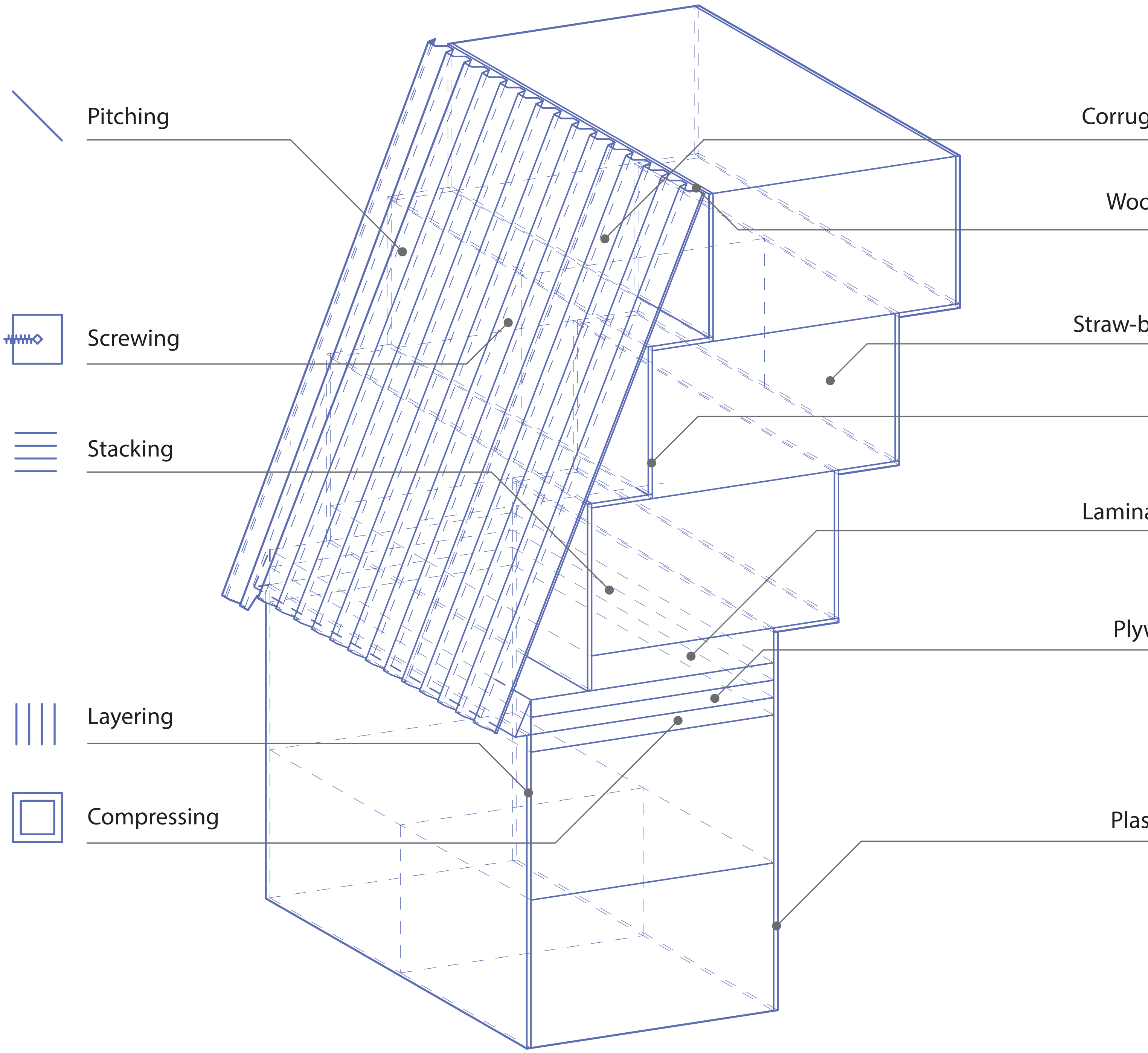
9) The straw bales are cut using a mechanical trimmer or similar tool to ensure the walls are even and free of protruding straw, creating a clean and uniform surface, before applying clay or lime plaster. It improves the adhesion and finish of the protective layer.

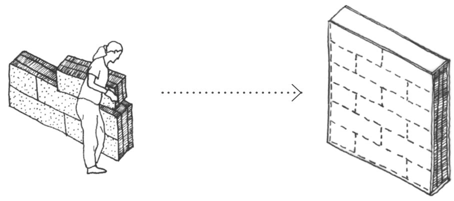
10) Once the assembly of walls and roof is complete, the exterior and interior surfaces are coated with clay and lime plaster to provide a waterproof and fire-resistant finish.



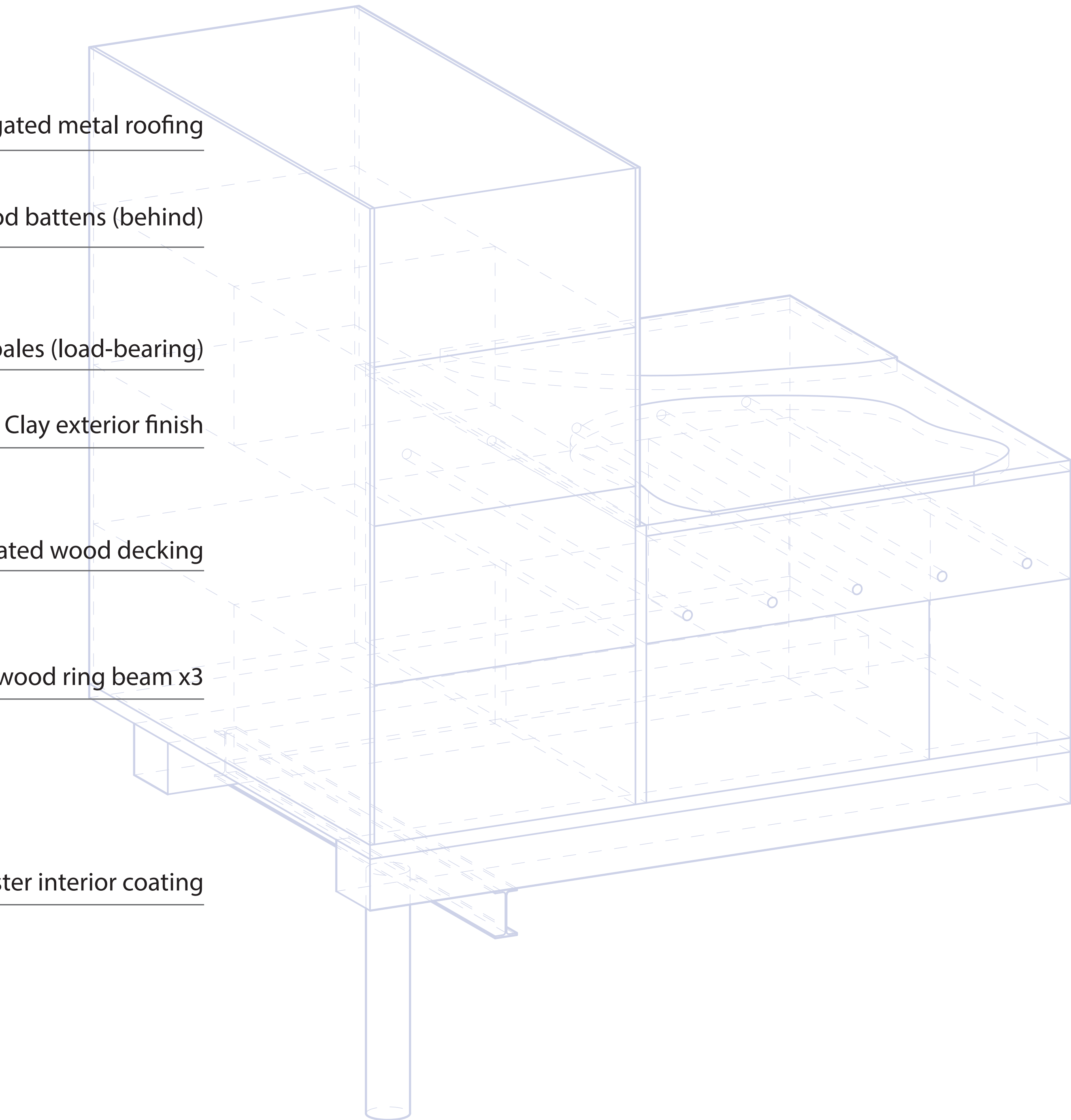
Tectonic Analysis

TECTONIC



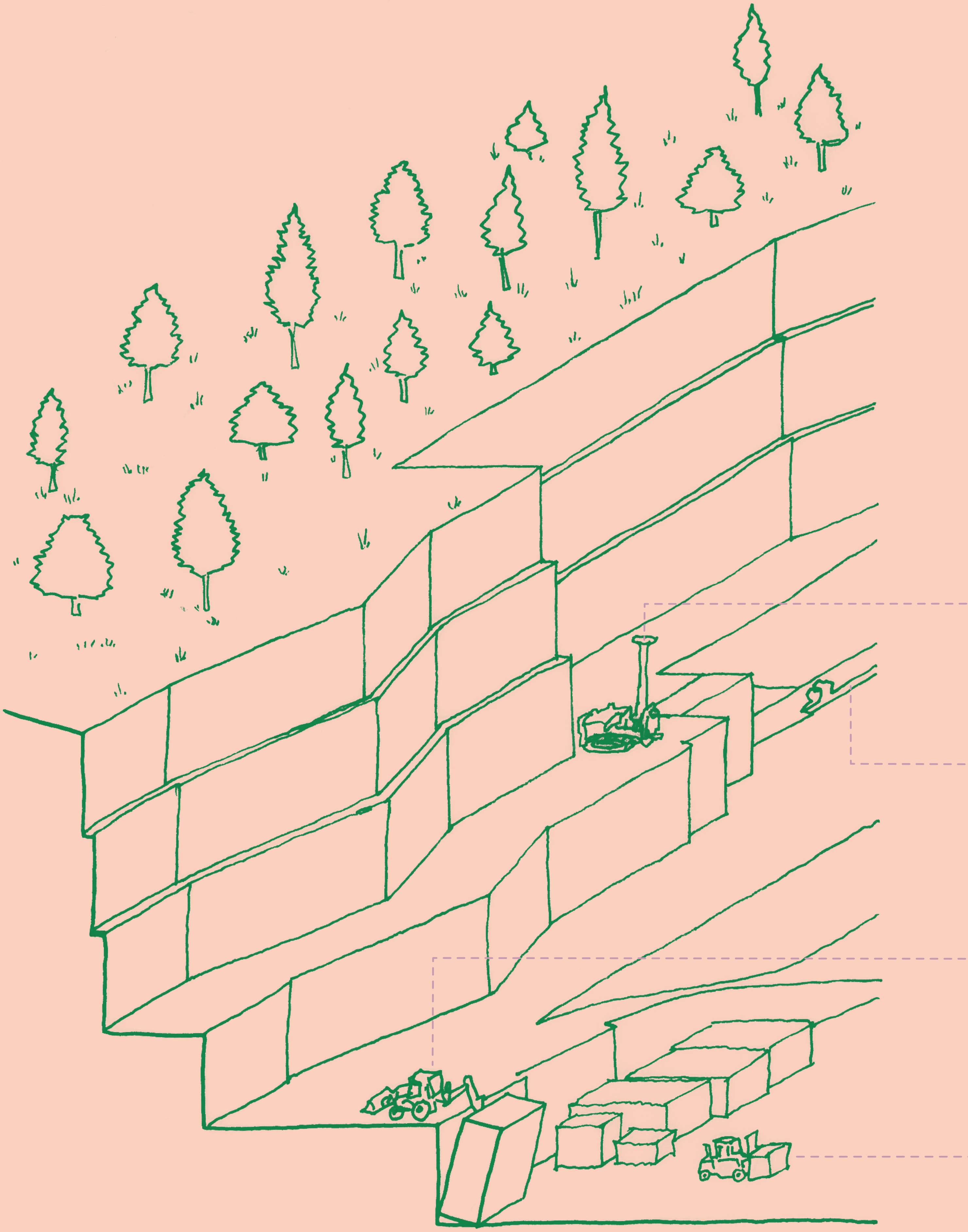


TECHNOLOGY


gated metal roofing
od battens (behind)
ales (load-bearing)
Clay exterior finish
ated wood decking
wood ring beam x3
ter interior coating

SECTION 2: GE

EO MATERIALS



CURRENT TYPICAL QUARRY OPERATIONS

Alternative to industrial quarrying, we can collect, sort and store the adundance of existing stone we have

COLLECTING EXISTING STONE

STONE

drilling rig

bore holes
for blasting

conveyor belt

transport stone,
dust, or gravel for
processing

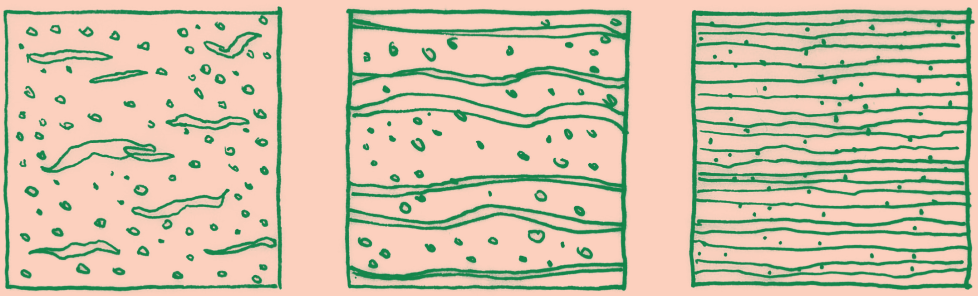
wheel loader

lift, move and
load stone
blocks

forklift truck

carries blocks for
processing

ROCK TYPES



igneous

granite
basalt

metamorphic

marble
slate

sedimentary

limestone
sandstone
travertine

Stone is a durable and abundant geological material that has shaped the built environment for millennia. Formed under natural geological processes, stone is quarried from the earth as a solid mass and used with minimal processing. Its long lifespan, strength, and resistance to fire and pests make it ideal for structural and architectural applications in both historical and contemporary contexts.

Different types of stone, including limestone, granite, sandstone, basalt, and slate, offer varied aesthetic and structural qualities. Stone can be cut, split, or shaped for load-bearing walls, paving, cladding, and even dry-stacked structures, enabling construction with no binders. While heavier and more energy-intensive to transport than biogenic materials, locally sourced stone has an extremely long service life and can be reused indefinitely.

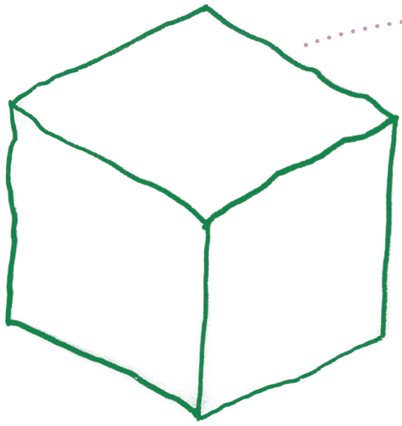
Stone's low embodied energy when locally sourced, combined with its thermal mass and minimal maintenance, positions it as a geo-material aligned with regenerative construction principles. Quarry by-products such as fines and offcuts can be reintegrated into building systems as aggregates or composite fillers.

Common Name	Stone
Geological Origin	Igneous, sedimentary, or metamorphic rock
Types	Limestone, sandstone, granite, basalt, slate
Formatin Time	Millions of years (geological processes)
Density	2,000–3,000 kg/m³ depending on type
Water absorbtion	0.1–10% depending on porosity
PH	Neutral to alkaline (esp. limestone)
Climatic Suitability	Performs in all climates; frost resistance varies
Appearance	Varies by type – from smooth white limestones to coarse granites
Processing Method	Quarried, cut, shaped, finished or used raw
Recyclability	Fully reusable; offcuts can be crushed or reused

stone processing + constru

QUARRYING

Today, common practice is to extract stone from huge open pit mines or quarries and then transport it very long distances sometimes across multiple processing points worldwide before even reaching the site. It causes vast enviornmental damage.

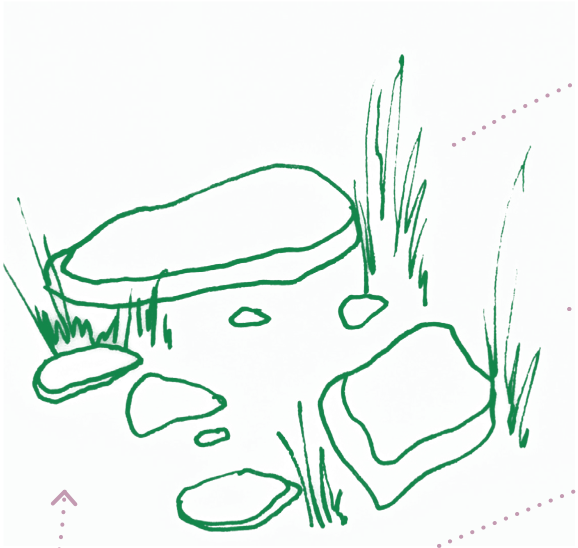


PROCESSING

It is cut into manageable sizes and shaped for specific applications such as for decorative detail features or unique textures.

COLLECTING

Stone can be gathered directly from natural landscapes or post-quarry sites without the need for industrial extraction.



CRUSHING

Stone can also be crushed and recycled as aggregate for new construction projects or left to degrade naturally over time.

DISA

Whol
reuse
stack
faster
disas

ction

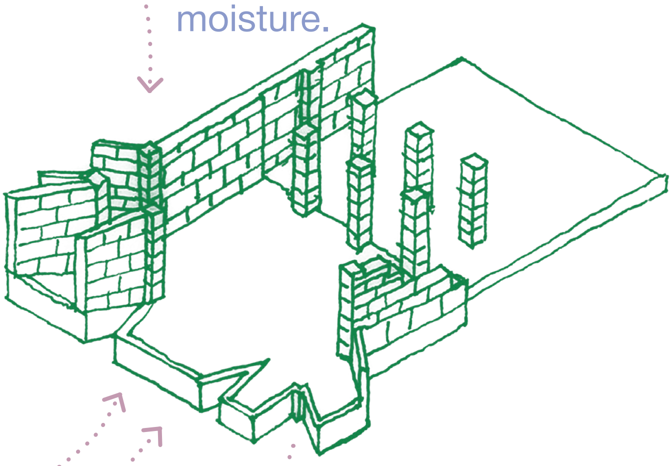
lifecycle

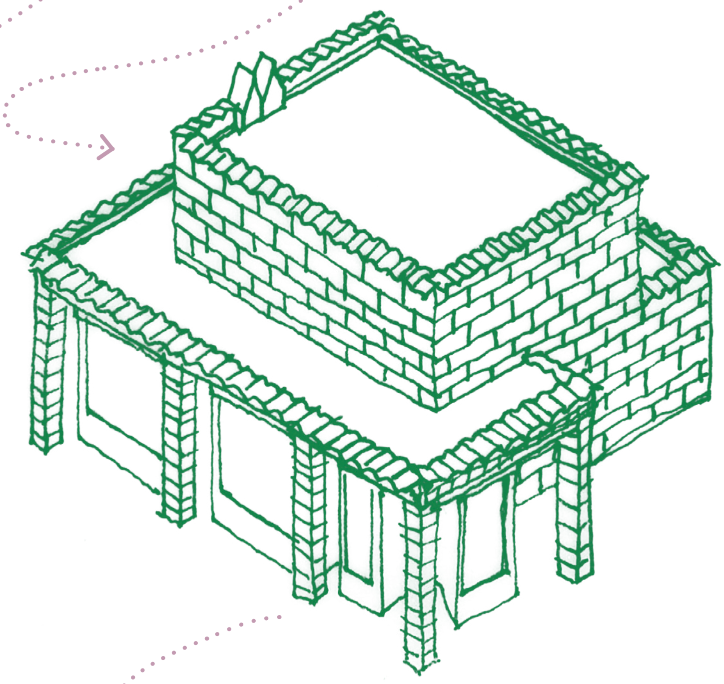
ASSEMBLY

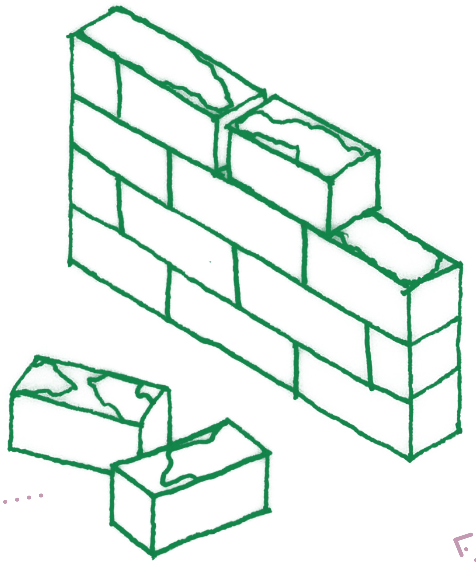
In modern construction stone is usually used as veneer for structural frameworks made of fossil-based materials such as steel or concrete. Traditional methods of load-bearing masonry can offer much better durability, reusability, with much lower emodied co2.

MORTAR

Clay, lime and/or cement are often used as a finish to protect from water and moisture.







IN-USE

A well-designed stone structure can endure for decades or even centuries with little maintenance.

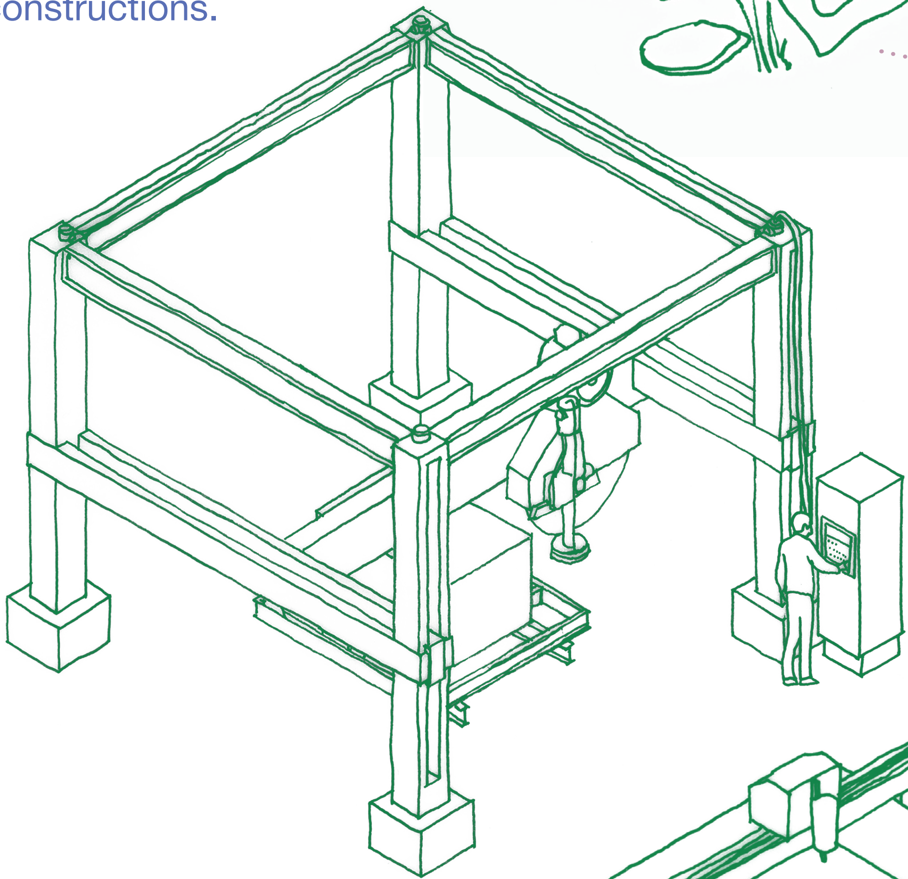
SSEMBLY

e stone blocks can be d or repurposed. Dry- ed or mechanically ned systems make sembly easier.

stone processing + constru

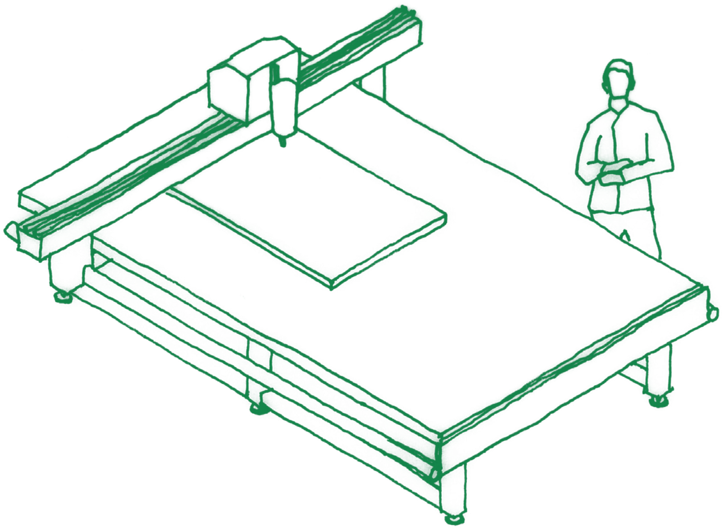
COLLECTING STONE

Found stone can be easily collected from abandoned quarries or from demolished sites and reused for new constructions.



MACHINE CUTTING

Generally, stone from quarries is processed in stone mills where automated saws cut large stone into smaller sizes and thicknesses.



CNC MILLING

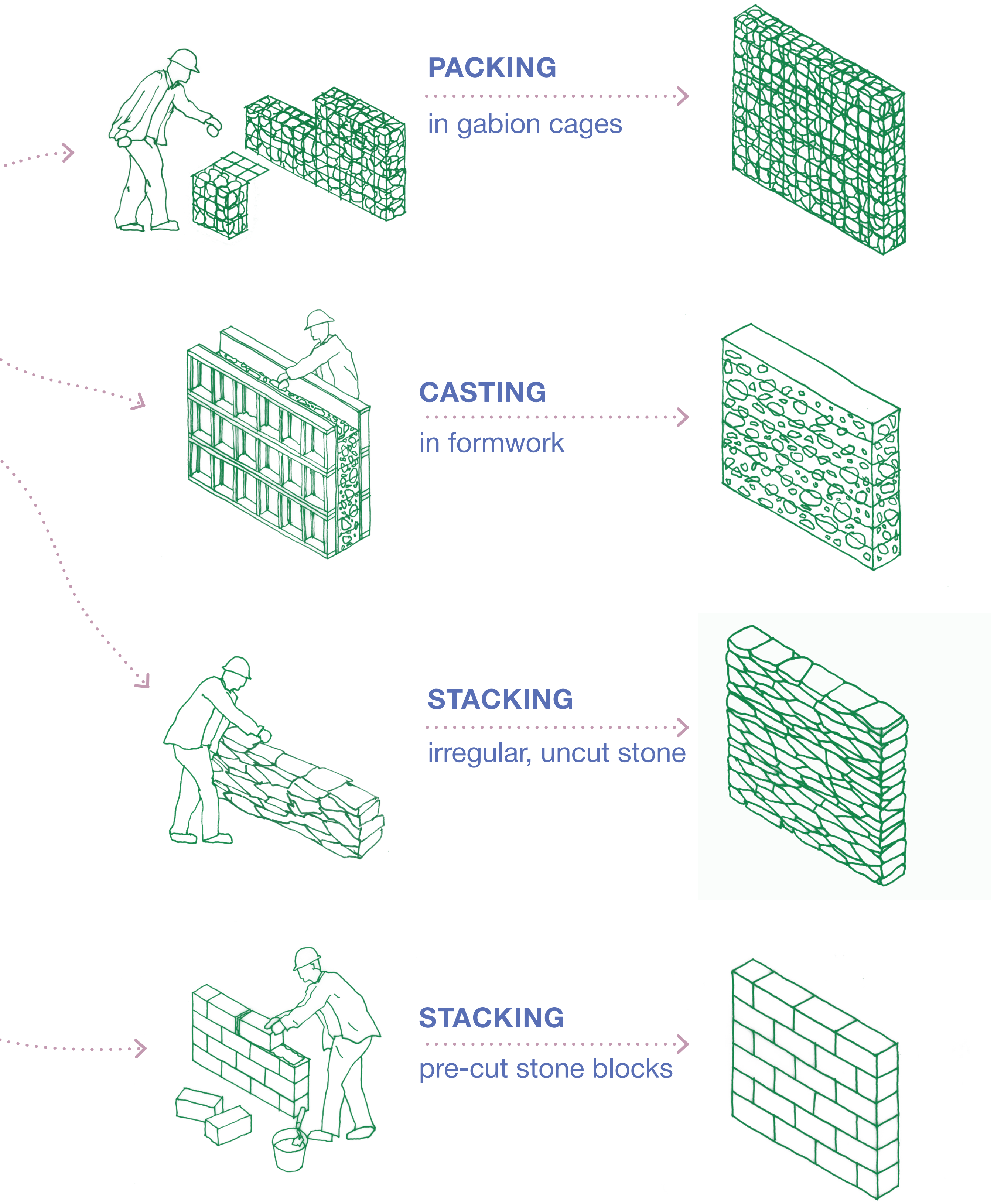
A CNC mill is commonly used in the stone industry for precision cutting, shaping, and texturing of stone slabs.

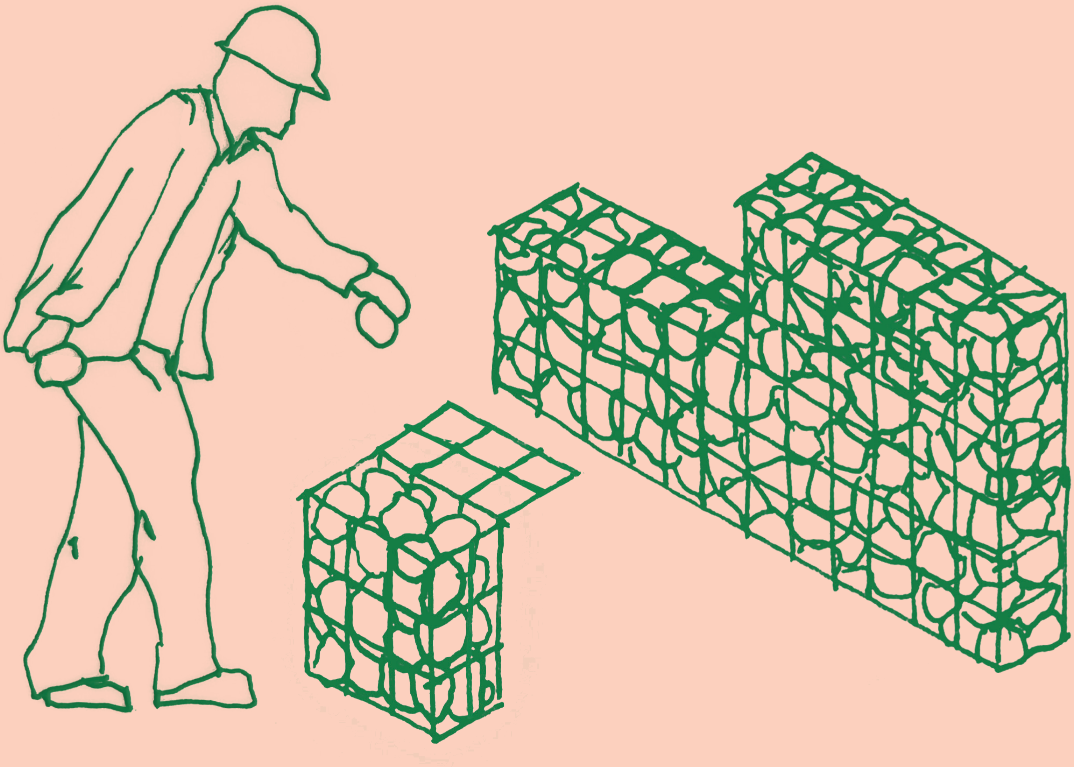
HAND CHISELING

A hammer and chisel can be used to further craft the stone into desired dimensions, finishes or propoertions.

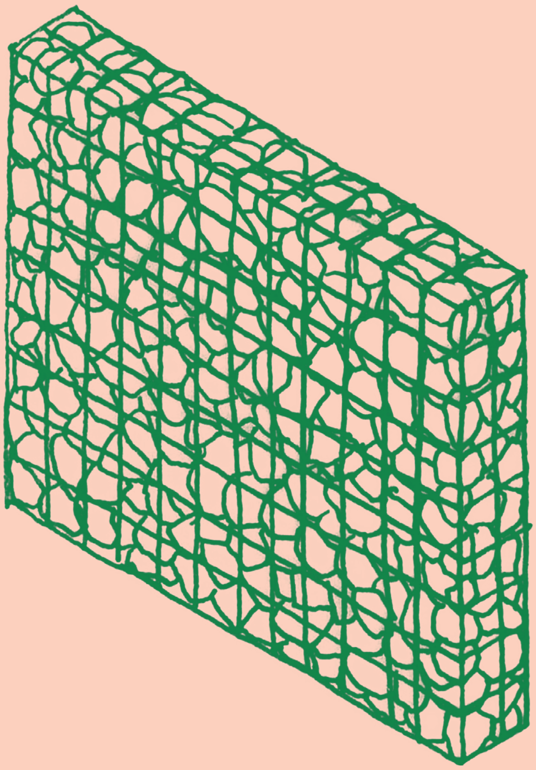
ction

techniques





IN GABION CAGES



TECHNIQUE: PACKING

Packing

Case Study: House 9x9

Location: Stadtbergen, Germany

Construction: Completed in 2003

Gross internal foor area: aprox. 162 m^2

Construction cost: Undisclosed

Architect: Titus Bernhard Architekten

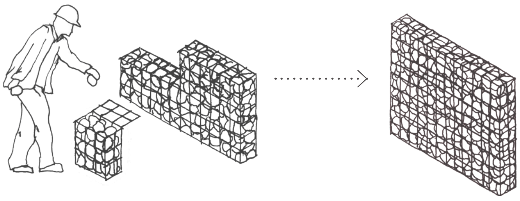
Client: Private

Structural engineer: Not specified

Manufacturers: Rothfuss (Gabion supplier)

Annual CO2 emissions: Not specified

The House in Stadtbergen, commonly referred to as House 9×9, is a two-story residential building designed as a habitable sculpture for a couple. Situated in a suburban community near Augsburg, Germany, the house was conceived as a statement against banal local design statutes and faced considerable resistance from municipal building authorities and neighbors during its development. The design features a square floor plan measuring 9×9 meters, from which it derives its name. The exterior is notable for its gabion (non-load-bearing cages filled with rubblestone) façade suspended from the insulated and sealed concrete structural shell. This innovative façade comprises 365 hand-filled cages, of about 40,000 stones, collectively providing between 30-40 tons of thermal mass that regulates thermal transfer and reduces the need for artificial heating and cooling. Instead of using visible gutters or downpipes, rainwater flows behind the gabion layer on a waterproof membrane to preserve the sculptural quality of the gabion-wrapped façade.

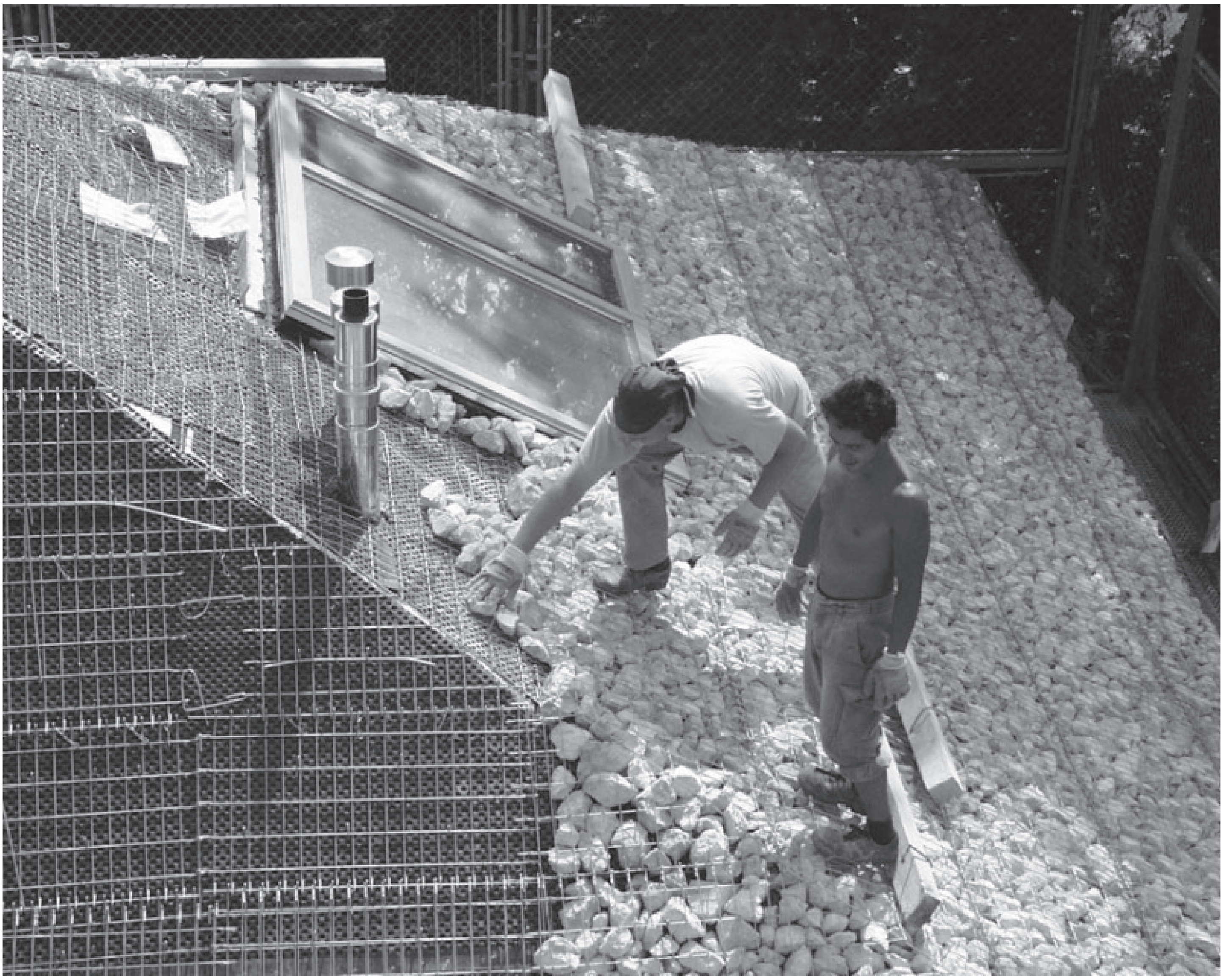


https://archiblock.com/casa-9x9-in-stadtbergen-alemania/titus-bernhard-architekten-stone-house_002/

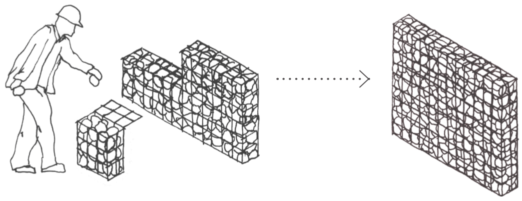
https://www.bernhardarchitekten.com

Packing

Case Study: House 9x9



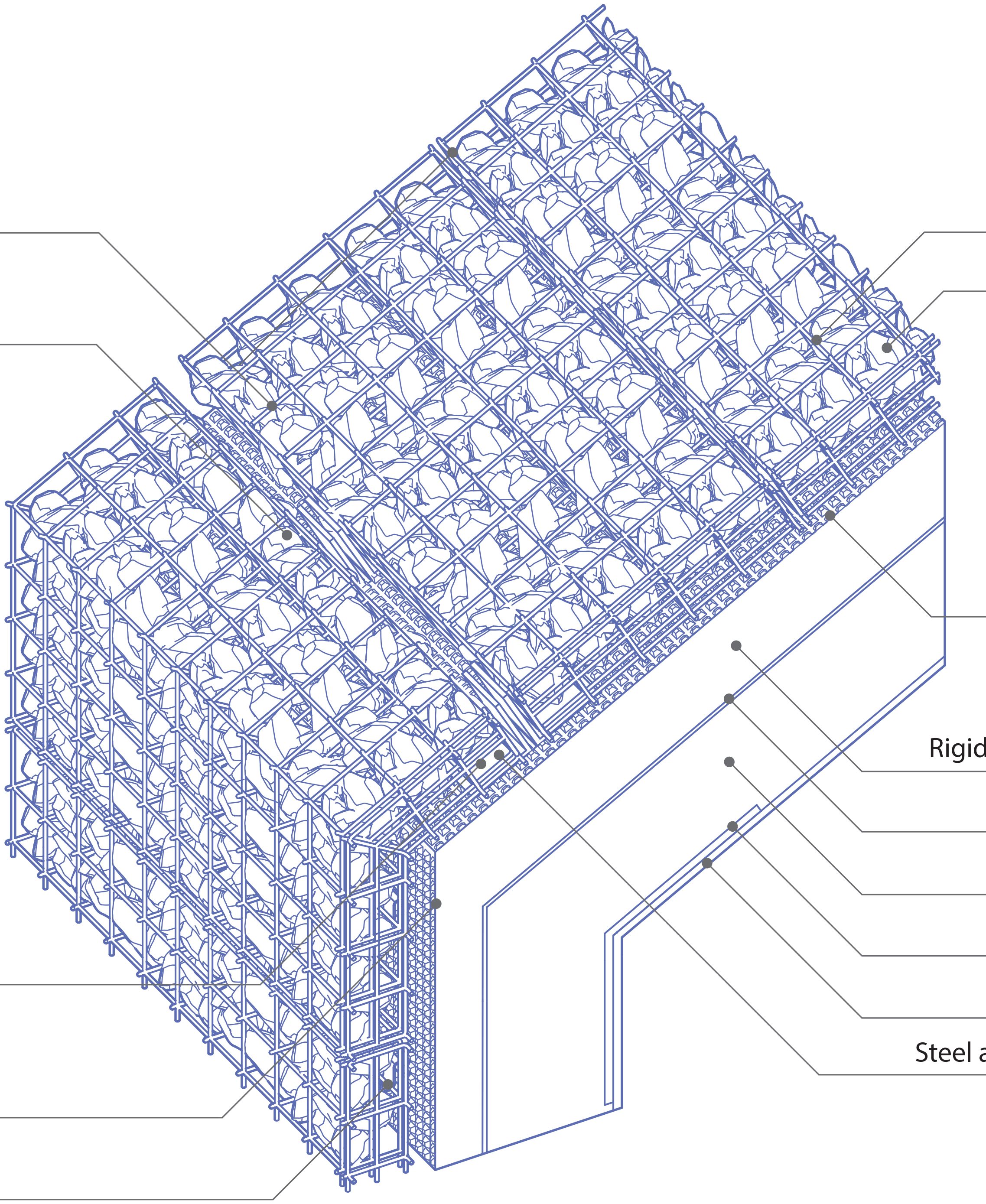
The outer façade is formed using prismatic gabion containers (100 × 50 × 12 cm) made of electro-welded galvanized steel trusses. These gabions are hand-filled with 'Dolomia of the Almühl Valley' rough stone (grain size 80–120 mm), arranged with continuous vertical and horizontal joints to create a regular lattice pattern. They are secured to the 22 cm reinforced concrete interior wall by means of a metal anchoring system comprising a 3 mm folded steel sheet rail and a 52/35 mm 'Halen' profile.

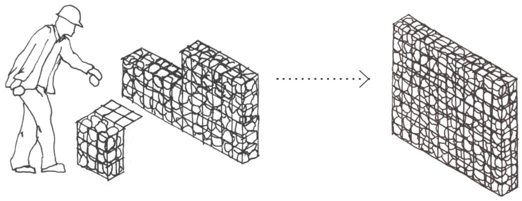


The rail is attached at discrete intervals using L-shaped steel profiles (140 × 70 × 10 mm), which are welded to a 200 × 150 mm anchor plate embedded in the concrete. These anchor points ensure sufficient clearance behind the gabions to accommodate a continuous layer of 140 mm rigid extruded polystyrene foam insulation which is installed following a 5 mm bituminous mastic waterproofing layer applied to the concrete wall.

Tectonic Analysis

TECTONIC





TECHNOLOGY

Galvanised steel wire basket

Local dolomitic limestone

Drainage mat with filter mat

l foam polystyrene insulation

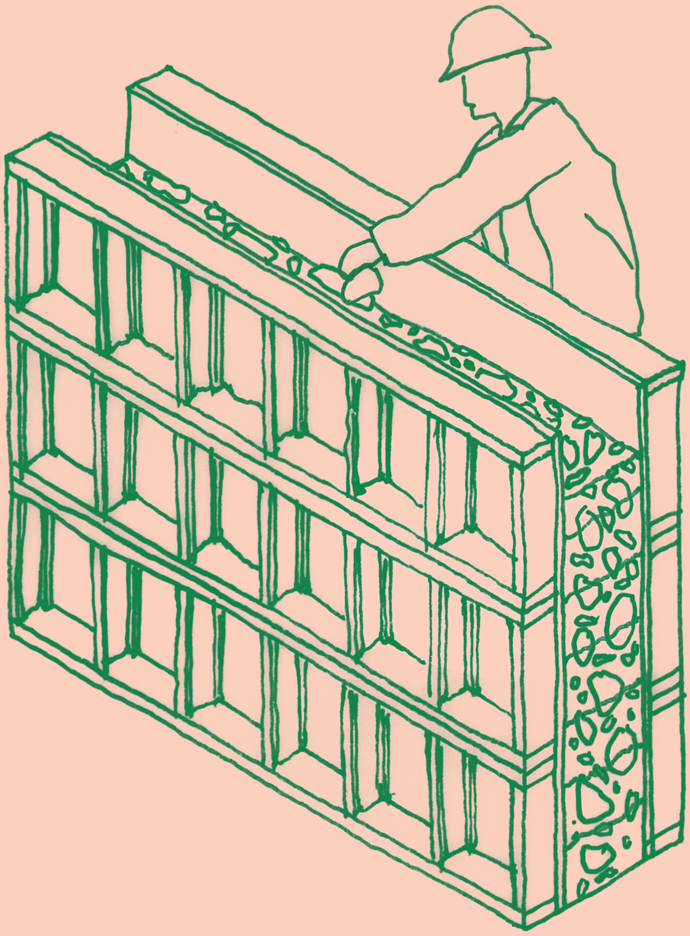
bitumen coat

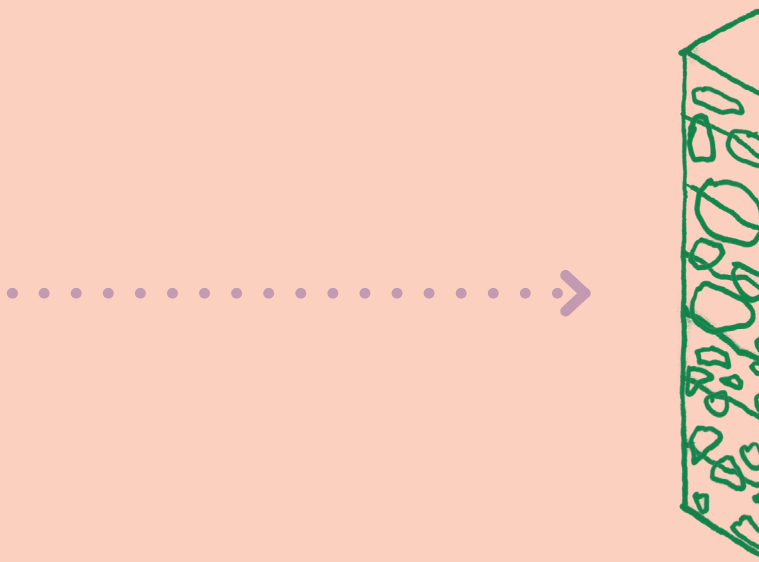
Reinforced concrete

Plaster baseboard

Lime gypsum plaster

angle welded to anchor plate





IN FORMWORK

TECHNIQUE: CASTING

Casting - Formwork

Case Study: Casa 1413

Location: Ullastret, Girona, Spain

Construction: 2016-2017

Gross internal foor area: 330 m^2

Construction cost: Undisclosed

Architect: H ARQUITECTES

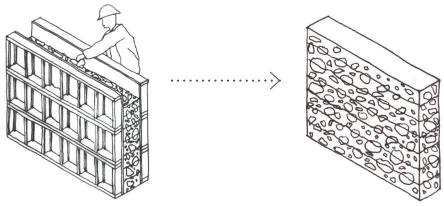
Client: Private

Structural Engineer: Unknown

Collaborators: Montse Fornés, Maya Torres

Annual CO2 emissions: Not specified

Casa 1413 is a single-story residence that reinterprets the traditional stone wall that once enclosed the property. Due to regulations requiring the widening of the adjacent street, the original wall had to be removed. In response, the architects designed the house to function as a new boundary, effectively acting as a wall that encloses the garden and restores urban continuity. The structure is built entirely with load-bearing walls, utilising stones from the original wall combined with aggregates from the site, limestone, and cement. To enhance insulation, small particles of recycled expanded glass were added to the traditional mortar mix. Instead of traditional stacking, the walls were constructed using a method akin to adobe and cyclopean techniques, with the exterior surfaces facing the street chipped to reveal the stone, while the interior surfaces display the formwork finish.

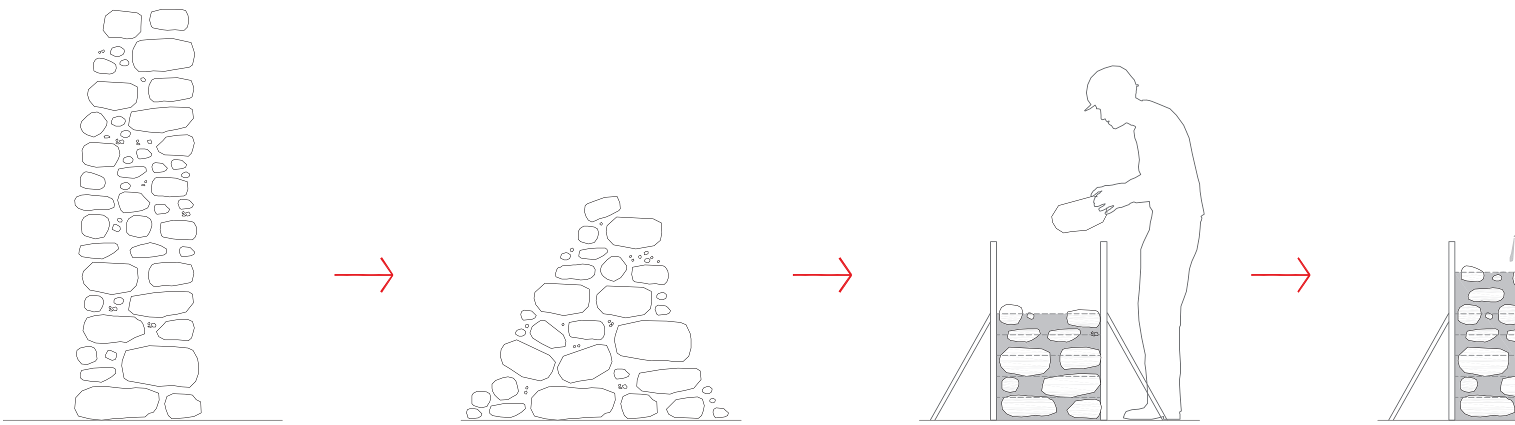


https://www.harquitectes.com/en/proyectos/house-1413/

https://tectonica.archi/projects/casa-1413/

Casting - Formwork

Case Study: Casa 1413

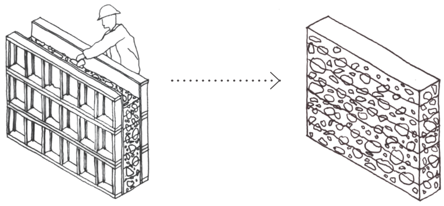


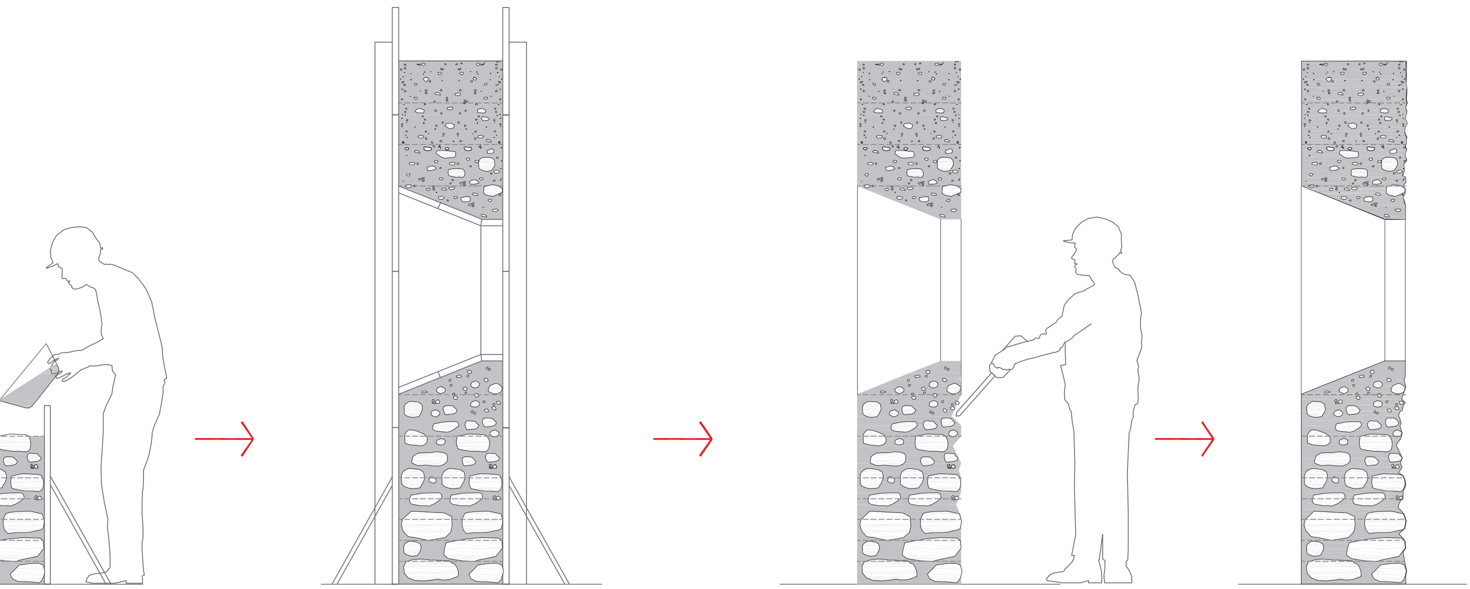
1) Existing stone wall

2) Disassembly of stones

3) Preperation of new stone wall in formwork

4) Pouring o





f new mortar

5) Elaboration of new wall openings

6) Remove the formwork and chip at the wall

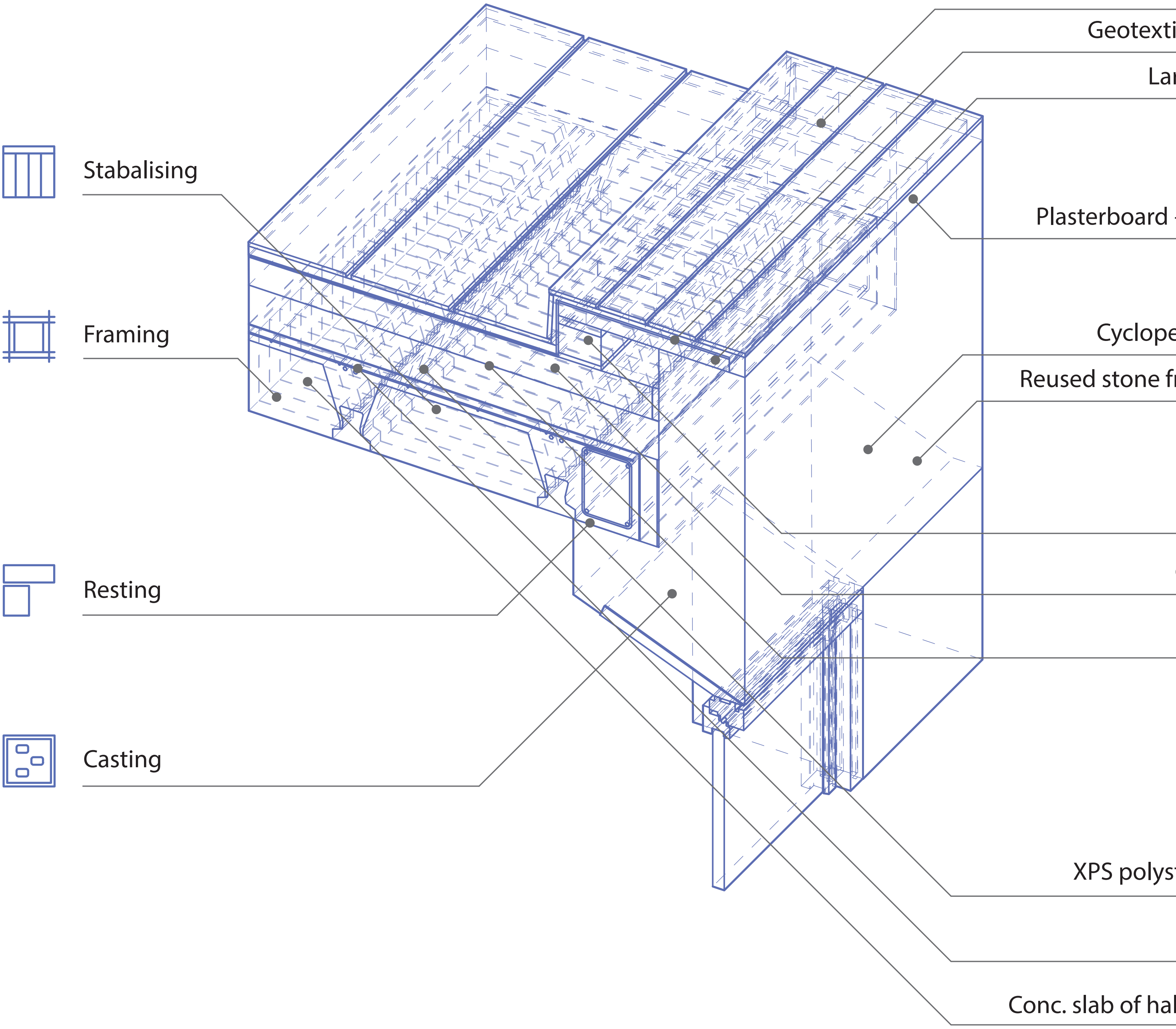
7) Finish!

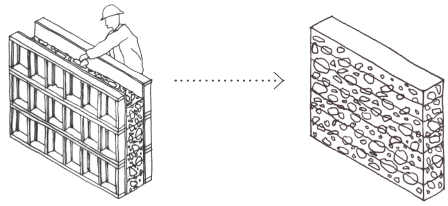
https://www.harquitectes.com/en/proyectos/house-1413/

https://tectonica.archi/projects/casa-1413/

Tectonic Analysis

TECTONIC





TECHNOLOGY

Ceramic tiles

le seperating foil

rge ceramic brick

+ rockwool insul.

ean concrete wall

rom existing wall

Openwork brick

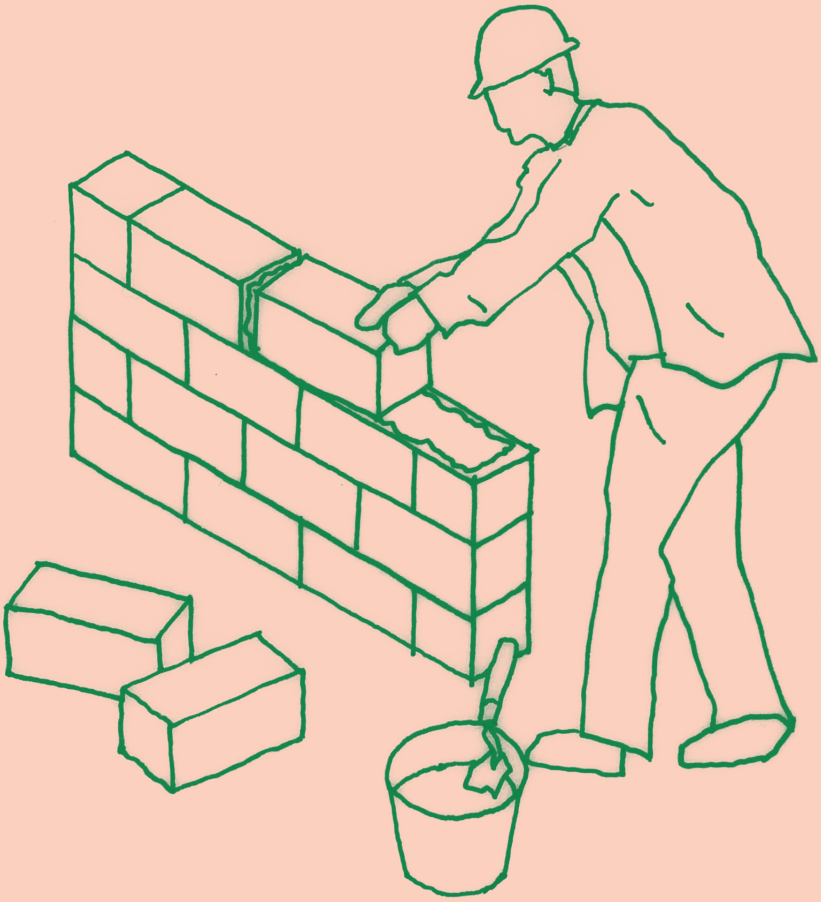
Cellular concrete

Geotextile

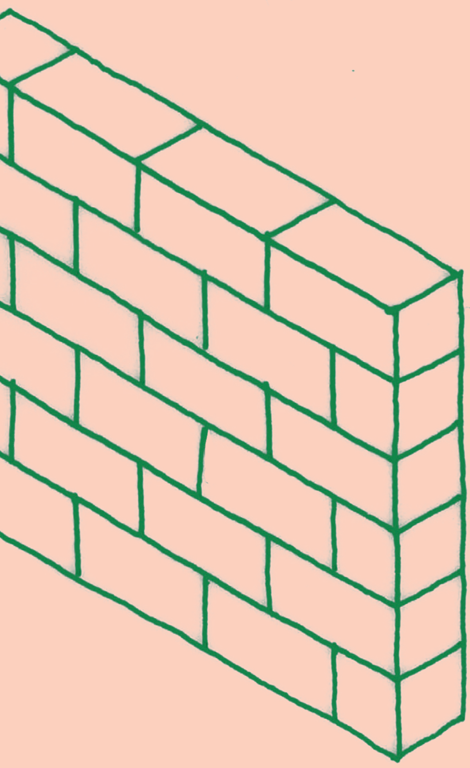
tyrene insulation

Vapour barrier

lf-joists + jack arc



PRE-CUT BLOCKS



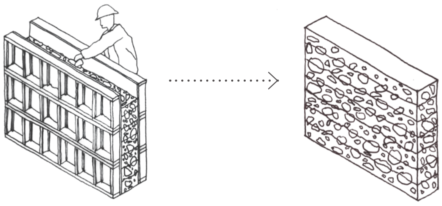
TECHNIQUE: STACKING

Stacking - Prefabricated blocks

Case Study: Social Housing 2104

Location: Palma, Mallorca, Spain
Construction: 2022-Ongoing
Built area: 1,610 m^2
Construction cost: Undisclosed
Architect: H ARQUITECTES
Client: Balearic Institute of Housing (IBAVI)
Structural Engineer: DSM-arquitectes (structure), M7 enginyers (engineer), Societat Orgànica (environmental consulting), MC acústica (acoustics engineer)
Collaborators: Anna Burgaya, Ángeles Torres, Cynthia Rabanal, Victor Jorgensen
Annual CO2 emissions: Not specified

Social Housing 2104, designed by Barcelona-based H ARQUITECTES, is a project in Mallorca, Spain, that exemplifies innovative repurposing of demolition materials. The site, formerly an abandoned school, was unsuitable for preservation due to its dilapidated state. Adopting an ‘urban mining’ approach, the project repurposed nearly all demolition debris for the new construction. Approximately 140 m³ of ceramic and concrete fragments were reused as fill for foundation pits. Additionally, 160 m³ of sandstone (whole marès stone) was recycled into 1,700 large cyclopean lime concrete blocks, each incorporating up to 40% recycled sandstone. These prefabricated blocks, measuring about 135 cm in length and 42 cm in height, have varying widths per floor (70, 60, 50 or 40 cm) and are stacked to form the load-bearing walls of the building. They gradually decrease in width by 10cm at each storey to allow the cross-laminated timber ceiling and roof structure to sit in the recesses.

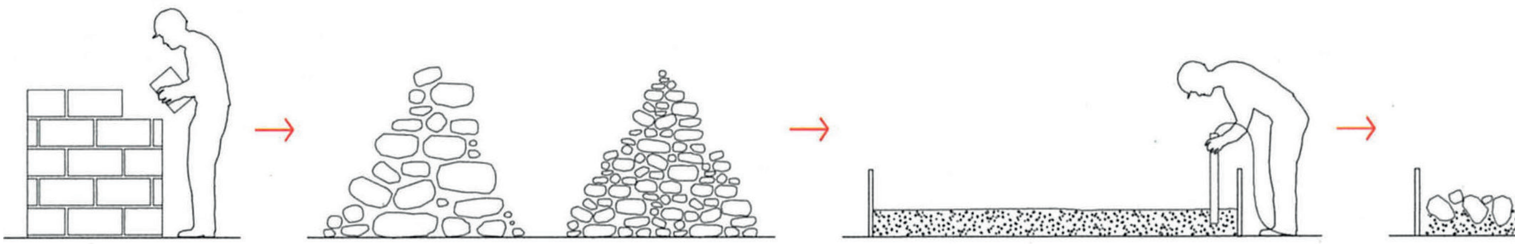


https://www.harquitectes.com/en/proyectos/ibavi-2104/

https://www.mallorcadiario.com/la-realidad-de-la-vivienda-publica-en-baleares:-obras-sin-empezar-y-deficiencias

Stacking - Prefabricated blocks

Case Study: Social Housing 2104

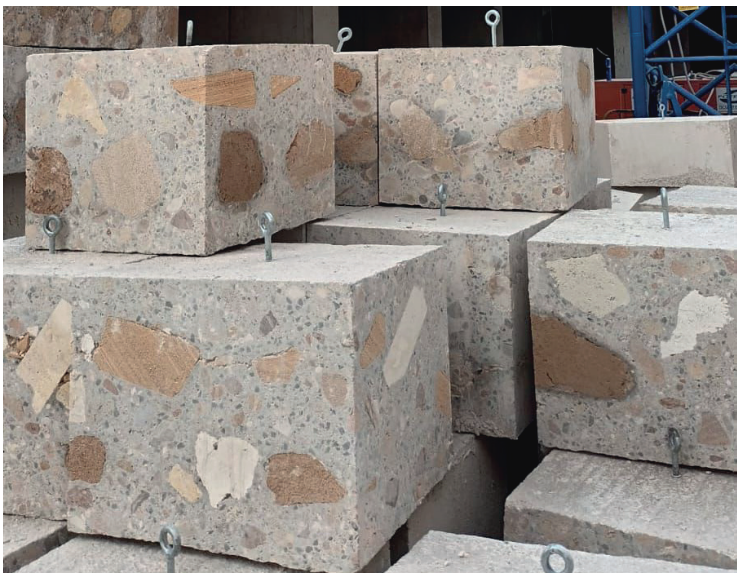


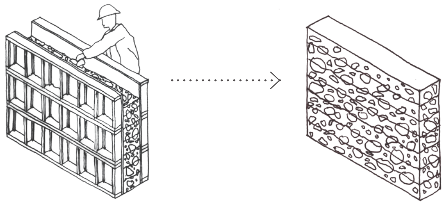
1) Selective
dismantlement of
existing building

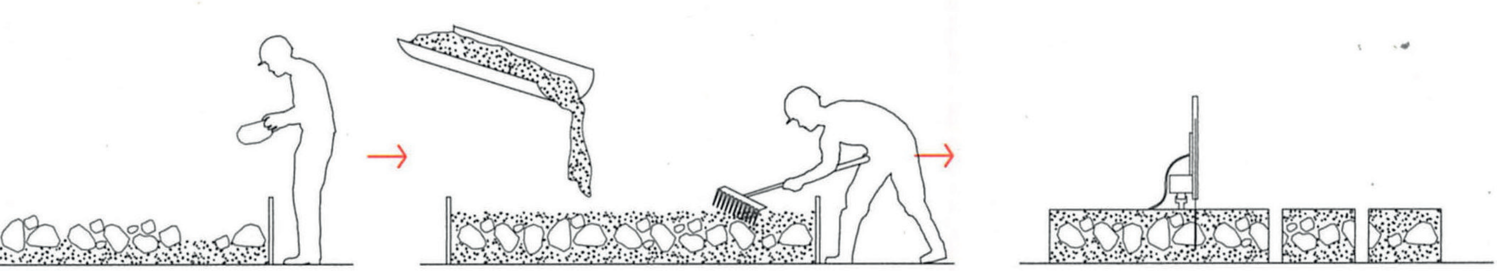
2) Selection:
50% marès rock > block
50% concrete > foundation

3) Formation of slabs:
poured and vibrated lime
concrete base

4) Fo
plac
marè







ormation of slabs:
ement of recovered
ès rocks

5) Formation of slabs:
poured, vibrated and leveled
lime concrete

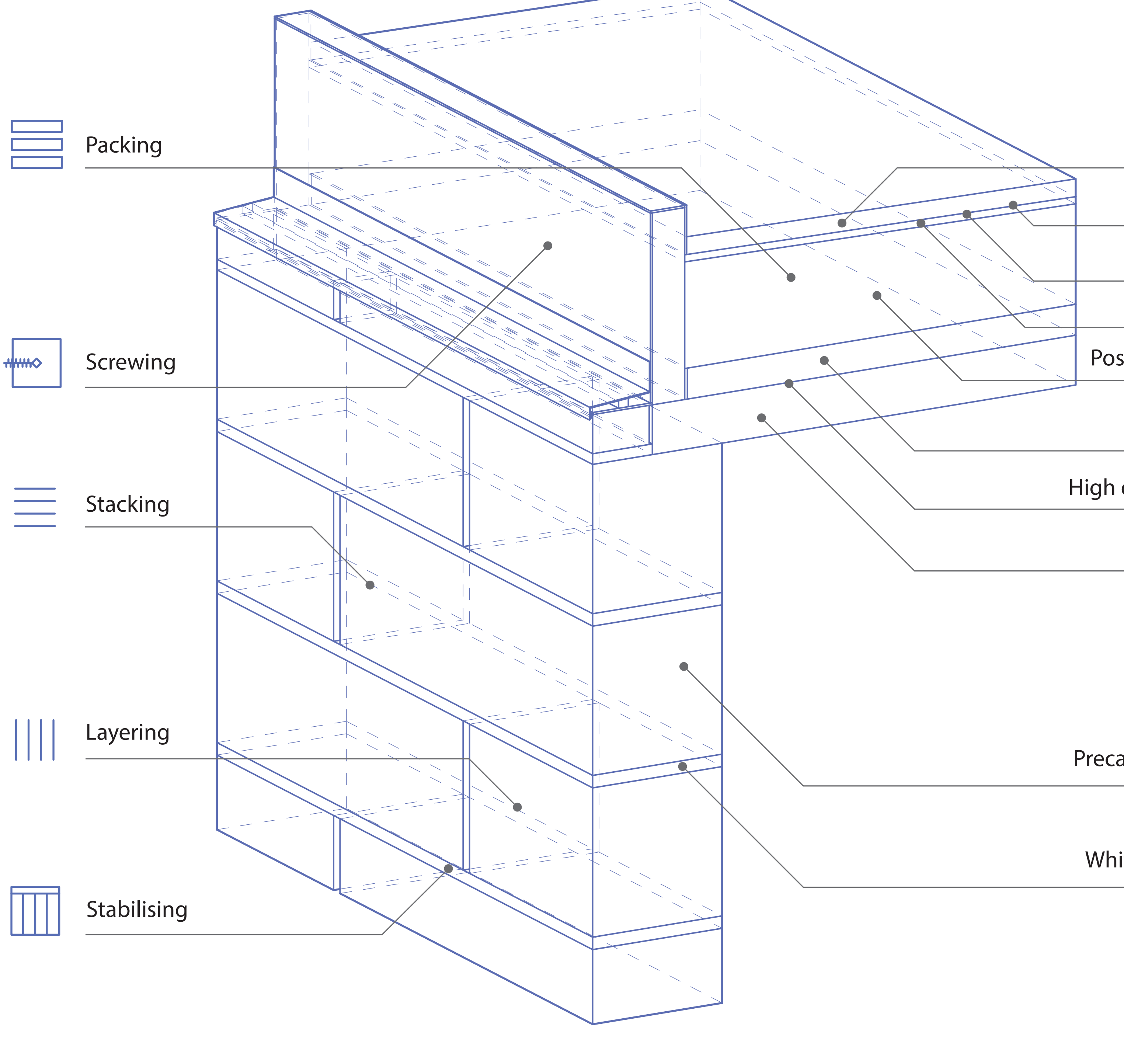
6) Cutting to make the blocks:
10 days after curing, slab is
cut using a circular saw

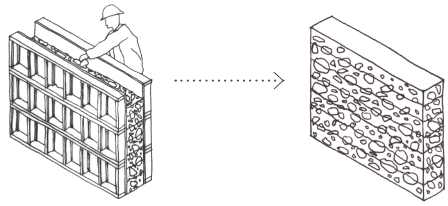
https://www.harquitectes.com/en/proyectos/ibavi-2104/

Scans from book: El Croquis 219 IBAVI 2019 2023, page 298

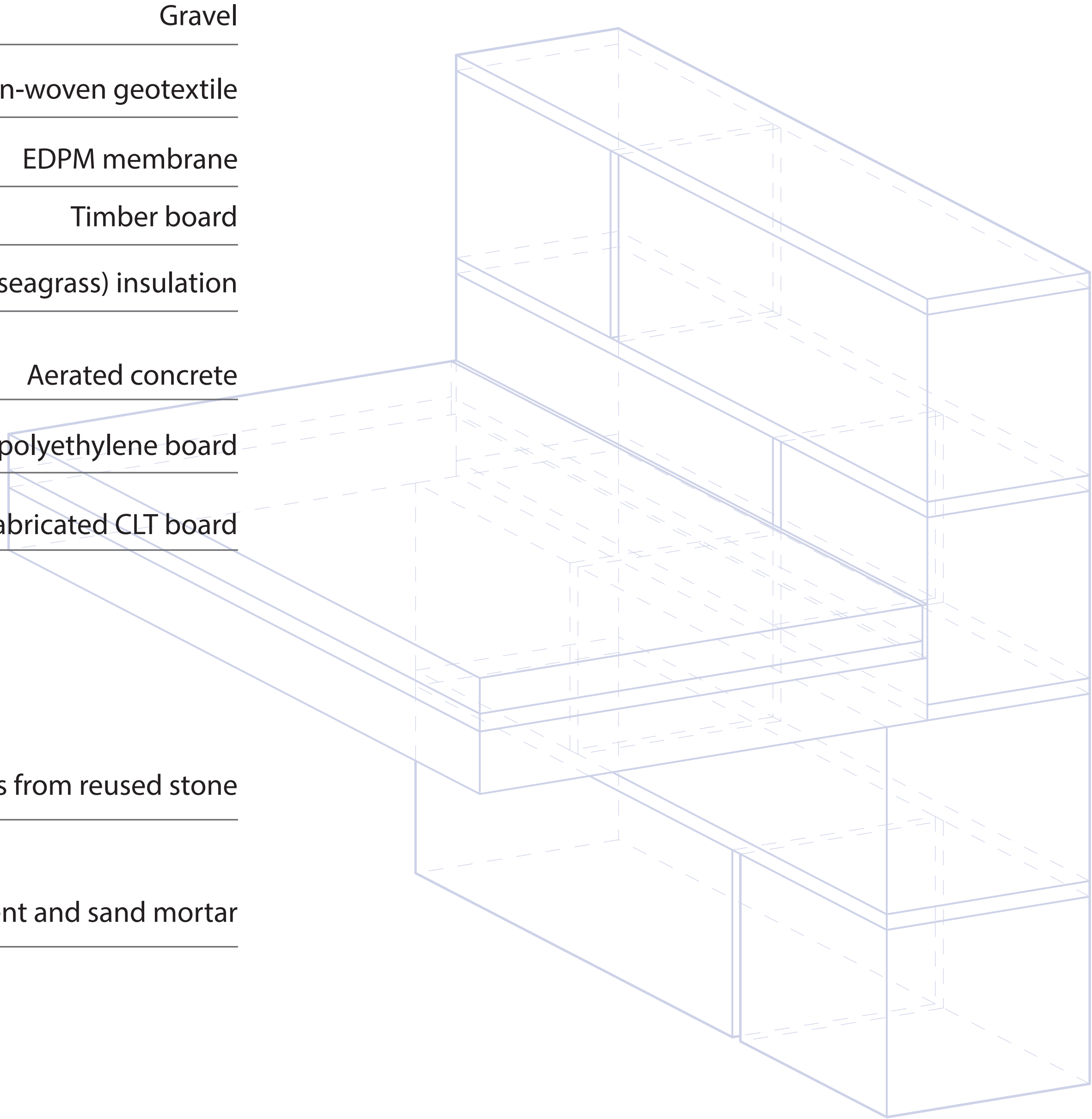
Tectonic Analysis

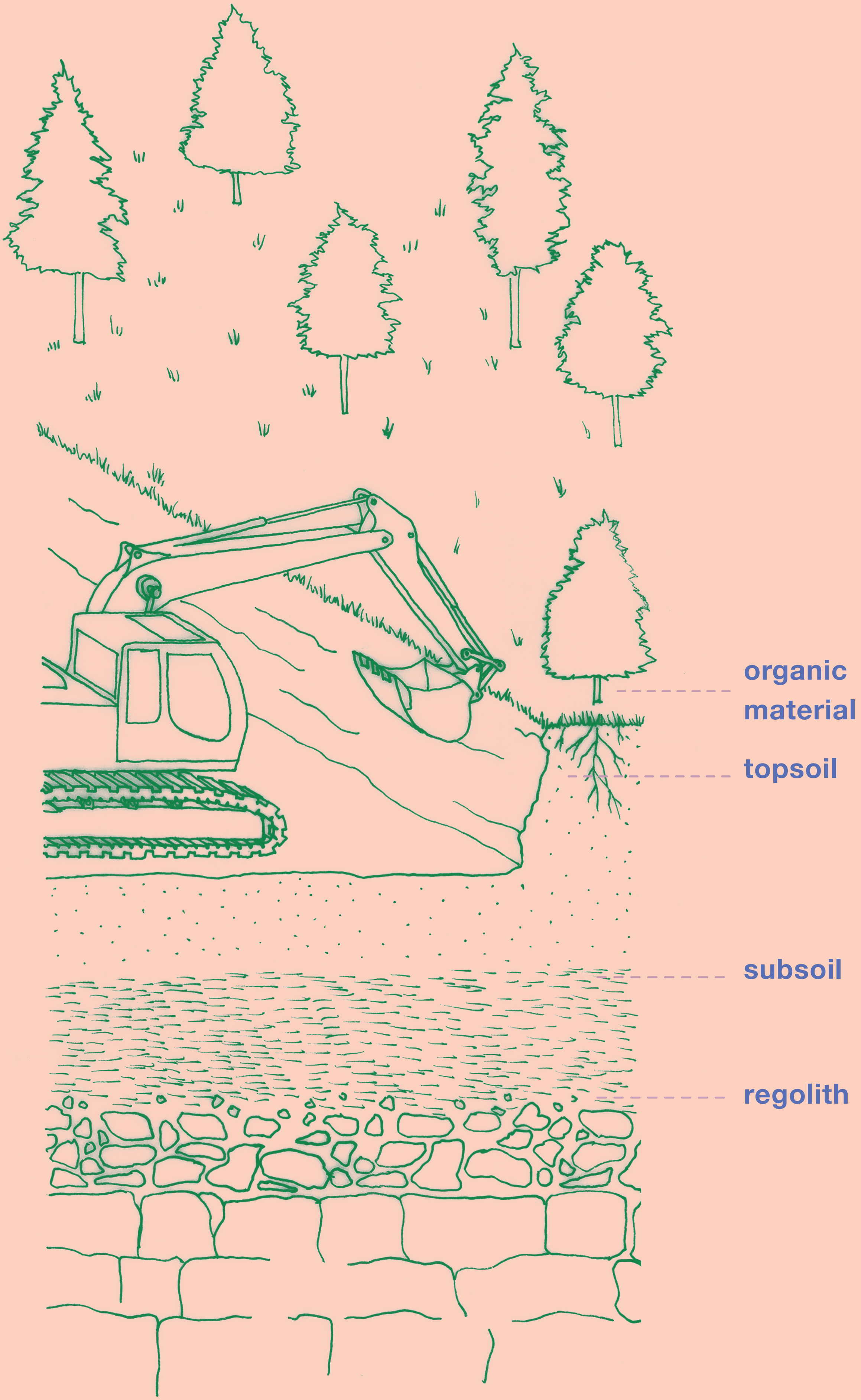
TECTONIC





TECHNOLOGY


Gravel
Non-woven geotextile
EDPM membrane
Timber board
idonia (seagrass) insulation
Aerated concrete
density polyethylene board
Prefabricated CLT board
st bricks from reused stone
te cement and sand mortar



SITE EXCAVATING

EARTH

Before fabrication, soil compositon needs to be tested. Soil can contain clay, silt, sand and aggregates but free of organic content, so should be taken from below the topsoil.

Earth is one of the oldest and most globally widespread construction materials, formed through the natural weathering and deposition of mineral and organic particles over millennia. Used by civilisations across climates and cultures, earth has remained relevant due to its accessibility, low environmental impact, and excellent thermal mass properties. Its performance depends heavily on composition, moisture content, and regional techniques such as rammed earth, cob, or adobe.

In construction, earth can be shaped while moist and hardens as it dries, making it suitable for self-building with minimal energy input. When stabilized with natural fibers or binders like lime or pozzolans, it offers enhanced durability and water resistance. Earth buildings naturally regulate indoor temperatures through thermal mass and humidity buffering.

Earth's embodied energy is among the lowest of any construction material, and when sourced locally, it requires no industrial processing. Additionally, earthen materials are fully recyclable and biodegradable, supporting a regenerative building culture.

Common Name	Earth
Geological Origin	Weathered rock fragments mixed with organic matter
Composition	Varies – mix of clay, silt, sand, and gravel
Texture	From fine clayey to coarse sandy soils
Moisture Content	8–25% (optimal for building use)
Soil Preference	Well-graded loamy or clayey soils with plasticity
PH	Typically 6.0 – 8.0
Climatic Suitability	Used in arid, temperate, and tropical climates
Appearance	Color varies by mineral content – ochres, browns, reds, etc.
Processing Method	Dug, mixed (sometimes with fibre or stabilisers), shaped
Recyclability	Fully reusable; can be re-moistened, re-formed, or returned to ground with no waste

1. Minke, Gernot. Building with Earth: Design and Technology of a Sustainable Architecture. Basel: Birkhäuser, 2006.

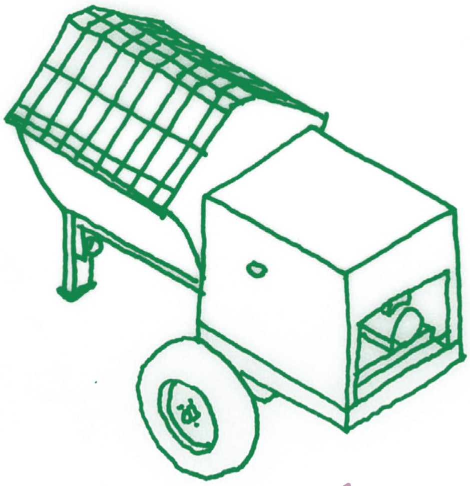
2. Houben, Hugo, and Hubert Guillaud. Earth Construction: A Comprehensive Guide. London: Intermediate Technology Publications, 1994.

3. CRAterre-ENSAG. Earth Architecture: Building with Earth Today. Grenoble: CRAterre-ENSAG & UNESCO Chair Earthen Architecture, 2011.

earth processing + constru

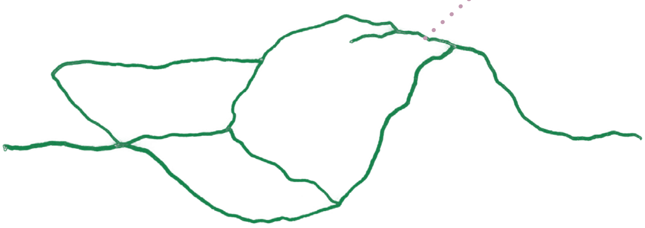
MIXING

Loam is mixed to meet specific performance standards. Clay particles are broken down to create an even mix and water is added to enhance binding. The mixes can be tested to check compaction, water content, cohesion and consistency.



MANUFACTURING

Loam is often shaped into modular blocks, which can be sun-/air-dried, or compressed manually or mechanically. Smaller blocks dry quicker and added natural fibers like straw improve strength.

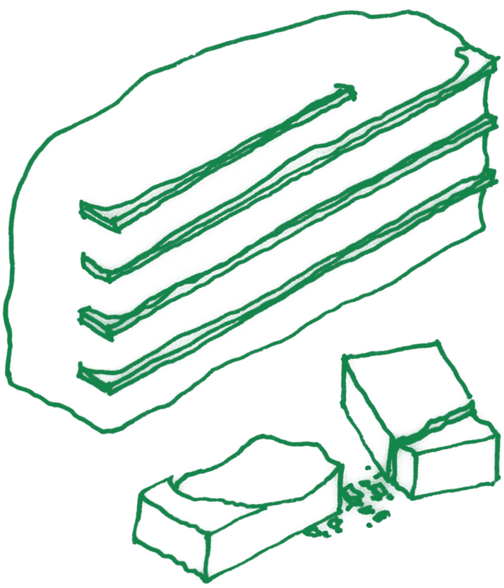


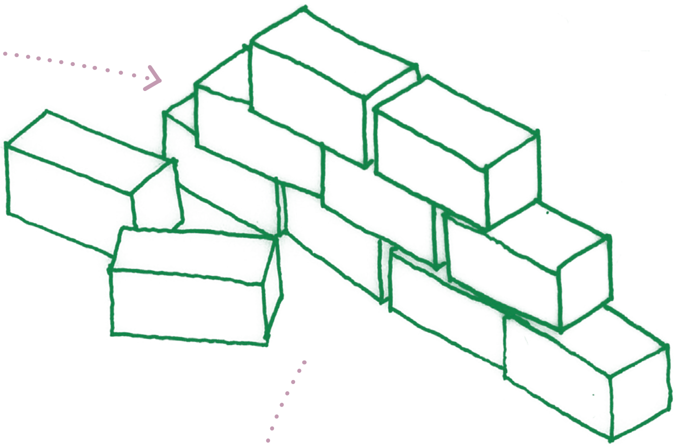
DIGGING/COLLECTING

Clay, sand, silt and gravel can be sourced locally from the site or from nearby quarries. Digging might be required to go below the topsoil for soil without organic content (since it rots).

DISASSEMBLY

One of the key benefits of earth as a building material is its recyclability. It can be reused multiple times without losing quality or returned to the ground without causing environmental harm.



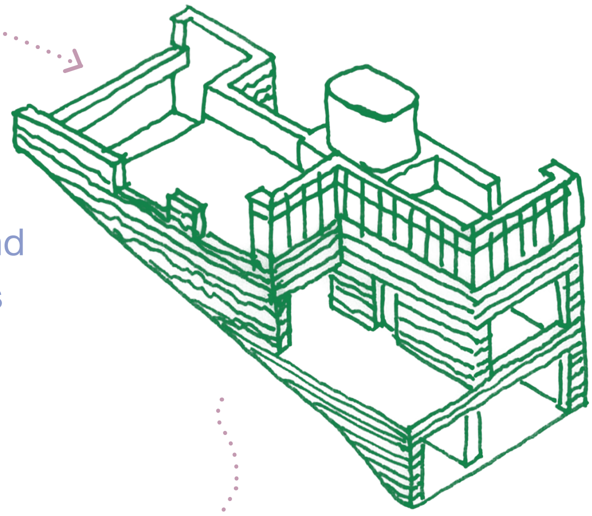


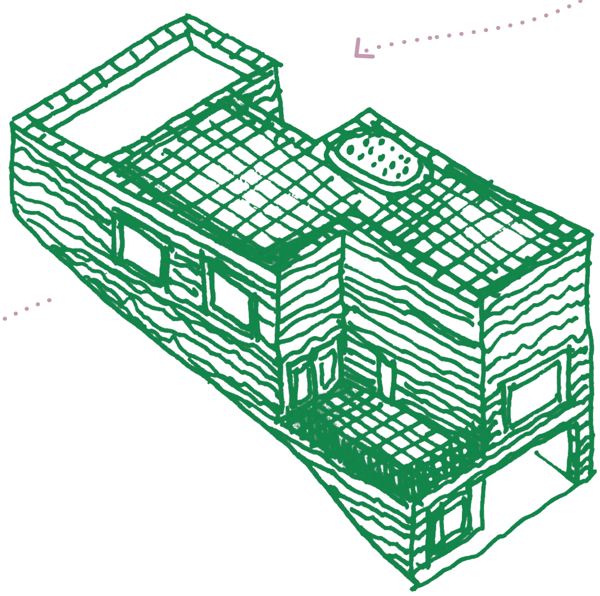
ASSEMBLY

Earth can be shaped into structures using rammed earth, compressed blocks with or without mortar, prefabricated panels, or hybrid designs combining infill and structural frames.

MORTAR

Mortar, made to match the properties of earth, can bind earth blocks and enhances structural stability while maintaining flexibility and breathability.



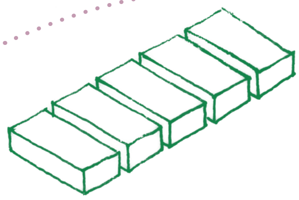


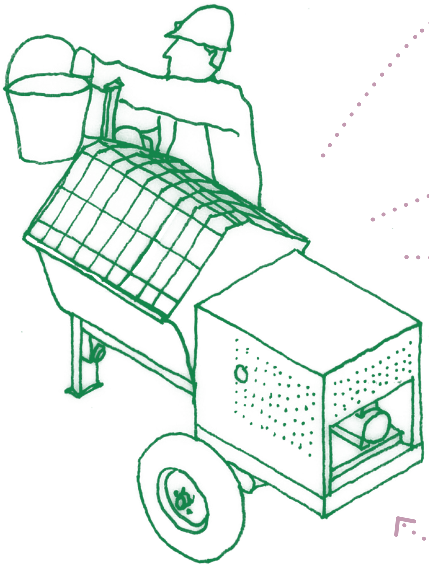
IN-USE

Earth requires careful detailing to withstand moisture and erosion. Coatings that allow vapor exchange and allow humidity-balancing properties work best. Impermeable layers may be needed to protect earthen walls from ground water and moisture.

earth processing + construc

FOR CURED OR STABALISED (NON-FIRED) EARTH



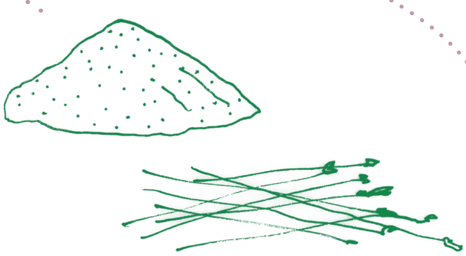


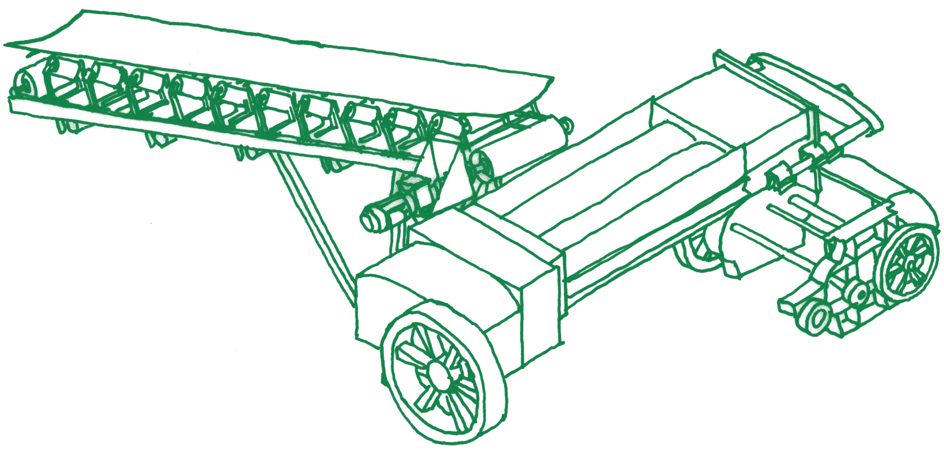
MIXING

Required ratios, dependant on soil and project type, of loam, water, and aggregates are mixed (by hand or machine).

ADDITIVES

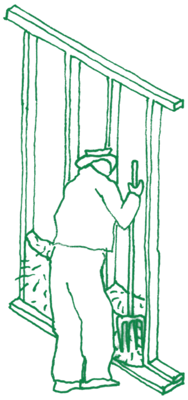
Stabilisers such as lime, certain clay blends, volcanic ash, or plant fibres can be used to improve the strength, durability, and resistance to water.





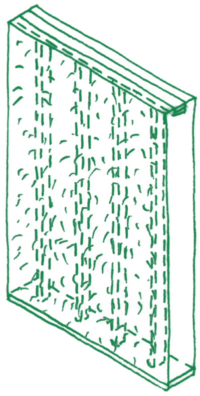
INDUSTRIAL MIXING

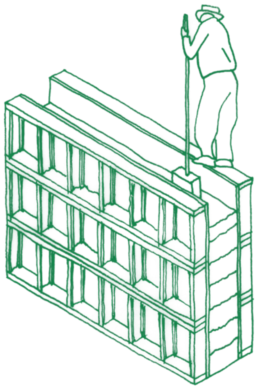
To save time, for larger-scale production (as for bricks) earth can be mixed in big industrial mixers, especially for helping to meet commercial standards.



LAYERING

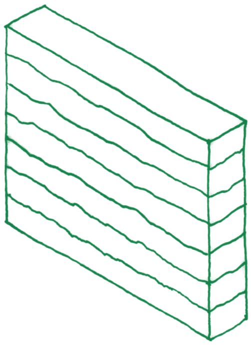
cob (earth and straw mix)

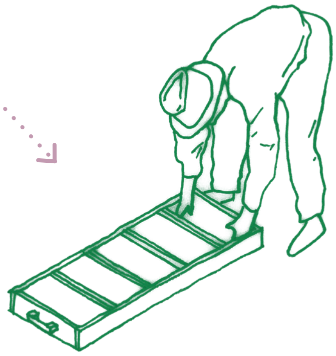




TAMPING

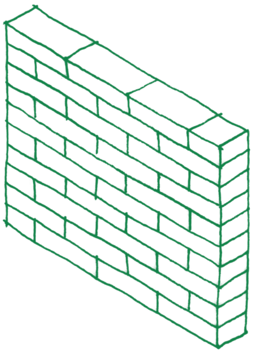
into formwork

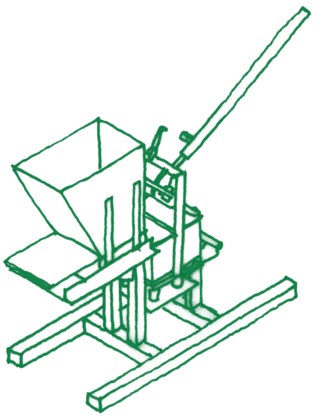




CASTING

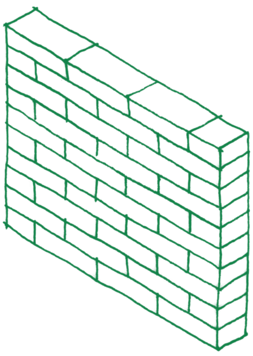
cast into moulds and left to cure (7-14days)



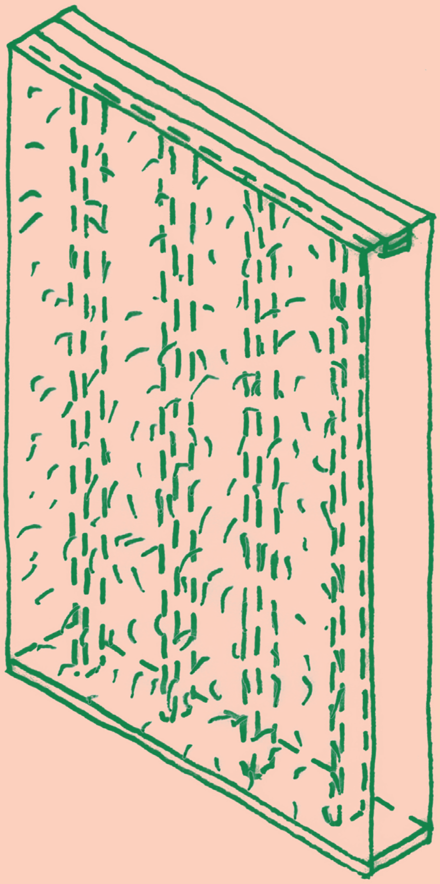


PRESSING

stamped by moulds (for more rigid clays with 7-12% moisture)



COBWORK



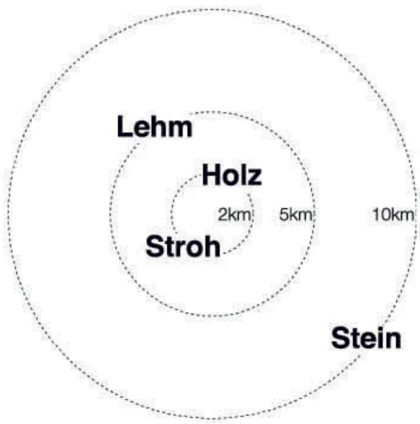
TECHNIQUE: LAYERING

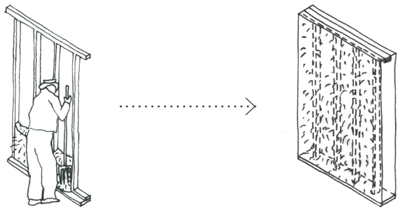
Layering - Cobwork

Case Study: Eco-Friendly House in Deitingen

Location: Deitingen, Solothurn, Switzerland
Construction: 2009-2010
Gross internal foor area: 241 m^2
Construction cost: ?
Architect: Spaceshop Architekten, Biel
Client: Ueli Fury
Structural engineer: TS Holzbauplanung, Ersigen
Earth construction: Ralph Künzler, Baubiologie Lehmbau, Winterthur
Annual CO2 emissions: Not specified
Embodied CO2: -55,327 $kgCO_2$

The Eco-Friendly House in Deitingen is a low-tech home for a gardener who was always interested in autarky, ecology and health. To do so energy and water supply needed to be independant of the public networks and the use of natural non-toxic materials with minimum grey energy was necessary. Rainwater is harvested via a planted roof, wastewater is recycled for irrigation, heating comes from a wood-fired boiler, and electricity is generated through photovoltaics on a nearby farmhouse. It features 80 cm-thick clay walls for thermal regulation, offering passive cooling in summer and retaining heat in winter. The energy for production, transport and subsequent disposal of building components was kept as minimal as possible. The house was built mainly using natural stone, clay, straw, and timber sourced within 10km. These were kept free of additional toxic substances and most were unprocessed. The basement walls and plinth were constructed from recycled stones (from demolished structures), combined with trass-lime mortar. For the ground floor wall construction a traditional building technique called cobwork (clay and straw construction) is employed to form the 80cm thick walls which achieve a U-value of 0.66 W/m^2K. In addition, all contractors, with the exception of the clay construction team, come from within 20km of the site.





https://www.spaceshop.ch/autarkes-wohnhaus-deitigen

https://materialarchiv.ch/en/ma-reference_object_8356?type=all

Layering - Cobwork

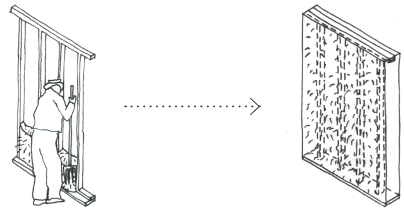
Case Study: Eco-Friendly House in Deitingen

1) Recycled natural stones were laid with trass-lime mortar to build the foundation (also the basement walls and plinth for the walls above).

2) Clay sourced from a neighboring community was mixed with straw on-site. The straw is added to the clay to create a cohesive and insulating material.

5) The clay walls are left to dry and cure naturally. The drying process ensures that the walls become stable and strong.

6) The clay walls were supported and framed by timber structures made of softwood sourced from a nearby forest. Joists were laid to a grid dimension based on the width of pressed straw bales used for the roof insulation.



3) The prepared clay mixture is manually applied in layers using tools like pitchforks and hands. The clay is pressed and shaped onto the walls without the use of formwork.

4) Each layer of clay (aprox. 60-90cm high) is allowed to dry slightly before being shaped and smoothed with tools such as spades, to create a uniform wall surface.

7) Once the clay walls are fully cured, the final layer is smoothed and finished to achieve the desired texture and appearance.

8) The completed clay walls are integrated with the timber roof and other structural elements, forming a cohesive and sustainable building envelope.

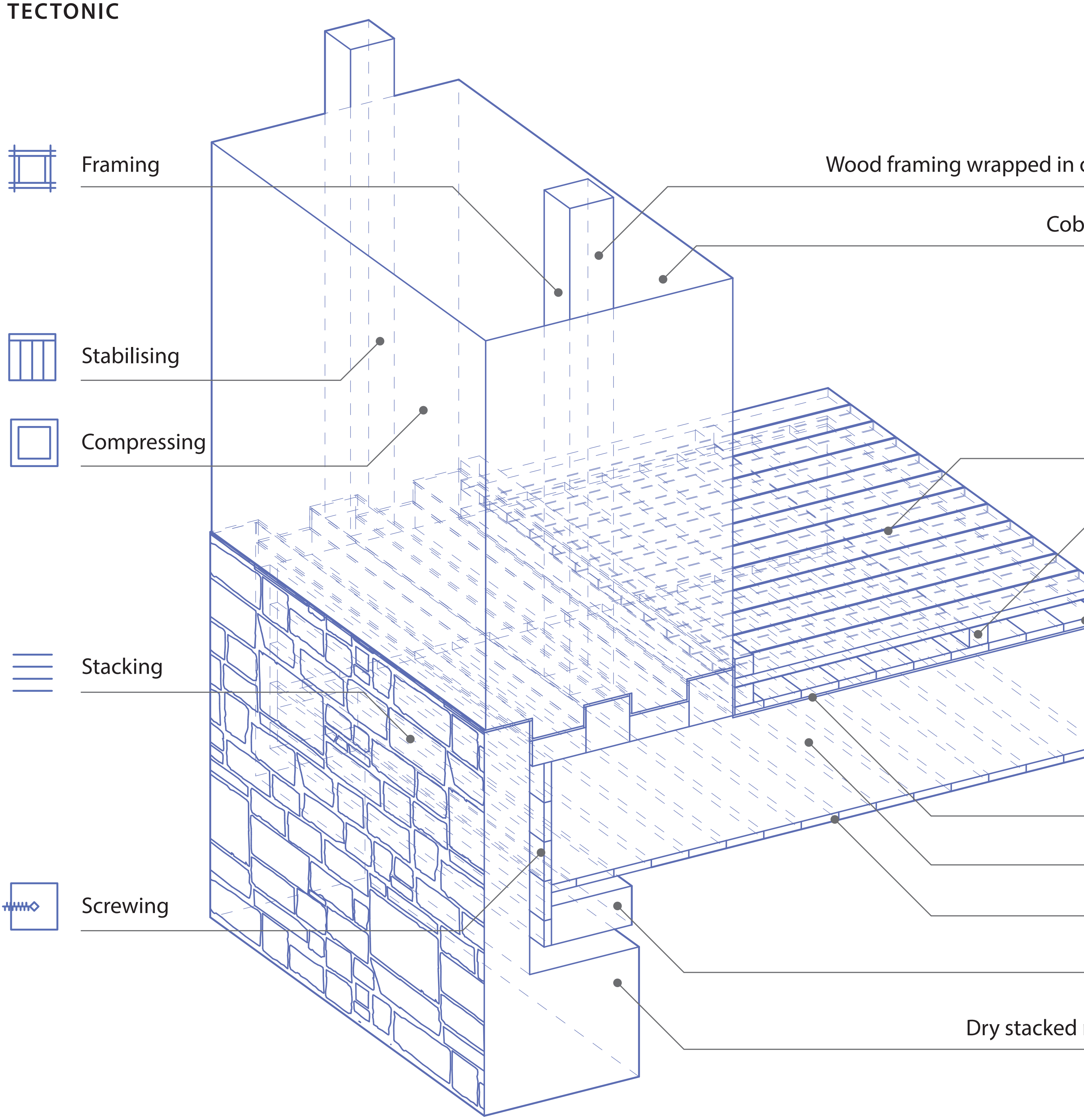
https:// www.baunetzwissen.de/gesund-bauen/objekte/wohnen/wohnhaus-flury-in-deitingen-1556003

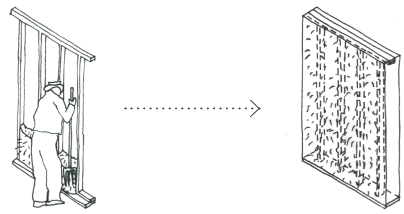
https://inspiration.detail.de/en/article/eco-friendly-house-in-deitingen-336

http-//lehm-michael-weser.de/galerie_wellerbau

Tectonic Analysis

TECTONIC





TECHNOLOGY

il-impregnated paper

(earth and straw) wall

Wood floor

Wood battens

Wood boarding

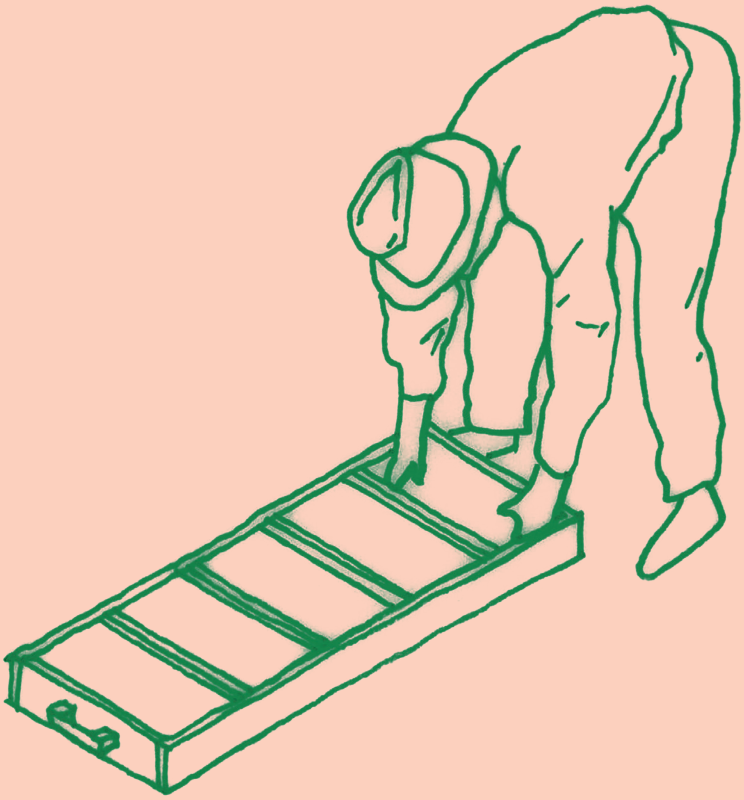
Vapour barrier

Straw insulation

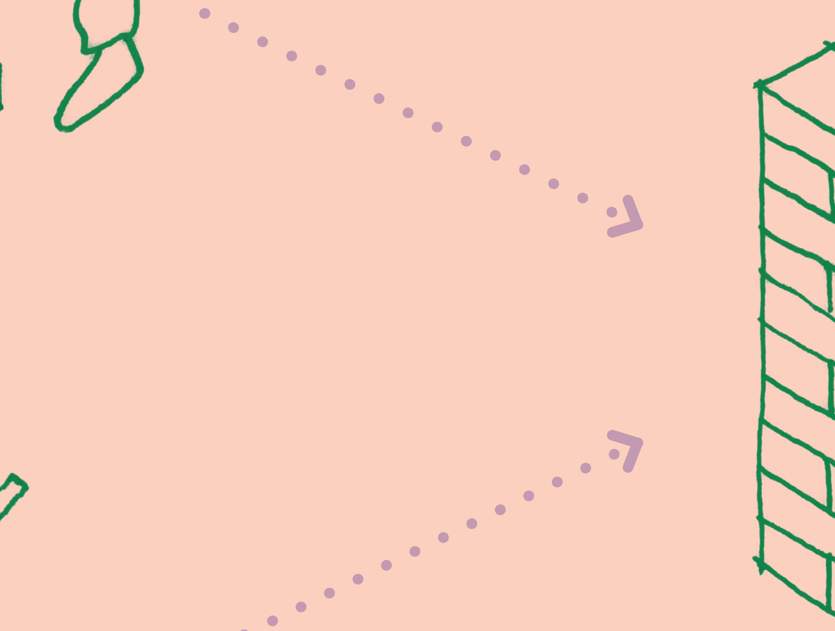
Wood boarding

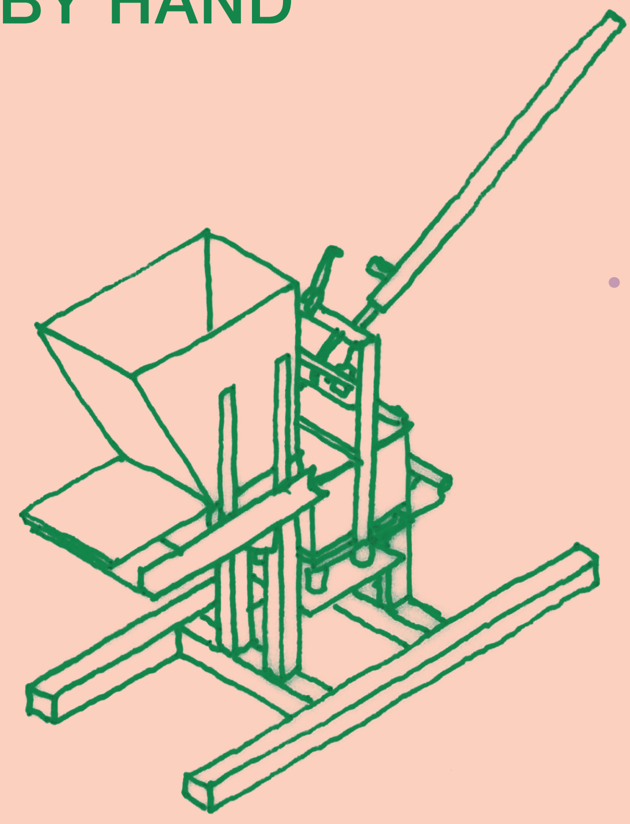
Wood sill

repurposed stone wall

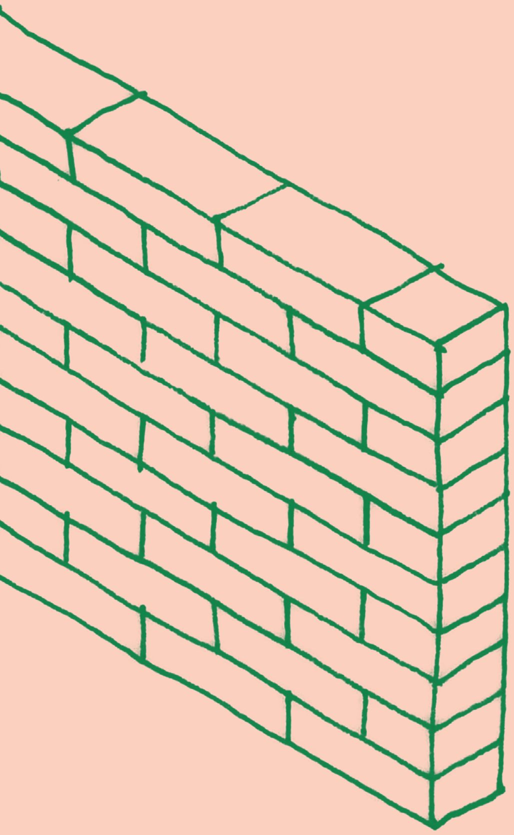


BY HAND





WITH DRY PRESS



TECHNIQUE: PRESSING

Compressed Earth Blocks

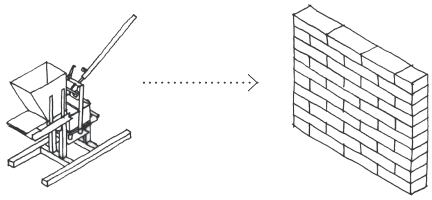
Case Study: Raw Rooms, 43 Housing Units

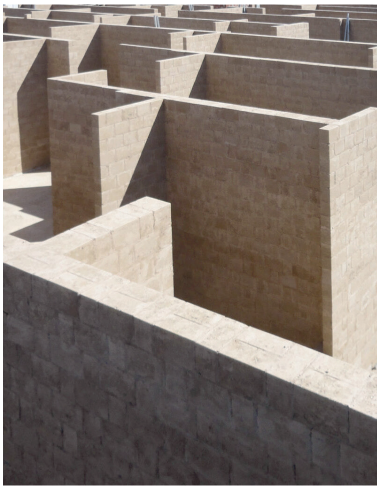
Location: Ibiza, Balearic Islands, Spain
Construction: Completed 2022
Gross internal foor area: 3,863.75 m²
Construction cost: €5,200,744
Architect: Peris + Toral Arquitectes
Client: Balearic Housing Institute (IBAVI)

Structural engineer: L3J Tècnics Associats SLP
Earth construction: Fetdeterra (provided TAPIALBLOCK® precast blocks)[1]
Annual CO2 emissions: Approximately 0.72 kg CO_2/m²
Embodied CO2: 420 kg CO_2/m², representing a 60% reduction compared to conventional buildings[2]

The Raw Rooms, 43 Social Housing Units in Ibiza by Peris + Toral Arquitectes is a pioneering residential project that merges sustainability, social engagement, and architectural innovation. Located in Ibiza, Spain, the development redefines social housing through a bioclimatic design approach aligned with the UN's 2030 Agenda for Sustainable Development. The project features 43 modular housing units built using TAPIALBLOCK® compressed earth blocks (CEB), made from locally sourced clay and aggregates, providing load-bearing support and regulating indoor temperatures through thermal inertia. The natural properties of clay in these blocks aid in regulating indoor humidity, enhancing overall comfort. Natural ventilation, cross breezes, and controlled sunlight exposure reduce energy consumption, resulting in 60% lower embodied CO_2 emissions compared to conventional construction. The building's communal design fosters social interaction through interconnected courtyards, shared terraces, and public spaces. The project exemplifies how traditional materials, contemporary design principles, and environmental consciousness can redefine affordable housing.


1. https://www.fetdeterra.com/en/proyecto/43-social-housing/
2. https://www.theplan.it/eng/award-2023-Housing/raw-rooms-social-housing-in-ibiza-guided-by-2030-agenda-peris-toral-arquitectes





Compressed Earth Blocks

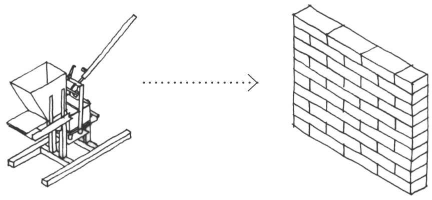
Case Study: Raw Rooms, 43 Housing Units

1) A precise mixture of local soils was prepared, mixed and placed into the mould of hydralic press. By operating the manual lever, the soil was compressed with a force of up to 15 tons, forming solid blocks before curing.

2) The blocks were prefabricated and brought to site. Above, a worker carefully aligns the first layer of blocks on a leveled base to ensure a stable foundation for subsequent layers.

5) Ensuring precise alignment and smooth joints between blocks is critical for achieving a seamless wall surface for the aesthetic and thermal performance of the walls.

6) Compressed earth blocks, prefabricated and lightweight at under 4 kilograms each, allow workers to efficiently handle and stack them manually without the need for heavy machinery.



3) Blocks are secured and aligned with vertical and horizontal reinforcements where necessary.

4) Walls are gradually built, layer by layer, following the design pattern depending on if it's an internal (single block) or external (double-layer block) wall.

7) Additional layers and blocks are placed and always secured with natural or lime-based mortar to create a durable bond.

8) Temporary props and scaffolding are installed to provide stability to the partially completed structure while additional layers are added.

Compressed Earth Blocks

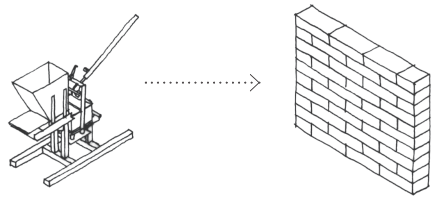
Case Study: Raw Rooms, 43 Housing Units

9) Workers finish constructing the vertical walls to their full height, preparing for the integration of structural floors or roofs.

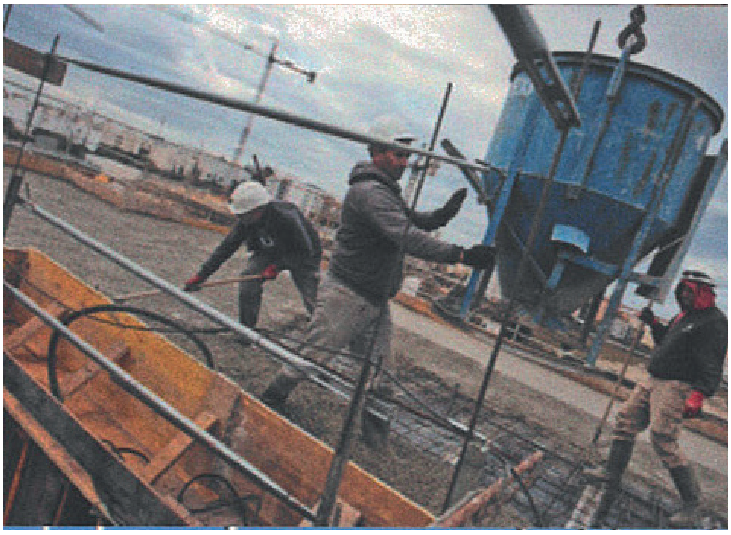
10) Assembly of precast floor system where precast concrete beams and hollow-core blocks are laid out on a strutctural framework for the floor slab.

13) The concrete is evenly distributed and compacted for the reinforced concrete slabs for the floors.

14) The process for the CEB walls and concrete floors is repeated until the last level.



11) Wooden blocks and boards are also lad out for the formwork, for the concrete to be poured over to form the soffit.



12) Concrete is poured into formwork using a concrete bucket attached to a crane. The steel reinforcement bars can be seen getting filled.

15) Workers distribute and level the locally-sourced ‘Posidonia oceanica’ seaweed insulation within the roof assembly framework.

16) The cork-based insulation panels are screwed to load-bearing CEB walls, before a lime plaster finish is applied.

https:// www.baunetzwissen.de/gesund-bauen/objekte/wohnen/wohnhaus-flury-in-deitingen-1556003

https://inspiration.detail.de/en/article/eco-friendly-house-in-deitingen-336

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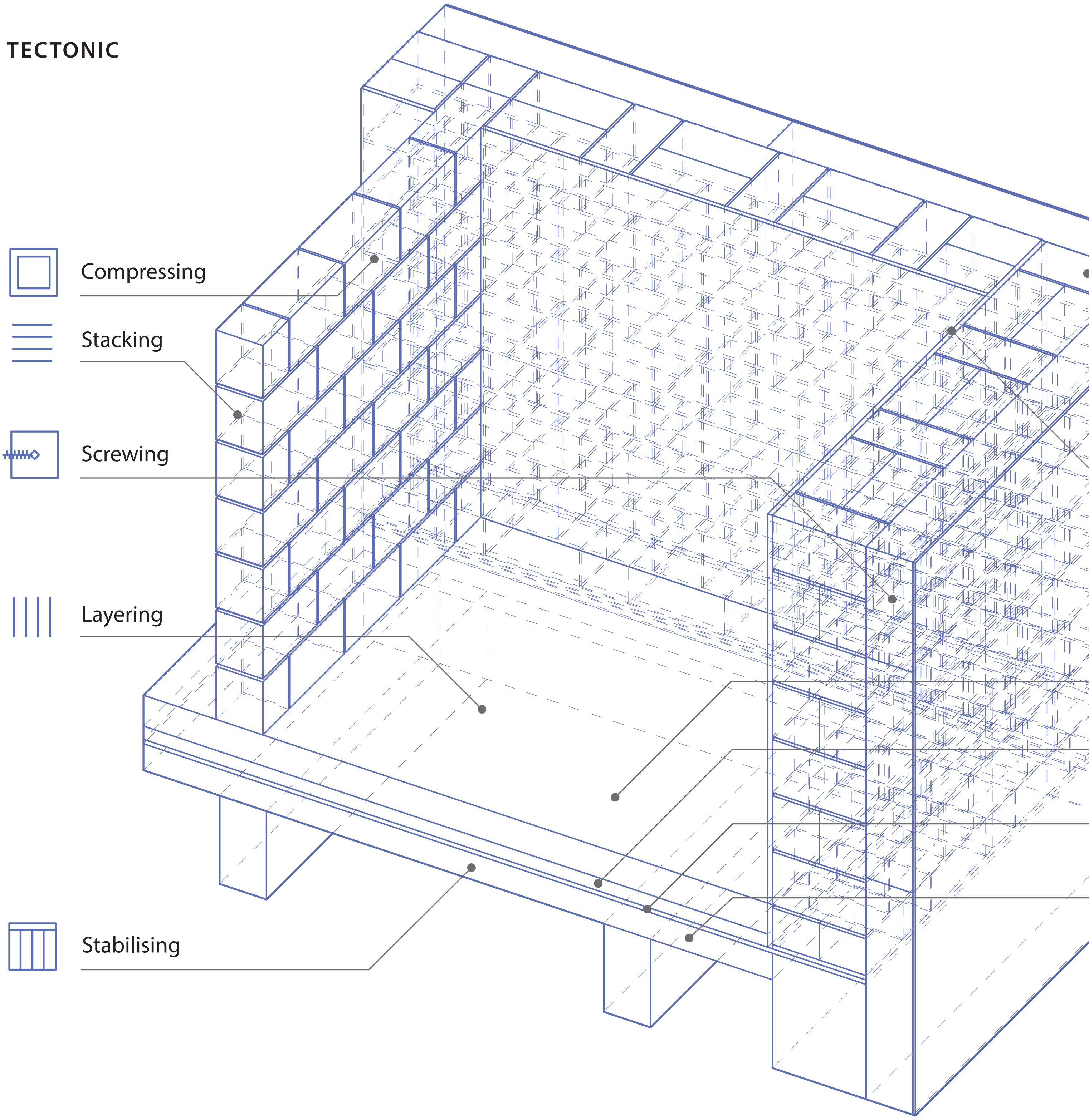
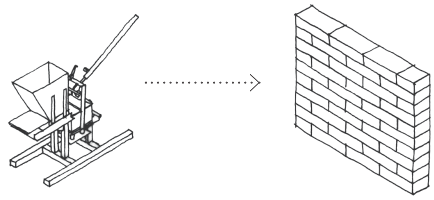
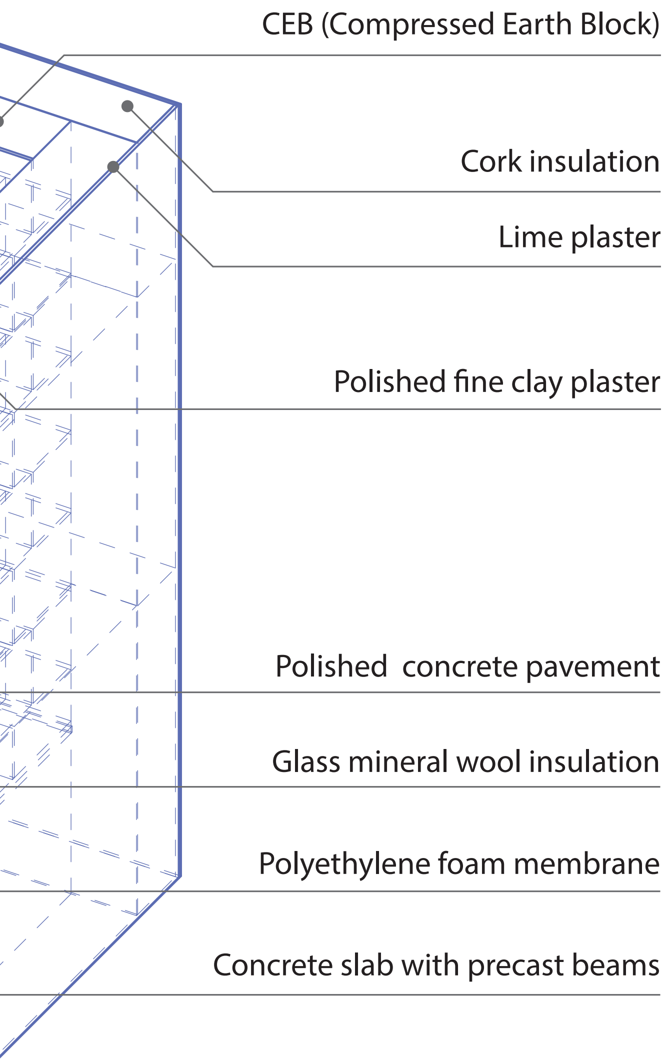
Tectonic Analysis

TECTONIC

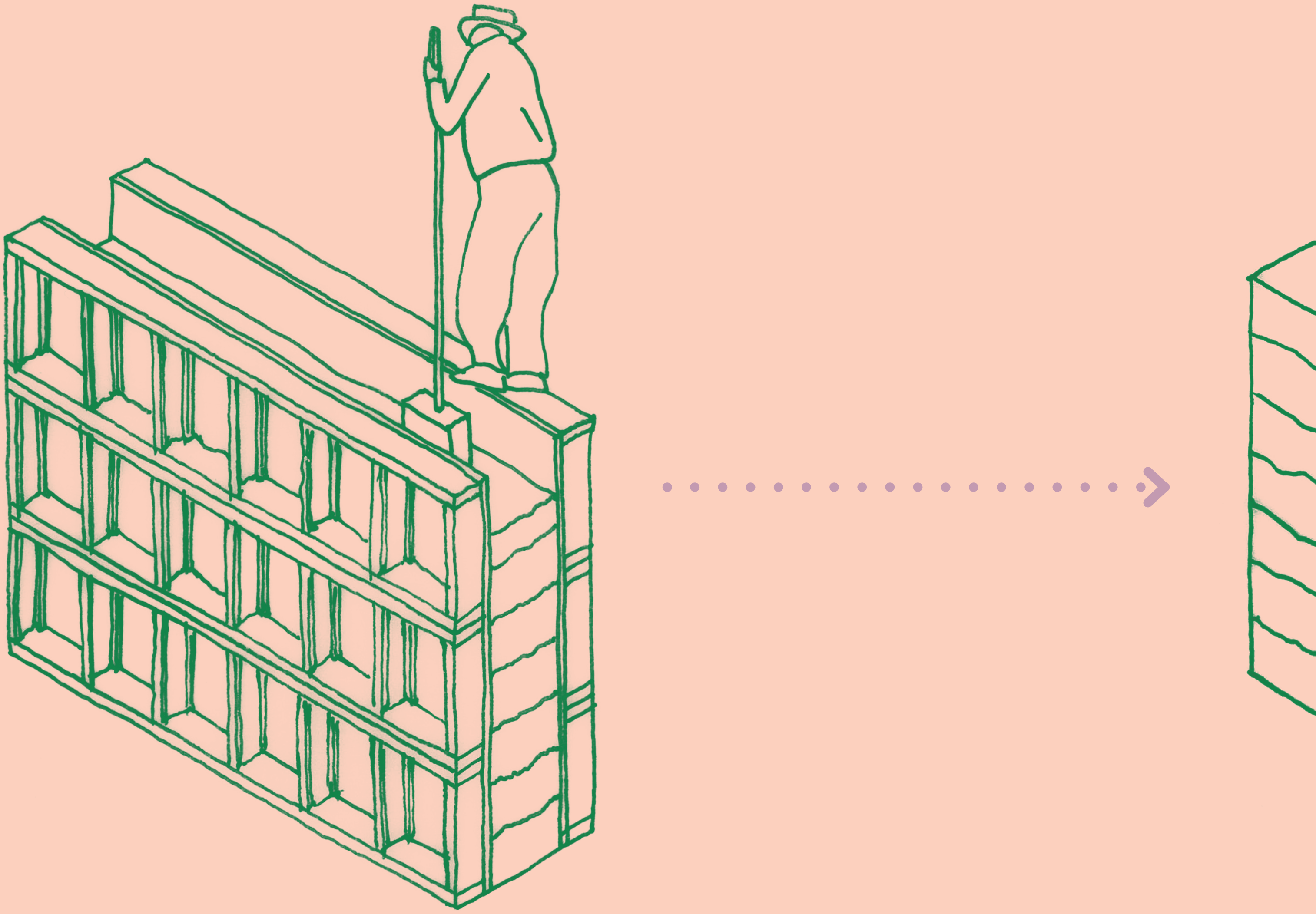




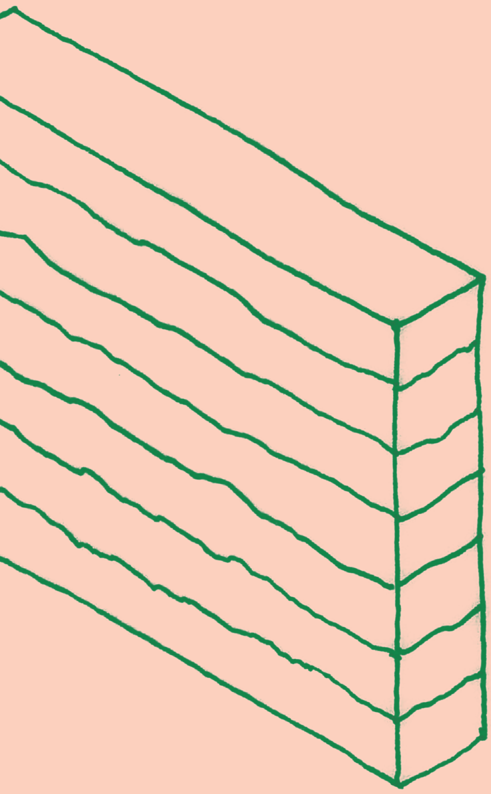
TECHNOLOGY



CEB (Compressed Earth Block)
Cork insulation
Lime plaster
Polished fine clay plaster
Polished concrete pavement
Glass mineral wool insulation
Polyethylene foam membrane
Concrete slab with precast beams



IN FORMWORK



TECHNIQUE: TAMPING

Tamping - Rammed Earth

Case Study: Public Protection Housing Palma

Location: Palma de Mallorca, Spain

Construction: 2021-2022

Gross internal foor area: 380 m²

Construction cost: Unknown

Architect: EDRA Arquitectura km0 and BUNYESC Architects

Client: Balearic Housing Institute (IBAVI)

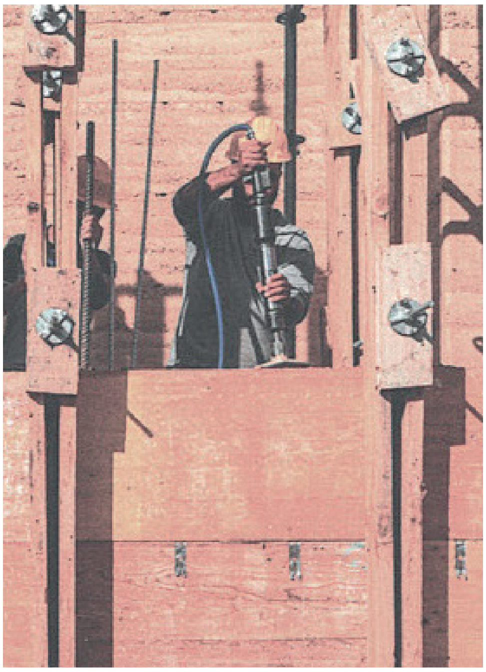
Structural engineer:

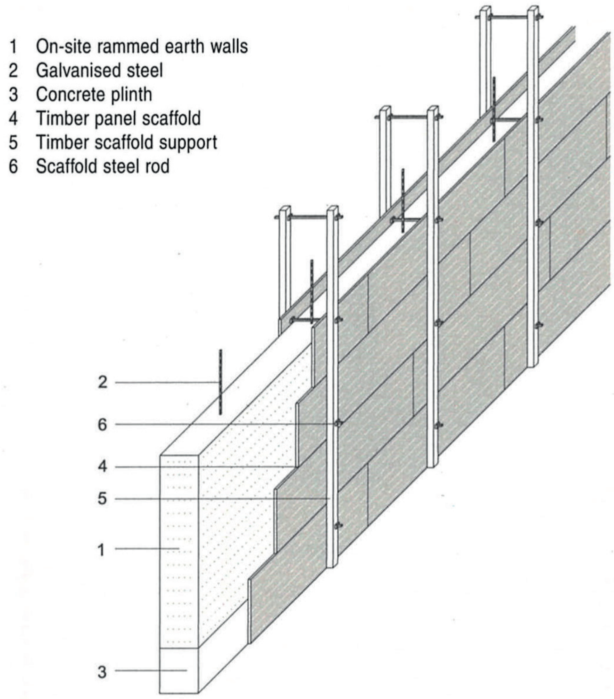
Earth construction:

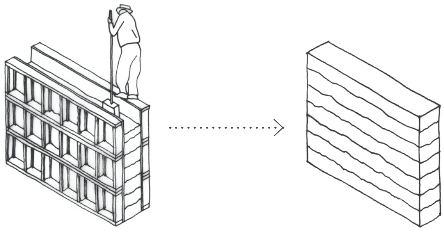
Annual CO2 emissions:

Embodied CO2:

The Viviendas de Protección Pública or Public Protection Housing in Palma de Mallorca is a sustainable public housing project featuring six rental units designed with a bioclimatic approach. The building centers around a rammed-earth core for thermal mass, wrapped in a double wooden facade that adapts to different orientations for insulation and ventilation. The south-facing facade functions as a passive solar collector with deciduous vegetation for shading. Local, eco-friendly materials such as rammed earth from excavation sites, pine wood from regional forests, and Posidonia Oceanica seaweed for roof insulation reduce the building's carbon footprint while fostering the local economy through partnerships with area craftsmen and suppliers. This approach combines sustainability, energy efficiency, and environmental stewardship with community-oriented construction practices.







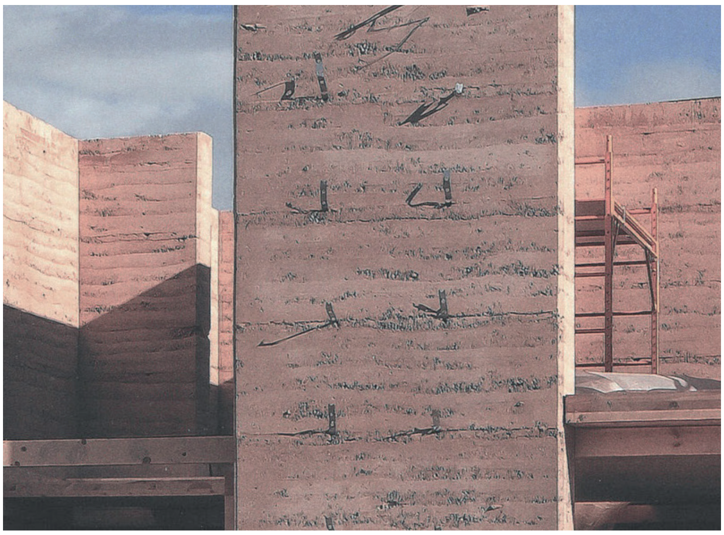

IBAVI
6 HABITATGES
DE PROTECCIÓ
A LA RIBERA
www.ibavi.com

Tamping - Rammed Earth

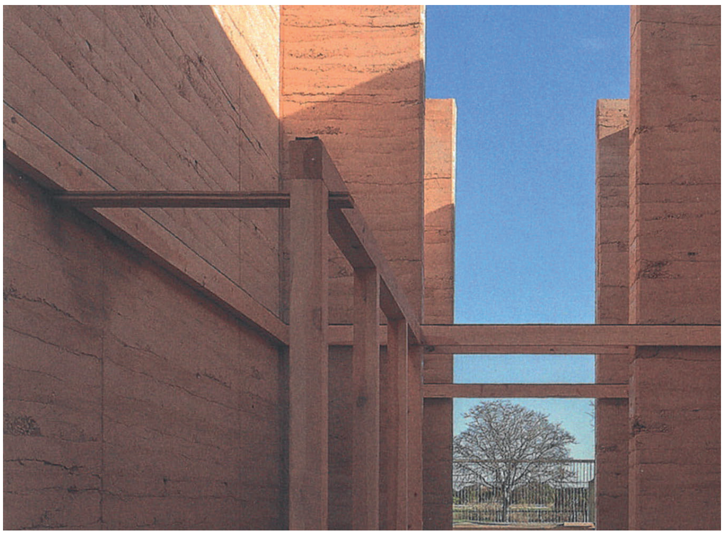
Case Study: Public Protection Housing Palma

1) A reinforced concrete foundation and plinth are laid to protect the rammed earth walls from ground moisture and ensure structural stability. It also ensures a level surface for the walls.

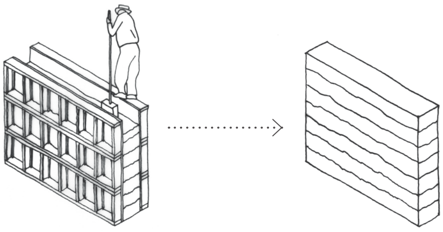
2) Wooden formwork panels are installed, supported by timber scaffolds and steel scaffold rods going through them for bracing. These define the shape and dimensions of the rammed earth walls (30 cm thickness).

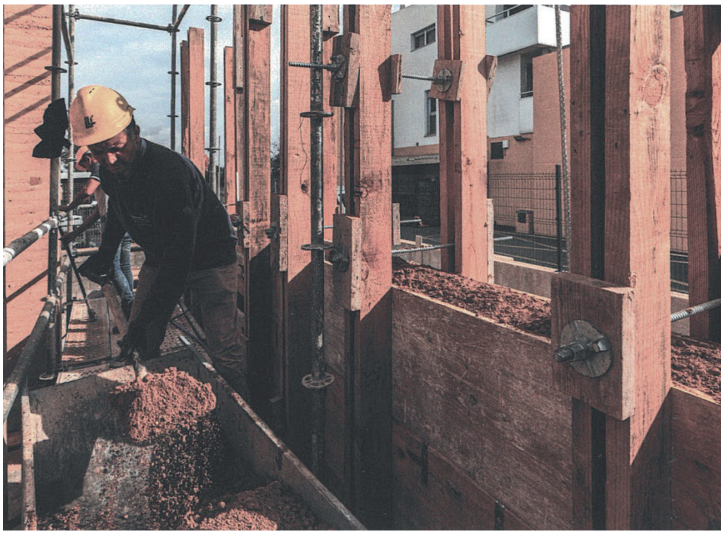


5) Throughout the construcction of the walls, steel brackets or plates are embedded into the rammed earth which act as anchor points.



6) The timber beams are secured to these anchor points and the timber frame for the partition walls are added.





3) Within the earth, galvanised steel rods are added for added reinforcement. Excavated earth, with the appropriate moisture content and composition, is shoveled into the formwork in layers of uniform thickness (e.g., 10–15 cm per layer). The soil mix may include binders such as lime or clay

4) Each layer of soil is compacted using a mechanical rammer to achieve the desired density and strength. This tool increases efficiency and reduces labor effort, compared to traditional manual rammers.

7) The supporting CLT floor slabs are then added to the supporting timber beams

8) The timber CLT roof slab is lifted by a crane. From the inside, a worker assists in aligning the slab accurately with the structural elements, ensuring a precise fit and proper positioning.

Scans from book: El Croquis 219 IBAVI 2019 2023, pages 260-267

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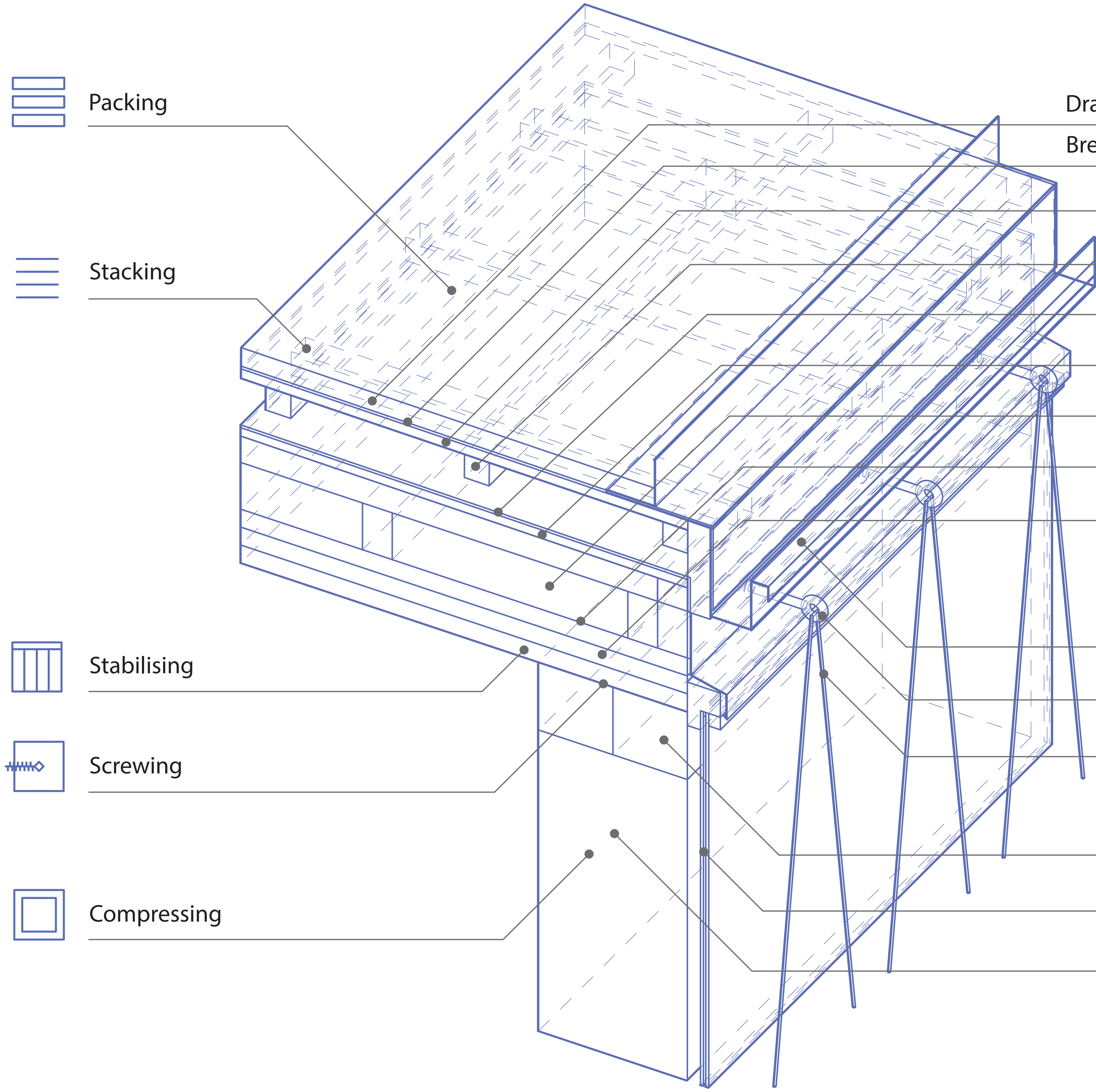
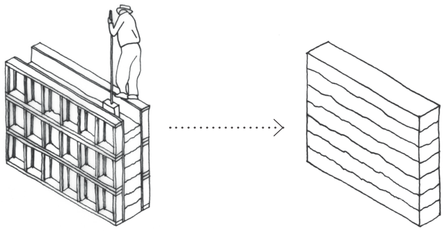
3

Tectonic Analysis

TECTONIC





TECHNOLOGY

ainage layer, crushed marès stone

eathable + waterproof membrane

Waterproof timber board

Battens, cross-battens

Vapour barrier

Waterproof timber board

Posidonia seagrass insulation

Vapour barrier

Cross-laminated timber

Gutter

Metal support hooks

Steel wire for vegetation

Timber beams

Glass for solar gains

Rammed earth wall