Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Juan Camilo Gomez Serrano
Student number	5426138

Studio		
Name / Theme	BT Graduation studio: Structural Design for change	
Main mentor	Stijn Brancart	Structural design & Mechanics
Second mentor	Olga Ioannou	Building production innovation
Argumentation of choice of the studio	The decision to choose this studio for my graduation project comes from two motivations: A personal interest in exploring the structural potential of timber as a material and my concern about making Reuse visible as an alternative in the refurbishing sector. The Structural design for change field is relevant to the construction industry's transition from a linear to a circular economy. By analyzing and optimizing the lifespan of existing and new structural systems and components, it is possible to limit negative environmental impacts by managing natural resources efficiently. The studio is relevant as research over one of the building's most complex and intensive systems (material-wise speaking): the structure. In the case of existing Reinforced Concrete structures, demolishing existing buildings to construct new ones with a higher capacity is the most common practice to respond to the increasing demand for new houses worldwide. This prompts a sustainability discussion as, in several cases, these demolished building structures are still in their service life phase, producing a large amount of waste. Significant literature has focused on studying Reinforced Concrete (RC), recycling and reuse of RC Components to limit (RC) waste in the construction sector. However, more research is also required to prolong the lifespan of concrete systems by reusing them.	

Graduation project	
Title of the graduation project	Timber Top-ups for existing reinforced concrete structure buildings.
Goal	
Location:	**The city of Delft, The Netherlands.** A building with a typological RC structure system relevant to the problem statement has been selected to develop the design of a structural system. The Gillisburt residential block in the Buitenhof district represents a relevant example of a Post-war tenement dwelling built with an RC structure.
The posed problem,	**1. The shortage of housing and the necessity of increasing dwellings capacity.** In the last six years, there's been a shortage in the housing supply in The Netherlands. According to the Dutch National Housing Agenda, the gap between supply and demand of housing spiked because of the following: a) the rapidly improving economy in 2018, b) previous measures on the housing market, c) catch-up demand from people who have waited out the crisis (Ollongren, K.H., 2018). Particularly in metropolitan areas with a tense market, the shortage is more evident, as the existing buildings are not responding to today's nor future needs of housing m2 society is requiring. To solve this, taking into account the demolition of 12 to 13 thousand homes per year, some 700 thousand homes would have to be built by 2025 to face the projected demand (Ollongren, K.H., 2018), meaning an average of 87.500 new homes per year, according to this agenda.

2. Demolition of Reinforced Concrete Structures.

In consolidated urban areas, these homes are being allocated in new high-density buildings where existing ones used to be, and are now being demolished. In the case of The Netherlands, 90% of the demolished buildings in the latest years corresponded to those built in the period between 1900 and 1970 (CBS, 2022). Most of these buildings have RC structures (Pardo Redondo, 2021);

This strategy prompts a challenge for the circular transition in existing RC structures because of two reasons: a) concrete output from demolishing has increased significantly in the latest years (Luangcharoenrat et al., 2019), and b) the embodied energy of the construction is underused and underexploited when an RC structure is demolished before its projected lifespan. Therefore, RC structures can only deliver their intended service over a short period. This implies a much greater embodied energy than a building with a longer life span. (Allwood, 2014).

In this sense, responsible use of natural resources to create new concrete and waste management of RC becomes crucial. It is known that the Construction Industry is responsible for exploiting over 32% of natural resources and generating one-quarter of the solid waste worldwide (Duarte , Maria et al., 2020).

3. Recycling of Reinforced Concrete (RC) and Reuse of (RC) components

There has been significant research from Academia and industries to study how to manage RC waste from demolished structures. Moreover, the literature focuses on two specific strategies with two perspectives: recycling concrete and steel from RC structures and dismounting and reuse of RC structural components.

Authors have analyzed the possibilities of crushing RC to be transformed into an aggregate called Recycled Concrete Aggregate (RCA) for its use in producing new concrete. It has been proved that under certain conditions, RCA can be used as a partial or complete replacement of coarse natural aggregate in new structural concrete. (Marinković et al., 2014). Although the latest literature shows a significant advance in this strategy, it faces two limitations: On one hand, as stated by Allwood (2014), recycling concrete generally involves a loss of quality impossible to control when compared with concrete produced with virgin material. On the other hand, new cement is required to produce new concrete, increasing its embodied energy.

On a component scale, there have been successful attempts to repurpose and reuse concrete elements by conferring them the capacity to be disassembled and reused. For instance, the Finnish company, Peikko, produces large bolted mechanical steel connections for concrete elements enabling disassembly for reuse in subsequent buildings, prolonging the elements' service life, and avoiding environmentally burdensome production of new concrete elements (Eberhardt et al., 2019).

4. Topping-Up with timber: An alternative?

Prolonging the life span of a building is a strategy in a higher hierarchy compared to recycling and Reuse. However, by extending End of Life (EoL) structures, the lack of housing problem still needs to be solved. It becomes necessary to intervene RC structures with another approach to increase building capacity by reusing as much possible of the existing embodied energy.

What would happen if it were possible to make existing RC structures more efficient system-wise? By intervening to make them support and transfer bigger loads represented in more building capacity (m2).

Timber is a material that can be used to create structural components. It has a strength parallel to grain, similar to RC, with the advantage of having a fifth of its weight (Michael H. Ramage & Henry Burridge, 2017). Although timber cannot match modern high-strength concrete in compression, it has a lower density than most conventional structural materials. This results in timber being an efficient material for long-span or tall structures (González-Retamal et al., 2022).

Therefore, if timber has a strength-to-weight ratio higher than concrete, replacing a certain amount of RC components with timber would allow the remaining structure to

	bare more weight. Therefore, the removed dead loads lead to the possibility of increasing the capacity of the building, avoiding total demolition (limiting the amount of waste).
research questions and	How to increase the capacity of existing Reinforced Concrete structure Buildings and limit the amount of demolition waste by using timber top-ups? **SQ. 1** Which structural timber systems can be more effective when topping up existing Reinforced Concrete Structure (RCS) buildings? **SQ. 2** What benefits and limitations have topping up an (RCS) building compared to demolishing and constructing a new one? **SQ. 3** How to make visible topping up in the decision-making for stakeholders when facing demolishing/building new? **SQ. 4** To what extent can the capacity of an existing RC building with timber be increased by reducing the weight of the RC structure?
Design assignment in which these results.	The expected result for the graduation project focuses on two deliverables: A decision-making design framework for Timber Top-Ups in existing RC buildings and a design proposal that will showcase how the Design framework can be applied. **Design Framework** The design Framework is intended to work as a guideline for stakeholders interested in topping up with timber when facing the decision-making for renovating/demolishing an existing RC structure building. **Timber Top-up Structural system design** The design aims to propose a timber Top-Up system for a specific building with an RC-relevant typology for The Netherlands. In this case: a Postwar Walk-Up Apartment building constructed with an (RC) structure.

Process

Method description

The project will be divided into five parts: Research, case study selection, Design through research (DtR), Experiment, and finally, Results & Conclusion.

The research will be conducted first through a literature review of what has been developed with timber top-ups—followed by two case studies where Timber-Top-ups have been applied to RCS. In addition, previous to the framework's design, Timber characteristics and properties will be analyzed to determine relevant evaluation parameters to Top-up concrete structures. Therefore, pertinent findings of technical literature related to Timber as a construction material will be exposed from the Structural mechanics and Circularity perspective.

The information will be categorized and analyzed based on its different product composition scales, starting from the minor scale: Timber as a structural material, followed by Timber as a product, timber products to create structural components, and ending up with timber components to create timber structural systems based in the current European structural code: The Eurocode 5.

Case study selection: A relevant case study of a concrete structure typology with the potential to be topped up in The Netherlands is proposed and analyzed. The suggested typology is the Postwar Walk-Up Apartments built between 1960 to 1975 (Tenements buildings). Moreover, for the design part, the building complex to intervene will be the group of dwellings located in the neighborhood of Gillisbuurt in the city of Delft.

Design through Research: After understanding the possibilities of timber as a structural material for topping up and selecting a case study comes the research through the design part (RtD), which intends first to create a design framework that will be used to propose a design approach for a top-Up structural system with timber for the study case.

Experimental part: For the demonstration part of the project, a simulation with two hypothetical scenarios is proposed:

To start the experiment, a scenario is proposed where the existing RCS building analyzed in the case study is topped up with the structural system proposed in the design part. First, an iteration is proposed where one story of concrete is removed from the structure to be replaced by two of timber (The previously structural defined parameters are studied). Next, an additional timber floor is added, and the parameters are studied again. The exercise will be repeated until one of the parameters shows an undesirable result, meaning that the structure no longer complies with the acceptable values for Ultimate Limit State (ULS) and Service Limit State (SLS) stated in Eurocode 5.

By determining the maximum performance of the Top-Up, a scenario is proposed where the existing RCS building is demolished, followed by the construction of a new timber framed structure building with the same m2, typology, and capacity as the one demolished, where The height will be the same as in the first scenario. This time, environmental parameters are analyzed for both scenarios to evaluate their impacts.

The structural feasibility of the first scenario will be assessed by performing a Limit State Design analysis where the following structural criteria will be studied: Deflection, vibration, fatigue, fire resistance, and collapse. To perform the hypothetical scenario, the first case studied will be analyzed using the parametric structural engineering tool Karamba3D+ BeaverStrcutures.

The environmental impacts in scenarios 1 and 2 will be assessed by analyzing: C02 emissions, Energy consumption, and waste generation. This analysis will be carried out with the help of the Ecoaudit Tool from the software GrantaEdupack after determining the volume of the structure, transformation processes, and source of the materials.

Finally, the results will be discussed, and conclusions will be drawn to answer the research question.

Literature and general practical preference

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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)?**

   The graduation project: *"Timber Top-Ups for existing reinforced concrete structure Buildings"* is directly connected with the topic of *"Structural Design for change"* and the *"Building Technology master track"* as it approaches an alternative strategy for existing concrete structures when facing the process of transitioning a building into the circular economy model by conferring the possibility of extending its life span by increasing the capacity. With the Master in the architecture program, the thesis intends to create a design Frame for stakeholders around the architecture and construction industry to facilitate and make visible structure reuse.

2. What is the relevance of your graduation work in the larger social, professional, and scientific framework?

In the social framework, the project intends to give the inhabitants an alternative to reconfigure current building conditions by increasing the capacity of the existing buildings they are living in. In that sense, the additional gained area can be used for different purposes in each specific situation: These Allocated spaces can be utilized for inhabitants' welfare or to create more vendible private areas to finance renovation works.

In the Professional framework, the project seeks to make Topping up visible to stakeholders in the architecture and construction field. With the Design framework comes a tool that can be useful in the decision-making process for renovation projects. From a scientific perspective. The project's relevance relies on the experimental part, which intends to evaluate the structural and environmental performance of Top-Ups by analyzing specific criteria through the experimental method.