Research Plan | aE Studio

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Title

Towards a Circular Construction Industry:
Designing for Disassembly with the Reuse of Reclaimed Concrete from End-of-Life Buildings

Graduation Project

Keywords

Circular Construction Industry, CO_2 Emissions, Concrete Reclamation, Concrete Structural Elements, Demolition, Designing for Deconstruction (DfD), End-of-Life Buildings, Material Recirculation / Reuse, Post 65 Era

Glossary of Terms

Circular Construction Industry: is an approach in construction that prioritizes sustainability and resource efficiency. It involves designing, building, and operating structures with minimal resource waste and environmental impact, following the principles of a circular economy that contributes to the well-being of humans and animals. This approach promotes the reuse and recycling of materials, reducing waste and conserving resources. (*About Us | Circulaire Bouweconomie*, n.d.)

CO_2 emissions: refer to the release of carbon dioxide gas into the atmosphere, primarily as a result of human activities and in this context related to the building industry, especially from the manufacture of cement. (Gilas, 2013)

Concrete reclamation: is the process of recovering and reusing concrete from structures, construction sites, thus reducing the need for new concrete production and minimizing environmental impact.

Concrete structural elements: refer to the load-bearing components of a building or structure that are made primarily from concrete. These elements are designed to provide stability, strength, and support to the overall construction. Common concrete structural elements include columns, beams, slabs, walls, foundations, and other essential components that contribute to the integrity and stability of the building.

Deconstruction: refers to taking a building or structure apart in order to preserve valuable elements for reuse. It aims to minimize the environmental impact of demolition by diverting materials from landfills and promoting a more resource-efficient approach to building removal. (*Demolitions and Dismantling*, 2014)

Demolition: is the process of taking down a building entirely, signifying the conclusion of its existence. Conventional demolition typically involves the use of heavy machinery to dismantle the structure, preventing the reuse of its components or materials. (*Demolitions and Dismantling*, 2014)

Designing for Deconstruction (DfD): is an approach that involves planning for the eventual disassembly and reuse of building materials at the end of a building's life cycle. It aims to facilitate the efficient recovery of materials for future use. (Bertin et al., 2022)

Downcycling / recycling: involves the conversion of waste materials into reusable objects to prevent waste of potentially useful materials. It often refers to the process of converting materials and products into lower-value products, usually of reduced functionality. (PCC Group, 2022)

End-of-Life buildings: refer to structures that have reached the end of their intended lifespan or are no longer deemed suitable for their original purpose, often required to be demolished.

Material recirculation / reuse: is the process of reintroducing materials into the production cycle after they have been used, without the need of remanufacturing - unlike downcycling / recycling - and thereby extending their lifespan and reducing the need for new resources. (El-Haggar, 2007)

Post 65 Era: A term referring to the period after 1965, characterized by the construction of numerous buildings with a lifetime of 50 to 60 years, of which some are currently facing demolition because of their end of life. (*Post '65*, 2023)

Problem Statement

The current construction industry significantly contributes to global environmental challenges, with notable CO_2 emissions, resource exhaust, energy use, and waste generation. In the Netherlands, urgency arises from programs like 'Nederland Circulair in 2050' and the 'Transitieagenda Circulaire Bouweconomie,' aiming for 50% circularity in 2030 and 100% in 2050 by emphasizing efficient material (re)use, renewable resource maximization, and efficient resource utilization. (Stichting Economisch Instituut voor Bouw en Metabolic, 2020) However, the current industry's environmental impact is multifaceted and alarming. In 2020, the construction sector's CO_2 emissions contributed up to 12% of global emissions, originating from material extraction, production, construction, and demolition (embodied emissions). (*Buildings and Construction*, n.d.)

The need for circular solutions is serious, especially in material recirculation and reuse, that can provide a viable path to reduce environmental impacts. Reuse minimizes construction and demolition waste, substitutes primary materials, and can lower the CO_2 footprint within the industry. This aligns with circular economy principles, offering not just environmental benefits but also significant economic potential due to the large volume of construction and demolition waste generated. (Bertin et al., 2022)

Concrete, one of the most used construction materials globally, becomes a major source of waste during demolition, with much of it being discarded or downcycled. Of particular significance is the extensive use of concrete in non-residential buildings, sometimes exceeding 70% of the total mass of building materials. Non-residential buildings, such as education buildings and offices, represent a substantial portion of the total demolished buildings. Interestingly, there is a relatively high rate of demolition for younger non-residential utility buildings constructed after 1970, with approximately 60% of the demolitions occurring in this category. (Stichting Economisch Instituut voor de Bouw, 2019) In addition, in many new building projects, complete new concrete elements are used for the load bearing structure. However, a more sustainable approach involves considering the reuse of existing concrete, by exploring techniques for reusing load-bearing elements, offering a significant opportunity to address the impacts of global warming. (Knutsson, 2023)

Objective

This research aims to provide a solution within the construction industry, with a specific focus on the reuse of existing concrete elements sourced from end-of-life buildings, with a still sound concrete structure. It also emphasizes the importance of making it easier to dismantle structures during the construction phase, the so-called ‘Designing for Deconstruction’ (DfD) principle. The primary objective is to formulate and present methods and strategies that facilitate the integration of reclaimed concrete into new construction projects. Through a rigorous process of research, analysis, and practical investigation, the paper delivers a set of outcomes:

- Insights: The research paper will uncover critical insights into the feasibility and practicality of reusing concrete elements from end-of-life buildings, considering various structural factors.
- Recommendations: Building on these insights, the paper will formulate evidence-based recommendations that offer a roadmap for the integration of reclaimed concrete into new construction projects, emphasizing DfD and resource efficiency regarding concrete.
- Practical Guidelines: Based on the research results, a series of useful instructions will be presented, designed specifically for a certain building that is planned for demolition. These instructions will outline specific plans for reusing concrete elements in the new construction plans. This will include taking into account the building's structure, evaluating its environmental impact, and establishing protocols for its operation.

The overarching objective is to set off a transformation within the construction industry by providing actionable solutions that promote DfD. By addressing the pressing need to reduce waste and CO_2 emissions associated with concrete production, this paper aspires to contribute to the construction industry's journey towards a more sustainable and resource-efficient (de)construction phase.

Overall design question

How can the principles of a circular economy be applied to the construction industry to emphasize resource-efficiency and minimize material waste?

Thematic Research Question

From the overall design question, a more specific thematic research question arises:

- *How can reclaimed concrete from end-of-life buildings be effectively integrated into new building projects and create future ease of disassembly and reassembly?*

To answer the thematic research question, sub-related questions are formulated. These questions will formulate a more specific context in where the answer will be found for the overall design question. The sub-questions are:

- *Which construction technique with concrete is commonly used in end-of-life buildings and suitable for reclamation?*
- *What kind of techniques are used for concrete reclamation, and which techniques are suitable for which construction type?*
- *How can reclaimed concrete elements be implemented in a demountable way for new construction purposes?*

When these sub questions are further elaborated, the last sub question can be asked. This question is based on the form of a specific case study:

- *How can a typical end-of-life building, planned for demolition, provide its concrete structure to facilitate the reuse of concrete elements for a demountable building project?*

The full analysis of this building will be an example to help answer the thematic design question.

Methodologies

Literature research:
This research will mainly be based on qualitative literature research. Information and data will be retrieved from different kinds of sources, varying form; scientific articles, news articles, websites from companies or stakeholders, interviews from experts, technical drawings, archival documents, etc. It will gain a deep understanding of the subject by interpreting and contextualizing information.

Case studies:
At a certain point in this research, a set of case studies will be incorporated to assess the applicability of the theoretical framework within the practical context. These case studies will be presented as buildings with concrete as the main construction structure, where concrete reclamation has taken place. Research is mainly driven by exploring literature, drawing observations, and design analysis. The buildings will also be reviewed by a comparative research analysis to understand the differences and similarities between the buildings. In the end, one specific case study (former Ministry of Social Affairs and Employment in The Hague) will be selected that is now facing demolition, to explore the possibilities of concrete reclamation and preparation for DfD, thus, to prevent full demolition.

Case studies already deconstructed:

- De Nederlandsche Bank, Amsterdam
- The Udden Project / The Nya Udden Project, Finspång, Sweden
- Elementen Flat, Vlaardingen & Maassluis

Case studies planned for demolition:

- Voormalige Ministerie van Sociale Zaken en Werkgelegenheid, Den Haag
- Hertzberger Park / Centraal Beheer, Apeldoorn
- De Beurs, Almere
- Voormalige Rijks Belastingdienst, Leiden

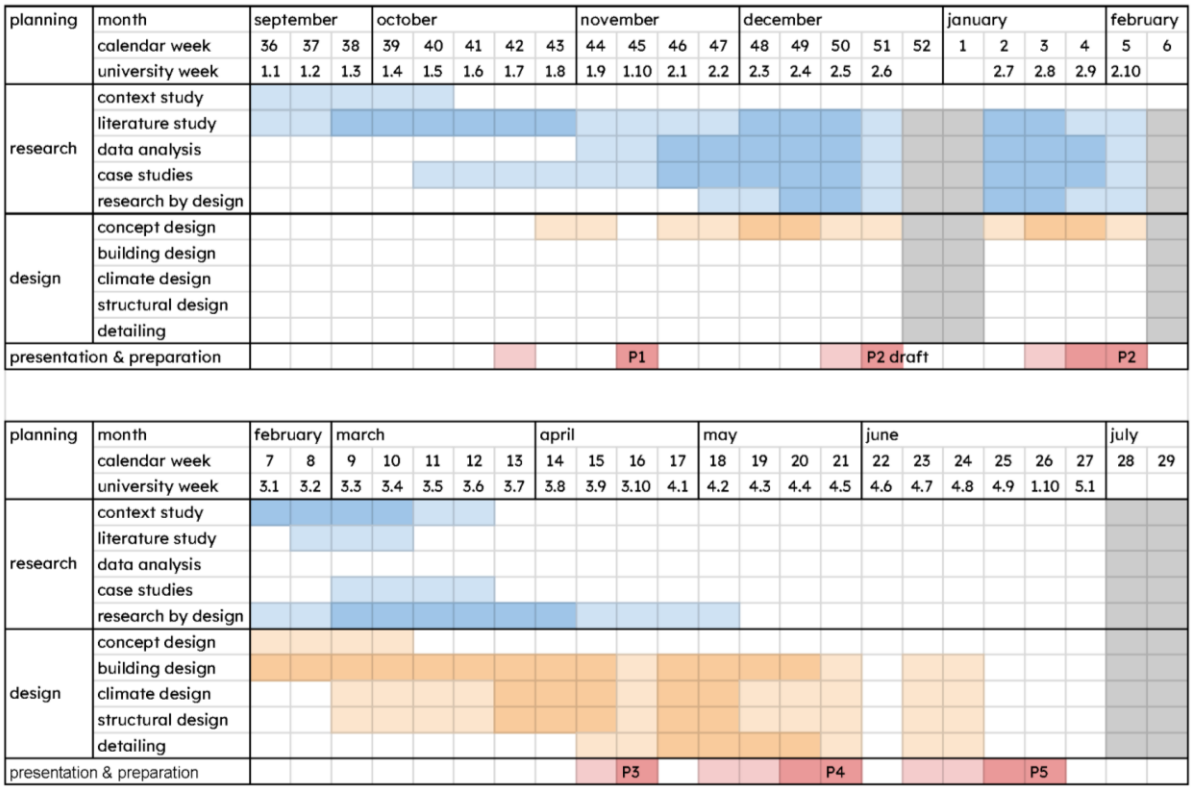
Material flow analysis:
In this paper, a material flow analysis (MFA) is introduced that will help to understand the lifecycle of concrete by exploring the different phases it undergoes, such as the manufacture, construction and deconstruction phase. It will track down the current situation of the material flow and it will give insights of where the pain points lay in the system. A more circular and sustainable MFA could be suggested at the end of this analysis.

SWOT analysis:
This analysis identifies the strengths and weaknesses, possible opportunities and potential threats of reclaiming and reusing concrete. The analysis provides a quick overview and it represents the balance of those four aspects regarding the reuse of concrete. By evaluating these four elements it gives us key insights that help us develop strategies to achieve goals and objectives.

Site visits:
The site visit goes hand in hand with the final case study that will be selected for this research. To gain a better understanding of the former Ministry of Social Affairs and Employment on a more detailed level, a site visit can be helpful. By doing thorough observations, measurements, and data recordings, a more elaborated case is presented, besides its literature documentations.

Interview with experts:
If necessary, interviews with experts in this field could help to collect more insights, opinions, and subjective perspectives. Examples of interesting individuals to be interviewed; people active in the circular building industry, experts on concrete, architects, constructors, etc. These interviews often involve open-ended questions and allow for in-depth exploration of ideas.

Planning



Relevance

This research focuses on the construction industry's contribution to waste generation and CO_2 emissions. Given the urgency of climate change and the need to reduce environmental impacts, it addresses a critical concern. It also aligns with the principles of the circular economy, a concept gaining importance in sustainability discussions. The circular economy of the construction industry emphasizes resource efficiency and reducing waste, making it relevant in the context of sustainability and circularity. This industry is a major contributor to environmental issues, thus making this research relevant not only for academics but also for different stakeholders active in the industry and policymakers seeking for sustainable solutions.

Furthermore, this research will end with recommendations and technical insights for the reuse of the concrete structure from a specific case study; the former Ministry of Social Affairs and Employment in The Hague. In March 2023, The Hague's municipal council announced plans to redevelop this site, proposing a mix of residential, office, and commercial spaces. The architect of the building, Herman Hertzberger, contested the decision, arguing that the 1990 building was still structurally sound and should not be renovated or demolished. Despite Hertzberger's objections, the developer VORM and the municipal council came to an agreement for the building’s renovation. (Weessies, 2023, july 6) On July 3, 2023, it was finally confirmed that the demolition of the former Ministry of Social Affairs and Employment building would proceed, triggering strong disapproval from AHH Architects. (Ahh, 2023) Although AHH themselves have developed a plan to preserve the

building and transform it into a healthy mix, primarily for residential purposes, the decision to demolish the building remains firm, citing that the calculations for preservation are not feasible, both financially and spatially. (Weessies, n.d.) AHH expressed disappointment in the municipality's and VORM's decision, resulting in the termination of any further collaboration. They questioned their claim on sustainability of their plans by not maintaining or using the existing building - especially the concrete structure - and therefore criticized the demolition as a wasteful and regressive measure. (Ahh, 2023) The architects leading this project are Barcode Architects and they have outlined a vision for a modern urban living environment accommodating approximately 1200 households, including plans for green areas, a new city park, and an upgraded station area. (Architectenweb, 2023)

Concluding, this paper results in a more specific research due to its focus on the construction industry and the reuse of concrete elements, and especially due to the chosen case study. However, the concepts and principles, such as sustainability, circular economy, and resource efficiency, are reaching different sectors. Therefore, its findings and recommendations can be valuable for a wider audience interested in sustainable practices and resource management.

Position statement

My role as a researcher is to investigate methods for reusing concrete from building structures, with the overarching goal of minimizing concrete wastage. The production of new concrete is associated with substantial CO_2 emissions, and conventional downcycling methods for concrete waste are not the answer to reduce these numbers. Currently, a number of buildings constructed after 1965 ('Post 65' era) are slated for demolition. In many cases I struggle with the choice of demolishing a building, and it is crucial to emphasize that I rather advocate for the repurposing of buildings through renovations and innovations. However, the practical reality often involves policy-makers determining that these buildings are fit for demolition, with time and cost efficiency as primary factors. Yet, our industry must transition towards sustainable and circular practices to reduce environmental impact.

Many of the buildings on the demolition list have reached the end of their intended lifespan. However, the concrete structures within these buildings often remain structurally sound and durable, with the potential to serve for many decades. With this paper I intend to formulate a proposal that outlines a circular approach for salvaging concrete elements from buildings, which, regrettably, are earmarked for demolition. The design objective is to repurpose these concrete components for use in future construction projects. By exploring innovative techniques for concrete extraction and reintegration, my research aims to contribute to a more environmentally friendly and resource-efficient approach to construction and deconstruction, aligning with the urgent need to reduce our carbon footprint.

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