Natural Materials - Materiality and construction of sustainable buildings - A one-to-one experience

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AALBORG UNIVERSITET

A&D CREATE





Materiality and construction of sustainable buildings




A one-to-one experience





NATURAL MATERIALS

A&D

MATERIALITY AND CONSTRUCTION OF SUSTAINABLE BUILDINGS

THE POTENTIAL OF LOCAL NATURAL MATERIALS IN ARCHITECTURE

Natural materials are offered with a variety in almost every location. Using their potential in contemporary architecture diminishes the environmental impact of buildings. Distinct local architectural designs can be developed which are suited to the local building tradition and the local climate conditions

This brochure constitutes the practical outcome of an experimental construction process in the course, Materiality and Construction of Sustainable Buildings, which was conducted during the period March 12th – May 10th 2019.

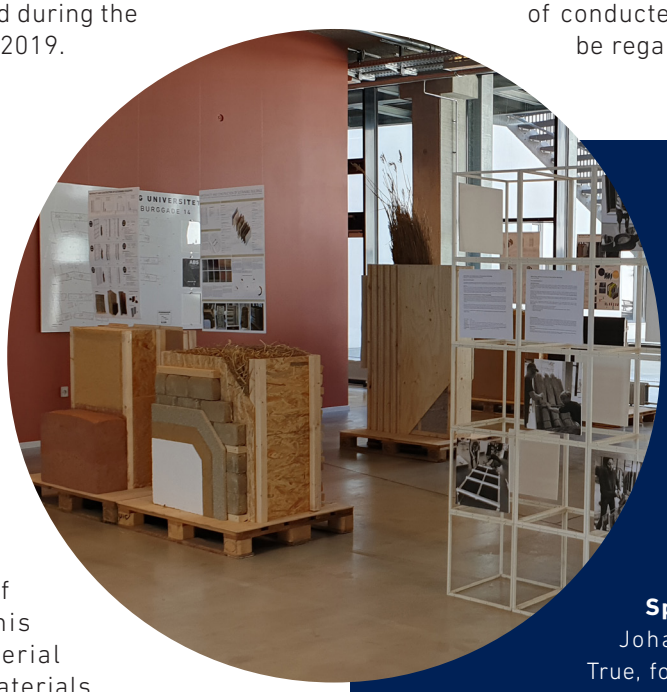
OBJECTIVES

The aim of the course is to provide an understanding of the diverse and specific qualities of building materials and constructions and their use in contemporary buildings. The course aims at providing an advanced understanding of material theory, experimental methods of working with materials and practice in design and evaluation of sustainable buildings. This includes insight into material performance of selected materials, certification systems as well as appreciation of how materials may be applied and perceived within the architectural realm.

LEARNINGS FROM THIS COURSE AND REMARKS ON THE 1:1 MODELS

Going from the design phase and detailed drawings to the construction phase and 1:1 modelling has brought awareness of the level of information embedded in the drawings, challenges related to material properties of real materials as opposed to general material characteristics, the importance of tolerances, etc. The process of designing and constructing the 1:1 model included also to work out a material list, which served to order materials for the workshop. In the further reflection process after having ordered the materials and even during the workshop some groups concluded that their design could be further improved.

Therefore, the material used in these models are in some cases a simulation of the real material to be used. The exhibited 1:1 models therefore express the result of conducted experiments and are not to be regarded as final design solutions.



Course module: 5 ECTS
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WORKSHOP 1:1 MODELLING WITH LOCAL NATURAL MATERIALS

EXPERIMENTAL PROCESS

The course comprises of two phases, which strengthen the student's ability to analyse, design, experiment, construct and critically reflect on the choice and application of natural materials in sustainable buildings. The course has included a combination of theoretical studies, lectures, design development (Phase 1), testing and constructing in scale 1:1 (Phase 2).

During the first phase, the students were introduced to life cycle assessment (LCA) of materials, constructions and buildings. Each student had to evaluate variations of a wall construction using natural materials and comparing it to conventional wall constructions. Based on the learning from the evaluation result of each student the groups decided on a wall design.

The groups chose to work with one of the following natural construction materials: reeds, seaweed, hemp, cellulose, earth (rammed earth or dried clay bricks) or different timber products, and the construction was to be designed with an eye to future "disassembly".

During the second - experimental construction - phase, eight groups of 1 to 5 students have further improved their design, worked out a material order list, evaluated and constructed a 1:1 section of an exterior wall, focusing, among others, on the:

- *Materials' environmental impact (through Life Cycle Analysis)*
- *Materiality of materials (how the materials are perceived)*
- *Technical performance of the materials regarding thermal conductivity and water vapour diffusion*
- *Meeting between materials*
- *Design for disassembly*

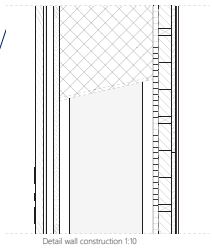
PARTICIPATING STUDENTS

Mette Sletting Jensen, Mathilde Vig Benfeldt, Tine Bredahl Terkelsen, Andreas Nygaard Mathiesen, Christine Damlund, Luna Nørgaard, Gevitz, Even Årsland Anderssen, Cecilie Bruun Jensen, Benjamin Rusch, Tanja Krogh Andersen, Morten Høgh Larsen, Mikkel Jong, Lykkegaard Pedersen, Gülay Eryüce, Søren Peter Nørgaard Mikkelsen, Christian Rejkjær Bülow, Clara Kirstine Simonsen, Rebecca Butler, Camilla Bjørcklund, Clarissa Nazzaro, Emilie Grønborg Rønnow Nielsen, Julie Melchior Skov, Camilla Hyttel, Luisa Vitolo, Barbara Høyer Johansen, Patrick Jørgensen, Kirstine Tone Hylleberg Beyer, Louise Bagge Mikkelsen, Maria Engelund, Abhay Kumar Kandula, Drashti Shantiv Mehta, Eleni Iro Papadopoulou, Natalia Maria Glapiak

MATERIALITY AND CONSTRUCTION OF SUSTAINABLE BUILDINGS

MSC02 ARCH-SUS, GROUP 3: BENJAMIN RUSCH, GÜLAY ERYUCE, MIKKEL JONG LYKKEGAARD PEDERSEN, MORTEN HØGH LARSEN, TANJA KROGH ANDERSEN

DETAIL



Detail wall construction 1:10

WALL CONSTRUCTION

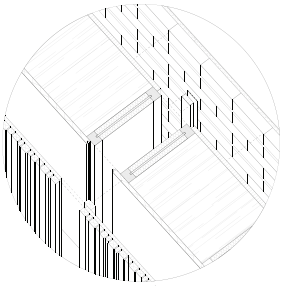
Cladding, recycled wood	20-40 mm
Plywood	16 mm
Air gap (Wooden crossbars 30x50 mm)	30 mm
Soft wood fibreboard	22 mm
Straw (I-profiles, wood 400x60 mm)	400 mm
OSB board, airtightly sealed	15 mm
Loam bricks (Battens 52x30 mm)	54 mm
Clay soft fibreboard	16 mm
Clay plaster	10 mm
Lime paint	3 mm
Total	606 mm

U -value 0,12 W/m²·K

DISASSEMBLY

As a sollution on how to design a wall that can easily be put together but also easily disassembled, this wall is built in three sections. The core of the construction is arriving as sandwich elements. It uses straw as insulation contained in a wooden construction of I-profiles and closed off with a soft wood fiberboard on the exterior and OSB-plates on the interior. Thes modules are connected using the boards, which also holds the cladding added in the next step. The OSB-board will be airtightly sealed.

When the main core is standing the exterior facade plates are applied with screws, so they can easily be reovomed or exchanged. These modules can both be prefabricated or made directly on site dpending on where the reclaimed wood is found. In the interior the bricks are built up using wooden batterns to hold them in place. This way, there is no use for mortar and they can be removed easily and reused in other projects.



CONSTRUCTION

RECYCLED WOOD

Uses wood otherwise intended as waste

Gives a diverse facade expression

Lightweight

Biodegradable

VENTILATED AIR GAP

Wooden battens hold the outer cladding, and are oriented vertically in case of any water needing to run down.

The air gap ensures ventilation from the inner layer in case of excess moisture

STRAW TIMBER CONSTRUCTION

Lightweight, strong and durable

Has a low thermal conductivity making it a natural insulation material

Straw is a waste product, which means the only energy needed when using them for construction is for the bailing process and the transportation to the worksite.

Fire retardant and mold reistand when pressed tightly together

CLAY BRICKS

High Thermal mass minimising temperature variastions

Regulating temperature, absorbing moisture and odours

Sound absorbing qualities

CLAY PLASTER

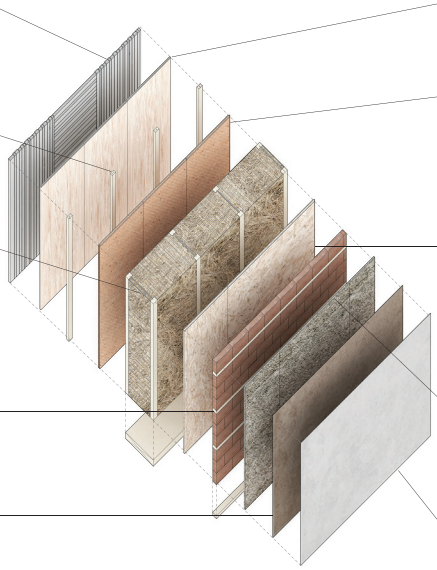
Strong, durable and flexible

Easy to repair and cost effective

High thermal mass making it warm to touch in winter and cool to touch in summer

Breathable ensuring the properties of the layers underneath to be exploited.

Recyclable, reusable



PLYWOOD BOARDS

Used for applying the recycle wood in an easy way

Can be premade as a modules

Protection for water

SOFT WOOD FIBRE BOARD

Homogeneous, no grain direction

Easy to work with and quick to install

Made of recycled wood

Breathable making excess moisture in the insulation evaporate.

Direct exposure to water can cause swell, so it needs to be protected from direct rain

OSB BOARD

High performance, structural, wood particle board

When sealed correctly in all openings it works as a natural vapor barrier

Stabilising the structural elements, making the wall stabil

Suitable for external and internal use

SOFT CLAY PLATE

Consisting of natural materials as clay, reed and hessian

High thermal mass minimising temperature variastions

Regulating temperature, absorbing moisture and odours

Sound absorbing qualities

LIME PAINT

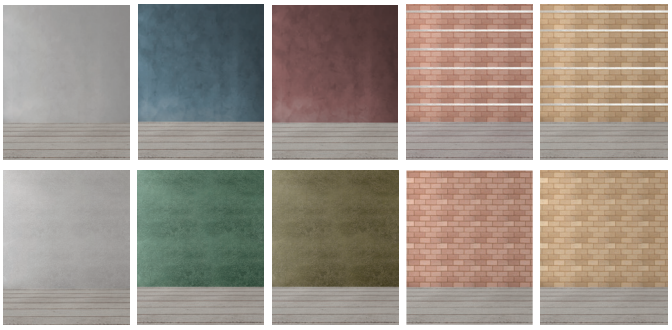
Natural product without any chemicals

Sustainable and carbon neutral

Moisture regulating

Breathable making it a mould and bacteria resistant paint. This also ensure the properties of the layers underneath can be exploited.

FINISH



EXTERNAL CLADDING

As outdoor finish recycled wood is used. This could be old facade remains or other wood residues that are not used. Recycled wood also gives a nice aesthetic facade expression, where the differentiation of various types of wood, gives a new expression with different colors and shades. The facade is a combination of horizontal and vertical list cladding, providing different expression and rhythm to the facade, using it as a way to interpret the interior og making different exterior zones. The horizontal lists are angled, so the rain water is not collected between the lists but instead runs off. The vertical lists enhance the height, where the horisontal makes the building seem lower and more grounded. Both types are applied with a small gap to avoid moisture getting stuck, creating mold etc. Both are applied to plywood plates, giving the entire facade a wooden finish playing with depth and shadows.

INTERIOR CLADDING

As indoor cladding different clay layers have been applied, but building the wall from scrath also open our eyes for the opportunity to use the different layers in other ways, enhancing different atmosphes.

First is the actual wall, were finish have been added. This makes for a cleaner surface, where different colors can also be added if desired but sticking with the original white color in the lime paint, enhaces the daylight immensely compared to leaving the clay exposed. Second option could be working without the layers from the soft clay board and out, ending up with exposed clay bricks and horisontal wooden battens. This uses less materials, and the wooden line may help enhance certain feature. The total thermal mass lowers though, as it is then reduces to 5,5 cm. A third option could be to stack the bricks using mortar, also exposing the clay finish. Doing this also opens for the oppotunity to play a little more with the depth of the wall, or creating a pattern.

Both options with exposed brick are limited in ways of color, as clay naturally has a brown or redish hue. This is not optimal for reflecting light, and other measure would have to be taken to get a satisfying daylight factor. This could be combining them with a lighter wall such as the third option, working with the openings in the envelope or other strategies that may drag light further into the room.

LCA

LCA AS A TOOL

Building a wall has a great impact on the environment, so in order to lessen this, a more eco-friendly wall have been constructed using the LCA as a tool for helping choose the different elements.

Making the analysis, a lot of numbers appear in very different sizes. In order to give a better understanding of these indicators, the results have been compared to values stated in DGNB as the maximum values. It is important to remeber, that the total of the reference value should include both wall, floors and roof etc. The calculations shown are only made for the wall piece but all indicators have room for several elements as all but the EP ar relatively low.

CHOOSING MATERIALS

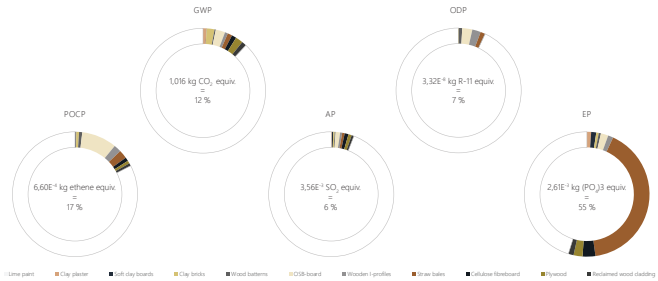
By doing ongoing analyses, the impact of each material has been evaluated. If a specific material performed poor in several categories, alternative materials were investigated. For instance instead of using regular mineral wool as insulation, a more natural material, straw, has been chosen. This is found directly on site and is a waste product otherwise used for feeding livestock or burned directly on the field. The results of the LCA analysis show the emission as it is currently used and produced, which actually means that the values don't count in our final calculation. Only if straw as an insulation material became so popular, that it needen to be produced for that specific purpose, then they of couse should be included in the calculations. For now though, we may actually disregard the majority of the emission. The same can be done for the reclaimed wood used for cladding. It has not been possible to find the EDP for any kind of recycled wood, instead the analysis show what impact a local pine would have. Using recycled wood would still have an impact on emission, as it would need to be adapted to the cladding system, maybe adding weather protection in form of oil or the like.

Other alternatives such as interior cladding have also been investigated. Du to the negative impact regular gypsum walls have on th environment, it has been substituted for a more environmental firend material, clay. Clay has also been chosen for it's great purposed as it can both regulate temperature due to its thermal mass, as well as it can regulate the level of moisture. It is also very sound absorbing and as a plus, clay is found directly on site as well, giving the interior a more natural correlation to the surroundings.

OTHER FACTORS IN PLAY

One of the factors not taken into consideration usin LCA-byg is for instance the distribution and tranportation. To obtain a sustainable approach in this category, materials from afar have been avoided. Also when using materials from the surroundings, considerations on how to further work with them have also been made. Here it's been prefered if the materials could be applied directly on site rather than transporting it to a factory and back again.

PERCENTEAGE OF DGNB REFERENCE VALUES

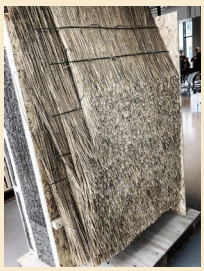


PHYSICAL MODEL

EXAMPLE OF PROJECT POSTER

MATERIALITY AND CONSTRUCTION OF SUSTAINABLE BUILDINGS

GROUP 2 - MSC_02 ARCH SUSTAINABILITY



THE FINAL REEDS FACADE

DESIGN AND QUALITIES

Egholm is an oasis in the middle of Limfjorden, yet still connected to the busy metropol, Aalborg. On Egholm you can feel isolated from the city life and feel re-connected with nature, by the sound of the waves from the fjord hitting the shore and the sound of the reeds wavering in the wind, tuning out the sound of cars and ecco from hard surfaces. The construction site includes long views over a flat wild field, a surrounding atmosphere by the tall trees and a dreamy feeling from the landscape of reeds, connecting the site to the water. The choice of materials will bind the building to the surrounding nature and create awareness on natural materials, in both a traditional and new manner. The aim of the choices is to leave a small carbon-footprint by using natural and local materials.

WALL FROM INSIDE

CUTTING THE SEAWEED BATTENS WITH A KNIFE

INSTALLATION LAYER

SPACKLE THE CLAYTEC BOARD WITH MOTOR

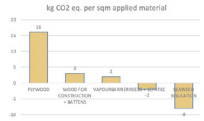
THATCHING THE REEDS ON THE FACADE

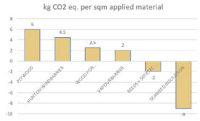
LIFE CYCLE ASSESSEMENT

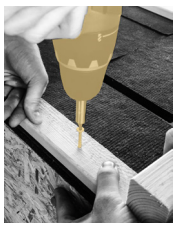
The LCA-analysis shows, that the eelgrass and reeds actually consumes more CO_2 than it releases during its whole lifetime. In principle this means, that the more eelgrass and reeds included in the wall, the less harmful the total CO2 footprint will be. Though, this will have impact on the LCC analysis, where a high use of any kind of material will have a negative impact.

Changing the inner cladding to clay, halves the CO_2 for the wall, compared to plywood. Here also the wanted atmosphere has to be considered.

Compared to a traditional timber wall, consisting of different layers of timber cladding, battens, plywood and rockwool, the wall B with no air gap is considered four times better per square meter. In a building perspective, this is an enormous difference for the total carbon-footprint.

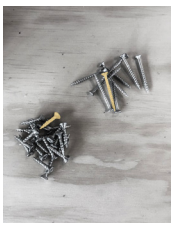






DISASSEMBLY FRIENDLY

The different construction layers in the climate screen, can be taken apart, layer by layer. The materials of the building can hereby be reused as new building material or decomposed as clean materials.



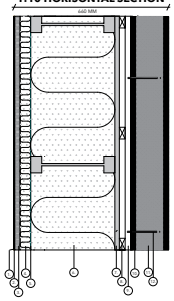
STANDARD JOINTS

By using standard joints, the construction will be easier to take apart and will fit to any joint when being used for another building.

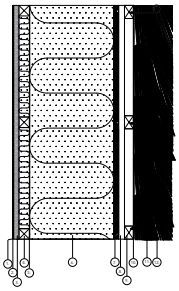
CENTRAL STRUCTURAL CORE

By having a structural core, it is possible to remove each layer from the outside and the inside, when constructing and deconstructing, while the building is still standing.

WALL A
1:10 HORISONTAL SECTION



WALL A
1:10 VERTICAL SECTION



WALL A: WITH AIRGAPS

PROS

- Sustainable material of wind barrier
- Construction behind reeds cladding is the same as behind wooden cladding (project)
- Reeds are not a part of the heated area - only 460 mm of the wall is heated

CONS

- Glass fiber sheet is used as fire protection
- Big amount of insulation
- Wall thickness of 660 mm
- More material used

WALL B: WITHOUT AIRGAPS

PROS

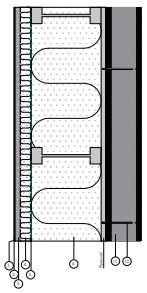
- U-value of reeds counts in the overall u-value
- Thinner wall of 550 mm
- Less use of material
- Joints of facades needs no air gap

CONS

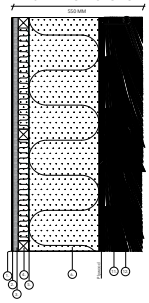
- Higher use of plywood
- Construction behind reeds differs from the one behind wood (project)
- Reeds are a part of the heated area and all 550 mm are heated

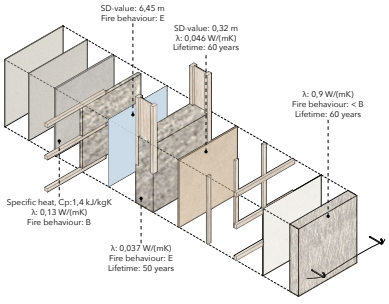
U-VALUE FOR BOTH WALLS: 0,095 W/m²*K

WALL B
1:10 HORISONTAL SECTION



WALL B
1:10 VERTICAL SECTION

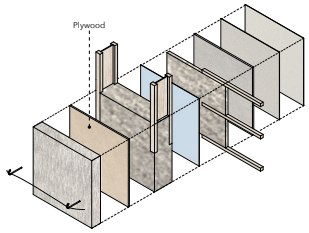




EXPLODED AXONOMETRIC DRAWING WALL A

INNER CLADDING - INNER CIRCLE

INNER CLADDING - OUTER CIRCLE



EXPLODED AXONOMETRIC DRAWING WALL B

INNER FINISH
1 CLAYTEC PAINT 2MM
2 CLAYTEC FINE CLAY MORTOR 3MM

Clay contributes with a great acoustic and a good indoor environment, because of it's porosity and as it is a moisture regulating material. It is not burned, which make it easily absorb and release the moisture (1).

CLAYBOARDS
3 CLAYTEC CLAYBOARDS 22MM

Clay boards are a combination of clay, reed and hessian and have great thermal and vapour diffusion properties. The boards can regulate temperature, and are able to absorb and release moisture (2).

INSTALLATION LAYER
4 SEAWEED & TIMBER BATTENS (45X45MM) 45MM

All the installations run in this layer to avoid breaking the vapour barrier. This layer needs to be insulated to avoid sound inconvenience from the different installations.

VAPOUR BARRIER
5 VAPOUR DIFFUSION RETARDER AND AIRSTOP FLEXTAPE

Diffusion open vapour barrier secures a breathable construction. This paper based vapour barrier secures that moisture can diffuse controlled through the insulation (3).

INSULATION LAYER
6 SEAWEED & TIMBER CONSTRUCTION 30MM

Seaweed contains minerals, which naturally works fire-resistant. It is made of 100 % renewable and reusable materials and produced by means of renewable energy and low energy consumption (4).

WIND BARRIER
7 HUNTON WIND BARRIER 19MM

This wind barrier stores the moisture and prevent condensation. The Hunton barrier is wind resistant, reduces thermal bridges and works as an insulation layer. In addition, it is made of renewable materials (5).

VENTILATED AIRGAP
8 TIMBER BATTENS & AIRGAP 25MM
9 TIMBER BATTENS & AIRGAP 25MM

The original thatched roof method was with fire protection and a ventilated air gap behind the reeds. Nowadays, the reeds can be attached directly on a plywood board and there is no need of fire protection (8).

FIRE PROTECTION
10 SEPATEC FIRE PROTECTION

This fire protection consists of a glass fibre mat and an edge protection mat. The glass fibre mat will melt when the temperature exceed 800 degrees. When it is placed close to the reeds layer, the fire can not behave itself (6).

CLADDING
11 REEDS 150MM
12 THATCHING SPARS & IRONTHREAD

The roof pitch should at least be 45 degrees to avoid moisture penetrate through the reeds layer. For every 5 degrees the roof drops, the lifetime increases with 10 years (7).

EXAMPLE OF PROJECT POSTER

MATERIALITY AND CONSTRUCTION OF SUSTAINABLE BUILDINGS

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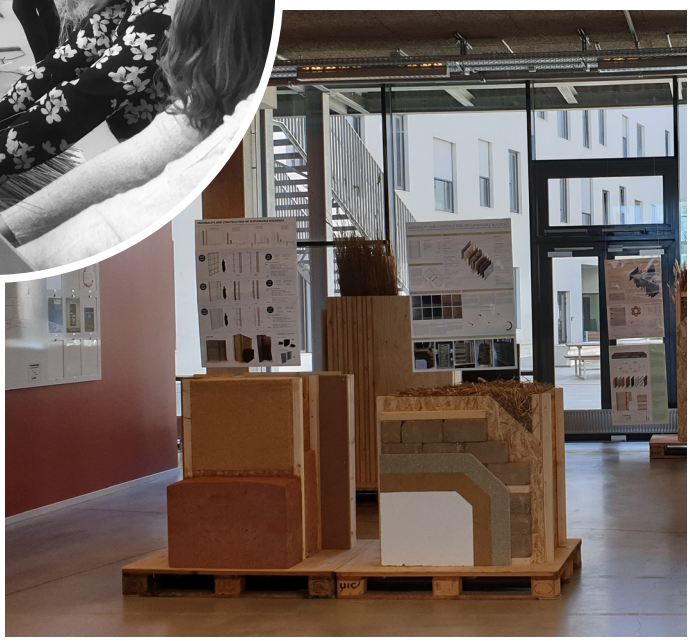

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