THE FLAX REBIRTH

P5 Presentation
Ruben Tjebbe Steinfort
5675138
Architectural Engineering Graduation Design Studio
June 19, 2024

Standardization led to cost reduction, however..

Standardization

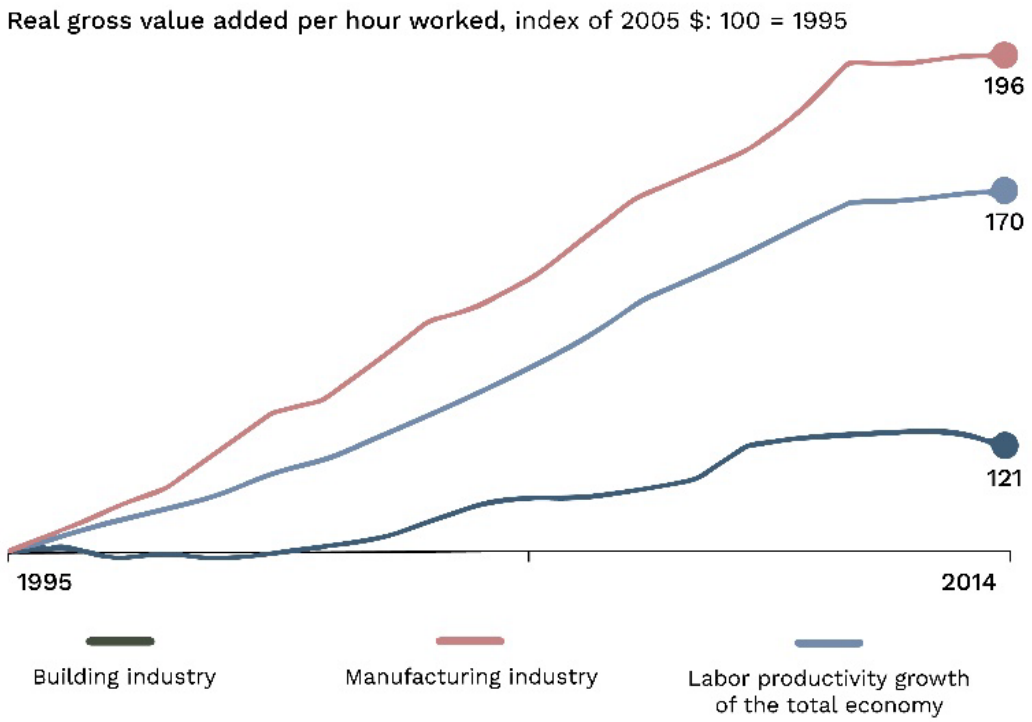
Cost savings

Illustration retrieved from: Building-industry-construction-site [Illustration]. Freepik. Accessed on January 25, 2024, www.freepik.com

Illustration retrieved from: Cost-reduction-illustration-with-decrease-price-minimising-or-falling-rate-of-profit-in-business [Illustration]. Vecteezy. Accessed on January 25, 2024, www.vecteezy.com

(ECESP, 2021)

Marginal efficiency increase in the Building Industry



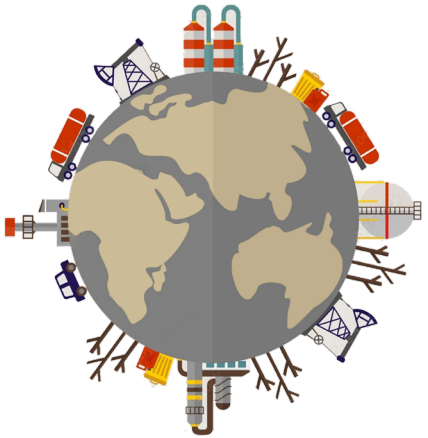
Graph retrieved from: REINVENTING CONSTRUCTION: A ROUTE TO HIGHER PRODUCTIVITY [Graph]. Mckinsey. Accessed on January 25, 2024, www.mckinsey.com

(Mckinsey, 2017)

Effects of the building industry on our planet

Material Waste

Pollution and Depletion



Emissions

Illustration retrieved from: Trash container [Illustration]. Vecteezy. Accessed on January 25, 2024, www.vecteezy.com

Illustration retrieved from: Construction materials set [Illustration]. Vectorstock. Accessed on January 25, 2024, www.vectorstock.com

Illustration retrieved from: Building industrial plants polluting the environment. [Illustration]. Adobe Stock. Accessed on January 25, 2024, www.stock.adobe..com

Illustration retrieved from: Pollution concept [Illustration]. Freepik. Accessed on January 25, 2024, www.freepik.com

(ECESP, 2021)

Demand for new resource efficient building materials and methods

~~**Heavy solid structures**~~

Lightweight open structures

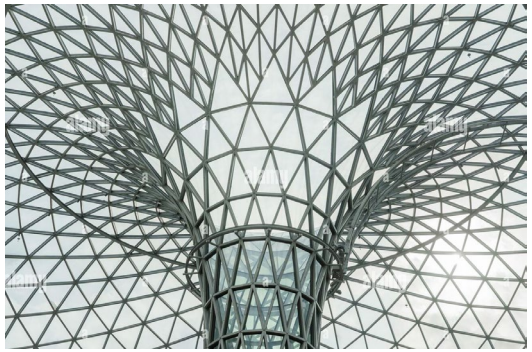


Image retrieved from: Concrete massive construction [Image]. Construcaocivil. Accessed on January 25, 2024, www.construcaocivil.info

Image retrieved from: Double-curve-funnel-shaped-skylight-architectural-glass-steel-structure-of-a-dome-parametric-design [Image]. Alamy. Accessed on January 25, 2024, www.alamy.com

Illustration retrieved from: Woman keeps heavy boulders from falling [Illustration]. Vectorstock. Accessed on January 25, 2024, www.vectorstock.com

Illustration retrieved from: Falling feather [Illustration]. Alamy. Accessed on January 25, 2024, www.alamy.com

(ECESP, 2021)

Reevaluation of our traditional building methods

Dematerialization

Modularity

Demountability

Concrete

Brick

Steel

Illustration retrieved from: Circular economy manufacturing cycle [Illustration]. Vecteezy. Accessed on January 25, 2024, www.vecteezy.com

Illustration retrieved from: Welding Service with Professional Welder [Illustration]. Vecteezy. Accessed on January 25, 2024, www.vecteezy.com

Illustration retrieved from: Mixing sand for workers in construction concrete mixers [Illustration]. Dreamstime. Accessed on January 25, 2024, www.dreamstime.com

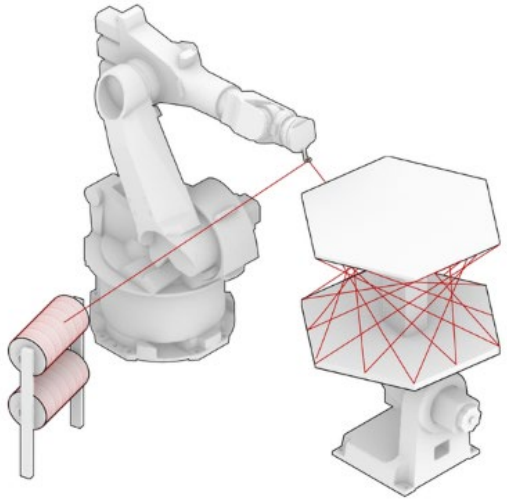
Illustration retrieved from: Contractor [Illustration]. 123rf. Accessed on January 25, 2024, www.123rf.com

“We as architects and engineers have to develop our own fabrication processes adapted for the needs of architectural and building construction” Jan Knippers

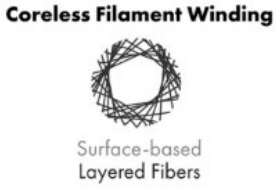
Image retrieved from: From laboratory to building practice [Picture]. Competitiononline. Accessed on January 25, 2024, www.competitionline.com

(Pérez, Guo, & Knippers, 2022)

Coreless Filament Winding using Fiber Filaments



Coreless Filament Winding



Flax Fibers

Illustration retrieved from: Spatial winding: cooperative heterogeneous multi-robot system for fibrous structures [Illustration]. ResearchGate. Accessed on January 25, 2024, www.researchgate.net

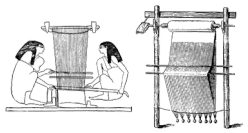
Image retrieved from: Flax fibers from flax for the manufacture of linen fabric and linen fabric [Picture]. Shutterstock. Accessed on January 25, 2024, www.shutterstock.com

(Duque Estrada, et al., 2020)

Prognoses

Techniques using Flax over time

- Which steps have to be undertaken to truly scale this up towards the building scale?



Hand Weaving

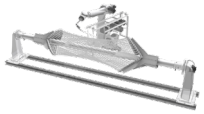
3000 BC- 1700's

Humans

Machine Weaving

1700's-2000's

Machines



Coreless Filament Winding

2000's-Now

Robotics

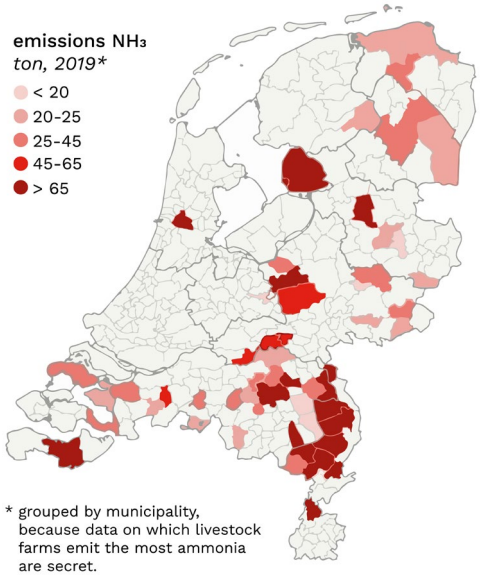
Research gap

Illustration retrieved from: 40 learning gaps stock illustrations [Illustration]. iStockphoto. Accessed on January 25, 2024, www.Istockphoto.com

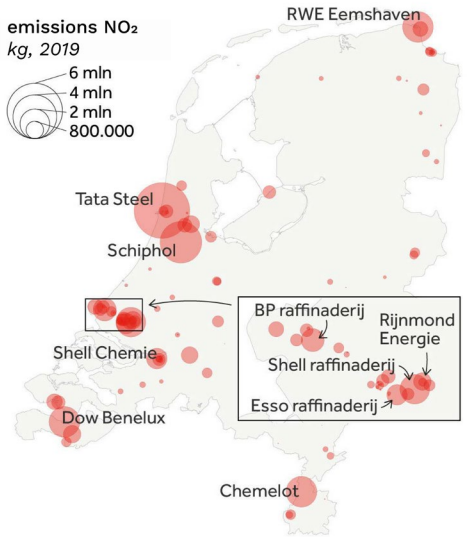
Contextual Problems

Contextual Problems

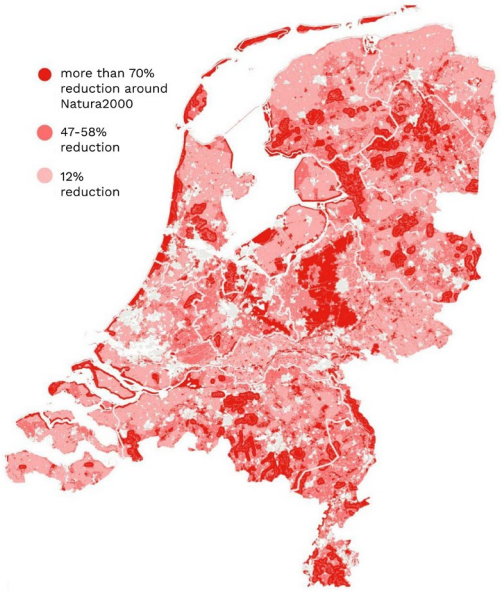
Nitrogen & Ammonia Crisis



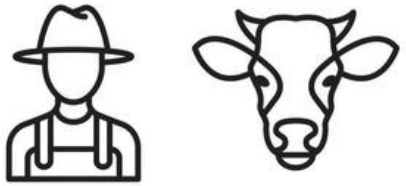
Largest emitters of ammonia: mainly livestock farms



Largest emitters of nitrogen dioxides



In these areas, nitrogen emissions must be reduced



Need to reduce Cattle size
=
Less work for Farmers

Graphs retrieved from: Het stikstofprobleem is echt Nederlands, uitgelegd in acht grafieken [Graph]. NOS. Accessed on January 25, 2024, www.nos.nl

(Rijksoverheid, 2023)

Contextual Problems

Contextual Problems

Graph retrieved from: Population Development 2022 [Graph]. Harveyotten. Accessed on January 25, 2024, www.Harveyotten.nl

Graph retrieved from: Percentage of over-65s per COROP [Graph]. Kennisvanstadenregio. Accessed on January 25, 2024, www.kennisvanstadenregio.nl

(CBS/PBL, 2019

Potentials

Historic image of flax farming in Groningen, The Netherlands in the 19th century

Potentials

Modernizing these industries

Exploring synergies between the farming and construction industries

Address the Nitrogen Crisis & Enhance economic prospects

Fostering environmental sustainability

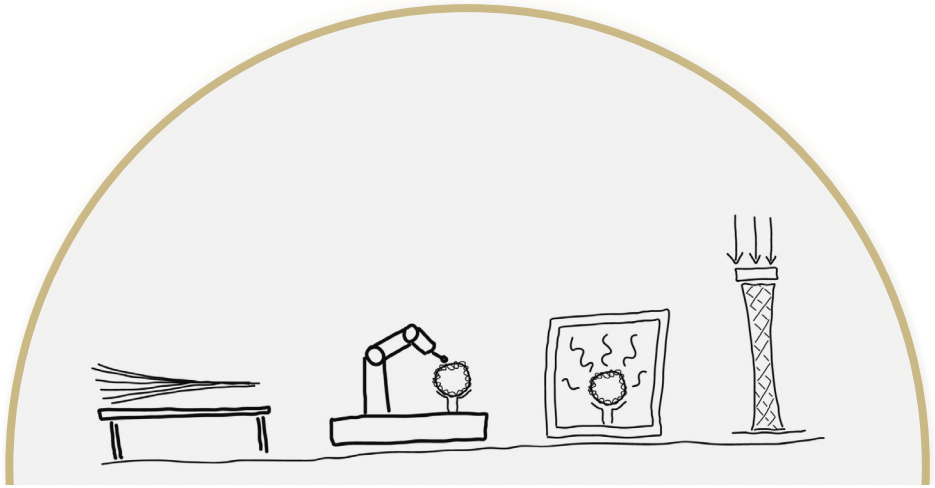
Illustrations retrieved from: Construction Worker Talking, Economic development, Meeting planning developing agenda [Illustration]. Freepik. Accessed on January 25, 2024, www.freepik.com

Illustrations retrieved from: Smart agriculture, Group of ecologists [Illustration]. iStockphoto. Accessed on January 25, 2024, www.istockphoto.com

Innovative Flax Weaving Facility

Which explores synergies between the farming and construction industries

Farming Industry



Building Industry

RESEARCH

A NEW VISION ON LIGHTWEIGHT FIBER-BASED BUILDING SYSTEMS

Image made by author (R.T. STEINFORT)

Thematic Research Question

How to create **lightweight fiber-based building systems** for large open spaces from (regionally harvested) **flax** fibers using coreless-filament winding, whereby **bespoke fibrous tectonics**, **dematerialization** and **modularity** are considered as guiding themes?

Material characteristics of Flax Fibers

	Flax Fiber	Hemp Fiber	Sisal Fiber
Tensile strength (MPa)	343-1500	270-900	353
Compression strength (MPa)	1200*	-	-
Elasticity (Young's module – MPa)	58.643	30.000 – 60.000	15.720
Diameter	10-80 µm	26 µm	121-411 µm
Fiber length	10-100 cm	1 – 5 cm	80-120 cm
Density (g/cm³)	1.4-1.5	1.48	1.45
Fire resistance	Bad	Bad	Bad
Fire retardance	Varies	Varies	Varies
Burning/Melting point	237 °C	118-131 °C	163 °C
Moisture absorption	Good	Good	Good
Moisture resistance	Bad	Bad	Bad
Thermal conductivity (W/mK)	0.038	0.038-0.042	0.038
Biodegradability	Yes	Yes	Yes
Eco-friendliness	Yes	Yes	Yes

Advantages

- High tensile strength
- Separation of fibers
- Optimal thermal insulators

Disadvantages

- Dematerialization & material characteristics
- Flammable
- Biodegradable & hydrophilic
- Not naturally weatherproof

Cycle of Flax

Life Cycle of Flax

- Harvested in 100 days
- Optimal for crop rotation
- Biological Cycle

Production phase

- Coreless-Filament Winding

End-of-Life phase

- Reuse
- Modular
- Shredding
- Decomposed
- Upcycled
- Particle boards or insulation

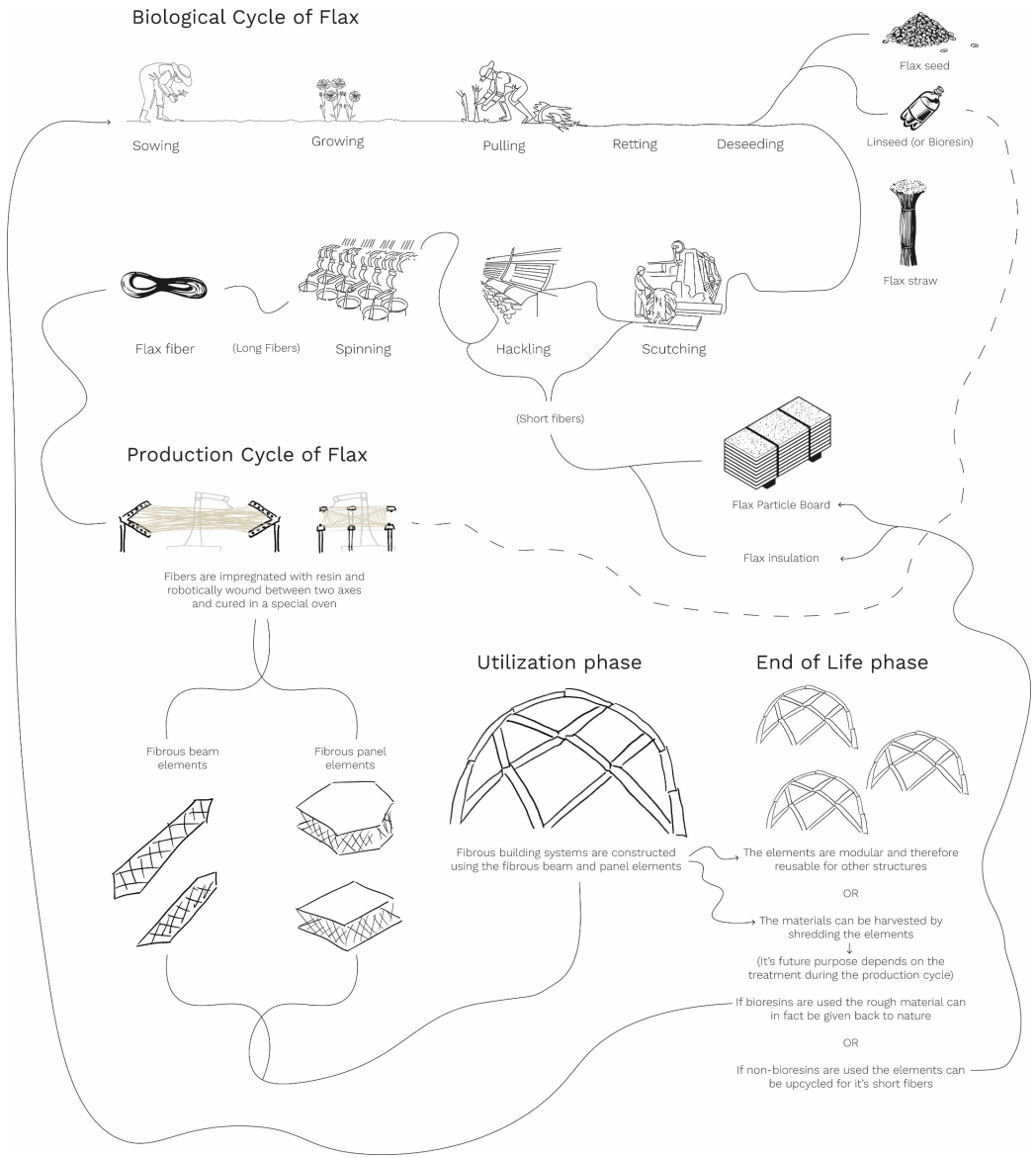
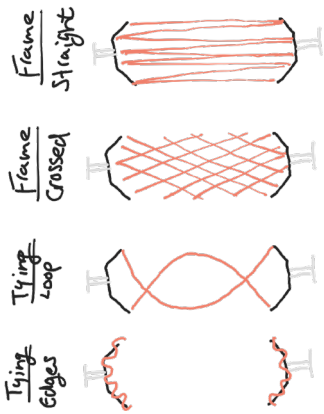


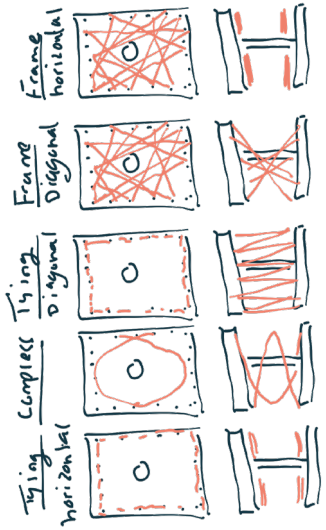
Diagram made by author (R.T. STEINFORT)

Technique

The key factors

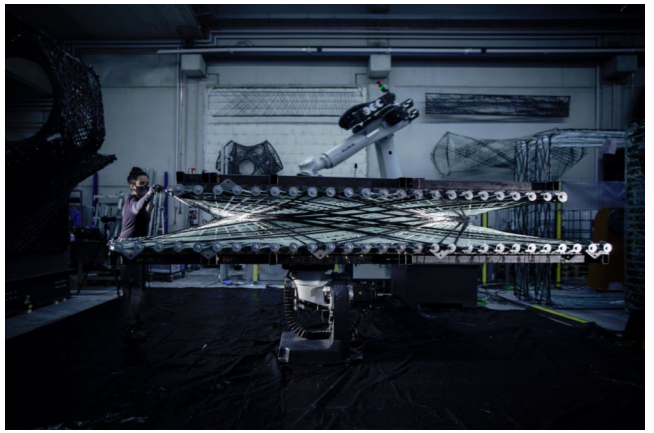
- Winding pattern
- Fiber-to-fiber interaction and orientation
- Structural abilities





Beams

Panels



Images retrieved from: Fabrication sequence of a fibre reinforced composite building element [Image]. ITKE University of Stuttgart. Accessed on January 25, 2024, www.itke.uni-stuttgart.de

Casestudies

ICD/ITKE Research Pavilion 2012
ICD/ITKE Research Buildings, Germany

BUGA Fibre Pavilion 2019
ICD Research Buildings / Prototypes
Bundesgartenschau Heilbronn 2019, Germany

Maison Fibre 2021
ICD/ITKE Research Buildings

LivMats Pavilion 2021
2021 ICD Research Buildings / Prototypes
Botanic Garden Freiburg, Germany

Image retrieved from: Overview of ICD/ITKE research pavilions and Demonstrators [Image]. ITKE University of Stuttgart. Accessed on January 25, 2024, www.itke.uni-stuttgart.de

Potential Forms

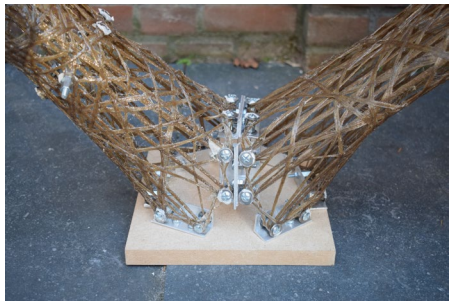
- Research-by-Design
- Structural typologies
- From conventional towards non-conventional forms
- Straight spans are not optimal I Axial compression -> Fibers are most optimally exerted on axial compression

Conventional ⟷ **Unconventional**

Diagrams made by author (R.T. STEINFORT)

Conclusions

- Connections are demountable
- Able to be thermally insulated
- Modular
- Form freedom & flexibility due to Production process





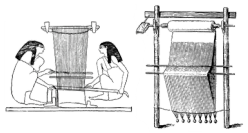
Images made by author (R.T. STEINFORT)

Prognoses

Techniques using Flax over time

- Which steps have to be undertaken to truly scale this up towards the building scale?

Research Gap



Hand Weaving

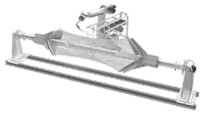
3000 BC- 1700's

Humans

Machine Weaving

1700's-2000's

Machines



Coreless Filament Winding

2000's-Now

Robotics

2.0

Coreless Filament Winding 2.0

Now-Future

Robotics

Building fully from Flax with CFW

Design input

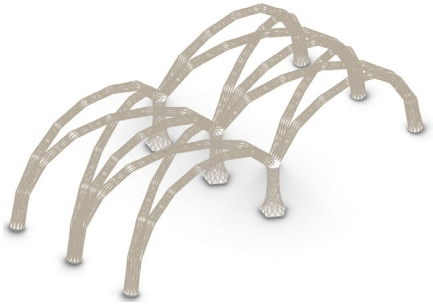
Optimal

Drawbacks

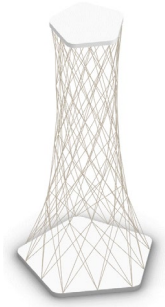
Structural

Dome

Tree column



Crossed barrel



Fibrous column

Material

?

Connections

?

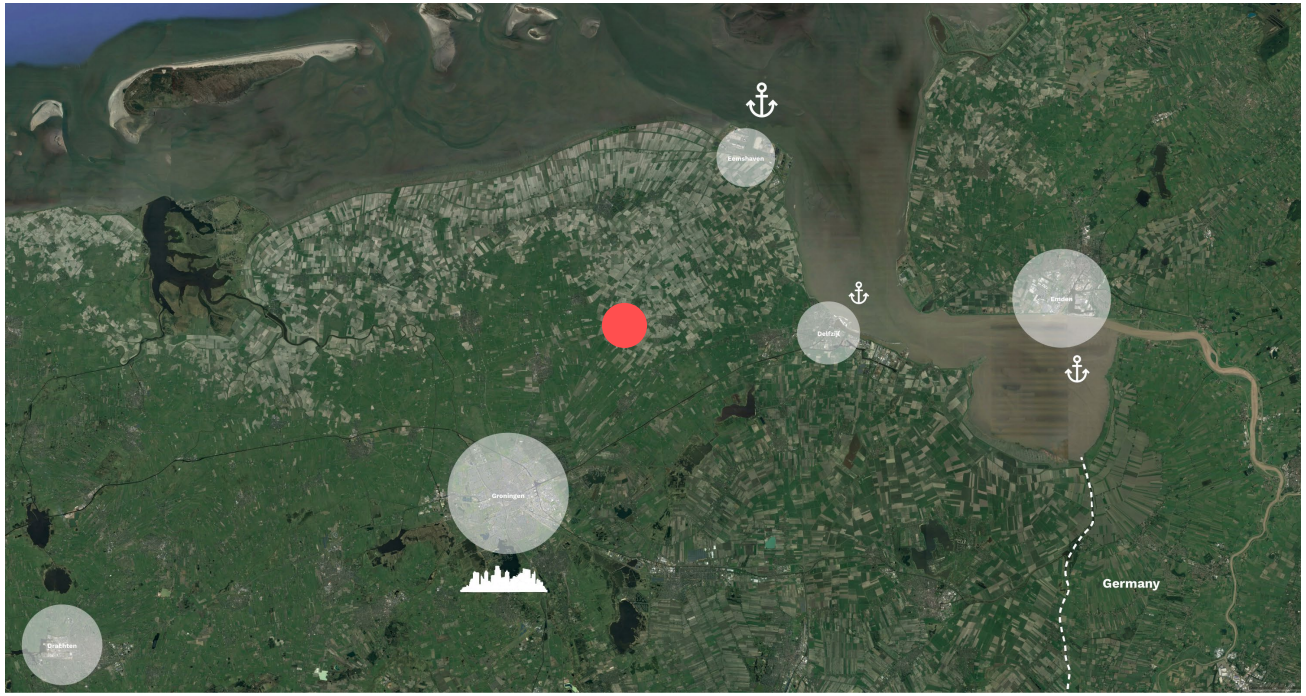
LOCATION

Context

- Northeast Groningen, The Netherlands
- Stedum
- 1000 inhabitants

Advantages

- Close to the German border
- International transport



Satellite view of Northeastern Netherlands I Scale 1:500.000

Image adjusted and retrieved from: Google Earth [Image]. Google Earth. Accessed on January 25, 2024, www.earth.google.com

(Google Earth, 2024)

Advantages

- Close to the German border
- International transport
- Close to the Capital of The Province
- Roads to major highways
- A7
- A28

Satellite view of Northeastern Netherlands I Scale 1:200.000

Image adjusted and retrieved from: Google Earth [Image]. Google Earth. Accessed on January 25, 2024, www.earth.google.com

(Google Earth, 2024)

Advantages

- Close to the German border
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- A28
- Close to major ports
- Eemshaven
- Delfzijl

Satellite view of Northeastern Netherlands I Scale 1:200.000

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- Roads to major highways
- A7
- A28
- Close to major ports
- Eemshaven
- Delfzijl
- Surrounded by Agricultural fields

Satellite view of Stedum, Groningen I Scale 1:50.000

Image adjusted and retrieved from: Google Earth [Image]. Google Earth. Accessed on January 25, 2024, www.earth.google.com

(Google Earth, 2024)

Advantages

- Close to the German border
- International transport
- Close to the Capital of The Province
- Roads to major highways
- A7
- A28
- Close to major ports
- Eemshaven
- Delfzijl
- Surrounded by Agricultural fields
- Flax Museum situated
- Collective memory flourishing flax industry
- Proposed site for the flax weaving facility

Satellite view of Stedum, Groningen I Scale 1:20.000

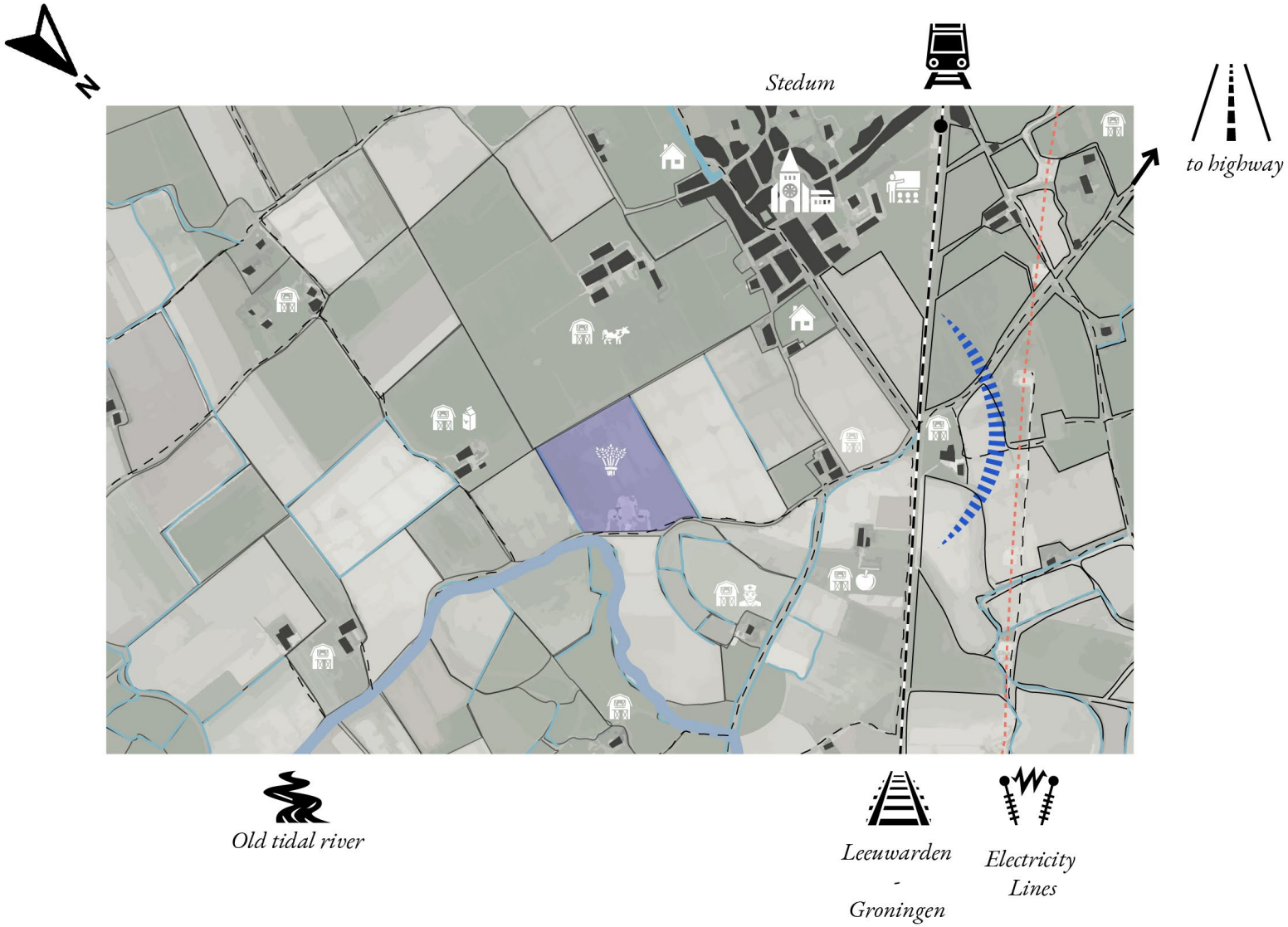
Image adjusted and retrieved from: Google Earth [Image]. Google Earth. Accessed on January 25, 2024, www.earth.google.com

(Google Earth, 2024)

Arial View of the plot with Stedum in the background

Arial View of the plot showcasing different farm fields in the area

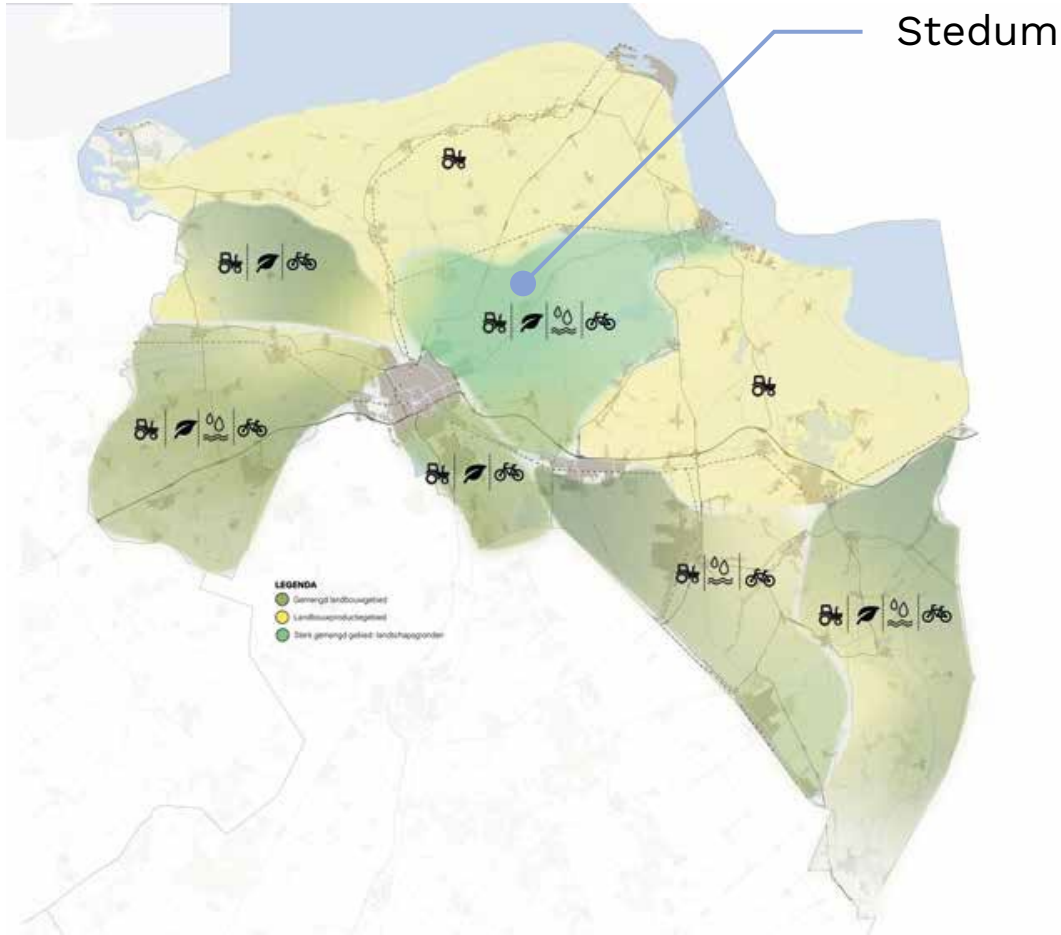
Plot Potentials & Threats



Contextual Influences

Vision of Province Groningen

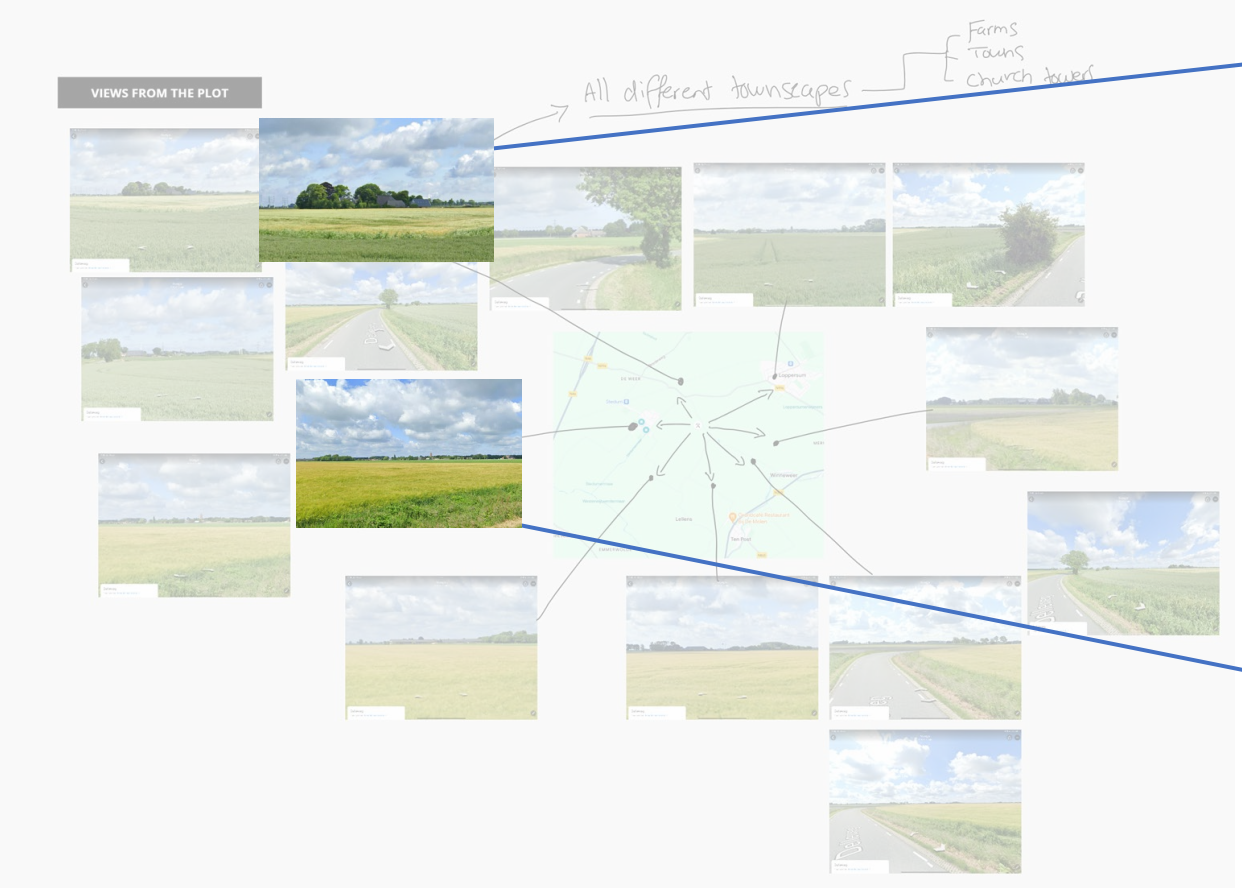
Harvest Building Materials



(Koersdocument Omgevingsvisie Provincie Groningen, 2022)

Contextual Influences

Undulating Landscapes



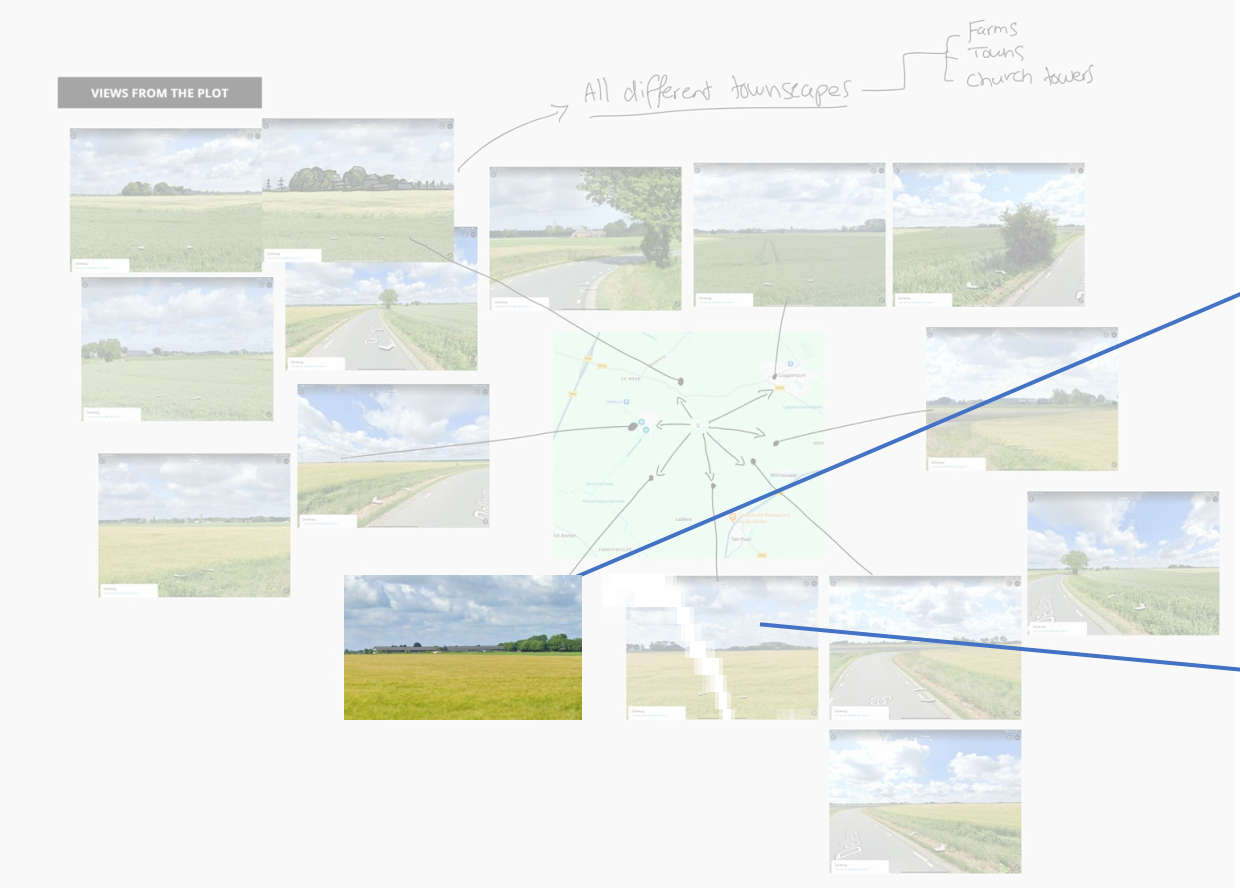
Treescapes

Treescapes

(Google Earth, 2024)

Contextual Influences

Undulating Landscapes



Treescapes

Treescapes

(Google Earth, 2024)

Contextual Influences

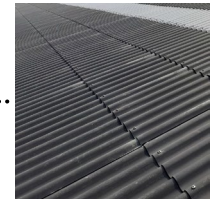
Architecture of Stedum

Timber Boards

Red Clay Roof Tiles

Grey Clay Roof Tiles

Corrugated Bitumen Roof



(Google Maps, 2024)

Design input

Earthquake Zone

Soil Subsidence

Technological

Form Language

Materials & Textures

Architectural

Community Involvement

Local Economy Growth

Societal

Strong Winds

Heavy Rainfall

Climatological

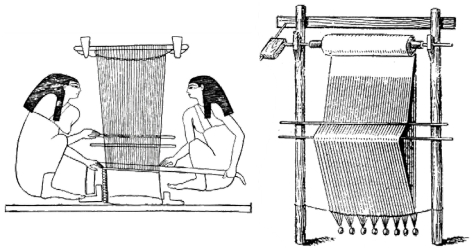
CONCEPT

REIMAGINING FLAX

Overall Design Hypothesis

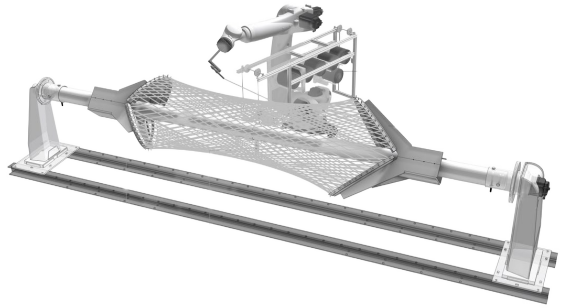
- A building design built with Flax
- Constructed using Coreless Filament Winding
- New Architectural Language
- Showcases full potential of Flax in Architecture

REIMAGINING FLAX



Vernacular
Flax Hand
Weaving

Traditional
Flax Machine
Weaving



Innovative
Flax Robotic
Weaving

Project Goals

Primary

Innovative
Production of Flax Fibrous Building Systems

Secondary

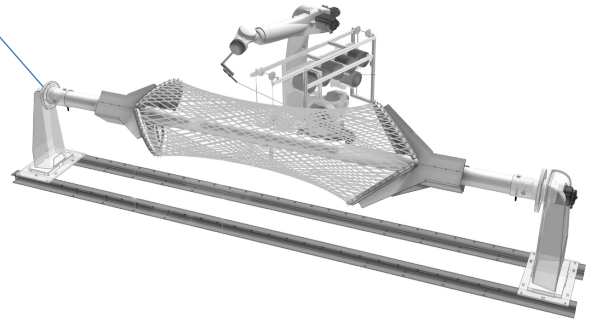
Inspiring & Educational
Showcasing the new building technique

Production of Flax Fibrous Building Systems

Primary

Innovative
Production of Flax Fibrous Building Systems

Flax Fibers



Coreless Filament Winding

Showcasing the new building technique

Secondary

Inspire & Educate
Showcasing the new building technique

Tectonics (Esthetics & Structure)

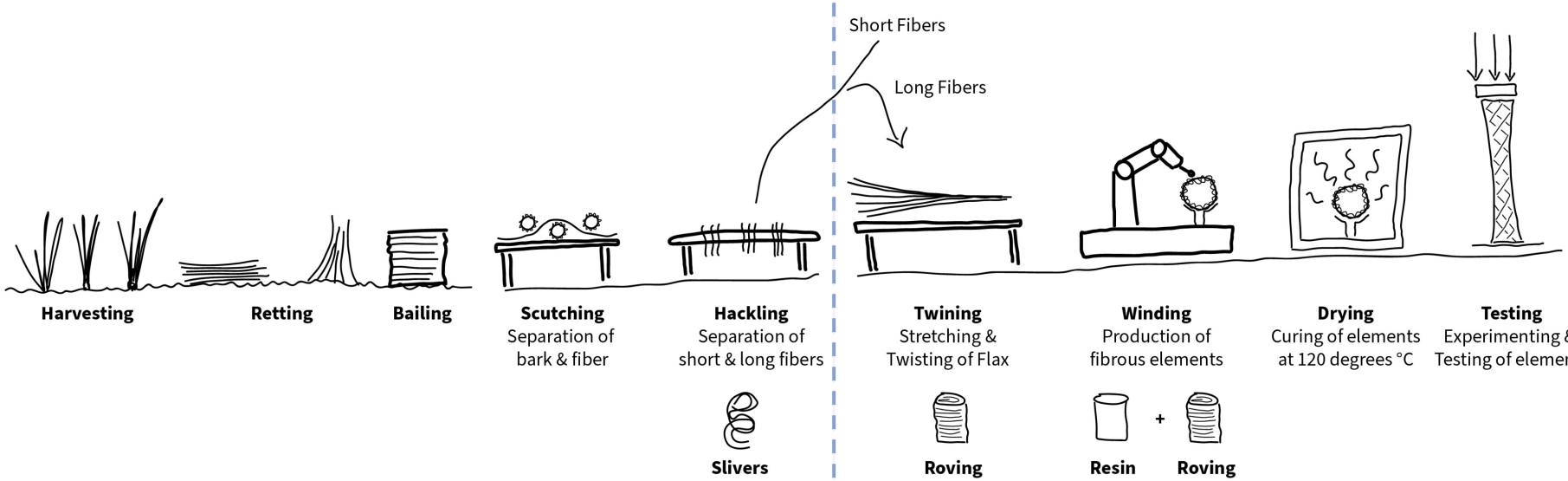
Tactile & Visual Experience

Building Focus

Production Process

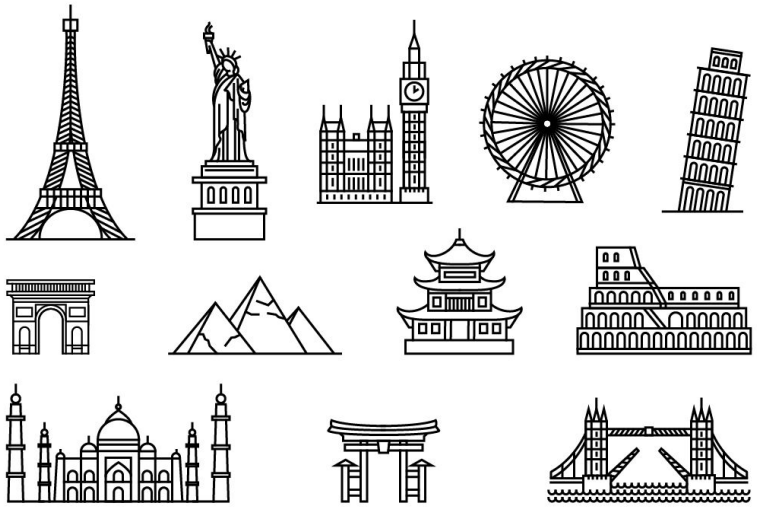
Regional Boost

Production with Expertise



Iconic versus **Alienation**

Iconic



VS

Alienation

Connection with the **surroundings**

Form Language

Materials & Textures

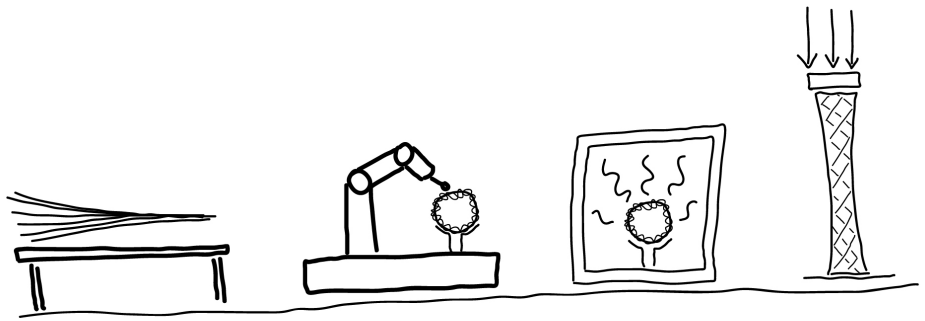
DESIGN

THE FLAX WEAVING HUB

Illustration by Grimshaw Architects

Organization

Product



Twining
Stretching &
Twisting of Flax

Roving

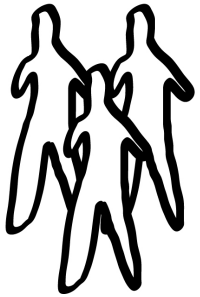
Winding
Production of
fibrous elements

Resin + **Roving**

Drying
Curing of elements
at 120 degrees °C

Testing
Experimenting &
Testing of elements

People

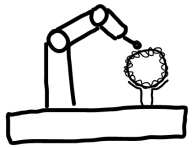


Employees & Visitors

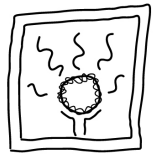
Relations

Linear

Twining
Stretching &
Twisting of Flax

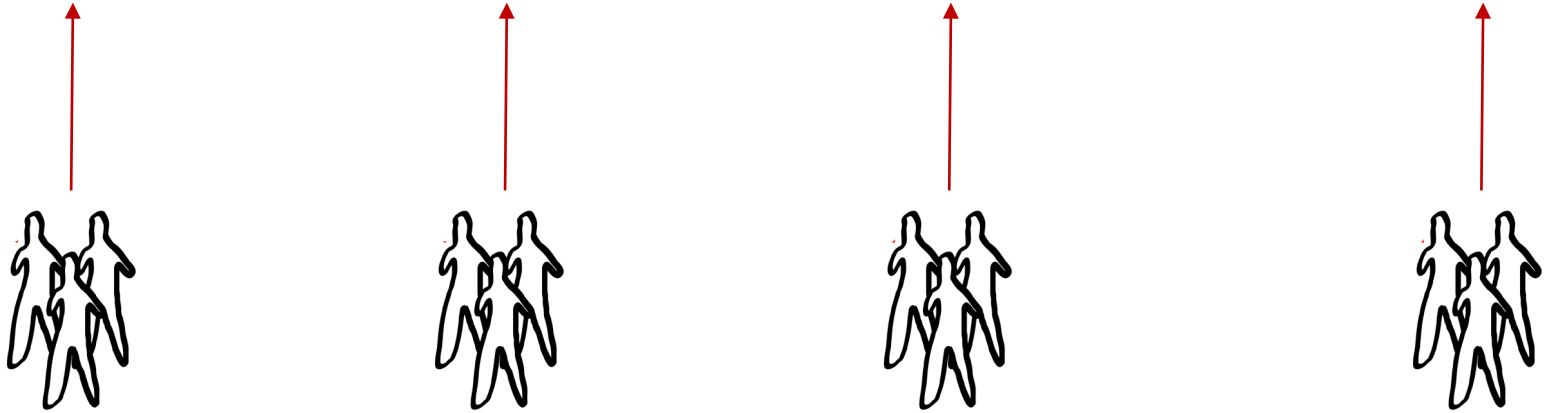


Winding
Production of
fibrous elements



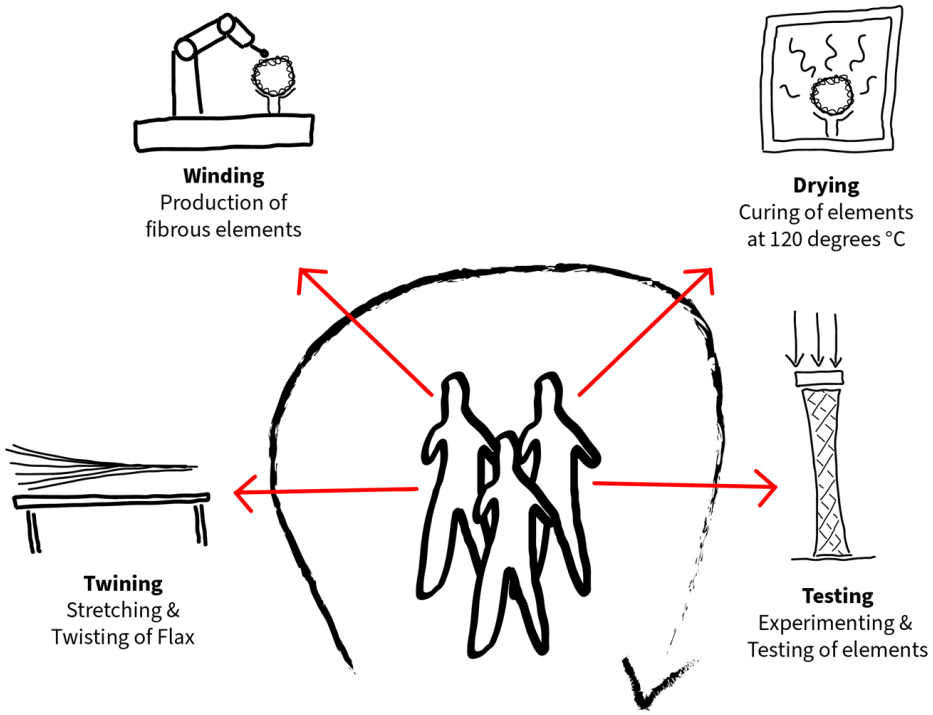
Drying
Curing of elements
at 120 degrees °C

Testing
Experimenting &
Testing of elements



Relations

Radial



Spatial x Structural Principles

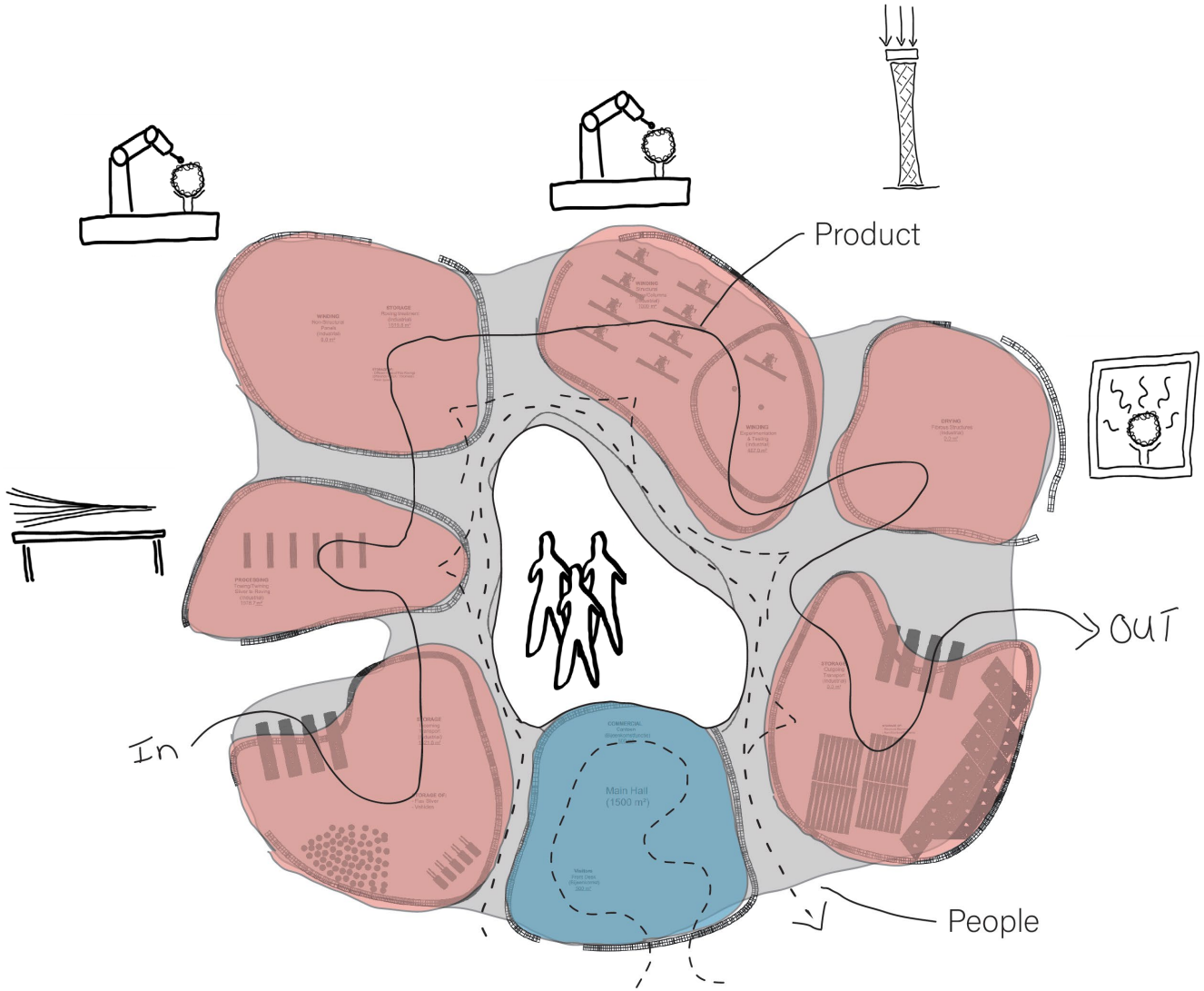
Primary Production Spaces

Secondary Supporting Spaces

Floor levels

Relations

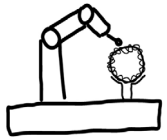
Diagram



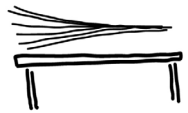
Functions

Characteristics

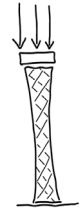
Panel Winding

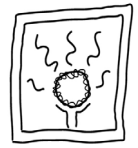


Beam Winding



Roving Storage





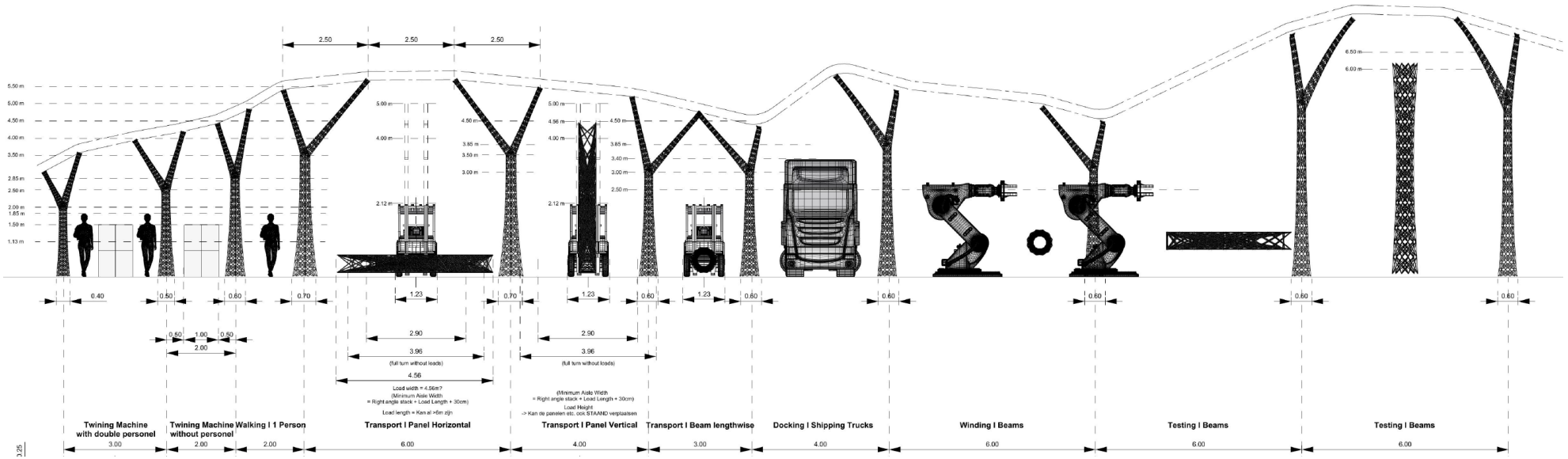
Storage IN

Storage OUT

Offices

Spatial Conditions

By Function



Twining — Internal Transport — External Transport — Winding — Testing

Program

INDUSTRIAL

MANUFACTURING 1000 m2

FABRICATION & EXPERIMENTATION 3000 m2

COMMERCIAL

OFFICE 1500 m2

CULTURAL

COMMUNITY 1000 m2

OTHER 2000 m2

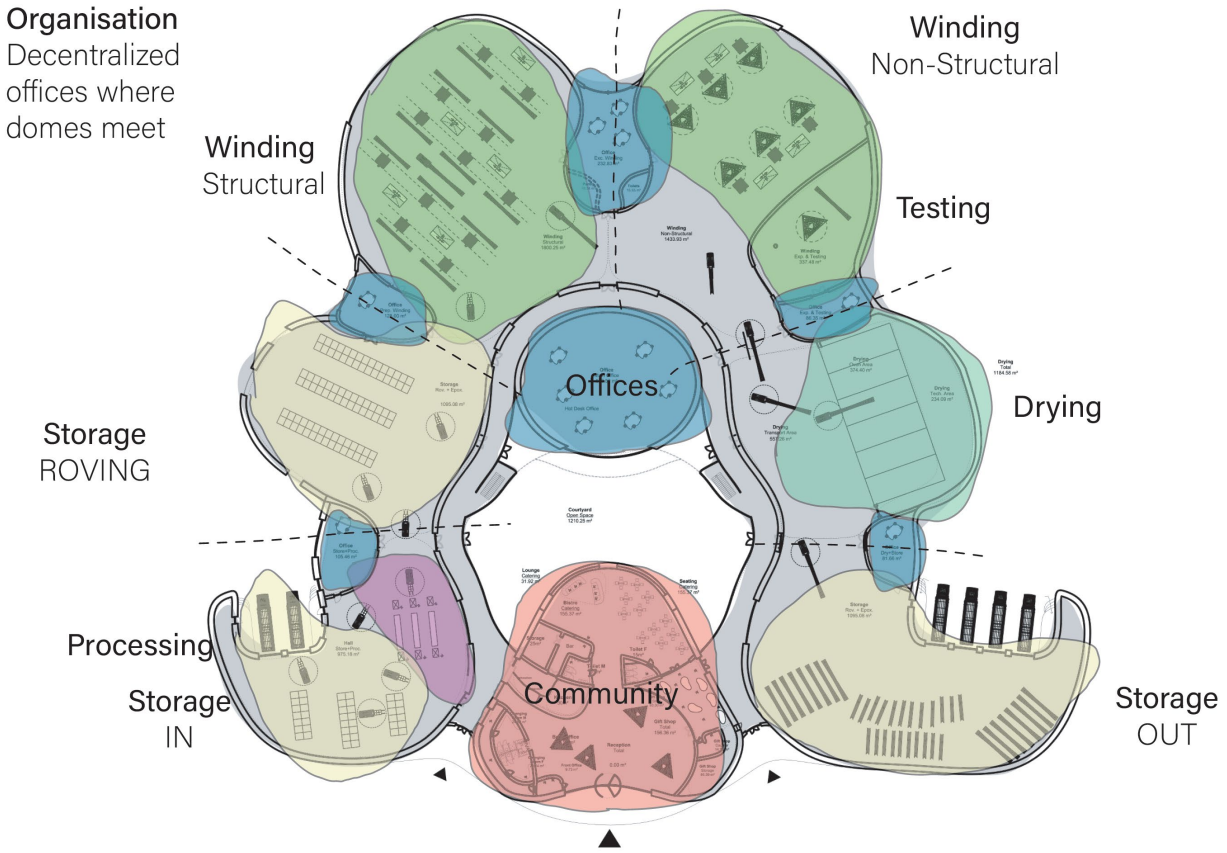
TOTAL **8500 m2**

Functions					Dimensions			Climate				Relationship	
Type	Function	Sub-Function	Spaces	Inventory	Area	Min. Span	Height	Dry	Heated	Light	Vent.	Direct	Indirect
Industrial	Processing				750 m²								
		Transport	Loading dock	2 Trucks	120 m²	5 m	6 m	yes	no	no	no	Stor. In	Proc.
		Per. Storage	Storage racks	100 pallet racks	500 m²	20 m	9 m	yes	no	no	yes	Stor. In	Proc.
		Processing	Assembly line	3 assembly lines	180 m²	10 m	6 m	yes	yes/no	yes	yes	Proc. + Stor	Stor. Rov
		Temp. Storage	Staging area: Raw material	6 staging places (3 in and 3 out)	60 m²	3 m	6 m	yes	yes/no	yes	yes	Proc. + Stor	Stor. Rov
		Temp. Storage	Staging area: Vehicles (forklifts)	2 forklifts	40 m²	3 m	6 m	yes	no	no	no	Proc. + Stor	Stor. Rov
		Dec. Office	Office	10 employees	100 m²	3 m	4 m	yes	yes	yes	yes	Stor. In	Proc.
Industrial	Fabrication				2000 m²								
		Per. Storage	Rov+Epoxy Storage	200 pallet racks	500 m²	15 m	6 m	yes	yes/no	yes	yes	Stor. Rov	Winding
		Dec. Office	Office Preparation	5 employees	120 m²	3 m	4 m	yes	yes	yes	yes	Stor. + Win.	Office
		Manufacturing	Winding area: Structural	12 winding robots	1000 m²	20 m	9 m	yes	yes/no	yes	yes	Winding	Drying
		Manufacturing	Winding area: Non-Structural	6 winding robots	750 m²	20 m	9 m	yes	yes/no	yes	yes	Winding	Drying
		Dec. Office	Office Execution	12 employees	250 m²	3 m	4 m	yes	yes	yes	yes	Winding	Office
		Var. Office	Variable offices	9 var. desks	-	3 m	4 m	yes	yes/no	yes	yes	Winding	Office
		Experimentation & Testing	Experimentation & Test area	1 beam testing 1 panel testing	200 m²	10 m	9 m	yes	yes/no	yes	yes	Exp. + Test	Winding & Drying
		Dec. Office	Office Exp. & Test.	4 employees	80 m²	3 m	4 m	yes	yes	yes	yes	Exp. + Test	Drying
		Manufacturing	Drying	6 ovens (10x4m)	600 m²	15 m	6 m	yes	no	yes	yes	Drying	Stor. Out
		Technical	Tech. area Drying	Sufficient for installations	200 m²	3 m	6 m	yes	no	no	no	Drying	-
Commercial	Office												
		Cen. Office	Main Office Hall	15 employees	750 m²	3 m	4 m	yes	yes	yes	yes	Winding	Courtyard
			Meeting Rooms	5 rooms	250 m²	3 m	4 m	yes	yes	yes	yes	Office	-
		Toilet	Male Toilets	3 toilets	20 m²	3 m	4 m	yes	yes	no	yes	Office	-
			Female Toilets	3 toilets	20 m²	3 m	4 m	yes	yes	no	yes	Office	-
		Canteen	Coffee Corner	2 coffee machines	20 m²	3 m	4 m	yes	yes	yes	yes	Office	-

Table made by author (R.T. STEINFORT)

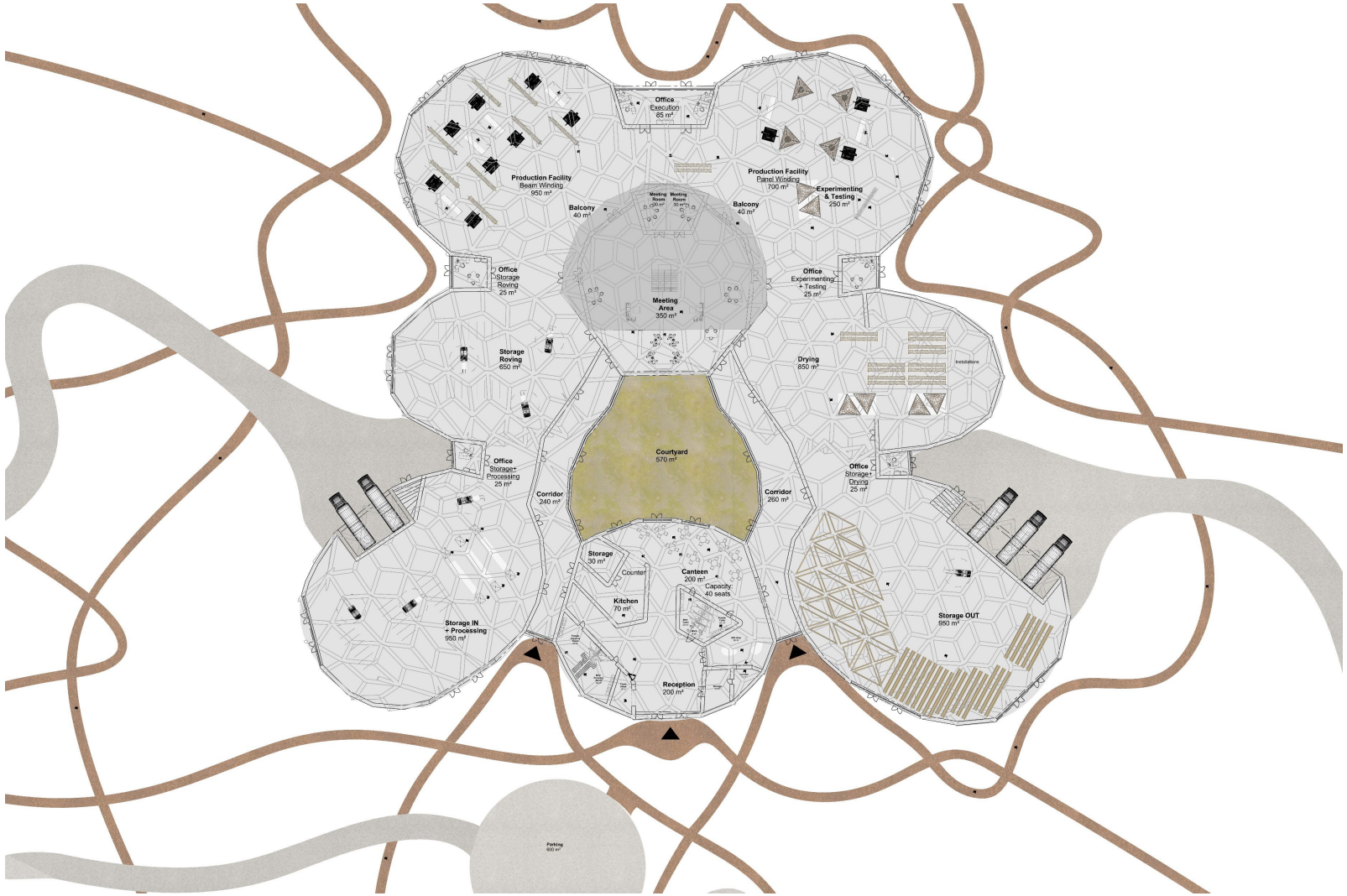
Principles

Organization

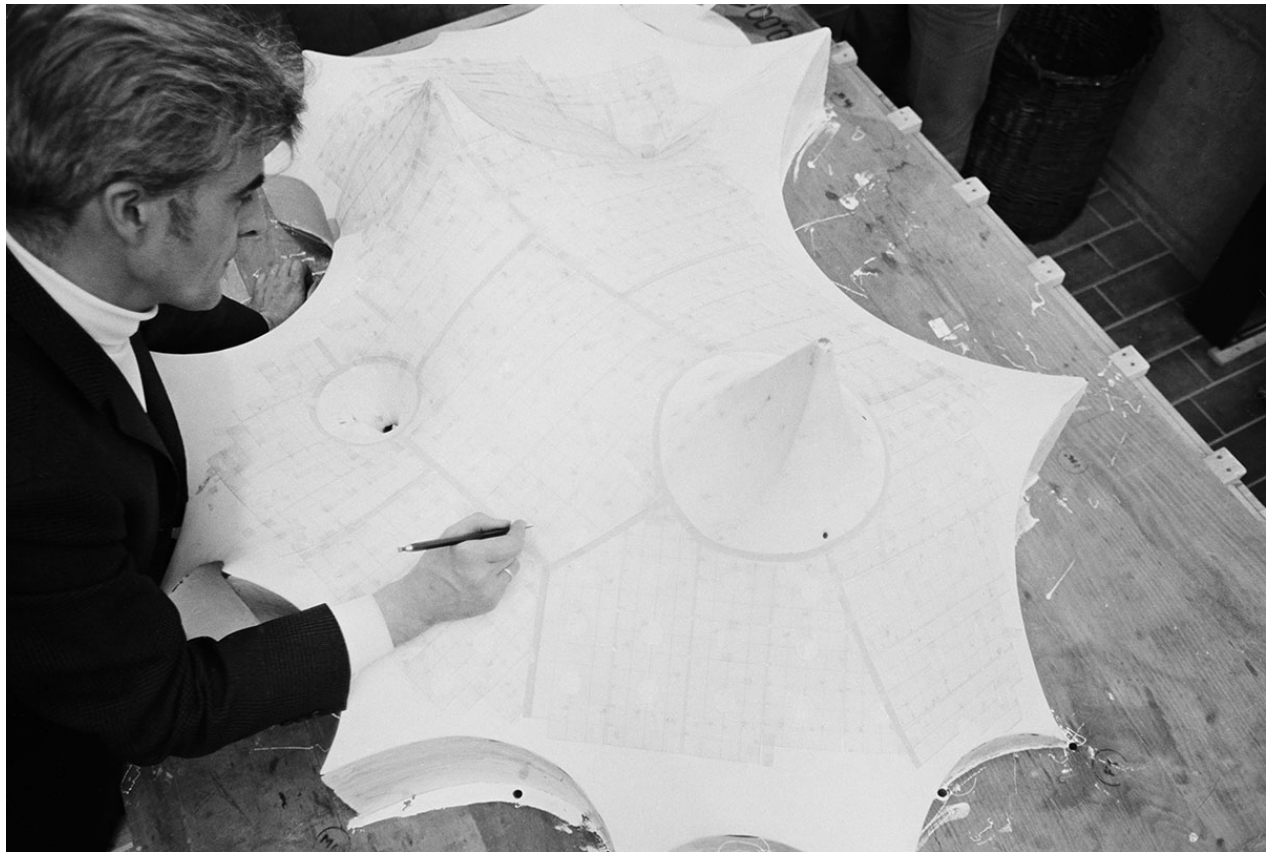


Ground Level

Overview

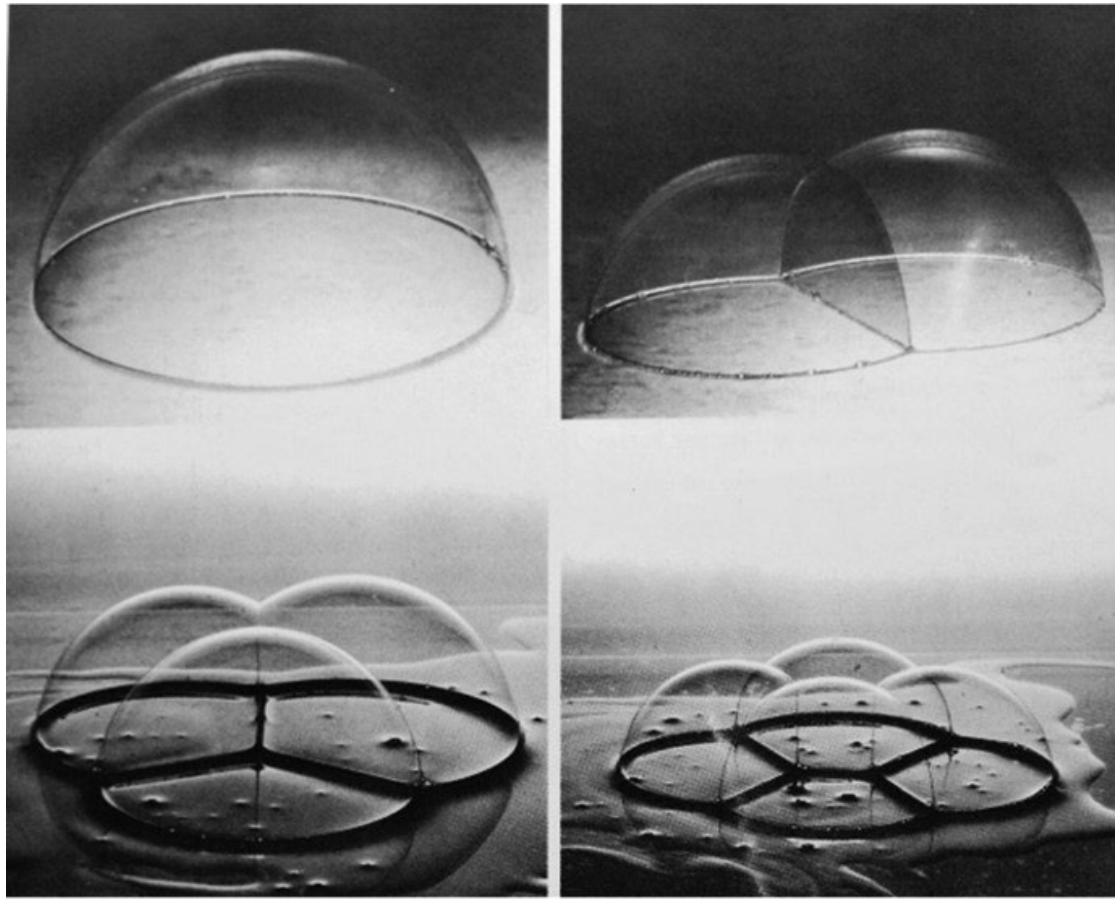


Connection of the different spaces



Frei Otto

Connection of the different spaces

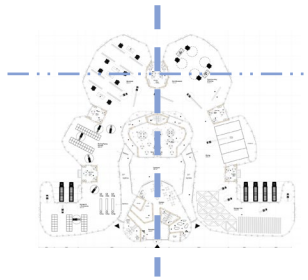


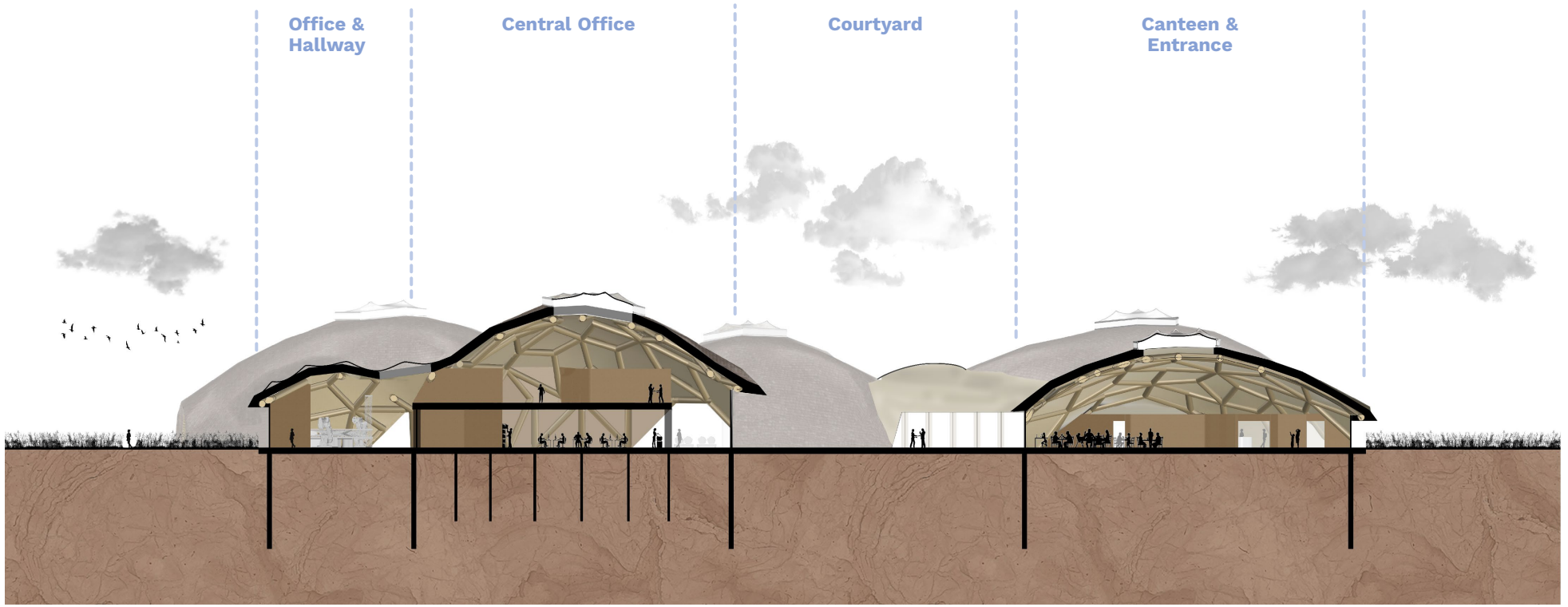
Soap Bubble Experiments Frei Otto, 1961

Sections

Overview

Long Section

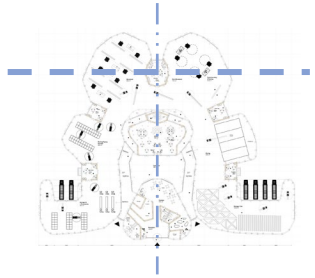


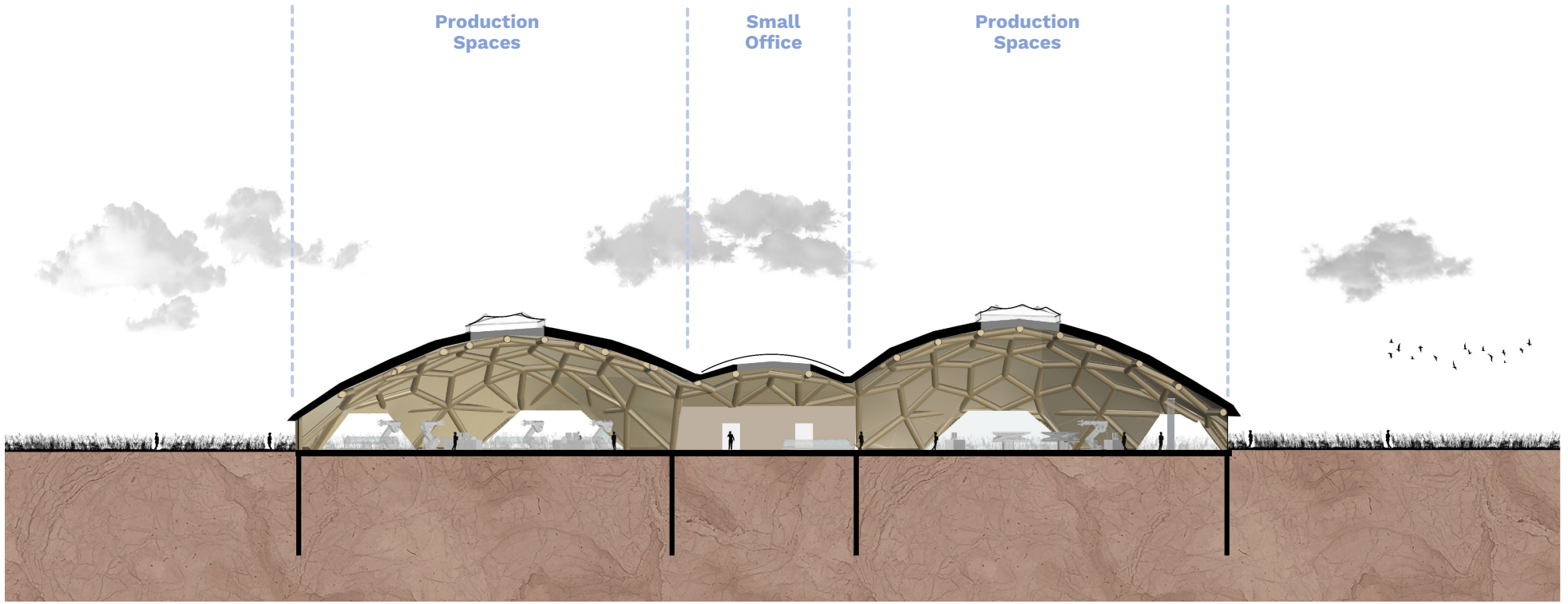


Sections

Overview

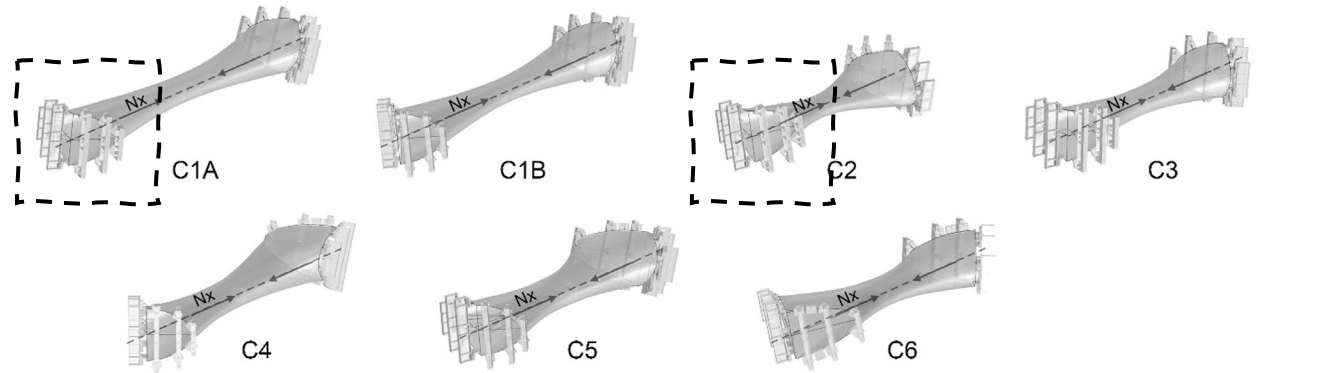
Cross Section





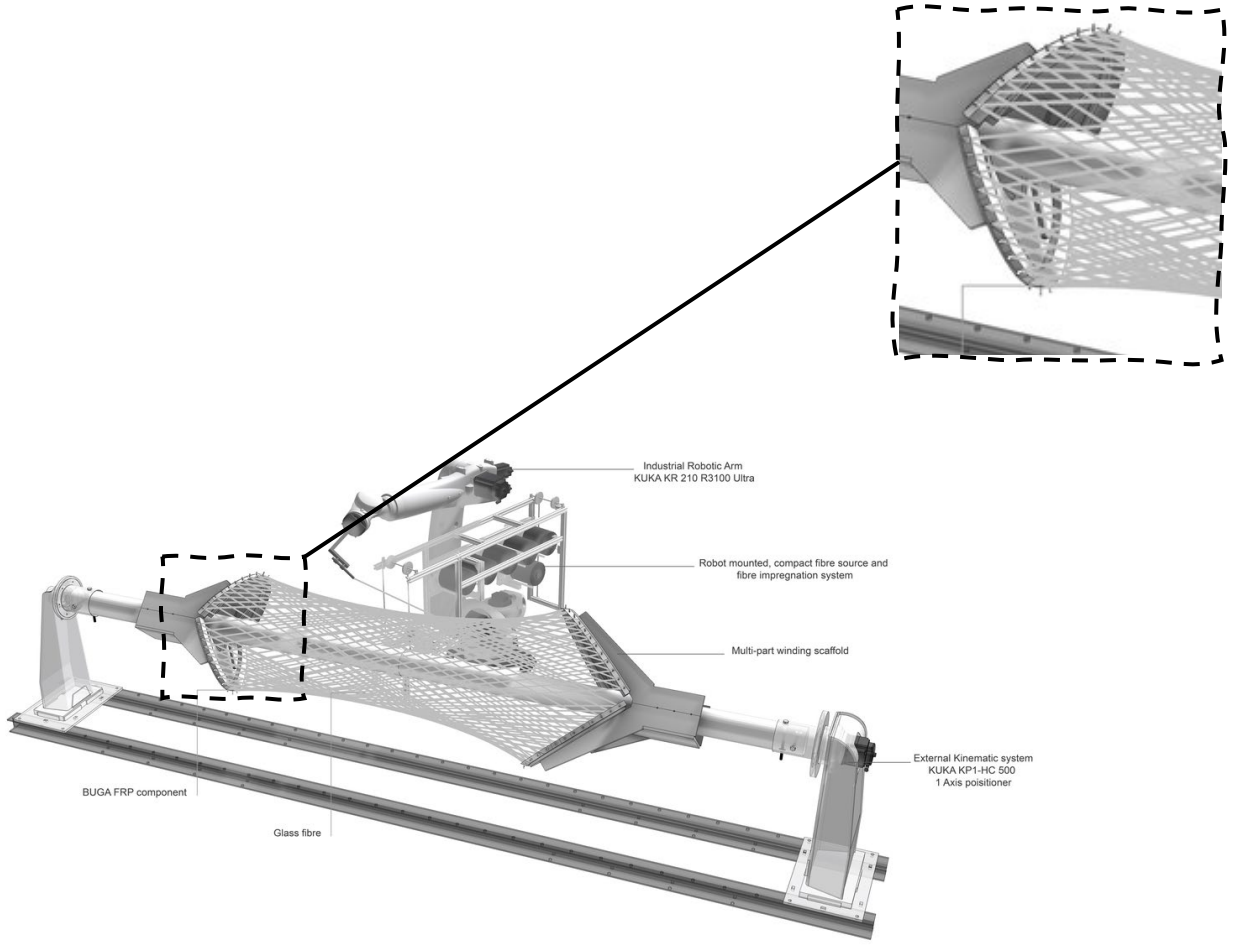
Construction System

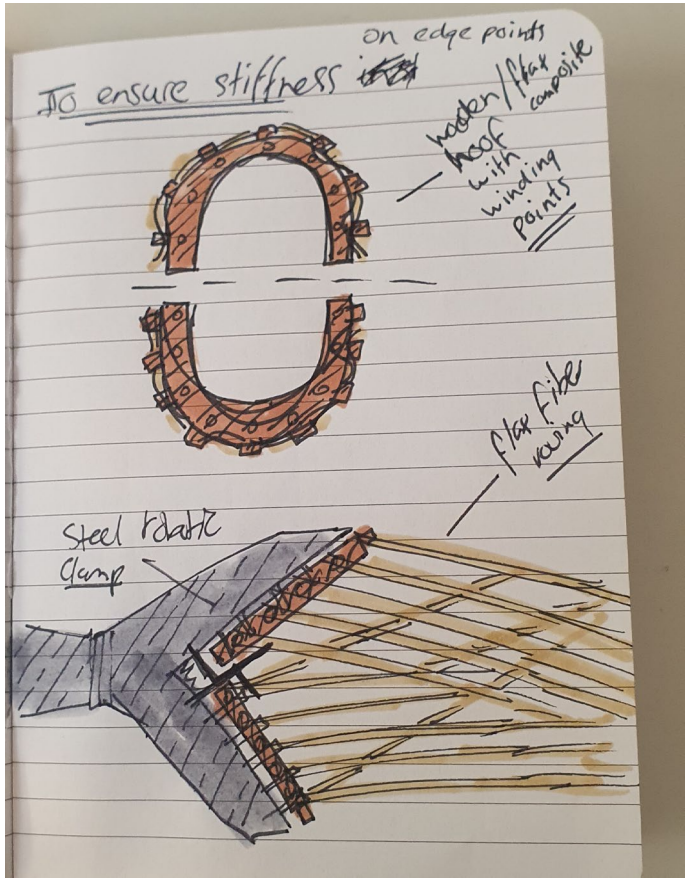
Winding Process



Construction System

Winding Process

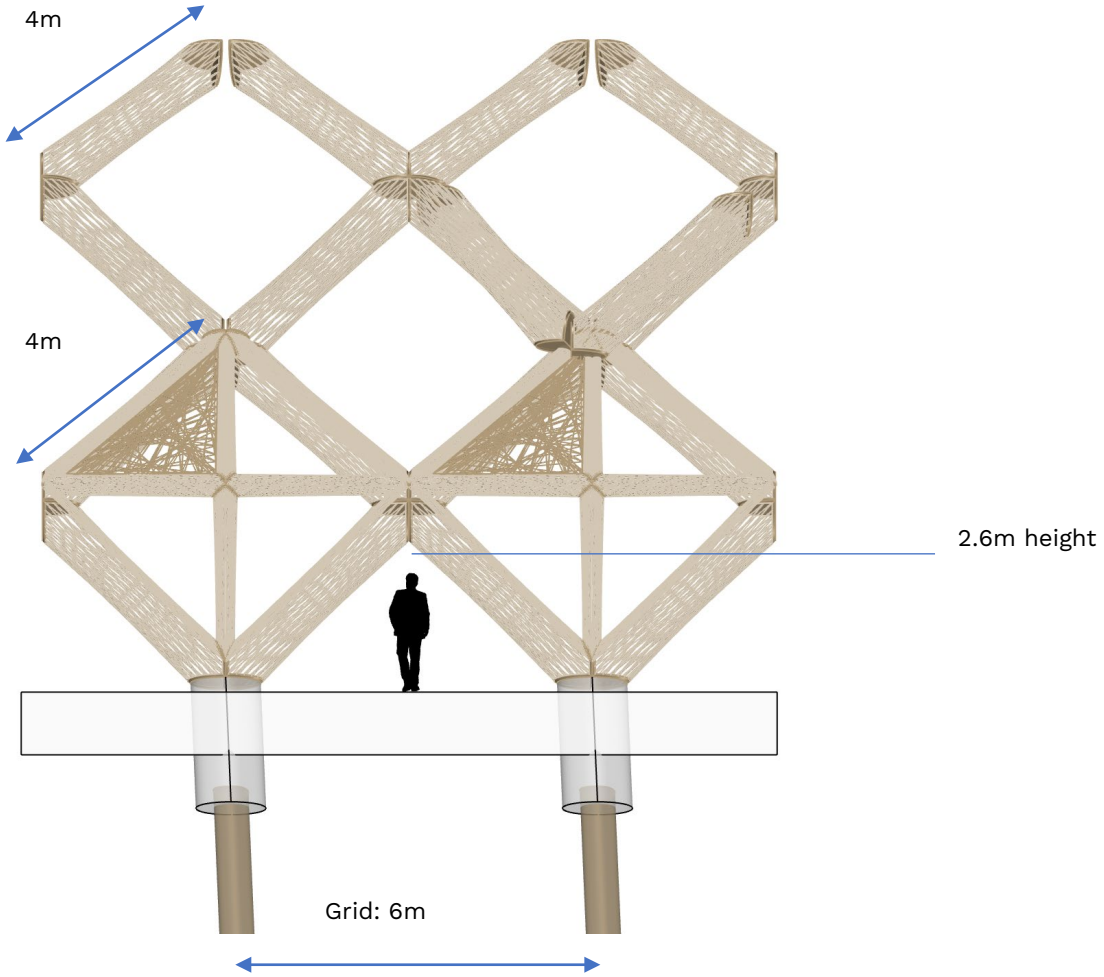




Flax Composite Winding Ring

Construction System

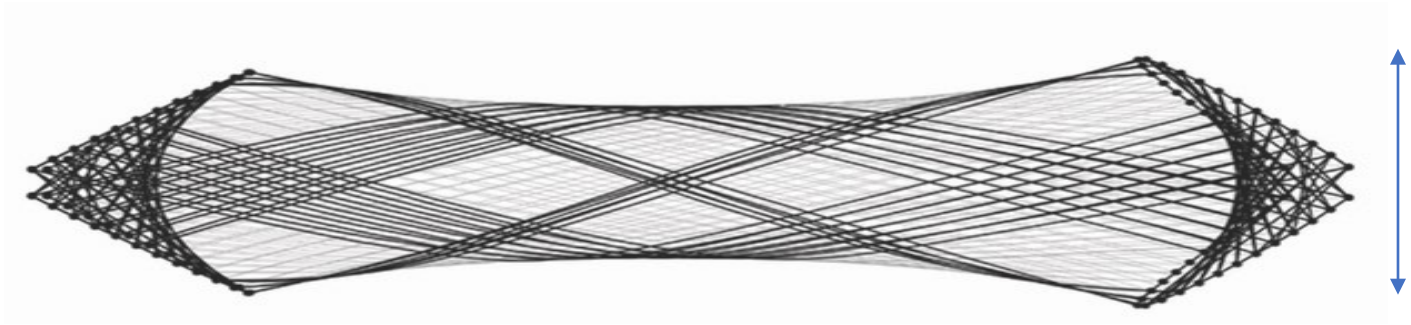
Domes



Construction System

Main Beam Dimensions

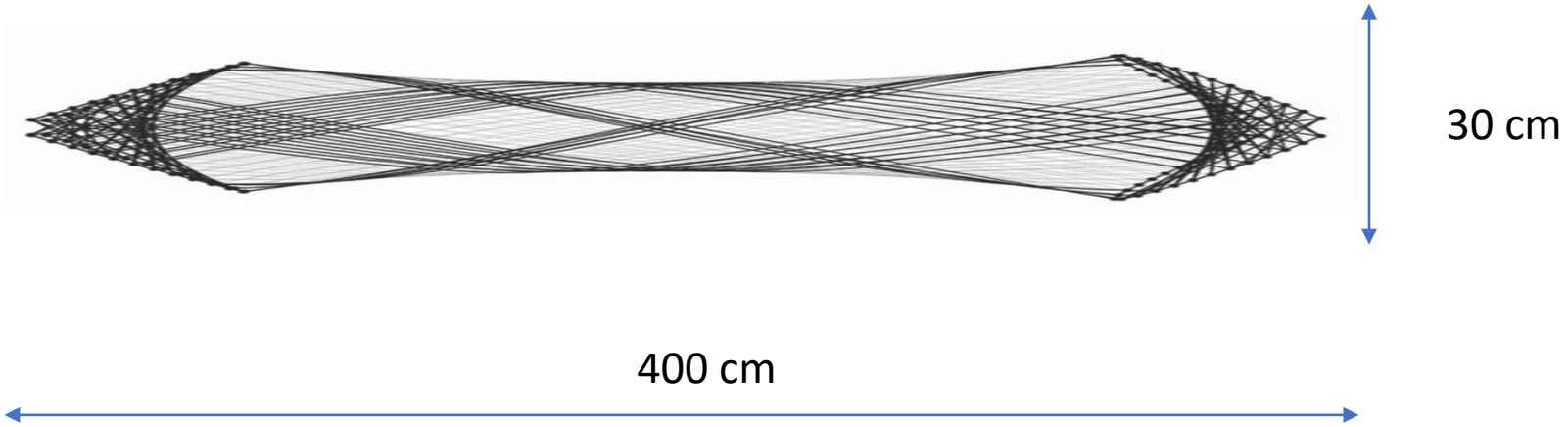
BUGA Fibre Pavilion 2019
ICD Research Buildings / Prototypes
Bundesgartenschau Heilbronn 2019, Germany



Weight: 42,5 kg
Can be lifted by 2 persons

Construction System

Sub Beam Dimensions

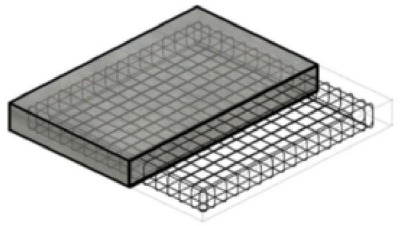


Weight: 18,75 kg
Can be lifted by 1 person

Construction System

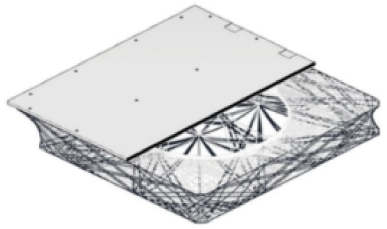
Panel Dimensions

Steel-reinforced concrete slab



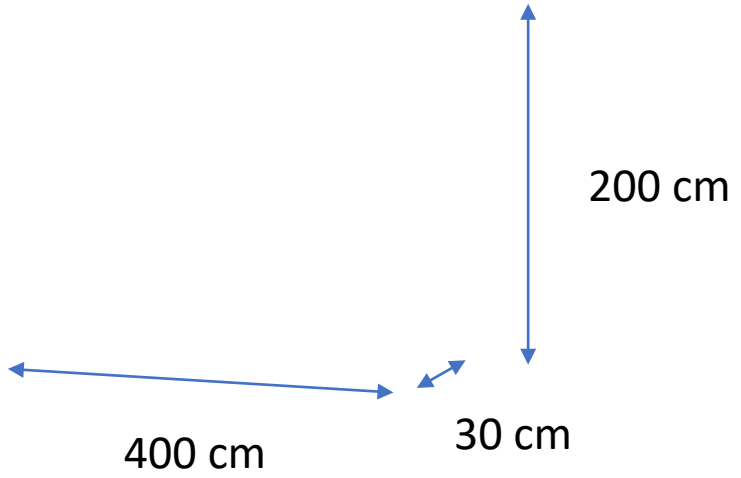
200mm concrete slab: **500 kg/m²** Weight

Hybrid slab timber + fibers



Fiber composite structure: **9,9 kg/m²** Weight

incl. 27mm timber floor: **23,7 kg/m²**



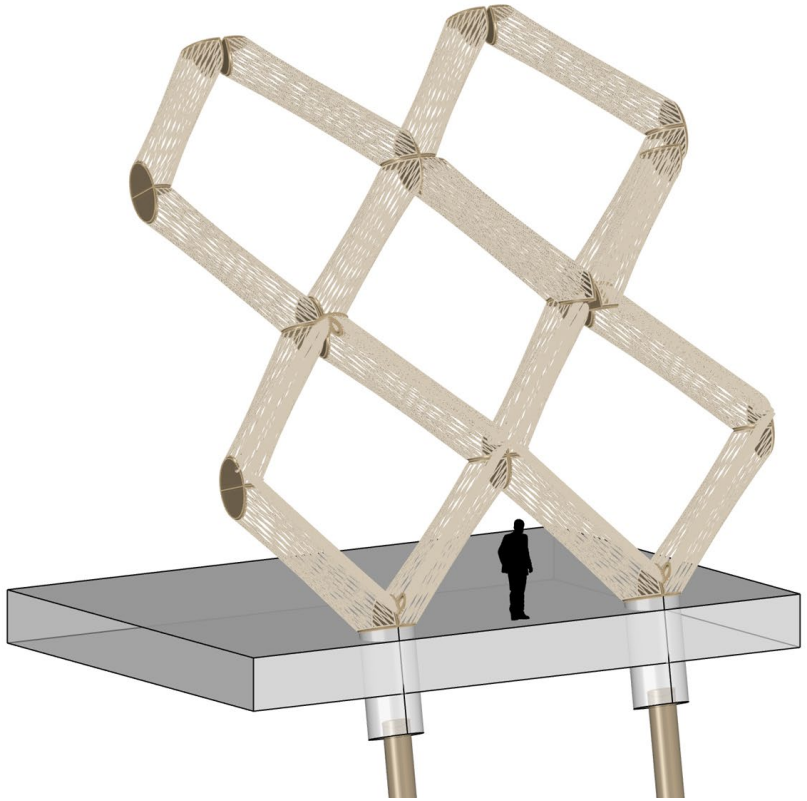
Weight: 59,4 kg (without insulation)
Can be lifted by 3 persons

Weight: 85 kg (with insulation)

Construction System

Main Structure

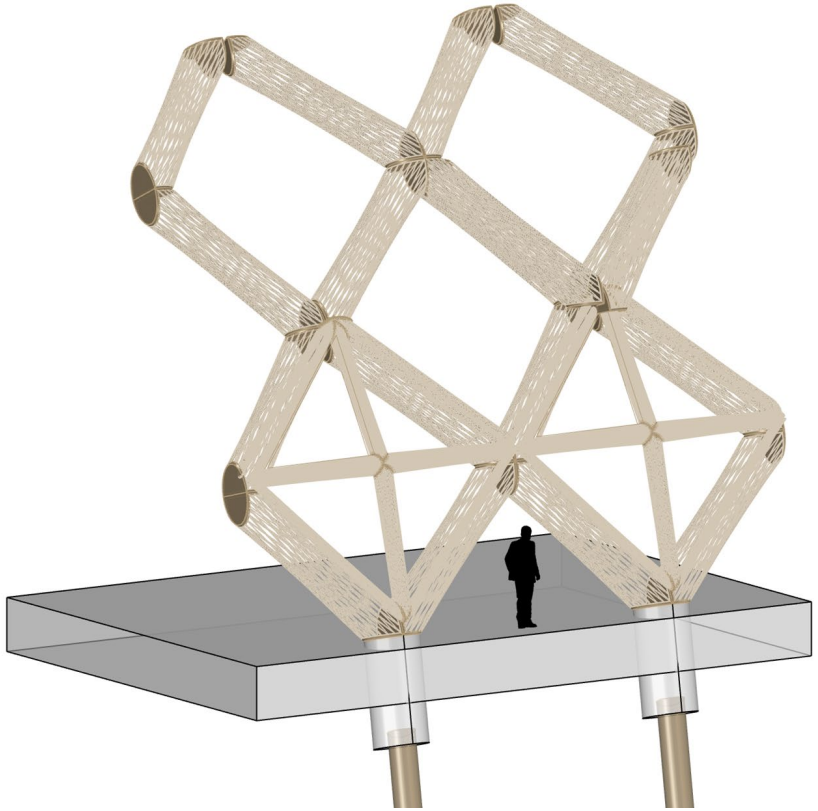
BUGA Fibre Pavilion 2019
ICD Research Buildings / Prototypes
Bundesgartenschau Heilbronn 2019, Germany



Main Structure

Construction System

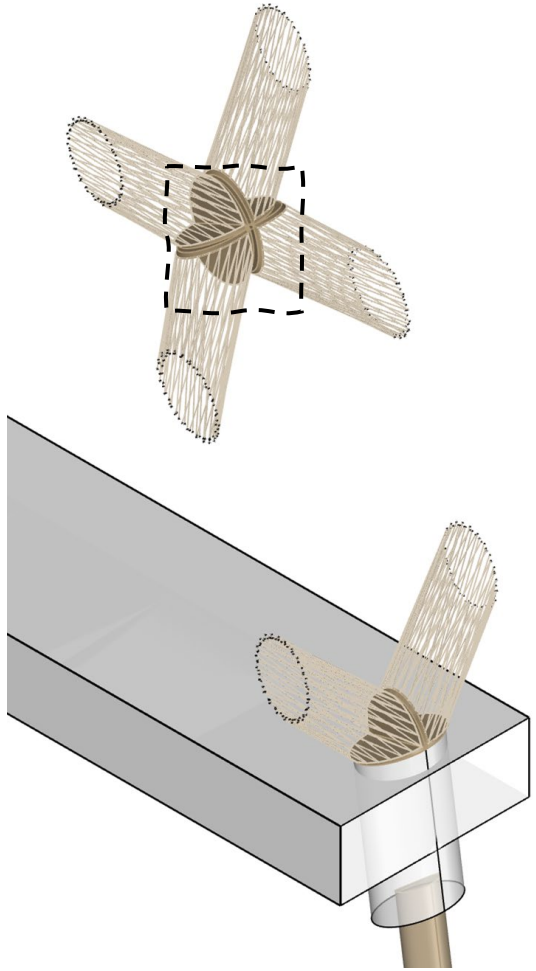
Sub Structure

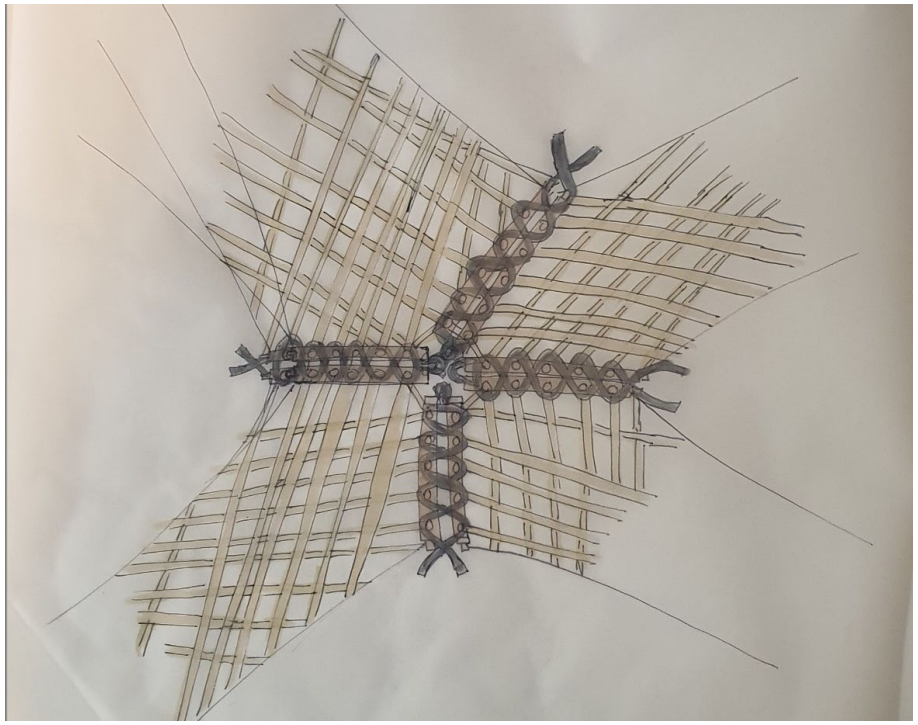


With Sub Structure

Construction System

Main Structure





Connections between the winding rings

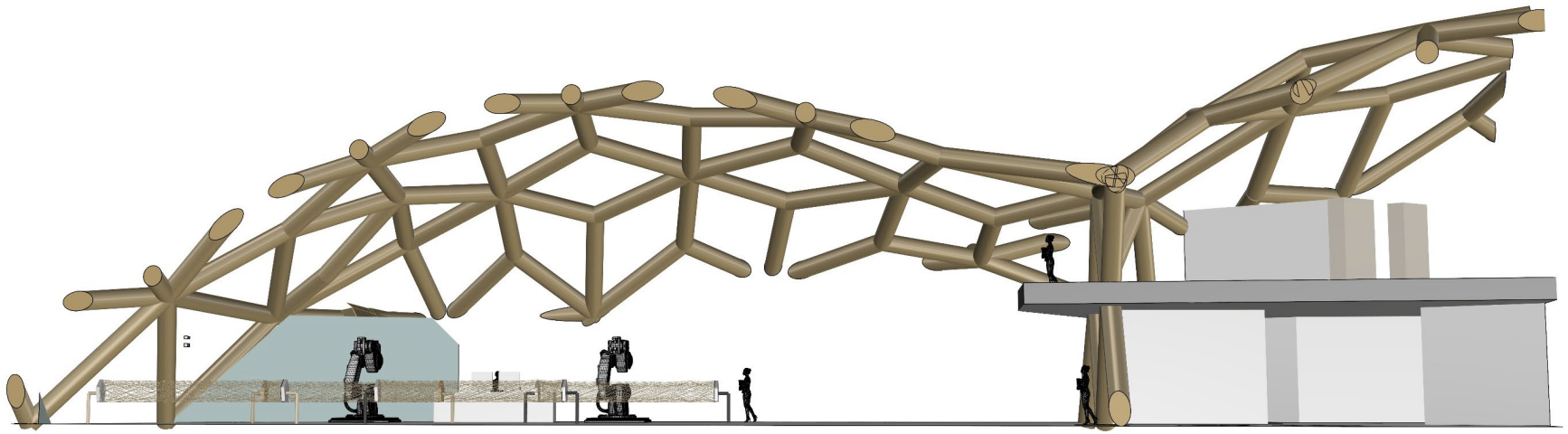
Connections

Lightweight & Easy Connections

BUGA Fibre Pavilion elements lifted with a small crane

Construction System

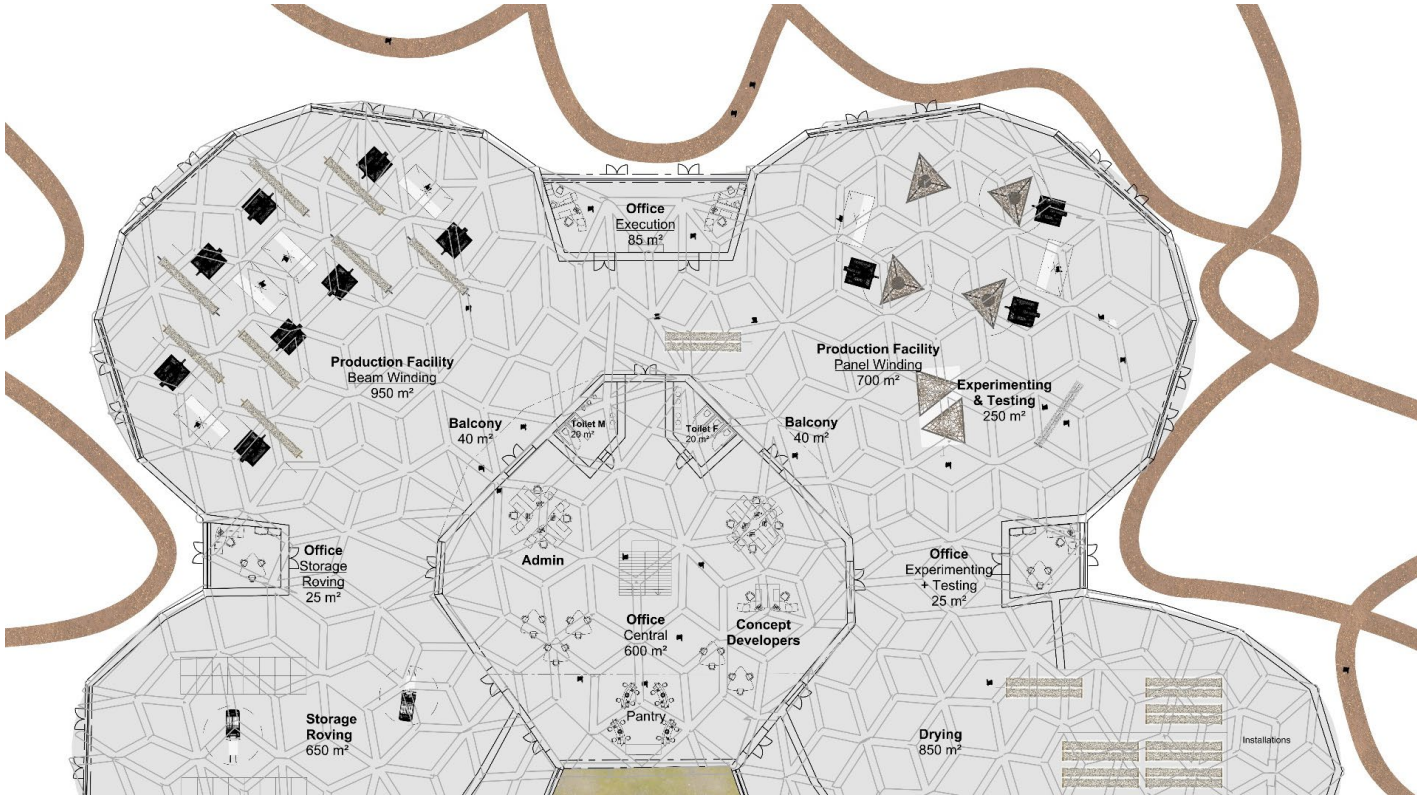
Domes

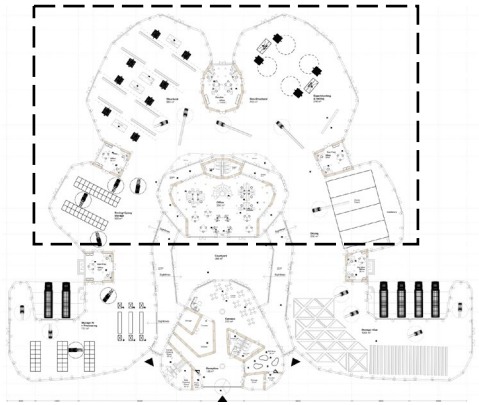


Dome Grid Shells I Section

Ground Level

Overview

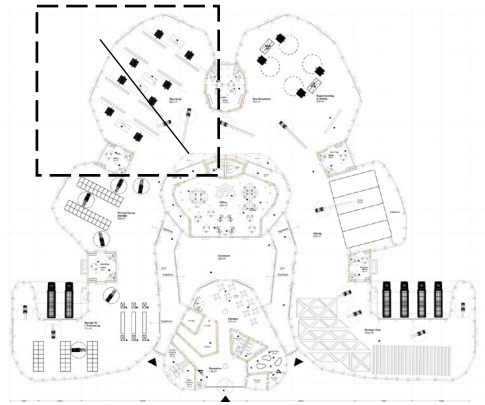


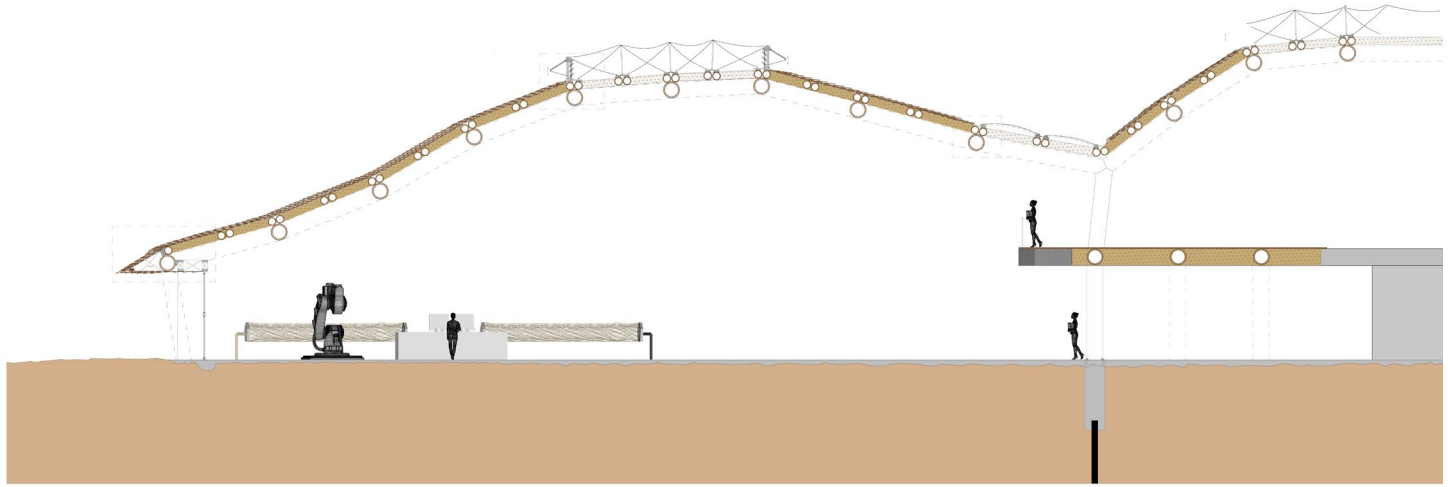


1:250

Ground Level

Production Spaces

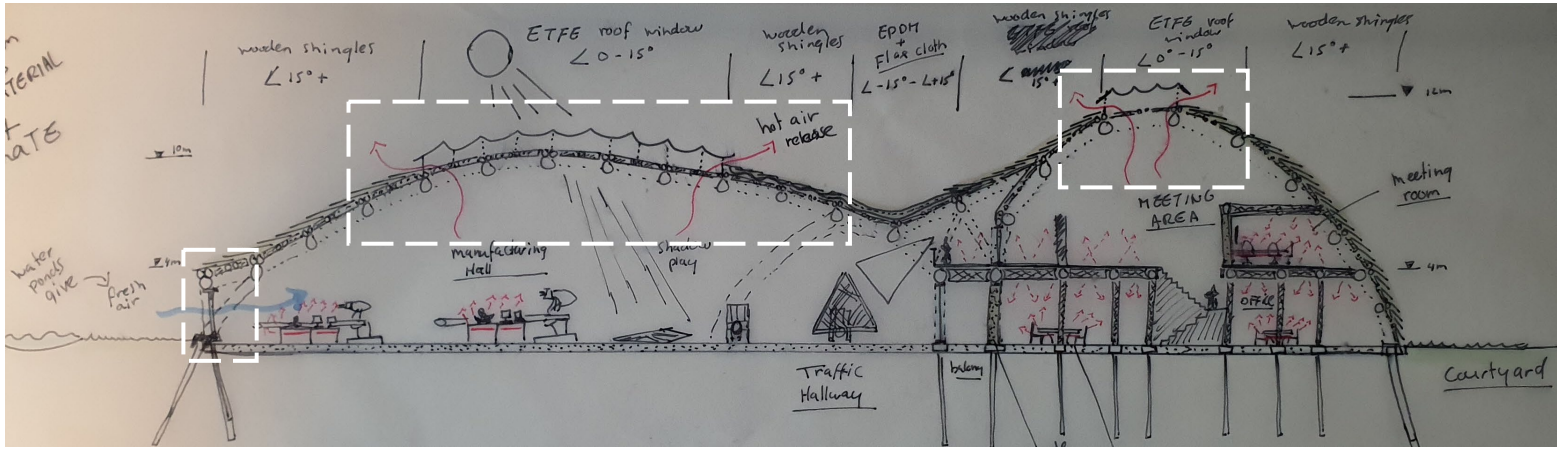




Fragment Production Spaces

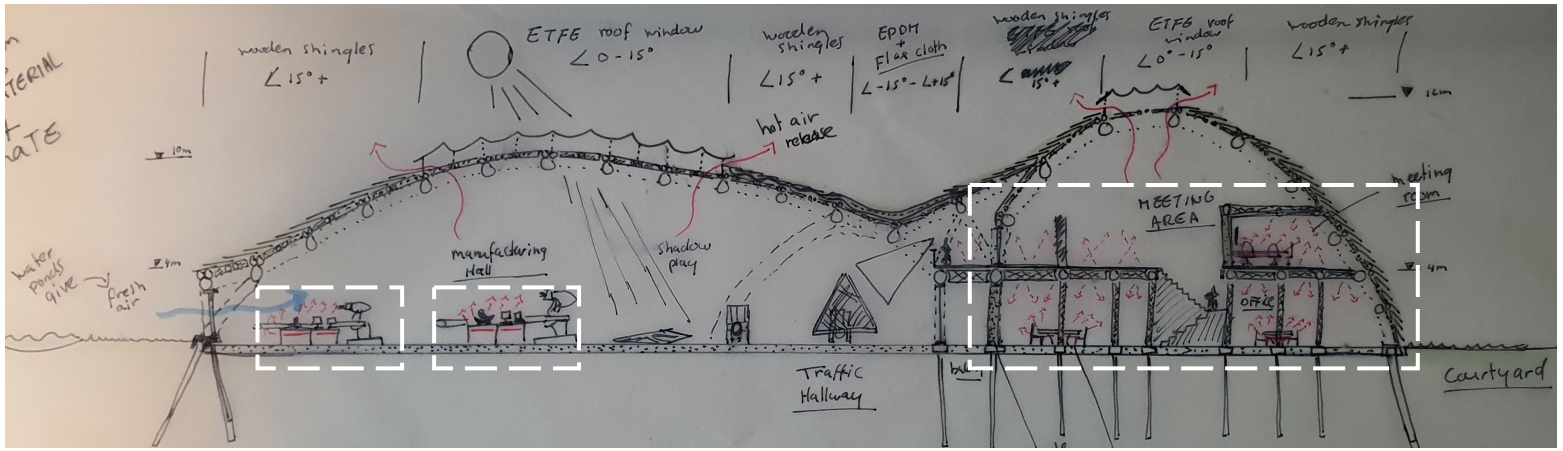
Climate

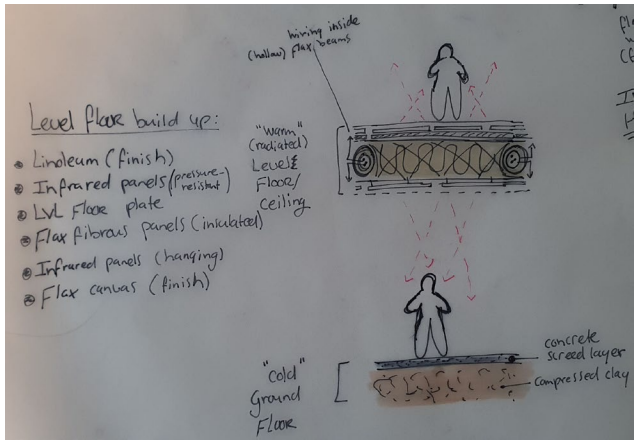
Summer

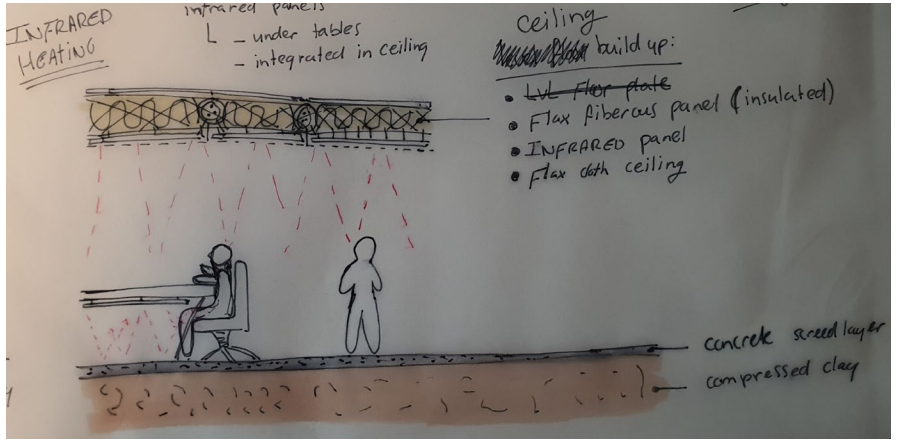


Climate

Winter

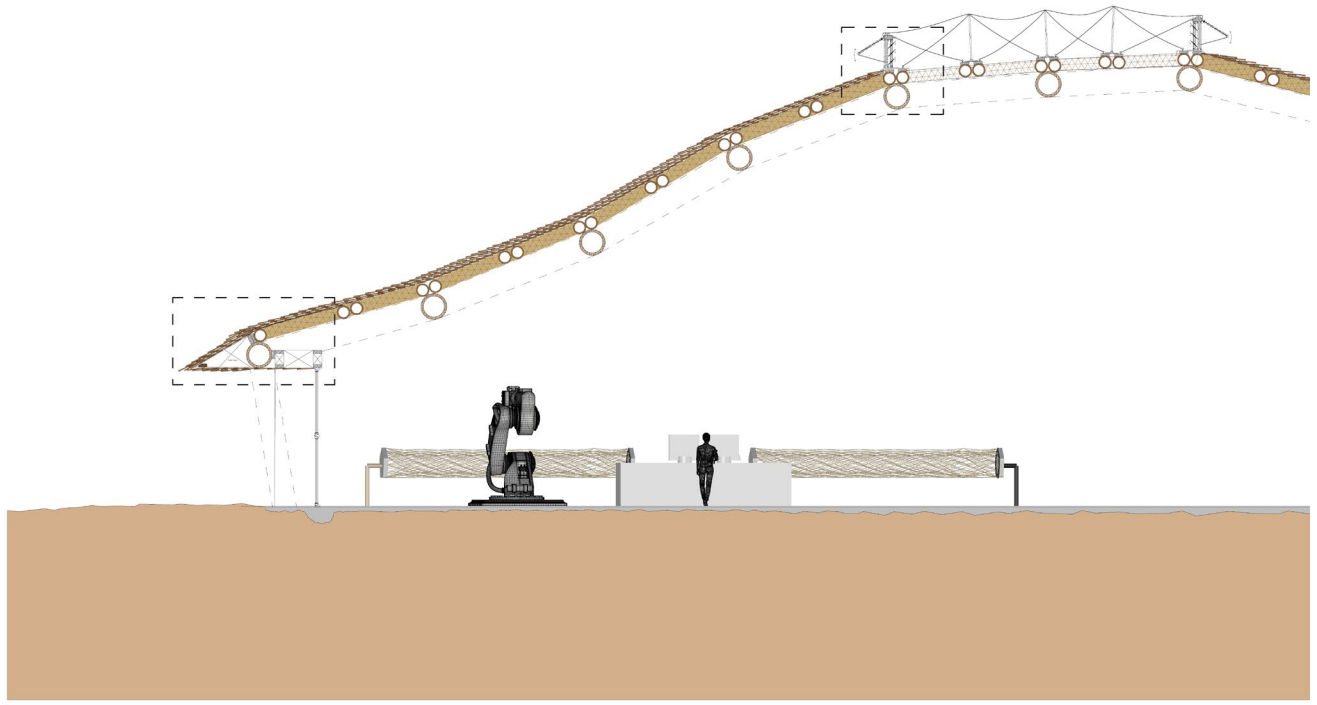




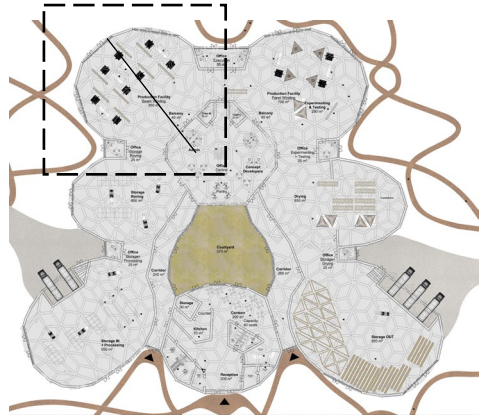


Ground Level

Production Spaces

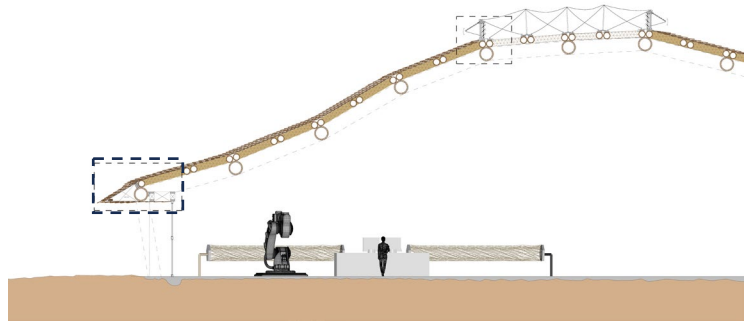


Fragment I 1:50

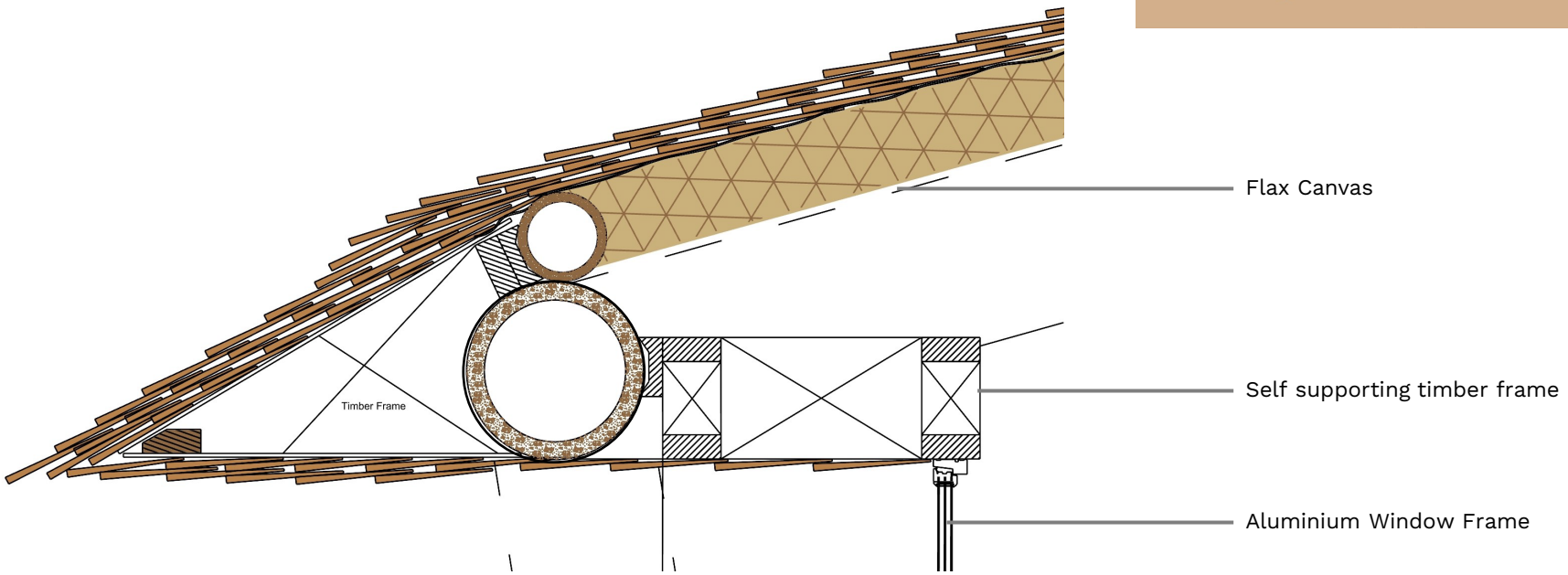


Tactile & Visual Experience

Ground Level

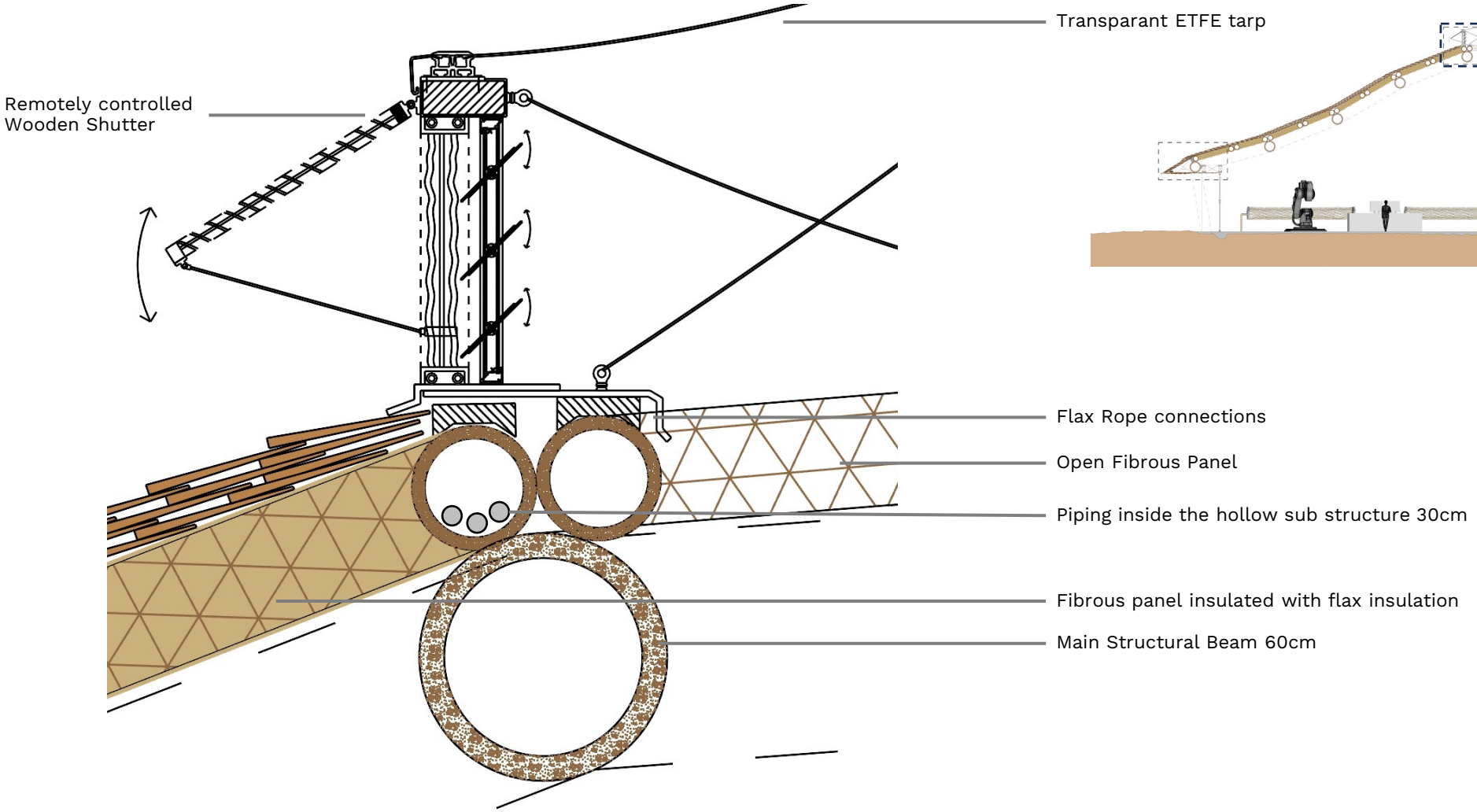


Fragment



Detail I Roof edge

Ground Level

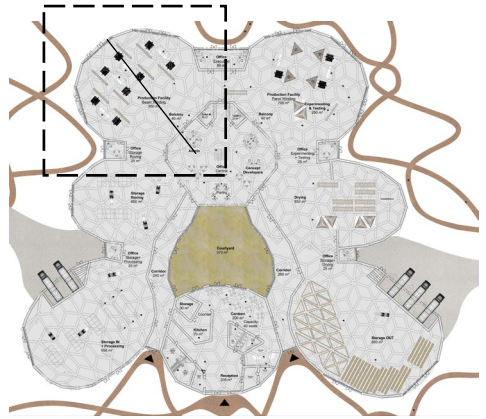


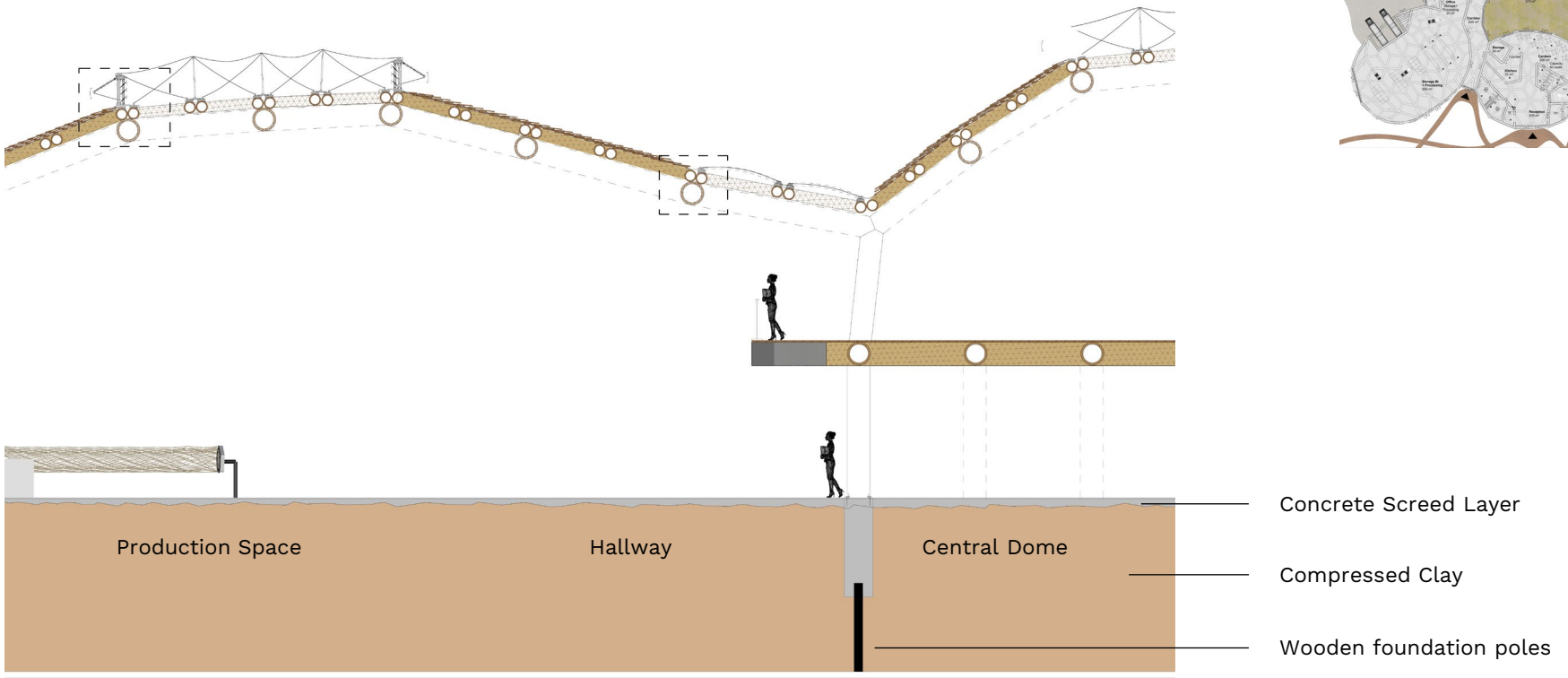
Fragment

Detail I Roof Window Connection

Ground Level

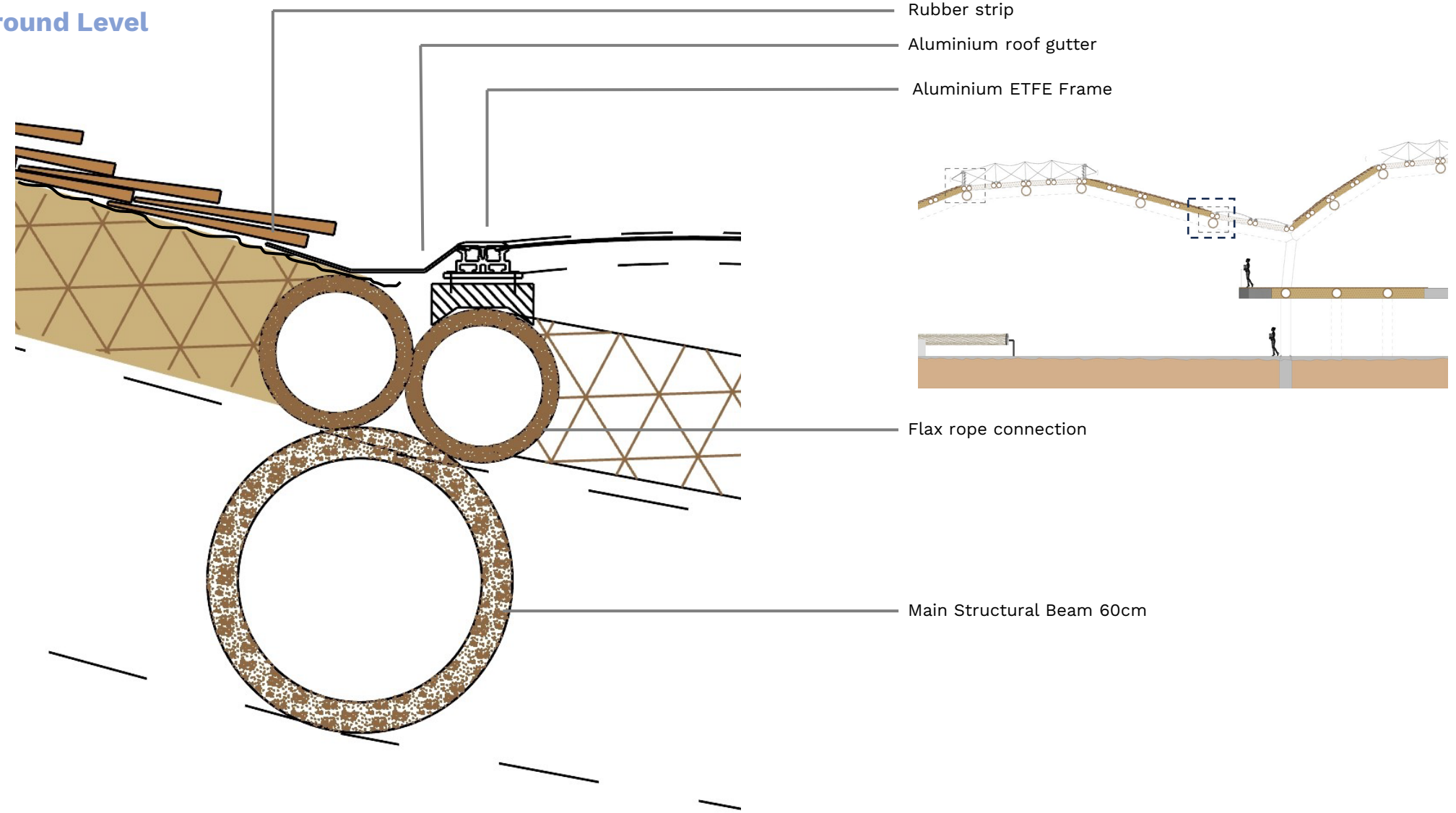
Hallway





Fragment I 1:50

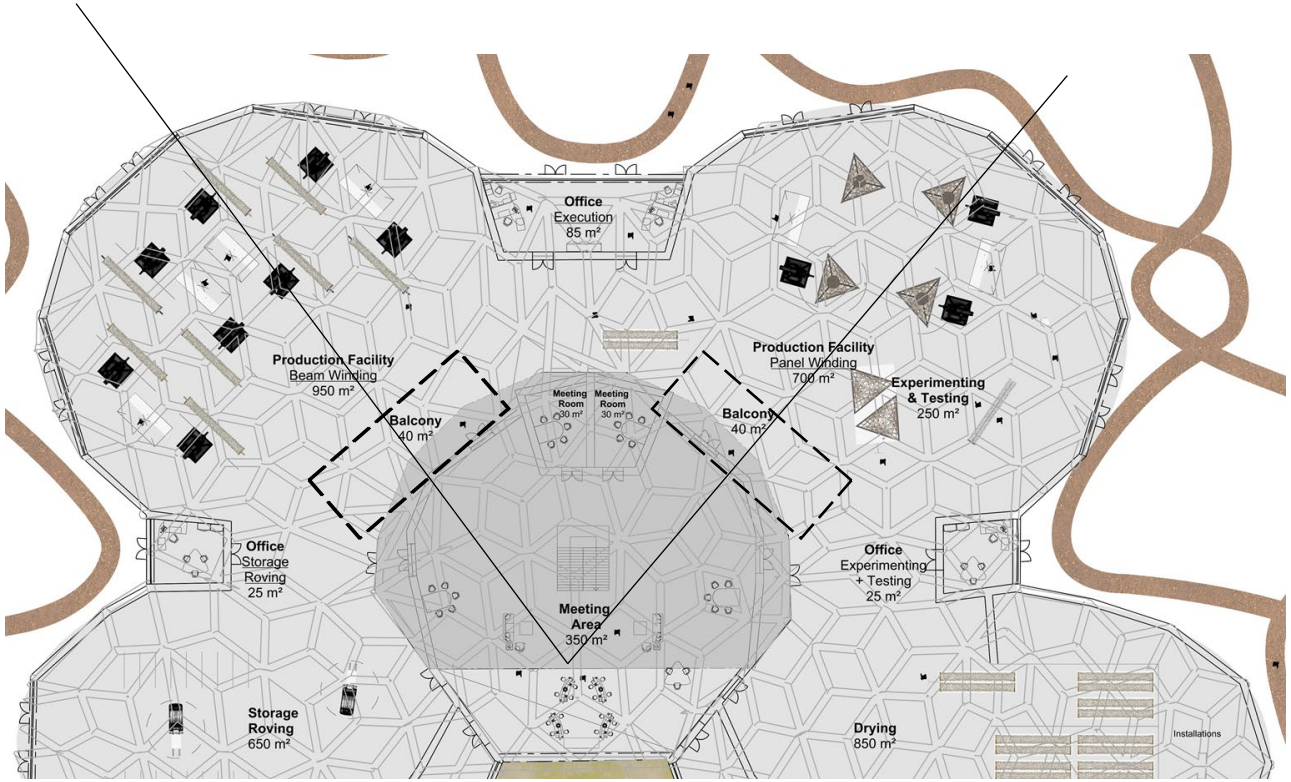
Ground Level



Detail I Roof Window Connection

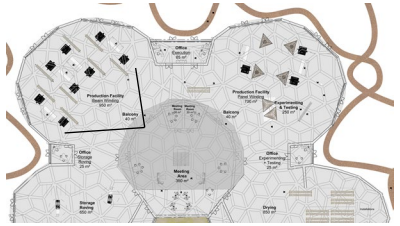
First Level

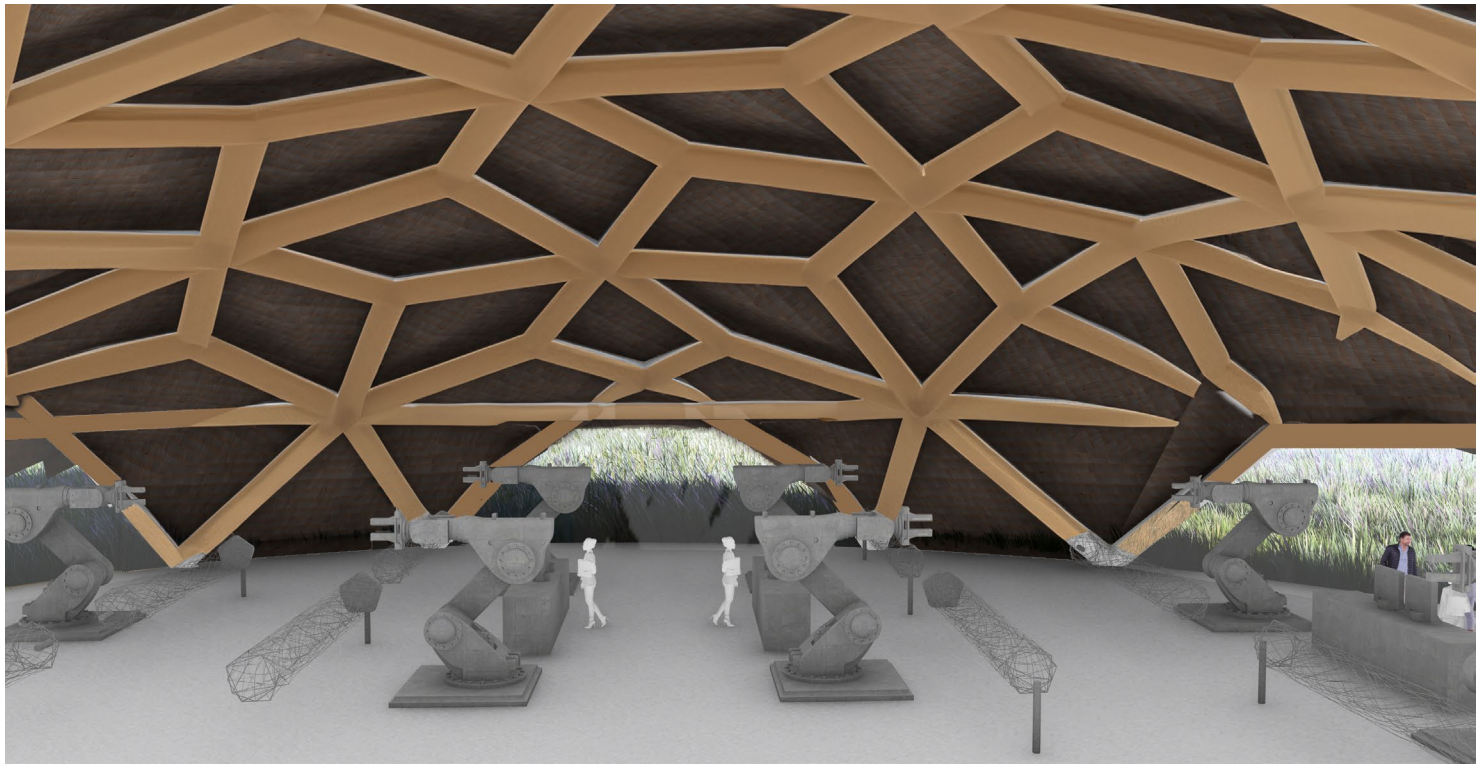
Balcony



First Level

Balcony

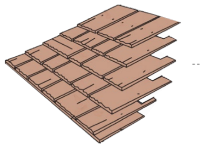




Material Harvesting

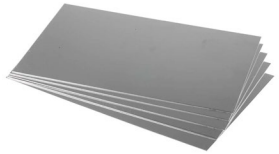
Facades

Larch Wood Shingles



Gutter

Metal Sheeting

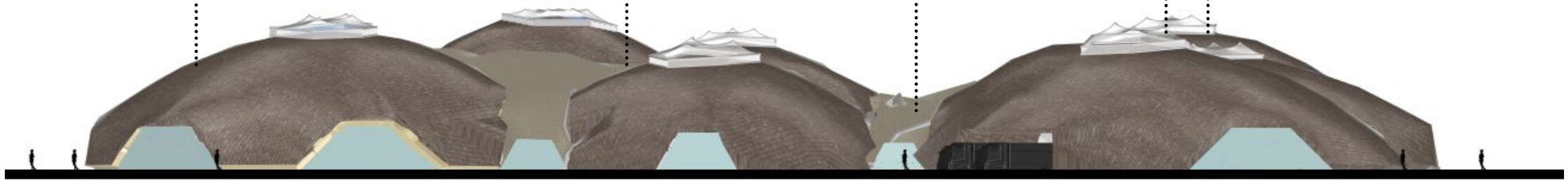


Rubber

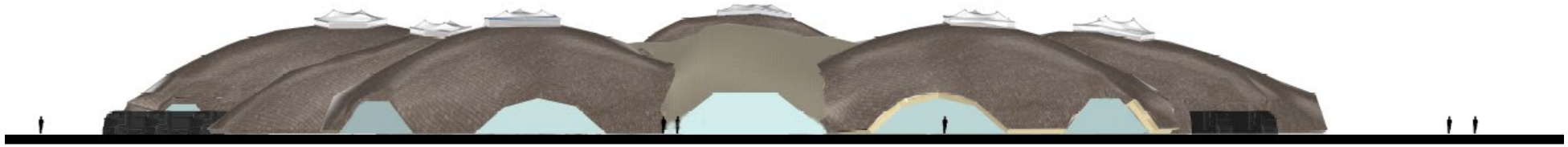
Flax Canvas

Transparant ETFE

Glass Window Louvres



East Facade



South Facade

Contribution to the local community

1:10.000

Contribution to the local community

1:1000

Contribution to the local community

Contribution to the local community

Contribution to the local community

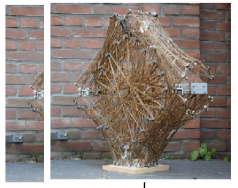
Contribution to the local community

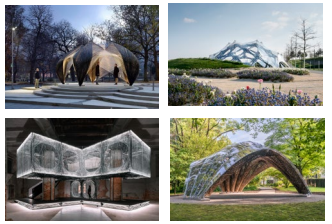
Contribution to Scientific and recommendations

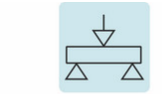
Techniques using Flax over time

- Which steps have to be undertaken to truly scale this up towards the building scale?

Research Gap

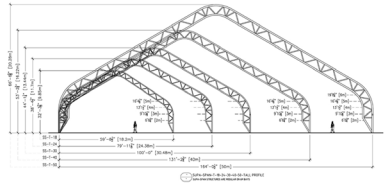


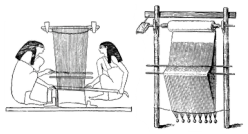




Mechanical strength

Moisture resistance





Hand Weaving

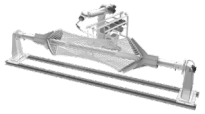
3000 BC- 1700's

Humans

Machine Weaving

1700's-2000's

Machines



Coreless Filament Winding

2000's-Now

Robotics

Coreless Filament Winding 2.0

Now-Future

Robotics

Building fully from Flax with CFW