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	Hidde van Nieuwenhoven
Student number	5008948

Studio		
Name / Theme	Building Technology Graduation Studio AR3B025 / New material from unrecycled metal waste streams for architectural purposes.	
Main mentor	Telesilla Birstogianni	Structural design
Second mentor	Marcel Billow	Façade and Product design
Argumentation of choice of the studio	I am interested in a hands-on graduation thesis with as much physical research as possible, this combined with interest in innovative solutions for a stuck industry let me to choosing this research studio.	

Graduation project	
Title of the graduation project	Urban mining & reuse of unrecycled metal waste – creating new material for architectural application.
Goal	
Location:	-
The posed problem	The metal production industry in Europe consumes over 120.00 TJ of energy annually (Eurostat, 2023c). Less than 0.15% of this energy is from renewable sources or biofuels (Eurostat, 2023a). Furthermore, the production industry is responsible for generating more than 77.676 MMt of CO2 emissions (Eurostat, 2023b). This carbon footprint shows the importance of researching more sustainable practices like improving recycling techniques for metal waste. Currently the recycling industry focusses on bringing back waste material to clean, primary like, raw material. This shows especially in the metal industry. Materials are created using compositions that difficult recyclability. These material compositions can be either created during manufacturing or at the end-of-life phase of a product. The processing of this metal containing waste is a costly and energy demanding process. This makes recycling economically nonviable. Due to high costs, a large amount of metal waste is exported to countries with low labor costs.

	Metal waste that is too expensive to sort and recycle, and even to export, is being landfilled or incinerated. A large amount of material goes to waste by doing so. Many studies are performed about separating these materials and recycling them into secondary raw material. However, there is a gap in research on experimental methods of recycling metal waste that is thus far too expensive or complicated to be recycled as raw material. Also, current research describes techniques to separate materials. The research does not focus on synergy between materials.
Research questions	**Main research question:** How can un-recycled, contaminated, mixed metal waste be reprocessed into new materials for architectural applications? **Sub questions:** - What is the current state of the art for metal recycling in Europe, what difficulties are faced, and which waste streams stay unrecycled? - What are the parameters for processing contaminated metal waste and how do they influence mechanical properties of the material? - What are potential architectural applications for these parameters and mechanical properties, and aesthetic qualities? To come to a realistic outcome, during the research the material supply chain will be considered to give guidance but will not be a main theme of this thesis.
Design assignment	This thesis aims to explore new purposes for thus far unrecycled metal containing waste streams. Offering promising opportunities to find processing strategies and techniques to create value and architectural purpose for wasted materials. After selecting and characterizing a material source different processing approaches will be designed. Depending on the mechanical, functional and visual properties of the material, multiple architectural purposes will be researched. Furthermore, this project aims to explore experimentally the different techniques to recycle metal waste, as well as available manufacturing techniques. By proposing a feasible application for currently non-recyclable materials, the research can lead to improved practices in the built environment and reduce material consumption. Therefore, it will contribute to a more circular economy.

Process

Method description

Literature research
The literature research is split up in three main parts. In the first part will focus on mapping metal waste streams in the European context. This section includes a general framework for material flow as well as metrics on material flow in Europe. Secondly, the main processes for recycling metal waste in the European context will be mapped and specific waste and recycling residue will be selected for further investigation. The last part of the literature review will focus on metal manufacturing techniques. This part of the literature review will later, in the experimental phase of the research, support the processing of the metal waste to create new material for architectural purposes.

Material selection
Most materials entering the recycling stream will be applicable to this research. However, some other criteria are important to consider when selecting a waste stream for the experimental testing. Waste streams being assessed are provided by the companies and retrieved from the literature review.

Material experimentation & testing
Residual metal containing waste will be collected, characterized and tested in the laboratory. Different metal forming techniques will be conducted to test possibly new material forming.

The newly formed material will be tested for example in a flexural strength test or a tensile strength test. Further testing will be conducted depending on the purpose of the material design.

Prior material research
Additional literature research about the selected waste material will be conducted, covering material properties and characteristics, production techniques and recycling possibilities.

Research by Design

Experiments are conducted in the following proposed workflow:

- Assess material sample properties using FTIR & XRF
- Perform different metal forming techniques and parameters with contamination in the material
- Perform different metal forming techniques and parameters without contamination in the material
- Assess material properties and correlate properties to processing parameters
- Research architectural purposes and feasibility

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 graduation thesis aligns closely with the faculty muli annual plan and the master track Building Technology. It addresses the topics of scarcity of resources, climate crisis and circularity in the built environment.

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

The relevance of this thesis extends beyond the context of waste metals and creates a framework for researching other waste materials for architectural or other purposes. Creating awareness of the complexity of modern materials and minimal recycling solutions is crucial to reduce waste production. Recycling is not the answer to consumption and recyclability in theory is different than recyclability in practice. Resource scarcity in the form of critical materials and climate crisis are both addressed.

This thesis uses a resourceful approach to come up with solutions for critical material consumption and material waste. By proposing a feasible application for currently non-recyclable materials, the research can lead to improved practices in the built environment, and waste management sectors. By experimental testing of nonconservative recycling techniques new material will be created. By assessing the properties of the created material, the physical quality of the material can be shared among professional for potentially future application.

Scientifically, this work contributes to the broader field of materials science and environmental engineering by exploring new recycling methods and correlating material processing to properties. It encourages further investigation into material properties, the technologies involved in recycling, and the potential environmental benefits of recycling complex or low-value materials.