Monolith

100% Hemp & Lime

Tom Boom

19-05-2025

Monolith

One Stone

structure or object made from a
single, solid piece of material

(Sturgis & Davis, 2013)

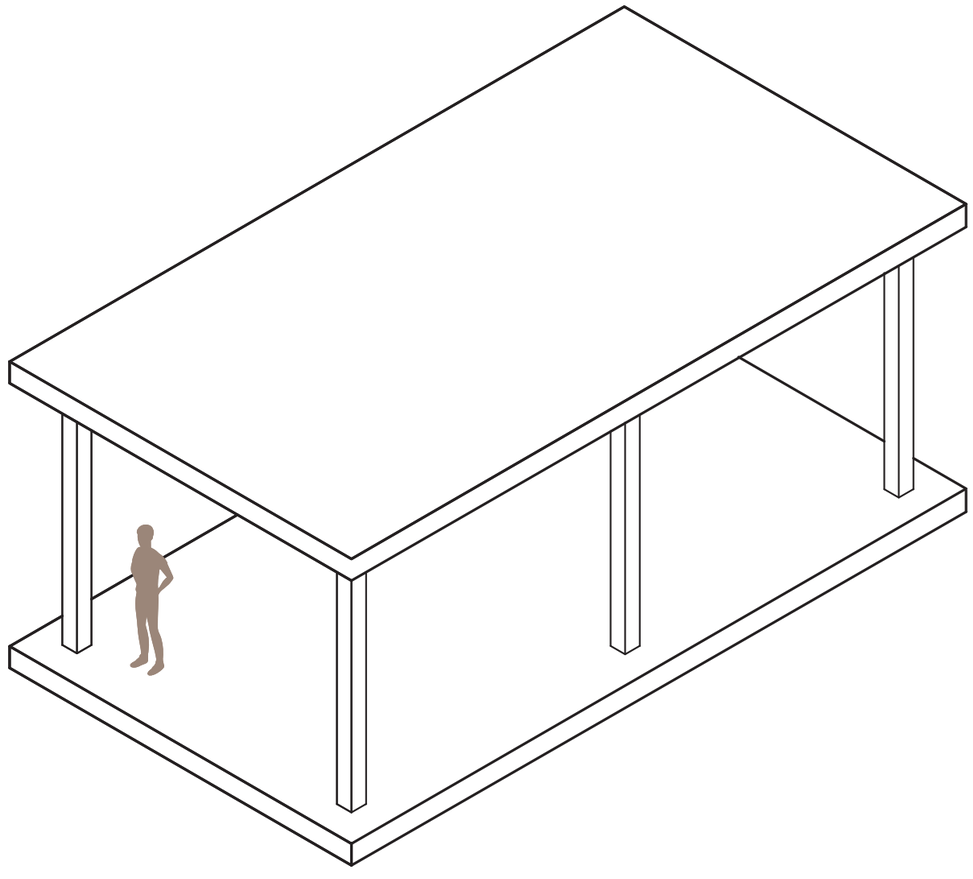
Monolithic

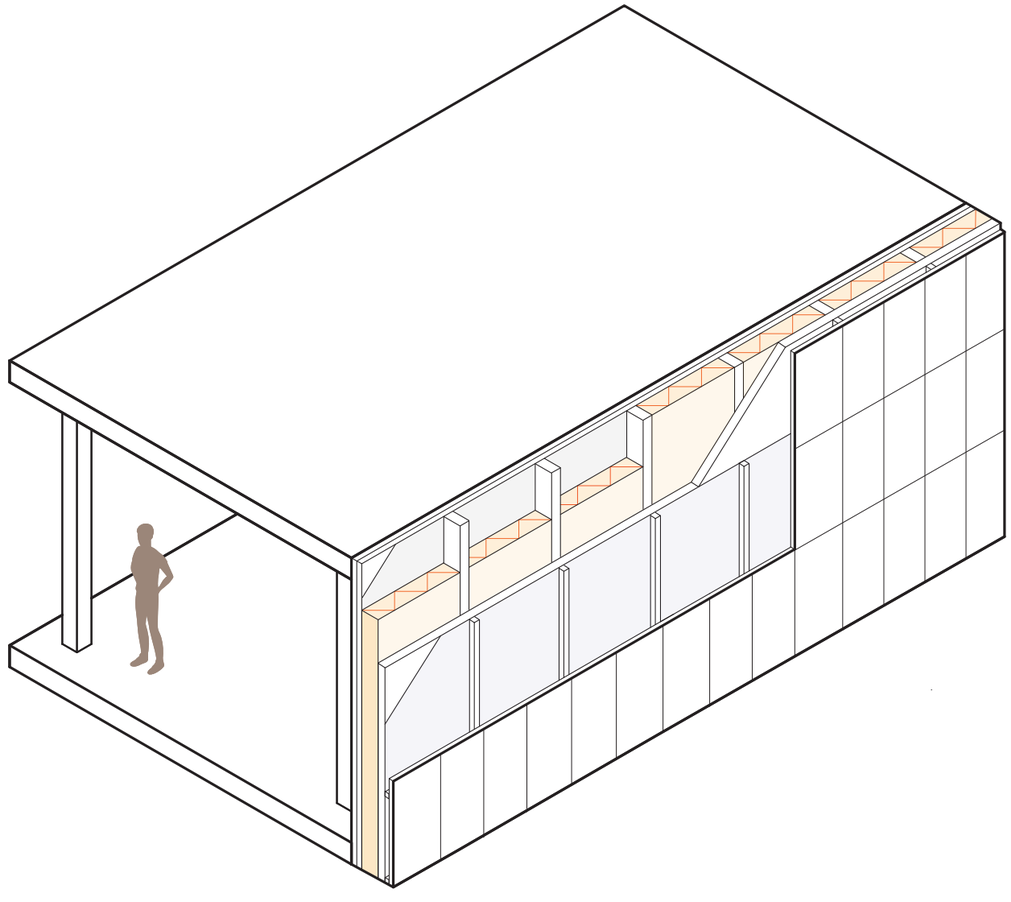
Architecture

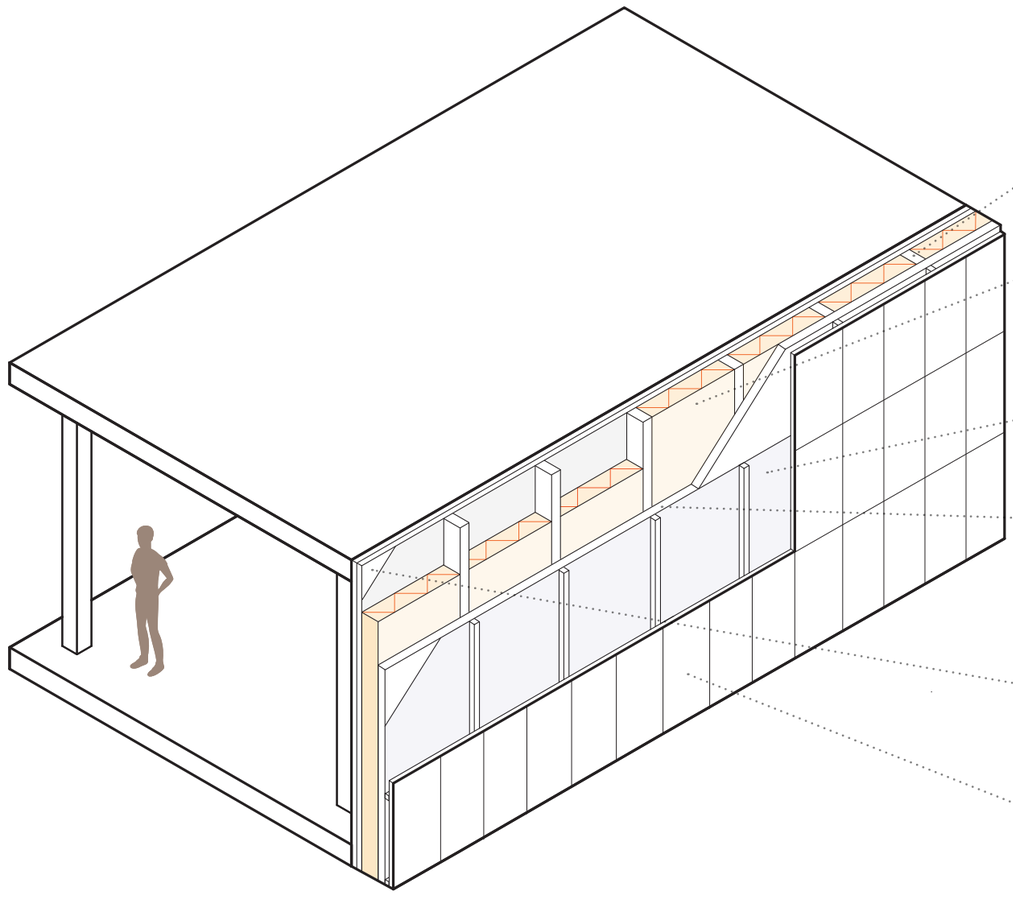
Ait-Ben-Haddou, Marocco. Photograph by Sia, Iwanderlista

Modern

Architecture







Structural
support

Insulation
thermal

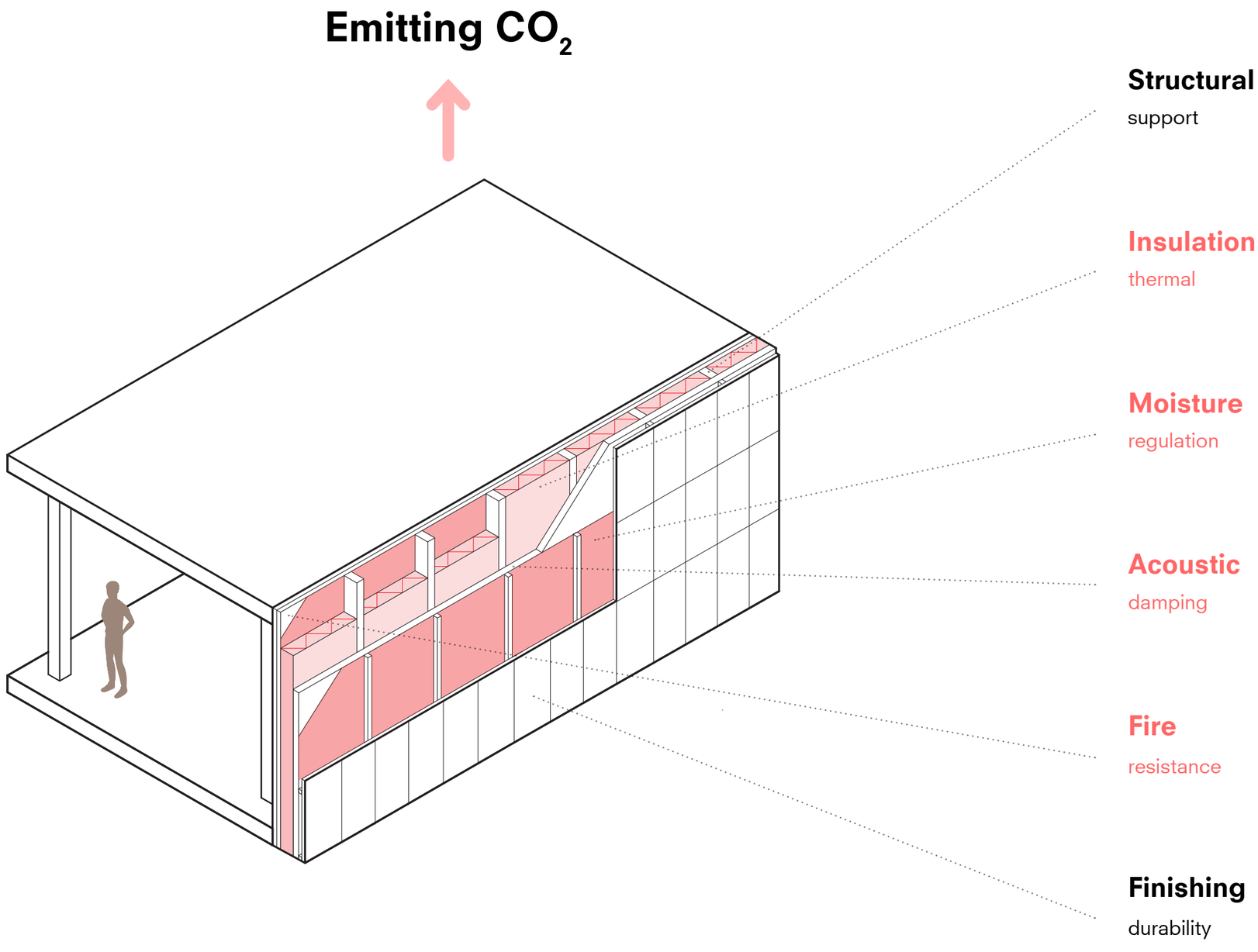
Moisture
regulation

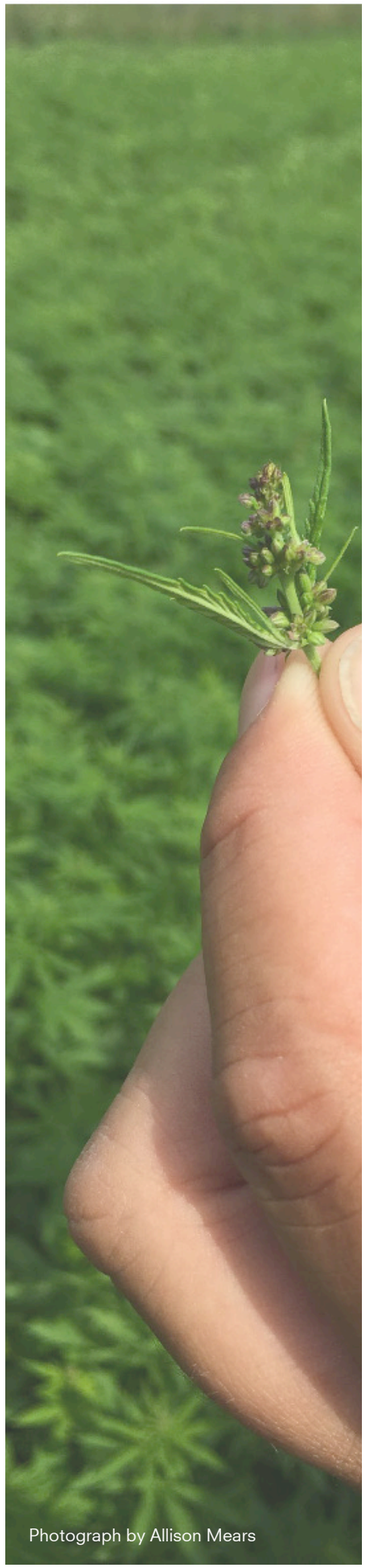
Acoustic
damping

Fire
resistance

Finishing
durability

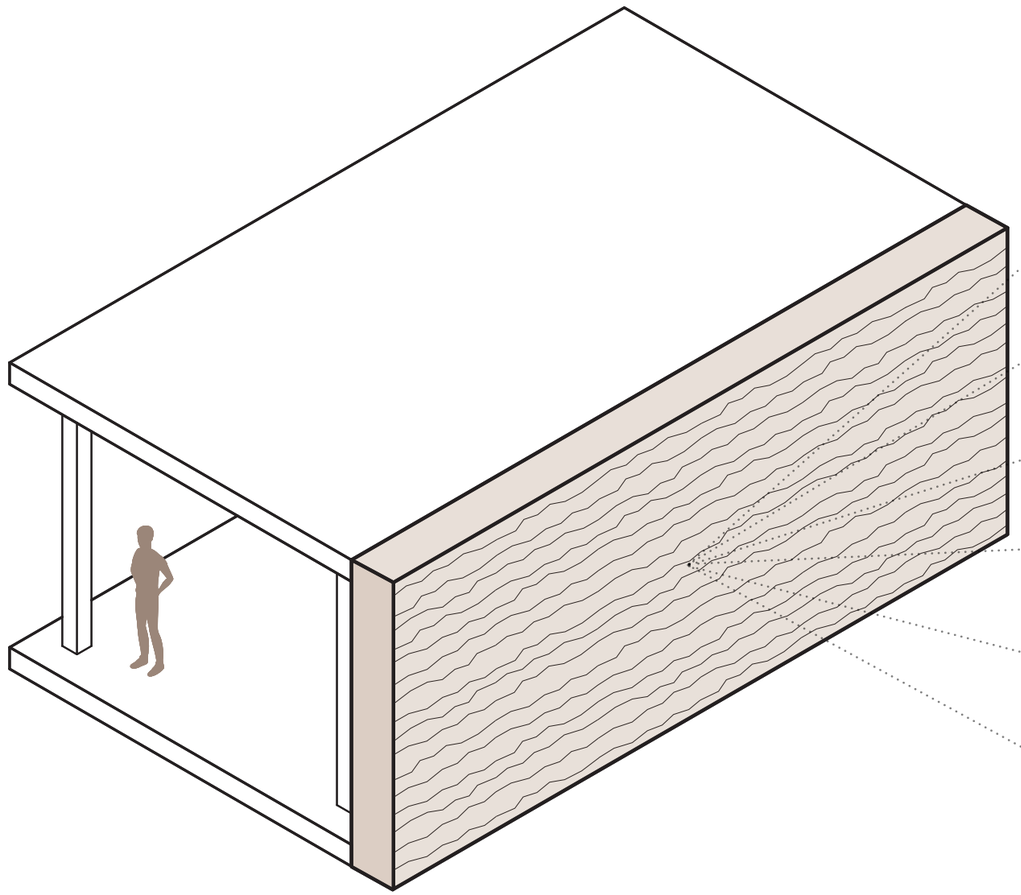
Photograph by Michelle Claire Gevint





Photograph by Allison Mears

Storing CO_2



Structural
support

Insulation
thermal

Moisture
regulation

Acoustic
damping

Fire
resistance

Finishing
durability

Hempcrete

Hemp + Lime

Industrial Hemp

Grown locally

Quickly renewable

Hemp Shiv

Flowers

- Pharmaceuticals
- Cosmetics

Seeds

- Food (proteins)
- Oil
- Ink

Shivs

- Mulch
- Fiberboard
- **Hempcrete**

Fibers

- Netting
- Canvas
- Carpet
- Clothes
- Bio composites
- Insulation

Stalks

- Biofuel
- Paper products
- Cardboard

Source: Parsons Healthy Materials Lab

Lime

Sourced in Europe

Easily accessible

Types of Lime

Air Lime

Hardens by reacting with air (CO_2)

Hydraulic Lime

Hardens by reacting with water

The Mix

Photograph by Hempitecture

Cast-in-situ

Project: De Twee Snoeken & EcoBouwSalland

Project: De Twee Snoeken & EcoBouwSalland

Structural
support

Insulation
thermal

Moisture
regulation

Acoustic
damping

Fire
resistance

Finishing
durability

CO_2 negative

Project: De Twee Snoeken & EcoBouwSalland

Structural
support

Insulation
thermal

Moisture
regulation

Acoustic
damping

Fire
resistance

Finishing
durability

Life Cycle Analysis

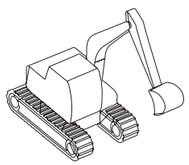
Resource	Manufacturing	Use	End of Life

65%

Hemp

-38 kg

($kgCO_2eq/FU$)



35%

Lime

+16 kg

($kgCO_2eq/FU$)

-22 kg

($kgCO_2eq/FU$)

Source: B-EPD EXIE CaNaDry

Life Cycle Analysis

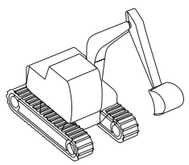
Resource	Manufacturing	Use	End of Life

65%

Hemp

-38 kg

(kgCO_2eq/FU)



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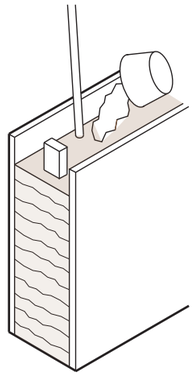


Source: B-EPD EXIE CaNaDry

Life Cycle Analysis

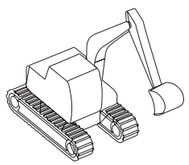
Resource	Manufacturing	Use	End of Life

65%

Hemp

-38 kg

(kgCO_2eq/FU)



35%

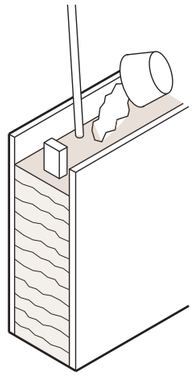
Lime

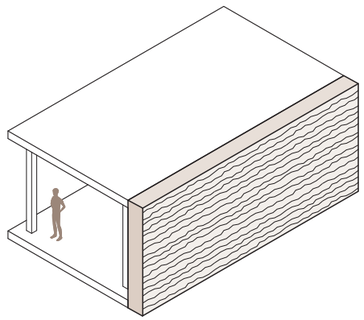
+16 kg

(kgCO_2eq/FU)

-22 kg

(kgCO_2eq/FU)





Source: B-EPD EXIE CaNaDry

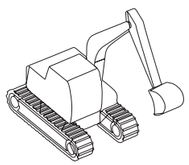
Life Cycle Analysis

65%

Hemp

-38 kg

($kgCO_2eq/FU$)



35%

Lime

+16 kg

($kgCO_2eq/FU$)

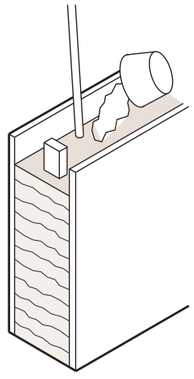
Resource	Manufacturing	Use	End of Life

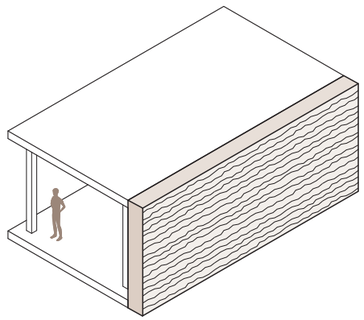
25% Incineration

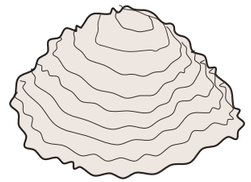
75% recycling

-22 kg

($kgCO_2eq/FU$)







=

-14 kg

($kgCO_2eq/FU$)

Source: B-EPD EXIE CaNaDry

Structural
support

Insulation
thermal

Moisture
regulation

Acoustic
damping

Fire
resistance

Finishing
durability

Let’s build those hemp walls!!

In other words:

How can a monolithic hempcrete wall be manufactured

in a way that reliable material performance is ensured?

Let’s build those hemp walls!!

In other words:

How can a monolithic hempcrete wall be manufactured in a way that reliable material performance is ensured?

→ **Challenge**

Let’s build those hemp walls!!

Project: HOP Architecten & YOMABOUW

Challenges

Manual
workflow

Subjective
compaction

Density
gradient

Uncontrolled
curing conditions

Project: HOP Architecten & YOMABOUW

Challenges

Manual
workflow

Subjective
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Project: HOP Architecten & YOMABOUW

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Project: De Twee Snoeken & EcoBouwSalland

Challenges

Manual
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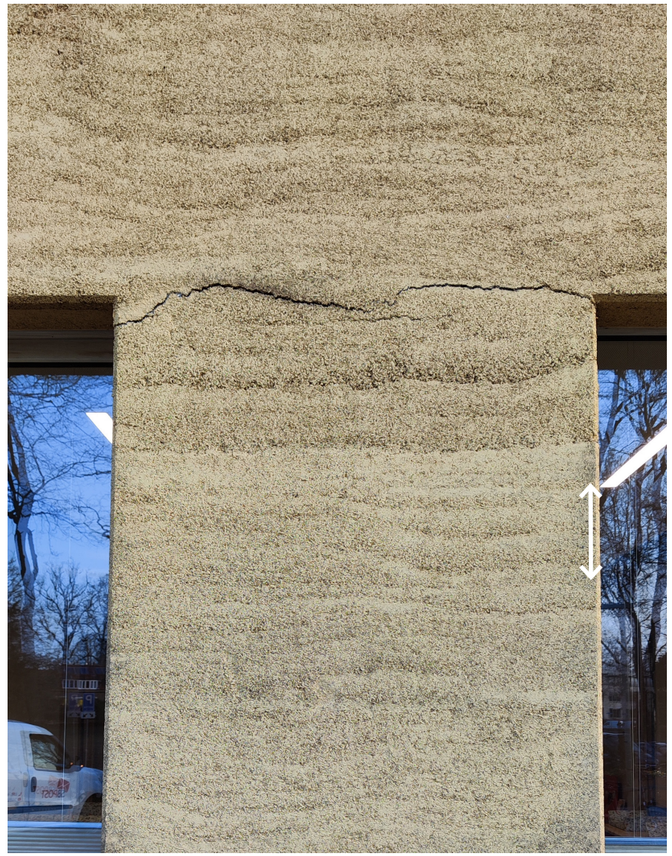
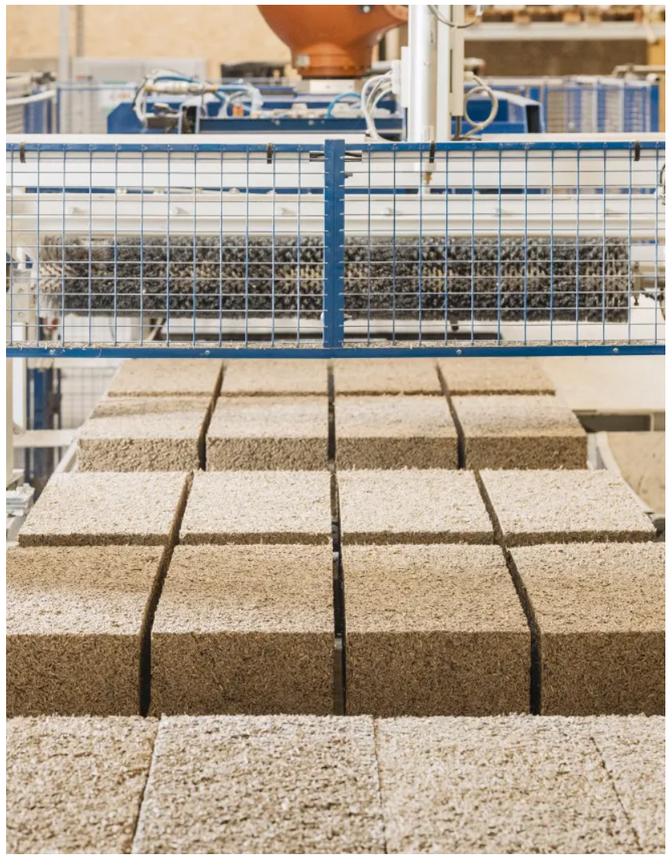


Project: De Twee Snoeken & EcoBouwSalland

Prefab?

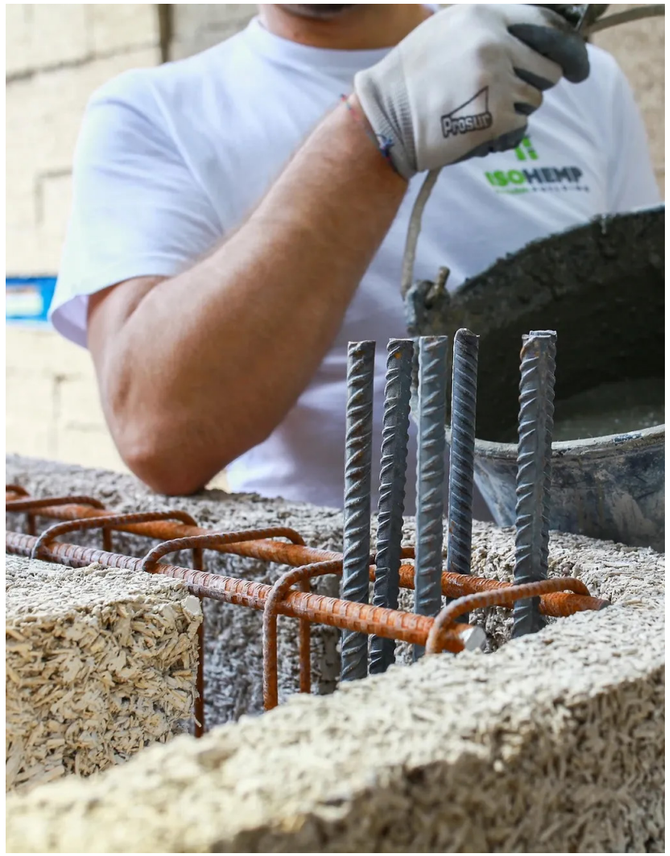
Hempcrete

Blocks



Source: IsoHemp

Blocks



Source: IsoHemp

Project: HOP Architecten & YOMABOUW

Project: Giesen Architecten & YOMABOUW

Robotic Rammed **Earth**

Photograph by Sia, Iwanderlista

Robotic **Rammed Earth**

Photograph by BC Materials

Robotic Rammed Earth

Lehm Ton Erde, Martin Rauch. Photograph by Hanno Makowitz

Robotic Rammed Earth

Lehm Ton Erde, Martin Rauch. Photograph by Hanno Makowitz

Robotic Rammed Earth

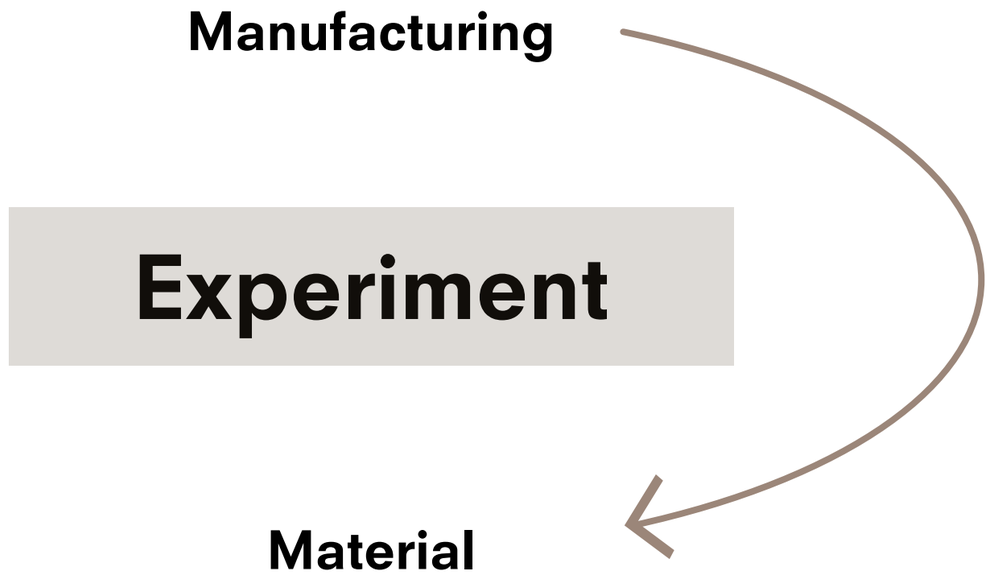
Lehm Ton Erde, Martin Rauch. Photograph by Hanno Makowitz

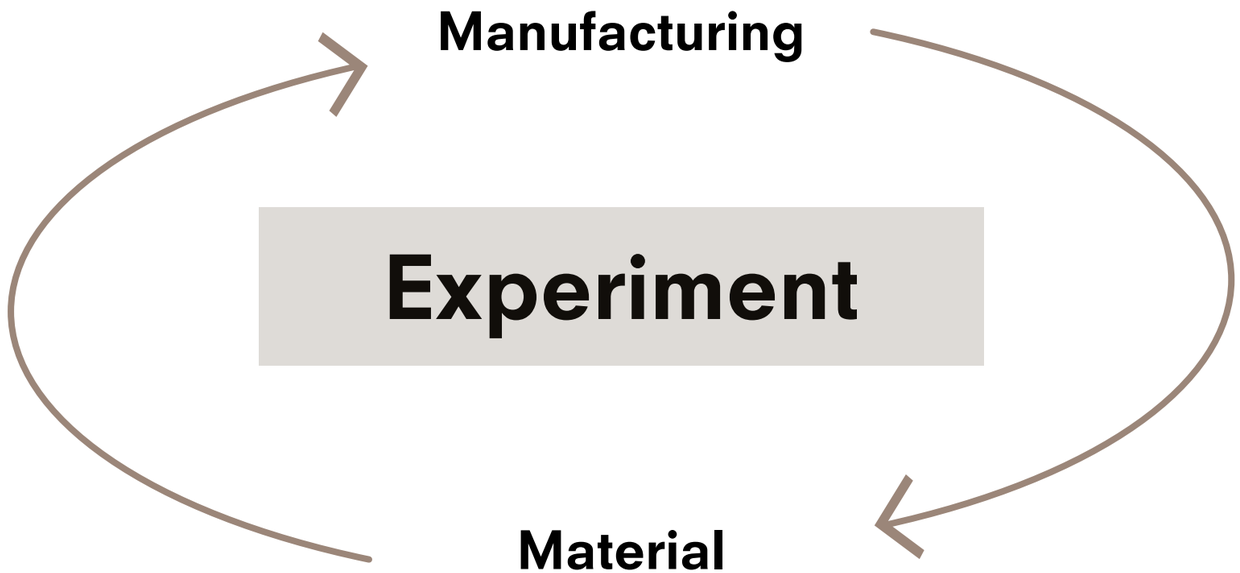
Robotic Rammed Hempcrete?

Manufacturing

How can a monolithic hempcrete wall be manufactured in a way that reliable material performance is ensured?

Material


Manufacturing
Experiment
Material


Manufacturing
Experiment
Material


Pure
Hemp and Lime

Considerations

Experiment Design

Binder
Material

Compaction
Manufacturing

Layer Height
Manufacturing

Orientation
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

B Binder

Material

Compaction

Manufacturing

Layer Height

Manufacturing

Orientation

Manufacturing

Transportation

Manufacturing

Carbon Footprint

Manufacturing

Air Lime

CaNaCrete (EXIE)

Air + Hydraulic Lime

ProKalk (IsoHemp)

B **Binder**
Material

C **Compaction**
Manufacturing

Layer Height
Manufacturing

Orientation
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

C (%) | 10% | 33% | 50% | 60%

B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

Orientation
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

Photos by Pia Fisher

L (cm) | **5 cm** | **10 cm** | **20 cm** | **30 cm**

B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

Orientation
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

B **Binder**
Material

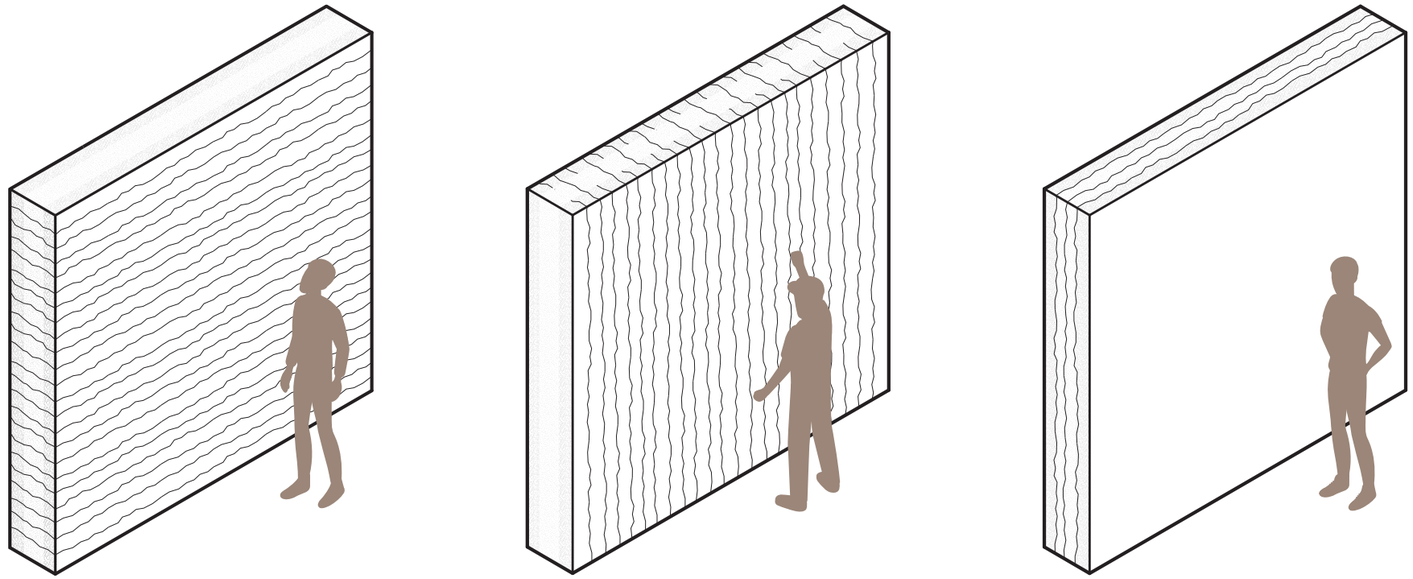
C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing



Top **Side** **Front**

B **Binder**
Material

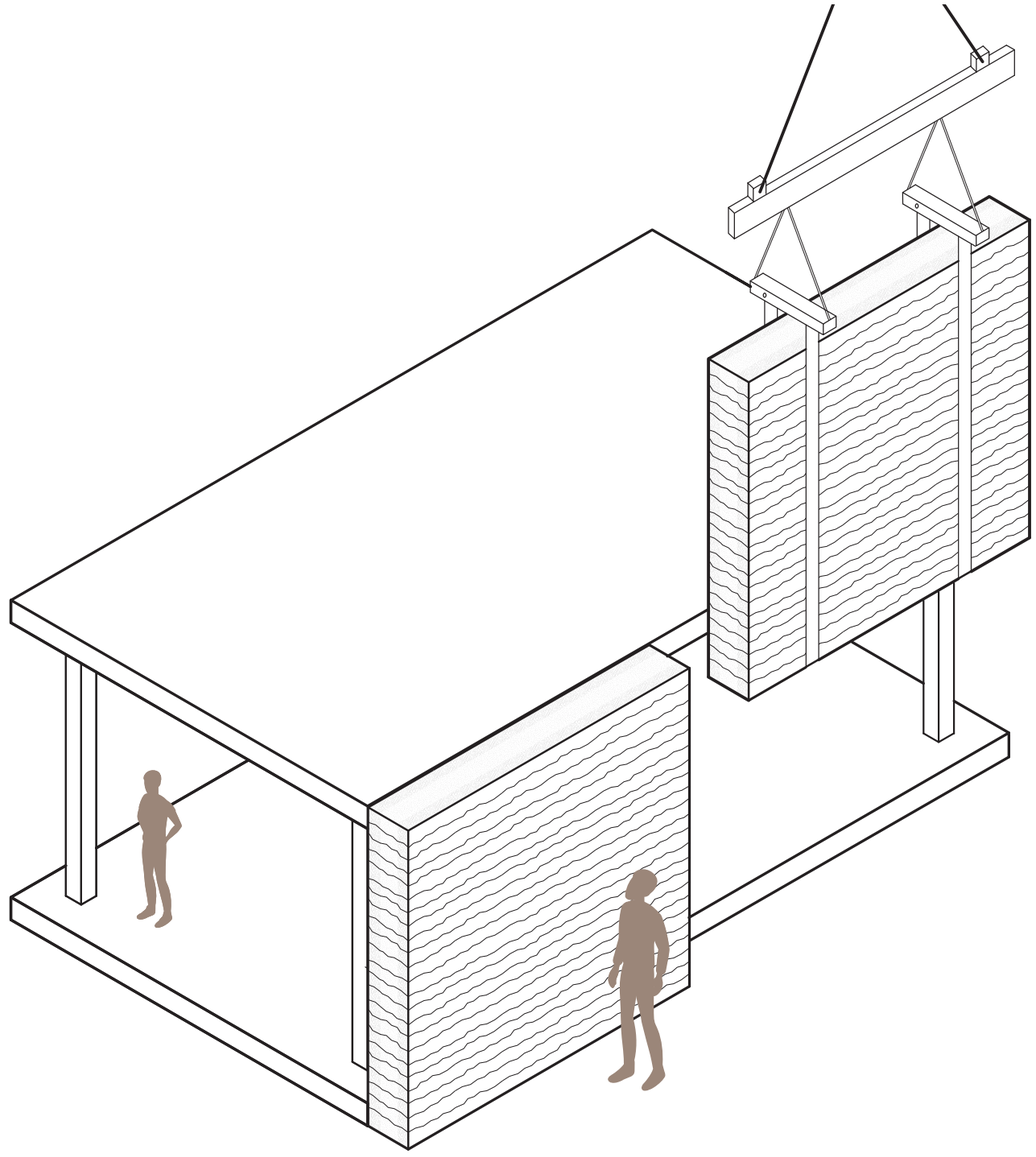
C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing



B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

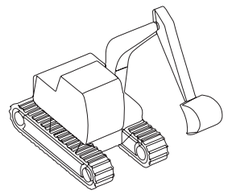
Carbon Footprint
Manufacturing

65%

Hemp

- 38 kg

(kgCO_2eq/FU)



35%

Lime

+16 kg

(kgCO_2eq/FU)

- 22 kg

(kgCO_2eq/FU)

B/H ratio	**0.54**
Density	**175** kg/m³

Source: B-EPD EXIE CaNaDry

B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

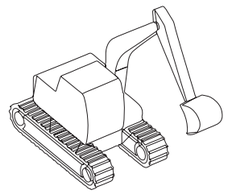
Carbon Footprint
Manufacturing

?%

Hemp

?

(kgCO_2eq/FU)



?%

Lime

?

(kgCO_2eq/FU)

B/H ratio	?	
Density	?	kg/m^3

?

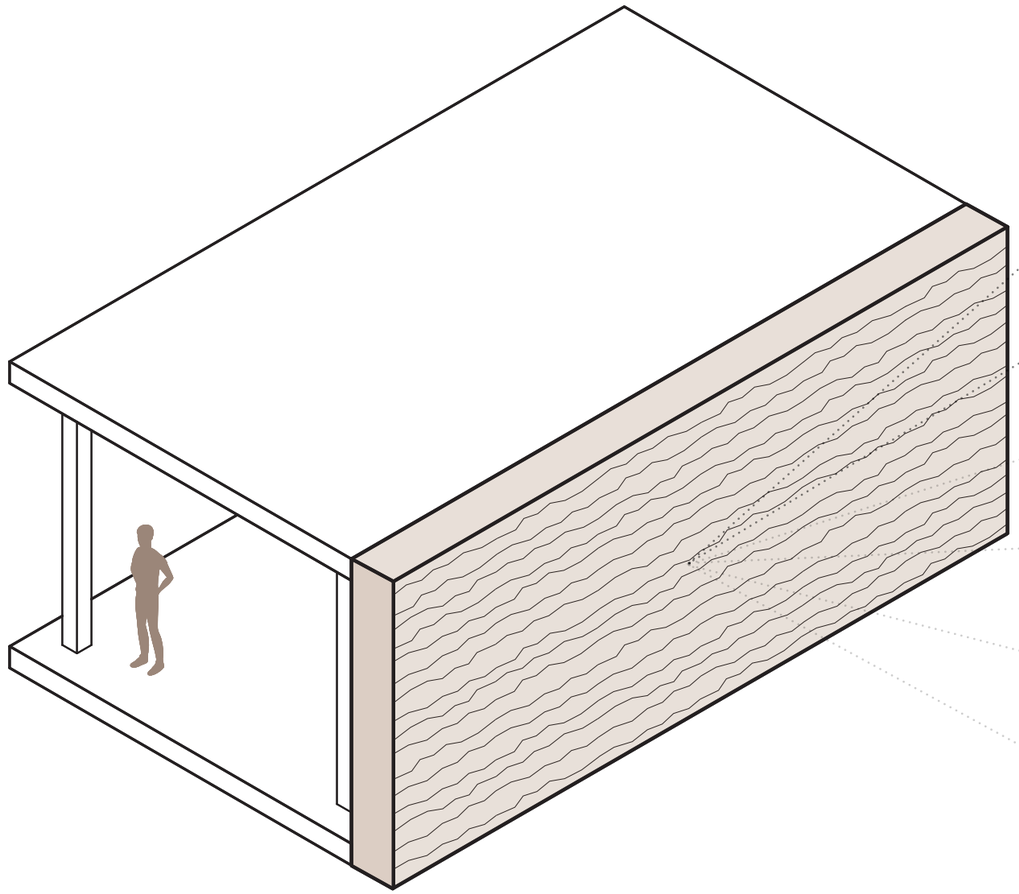
(kgCO_2eq/FU)

B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing



Structural
support

Insulation
thermal

Moisture
regulation

Acoustic
damping

Fire
resistance

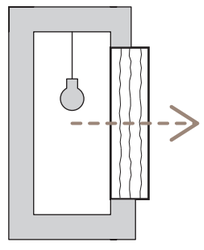
Finishing
durability

Hotbox
Thermal Conductivity

Compressive
Compressive Strength

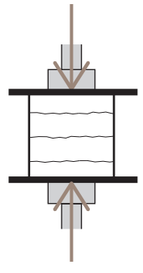
4 Point Bending
Bending Strength

B	**Binder** Material	?	?	?
C	**Compaction** Manufacturing	?	?	?
L	**Layer Height** Manufacturing	?	?	?
O	**Orientation** Manufacturing	?	?	?



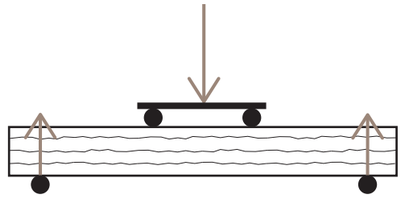
Hotbox

Thermal Conductivity



Compressive

Compressive Strength



4 Point Bending

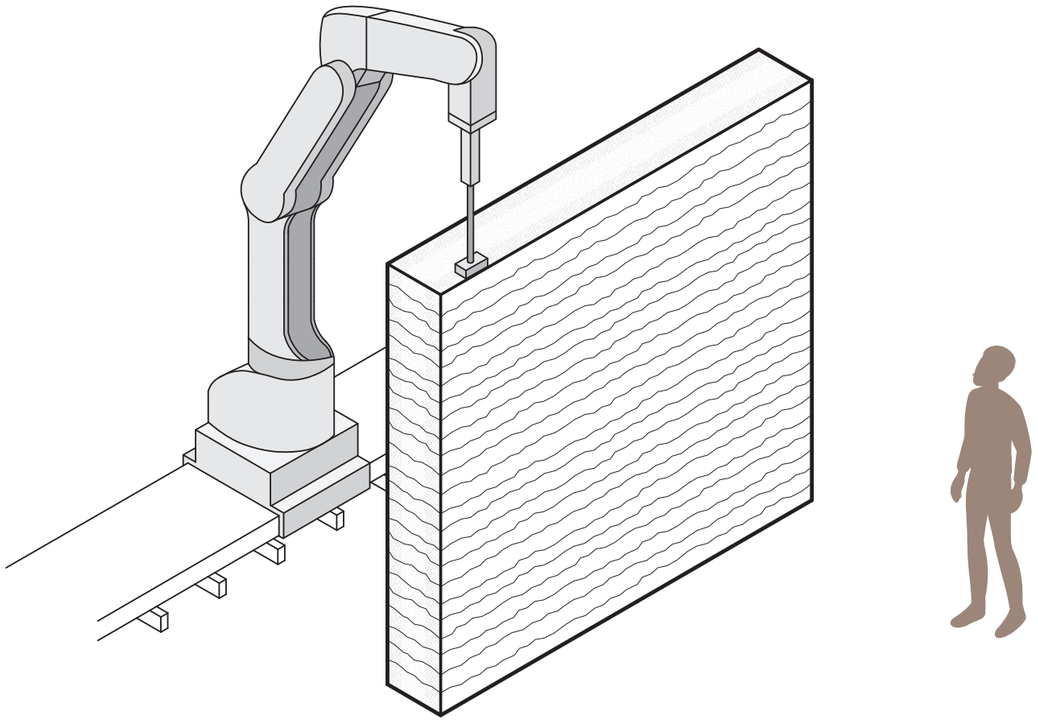
Bending Strength

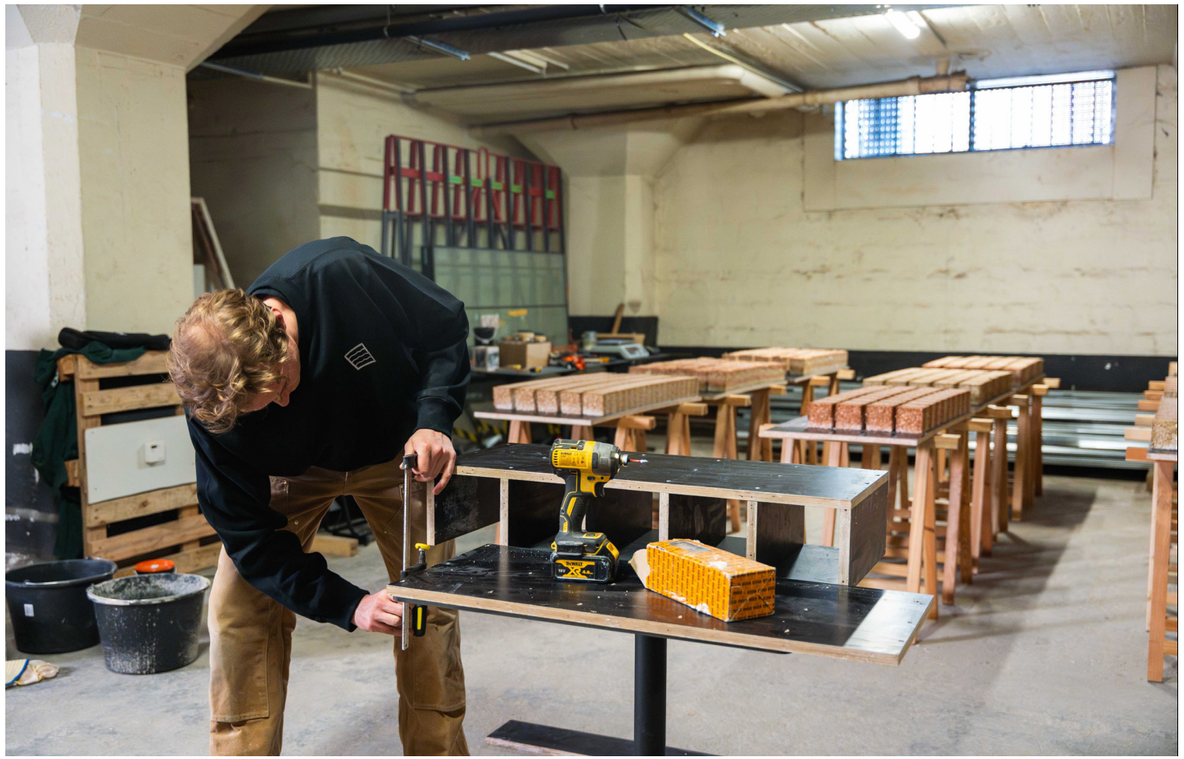
Production

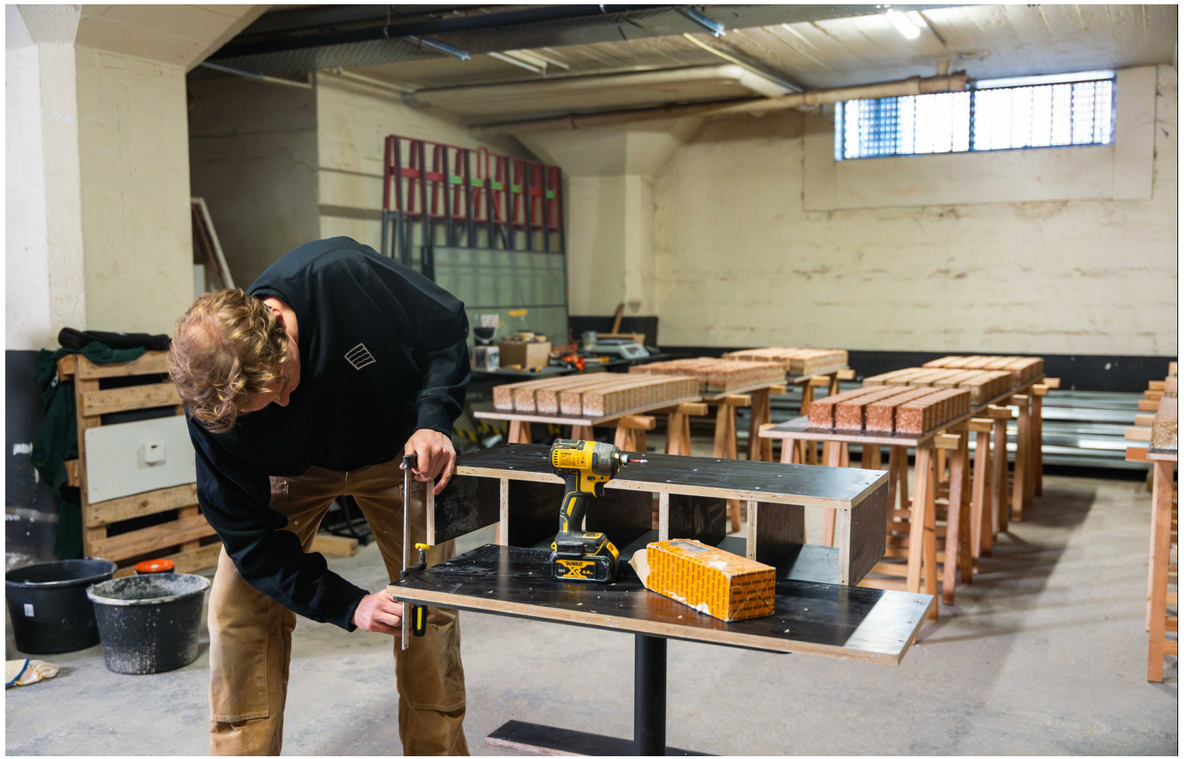
Samples

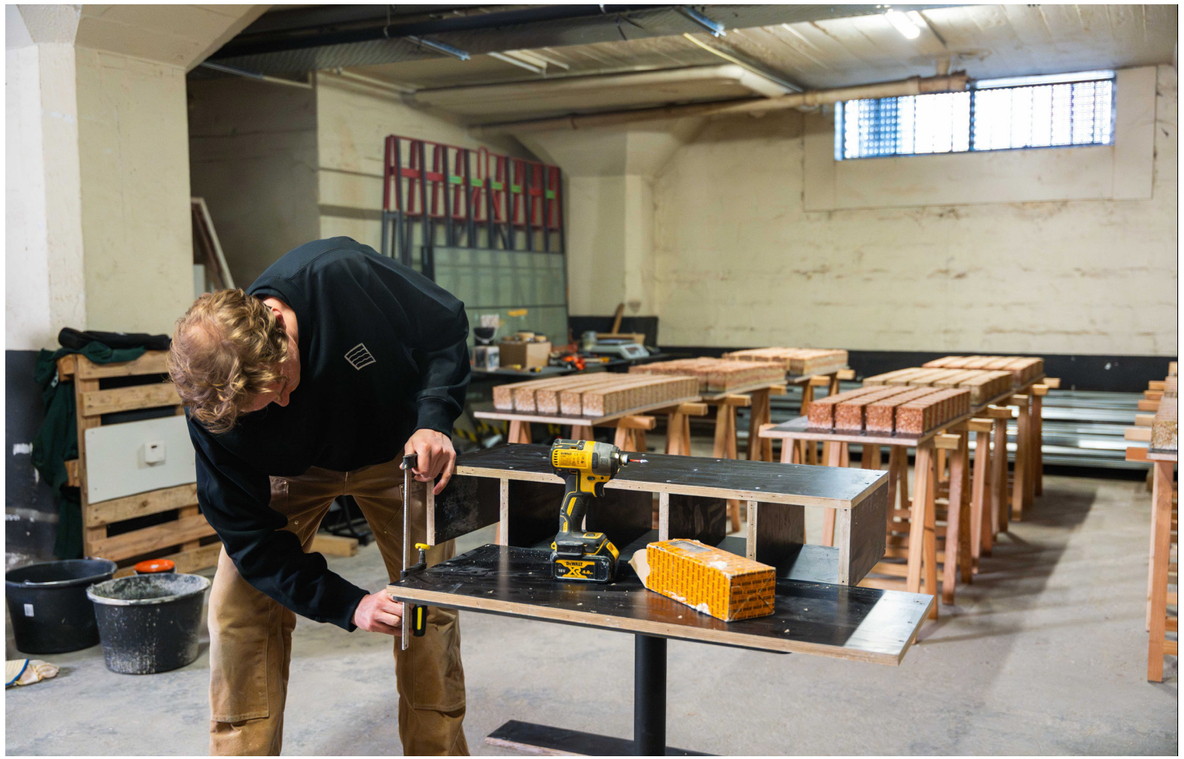
Production Site

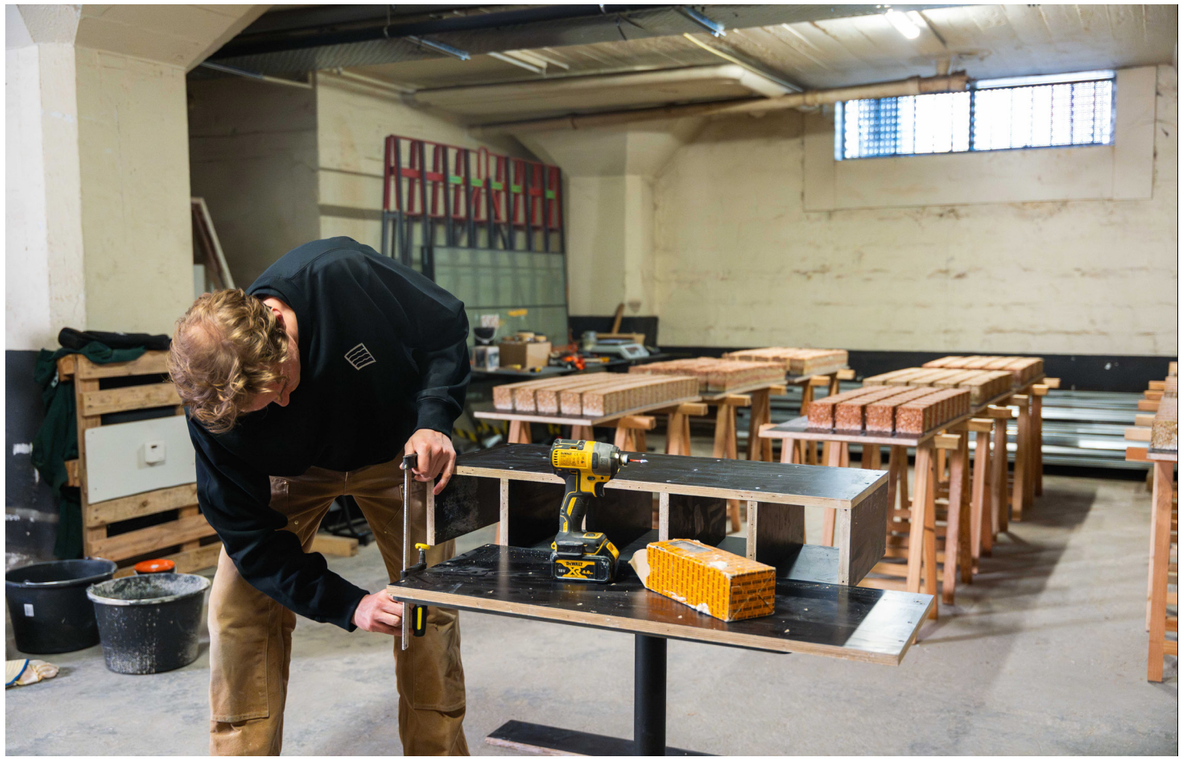
Production Machine











7 Configurations

3 Orientations

3 Geometries

113 Samples

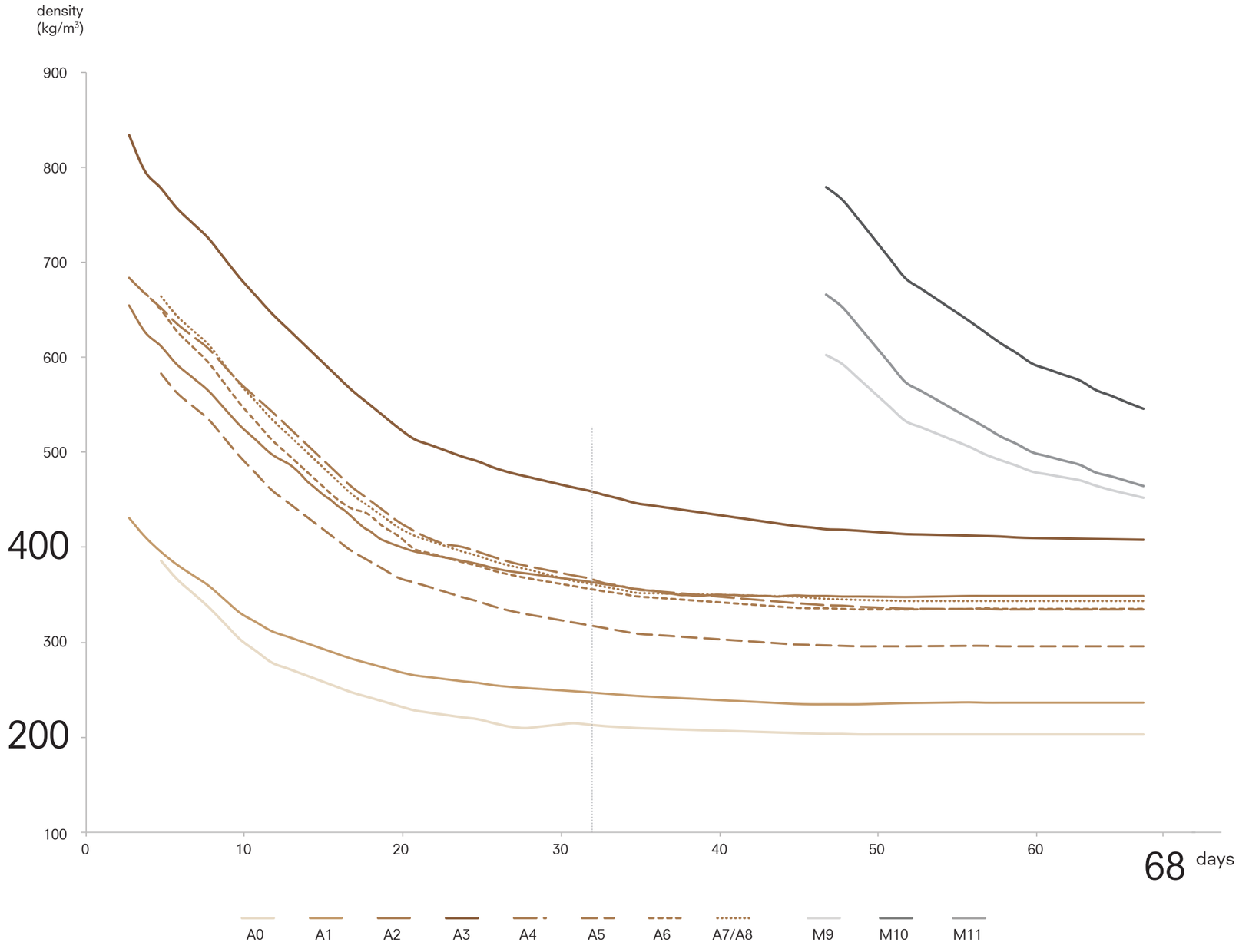
Testing

Performance

Dry Density

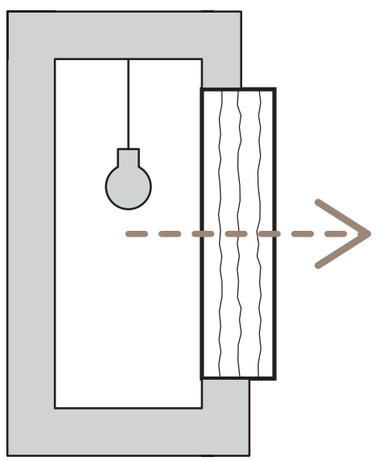
Dry Density

Timeline



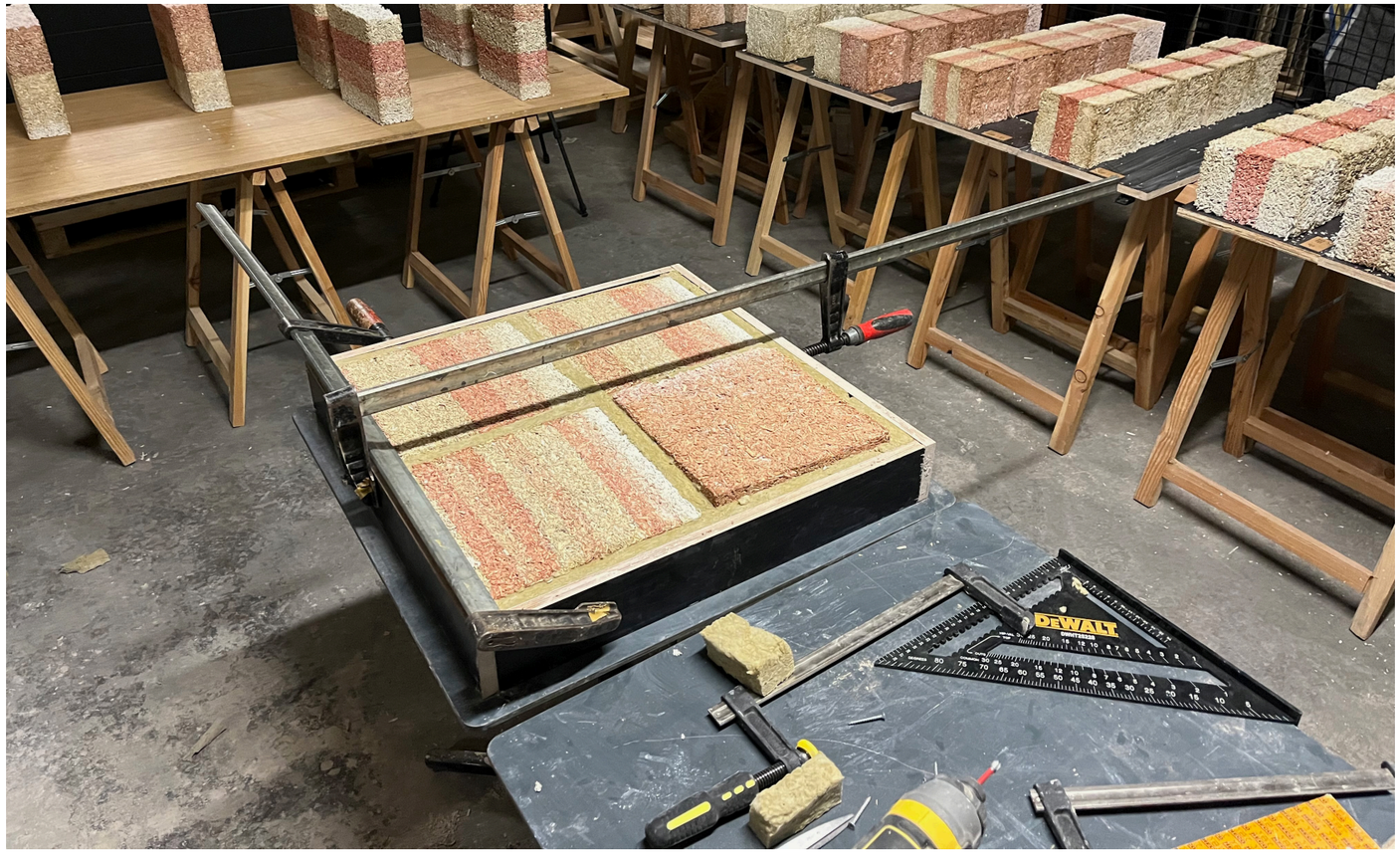
Hotbox Test

Thermal Conductivity



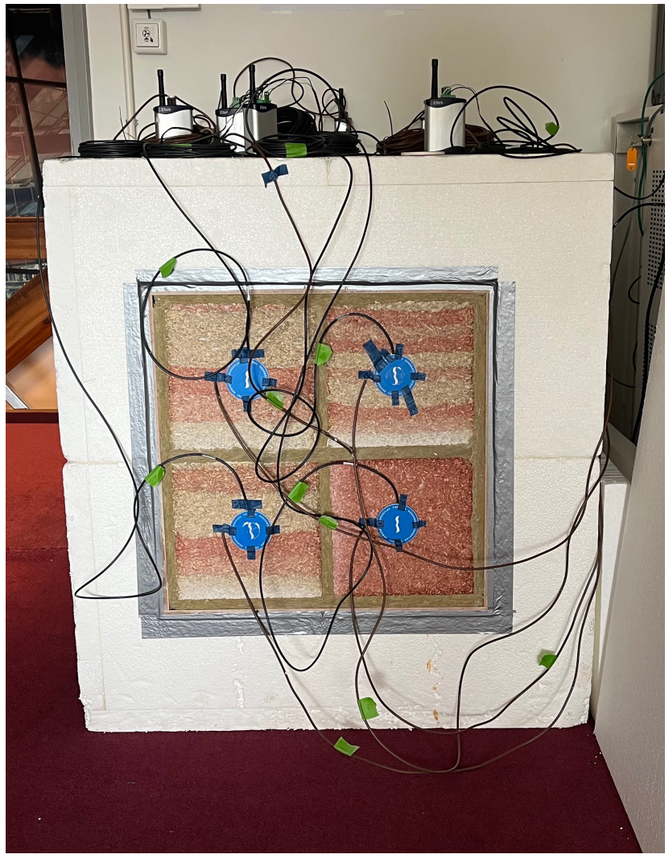
Frame

Thermal Conductivity



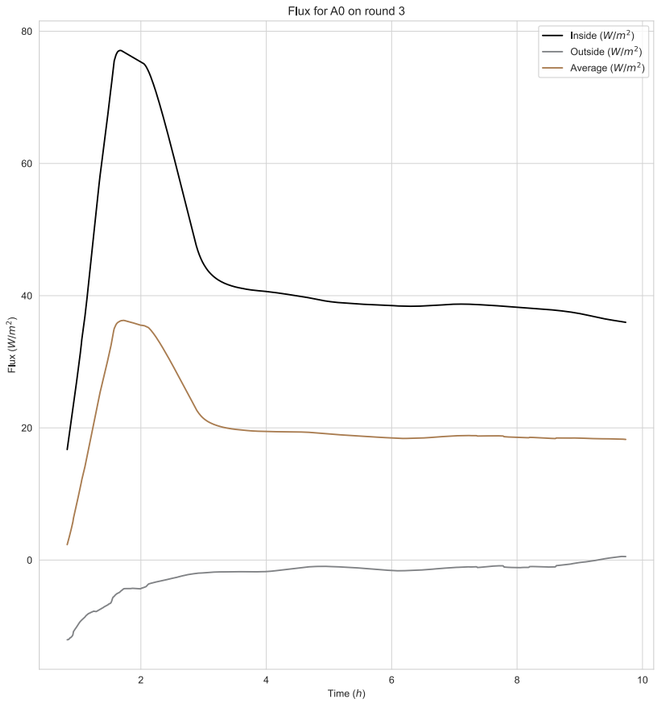
Flux Sensors

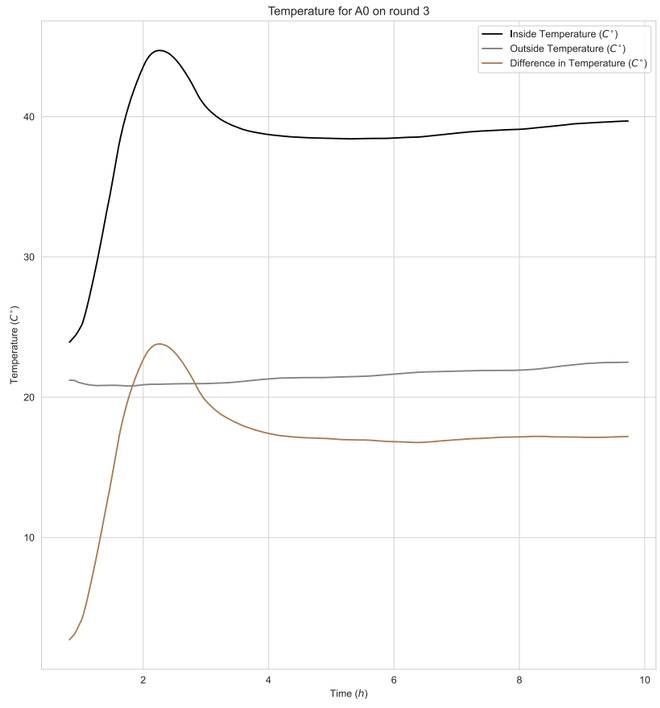
Thermal Conductivity

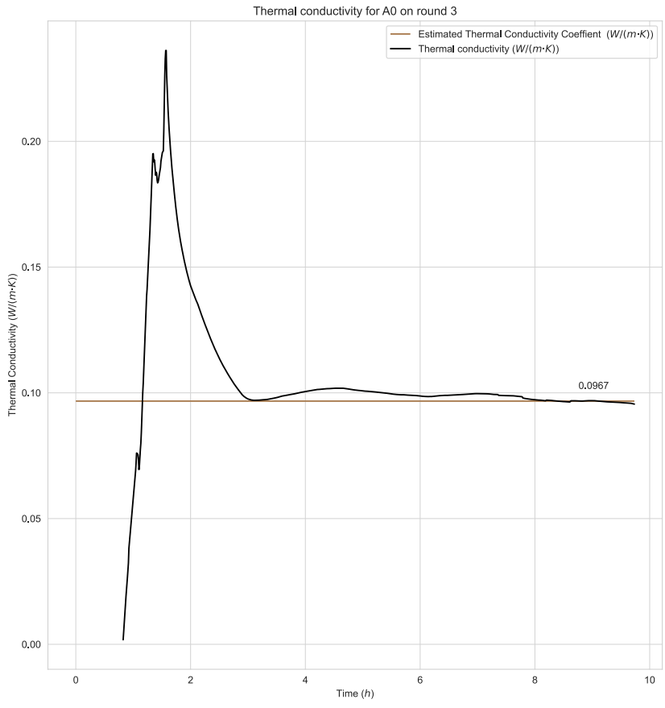


Measurements

Thermal Conductivity

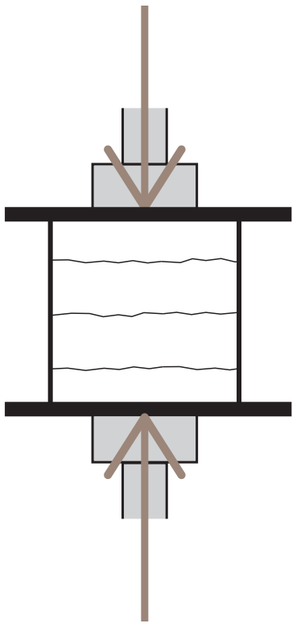






Compressive Test

Compressive Strength



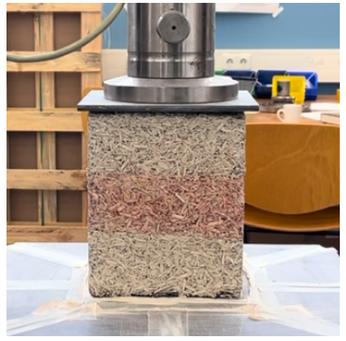
Compressive Test

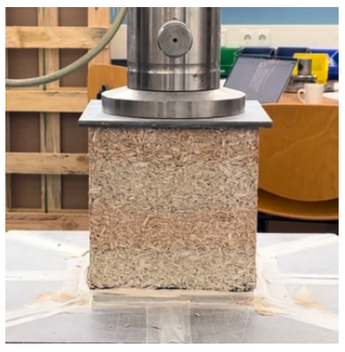
Compressive Strength







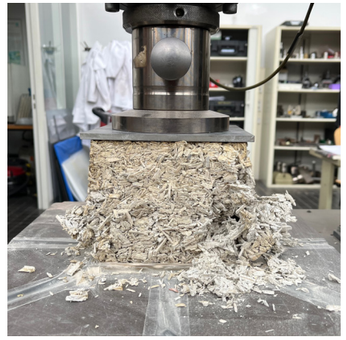




Compressive Test

Compressive Strength





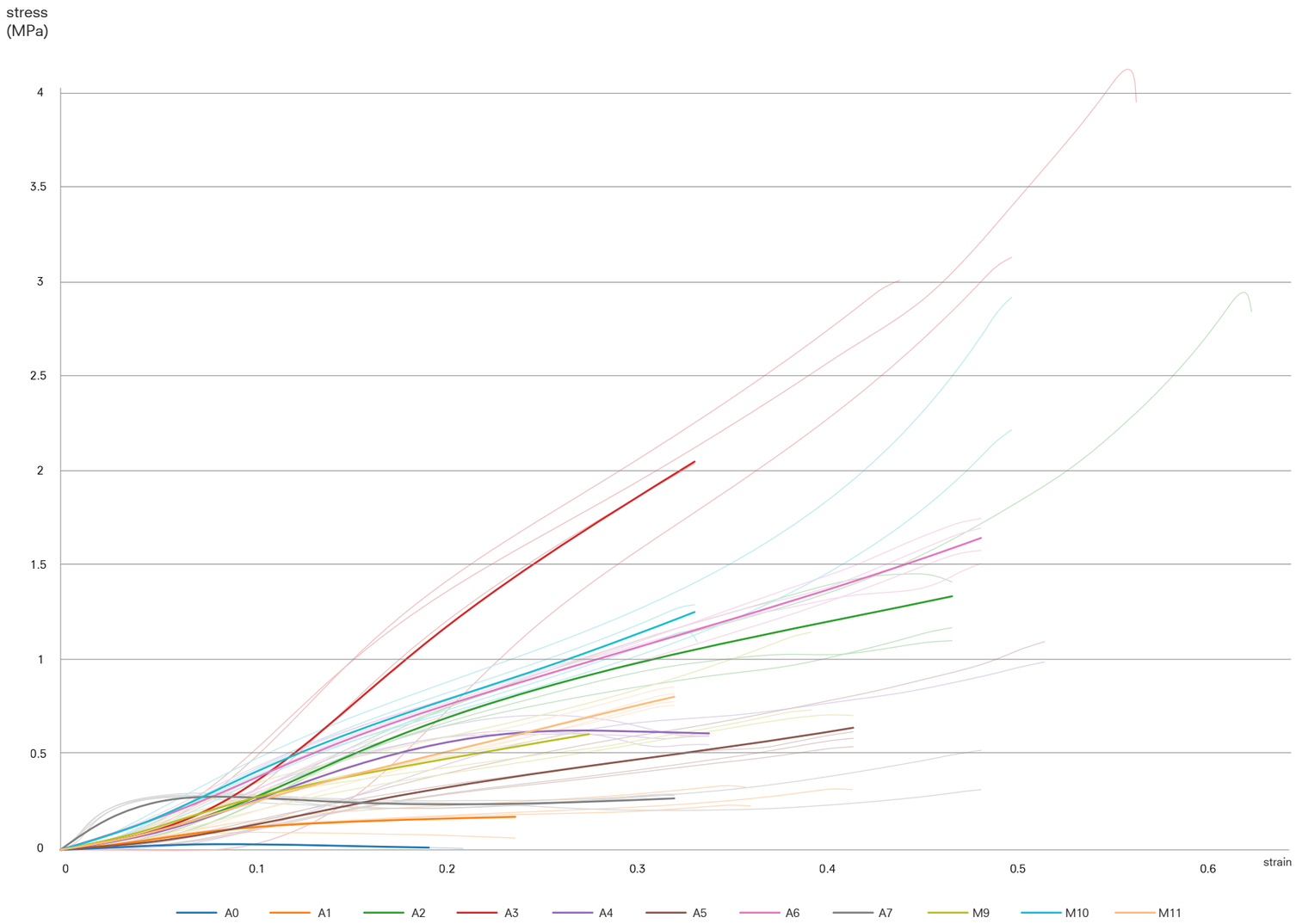







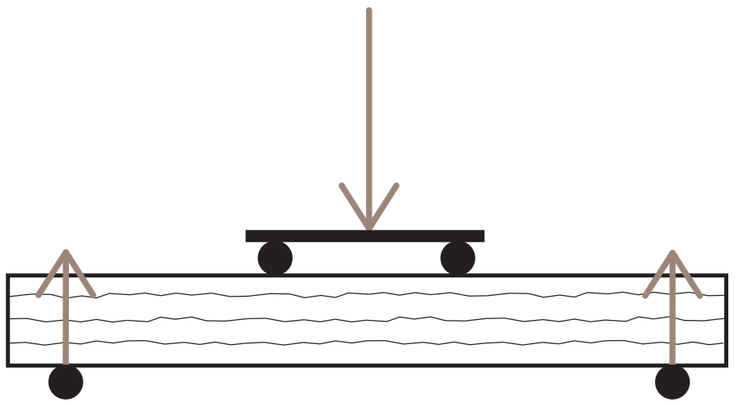
Stress-strain curves

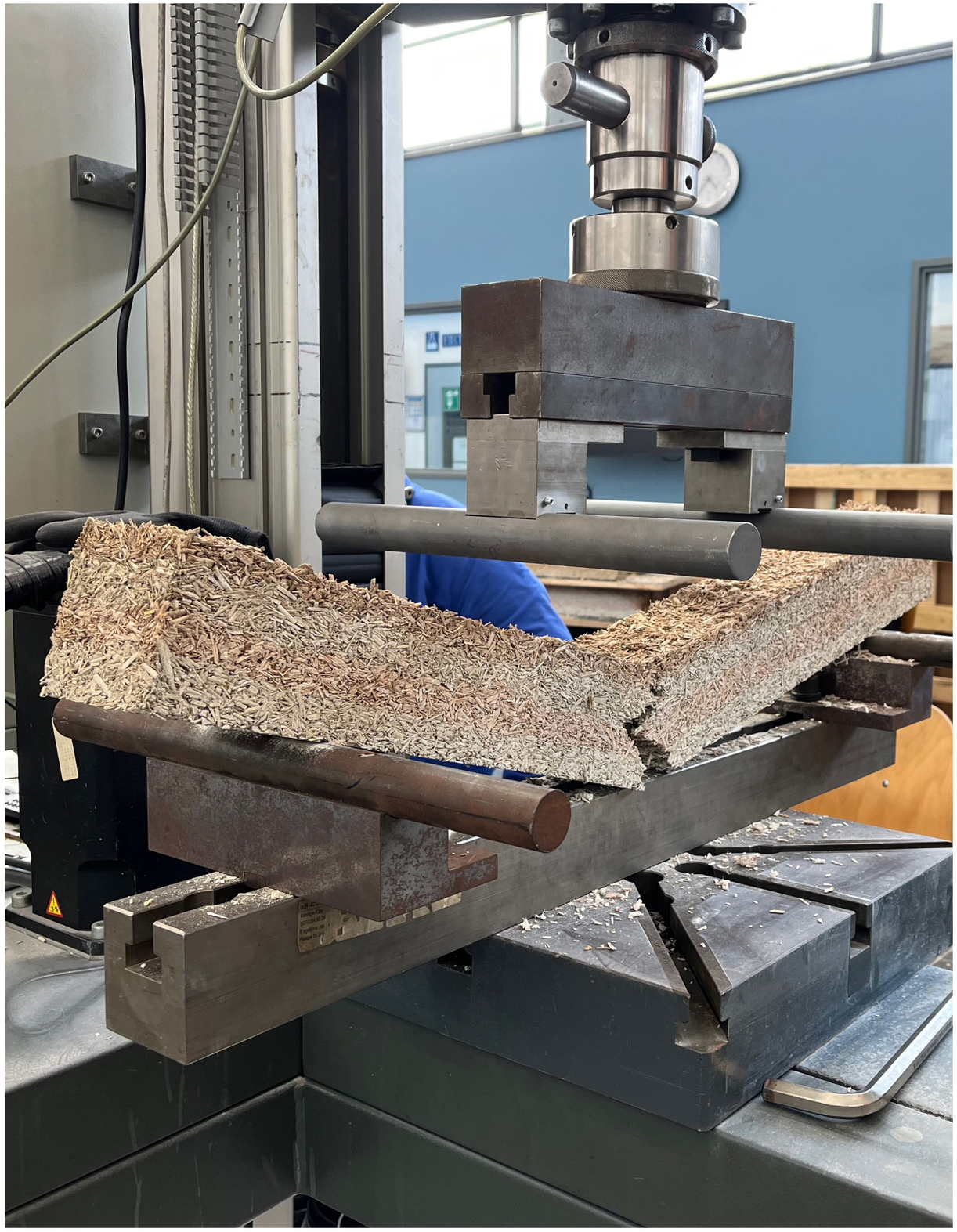
Compressive Strength



4 Point Bending Test

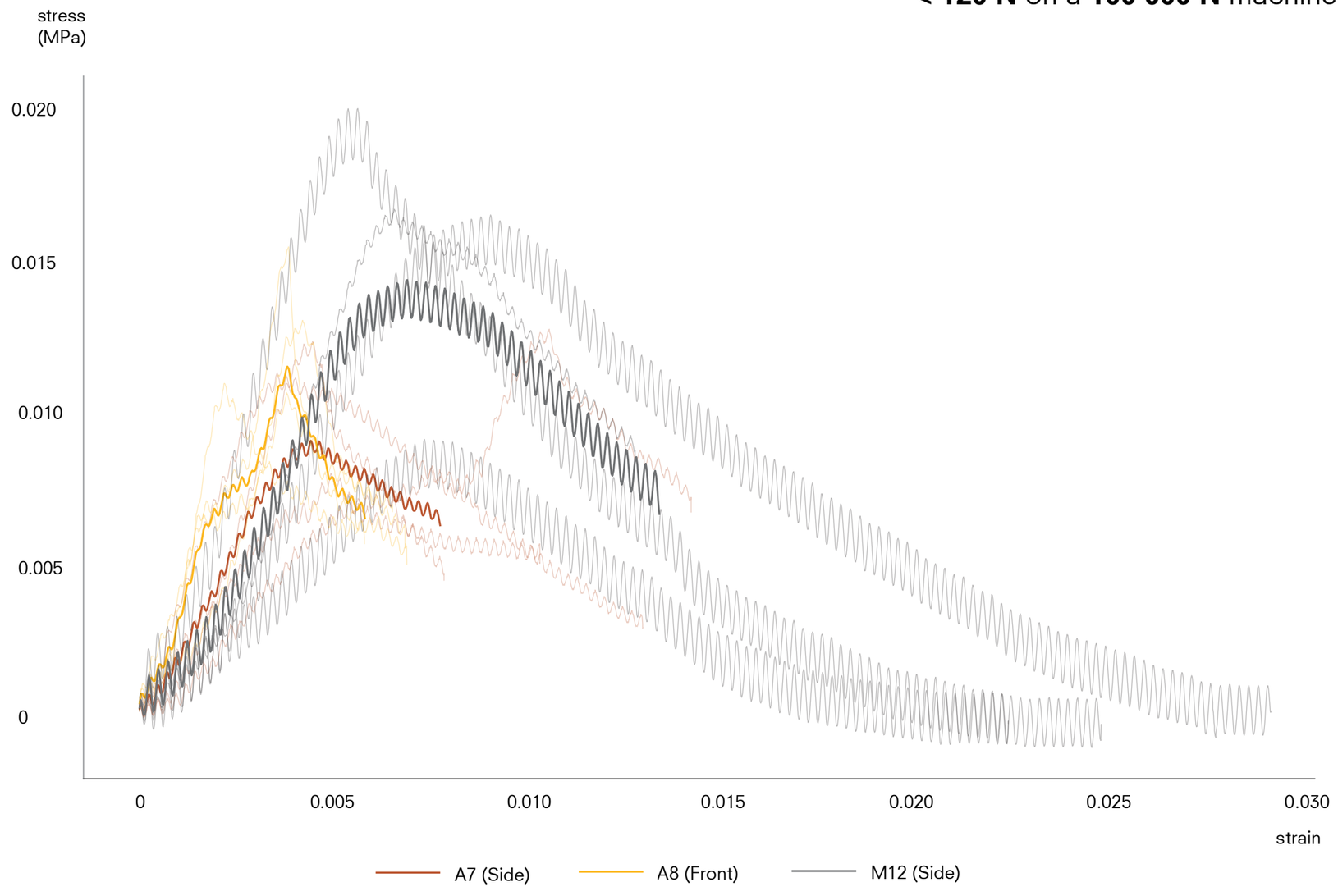
Bending Strength





Stress-strain curves

Bending Strength



< 120 N on a **100 000 N** machine

Conclusions

Experiment

ρ_{dry} = 205 kg/m³	λ = 0.077 W/mK
$\sigma_{c,y}$ = 0.03 MPa	E = 0.49 MPa

ρ_{dry} = 235 kg/m³	λ = 0.080 W/mK
$\sigma_{c,y}$ = 0.10 MPa	E = 1.53 MPa

ρ_{dry} = 330 kg/m³	λ = 0.106 W/mK
$\sigma_{c,y}$ = 0.51 MPa	E = 5.01 MPa

ρ_{dry} = 405 kg/m³	λ = 0.127 W/mK
$\sigma_{c,y}$ = 1.11 MPa	E = 9.63 MPa

ρ_{dry} = 330 kg/m³	λ = 0.101 W/mK
$\sigma_{c,y}$ = 0.52 MPa	E = 4.76 MPa

ρ_{dry} = 330 kg/m³	λ = 0.101 W/mK
$\sigma_{c,y}$ = 0.20 MPa	E = 9.76 MPa

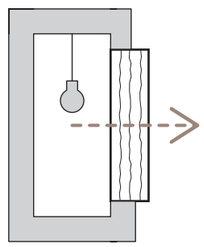
ρ_{dry} = 330 kg/m³	λ = 0.085 W/mK
$\sigma_{c,y}$ = 0.48 MPa	E = 3.84 MPa

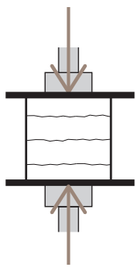
ρ_{dry} = 330 kg/m³	λ = 0.101 W/mK
$\sigma_{c,y}$ = 0.27 MPa	E = 2.22 MPa

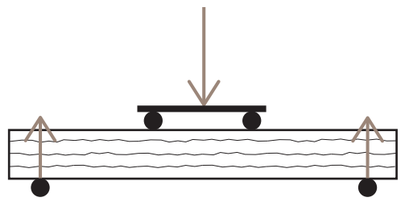
B **Binder** Material	not tested	inconclusive	inconclusive
C **Compaction** Manufacturing	observed	observed	not tested
L **Layer Height** Manufacturing	observed	observed	not tested

O **Orientation**

not observed | observed | inconclusive







Hotbox
Thermal Conductivity

Compressive
Compressive Strength

4 Point Bending
Bending Strength

B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

Air Lime
CaNaCrete (EXIE)

Air + Hydraulic Lime
ProKalk (IsoHemp)

B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

$R_c \geq 4.7$ m²K/W

Hotbox
Thermal Conductivity

Compressive
Compressive Strength

B **Binder**
Material

C **Compaction**
Manufacturing

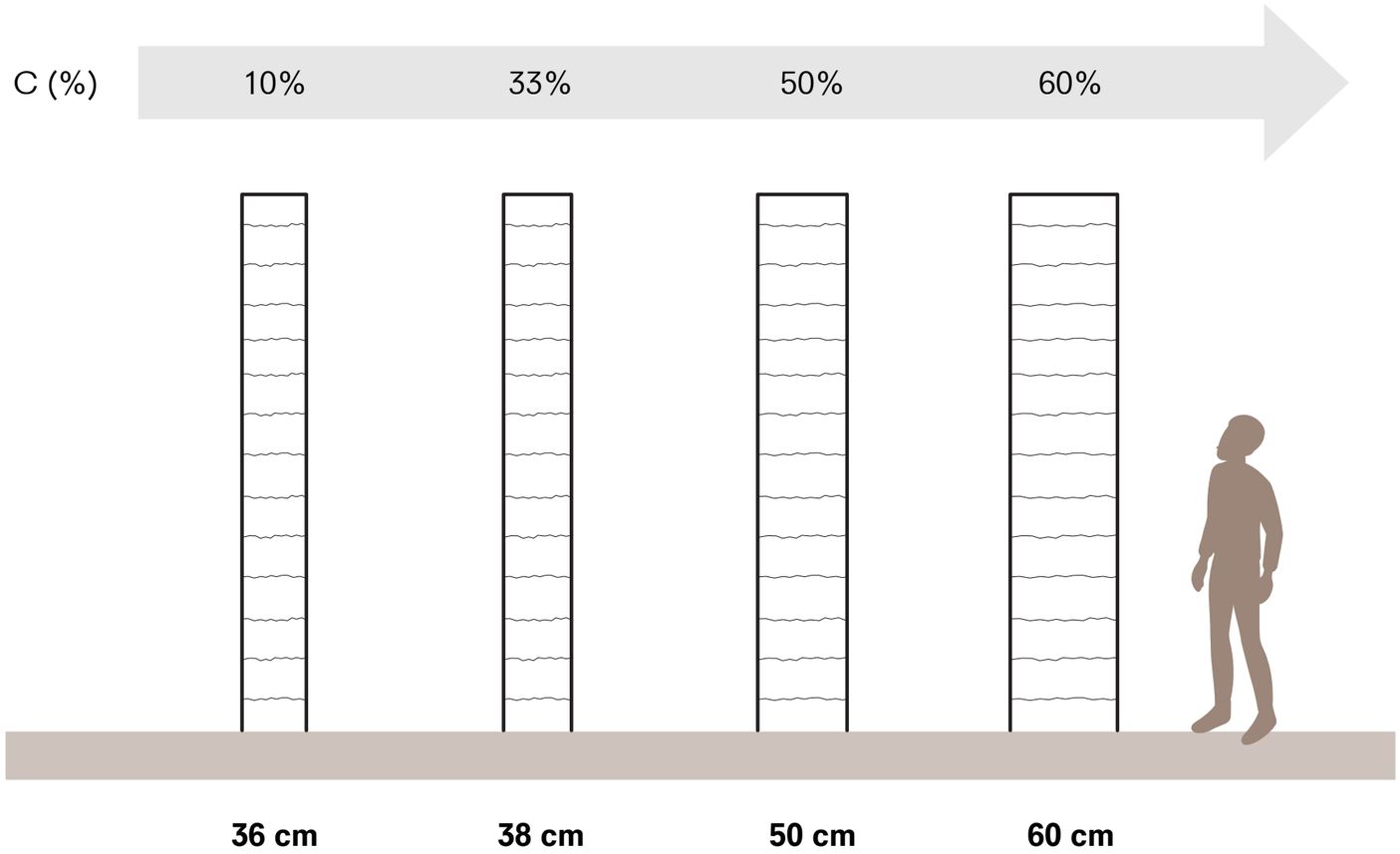
L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

$R_c \geq 4.7$ m²K/W



Hotbox
Thermal Conductivity

Compressive
Compressive Strength

B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

Hotbox
Thermal Conductivity

Compressive
Compressive Strength

B Binder
Material

C **Compaction**
Manufacturing

L Layer Height
Manufacturing

O Orientation
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

B **Binder**
Material

C **Compaction**
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L **Layer Height**
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O **Orientation**
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Transportation
Manufacturing

Carbon Footprint
Manufacturing

● **Hotbox**
Thermal Conductivity

● **Compressive**
Compressive Strength

B **Binder**
Material

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Manufacturing

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O **Orientation**
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Transportation
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Carbon Footprint
Manufacturing

Hotbox
Thermal Conductivity

Compressive
Compressive Strength

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Material

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L **Layer Height**
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O **Orientation**
Manufacturing

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Carbon Footprint
Manufacturing

Minimise density gradient

L ≤ 10cm

B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

$\lambda = 0.104$ W/mK ≈ $\lambda = 0.101$ W/mK

49 cm **47 cm**

Hotbox
Thermal Conductivity

Compressive
Compressive Strength

B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

$\sigma_{c,y} = 0.52$ MPa > $\sigma_{c,y} = 0.20$ MPa

Hotbox
Thermal Conductivity

Compressive
Compressive Strength

B **Binder**
Material

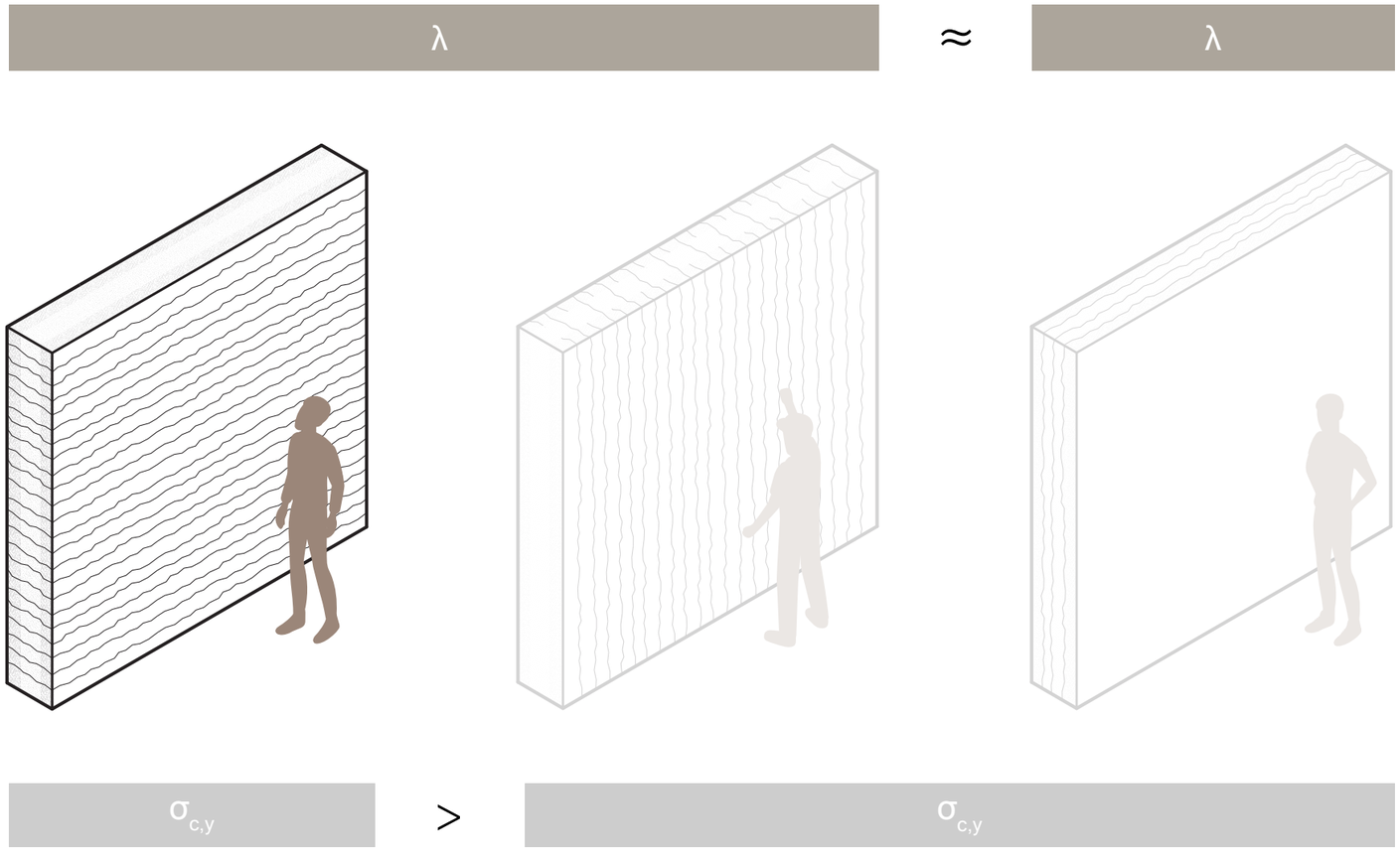
C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing



B **Binder**
Material

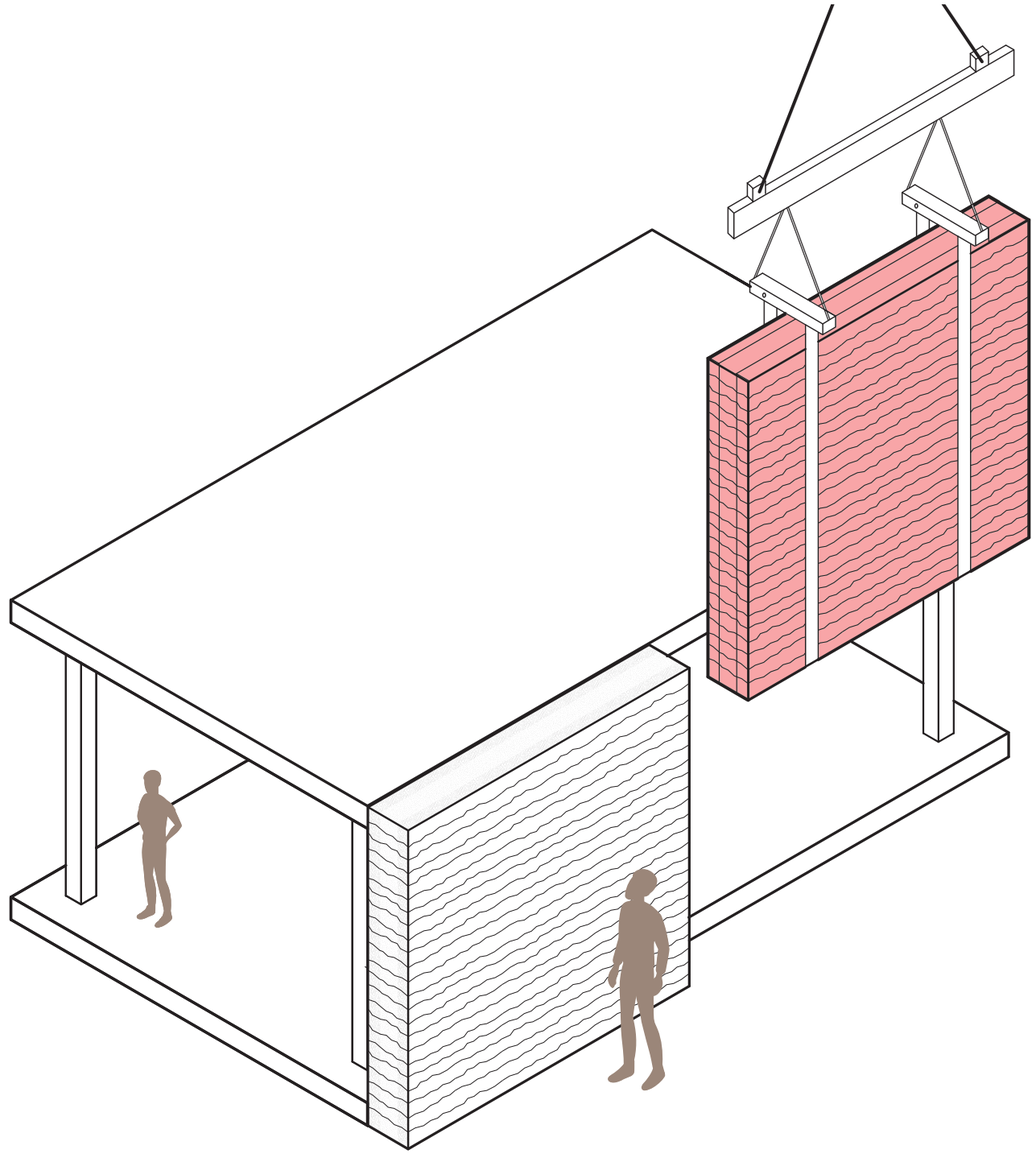
C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing



B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing

Further Research

- Transporting?
- Element connections?
- Mounting to the building?

Photos: Salem Mostefaoui (2022)

B Binder
Material

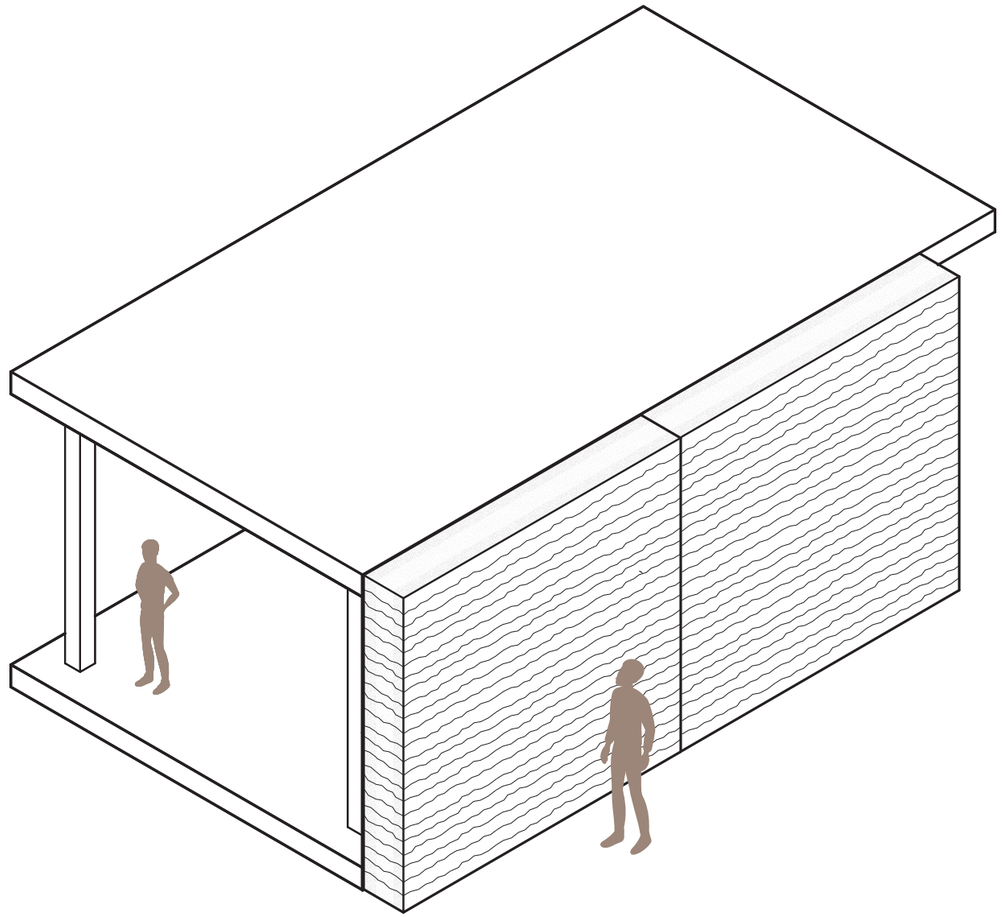
C Compaction
Manufacturing

L Layer Height
Manufacturing

O Orientation
Manufacturing

Transportation
Manufacturing

Carbon Footprint
Manufacturing



Further Research

- Transporting?
- Element connections?
- Mounting to the building?

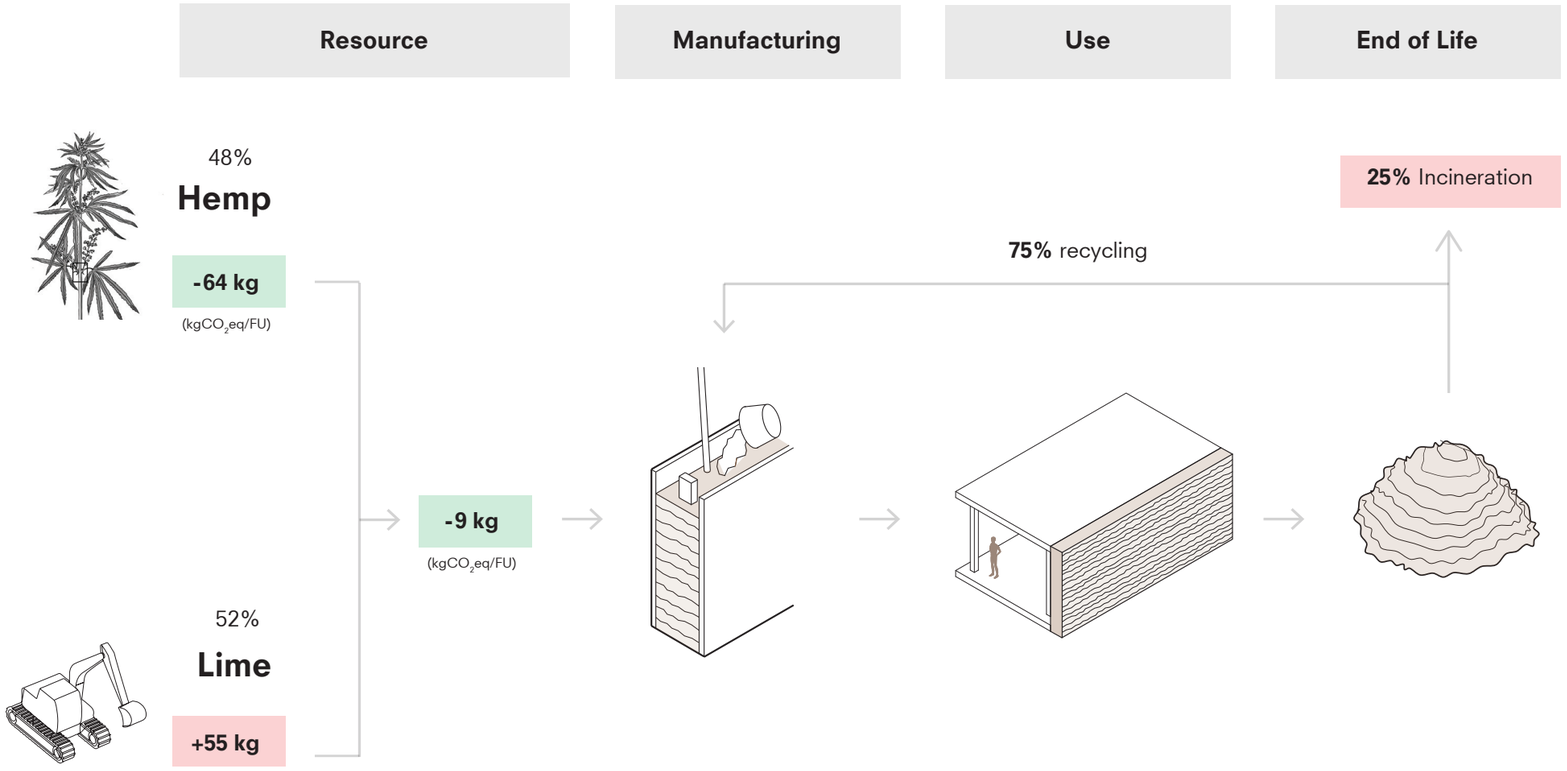
B Binder
Material

C Compaction
Manufacturing

L Layer Height
Manufacturing

O Orientation
Manufacturing

Transportation
Manufacturing



Carbon Footprint

Manufacturing

B/H ratio	**0.54**	**1.09**	
Density	**175**	**275**	kg/m³

B **Binder**
Material

C **Compaction**
Manufacturing

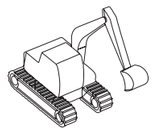
L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing

48%
Hemp

-64 kg
($kgCO_2eq/FU$)



52%
Lime

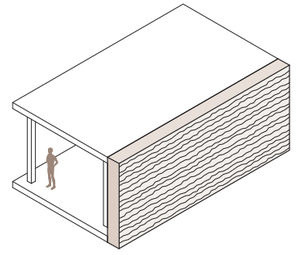
+55 kg

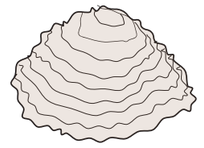
Resource	Manufacturing	Use	End of Life

25% Incineration

75% recycling

-9 kg
($kgCO_2eq/FU$)





=
-0.02 kg
($kgCO_2eq/FU$)

≈
0

Carbon Footprint
Manufacturing

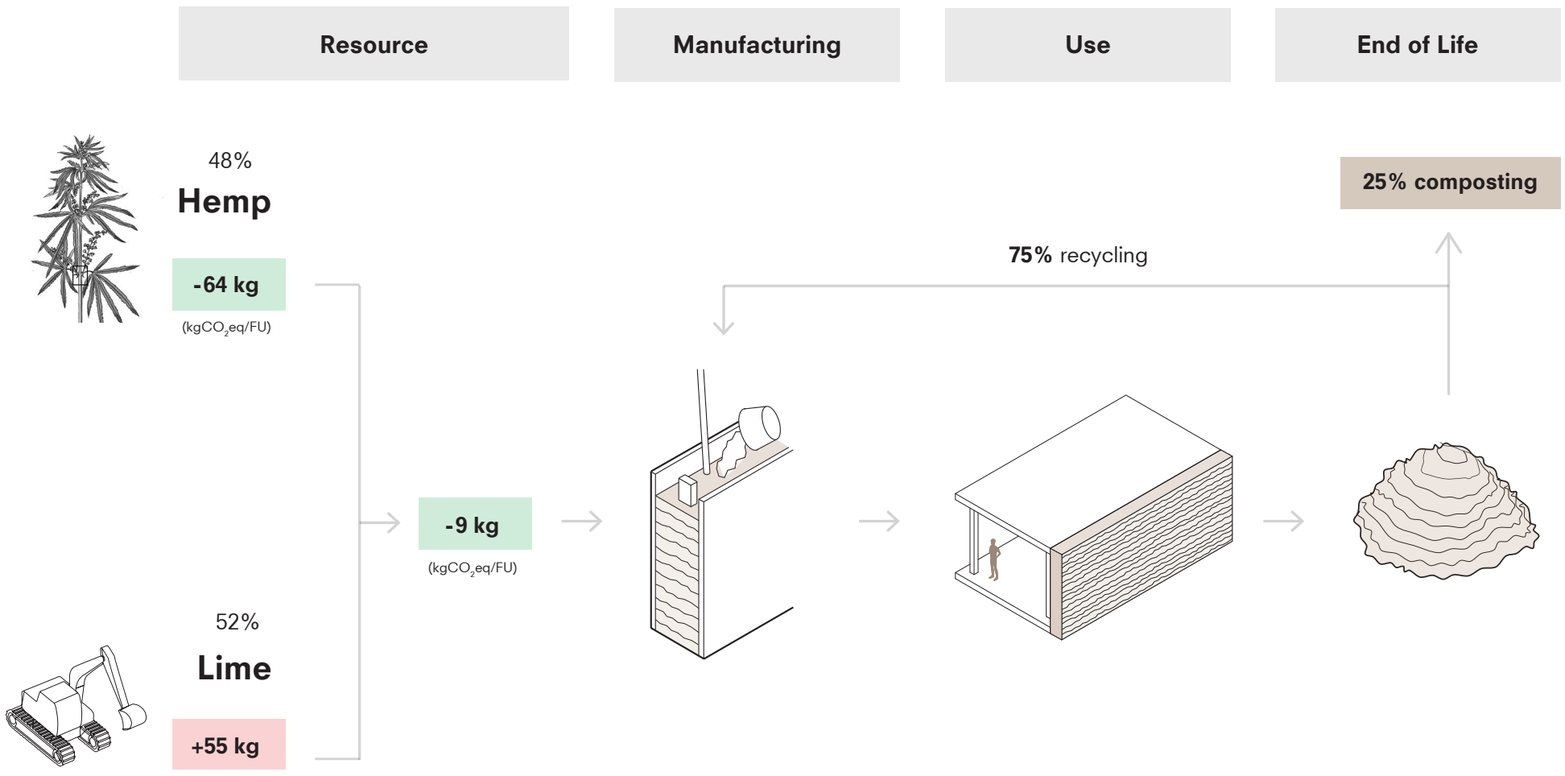
B **Binder**
Material

C **Compaction**
Manufacturing

L **Layer Height**
Manufacturing

O **Orientation**
Manufacturing

Transportation
Manufacturing



Carbon Footprint

Manufacturing

B Binder
Material

C Compaction
Manufacturing

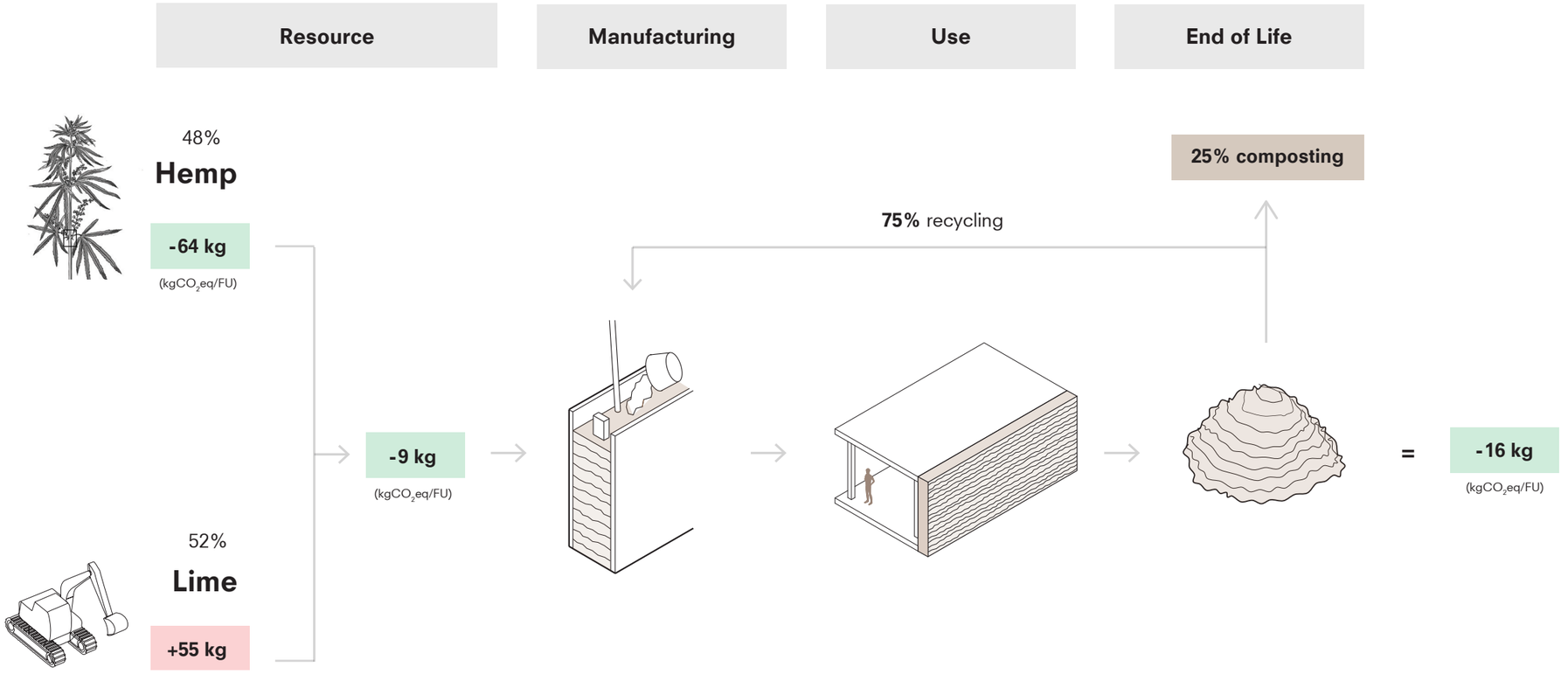
L Layer Height
Manufacturing

O Orientation
Manufacturing

Transportation
Manufacturing

Further Research

- 25% composting?
- Ratio with fresh material?
- 75 years service life?



Carbon Footprint

Manufacturing


Monolith?
Performance

Exterior
9cm
C = 50%
L = 10cm

λ = 0.106 W/mK

Interior
18cm
C = 0%
L = 10cm

λ = 0.071 W/mK

Exterior
9cm
C = 50%
L = 10cm

λ = 0.106 W/mK

4.23
m²K/W

Own weight

3x3m element

60x

$\sigma_{c,y}$ = 0.00825 MPa **<** $\sigma_{c,y}$ = 0.51 MPa

Safe

behaviour

Own weight
3x3m element

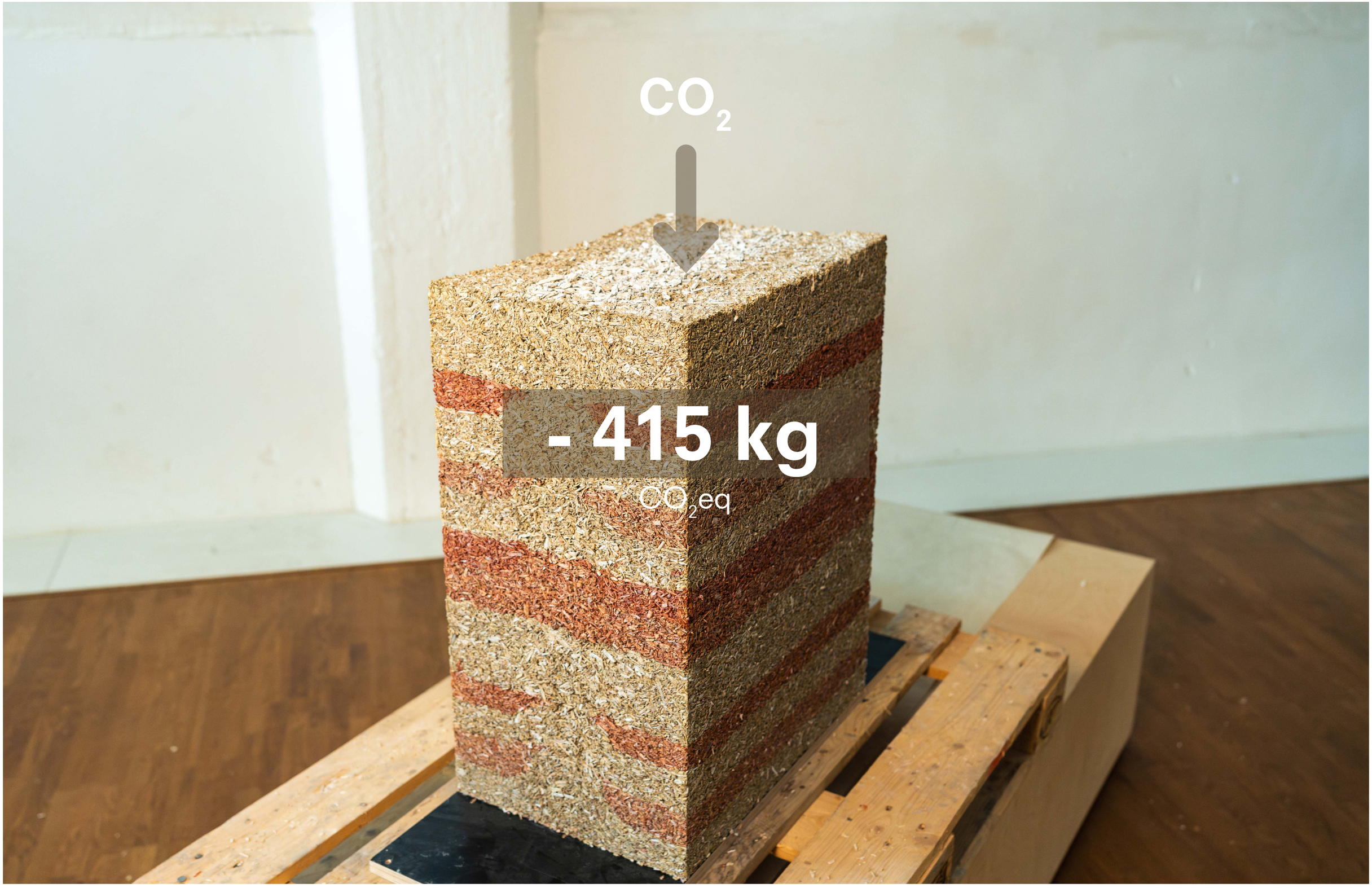
13.5 cm (4.5%)

Safe, but deformable

behaviour

Further Research

- Scaling?
- Reinforcement for wind?
- 3 zone density?


CO_2
- 415 kg
CO_2eq

Future

Hempcrete

Biobased Interest

Photograph by Rob Boogaarts

Quooker factory

Project: HOP Architecten & YOMABOUW

Render by the Urbanisten & GroupA

Hempcrete Plinth

1200 m^2

Render by the Urbanisten & GroupA

Questions?