Possibilities of applying biodegradable materials in solid building envelopes in the Netherlands

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1st mentor: Dipl.-Ing. Tillmann Klein - Leader Facade Research Group
2nd mentor: Dr.ir. Fred Veer - Assistant professor of Materials Science, Research coordinator
3rd mentor: MArch Ahmed Hafez
• Motivation
• Problem statement
• Research question
• Analysis
• Design subject
• Material selection
• Study case
• Design strategy
• New design
• Evaluation
• Conclusion
“I just happen to think that in life we need to be a little like the farmer, who puts back into the soil what he takes out”

Paul Newman
Sustainability

Construction process

Waste
Problem Statement

Waste production
Problem Statement

Number of landfills

Population growth

C & D Waste % of all solid waste entering landfills

<table>
<thead>
<tr>
<th>Country</th>
<th>C&amp;D waste (by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Netherlands</td>
<td>26</td>
</tr>
<tr>
<td>Australia</td>
<td>20 – 30</td>
</tr>
<tr>
<td>United States</td>
<td>20, 23, 24, 29</td>
</tr>
<tr>
<td>Germany</td>
<td>19</td>
</tr>
<tr>
<td>Finland</td>
<td>13 – 15</td>
</tr>
</tbody>
</table>
How can we apply biodegradable materials in the façade construction in the Netherlands?
The analysis and research part
ANALYSIS CONCLUSIONS: SBR

COLD FACADE

TYPE A

1. load-bearing construction
   insulation layer (material + cavity)
   weatherproofing layer (thin cladding)

2. load-bearing construction
   insulation layer (material + cavity)
   weatherproofing layer (thin cladding)

TYPE B

1. insulation layer (material + cavity)
   load bearing structure
   weatherproofing layer

2. insulation layer (material + cavity)
   load bearing structure
   weatherproofing layer

WARM FACADE

TYPE C

1. load-bearing construction
   insulation layer
   weatherproofing layer

2. load-bearing construction
   insulation layer
   weatherproofing layer
ANALYSIS CONCLUSIONS: SBR
Type A1
ANALYSIS CONCLUSIONS: SBR
Type A2
ANAYSIS CONCLUSIONS: SBR
Type B1
ANAYSIS CONCLUSIONS: SBR
Type B2
ANAYSIS CONCLUSIONS: SBR
Type C
BIODEGRADABLE MATERIAL ANALYSIS

Analysis

Materials

- Traditional
- Earth
- Forestry
- Farming
- Agriculture
- Mattress
- New technologies-Composites
Why, the natural materials, are not used in a great extend in the building envelope anymore?

Concrete and brick advantages

Natural construction materials and techniques drawbacks
Why, the natural materials, are not used in a great extend in the building envelope anymore?

Concrete and brick advantages
- Structural properties
- Flexibility
- Long history
- Architects’ interest
- “Modern” movement
- Researches
- Standardization
- Mass production
- Mass production
- Emotional reliability
- Availability
- Weather

Natural construction materials and techniques drawbacks
- Construction time
- Weather
- Not in use for long time
- Empirical approach
- Old fashion techniques
- Legislation
- Availability
- No standardization
- No quality control
- Structural properties
- Emotional unreliability
- Appearance
- Maintenance
The design part
- Unlimited options
- Not important environmental benefit if applied in such a small scale

- Materials’ availability limits
- Important environmental benefits
- Time limitations

- 10,000
Design goal:
Design the outer architectural shell of 10,000 double storey houses in the Netherlands so that the walls are 80% biodegradable.
Why, the natural materials, are not used in a great extend in the building envelope anymore?
Why, the natural materials, are not used in a great extend in the building envelope anymore?

- Natural construction materials and techniques drawbacks
- Construction time
- Materials dependence
- Industrialization
- Weather
- Maintenance
- Structural properties
- No standardization
- Availability
- No quality control
- User
- Empirical approach
- Emotional unreliability
- Appearance
Improvement:

- **Materials dependence**
- **Industrialization**
- **Availability**
- **User**

- **Chosen aspect for improvement**
- **Prefabrication**
- **Work with local materials**

An aspect that is going to be improved by time, as natural buildings gain popularity. Work for more contemporary building appearance.
According to the analysis the possible materials are:

<table>
<thead>
<tr>
<th>Earthen</th>
<th>Forestry</th>
<th>Farming</th>
<th>Agriculture</th>
<th>Composites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat</td>
<td>Wood</td>
<td>Wool</td>
<td>Straw</td>
<td>BatiPlum feathers</td>
</tr>
<tr>
<td>Clay</td>
<td>Wands/bamboo</td>
<td>Dung</td>
<td>Hemp</td>
<td>Mushroom material</td>
</tr>
<tr>
<td>Lime</td>
<td>Cork</td>
<td>Hair (horse,...)</td>
<td>Burlap</td>
<td>Canatex</td>
</tr>
<tr>
<td>Chalk</td>
<td>Sawdust</td>
<td></td>
<td>Rice hulls</td>
<td>Coconut fiber</td>
</tr>
<tr>
<td>Sand</td>
<td>Paper</td>
<td></td>
<td>Cotton</td>
<td>Pine Sap</td>
</tr>
<tr>
<td>Stone</td>
<td>Natural rubber</td>
<td></td>
<td>Goose down</td>
<td>Zelfo</td>
</tr>
<tr>
<td>Gravel</td>
<td></td>
<td></td>
<td>Linen</td>
<td>Moniflex</td>
</tr>
<tr>
<td>Volcanic rock</td>
<td></td>
<td></td>
<td>Seaweeds</td>
<td>Ingeo</td>
</tr>
<tr>
<td>Pumice</td>
<td></td>
<td></td>
<td>Corn</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Material Selection

### Availability:

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthen</td>
<td>The earthen materials are generally between the most approachable materials. What is more, in general they have no other use.</td>
</tr>
<tr>
<td>Forestry</td>
<td>They are available in limited quantities and so they are possible to be used for thermal insulation and supporting proposes.</td>
</tr>
<tr>
<td>Farming</td>
<td>The materials described here are in general used as reinforcement additives.</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Used in many other proposes, so I will keep them as supplemented materials.</td>
</tr>
<tr>
<td>Composites</td>
<td>Available in very small amounts or even not available at all.</td>
</tr>
</tbody>
</table>
Material Selection

Construction techniques:
- Peat sod
- Cordwood
- Rammed earth

Simple material:
- Compressed Earth Blocks
- Adobe/Mud bricks

Material Selection
Material Selection

Why rammed earth:

- Very clean construction process.
- It produces sharp wall shapes as resilient as concrete with color variations.
- Considerably smaller thickness than the rest natural building techniques.
- Not so labor intensive and time consuming as other types of building with earth.
Material Selection

Mini-city in Luanda, Angola, Africa, 2010

Dutch Embassy Ethiopia
Material Selection

Rammed earth wall samples
Hageneiland Housing, Ypenburg, MVRDV
Study Case
Study Case

B1 type

highly ventilated cavity
cladding
waterproof layer

crack sealing
insulating glazing

seam sealing

waterproofing and vapor permeable layer styles 38x140 mm mineral wool 140 mm ($\lambda \leq 0.033$ W/m.K)
vapor barrier inner plate
cladding

highly ventilated cavity

waterproofing and vapor permeable layer mineral wool 80 mm anchoring

seal anchoring subfloor formwork slab floor

waterproof layer

GROUND LEVEL 125-P insulation with closed cells 70 mm side board

370-P
Study Case

waterproofing and vapor permeable layer styles 38x140 mm mineral wool 140 mm ($\lambda \leq 0.033$ W/m.K)

vapor barrier inner plate

insulation 100 mm
insulation 80 mm
anchoring sealing tape
synthetic rubber profile

seal

seam sealing

insulating glazing

cladding highly ventilated cavity

synthetic rubber profile

crack sealing

cladding acoustically decoupled not linked anchorage

waterproofing and vapor permeable layer

insulation 80 mm
How would this project look like if it had been designed with rammed earth exterior wall system.

1. Rammed earth as cladding material

2. Rammed earth as interior coating material

3. Load bearing structure

Type B2
Type A1
Type A2
1. Rammed earth as cladding material
2. Rammed earth as interior coating material

Type A1
3.A. Rammed earth wall – non load bearing element

Type A2
3.B. Rammed earth wall – load bearing element
Demand:
In a board form
## Insulation

<table>
<thead>
<tr>
<th>Name</th>
<th>R-value/inch</th>
<th>Common width (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral wool</td>
<td>3.14</td>
<td>14</td>
</tr>
<tr>
<td>Natural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straw</td>
<td>2.68</td>
<td>16,4</td>
</tr>
<tr>
<td>Cork</td>
<td>3</td>
<td>14,7</td>
</tr>
<tr>
<td>Papercrete</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>Wool</td>
<td>4.2</td>
<td>10,5</td>
</tr>
<tr>
<td>Hemp</td>
<td>3.5</td>
<td>12,6</td>
</tr>
<tr>
<td>Goose down</td>
<td>4.4</td>
<td>10</td>
</tr>
<tr>
<td>Cotton</td>
<td>3.4</td>
<td>13</td>
</tr>
<tr>
<td>Engineered bamboo</td>
<td>0.96</td>
<td>45,8</td>
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<td>Sawdust</td>
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</tr>
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New design

Rigid hemp fiberboard
1. Ground level

Protection from capillarity effects: standard concrete basement, 10cm distance
Insulation: Mineral wool instead of hemp board
2. Window connection
2. Window connection

Drawbacks:

Construction time
Labor intense
2. Window connection

Drawbacks:

Construction time
Labor intense

Opening construction
Window box installation
2. Window connection

Window sill (CEB)

Drawbacks:

Not reinforced unit
More vulnerable to the weather conditions
2. Window connection

Window sill (CEB)

Drawbacks:
Not reinforced unit
More vulnerable to the weather conditions

Concrete block/wood
3. Top connection

The roof must necessarily overlap

\[ \downarrow \]

Change the architectural view of the building
3. Top connection

- CEB (cement reinforced)
- batten 35x50mm
- batten 40x25mm
- waterproofing and vapor permeable layer traces 36x220mm, h.o.h. 600mm
- 258mm straw
- vapor barrier sheet 10mm
- treated against moisture
- seam sealing
- wall plate
- anchoring
- hemp ins.
- concrete block
3. Top connection

Not possible compressed earth roof blocks – weather conditions
4. Floor connection

- Wooden beam 150X70 mm
- Plywood board
- 30mm hemp ins.
- Floor planks
4. **Floor connection**

Wooden columns incorporated in the rammed earth wall support the floor beams.
4. Floor connection

Wooden columns incorporated in the rammed earth wall support the floor beams

Prefabricated concrete block
Overall estimation

<table>
<thead>
<tr>
<th>Situation</th>
<th>Cladding</th>
<th>Int. coating</th>
<th>Non-load bearing wall</th>
<th>Load-bearing wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodegradable part / total mass</td>
<td>92</td>
<td>96</td>
<td>90</td>
<td>97</td>
</tr>
<tr>
<td>Wall thickness approximation (cm)</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>46</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
</tr>
</tbody>
</table>
Conclusion

Design goal:

Design the outer architectural shell of 10,000 double story houses in the Netherlands so that the walls are 80% biodegradable.
Design goal:

Design the outer architectural shell of 10,000 double story houses in the Netherlands so that the walls are 80% biodegradable

Fulfilled
Advantages:

- Balanced air humidity: 40-60% for the entire year
- Obtain high thermal mass
- Smaller environmental footprint
- Very good fire resistance
- Great availability
- Sharp wall shapes
- Appearance variations by adding iron oxides
- Not time consuming – depending on the detailing

Disadvantages:

- Expensive, depending on the design
- Thicker than normal walls
- Heavy walls
- Maintenance
Further research

Follow the same process for other biodegradable material of the list

Material research

Demolition process research
Thank you for your attention