Growing buildings: how to design circular and sustainable buildings by using living organisms in architecture

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Circular CPC housing typology with building elements and materials prepared on site by living organism, providing food and energy for inhabitants.

Elaboration on the relationship between the graduation project and the wider social, professional and scientific, framework, touching upon the transferability of the project results.

In recent years, architecture has shifted towards more sustainable and circular design. The scarcity of building materials and environmental awareness of the building industry generated a need for new techniques and developments, pushing architects and designers to increasingly turn towards biological and natural processes. Nonetheless, the related insight is still scattered, whereas growth and development of new technologies are constantly accelerating.

The urgent need for new, sustainable solutions is clearly visible in the Dutch housing market. At the start of 2018, the Netherlands had a shortage of around 205 thousand homes. By 2020, that shortage is expected to reach 235 thousand homes[1]. Not enough dwellings are being provided to fill this gap. Furthermore, the majority of homes constructed now are designed for so-called ‘starters’ - providing studio or one-bedroom apartments for people entering the housing market, creating an unsustainable unbalance in the variety of dwellings.

The primary aim of the project was to indicate a new approach towards modern, sustainable and circular architecture, by designing not only a building but primarily a circular housing typology with building elements and materials prepared on site by living organism, providing food and energy for inhabitants. Hence the final product, despite being designed on a specific location (Binckhorst, the Hague), is transferable to other positions, and flexibility embedded in the very idea of the project allows for further modifications.

The relationship between research and design.

The relationship between my research and my design is direct and clearly visible. The final paper of my research constitutes a toolbox for architects, collecting data about different

[1] NETHERLANDS HOUSING SHORTAGE TO LAST THROUGH 2020: REPORT [https://nltimes.nl/2018/02/05/netherlands-housing-shortage-last-2020-report]

techniques aimed at applying living organisms in architecture, hence easing the design with this methods. After finalizing the research, I used the design tool, trying to show the best usage of aforementioned techniques in form of circular, sustainable and self-producing housing in the Hague, Netherlands. Only by applying these specific methods, it was possible to craft an on-site production able to manufacture biodegradable or reusable building materials without negative impact on the dwellers, along with closed circulation systems that achieve their primary goals, all joint together to create an attractive and pleasant environment.

USED PRODUCTS:

1. Baubotanik - engineering the building construction with living trees. To achieve this, the plants are connected with non-living elements into one system. The technology has been developed at the Department of Architecture at the Technical University of Munich.
2. Mycelium thermal insulation - material made by growing mycelium on low-value crop waste. 15% thicker layer has comparable thermal insulation properties to EPS.
3. Bacteria brick - technology developed my bioMASON, based on a well-known method in the biology cement production, used for creating mussels. Brick are solidified without using high temperature, which allows on-site production.
4. Self-healing concrete - Developed at TU Delft, in the Delft Center for Materials (DCMat), the technology employs calcite-precipitating bacteria to prevent cracks in concrete constructions.
5. ETFE algae panels - technology developed by EcoLogicStudio, where microalgae are harvested within the outer layer of ETFE cushion. The amount of algae in each compartment (hence, the thickness of the shading layer) grows in sunny days. The pressure and fluid dynamic in the cushions allow to change their shape.
6. Aquaponics - a method of farming where water-based plants are introduced into the same ecosystem with fish and microbes. The system is based on the following cycle: waste from fish production (ammonia) is converted by microbes into nitrates, fertilizing the plants. Then, solid fish waste is used as compost. Plants are used for filtering water for fish.
7. Living Machine System - a water treatment system, concluded with set of tanks hosting wetland plants, microorganisms and small animals (eg. snails or insects).

The relationship between your graduation (project) topic, the studio topic (if applicable), your master track (A, U, BT, LA, MBE), and your master programme (MSc AUBS).

My graduation topic was derived from my personal fascination for the introduction of nature into architecture. Tools provided by the Explore Lab allowed me to investigate the topic in an unconventional, broader sense, leading me to little-known techniques and design ideas.

Functional aspects: such as programme, requirements, order and circulation, dimensions and physical conditions

The primary idea of the new housing typology was not only to provide flexible dwellings for inhabitants, but also a production line of building materials, that are supposed to be used in the construction process of the edifice, together with greenhouses providing fresh vegetables and fish for the community. For this reason, the whole project was divided into three zones.

1. Production - located on the ground floor, partially double-height, includes wood workshop, mycelium board production, bacteria brick production, design and research office. Since most of the production should not be exposed to sunlight, such spaces were located in the middle of the building, surrounded by commercial spaces. After the construction, production can be minimized, leaving room for other activities: in this project, they were utilized as a market.
2. Housing - located on top of the production part, it is not created by providing finished apartments, but rather a shell-space, created for future inhabitants to design. To form initial boundaries for the division of the housing blocks, for one housing 'model' it is adopted 7,2x9,6m module, with double exposition. By multiplying (vertically and horizontally) this basic module, future dwellers can create basic spaces that can be later transformed into tailored apartments. By constructing with biodegradable and reusable materials, these apartments can be additionally shifted, re-created or divided, in order to suit tenants needs.

   As an additional part of the dwellings, a common inner yard is provided, with the Living Machine System acting as a garden and water purifier.
3. Greenhouse - Located on the upper floors, stepped to provide maximum daylight. Areas less exposed are designated for fish tanks (as part of aquaponics system). Part of the space is assigned to be a common event area, open to all tenants.

In order to not just design one complex, but rather a new typology, the exact details of the programme may vary, but the basic proportions of space dedicated for each zone is:

~62% housing
~30% greenhouse
~4% production
~1% Living Machine System
+ commercial space

This allows to produce needed materials in around 3 months, and have a first fish harvest from aquaponics in 7 months, providing enough green vegetables for each inhabitant.

Spatial aspects: such as experiencing space, by circulation, composition, light, texture, colour, shape and mass

In spatial aspects, the important feature is the division between public, semi-public and semi-private spaces. Enclosed courtyards are visible from all apartments, creating the feeling of community and allowing inhabitants to have bigger control over this space. By elevating parts of

the open spaces, more informal and less public zones are created - providing fluid direct connections between different parts of the complex, as well as formulating distinctive areas for outsiders and residents.

To promote the creation of smaller, closer communities, the complex was divided into three parts, two of them containing mostly apartments, and one created to include services decided by the community itself. The size and height of each element were adjusted to provide enough sunlight to each dwelling and each level of the greenhouses.

To stress the division of different usage of the edifice, three distinct architectural languages were created - regular mycelium arches indicate public zones, providing commercial spaces and production line; regular, orthogonal brick grid signifies dwelling area, with spaces dedicated only to the community of inhabitants; inverted glass/ETFE arches, showing the location of greenhouses, and crowning the structure. The fourth element, in a form of horizontal stripe of greenery in places supported by baubotanik, connects all three buildings with each other, together with the surroundings. The use of red brick on the facades creates connections to the nearby housing buildings, in opposition to steel and corrugated sheet covering warehouses in the area, sending a message of change in function and mood.

Material and technical aspects: such as material, detailing, physics, structure, construction, and climate design

As the functions of the complex are clearly divided into three themes, so is the materialisation of each one. Production and commercial space, due to the need of wide open spaces and thick soundproof insulation, are designed in form of mycelium arches, supported by glulam frame. Dwellings are constructed as a mix of glulam framework, wooden floors and sandwich panels created by ingrowing mycelium (insulating material) into wooden boards (finishing material), hence the use of glue is avoided, making all the non-bearing elements biodegradable. To provide maximum flexibility of design to each apartment, separating walls are technical, containing a void for sanitary and electrical connections; flooring is elevated by wooden beams, allowing for the pliable distribution of piping and electrical cords. Ultimately, the greenhouse is covered by wine-glass shaped steel columns, with ETFE algae cushions spread on the grid-creating ‘shoulders’ of the construction. To provide additional shading during summer, southern facades of greenhouses are shielded with algae-panels. To accommodate three different construction methods, each one is separated with the self-healing concrete table.

In order to provide safe conditions for the Living Machine System, two dwelling courtyards are enclosed by glass, openable roof, creating winter garden for all apartments. By ensuring double-exposition of each dwelling, cross ventilation is available, hence mechanical ventilation is provided only for the production hall.

Contextual aspects: such as site, response to the surroundings in shape, composition, mass, function and circulation

Binckhorst, as an area dedicated to re-development from industrial to urban neighbourhood, is changing significantly over the course of the last years. As a consequence of

the municipality ‘acupuncture’ approach, the exact future development of the chosen area is not exactly known - which brings challenges (lack of points of reference), as well as visible advantages, leaving room for experimentations and bold, innovative investments. Creating ‘example 0’, with the introduction of the production line of building materials, the presented project can be a great igniter and case of point for incoming reconditioning projects.

Socio-cultural aspects: such as socio-cultural, ethical, historical, philosophical, economical aspects – in particular sustainability

The whole project was designed as an example of Collective Private Commissioning (CPC), which supports more social, flexible and interactive way of creating architecture. Future inhabitants, being involved in the creation process from the very beginning, can have a direct influence on the shape of the complex, including functions and maintenance methods. Moreover, the community is able to create a strong bond before even moving in together, creating a better neighbourhood afterwards.

Omitting one site of the party (private developer) can lower the prices of the construction, compared to the traditional building process. Providing more tailored and flexible apartments is also a better way of keeping the community together, without pushing the tenants out if their current apartment does not suit their needs anymore. In addition, placing the production on site raises the awareness of the ecological impact of the building, educating the inhabitants. By being direct eye-witnesses of building circulation, processes needed to keep the edifice well-maintained and by having a direct influence on their direct surroundings, inhabitants can become more aware of the gravity of their actions, teaching them how to make more conscious and responsible choices.

Elaboration on research method and approach chosen by the student in relation to the graduation studio, methodical line of inquiry, reflecting thereby upon the scientific relevance of the work.

This research aims at presenting and categorizing techniques integrating living organisms in architecture, along with their potential benefits in terms of sustainability and circularity. The chosen method was decided to be a combination of literature study, case studies and interviews with designers and architects working with the proposed techniques. Most of the knowledge is based on research papers published by the inventors themselves, official websites of companies or individuals involved in the technique development. When the data is insufficient or unclear, questions were asked directly to developers or users of the method.

To provide clear classification and ease the comparison, each technique is described with the help of additional categories and catalogued by living organisms involved. To deepen the possibility of comparison, the outcome of the research is presented in tables, each focusing on different aspects which can influence the method choice. The results of the research, in form of a design tool, can be useful for architects and designers in making the decision of incorporating living organisms in their design.

Discuss the ethical issues and dilemmas you may have encountered in (i) doing the research, (ii, if applicable) elaborating the design and (iii) potential applications of the results in practice.

The biggest issue that can influence potential application of this typology is the challenge of commitment. CPC method, apart from having many visible advantages, is a complex project, requiring strong engagement. Nonetheless, successful examples of CPC housing in the Netherlands give hope for a success. In addition, biology is far less predictable than physics or chemistry, so including living organisms requires to take higher responsibilities for the created ecosystem, with the awareness that the results may not be always identical. Some of the methods included in this project are still in developing phase. Even if their elaboration allows me to claim the possibility of realisation, some of the technical details may result in the future as possible obstacles. Making inhabitants directly responsible for the success of the whole project may discourage them. That is why I believe the municipality should have a strong role in this process, not only as a mediator but also as directly involved party.