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	Bryan Zwakkenberg
Student number	

Studio		
Name / Theme	Discrete timber systems	
Main mentor	Stijn Brancart	Assistant professor of structural design at the department of Architectural Engineering & Technology
Second mentor	Alex de Rijke	Professor of Timber Architecture at the department of Architectural Engineering & Technology
Argumentation of choice of the studio	The argumentation for choosing discrete timber as a graduation topic, originates from my interest in computational design, which plays a significant part in discrete systems. In addition, sustainability is an increasingly more important aspects within all, but also the construction industry, the second aspect of my research is therefore that of modular design with possible novel joints in discrete timber elements to improve the end-of-life scenario (by allowing for demounting, refiguring and/or reusing).	

Graduation project	
Title of the graduation project	Structural calculation of discrete timber systems with reversible joints.
Goal	
Location:	Delft, the Netherlands.
The posed problem,	If no changes occur to global greenhouse gas (GHG) emissions, it is likely that the temperature goals that have been set in the Paris Agreement from 2015, are not reached (Copernicus Climate Change Services, 2018, 2023). The construction industry plays an important role in reducing the global GHG emissions, because it is accountable for approximately one third of the total global GHG emissions. Greenhouse gas emissions in the construction industry are divided into two groups: operational and embodied carbon.

Greenhouse gas emissions in the operational phase are assumed to be higher and have therefore been subject to more research and innovation in order to reduce this, resulting in various energy efficiency and renewable energy solutions. However, different studies have shown the increasing share of embodied carbon emissions. Reducing embodied carbon emissions can be done by replacing materials that are generating high emissions in production, but also by improving the end-of-life scenarios to extend a building life, reusing materials elsewhere and this way postponing the need for newly produced materials (Hekma et al., 2021; Ibn-Mohammed et al., 2013; Jarrett, 2023). Improved end-of-life scenarios can be ensured by following different design principles for structural adaptability, such as Design for Disassembly/Deconstruction, design in layers, and design for reuse (Ottenhaus et al., 2023).

There are multiple studies showing the advantages of using timber as a construction material instead of concrete or steel for example. Hart et al., (2021) showed that the whole life embodied carbon for engineered timber frame constructions is 35.7% lower than for its equivalent in concrete, and even 47.8% less than its equivalent in steel.

There is also research stating that structural discrete timber systems offer some advantages over conventional structural timber (sawn, massive, and engineered). Discrete in 'discrete systems' comes from 'discreteness', which refers to something being separate and individual. In the context of 'discrete systems' this translates to the elements in this system being somewhere in the spectrum between building element and particle, only having a function when they are combined with other discrete elements (Retsin, 2019a, 2019b, 2016b).

For example, it fits in economies of scale by producing only a single digit number of parts (that do not have a pre-defined function) rather than all pre-defined, customised, and optimized building parts, which results in a more time and cost efficient production. Furthermore, discrete systems are closely related to automation, resulting in fast assembly and complexity (Retsin, 2016a, 2019b). Additionally, in current society it is more efficient and cheaper to waste material

	instead of labour. Allowing material waste seems contradictory, which is the case for concrete for example, but for timber it can be said to be advantageous due to the carbon sequestering happening (Retsin, 2019b). However, the application of discrete timber systems is mainly limited to just theoretical research, research prototypes, or small scale projects without calculations on the loadbearing capacity. Projects that did take the loadbearing capacity, or stress, into consideration are the 're-voxlam truss', 'robotic reversible timber beam', and 'reconwood slab' by SDU Create (CREATE SDU, 2019, 2023a, 2023b). Only these were more specific applications to their design, making it less applicable to other cases. Additionally, the current discrete timber systems are not optimally tailored following a design principle for structural adaptability. To make discrete timber systems scalable in the industry, a method for structurally verifying different systems, that are designed for structural adaptability, is needed.
research questions and	This thesis aims to create a method to calculate structural capacity of reversible discrete timber systems. In doing so it aims to answer the following research question: *"How can a structural discrete timber system be a feasible and reversible alternative to conventional structural timber?"* For answering this main research question, the following sub-research questions are needed. 1. *How can the aggregation structure in discrete timber systems be set-up to enhance reversibility?* 2. *What makes for feasibility in discrete timber systems?* 3. *What is the structural performance of discrete timber systems?* 4. *Which reversible joinery techniques are applicable to discrete timber systems?* 5. *What is the structural performance of joints between discrete timber elements?* 6. *What are the advantages of replacing a conventional timber structure with a structural discrete timber system?*
design assignment in which these result.	The goals of this thesis are to design a method for structurally calculating discrete timber systems, and to research and apply reversible joints for discrete timber elements. The resulting knowledge from these goals will then

	be applied to a case study, which can be used to verify the result.

Process

Method description

This thesis consists of 4 phases:

The goal of the first phase is to gather relevant literature and conduct a systematic literature review. In this phase, various scientific papers, theses, books, and magazine articles covering the broader spectrum surrounding 'structural theory of timber' and 'reversible joints in timber' are expected to present valuable information needed to answer the research questions.

In the second phase, the knowledge gained from the first phase will be applied to new research. This new research will consist of parametric structural design (for the structural capacity of discrete timber systems) in Grasshopper for Rhino, and a Finite Element Model (for the reversible joints of the discrete elements) in Ansys.

The third phase will apply the new knowledge gained in phase 2 to a case study. This case study aims at confirming the use of structural discrete timber systems with reversible discrete elements, as alternative for conventional structural timber.

The final phase will summarize and conclude the findings and answer the main research question. The final result will be an evaluation of a case study to which the new information is applied. This part also elaborates on possible further research.

Literature and general practical references

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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)?**
   This thesis addresses a structural calculation method for discrete timber systems with reversible joints. For understanding and creating a method for structural calculation, structural knowledge in timber structures is needed. For creating, or applying reversible joints to discrete timber elements, knowledge in both timber and timber connections is needed. The former has strong links to the structural design department, and the latter has links to timber and timber design. This research will be making use of Grasshopper for rhino for parametric structural design, and Ansys for Finite Element Modelling of the joints for the discrete elements. Computational design is an important aspect of this research project.

2. **What is the relevance of your graduation work in the larger social, professional and scientific framework.**
   <u>Social relevance</u>
   The construction industry is a large contributor to greenhouse gas (GHG) emissions, waste production, and material usage. As recent numbers show, it is important that the global GHG emissions are reduced, otherwise this could carry serious consequences. This thesis aims to create a method to calculations structural discrete timber systems with reversible joints. The result from this allows a wider application of structural discrete timber systems. A system for which the amount of unique elements is reduced and the end-of-life is improved. Both supporting a more sustainable construction and thereby reducing GHG

emissions, waste production and material usage. In the end resulting in a better global living environment.

Scientific relevance

Currently there are no methods for calculating structural performance of discrete timber systems, or jointing techniques for reversible joints in discrete timber elements. This thesis aims to fill both these research gaps. It also opens up opportunities in further research for, amongst others, novel joints and robotic assembly for the reversible joints.