**Personal information**

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**Studio**

Name / Theme: AR3B025 Sustainable Graduation Preparation/Studio  
Main mentor: Ir. Arie Bergsma  
Second mentor: Ir. Rafail Gkaidatzis  
External mentor: Ir. Christiaan de Wolf

Argumentation of choice of the studio: I have chosen the Building Technology track since I have learned during the bachelor that I liked the technical approach to design most. During the master the façade technology interested me, therefore I chose to do my graduation in this direction. To my opinion there is a strong demand for sustainable solutions in the building industry, especially when looking at the amount of produced waste and CO2 emission. This studio allows the combination of new technical design with sustainable solutions.

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**Graduation project**

Title: A circular biobased composite façade; Research on a high performance and circular application of biobased composite on a façade.

Goal:

Location: Buildings in the Netherlands, with extension for the European market.

The posed problem: The building industry produces too much waste and CO2 emission. Currently in the Netherlands the building industry produces 40% of the total amount of waste. One of the main problems is that waste is not sufficient separated at the building site which withholds recycling. More interesting is that building materials or products are not yet designed in a way which makes recycling possible. Connections between materials with different recycling circles or degradation time are often not demountable. Materials are regularly obtained from finite resources and cannot be recycled or can only be downcycled.

Research questions:

What is possible with biobased composite, when used for a circular facade?

1. **What is biobased composite?**
   1) What is biobased composite, for what can it be used, and for what not?  
   2) Why application for façade design?  
   3) Which types of biobased composites are applicable and what are the first restrictions related to the facade quality demands?  
   4) Which production processes are useful to produce a façade?  
   5) What does this mean for the façade design?

2. **How can a biobased composite façade be designed circular?**
   1) What does circular mean?  
   2) How can biobased composite be used in the most circular way?  
   3) Which modular types of facades are there, and which are most suitable for this design?  
   4) How does this influence the façade design?
3. Final design/Case study
1) Pre-design
2) How can the façade be adapted to meet the facade quality demands?
3) What are the effects of these adjustment for the design?

4. Design/Case study.
1) What is the best biobased circular modular façade design regarding the quality demands for the situation of... Case study.
2) How does the façade relate to other facades in terms of lifetime, costs, production time, waste, CO2 emission and energy.

Design assignment
A design proposal (in drawings) for a circular biobased composite façade. In the end the design will be compared to other renewable facades in terms of CO2 emission, waste, lifetime, building time and building costs. Besides this, tests will be carried out on the recyclability of biobased composite and the quality of these recycled samples, these test results will result in “design rules” for the design.

Hypothesizes about the research questions:
What is biobased composite and for what can it be used?
A biobased composite façade can be used for all the same applications as a chemical composite façade can be, if diverse design criteria are taken into account.

How can a biobased composite façade be designed circular?
There are several ways to introduce circularity into a biobased façade. The main conclusion is that, because the facade will be constructed out of more than one material and it is very likely that these materials cannot be recycled in exactly the same way, they need to be demountable. This should be implemented into the design at the very start of the design process. The quality of the re-used product determines whether the process will result in recycling or down cycling, and this has significant influences on the lifecycle of the product. The actual recycling process which splits the fibres and resins can be processed by the use of specific chemicals, however to what extend this influences the material properties should be determined.

Which façade quality demands are interesting to research for a circular biobased composite façade, and how do these influence the design?
The more difficult to achieve quality demands of a chemical composite façade (fire safety, UV-resistance), supplemented with the specific demands of a biobased composite (waterproofing, age resistance). It will be the most difficult to reconcile these demands with circularity, since this aim will probably lead to divergent design rules, for example preventing gluing.

Final design/Case study.
The outline of the design is based on the outcome of the previous research question. For circularity, I expect the design rule to be that the whole facade should be demountable into different pieces whith the same recycling process. The recycling processes themselves can probably be divided into stages of downcycling, recycling or upcycling (this will depend of the tested material properties). The most environmental friendly method will be the result of a composition of the best material with the environmental friendliest production process and a high circularity.
**Process**

**Method description**
A full description per task is added at the second last page (since this is a large table).

**Literature and general practical preference**

General practice about:
- Rules and regulations for facades in the Netherlands/the European market (quality demands)
- Fibers and Resins available
- Production techniques
- Recycling techniques
- Circularity methods

Literature study:
- Projects with biobased composite (reference projects)
- Literature on biobased composites
- Literature on circularity
- Dutch building laws and European standardization
- Literature on recycling of (biobased) composite

Design research:
- Collect data from the three subjects (biobased composite, circularity and recycling) to form “design rules” for the design
- Compare the design to “similar” façade designs

**Resources:**
Internship at the company DGMR in the Hague, at the department of façade technology. DGMR has lots of experience with façade design and failure analysis.

**Persons and institutions already consulted and to be contacted (status)**

**Already consulted**
Jean Frantzen (DGMR): Specialist circular buildings. Consulted, provided me with information about possible facades for the comparison between the four “to be determined” facades and which programs to use for the CO2 emission calculation.

Alwin Hoogendoorn (Avans hogeschool Breda): Researcher recycling methods of biobased composites. Consulted, received an extensive list of literature about the subject of recycling biobased composite. A meeting was planned with Alwin and second mentor Rafail Gkaidatzis about the possibilities of testing the recyclability of biobased composites and the influence of recycling on the material.


TNO and LNEC on behalf of the results from the research "Beperkingen en kansen van bouwen met biocomposiet". These results turned out to be confidential.
Interviewed:
Frank Lambregts (DGMR), specialized in Acoustics.
Johan Kouidijs (DGMR), specialized in Fire-safety.
Kevin Lenting (DGMR), specialized in Façade Technology.
Jean Frantzen (DGMR), specialized in Sustainability.

To be consulted
NPSP composites: manufactures of the world`s first biobased composite façade (Dinteloord), planned for Friday January 13th.

Dr. Schirp, Fraunhof institute Braunschweig. Research on recycling of WPC’s (wood-plastic composites).

Literature studied:

Biobased composite


Thesis:

Circularity

Geldermans, R. J. (2014). Circulair bouwen in de gevelindustrie: Een verkennende studie naar de sociale aspecten (In opdracht van VMRG en VKG). Retrieved from uuid:19baa7fd-4f85-4a1d-ad11-77c0f3c01f48


Recycling


### Reflection

#### Relevance

**Societal relevance**
- Increase the ability to design facades using biobased composites.
- Insight in the possibilities of biobased composites for façade design used in a circular way.
- Increase the ability to design circular materials/products.
- Develop an environmental friendly façade as alternative for facades causing waste and emission.

**Scientific relevance**
- Increase insight in the criteria for a biobased composite façade.
- Increase the insight in the different methods of recycling biobased composite and their influence on the (material) properties.
- Increased insight in circular design of materials (biobased composite) or products.
- Increase insight in alternative options for an environmental friendly (façade) constructions.

**Projected innovation**
1. Research into several façade quality demands of a biobased composite façade, and their effect on the design.
2. Research into the possible methods of recycling biobased composites, and the suitable material and production processes.
3. Research (through testing) into the effects on the properties of biobased composite when being recycled.
4. Elaboration of the first circular biobased composite façade into drawings and details at the required level of detail.

**Personal interest**
During my master, my interest in façade technology has grown. After a half-year internship at technical consultancy office DGMR at the department of façade technology, I decided that this was the track which I wanted to explore further. Regarding façade design, I find it best when a façade is simple in design but well performing during its designed lifetime.

One of the main projects I worked on at DGMR was a building with a façade out of composite material, and the possibilities of this material now and in the future appealed to me.
As a nature friend (hiking, climbing, mountain biking) sustainability and environmental friendly solutions seem of great importance to me. During another project at DGMR I came in contact with Biobased Composites; a new and developing group of materials which have enough positive properties to convince me that this material could be an alternative for other harmful materials. Since not all biobased composites are biodegradable (a longer lifetime means less biodegradable) and out of interest of DGMR, the question appeared whether such a façade could be circular designed, and what the consequences for the design would be.

**Personal learning objectives**
- The setting up of a complete scientific research framework, and demarcation of the research content,
- The setting up of a test design,
- Involve different parties in the test design while continue to meet everyone’s expectations,
- Being able to perform a chemical tests on the recyclability of biobased composites and to process the results.

**Personal ambitions**
It is always my ambition to design something that can actually been built. The achievable level of detail of the final design will depend of the necessary level to explain the design and the remaining time, however my ambition is to make drawings which make it credible that the façade can be built and perform as designed. The design should be as environmental friendly as I can possibly design it, therefore the designed life time should be in proportion with de degradation time of the façade, the necessary energy for the building process, the necessary resources and the resulting pollution. The whole research should appear in a clear report including summarizing graphs on the conclusions of the chapters shortly explaining their content.

**Time planning**
The complete planning with week-tasks and week-goals is added on the last page (since this is a large table).
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Question</th>
<th>approach</th>
<th>Methodology</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Methodology</strong></td>
<td></td>
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<tr>
<td>1.1</td>
<td>Problem definition</td>
<td>Short problem definition.</td>
<td>Explanation from P1</td>
<td>Half page text.</td>
</tr>
<tr>
<td>1.2</td>
<td>Goal of the research</td>
<td>Short explanation of the goal of the research.</td>
<td>Explanation from P1</td>
<td>Half page text.</td>
</tr>
<tr>
<td>1.3</td>
<td>Research questions</td>
<td>Research questions and sub-questions.</td>
<td></td>
<td>One page text.</td>
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<tr>
<td>1.4</td>
<td>Introduction into biobased composites</td>
<td>i) Short introduction on biobased composite, definition and examples. ii) Technical properties of biobased composite, examples of applications now and in the future. Making clear for what it can be, or can better not be used. iii) Define which quality demands form the requirements the facade should at last meet, based on literature and interviews with specialists.</td>
<td>Literature study on papers and former thesis’ on biobased composites and their properties. Literature study on Dutch building regulations and interviews with specialists on fire safety, façade design and biobased composites.</td>
<td>8-12 pages tekst, pictures and interviews.</td>
</tr>
<tr>
<td>1.5</td>
<td>Types of biobased composites.</td>
<td>Summary of the applicable fibres and resins for this design.</td>
<td>Literature analysis (including existing thesis’).</td>
<td>5-6 pages text, including pictures and one page-sized graph of the materials (a graph which can be linked to the one of question 1.7).</td>
</tr>
<tr>
<td>1.6</td>
<td>Production processes</td>
<td>Analysis of the useful production processes of biobased composite, pointing out the environmental impact of these methods.</td>
<td>Literature analysis (including existing thesis’).</td>
<td>5-6 pages text, including pictures of the methods and one page-size graph of the processes (a graph which can be linked to the one of question 1.6).</td>
</tr>
<tr>
<td>1.7</td>
<td>Overview</td>
<td>Clear conclusions on the effects of the adaptations on the facade design, supported by graphs/ simple drawings.</td>
<td>Both graphs connected: Which materials can be applied in combination with which production technique?</td>
<td></td>
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<tr>
<td>2</td>
<td><strong>Circularity</strong></td>
<td></td>
<td></td>
<td>10-17 pages tekst and pictures.</td>
</tr>
<tr>
<td>2.1</td>
<td>Definition</td>
<td>Define the meaning of circularity in this research.</td>
<td>Literature survey, including examples.</td>
<td>2-3 pages text with different approaches, comparing them, ending in one conclusion on the approach during this research.</td>
</tr>
<tr>
<td>2.2</td>
<td>Circular design with biobased composite</td>
<td>First point out the possibilities of recycling of biobased composite, based on literature and previous research. Secondly test one or more method(s) of recycling biobased composite. In possible test some interesting properties of these samples, drawing conclusion on the influence of recycling and possible effects on the design.</td>
<td>Literature survey, if possible interview with other researchers on this subject (Avans).</td>
<td>5-10 pages of text, pictures, interviews and pictures. Also test method and results shown.</td>
</tr>
<tr>
<td>2.3</td>
<td>Circular biobased façade</td>
<td>i) Make clear which modular type of façade exist. ii) Search out which of these façade types are suitable for this design, making clear why.</td>
<td>Literature survey.</td>
<td>2-3 pages text and simple drawings of the different types.</td>
</tr>
<tr>
<td>2.4</td>
<td>Overview</td>
<td>Clear conclusions on the effects of the adaptations on the facade design, supported by graphs/ simple drawings.</td>
<td>One page-size graph on the types of façade, pointed out which ones are suitable.</td>
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<tr>
<td>3</td>
<td><strong>Design</strong></td>
<td></td>
<td></td>
<td>11-18 pages tekst, pictures and graphs</td>
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<tr>
<td>3.1</td>
<td>Pre-design</td>
<td>Technical solutions (&quot;design parameters&quot;) for the restrictions caused by the demands, supported by simple drawings explaining the solutions. Clear conclusions on the effects of the adaptations on the facade design, supported by graphs/simple drawings.</td>
<td>Studying examples for specific similar solutions, if necessary completed with extra information from façade technology specialists (DGBR).</td>
<td>6-8 pages text and drawings.</td>
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<tr>
<td>3.2</td>
<td>Design</td>
<td>Complete design of the façade in (AutoCAD) drawings. Detailing, views and a 3D impressions. Design process based on the results from previous research questions. Comparison between five (four other) façades in term of energy, CO2 emission, production time, waste, circularity, assumed costs and designed lifetime.</td>
<td>Compare the design with other façades in terms of lifetime, costs, production time, waste, CO2 emission and energy, making use of the DGBR material tool to calculate the Co2 emission and the environmental impact and project data for the other aspects.</td>
<td>5-10 pages drawings fit into the report. Drawings attached in full size in the appendix. 3-6 pages description of the process and choices made, accompanied by pictures of the developing design. 2-4 pages with summarizations of the data per façade, ordered in a way which makes it easy comparable.</td>
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<tr>
<td>4</td>
<td><strong>Manufacture and installation</strong></td>
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<td></td>
<td>2-3 pages tekst and drawings</td>
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<tr>
<td>4.1</td>
<td>Manufacture and installation</td>
<td>Description of the manufacturing and installation method.</td>
<td>Drawings of the assembly method, and step-by-step drawing of applying the façade.</td>
<td>2-3 pages tekst and drawings.</td>
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<tr>
<td>5</td>
<td><strong>Conclusions and recommendations</strong></td>
<td></td>
<td></td>
<td>1-2 pages text, if necessary accompanied by pictures from earlier chapters if necessary.</td>
</tr>
<tr>
<td>5.1</td>
<td>Conclusions and recommendations</td>
<td>Conclusions on the complete research and write recommendations for further research.</td>
<td>Draw conclusions on the results.</td>
<td>1-2 pages text, if necessary accompanied by pictures from earlier chapters if necessary.</td>
</tr>
<tr>
<td>6</td>
<td>Literature</td>
<td>Complete list of all cited literature.</td>
<td>Collect though the process all cited literature in the right format.</td>
<td>1-3 pages with references to literature.</td>
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<td>Occasion</td>
<td>Planning</td>
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<td>Week</td>
<td>Subject/Book</td>
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<td>Start</td>
<td>November 7th</td>
<td>12th</td>
<td>1st</td>
<td>Planning</td>
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<tr>
<td>1st project</td>
<td>P2</td>
<td>15th</td>
<td>1st</td>
<td>P2 project</td>
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<tr>
<td>P3 November 15th</td>
<td>2</td>
<td>18th</td>
<td>1st</td>
<td>P3 project</td>
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<tr>
<td>Planning and assessment of graduation process (First taste of the graduation project, conceptual research framework, present written project outline)</td>
<td>P3 project presentation</td>
<td>P3 project session</td>
<td>Oral presentation</td>
<td>P3 project presentation</td>
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<td>P4 November 22nd</td>
<td>3</td>
<td>21st</td>
<td>1st</td>
<td>P4 project</td>
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<td>Planning and assessment of graduation process (First taste of the graduation project, conceptual research framework, present written project outline)</td>
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<td>P4 project presentation</td>
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<td>P5 November 29th</td>
<td>4</td>
<td>24th</td>
<td>1st</td>
<td>P5 project</td>
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<td>Planning and assessment of graduation process (First taste of the graduation project, conceptual research framework, present written project outline)</td>
<td>P5 project presentation</td>
<td>P5 project session</td>
<td>Oral presentation</td>
<td>P5 project presentation</td>
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