GRADUATION PLAN

Personal Information

Stefanie Tseggai
1513613
Bloemstraat 204, 1016 LK, Amsterdam
0031-633053596
stefanie.tseggai@gmail.com

Studio

Architectural Engineering & Technology
Tutors: Job Schroen (architecture), Jan Jongert (research)
Argumentation of choice studio: Possibility to combine technical approach in design with extensive aesthetic explorations.

Title

Infinite Mining for Structural Composites
A factory made of natural composites from overabundant waste streams

Goal & Problem Statement

In Western society waste is produced in large quantities, often without acknowledging the qualities it might still have. In 2010 the Netherlands produced almost 60 kton of waste (Compendium voor de Leefomgeving, 2010). In processing of this waste 88 per cent is designated as 'useful application', 9 per cent is burned, 2 per cent is land filled and 1 per cent is dumped (Ibid.). 'Useful application' includes preparation for re-use, recycling and use as fuel, indicating more waste is burned than merely 9 per cent. Indeed in 2010 an extra 1268 kton was incinerated (Compendium voor de Leefomgeving, a 2015)

Yet at the other end of our consumer society, the start, a constant shortage of primary material resources is apparent. In the Netherlands the total demand for building materials is approximately 150 million tons per year, dependent on large-scale infrastructural projects (Compendium voor de Leefomgeving, b 2015). Up to 20 per cent consists of reused secondary building materials and the majority of the remaining part consists of surface minerals, which are mainly derived in the Netherlands, although an increasing part is imported (Ibid.). Whereas the government attests that the Dutch stock of surface minerals is geologically 'very large', mainly spatial, societal and economical aspects determine its finiteness (Ibid.).

Annually 100 to 150 ha land area is used for the extraction of surface minerals (gravel and sand for concrete and masonry), mainly in provinces rich in sand: Gelderland, Overijssel, Noord-Brabant en Limburg (Rijksdienst voor het Cultureel Erfgoed, 2009). In Limburg also silver sand, lime and marl is extracted (Ibid.). In the southeast of Limburg deep mining for coal constituted the industry, which especially provided great economic prosperity for the region. The coalmines were closed between 1965 and 1974 and despite initiatives of the national government to provide new job opportunities, closing of the mines resulted in a decline of local economy (Bontje, 2009, p. 28). A development reciprocally accompanied by demographic changes, i.e. migration of the working population, younger generation and higher educated, which is dubbed *krimp* (shrink) in Dutch.

Eight municipalities in the southeast of Limburg, formerly known as the Eastern Mining Area, have formed a collective body *Parkstad Limburg* in order to transform the region. They have decided to accept the demographic changes and use it as a change to improve environmental living and work quality (Structuurvisie Parkstad Limburg, 2009, p. 3). Moreover, the region has recently been designated as *Internationale Bau Ausstellung* (IBA) to invigorate local economy, space and society (IBA Open Oproep, 2013, p. 2). Until a final exhibition in 2020 IBA Parkstad will function as a laboratory and empowerment for innovative ideas and projects (Ibid.).

Combining the before mentioned issues of excessive waste, scarcity and the discontinuing of traditional mining in Parkstad, an answer is offered by forward-thinking theories, which eliminate the concept of waste, like industrial ecology, the Blue Economy, Cradle2Cradle and Urban Mining. For example, in his book the Blue Economy, Pauli (2010, p. 6) explains learning from models in natural ecosystems could be the solution to both the environmental challenges of pollution and the economic challenges of scarcity, since 'in nature, the waste of one process is always a nutrient, a material, or a source of energy for another.' He exemplifies that many industrial processes are inefficient, using resources we do not have and generating (often toxic) residues; natural ecosystems on the other hand are self-sufficient, often achieving overabundance and diversity, while only using locally available resources (Ibid., p. 8-9). Therefore Pauli emphasizes that in designing industrial processes we ought to learn from natural ecosystems.

Cyclifiers are defined as metabolic processors that decrease system-level inputs and outputs by operating in ecological niches, creating symbiotic connections, and increasing resource efficiency (Jongert, Nelson & Korevaar, 2015, p. 1).

This project aims to comprehend the complete process of producing a structural composite made of uniform and consistent waste streams, abundantly available in or close to the Parkstad region. The starting point for development of this novel building material constitutes of using bacterial alginate (ALE) as a binder. ALE is retrieved from the Nereda wastewater treatment process, researched by PhD student Jure Zlopasa from the faculty of Civil Engineering at Delft University of Technology.

The goal is to design a building, which functions as a cyclifier, connecting local physical flows, such as waste and water, and local flows of value, such as knowledge, identity and culture. This architectural design of a cyclifier ought to function as a business model (generating multiple revenues) rather than a static object that requires investments for maintenance. Therefore a factory building will be designed made of the composites, which are developed in the research phase and are sourced from local overabundant waste streams.

Overall Design Question

How to design a factory in Iba Parkstad (next to a Nereada Wastewater treatment plant) for a structural composite made of wastewater derived materials and other local waste streams, which functions as a cyclifier and illustrates the architectural possibilities of this new local building material?

Thematic research question

How to design a cyclifier factory where a structural composite can be produced and applied, which is made of bacterial alginate (ALE) as a binder and (biomass) waste materials as aggregate and fibre?

In order to answer the main question the following sub questions are formulated: (1) What are the properties of ALE and reference composites with ALE as binder? (2) How can the non-waste components be substituted by local rest or waste streams using Material Flow Analyses? (3) Which model making and fabrication methods are suitable to explore the architectural possibilities of the composite?

Question Research Methods

Considering the technical development of bio-based composite materials, their fabrication and application, how can we define its architecture?

Methodologies

During the research is focussed on the rational composition of the material. First, by discussing reference studies a description is given of its origin, fabrication and subsequent mechanical and perceptible characteristics. Then, based on the ratio and role of the composite's components an inventory is done of locally available waste resources. The inventory and initial fabrication process form the foundation for a Material Flow Analysis of an industrial intervention by means of a composite factory. Simultaneously, based on logistic and spatial requirements, a few locations for this factory are selected.

In the final research phase the focus shifts to the architectural implications of such a composite material. First, a survey is done of model making and fabrication methods, which are suitable to explore the architectural possibilities of the composite material, i.e. structure and details. Then, conform the machines, tools and actions of these methods a program of requirements is defined for the composite factory. Essentially, the 'black box' of the composite factory in the previous Material Flow Analysis is specified.

The selection of model making and fabrication methods is based on a few material samples, technical literature and architectural theory. Moreover selection is founded on an analogy with existing composite material types and accompanying processing techniques: bio-based (structural) composites and strain hardening cementitious composites.

In the design phase different configurations of the program and composite material will be explored, using the model making and fabrication methods selected during the research. Moreover, the consequences of the design for its location will be defined further. Strived is for a logic plan tailored to the processes, but still offering the possibility of change.

For inventorying local waste materials and defining the production processes, principles and tools are employed from industrial ecology. Industrial ecology considers non-human natural ecosystems as models for industrial activity, with a focus on manufacturing processes and product design (2012 architecten and Goossens, 2009, p. 3). It signifies a holistic approach, since it takes into account the total functioning of a system rather than particular parts (Ibid. p. 10). This 'system perspective' and 'system analyses' aim to prevent limited and incomplete studies, which might lead to poor designs with negative effects (Ibid.). Principles are for example recycling of materials, cascading of energy, symbiosis and diversity. Tools can be divided into two types: with a focus on the product, the products life-cycle and product chain; or with a focus on analysis of the metabolism and flows of a system (Ibid., p. 16).

Relevance
The subject of investigation in the proposed project emanates from the need to be independent of finite fossil and mineral resources, the issue of excessive waste and the need for a new industry in IBA Parkstad Limburg.

Literature

Exploration
- Websites
  - www.materia.nl
  - www.biobasedplastics.nl
  - www.dpivaluecentre.nl
  - www.nrk.nl (Federatie Nederlandse Rubber- en Kunststofindustrie)
  - Vereniging Kunststof Composieten Nederland (VKCN)
  - www.rwsleefomgeving.nl/onderwerpen/afval/afvalcijfers/
  - cyclifier.org
  - insideflows.org
  - upstyleindustries..nl
  - superuse.org
  - oogstkaart.org
  - woodguide.org
  - theblueeconomy.org
  - zeri.org
  - gro-holland.com
- Journals
  - Journal of Bio-based materials
  - Bioplastics magazine
- Articles
  - Dweib, M.A., Hu, B., A., Donnell, O., Shenton, H.W., Wool, R.P. (2003). *All natural composite sandwich beams for structural applications*. Elsevier.
  - Dweib, M.A., Hu, B., Shenton, H.W., Wool, R.P. (2005). *Bio-based composite roof structure: Manufacturing and processing issues.* Elsevier.
  - Zini, E., Scandola, M. (2011). *Green Composites: An Overview*. Italy: University of Bologna.
- Books
  - Peters, S. (2011). *Material Revolution*. Birkhäuser.
  - Peters, S. (2013). *Material Revolution II.* Birkhäuser.
  - Wool, R. P. (2005). *Bio-based polymers and composites*. Elsevier.
  - Smitthipong, W. (2014). *Bio-Based Composites for High-Performance Materials*. Taylor and Francis.
  - Kabasci, S. (2013). *Bio-Based Plastics: Materials and Applications*. Wiley.
  - Harmsen, P. (ed.), Bolck, C., Ravenstijn, J., Molenveld, K. (2012). *Bio-Based Plastics*. Wageningen UR.
  - Bos, H. (ed.), Molenveld, K., Oever, M. van den (2012). *Biocomposieten 2012; Natuurlijke vezels en bioharsen in technische toepassingen.* Wageningen: Wageningen UR.
  - van Dam J., van den Oever, M. (2012). *Catalogus bio-based bouwmaterialen*. Wageningen: Popress.
  - SHR Hout Research, ATO B.V., TNO-Bouw. *Hernieuwbare grondstoffen als bouwmateriaal; Tien leverbare producten.*
  - Ashby, M.F. (2010). *Materials and design*. Butterworth-Heinemann.
  - Rijkswaterstaat (2014). *Afvalverwerking in Nederland, gegevens 2013, versie 1.1*.
  - Rijkswaterstaat (2014). *GFT/swill en groenafval.*
- Interviews
  - Frans Kappen, Wageningen UR, senior researcher
- Student Works

- Gkaidatzis, R. (2014). *Bio-based FRP structure; a pedestrian bridge in Schiphol Logistic Park*. TU Delft.
- Rosen Jacobsen, L. (2014). *Rethinking the Unwanted: Exploring the possibilities of implementing waste materials in architectural design*. TU Delft.

Research Paper

2012Architecten & Goossens, F. (2009). *Recyclicity: industrial ecology applied in the urban environment*. Place: Publisher.

Bontje, M. (2009). Parkstad Limburg; Krimpregio op zoek naar identiteit en toekomst. *Geografie* (18), 28-31. Retrieved on 24 May, 2015 from http://dare.uva.nl/document/2/71522

Braungart, M. & McDonough, W. (2002). *Cradle to cradle: Remaking the way we make things*. London: Vintage Books.

Brdjanovic, D. & Van Loosdrecht, M.C.M. (2014). Anticipating the next century of wastewater treatment: advances in activated sludge sewage treatment can improve energy use and resource recovery. *Science magazine*, 344(6191), pp. 1452-1453. Retrieved on 8 May, 2015 from www.sciencemag.org.

Carr, N. (2015). PhD student *BioCement*. Interviews May and June 2015.

Chollakup, R., Nardin, M. & Smitthipong, W. (2015). *Bio-Based Composites for High-Performance Materials: From Strategy to Industrial Application*. Boca Raton: CRC Press, Taylor & Francis Group.

Compendium voor de Leefomgeving (2010). *Vrijkomen en verwerking van afval per doelgroep, 1990-2010.* Retrieved on 24 May, 2015 from http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl0206-Vrijkomen-en-verwerking-van-afval-per-doelgroep.html?i=1-4

Compendium voor de Leefomgeving, a (2015). *Afvalverbrandingsinstallaties, aantal en capaciteit, 1970-2013.* Retrieved on 24 May, 2015 from http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl0394-Aantal-en-capaciteit-van-afvalverbrandingsinstallaties.html?i=1-3

Compendium voor de Leefomgeving, b (2015). *Winning en verbruik van oppervlaktedelfstoffen, 1980-2012.* Retrieved on 24 May, 2015 from http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl0067-Winning-en-verbruik-van-oppervlaktedelfstoffen.html?i=15-18

Galán-Marín, C., Rivera-Gómez, C. & Petric, J. (2010). Clay-based composite stabilized with natural polymer and fibre. *Construction and Building Materials*, 24(2010). pp. 1462-1468. doi:10.1016/j.conbuildmat.2010.01.008

Gkaidatzis, R. (2014). *Bio-based FRP structure; a pedestrian bridge in Schiphol Logistic Park*. TU Delft.

de Graaf, P. (2015) *In strijd tegen de krimp vecht Limburg ook tegen leegstand*. De Volkskrant, 6 May, 2015.

IBA Open Oproep (2013)

Jongert, J., Nelson, N. & Korevaar, G. (2015). *Cyclifiers: an investigation into actors that enable intra-urban metabolism*. Place: Publisher.

Lin, Y., de Kreuk, M., Adin, A., van Loosdrecht, M.C.M. (2010). Characterization of alginate-like exopolysaccharides isolated from aerobic granular sludge in pilot-plant. *Water Research*, 44(11), pp. 3355–3364. doi:10.1016/j.watres.2010.03.019

Lubelli, B. (n.d.). *Mortar; use and development during the centuries*. Reader Construction History AR0014, version 2014, TU Delft.

NNOP (n.d.). Partners. Retrieved on 8 June, 2015 from http://www.neredannop.nl/partners/

Otto, F. (1960). *Finding Form*.

Pauli, G. (2010). *The Blue Economy; 10 years, 100 innovations, 100 million jobs.* Taos: Paradigm Publications.

Picken, S. (2015) Professor Biotechnology Deflt University of Technology. Interview

Pronk, A., Erinkveld, D., Schipper, R., Eigenraam, P. (2015). Een flexibele mal voor glas, beton en kunststof. *Stedenbouw en architectuur*, 2(April), pp. 12–13.

Provincie Limburg (n.d.). *Het Limburgs duurzaam sloopprotocol*. Retrieved on 20 May, 2015 from

Rademaker, J. (2015). Employee Parkstad Limburg, Housing department. Telephone interview. 20 May 2015.

Rijksdienst voor het Cultureel Erfgoed (2009). *Delfstoffenwinning*. Retrieved on 24 May, 2015 from http://erfgoedbalans.cultureelerfgoed.nl/ruimtelijke-ontwikkelingen/het-cultuurlandschap/delfstoffenwinning

Royal Haskoning DHV a, Nationaal Nereda Onderzoeks Programma (Commissioner), Jotja Bessems AV Producties (Producer) (2014). Nereda in Dutch practice: Vroomshoop and Dinxperlo [Video], from https://www.youtube.com/watch?v=Yfz0lvVddFE.

Royal HaskoningDHV b (2014). Australia pioneers Dutch wastewater treatment solution. Retrieved on 28 May, 2015 from http://www.royalhaskoningdhv.com/en-gb/nereda/news-and-events/20141119n-australia-pioneers-dutch-wastewater-treatment-solution/3918

Royal HaskoningDHV c (2015). *Nereda, the sustainable and innovative wastewater treatment technology*. Retrieved on 1 June, 2015 from http://www.royalhaskoningdhv.com/en-gb/nereda

Sierra-Beltran, M. G. (2011). *Ductile cement-based composites with wood fibres; Material design and experimental approach.* Delft University of Technology.

Stadsregio Parkstad Limburg (2011). *Geactualiseerde envelop; Herstructureringsvisie Parkstad Limburg 2010-2010*. Heerlen.

Structuurvisie Parkstad Limburg (2009)

Verdygo (2015). *Showcase*. Retrieved on 6 May, 2015 from http://www.verdygo.com/showcase

Waterschapsbedrijf Limburg (2013). *Technologisch jaarverslag 2013*. Roermond. Retrieved on 1 June, 2015 from http://www.wbl.nl/jaarverslagen/2013/technologisch/Pages/Downloads.aspx.

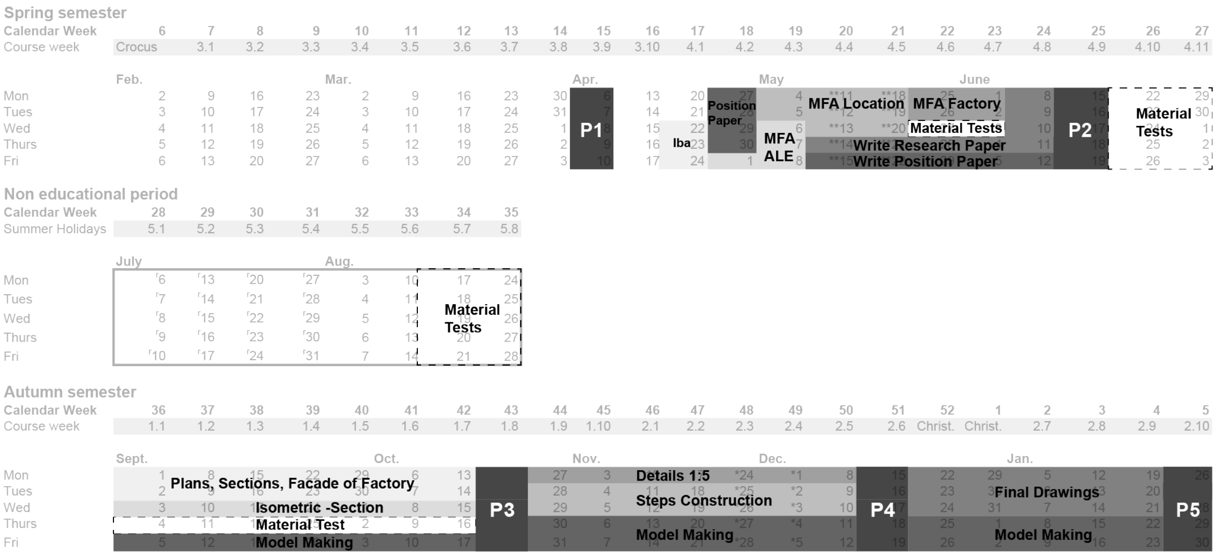
Zlopasa, J. (2015). PhD student *ALE*. Interviews May and June 2015.

Zlopasa, J. Norder, B., Koender, E.A.B. & Picken, S.J. (2015). Origin of Highly Ordered Sodium Alginate/Montromorillonite Bionanocomposites. *Macromolecules*, 48 (4), pp. 1204–1209. Retrieved on 8 May, 2015 from http://pubs.acs.org/doi/abs/10.1021/ma502147m.

Zlopasa, J., Koenders, E.A.B. & Picken, S.J. (2014). Using bio-based polymers for curing cement-based materials. Proceedings of the 1st Ageing of Materials & Structures Conference, Delft, The Netherlands, 26-28 May 2014. Retrieved from http://repository.tudelft.nl/view/ir/uuid:dd760c59-7f6f-40b1-9ed7-c96567921a94/

Zlopasa, J., Bijl, A., Redeker, J., Marinus, A. & Lanting, M. (2015). *Building your future; Making bricks with alginate in South Africa*. Not published.

Planning



P2 (19 June)

MFA Bacterial alginate (ALE) / Nereda process
MFA ALE Composite Factory
MFA Location

Research Paper (12 June)

Position Paper (15 June)

Graduation Project (12 June)

P3

MFA ALE Composite Factory

Composite material 1:1
Model Factory 1:100 / 1:50

(Plans 1:100)
(Sections 1:100)
(Elevations 1:100)

Isometric - Section 1:33 1/3

P4

Isometric - section
1:33 1/3

Details 1:5
Steps Construction

P5

Model Factory 1:50
Model detail 1:1

MFA ALE Composite Factory

Isometric - section 1:33 1/3

Details 1:5
Steps Construction