RE-CONSTRUCTING GLASS - a material study of recycled glass implemented in a design proposal for the Circular Hub of Gothenburg

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Examiner: Mikael Ekegren Supervisor: Björn Gross Department of Architecture and Civil Engineering | CHALMERS UNIVERSITY OF TECHNOLOGY

MASTER'S THESIS SPRING 2021

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Cover: an up-close photograph of cullet glass fusion showing the bumpy texture, for more detailed information see page 21-27

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Abstract

Global extraction of sand has become one of the great environmental problems of our time. The objective of this thesis is to explore how to up-cycle container glass into facade cladding, hence utilizing the wasted glass as a resource instead of extracting sand for new glass. How can discarded glass be reused with in the frame of architecture? Södra hamngatan 47 in the historical center of Gothenburg is the site of the project design proposal where the glass explorations will be implemented in a public building.

Since the former building burned down the informal name for the site has been "Brända tomten" meaning the burned plot. The introduction explains the context, history and conditions of the small, urban and wildly discussed plot where the infill design proposal is situated. Along with a brief description of glass, its properties and historical use summarizes the background of the project.

The aim is to contribute to the discourse around circular material flow thinking. When designing we as architects need to start thinking of objects, buildings, and waste as material resources for new design. Inspired by several material studies on the same theme this study strives to give a scalable and believable implementation of up-cycled glass.

Literature studies, case studies, iterative design in various media and creation of material samples through glass fusion are the methods driving the process leading up to the final Circular Hub design proposal. The program is connected to the discourse of the project and is intended to be the circular economy meeting place of Gothenburg. Easy to access from all parts of the city and region this Hub is open for the public to be educated on the possibilities with circular thinking, while simultaneously being a natural meeting point for industries.

Glass is somewhat of a challenging material and discarded glass even more so since it comes with remains from other materials. With this thesis a way of using discarded glass within architecture is proposed by see value in glass for not only its translucency but for its cladding potential.

Keywords glass, facade cladding, research by design, circular economy, Gothenburg

Reading instructions

Introduction

Presents the aim and purpose along with the thesis question connected to the subject of circular development. The method, theory and delimitations of the thesis are also briefly described, followed by acknowledgments and student background.

Background

As a foundation the problems with sand mining are explained and the connection to the project. Followed by a summary of glass recycling and facts about the site for the building design.

Methods

Research by design has been the main methodology by doing glass fusions experiments and design iterations, and the process in general is shown and described in this chapter.

Design proposal

Presenting the building design proposal in its urban context, showing in detail how the glass cladding samples have been implemented as facade cladding. A material celebration in the program of a Circular Hub which is a meeting place for circular innovations.

Conclusions

Summarizes and reflects on how the thesis question has been answered. Discussing the potential of scalability for using the glass fusion claddings, examining the contribution of the thesis to the development of the research topic of circular building.

Glossary

Cullet - Glass that is crushed and ready to be remelted is called cullet. External cullet is waste glass that has been collected or reprocessed with the purpose of recycling. External cullet (which can be pre- or post-consumer) is classified as waste. The word "cullet", when used in the context of end-of-waste, will always refer to external cullet.

Circular development - Is a model of economic, social, and environmental production and consumption that aims to build a sustainable society based on a circular model. It aims to develop recyclable and sustainable resources to protect society from waste. The purpose is to be able to form a model that is no longer linear but circular.

Research by design - Research within the arts is normaly on, for, and by design and research by design is a form of research where creating and doing is what drives the reasearch and discovering forward.

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INTRODUCTION

Global extraction of sand has become one of the great environmental problems of our time. The objective of this thesis is to explore how to up-cycle container glass into facade cladding hence utilizing the wasted glass as a resource instead of extracting sand for new glass. Södra hamngatan 47 in the historical center of Gothenburg is the site of the project design proposal where the glass explorations will be implemented in a public building.

Aim & purpose

The aim is to contribute to the discourse around circular material flow. When designing, we as architects need to start thinking of objects, buildings, and waste as material resources for new design. Inspired by several material studies on the same theme, this study strives to inspire a broader usuage of wasted glass.

Thesis question

- How can packaging glass cullet be reused within the frame of architecture?

Methodology & theory

The theoretical train of thought for this thesis stems from theories on circular development, where finding value in what normally is considered waste is demed necessary. The methodology used in this thesis is Research by design. The creation of the glass fusions was a way of learning about the material and its properties. Iteratively designing in different medias, both digital and analog, has continuously driven the work forward. Input from literature studies, interviews and tutors has been an important part of the project.

Delimitation

This thesis departs from design-based research rather than technical research, which for example means that technical performance of the glass cladding has not been tested. The master's thesis course is 30 credits and due to the COVID-19 pandemic it was carried out by distance learning. As the thesis is conducted in the studio Building & Tectonics it aims to design a building that fulfils all the demands regarding spatial program, construction and tectonics required by the studio. The size of the plot has limited the size of the building which has impacted the program for the suggested Circular hub.

Student background

Sara Waldén grew up in Karlstad, Sweden and after having lived abroad she begun studying architecture in Gothenburg while simultaneously learning from jobs and internships relating to the studies.

Education

2019 - 2021	Master of Architecture and Urban Design 120 ECTS Chalmers University of Technology Thesis Studio Building and Tectonics Thesis preparation 1 & 2 Studio Matter, Space, Structure 2 Urban Planning and Design Theory Nordic Architecture Studio Material & Detail Sustainable Development and the Design Professions Credited courses
2016 - 2019	Bachelor of Architecture 180 ECTS Chalmers University of Technology
2015 - 2016	Civil Engineering Technical Design [1/5 yrs] Chalmers University of Technology
Experience	
fall 2020	Student Employee Commercial Property Management, Västfastigheter. Gothenburg
fall 2020	Freelance Architect Extension and renovation projects, private clients. Sunne
summer 2020	Carpenters assistant Building Carpenters Persson & Stenbäck. Sunne
summer 2019	Intern Architect City Planning Office, City of Gothenburg. Gothenburg
summer 2018	Intern Architect Architectural Office LoCa Studio. Barcelona
spring 2018	Course Lead for Architecture & Gender 3 ECTS Chalmers University of Technology. Gothenburg

Acknowledgments

This thesis is dedicated to my family and friends for their constant love and support during my studies. I want to thank my thesis supervisor Björn Gross, examiner Mikael Ekegren, course lead Naima Callenberg and Maja Kovacs of the Department of Architecture and Civil Engineering and Professor Christer Persson of Department of Industrial and Materials Science for their guidance and support in the process of conduction this master's thesis. My sincere appreciation also goes to Anna-Karin Larsson at Svensk Glasåtervinning for donating the glass cullet material and to the whole of Chalmers University of Technology which provided the facilities.

> "Last but not least, I wanna thank me. I wanna thank me for believing in me." - Calvin Cordozar Broadus Jr.

Sara Waldén, June 2021



BACKGROUND

Glassbricks are booming and architects have a new found fasination for the aesthetic and material properties of this unique architectural element, pushing toward new boundaries of glass and light in architectural design. (Cao, L. 2020). This current discurse around glass within the field of architecture and the global sustainablity movment provides the context for the thesis glass explorations.

Sand mining

Sand is often used in manufacturing building materials such as concret and more relevent for this thesis: glass. It is composed of finely divided rock and mineral particles and is a non-renewable resourse. Sand is commonly extracted through open pit, but also from beaches or the bottom of the ocean mining. The massive extraction has had a negative impact on biodiversity, water turbidity and landscape along with socioeconomic and even political consequences (United Nations Environment Programme. 2014).

Glass recycling

The material glass has existed for about 9000 years and already 100 years BC. the production of glass in the modern sense started. In the 1870s, glassworks began to buy back discarded glass from the breweries for use as raw material in new glass bottles. Today, Swedish Glass Recycling recycles 94 percent of all glass packaging in Sweden (Svensk Glasåtervinning, 2017).

Södra hamngatan

The site for the design proposal of this thesis is located in the district "Inom Vallgraven" which is the historical center of Gothenburg, Sweden. In 2005, Södra Hamngatan 47 was destroyed in a fire and has since been nicknamed "Brända tomten", meaning the burned plot. The original house was built in 1887 and was a residential building with space for shops facing the street. Restaurant Johanna was opened in 1973 with the taverns Leif Mannerström and Christer Svantesson as owners (Hallén, P. 2014).

Circular vision of the city

Today, the whole world is facing enormous environmental and climate challenges that require a systemic change of society in a short time. To succeed in reversing the trend, we need to drastically reduce our production and consumption of new products, by designing, producing, and use our resources smarter, with increased longevity and increased sharing. The government has adopted a national strategy for the transition to a circular economy. This strategy needs to be anchored and implemented at regional and local level and can be made possible throughout the city by broad participation from different actors in Gothenburg (Cirkulära Göteborg, 2021).



Orthophoto of Gothenburg scale 1:50000



Gothenburg map scale 1:20000

BACKGROUND



To the left Södra hamngatan 47 in 1989 SKB 0335/06. (2008) [photograph] and to the right by Lindberg, B. (1980). Crister Svantesson and Leif Mannerström at Resteaurant Johanna [photograph]. Werner Magazine issue 1, 2014.



Firefighting on site in 2006. N.d. (2005). [Photograph]. Göteborgs Posten.



BACKGROUND



View of the site and traffic by Waldén, S. (2021). Södra hamngatan 47 [Photograph].



View of site in its context taken from Brunnsparken by Waldén, S. (2021). Södra hamngatan 47 context [Photograph].

Kvarteret Härberget the block - 55 x 110 m



Johannatomten the plot - 430 sqm







Case studies, iterative design in various media, creation of material samples through glass fusion and literature studies are the methods driving the process leading up to the final Circular Hub design proposal.

Tools

During the process tools like a process diary, time keeping and regular reflective conversations about the process with fellow student is important aspects in making the most of the methods chosen. Also, tutorials with my supervisor Björn Gross have driven the project forward. Visit to Stievens Glashytta, phone interview with Anna-Karin Larsson at Svensk Glasåtervinning and participating the Re:bygg Hachathon 2021 was a way of quickly learning about glass as a material.

Case study

The Re3 Glass PhD research project from Delft University of Technology has been a great inspiration in the way it explores new possibilities for glass as a building material. It was conducted in 2014 by Telesilla Bristogianni and Faidra Oikonomopoulou and part some of the results where later implemented in Crystal Houses my MVDVR.

Glass fusion

The clear, green, brown glass and waste fractions used to create the samples were donated from Svensk Glasåtervinning (Swedish glass recycling). Christer Persson and the Department of Industrial and Materials Science has provided the knowledge, facilities, and tools for the glass fusion.

Iterative design

Throughout developing the building design proposal re-working and creating different versions has been a great tool in evaluating difference aspects of the proposal. Quick hand sketches of floor plans, physical structure model, volume studies, facade iterations etc., are some of the ways iterative design has been implemented within the frame of this project.



Oikonomopoulou, F. (2019). Glass marble capsule [Photograph].



MVRDV. (2016). Crystal Houses [Photograph].



Oikonomopoulou, F. (2019). [Photograph].



Oikonomopoulou, F. (2019). Re3 Glass [Illustration].



GLASS FUSION



Washing the glass and waste fractions before processing it further



Weighing to get approximately same sized samples



Drying, crushing, filtering, and combining different fractions



Two samples ready for fusion in the kiln



Clear glass cullet



Brown glass cullet



Green glass cullet



Waste fraction



1.1



2.1



3.1



4.1



1.2



2.2



3.2



4.2

GLASS FUSION



5.2



6.2



7.2

Sample	Fraction	Size	Max temp
1.1	Clear	Cullet	930°C
1.2	Brown	Cullet	930°C
2.1	Clear	Crushed	1050°C
2.2	Clear	Cullet	1050°C
3.1	Clear	Crushed	1050°C
3.2	Brown	Crushed	1050°C
4.1	Waste	Crushed	1150°C
4.2	Waste	Cullet	1150°C
5.1	Green	Filtered	1150°C
5.2	Green	Cullet	1150°C
6.1	Brown/Clear	Filtered/Crushed	930°C
6.2	Green/Waste	Filtered/Lightly crushed	930°C
7.1	Clear/Green	Filtered	1050°C
7.2	Brown/Clear	Filtered	1050°C



5.1



6.1



7.1













Building volume iterations | NW

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Street facade iterations | 1:400



DESIGN PROPOSAL

The final outcome of this thesis is a building design proposal where the glass fusion experiments are implemented which answers the thesis question of "How can glass cullet be reused with in the frame of architecture?".

Concept

Combining the experiments of recycling container glass and the program of a circular meeting place is a way reusing the matierial within the frame of architecture where it serves both as a new sustainable material but also as a way of branding, giving an identity or history to a new building.

Circular Hub of Gothenburg

The program for the building is a semi-public building where the public is invited to learn about the vision of circular economy that the City of Gothenburg has. But also a place where different industris can meet, connect and create innovative ways to transition from liniar to cicular economy.

Bulding

Horizontally each floor makes for a seperat function, the ground and 1st floor are for the public to enjoy exhibitions on the theme of cirularitey and to access knowledge about the topic. The 2nd and 3rd floors are the confrens floors and the top floors is where the office hotel is located. Verticalt the building is devided in two sections, on the east side is the comunication and on the west side are the floor specific programs. Cross laminated timber serves as the structural system of the building. Used in walls, floors and roof with the longest beam span on the 1st and 2nd floor of 12 m, this to create a flexible building.

Glass

In the facade the glass samples are used as cladding which gives the building its character. Glass is a durable cladding material, with the cladding system the panels can easly be interchanged and the used panels semlessly returned to the container glass recyling system.



Gothenburg map scale 1:20000



Building proposal in its urban context by Brunnsparken in central Gothenburg [3d-model].

DESIGN PROPOSAL





Street view of building proposal from the opposite side of Brunnsparken [3d-model].

DESIGN PROPOSAL







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Facades Södra hamngatan | 1:1000



Facades Fredsgatan | 1:1000



Recep	otion	
	Exhibition	33 sqm
	Entrance hall	20 sqm
	Reception	11 sqm
	Back office	14 sqm
	Toilet	2 sqm
Cafe		_
	Counter	13 sqm
	Seating area	44 sqm
	Kitchen	9 sqm
	Dish wash	6 sqm
	Toilet	16 sqm
Libra	ry	
	Book hall	105 sqm
	Reading room	24 sqm
	Toilets	16 sqm
Confe	erence	
	Main lecture hall	90 sqm
	Lobby	105 sqm
	Lecture halls	104 sqm
	Storage	21 sqm
	Toilets	32 sqm
Office hotel		
	Offices	160 sqm
	Meeting rooms	160 sqm
	Cloak room	16 sqm
	Pentry	5 sqm
	Copy & print	5 sqm
	Storage	7 sqm
	Toilets	32 sqm
Basen	nent	
	Storage	61 sqm
	Tech	42 sqm
	Recycling	15 sqm
	Staff	50 sqm



Exterior perspective from Brunnsparken [Illustration].



Facades Södra hamngatan | 1:200



Exterior perspective from across the street [Illustration].

BUILDING



Section B-B | 1:200







Facades Fredsgatan | 1:400



Section A-A | 1:400



 \bigcirc

BUILDING





Interior perspective of lecture hall showing brown glass panels used as flooring [Illustration].

BUILDING





Interior perspective of corridor with glass flooring and balcony towards courtyard showing green glass panels integrated in railing [Illustration].

BUILDING





Clear glass as facade and flooring [Photo].



Brown glass as flooring [Photo].



Green glass in balcony railing [Photo].





DETAIL

Street facade | 1:100



The cladding system carries glass facade, glass tiles make up the interior flooring and the load bearing structure is made out of cross laminated timber [Illustration].



Courtyard facade | 1:100



Sedum roof axonometry | 1:20



Roof facade | 1:20



Wall and floors axonometry | 1:20



3rd floor street facade | 1:20



Wall and ground floor axonometry | 1:20



Ground floor street facade | 1:20



CONCLUTIONS

The thesis has added to the discourse around circular materials and the need to combine already existing materials with recycling systems to create new and innovative solutions. This by combining the already greatly developed recycling system for packaging glass and creating a building material that uses less energy than other ways of recycling glass. Since the method of creating the glass sample is simple, the scalability potential for this material is great. What is more unknown is how durable it is, how it would handle changes in temperature, and how much pressure it endure? The building itself stands out with a facade that arouses curiosity, but has areas where it can be developed further such as the top floors exterior, the placement of the stairs in the exhibition area on the first floor, and depth in the facade.

As for the process of the project it has been energizing to work from the hands on and detailed scale of creating material samples, to the city planning scale of where a Circular Hub would benefit from being located. Writing the thesis individually and with online remote tutoring has been challenging, but has also forced a self-reliance which in the end has led to great development in being able to evaluate once own work.

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Images

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Appendix I











Image from top left to right:

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Image from top left to right:

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Appendix III



Image from top left to right:

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Appendix IV




Photos taken from and nearby the site in March during the thesis process. Waldén, S. (2021). [Photographs]. Central Gothenburg.

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