Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

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Architectural Engineering; Second Life
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Personal information	
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Studio		
Name / Theme	Architectural Engineering – Second Life	
Main mentor	Annebregje Snijders	Architecture
Second mentor	Bob Geldermans	Architectural research – circular building
Argumentation of choice of the studio	The studio of Architectural Engineering reacts with its different assignments on urgent present day challenges facing the architectural profession, thereby preparing students for practice after graduation.	

Graduation project	
Title of the graduation project	Open building transformation of the Palace of Justice in Arnhem

Goal	
Location:	Palace of Justice, Arnhem, the Netherlands

The posed problem, research questions and design assignment in which these result:

Studio objective

The second life assignment seeks strategies to extend the lifespan of office buildings of Government Building Agency (Rijksgebouwendienst). The majority of these office buildings are constructed in the last 50 years and are problematic. The buildings often do not meet the required standards architecturally, functionally, technically and are built in a low quality. This results in high vacancy rates and some are even considered to be demolished after only 20 years of serves. The increased energy performance requirements, every office building should at least have energy label C by 2023, puts the owners of office buildings to a challenge. What are the possible strategies for these low value office buildings to prolong their lifespan, get them up to todays standards and prevent vacancy or even demolition.

Thematic research

Conventionally buildings are transformed mainly considering economic prospects. Although it is relatively well known transformation and renovation projects have a smaller environmental impact compared to demolishing and the construction of a new building, but specific insight in the environmental benefits are unknown to me. Therefore my initial research objective was to provide a theoretic foundation of the environmental benefits of prolonging the lifespan of the structure of buildings by transformation or an extensive renovation. Along the way the enormous environmental impact of concrete became known to me and since the majority of buildings in the Netherlands are built from this material it seemed a relevant research topic. Concrete is the most used man-made material in the world and its production is responsible for 8% of global CO_2 emissions (More than the whole transportation sector combined; cars, boats, airplanes, etc). Furthermore there are very limited reuse and recycling possibilities for concrete today. This is unacceptable considering current transition into a circular economy, in which materials are expected to be reused and recycled over and over again. This resulted into a more general research into reuse and recycle possibilities of concrete, the related potential environmental benefits and an alternative strategy of concrete use in the circular economy.

Research question

"How can the environmental impact of concrete in the built environment be reduced by following the reuse and recycle principles of the circular economy?"

To answer this question the research is divided in three sections. First the current situation regarding the use of concrete, the linear sector and the consequential environmental impact is analysed. Second the reuse and recycling principles related to the circular economy are introduced and applied to concrete specifically. This results in three levels of concrete reuse, which are discussed separately according a set format. These different value cycles of concrete reuse are, in order of preference; : the reuse, in situ, of a whole building or some of its parts; the reuse of components that have been removed from one building, then refurbished or reconditioned and used in a different building; finally there is the use of recycled materials. Finally the different reuse strategies will be integrated and combined into a strategy of concrete use in which the environmental impact is reduced, answering the main research question.

Key findings of the research:

Reuse of structures is preferred as this means prolonging the lifespan of an exiting structure. This implies spreading the initial environmental impact of construction over a longer period of time an thereby reducing the average impact. Furthermore reusing a structure will often prevent a new building from being built. When a transformation project and new construction are compared on environmental impact it turns out a transformation project reduces the environmental impact by 53-75%.

Reuse of elements designed to be reused can easily be removed from the building, checked and transported to the new construction site. However reuse of elements from buildings not intended to be extracted prove to be more problematic. For example prefabricated concrete floors are connected by a screed layer joining two elements together, to extract these elements from a building is an energy and labour intensive process.
For the reuse of building elements in general several conditions have to be met to ensure an effective implementation. Making an inventory, evaluating, harvesting and distributing are among the logistical difficulties towards a wide application of the principles of Urban Mining.

Recycling of concrete

A key principle of cradle to cradle and circularity is recycling materials up to the initial level once something lost it use. For concrete this is currently the most problematic step, only 3% of concrete waste finds its way back into construction material, the majority is reused as foundation material for road construction.

An innovative crushing technology seeks to change this statistic. The Smart Crusher, as the crusher is called, focusses its forces on the weakest link of the different components in concrete. The weakest link in concrete are the bonds created by the hydrated cement once reacted with water. As a result the original ingredients, gravel, sand and cement, are recovered. The aggregates, making up to 75% of the concrete mixture, are recovered with even a higher quality compared to aggregates from primary resources. Unique about this technique is also the fact cement is retrieved in a substantial share, 30-50%. This is possible because the concrete mixture has a maximum hydration degree of 70%, and therefore there is a large share of cement that has never reacted with water. The Smart Crusher allows this un-hydrated cement to be separated and retrieved. The share of hydrated cement has several options to be reused in the production process of concrete. First it can directly be reused as a filler fraction next to sand to fill in the gaps between the gravel, reducing the amount of cement needed to up to 5%. Secondly this hydrated cement can be dehydrated by heating it to 500 degrees Celsius and be reused as a super activator in slag cements, replacing the initial share of blast furnace slags by up to 30%. Finally, pure Portland cement can be reactivated, by heating it to 1450 degrees Celsius, similar to the initial production process but without the additional CO_2 emissions. This last steps proves problematic as the crushed fraction of fines is contaminated with several particles influencing the chemical reaction of reactivation (the creation of C_2S and C_3S).

Strategy of concrete use in circular built environment.

> Reduce the amount of concrete. Find alternative construction materials
> Prolong the lifespan of existing structures & elements
> High value recycling.
> Optimise production of concrete

Design objective

The Palace of Justice in Arnhem consist of two building parts. One monumental building, in a functionalist style, built in the 1960's and an extension building built in in the late 1990's. The extension building is already considered to be demolished after only 20 years of service. Design plans for a new extension on another side of the monumental building are already in an advanced phase.
The goal of this graduation project is to transform the existing extension building, which is basically a standard office building like many others in the Netherlands, into a flexible monumental structure, allowing for programmatic changes if necessary and thereby maximising the lifespan of the existing concrete structure.

Design research

From looking at both building parts of the Palace of Justice it becomes immediately apparent there are fundamental differences in architectural expression, organisation, urban positioning etc. In many ways the extension building is totally dependent on the initial monumental building, which of course makes sense, as it is intended to be supplementary. However if the programmatic function is lost, this building has little to no identity and all that is left is a chaotic assembly of volumes with an unappealing expression and no clear design language. It is my intention to change this unwanted building into a self-contained, autonomous building, with a clear expression and hierarchy, both in organisation and façade. In order to facilitate this idea, it would be beneficial if the structures provide a certain presence and language that can be appreciated. Therefore a comparative analyses of both building parts of the Palace of Justice will be performed in order to gather insights in ordering principles that set both buildings apart.

Design question:

"To what extend does the extension building of the palace of justice need to change in order to transform it into an 'adaptable' monumental structure?"

This research question consists of multiple aspects that need further research.

First there is the notion of being an adaptable building:

Building not specifically for one function and allowing changes to be made. An emerging concept supporting this is 'Open Building'. Based on the principles of John Habraken buildings are constructed making a division between 'Support' and 'Infill'.

Second there is the notion of monumentality:

Monumentality in this context is not the cultural heritage as monuments are currently referred to, but it is rather about a change in the approach and mindset towards these structures. From an environmental perspective it is best to maximise the lifespan of a building, and therefore demolishment should not be considered if transformation is also possible, hence these buildings should be approach as if they are monuments.

Finally there is the context of this project, city center of Arnhem:

Although this graduation project argues the programmatic infill of a structure is of secondary importance, it is still crucial to find the right infill at a certain moment. By choosing the right infill, changes in program can be reduced, saving materials and energy needed to adapt the building. So even though this project enables flexibility it should be the goal to prevent this from happening by performing an extensive contextual analyses.

Process

Method description

During this graduation project several methods of research and information gathering will be and have been used.
Research:

Literature review is used to determine the status quo concerning current concrete production, the scale of concrete use and the environmental impact. Literature has also been used for determining and evaluating the reuse and recycling options of concrete.

Interviews / conversations / site visit
During relevant events interviews with stakeholders from the Dutch concrete sector have been performed to get insight in this sector and to know where to look for information. The innovative technique of crushing concrete is researched in greater depth, this included a site visit to the first real scale crusher in Zaandaam and interviews / conversations with the inventor and project leader.

Design:

Literature on monumentality and the concept of open building will be implemented
Research by design / model making

Literature and general practical preference

Research :

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Design :

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Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?
2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

The implementation of the principles of the circular economy into the building industry can be seen as the biggest challenges facing the industry as a whole. Especially regarding the implementation of recycling and reusing concrete, responsible for 8% of global CO_2 emissions, will be a big challenge. Alternative construction materials as steel and other metals are already recycled on a large scale, or come from renewable resources (wood). Concrete however is lacking widely implemented recycling principles. As the worlds most used man-made material it is especially relevant to explore the reuse possibilities and it is essential to a sustainable use of concrete in the circular built environment.

Furthermore the transformation of (office) buildings is an ever increasing trend and transformation projects will comprise a substantial part of the architectural profession. Having the right approach to these projects, maximising the lifespan of the buildings are of great (environmental) importance.