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	Ramya Kumaraswamy
Student number	5555515

Studio		
Name / Theme	Building technology graduation studio/ Sustainable structures	
Main mentor	Mrs. ir. T. (Telesilla) Bristogianni	Chair Structural Design & Mechanics
Second mentor	Dr. Olga Ioannou	Chair Building Product Innovation: Product Development, Production Technologies, Façade Design
Argumentation of choice of the studio	Plastic, often mistakenly perceived as environmentally unfriendly due to recycling challenges, provides valuable insights for material development when analyzing these difficulties. As the world shifts towards sustainability, incorporating waste streams into material development helps mitigate carbon dioxide emissions. Both chairs contribute to my understanding and development of materials development from waste stream and tailor them specific needs.	

Graduation project	
Title of the graduation project	**Re-P-Tile Recycling PVC into a façade Tile** – Exploration of the potential of recycled PVC waste streams from construction and demolition industry to engineer a façade sheet material as an architectural product
Goal	
Location:	Europe for contextual analysis and The Netherlands
The posed problem,	The prevalent issue within the realm of plastic recycling lies in the inherent complexity arising from the multitude of plastic types distinguished by their diverse compositions, contaminants, and fillers. This poses significant challenges to the recycling process. Moreover, with each recycling iteration, the material properties experience a noticeable decline, contributing to a diminishing structural integrity and overall performance. In response to these challenges, an alternative approach emerges – the extension of product lifespan through reuse integrated into product design. However, this potential solution faces economic hurdles, primarily due to the accessibility and cost-effectiveness of virgin plastic, rendering recycling economically non-viable. Another critical concern comes from the deleterious effects of UV radiation when used on an external surface, inducing photodegradation and resulting in material loss, thereby compromising structural stability. This not only addresses the material degradation, but also questions the location of application of the material and to facilitate the reuse of the material without the

	necessity of recycling, thereby offering a comprehensive and innovative approach to mitigating the challenges inherent in plastic recycling.
Research question and sub-question	Main research question: "How can PVC waste streams originating in windows and pipes be processed to develop sheet materials for facades cladding??" The sub-questions are formulated to inform the broader research methodology and assist in organizing the research progress chronologically, using the results of previous sub-questions as a starting point for subsequent ones. The sub-questions are as follows: • What are the key challenges in plastic recycling, specifically with PVC, and what strategies can be employed to address these challenges effectively? • How do we determine the compositional differences and material behaviour in PVC waste from various sources, colors, and applications, which complicate the recycling process? • How do the compositional differences in the waste streams and production parameters, such as temperature, pressure, and dwell time, influence the processing of PVC into flat tile materials? • How do variations in shred size and composition affect the mechanical properties of the resulting tiles? • How can we effectively evaluate the strength of recycled PVC tiles and analyse the causes of failure using morphological analysis and sample homogeneity? • What role does compositional variation play in influencing the UV stability of these tiles? • How do aesthetics and material application correlate with sustainability, considering factors like R-strategies to map the waste management hierarchy, carbon footprint, and benchmarking against conventional materials typically used in façade systems?
Design assignment in which this result.	This thesis aims to analyse the PVC waste stream- one of the largest plastic resins in construction and demolition waste, considering compositional variations and contamination levels, to identify an optimal mix through the validation of the material's flexural strength. Subsequently, an assessment of the material's suitability for façade components and interior wall panels is conducted, focusing particularly on parameters such as UV degradation, compatible extrusion process and flammability.

Process

Method description

The thesis is structured around five integral phases, each contributing to the overarching goal of developing a sheet material for an architectural product from a recycled plastic waste stream:

Phase 1 - Literature review and interviews

In this initial phase, a comprehensive literature review is conducted to identify non-recyclable plastic waste streams. The primary objective is to analyse the material flow of plastic waste, mapping out the various types encountered. The research involves understanding the challenges associated with recycling, which include economic, logistical, technical, regulatory, and societal aspects.

Another important part of the literature is to engage with various research experts, companies operating in a similar domain, and fellow master's thesis students for gaining a comprehensive understanding of the challenges involved. Conversations with research experts provided insights into potential technical innovations. Interacting with other master's thesis students offers valuable leads and practical tips and companies shed light on business challenges and the complexities of transitioning from product development to large-scale production. These interactions collectively helped in a better understanding of the material and the reason behind the challenges encountered.

Phase 2 - Choice of plastic resin
The next phase involved the selection of the preferred resin. This choice was dependent on the inherent properties of virgin plastic and the intended location of the architectural product that is being crafted. Various factors, such as the cost of virgin plastic, mechanical properties, flammability, and waste production percentage, were considered during this selection process. This step is very important as it also affects the type of component that can be created, and the properties that can be dealt with.

After a comprehensive analysis of all the important properties of the material, PVC was chosen as the ideal plastic resin due to its significant waste generation volume, self-extinguishing material characteristics, and the array of material properties it offers. Following this, samples of the PVC were tested to understand their composition, as additives can influence material properties. This testing was conducted both at macro and micro levels, evaluating factors such as the purity of the shreds, the presence or absence of hazardous substances, and the glass transition temperature.
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Phase 3 - Experimentation
Following the scientific analysis of sample composition, the rPVC shreds underwent various fabrication techniques that seemed suitable and had the potential to yield the desired outcomes. Initially, the sampling was conducted to ascertain temperature and pressure requirements, followed by using a mould for larger sample production. Due to limited literature on hot pressing PVC samples, extensive experimentation was carried out to determine the optimal pressure for sheet pressing. Initial experiments aimed at maintaining constant composition and thickness of the sheet material while adjusting pressure levels. Subsequently, temperature variations were introduced alongside composition adjustments to understand their interplay. The experimental phase aimed to produce a number of samples at the end of the experimentation phase with varying compositions and thicknesses for validation.

Phase 4 - Validation and analysis
The validation phase consists of a range of standard procedures aimed at assessing the viability of the designed material as a competitive alternative to conventional materials used in similar applications. These tests include conducting accelerated UV tests to gauge long-term effects of UV exposure, as well as flexural strength tests to evaluate its capacity to withstand loads. Additionally, the samples were inspected under the microscope to understand the reason of fracture. Furthermore, the conclusion aims to also address the avenues for further research and development.

Phase 5 - Application and circularity strategies
Based on the extensive study conducted on the material, the final phase includes designing of a component. Various criteria and building requirements are taken into account to choose the location of application. The phase further explores in mapping of R-strategies for waste managemnet hierarchy of the material and determining the carbon footprint with the results are benchmarked with some of the conventional materials used in the application. The application section also focuses on designing facade tile by two methods - (a)by using a mould designed by NPSP.B.V to produced a facade tile and (b) layering technique of the shreds. The section also provides few visualisations of the product in use.

Literature and general practical references

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