PD LAB
THE DEVELOPMENT
OF A BIOBASED
CLADDING SYSTEM

by Mitchell Mac-Lean

P5 presentation
29th of June 2018

prof. dr. ir. Tillmann Klein
AE+T: Design of Construction

dr. David Peck
AE+T: Climate Design and Sustainability

ir. Pieter Stoutjesdijk
AE+T: Architectural Engineering

Delegate member
dr. Wouter Jan Verheul
MBE: Urban Development Management
WHY
HOW
WHAT
let’s start with some figures
40% of energy consumption worldwide

Source: Azavea.com
40% of material use worldwide

Source: 123rf.com
35% of waste generation worldwide

Source: Apave.com
what are the causes?
the lifecycle of buildings
the lifecycle of buildings

1. DESIGN
   - quality

2. ENGINEERING
   - quality

3. REALIZATION
   - energy

4. USE
   - materials

5. DEMOLITION
   - energy
the lifecycle of buildings

1. **Design**
   - Quality

2. **Engineering**
   - Quality

3. **Realization**
   - Energy
   - Materials

4. **Use**
   - Energy

5. **Demolition**
   - Quality
   - Energy
   - Materials
   - Waste
how to solve this problem?
the lifecycle of buildings
the lifecycle of buildings

USE IN A CIRCULAR ECONOMY

DESIGN  ENGINEERING  REALIZATION
translation to practice
circular building system

modular & adaptable

source: Lego.com
digital manufacturing techniques
structure

source: Van der Knaap (2016)

rainscreen cladding

source: Van Veen (2016)
structure

rainscreen cladding

source: Van der Knaap (2016)

source: Van Veen (2016)
ECOBOARD

Biobased
Organic
Renewable
structure

source: Van der Knaap (2016)

rainscreen cladding

source: Van Veen (2016)
REYNOBOND

Non-renewable
Hard to recycle
RESEARCH GOAL

DESIGN
rainscreen
cladding system

MATERIAL
biobased material
How can biobased materials be applied to develop a modular and demountable cladding system for the PD lab?
let’s start!
REYNOBOND

Non-renewable
Hard to recycle

Source: Van Veen (2016)
product development lab

no space for adjustment

Source: Bilow (2017)
product development lab

gaps

source: Bilow (2017)
biobased materials
biobased materials

organic

renewable

can be biodegradable
familiar categories

WOOD
PAPER, CARDBOARD
LEATHER, HIDE
METAL
GLASS, CERAMICS
PLASTICS
COMPOSITES
TEXTILES
STONE
CONCRETE
biobased categories

WOOD
PAPER, CARDBOARD
LEATHER, HIDE
METAL
GLASS, CERAMICS
PLASTICS
COMPOSITES
TEXTILES
STONE
CONCRETE
suitable for cladding

- Wood
- Paper, cardboard
- Leather, hide
- Metal
- Glass, ceramics
- Plastics
- Composites
- Textiles
- Stone
- Concrete
material selection

- Wood
- Traditional material
- Comfortable look and feel
- Far developed processing techniques
PLASTICS

innovative building material
able to be moulded
enables complex shapes
material selection

COMPOSITES

- plastics + reinforcement
- strength - weight ratio
material selection

WOOD

traditional

PLASTICS

innovative

COMPOSITES

innovative + extra strength
material selection

WOOD

PLASTICS

COMPOSITES

traditional

innovative

innovative + extra strength
market products

- TRESPA
- N8010
- RESYSTA
Material Selection Assessment

<table>
<thead>
<tr>
<th>MARKET PRODUCT</th>
<th>BIOBASED &gt;50%</th>
<th>WATER RESISTANT</th>
<th>WATER ABSORPTION</th>
<th>DENSITY</th>
<th>FLEXURAL MODULUS</th>
<th>SUITABLE PROCESSES</th>
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<th>FIRE SAFETY CLASS</th>
<th>MAX SERVICE TEMPERATURE</th>
<th>COSTS</th>
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</thead>
<tbody>
<tr>
<td>REYNOBOND (BENCHMARK)</td>
<td><img src="image" alt="REYNOBOND" /></td>
<td><img src="image" alt="TRESPA" /></td>
<td><img src="image" alt="N8010" /></td>
<td><img src="image" alt="RESYSTA" /></td>
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**REYNOBOND (BENCHMARK):**

- **MARKET PRODUCT:**
- **BIOBASED >50%:**
- **WATER RESISTANT:**
- **WATER ABSORPTION:**
- **DENSITY:**
- **FLEXURAL MODULUS:**
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- **COSTS:**

**TRESPA:**

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- **COSTS:**

**N8010:**

- **MARKET PRODUCT:**
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- **DENSITY:**
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- **FIRE SAFETY CLASS:**
- **MAX SERVICE TEMPERATURE:**
- **COSTS:**

**RESYSTA:**

- **MARKET PRODUCT:**
- **BIOBASED >50%:**
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- **SUITABLE PROCESSES:**
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- **BIOBASED SHARE:**
- **RECYCLING RATE:**
- **FIRE SAFETY CLASS:**
- **MAX SERVICE TEMPERATURE:**
- **COSTS:**

---

**MARKET PRODUCT:**

- **BIOBASED >50%:**
- **WATER RESISTANT:**

**WATER ABSORPTION:**

- **DENSITY:**
- **FLEXURAL MODULUS:**

**SUITABLE PROCESSES:**

- **AVAILABLE COLOURS:**

**BIOBASED SHARE:**

- **RECYCLING RATE:**

**FIRE SAFETY CLASS:**

- **MAX SERVICE TEMPERATURE:**

**COSTS:**

- **EUR/m²**
### Material Selection Assessment

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<tr>
<td></td>
<td></td>
<td></td>
<td>mass.%</td>
<td>g/cm³</td>
<td>MPa</td>
<td>-</td>
<td>-</td>
<td>mass.%</td>
<td>vol.%</td>
<td>-</td>
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<td>EUR/m²</td>
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**TOTAL**

| REYNOBOND      | 52            |                 |                 |        |                  |                     |                   |                 |                 |                     |                      |       |
| TRESPA         | 60            |                 |                 |        |                  |                     |                   |                 |                 |                     |                      |       |
| N8010          | 56            |                 |                 |        |                  |                     |                   |                 |                 |                     |                      |       |
| RESYSTA        | 67            |                 |                 |        |                  |                     |                   |                 |                 |                     |                      |       |

**MARKET PRODUCT** Rating: 5
**BIOBASED >50%** Rating: 4
**WATER RESISTANT** Rating: 4
**WATER ABSORPTION** Rating: 3
**DENSITY** Rating: 4
**FLEXURAL MODULUS** Rating: 3
**SUITABLE PROCESSES** Rating: 4
**AVAILABLE COLOURS** Rating: 3
**BIOBASED SHARE** Rating: 0
**RECYCLING RATE** Rating: 2
**FIRE SAFETY CLASS** Rating: 3
**MAX SERVICE TEMPERATURE** Rating: 3
**COSTS** Rating: 3

**TOTAL** Rating: 52 to 67
### Material Selection

#### Assessment

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<td>56</td>
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<td>3</td>
<td>3</td>
<td>4</td>
<td>67</td>
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</tbody>
</table>

**values:**
- **mass.%**
- **vol.%**
- **Density (g/cm³)**
- **Flexural Modulus (MPa)**
- **Suitable Processes**
- **Available Colours**
- **Biod-based Share**
- **Recycling Rate**
- **Fire Safety Class**
- **Max Service Temperature (°C)**
- **Costs (EUR/m²)**
suitable processes
decking profiles
TECHNICAL FINDINGS

MATERIAL CRITERIA

DESIGN CRITERIA

APPLICATION & METHODOLOGY IMPROVEMENTS

MATERIAL CRITERIA

assembly connection hor. joints vert. joints sub-structure panel stiffness processing techniques

DESIGN CRITERIA

ASPECTS

biobased materials material choice

PD LAB design problem

BIOBASED MATERIALS

CONCEPT DEVELOPMENT

BIOBASED MATERIALS

CONCEPT DEVELOPMENT

PROTOTYPING

FINAL DESIGN

methodology

52/110
concept development
TECHNICAL FINDINGS

MATERIAL CRITERIA

DESIGN CRITERIA

APPLICATION & METHODOLOGY IMPROVEMENTS

MATERIAL CRITERIA

assembly
connection
hor. joints
vert. joints
sub-structure
panel stiffness
processing techniques

DESIGN CRITERIA

ASPECTS

biobased materials
material choice

PD LAB
design problem

BIOBASED MATERIALS

CONCEPT DEVELOPMENT

DESIGN DEVELOPMENT

PROTOTYPING

FINAL DESIGN

categories

methodology
aspects

- ASSEMBLY
- CONNECTION
- HORIZONTAL JOINTS
- VERTICAL JOINTS
- SUB-CONSTRUCTION
- PANEL STIFFNESS
- PROCESSING TECHNIQUES
ASSEMBLY

- Structural Safety
- Drainage
- Thermal Expansion
- Risk of Errors
- Building Speed
- Cognitive Ergonomics
- Physical Ergonomics
- Adaptability
- Maintenance
- Accessibility
- Disassembly
- Freedom of Design
- Finishing (Aesthetic)
Possible to (dis)assemble single panel
Assembly by one person might be difficult
Complex rainwater drainage

- Concept development
- Possible to (dis)assemble single panel
- Assembly by one person might be difficult
- Complex rainwater drainage
concept development

60/110
concept development

PANEL STIFFNESS
panel stiffness

Zigzag
Pleated structure
Ribs edges
Folded surface
Folded surface and edges
Convex
Ribs triangular
Ribs crossed
Ribs convex
Hollow profiles
panel stiffness

- Zigzag
- Pleated structure
- Ribs edges
- Folded surface
- Folded surface and edges
- Convex
- Ribs triangular
- Ribs crossed
- Ribs convex
- Hollow profiles

concept development
panel stiffness
concept development
processing techniques

CUTTING
- Sawing
- Cutting
- Punching

DEFORMING
- Folding/bending
- Calendering
- Thermoforming
- 3D printing

MACHINING
- Drilling
- Milling
- Turning
- Routing

MOULDING
- Founding
- Forging
- Sintering
- Cast moulding
- Resin moulding
- Injection
- Rotational moulding
- Extrusion

Based on: Kula et al., 2013
what does the material want?
concept development

ASSEMBLY

CONNECTION

HORIZONTAL JOINTS

VERTICAL JOINTS

SUB-CONSTRUCTION

PANEL STIFFNESS

PROCESSING TECHNIQUES

73/110
detail 3
Bracket, aluminium
Vertical gutter, Resysta
Horizontal gutter, Resysta
Cladding panel, Resysta

detail 2
Cladding panel, Resysta
Lock pin
Bracket, aluminium
Roof top cover profile, Resysta
Vertical gutter, Resysta

detail 4
Cladding panel, Resysta
Lock pin
Bracket, aluminium
Horizontal gutter, Resysta
Vertical gutter, Resysta

detail 5
Cladding panel, Resysta
Vertical gutter, Resysta
Bracket, aluminium
Window sill, aluminium

detail 6
Cladding panel, Resysta
Vertical gutter, Resysta
Bracket, aluminium
Window sill, aluminium
Lock pin
concept development

2D: design freedom

continuous production
2D: design freedom
3D: fixed cross section

continuous production
high investment costs

max. 300 mm
1:1 prototype
Concept Development

- Assembly
- Connection
- Horizontal Joints
- Vertical Joints
- Sub-Construction
- Panel Stiffness
- Processing Techniques
TECHNICAL FINDINGS
MATERIAL CRITERIA
DESIGN CRITERIA
APPLICATION & METHODOLOGY IMPROVEMENTS

MATERIAL CRITERIA
assembly, connection, hor. joints, vert. joints, sub-structure, panel stiffness, processing techniques

DESIGN CRITERIA
ASPECTS
biobased materials, material choice

PD LAB
design problem
BIOBASED MATERIALS
CONCEPT DEVELOPMENT
DESIGN DEVELOPMENT
PROTOTYPING
FINAL DESIGN

categories
methodology

TECHNICAL FINDINGS
MATERIAL CRITERIA
DESIGN CRITERIA
APPLICATION & METHODOLOGY IMPROVEMENTS

biobased materials categories
material choice

84/110
design development

functions
+
production
functions

ASSEMBLY

SPACE FOR ADJUSTMENT

SPACE FOR THERMAL EXPANSION
processing technique #1

CNC-MILLING
processing technique #2

WARM BENDING
production steps

1. SHEET MATERIAL
2. CNC-MILLING
3. BENDING LINES
4. WARM BENDING
TECHNICAL FINDINGS
MATERIAL CRITERIA
DESIGN CRITERIA
APPLICATION & METHODOLOGY IMPROVEMENTS

ASPECTS
DESIGN CRITERIA
MATERIAL CRITERIA

PD LAB
design problem

BIOBASED MATERIALS

CONCEPT DEVELOPMENT

DESIGN DEVELOPMENT

PROTOTYPING

FINAL DESIGN

biobased materials
categories
material choice

linear process?
methodology
final design
overview

sectional profile + window

integrated functions

- drainage
- aesthetics
- assembly
- space for adjustment
detailing
conclusions
research question

How can biobased materials be applied to develop a modular and demountable cladding system for the PD lab?
reflection
relevance

MATERIAL
biobased materials

DESIGN
PD lab cladding system

METHODOLOGY
expanded (materials) and improved (total concept)
relevance

MATERIAL
biobased materials

DESIGN
PD lab cladding system

METHODOLOGY
expanded (materials) and improved (total concept)
Reflection: what other combinations are possible?

Minimizing production steps

Limitations of extrusions: open ends, inflexible production and a max width of 300mm
points of improvement

PROCESSING TECHNIQUES
Lack of knowledge of limitations

DEFICIENT ASSESSMENT
Room for discussion at concept assessment

CIRCULAR ECONOMY
Focus on technological implementation
recommendations
possible improvements

PROCESSING TECHNIQUES
Further research on industrial production

DEFICIENT ASSESSMENT
Keep complete system in sight

CIRCULAR ECONOMY
Also focus on: Economy, environment, behaviour, society and government
thank you!