BUILDING WITH BUILDINGS

- An investigation of the demolition stock in Sweden and how these buildings could be turned into resources again

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Master's thesis 2022

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ABSTRACT

In Sweden we use resources four times beyond our planetary boundaries. One of the reasons are that objects, goods and even buildings are treated as if they were disposables that become waste and gets demolished when they are not useful or wanted anymore. The building industry stands for 45% of Sweden's resource extraction, 40% of our amount of greenhouse gas emissions and 40% of our waste production. This a cycle of events that could be decreased remarkably if already built buildings were treated as resources and material banks instead of being crushed through demolition when they are not wanted anymore.
Against this background following questions are asked:

Q1: What type of buildings are being demolished in Sweden?

Q2: What are the aspects that could enable an industrial reuse of building elements in new construction?

Q3: How could building elements from the demolition stock in Sweden be turned into resources suitable to use in new construction in a systematic way?

To answer these questions the thesis is mapping demolition permits from three municipalities in Sweden showing both types, the amount, and local characteristics of the demolition. Through literature studies, reference studies and interviews the thesis investigates how these found resources can be used. It discusses what the major differences are with a reuse project compared to conventional new construction and what the aspects are that could enable an industrial reuse in practice.

Findings are that the biggest difference is the reliability on the resources and the amount of labour that is needed to ensure them . The reliability concerns both the supply and the difficulties in ensuring technical aspects. The suggested answer to found problems, possibilities, and resources is a general design proposal with a loadbearing wooden construction that use reused building elements as filling. This is tested through a redesign of a multifamily building in Gothenburg examining the impact on expression, floorplan, and overall layout of the building.

KEYWORDS: Circularity, Deconstruction, Demomlition, Reuse

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INTRODUCTION

WHAT IS THE PROBLEM?

In today's building industry buildings are treated as if they were disposables. Even though demolition is identified as a climate-damaging activity and therefore should be avoided as far as possible, fully functional buildings are being demolished to make place for new ones. There is no gathered information or documentation about what is being demolished in Sweden and no one knows what and how much resources we have that easily could be used again. Instead of taking advantage of that the materials in these buildings already are put together in building components such as walls, slabs roofs etc, they are being crushed into small pieces and then recycled into energy, new materials or gets disposed of in landfills.

WHY IS THAT A PROBLEM?

In Sweden we use resources as if there were four earths. The building industry stands for 45% of Sweden's resource extraction, 40% of our amount of greenhouse gas (GHG) emissions (Moberg, Roupé & Haeggman, 2021) and approx. 40 % of our waste production. (Naturvårdsverket, 2020a) A lot of emissions are produced in the production of building materials and then a lot of waste is (~50% of CDW) created due to leftover material during new construction. If not wanted buildings were treated as resources instead of as waste a substantial part of these chain effects could be avoided, Sweden would reduce its resource extraction and the climate would experience major positive effects.

HOW COULD THIS BEE DONE?

The aim of this thesis is to highlight the available resources and possibilities we have in not wanted buildings, and what we could do instead of letting them end up in landfills as waste or being recycled into energy. The result is a design proposal showing one way of using the demolition stock as a resource in an efficient, industrial, and systematic way.

Fig. 1, A Fall of Ordinariness and Light - Graphite drawings by Jessie Brennan

RESEARCH QUESTIONS

Q1: What type of buildings are being demolished in Sweden?

Q2: What are the aspects that could enable an industrial reuse of building elements in new construction?

Q3: How could building elements from the demolition stock in Sweden be turned into resources suitable to use in new construction in a systematic way?

METHODOLOGY

The thesis has three main parts, each with one research question tied to it. Different methods are implemented to reach an answer to each of the questions.

The challenges that the thesis addresses are lifted in the background. They have been investigated mainly through literature studies of scientific articles and reports from international and national organizations and foundations.

PART ONE – RESEARCH ON DESIGN
The first part is practicing research on design. It answers Q1 by mapping what is being demolished in Sweden during one year. The mapping is done by analyzing and categorizing demolition permits from three municipalities, Göteborg, Linköping and Umeå, carried out through 2020. It is a total of approximately 500 demolition permits covering everything from smaller garages to large schools and industries.

The demolition permits are firstly sorted by type and scale of building, giving rough statistics on what is being demolished, and secondly a selection of permits from larger scale buildings are studied more thoroughly. By comparing number of inhabitants and housing units in the municipalities and in the whole country, estimated numbers of demolition in Sweden are calculated.

What is also found is that there are differences in local character of the demolition stock, yet that it in each municipality is remarkably homogenic. This is investigated further through collage techniques.

PART TWO – RESEARCH FOR DESIGN
The second part answers Q2 by practicing research for design. Literature studies, reference studies, and interviews are done to find an answer that is anchored in both theory and practice. The literature studies focus on the theory of building with reused building elements, while reference studies and interviews are done to get an understanding of how it works in practice. The triangulation of these methods is a way to ensure accuracy of the information that is found, as well as giving a broad and covering image of the possibilities and problems in the field.

PART THREE – RESEARCH BY DESIGN
The third part is a design proposal that answers Q3. This part is focusing on research by design, implementing and combining the findings from part one and two, showing how the demolition stock in Sweden could be used instead of treated as waste. This is done through a reuse design concept that later is applied to redesign a multifamily building in Gamlestan, Gothenburg.

Part three ends with a discussion on how the proposed design concept with reused building elements could be a part of the answer to the challenges stated in the background of the thesis.

DELIMITATIONS

There are many parameters that affect the possibility to use building elements from deconstruction as resources in new construction and it will not be possible to address them all in this thesis. The subject of material testing and classification will not be lifted. The economical aspect, whether it is profitable or not, will be lifted in the discussion.

In the thesis there is also a delimitation on which municipalities that are being investigated. Göteborg, Linköping and Umeå are chosen due to their differences in sizes and in location. The combination of the three gives a good picture of the demolition in Sweden and this makes it possible to draw some conclusions.

When redesigning the multifamily building in Gamlestan focus is on one façade and two typical apartments, even though the design system can be adapted to the whole building.

NOTIONS

BUILDING ELEMENT
Part of a building that is a constructive element for the house e.g an exterior or interior wall, a slab, a part of a roof etc. It does not count for furnishings or installations such as windows or doors.

DECONSTRUCTION
After life treatment of buildings that carefully picks down the building piece by piece without them getting damaged by the process. This treatment is a necessity to be able to practice reuse of building elements.

DEMOLITION
After life treatment of buildings that includes smashing and crushing of the structure, turning the building into small pieces. These pieces can then be either incinerated, disposed of, or recycled by material.

DEMOLITION PERMIT
When you want to demolish a building, you must apply for a demolition permit. It is similar to a building permit in that way that you have to hand in floorplans, sections and elevations of the demolition object, but instead of an approval to build you get an approval to demolish.

DEMOLITION STOCK
Same as building stock, but that instead describes the total number and character of buildings that gets demolished in a country or area

INDUSTRIAL REUSE
A reuse that is practiced in a way that it can be done repeatedly, and systematically, without the need for project specific solutions.

CONVENTIONAL NEW CONSTRUCTION
New construction projects that follow the industry standard, which today often is to build with prefabricated concrete elements.

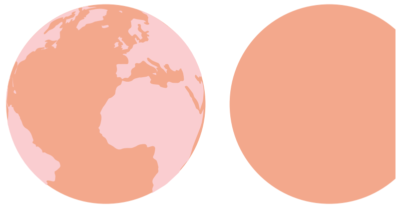
BACKGROUND

DEMOLITION - BUILDINGS BECOMING WASTE

To begin this thesis, we will start by examining the notion of waste and demolition. Both in a bigger sense, 'what is waste?' and in a smaller looking at where all the demolished buildings go. What would happen if we instead made use of them and practiced a circular thinking treating them as resources in new construction?

OVERSHOOT DAY: OUR EXCESSIVE DEMAND OF RESOURCES

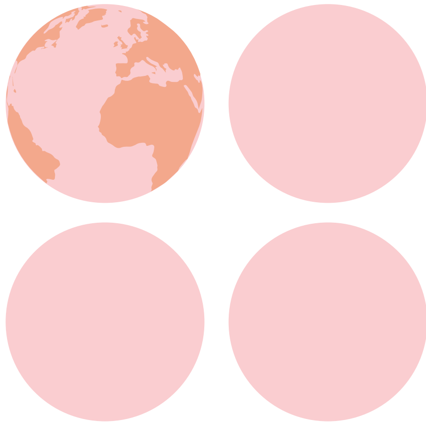
We use resources from our earth beyond its limits. With that means that the resource extraction is higher than what the earth is managing to recover. Eventually this will lead to a runout of resources. It also means that we produce greenhouse gas emissions at such a rate that the earth does not manage to neutralize it, which has led us to global warming and climate change as result.



Avarege resource demand is equal to 1.8 earths

Overshoot Day marks the date when the demand for resources for a year exceeds what the earth can regenerate. It means that our assigned resources for that year is finished and the remaining time until new year's, we are using up resources from future generations. The global overshoot day last year, 2021, landed on July 29. That equals a need of 1.8 earths to cover for our demands. (Earth Overshoot Day, n.d. a)

In Sweden we use more resources and produce more greenhouse gas emissions than the global average. Our overshoot day this year, 2022, was on 3rd of April. If everyone lived like we do, we would need four planets to make it through. (Earth Overshoot Day, n.d. b)

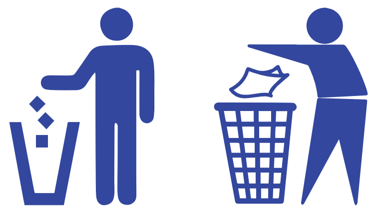


Sweden's resource demand is equal to 4 earths

RESOURCES AND WASTE

Even though our resource extraction is beyond our planetary boundaries we have this thing called waste. We live in a culture were objects, goods and even buildings lose their value when they are not wanted or needed any more. They become waste that we throw away, creating a need to extract new resources since we often replace the not wanted or needed product with a new. This practice comes from the so called linear (take-make-waste) economy and way of living that will be described on page 18.

Fig. 2, Construction and Demolition Waste



Common symbols showing how to deal with waste

"Waste (or wastes) are unwanted or unusable materials. Waste is any substance which is discarded after primary use, or is worthless, defective and of no use." -Wikipedia ("Waste", 2022)

In English the noun 'waste' also has several meanings besides the above mentioned most common meaning. It can describe an unnecessary or wrong use of money, substances, time, energy, abilities, etc. Something can also go to waste e.g., an opportunity, meaning that you miss out on something. (Cambridge Dictionary, n.d.)

LINEAR vs. CIRCULAR ECONOMY

The linear economy has been, until recently, the leading business model all over the globe. It is a model based on the idea to produce and sell as many products as possible and by that create value through the economic system. It is called linear since the flow of the material is linear. First it gets extracted from earth, secondly transformed into a product that are used until it lastly is discarded and treated as waste. The material makes a journey from being a resource full of value to becoming waste without any value. To produce new products, new resources need to be extracted from earth and turned into products that later gets discarded and so on.

Since this way of treating materials and products has given us climate change, global warming, and an impending run out of resources, initiatives are on changing the linear model into a circle – a so called circular economy. (Ellen MacArthur Foundation, n.d.)

The main concept is that no longer wanted objects and materials can replace the "take" part and thereby minimize the demand of extracting virgin raw materials from our earth by instead use what we already have taken out from it. In so doing the "waste" part also gets replaced which minimizes the

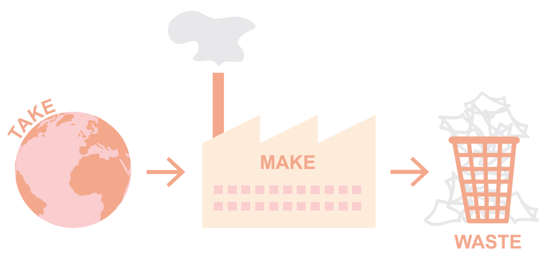


Illustration linear economy

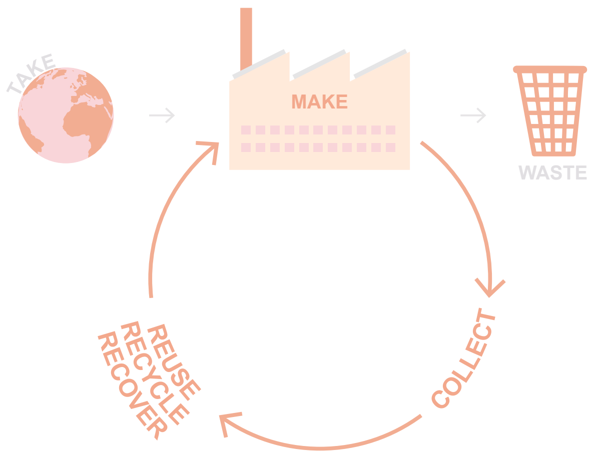


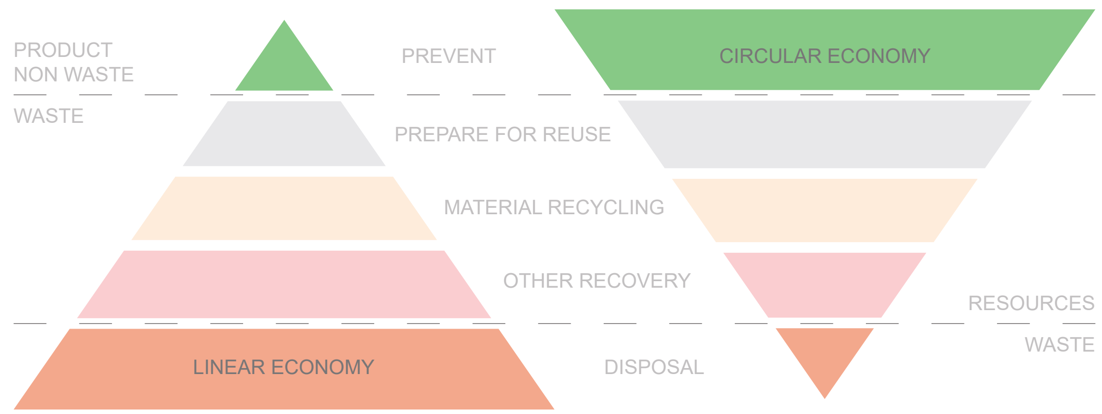
Illustration circular economy

amount of waste that need to get disposed of. (UNCTAD, n.d.)

Instead of wasting resources at the end of a products lifecycle, they will be collected. And instead of taking new resources from earth when producing new products, the collected resources will through reuse, repurposing, recycling or recover be turned into new products that we can utilize. This is the circular economy. What ones was considered a resource will be kept a resource even after its first lifecycle goes to an end.

The circular economy is now part of both national and international goals. Our government in Sweden as well as the European Union have guidelines on how we as nations and individuals should change our view on resources from a linear to a circular perspective.

The UN also addresses circular economy as a way to fulfil several of the global goals that are part of agenda 2030. Two of them are closely connected to the building industry, namely goal 11; Sustainable Cities and Communities, and goal 12; Responsible Consumption and Production.



WASTE HIERARCHY

The waste hierarchy provides guidance on how waste should be handled and treated and is since 2016 integrated in the Swedish Environmental Code, SFS 2016:782 (Miljödepartementet, 2016). The waste hierarchy tells us that waste should at firsthand be prepared for reuse, if that is not possible undergo material recycling, after that treated through other recovery and lastly through disposal.

For each step downwards in the waste hierarchy the product looses value and utility. More energy is also needed to again bring the waste into a product after the waste treatment. This is costful both for our planet and environment and it is therefor important to try to treat waste at the highest possible level in the waste hierarchy.

When talking abourt circular economy all three steps in the middle count as circular actions, while when something goes of to disposal or incinerators no value or utility of the products is taking advantage of. It all goes to waste and we need to extract new resources from our planet.

There is a reason that the waste hierarchy is portrayed as a pyramid. The idea is to reflect how the waste treament is being conducted in reality. Then it is also easy to flip it upside down to show how it should be done. The most important thing is to prevent a product, material or building from becoming waste. When waste can not be avoided it sholud be turned into a resource at the highest possible level in the waste hierarchy. If we manage that, the pyramid is turned upside down and we practice a circular economy instead of a linear one.

PREPARE FOR REUSE

When waste gets prepared for reuse it means that the whole product will be possible to use in a new way or setting, without the need of being turned into its smaller constituents.

MATERIAL RECYCLING

Waste undergo material recycling when it gets turned back into its basic materials, such as glass, paper or steel. These materials can then be be used instead of raw material when making new products.

OTHER RECOVERY

With other recovery means that the resource gets used ones more through e.g. incineration were energy gets recovered. After the waste treatment the reaource can not be used again and the value is gone.

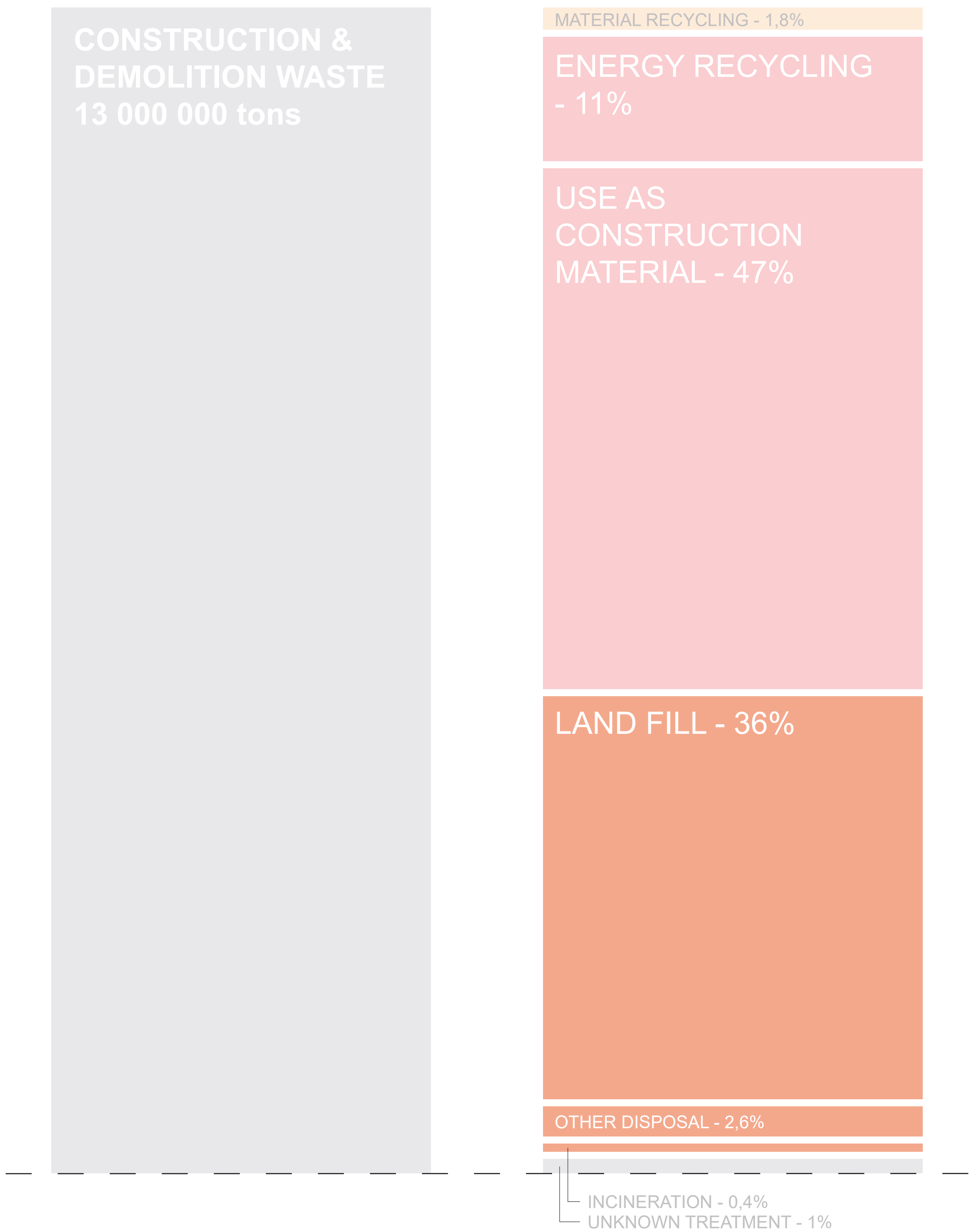


Fig. 3, Waste treatment of CDW in Sweden during 2018

WHERE DO ALL THE DEMOLISHED BUILDINGS GO?

In 2018 13 milion tons of construction and demolition waste (CDW) was produced in Sweden. Though Sweden is a country of statistics, bureaucracy, and documentation, no one can tell how much that come from demolition and how much that are produced during new construction. (L. Viklund at Naturvårdsverket, personal communication, 3 November, 2021)

Neither is it possible to get information about how much CDW each municipality have produced. (L. Viklund at Naturvårdsverket, personal communication, 16 February, 2022) But even so, the numbers on CDW can still tell us about how we treat waste in the building industry and thus also what happens with the demolition stock.

As displayed in the table on the left side there are three bigger strategies that dominate the waste treatment; energy recycling, use as construction material, and landfilling (see next page). If we order them according to the watse hierarchy we see that the majority of the CDW are being treated through other recovery, which is the lowest step that counts as a circular action. Only 1,8 % qualifies for the middle step and more than one third are treated without any form of recovery.

According to the numbers there is a gap in how we treat waste in the building industry. Even though the environmental code tells us to aim at a circular buisness model the amount of waste that gets prepared for reuse is non-existent.

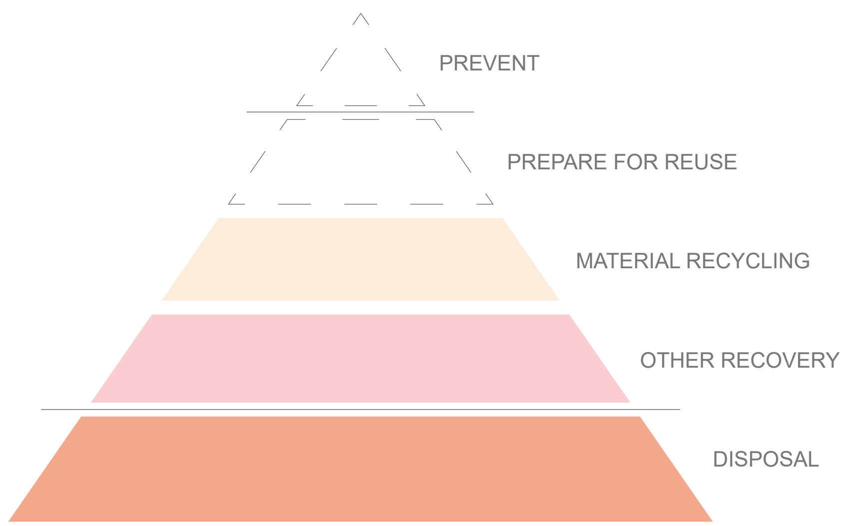
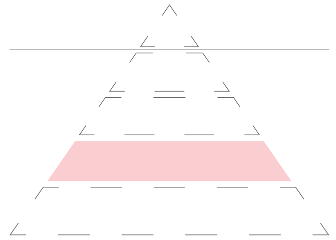


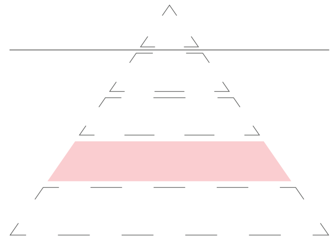
Fig. 4, Demolition

ENERGY RECYCLING - 11%



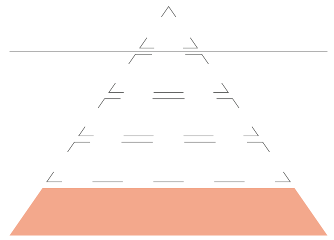
Energy recycling is, as described on previous pages, a common treatment in the theme of other recovery. It refers to incineration where the waste is used as fuel and the energy is utilized. When it comes to CDW it is mostely wooden waste that gets treated this way. (Naturvårdsverket, 2020 b)

USE AS CONSTRUCTION MATERIAL - 47%



To use waste as a construction material is a form of landfill or disposal that takes place underneath roads or constructions as a constructive material replacing e.g. macadam. Hence, it is a waste treatment practicing other recovery. Not much of the products' or materials' value is taken advantage of and they can not be used again. When it comes to CDW it is mostely mineral waste such as concrete or bricks that gets "used as construction material". (Naturvårdsverket, 2020 b)

LANDFILL - 36%



Landfilling qualifies for the lowest step in the waste hierarchy, that is disposal. In disposal nothing of the resources' value is taken advantage of and instead the waste is disposed of or stored permanently. When it comes to CDW it is mostely spoil that gets disposed of in landfills but also hazardous mineral waste. (Naturvårdsverket, 2020 b)

Fig. 5, Demolition

WHAT CIRCULARITY COULD DO IN THE BUILDING INDUSTRY

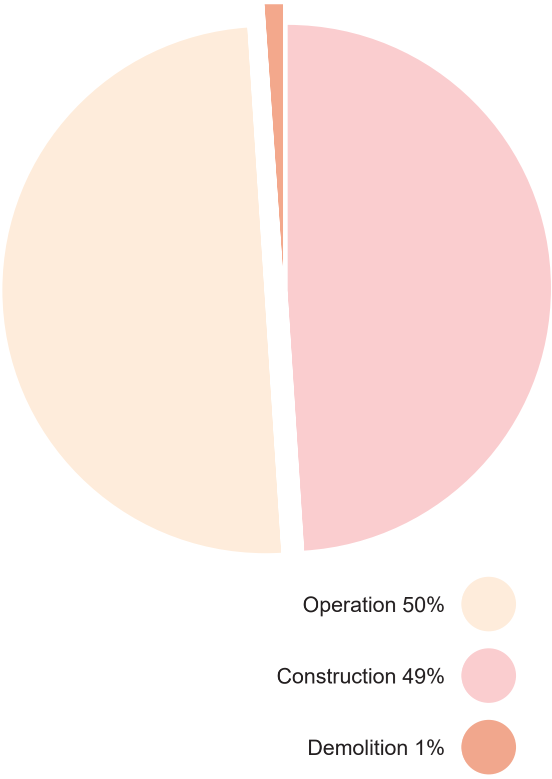
The building industry stands for 45% of Sweden's resource extraction, 40% of our amount of greenhouse gas (GHG) emissions (Moberg, Roupé & Haeggman, 2021) and 40 % of our waste production. (Naturvårdsverket, 2020a) This a cycle of events that could be decreased remarkably if already built buildings were treated as resources and material banks instead of being crushed through demolition when they are not wanted anymore.

As seen in the diagram to the right, the demolition itself produces only about 1% of a building's GHG emissions, while the new construction and the operation of the building stands for about half of the emissions each. (Erlandsson & Larsson, 2016)

25% of the buildings demolished in Sweden since 1980, were less than 30 years old.
-Andersson & Nilsson, 2020

Interesting for this thesis are the construction and demolition phase. Construction includes everything from raw material supply to manufacturing of products, transport, and the construction of the building, while the demolition phase includes demolition, transport, waste processing and disposal. (Erlandsson & Larsson, 2016)

In "Exploring environmental benefits of reuse and recycle practices: A circular economy case study of a modular building" by Minunno et.al. (2020) a case study is displayed investigating the difference in LCA of two prototype villas; one purpose-built and modular building designed for disassembly and reuse of building parts (circular principals), and one with a contemporary construction approach whose materials are recycled or disposed to landfill at demolition stage (linear principles).



What they saw was that the house designed for reuse and disassembly had 88% less of GHG emissions compared to the villa that was designed for material recycling. Worth mentioning is though that the focus on their research was only on the materials, not taking transport into account.

Another similar comparison was made by Roth & Eklund (2000) were they instead compared LCA of a building that used reused concrete element as loadbearing structure (circular principles), and one prototype building with a conventional cast-in-situ concrete structure (linear principles). They also took transportation into their calculations and got results showing savings of 50% on GHG emissions for the building with a reused concrete structure.

One other argument for keeping materials and products in use for longer time is found in Johansson's (2021) work "Cheaper but Better". His findings show that when the lifetime for a villa prolongs from 25 to 100 years, the CO2 emissions that the house produces per year lowers by 36%, operational emissions included. This means that when the materials and products are used over a longer time, their GHG emissions also lowers.

These three studies show that if we start using materials and products more than one time, ie a longer time before they get disposed of, it will have a great influence on the total LCA of individual buildings, but also the whole industry aswell as its resource extraction and waste production.

REUSE IN HISTORY-SPOLIA

Reuse is not a new thing. In late antiquity and later throughout the Middle Ages the phenomenon ‘spolia’ was widely spread. The word spolia comes from Latin ‘spolis’ and means repurposed building stone for new construction. (Bertino et.al., 2021)

There are mainly two types of spolia. The first derives from a will to show triumph and concur. It often exists of statues or parts of monuments from defeated cities and empires that are well integrated in their new construction. This type of spolia can be hard to recognize and one example is the arch of Constantine in Rome that is built up by stones coming from several different times and places. (Kinney, 2011)

The other is more based on the ‘take what you have’-principles and make use of building parts from ruins or parts from buildings that are worn out and have lost their purpose. This type is of greater interest for this thesis since its principles are similar to the ones of circular economy. The difference is though that for ancient and medieval practices reuse was unavoidable and banal due to the scarcity of extracted resources. Today we instead have created an abundance of extracted resources and with them a climate change and are therefore obliged to make use of what we already have to not develop it further. (Kinney, 2011)

The ‘take what you have’-spolia is more visible and reminds of a patchwork. The old stones are used as merely a construction material instead of as decoration or to communicate a message. It appears in all kinds of constructions such as walls, churches, and ordinary houses. The clocktower of Santa Maria Maggiore della Pietrasanta in Naples is a typical example. Its base is built up by a jumble of stones with different origin and initial purpose. Among other things, one can find reused marble stones from a roman temple that had been standing in the same place, lava rocks that during the Roman ages were used as pavement, and a marble slab that hade been a game board for a popular Roman game similar to chess. (Bertino et.al., 2021)

Kalakoski & Huuhka (2018) stresses that a crucial characteristic for spolia is that it is a distinction between the old parts and the new structure that they are being put into. Spolia is true to its history and its present. To replace damaged parts in an old house with old parts is not spolia. Spolia is when the old blocks are used in a new construction, with a new purpose.

There are today plenty of books and research articles about spolia. Many of the spolia-buildings are pointed out on TripAdvisor as worthy a visit. These buildings and the practice of spolia is found intriguing by both architects, historians, archaeologists, and common tourists. It makes people engage in the architecture wondering about the stories behind it all, while the unexpected combination of building blocks makes us curious.

Reused marble blocks from an old Roman temple

Fig. 6, Spolia at the clocktower of Santa Maria Maggiore della Pietrasanta, Naples.

old gameboard

Lava rocks previously used as pavement

Fig. 7, Details of the base.

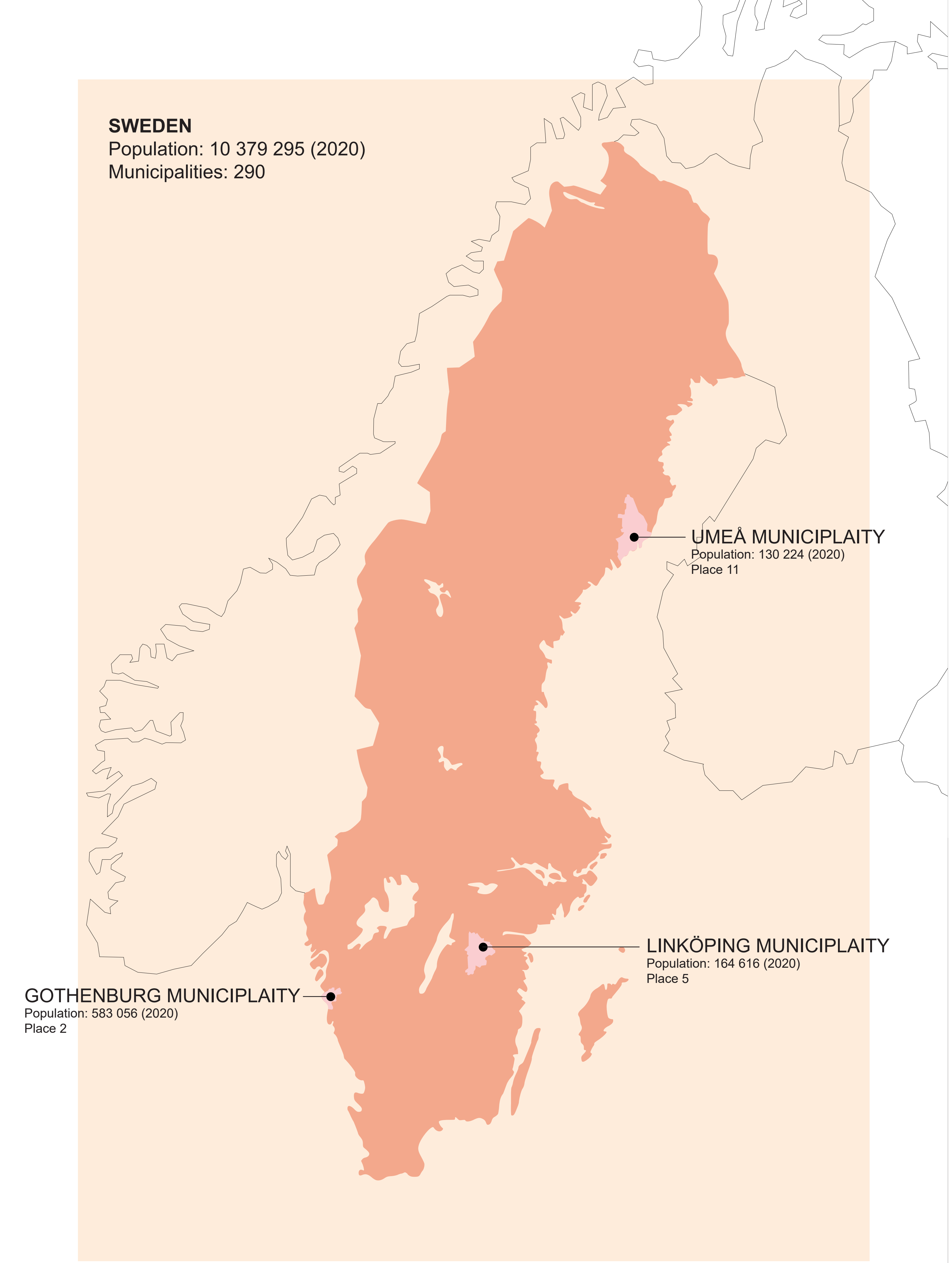
WHAT TYPE OF BUILDINGS ARE BEING DEMOLISHED IN SWEDEN?

DEMOLITION IN SWEDEN

To be able to practice a systematic reuse is it crucial to know what is being demolished in the first place. In Sweden there is unfortunately no gathered information about the demolition stock and if you want to practice reuse when doing new construction, it can be a lot of work to just investigate what resources you can find and make use of.

The documentation about demolition is similar to the documentation of CDW and is as inadequate. You have to apply for a demolition permit and send a demolition plan together with an environmental investigation to your municipality. Hence every demolished building is registered and documented, but then there are no guidelines on how this information will be archived. Sometimes the demolition permit is combined with the building permit of the new building replacing the demolished one. Sometimes the word "demolition" is part of the description line when the permit is put into an archive and sometimes not.

Since no one can say neither how much nor what kind of buildings that are being demolished it seemed like the obvious start in this investigation. What can you count on finding when you look for resources in the demolitions stock?



DEMOLITION IN SWEDEN DURING ONE YEAR

To investigate the demolition in Sweden three municipalities of different size, location and character have been chosen: Gothenburg, Linköping and Umeå. From them I have ordered out lists of demolition permits that got approved during 2020 together with building permits that mention 'demolition' in their subject line. The lists contained demolition objects as followed:

- Gothenburg: 204 st
- Linköping: 136 st
- Umeå: 164 st

The material received from the municipality in Linköping was not as extensive as the material from the other two municipalities. Most of the demolition permits from here delt with non-buildings, such as chimneys, balconies, and cantilevered roofs. But even if the material from Gothenburg and Umeå was more comprehensive, they also stressed that the delivered lists do not give a complete image of the demolition made in their municipalities either. The actual demolition is bigger.

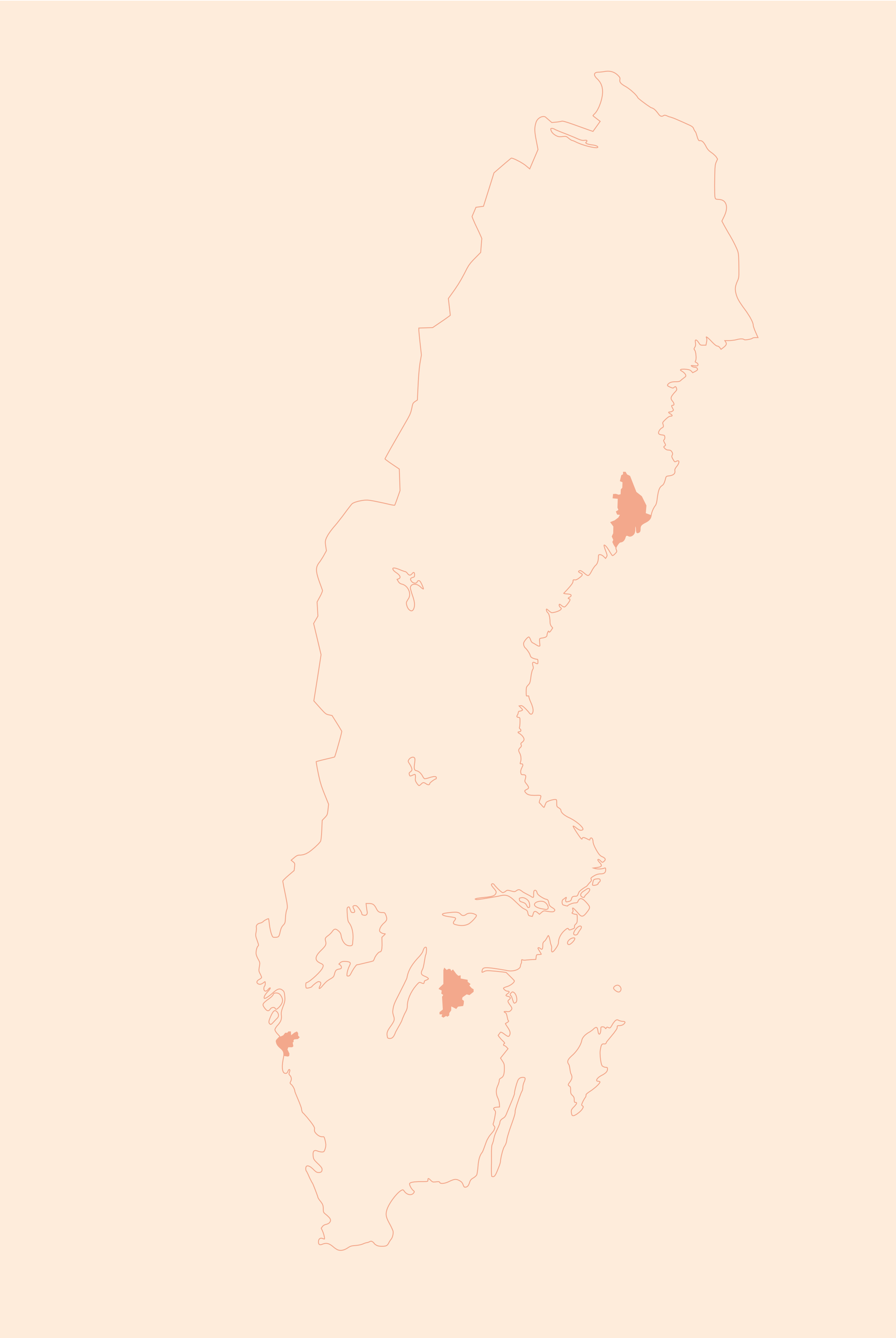
The information in the material from the municipalities was unfortunately also inadequate and needed to be complemented. In many cases it said "demolition of building" not specifying what type of building that got approved for demolition. There were also documents that were not specified by either typology or specific address, or that said "buildings" in plural, which made the complementing work like a hide and seek through the different map services on internet.

Eventually a compilation started to get into shape. On the next spread, p. 32-33, the demolition in the chosen municipalities is shown. The numbers are actual numbers even though, as mentioned, the total demolition is bigger. Most of the numbers in the statistics are complete buildings that get demolished but a few of them are only parts of buildings but that yet need a demolition permit.

To get a picture of the total demolition in Sweden the number of inhabitants in the chosen municipality was compared to the number of inhabitants in Sweden, resulting in a factor of 11,82. Also the number of housing units in the municipalities and throughout the country was compared and gave a factor of 11,37. These two factors are so close to each other that even if they do not give a correct picture of the reality, they can still give a hint of what the general demolition in Sweden probably is like.

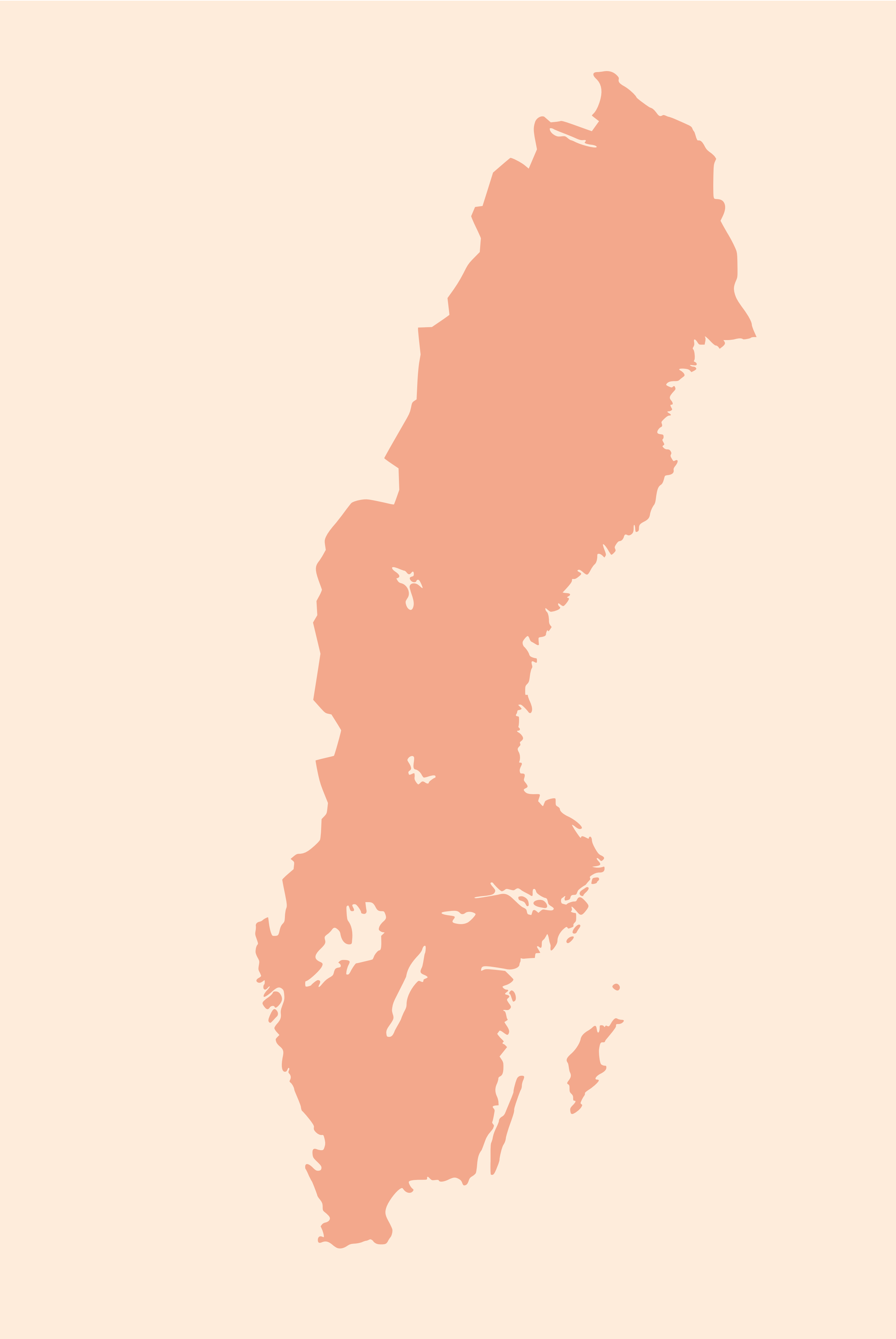
Therefore, the factor 11,0 was chosen and multiplied with the numbers of demolition from the three municipalities (p. 34-35). This is an estimation of the demolition in Sweden during 2020, but as with the demolition in Gothenburg, Linköping and Umeå, the actual demolition is most likely bigger.

To investigate the demolition stock in a deeper sense than typology a selection of demolition permits from larger scale buildings designed for human activity were studied more thoroughly. Examples of these buildings are schools, offices, healthcare facilities, retail buildings, multifamily buildings etc. They were chosen since they probably are the most suitable and easy to reuse in new construction. Construction type and construction year, as well as façade material and original purpose were investigated. The findings are presented in the next section "local characteristics".



DEMOLISHED BUILDINGS IN CHOSEN MUNICIPALITIES

76	Smaller Garages
73	Single Family Houses
67	Holiday Homes
36	Ancillary Buildings
33	Storehouses
28	Industries
11	Other Smaller Buildings
11	Technical Shelters
9	Multi Family Houses
8	Offices
8	Pre Schools
7	Schools
6	Recycling Houses
5	Barns
4	Bigger Parking Garages
4	Other Public Buildings
3	Clubhouses
3	Retail Buildings
3	Retirement Homes
3	Gasstations
2	Kiosks
1	Hospital Buildings
103	“Non Buildings”
504	Demolition Objects



ESTIMATION OF DEMOLISHED BUILDINGS IN SWEDEN

836	Smaller Garages
803	Single Family Houses
737	Holiday Homes
396	Ancillary Buildings
363	Storehouses
308	Industries
121	Other Smaller Buildings
121	Technical Shelters
99	Multi Family Houses
88	Offices
88	Pre Schools
77	Schools
66	Recycling Houses
55	Barns
44	Bigger Parking Garages
44	Other Public Buildings
33	Clubhouses
33	Retail Buildings
33	Retirement Homes
33	Gasstations
22	Kiosks
11	Hospital Buildings
1133	“Non Buildings”
5544	Demolition Objects

LOCAL CHARACTERISTICS AND OUR UNCONSCIOUS HERITAGE

A discovery from the investigation of demolition permits is that the demolition stock of each city shows specific characteristics of the facades and in the expressions of the buildings.

To investigate these characteristics Anastasia Savinova's collages series 'Genius Loci' have been the inspiration. Savinova wants in her collages to explore the visual character and spirit of different places. She does so by composing photographs of forms, colours, and textures into one picture that in a clear way communicates the specific atmosphere and environment of a place.

In Savinova's collages it is shown that every place has its own character and its own spirit, which also is the case for Gothenburg, Linköping and Umeå. This is something worth noticing and make use of. Because, what the collages on upcoming pages also show beside the demolition stock of each municipality is the unconscious heritage of an area. Most of these buildings disappear without no one noticing it. They are not culturally-historically important, cared for or beautiful, they are just not wanted buildings. But even they carry a heritage that with them slips away, the unconscious heritage.

The collages are made of print screens from google street view of buildings approved to be demolished in 2020. When I was walking around in the streets it became clear how fast the demolition process can be. Many of the houses where already gone in the photos taken in 2020 and 2021. Fortunately, you can change the date to an earlier photo collection and there the houses showed up.

Fig. 8, Genius Loci / Kiruna by Anastasia Savinova

GOTHENBURG

The material on the facades of the demolition stock in Gothenburg is firstly corrugated metal sheets and secondly bricks. The production time varies but most of the houses are from around the 70's and the 80's. Ribbon windows are common. The colours on the corrugated metal sheets facades are almost exclusively white, silver, and blue.

- Does that relate to the nature around Gothenburg? The sea, the cliffs, and the light?

Compared to the other municipalities there is also a local difference in how empty buildings are being treated. Threw the photos in google street view the lifecycle of the buildings' afterlife gets clear. First, they are used, then empty, then it becomes "everyone's" and painted in graffiti before it gets demolished. Looking at Umeå and Linköping this course of events is not visible.

LINKÖPING

In Linköping are the materials on the facades of the demolition stock mainly bricks and secondly corrugated metal sheets and plaster. Details are made in wood. The production time varies but most of the houses are from around the 60's. The colour scheme is greyish and beige with red as the accent colour. This is the case for everything from industries, shops, offices and schools to single family houses and hospitals.

- Does that relate to the nature around Linköping? The fields and the barns?

UMEÅ

The materials on the facades of the demolition stock in Umeå are mainly wood and corrugated metal sheets. Houses with permission for demolition here are averagely older than in the other municipalities in the study. Most of them are built around the 30's to 40's and they are a bit smaller than the buildings in Linköping or Gothenburg. Gable roofs are common, and windows have standing proportions with a division in the middle. The main colours are different nuances of yellow and orange.

- Does that relate to the nature around Umeå? The birch leaves in the autumn that contrasts beautifully to the snow?

A local difference is also that the houses do not look as worn out before demolition as they do in Gothenburg or Linköping.

WHAT ARE THE ASPECTS THAT COULD ENABLE AN INDUSTRIAL REUSE OF BUILDING ELEMENTS IN NEW CONSTRUCTION?

PART TWO - REUSE IN PRACTICE

DEMOLITION AS A RESOURCE

The process of a reuse project differs in some ways from the process of a conventional new construction. In this section of the thesis a couple of built references as well as written references on reuse are summarized to get a deeper understanding of the reuse process. What are the aspects that lead to the greatest differences compared to conventional new construction, and what are the challenges to overcome in order to be able to practice an industrial reuse?

Fig. 9. Mass demolition of 15 unfinished skyscrapers in Kunming, China 2021.

WHY DO BUILDINGS GET DEMOLISHED TODAY?

There are different reasons why buildings get demolished, but common motives are a desire for higher exploitation, that the existing building is "too small for the value of the plot" or simply that the building is worn out. (P. Säfvendahl, personal communication, 19 November 2021)

The last reason is not seldom a result of one of the first two motives for demolition. When a property owner seeks a higher exploitation of its property, the maintenance and replacement of broken parts can fall behind resulting in a need for demolition when the building has become that worn out that a refurbishment would cost a lot more than the demolition. This could happen to even culturally and historically protected and valuable buildings. In my investigation of demolition permits this has been a recurrent phenomenon that I have encountered.

What I have also seen is that the reason for possible higher exploitation or financial gain is enough without the building needing to be worn out. When reading demolition permits these two motives are often stated as predominant reasons in the demolition approval from the municipality even though investigations stress that the building has a cultural historical value that will get lost.

The condensed answer to why buildings get demolished is thus economy and financial gain.

ASPECTS OF REUSE

THE TIMING ASPECT

Anton Franker, a reuse consultant situated in Gothenburg, stresses that timing is one of the biggest issues to solve if you want to succeed with a reuse project. (Gunne, 2021) Timing, however, is difficult to meet since a building process normally takes between 2-15 years, while a demolition process can be as short as 10 weeks from the decision to finalisation. (Björklund & Lindborg, 2021) Problems occur when the material needed for a construction project seldom are decided to be demolished when the planning process of the new construction needs to know what resources they can count on using. It is especially true when so called off-site reuse is practiced.

REUSE OFF SITE

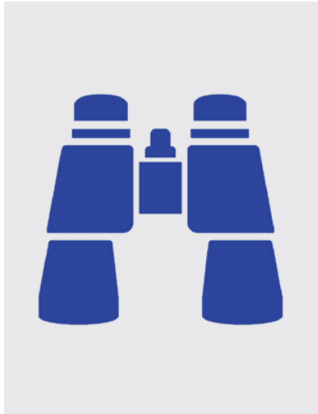
When using an off-site supply the reused parts are found outside the site, saved from other buildings that is going to be demolished or remodelled. Due to the difficulty with timing, the design must either be done with uncertainty and flexible measures that can adapt to what is available in time for construction, or the scouting for reused parts can be done on beforehand. That though makes it necessary to store the saved material, which can be costful. (Björklund & Lindborg, 2021) This kind of reuse is what this thesis is focusing on.

REUSE ON SITE

Reuse on-site is easier and more often practiced, though with smaller possibilities than reuse-off site. It is when the project is a remodelling project where reused parts come from the same building as they will end up in again but in a new purpose or place. You own the material from the beginning, there is no need to store it, and the knowledge about the material is good. As soon as an inventory is done the found material can be implemented in the planning process with its specific technical aspects. (Björklund & Lindborg, 2021)

SCOUTING AND INVENTORY

Compared to when doing conventional new construction, you need to scout for suitable material to use in the project. As described in part one, there is no gathered information about the demolition in Sweden which, together with the timing aspect, can make this work both hard and time consuming. When then the wanted material is found it needs to go through inventory to ensure technical aspects. Franker (Gunne, 2021) points out the importance to start with the inventory early in the planning process to know what material you have and how it is best implemented. Unfortunately, this is often done too late resulting in a smaller proportion of saved material than could have been possible.



TECHNICAL ASPECTS

Ensuring the technical aspects is also hard in itself after the wanted material is found. There are so far no standards regarding how reused materials should be classified nor tested, and to be able to trust it, an even more extensive inventory of the found material is needed. Sometimes that is not enough. In a reuse project in Linköping where prefabricated concrete structures were moved from old houses in Norrköping, the constructors could not ensure the technical aspects of the elements, which resulted in a large supporting steel construction and less environmental gain for the project. (G. Sundbaum, personal communication, 7 February 2022)

WHAT IS SUITABLE TO REUSE?

It is easy to say that you want to reuse everything form a building, but it is important to think of how the deconstruction will be carried out. There are components that can be saved and reused and those that are not suitable for that. Partition walls is a common example. They are often fixed between slabs with binder, which makes it hard to pick them down without them getting damaged. Still, they can be deconstructed but with the purpose of downcycling or recycling instead of reuse. (Bertino et.al., 2021)

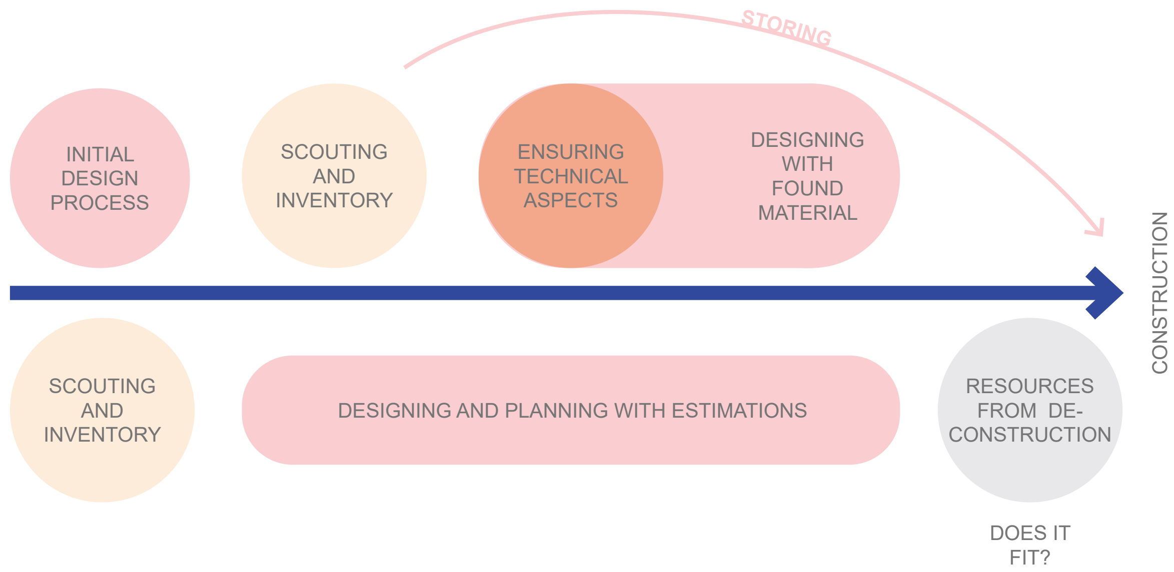


Illustration of two possible reuse processes

ECONOMY AND REUSE

Reuse projects tend to cost more than conventional new construction. It is cheaper to demolish a building, dispose of its material, and build a new one of virgin material than it is to make use of the old one as a material bank for the new construction.

This is mostly due to that the cost of material is relatively low compared to the cost of labour. When realizing a reuse project, the cost for the material could be almost zero, while the need for labour is extensive. (Andersson & Nilsson, 2020)

All aspects from the deconstruction, the inventory, and the work of ensuring the reused components technical aspects require labour. Since the reused components are not standardized there is a higher workload in as good as every reuse project.

One other reason for the higher cost is the probable need for storing. Storing is expensive and should be avoided as far as possible. (P. Carlfjord, personal communication, 16 February 2022)

When you work with reuse you cannot rely on that the wanted material will be available when needed. This leaves you to either buy reused products in the beginning of the process so you can design the building with them and store them until it is time for construction, or to do a thorough investigation on beforehand so you know what will be available at the time for construction, which instead requires an even more extensive scouting due to the difficulties with timing.

BUILT REFERENCES

THE RESOURCE ROWS

The resource rows is a project in Copenhagen designed by Lendager Group. It was built in 2015-2019 and is a well published project using old brickwork from an abandoned brewery in Copenhagen as facade.

For this thesis it has been an interesting project to study since it uses the element principle of the reused parts. Instead of reusing the bricks one by one, they used them in hole modules as they were put together in the old houses.

These modules were then combined in larger building elements casted in concrete and mounted with steel brackets, which is a rational way of enabling the combination of reuse and conventional building techniques. Other reused materials are windows and larch wood, which is used for the roof top terrace.

The rest of the house is a conventional concrete building with concrete in both exterior walls, interior walls, slabs etc. The reused brick panels are more of a cladding on a building constructed with otherwise virgin raw material.

But even this small amount of reuse gave results in the LCA made on the project. Their calculation shows that 10% of the material for the project were reused material (bricks, windows and wood) which resulted in a 12% saving of CO_2 emissions. (Lendager Group, 2020)

The cost for the project was about 10% higher than it would have been if it was built completely as a conventional new construction. In an interview with Anders Lendager, CEO of Lendager group, he explains that it is often the case with their pilot reuse project, but they have seen that when they implement their solutions two or three times and increase the production volume accordingly, the savings have become up to 70%. (Schoof, 2021)

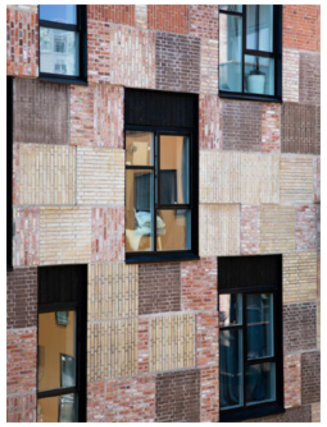


Fig. 10, The reused brickwork facade of the Resource rows

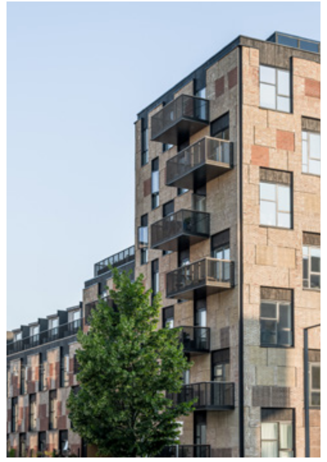


Fig. 11, The Resource rows

Fig. 12, Sawing out brick modules from the old Carlsberg brewey in Copenhagen

Fig. 13, The construction of Svartlamon townhouses

SVARTLAMON

However, there are reuse projects that manage to end at a lower cost than conventional new construction already from the beginning. Svartlamon in Trondheim is an example of that. It is a row of five self-built townhouses designed by Nøysom arkitekter and built in 2017.

The houses were designed with a simple stud frame construction that easily could adapt to the found material. According to the architects the main criteria was that the houses would be easy to build, with minimal use of specialists and that it would accommodate reused materials and components.

In the project a sort of take-what-you-have mentality was created, which helped the residents to end at a total cost of only one fifth of the market prize on square meters. It also contributed to the varied expression of the townhouses where not one of them look alike even if their floorplans are almost exactly the same. (Nøysom arkitekter, 2022)

Andersson & Nilsson, (2020) makes a comparison of the Svartlamon townhouses and Upcycle studios by Lendager Group, on how the costs of a reuse projects are related to how much the reused materials are reshaped. In Upcycle studios the reused material is processed and reworked to a uniform unity, while they in Svartlamon are put into the construction as they are. This has much to do with preferred aesthetics, but it also has an enormous impact on the cost of the project. Keeping reuse as it is is cheap, while refining it takes a lot of workmanship and generates therefore a higher cost.

What is interesting in this project for this thesis is how they show that a general loadbearing construction can support what ever reused material you find, and that the combination of new material in the loadbearing construction together with reused materials as infill is a pragmatic way of working.

Fig. 14, Wall arriving at the construction site

UDDEN

To get a deeper understanding of the reuse process a more thorough investigation of one built reuse project has been made. This project is called Udden and was realized more than 20 years ago in Linköping. A lot have changed in the building sector since then regarding energy efficiency and other climate friendly upgrades, but when it comes to reuse of building elements it is as if the time had stood still and not much have been developed.

To cover this project both literature studies of research made on the project have been done as well as semi structured interviews with Gunnar Sundbaum, project manager and initiator; Per Carlfjord, construction site manager; and Anders Falk, lead architect.

SUMMARY: During the 1990's Sweden went through a development were people moved from industrial towns and smaller communities to larger cities and suburbs associated with universities. This led to empty buildings and a surplus of housing in some areas, and housing shortage in others. This was the case in Finspång, a former industrial town with population decline, and Linköping that instead had a high urban drift. (Eklund et al., 2003)

Gunnar Sundbaum, owner of Sundbaum Bygg och Miljö AB, came with the idea to try to "move" the apartments from Finspång to Linköping in a pilot project examining the potentials of reuse of structural building components, with the aim on preserving our planet and limiting the building industry's climate impact. (G. Sundbaum, personal communication, 7 February 2022)

Udden was the first project of its kind in Sweden. Reusing of prefabricated concrete structures had been done before but to saw a cast-in-situ concrete structure was something that had not been made. The goal was to develop new techniques and methods that would make it easier to practice reuse in the building industry. (Alén et al., 1999)

In 1999, the new house in Linköping was completed. About 50 bigger apartments from two three story-buildings in Finspång was turned into one two story-building with 22 smaller student apartments in Ryd, Linköping. In total they manage to build Udden with 60% reused material. (Alén et al., 1999) Looking at the concrete structure the reuse rate was 80% (the foundation was casted in new concrete), which saved the environment about 50% of greenhouse gas emissions compared to if only virgin raw materials had been used. (Roth & Eklund, 2000)

THE BUILDING PROCESS: OFF-SITE REUSE WITH ON-SITE LOGICS

The process of building Udden required thorough inventory of resources and planning of the flow from deconstruction to transport and new construction. Udden is an example of off-site reuse but with the logics of on site. In the beginning of the design and planning process the property developer, Stångåstaden, got to buy the old buildings in Finspång for 1 SEK. (G. Sundbaum, personal communication, 7 February 2022) This made it possible to know already in the beginning of the design and planning process what materials and resources they could use and what technical aspects they had, even though they not were on the specific site, and at the same time without any need for storing.

Deconstruction: In the Udden project the material bank was larger than the new construction and it was easy for the constructors to pick the best parts. They search through the old buildings' construction drawings and chose the parts that had the right characteristics and assigned them to a specific spot in the new building. All elements were thus planned on beforehand and marked at the demolition site, then sawn out using a diamond saw with exact measures, transported to Linköping by truck, and mounted on the building site. This made it possible to gain the most out of the already built-in qualities. The technical solutions were found quite fast and were not extra complicated. What took time were instead the inventory, organisational planning, and the careful deconstruction of the buildings. (P. Carlfjord, personal communication, 16 February 2022)

Other materials that were saved from Finspång and used in the new house were doors, windows, parquet floor, bricks, insulation, toilets, cabinets etc. Altogether 90% of the material from the houses in Finspång were reused or recycled. (Alén et al., 1999)

Transportation and organisation: The distance between the demolition site in Finspång and the construction site in Linköping was 64 km one way, 128 km as a round trip. It was important to plan the flow of deconstruction, transportation, and construction in a rational

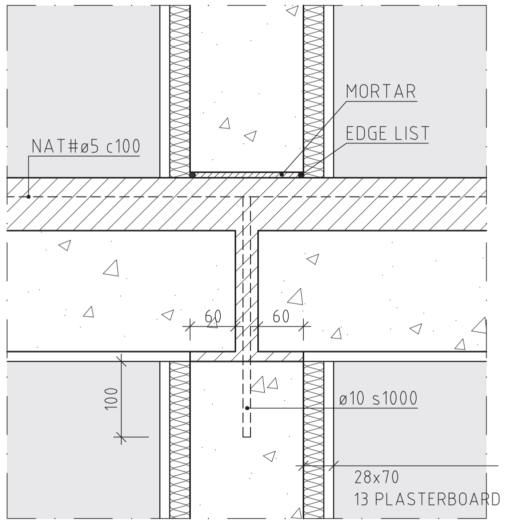


Fig. 15, Connection slab and interior wall, 1:10

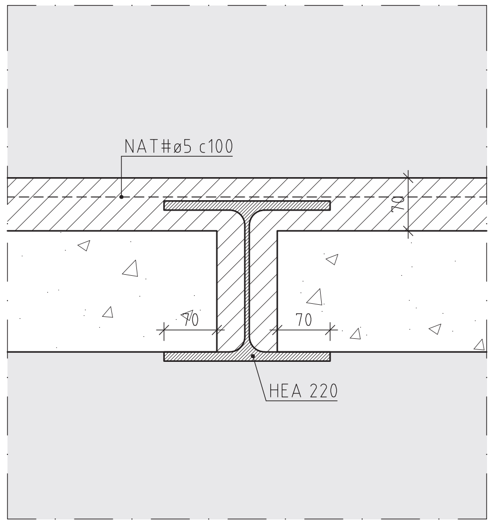


Fig. 16, Lintel beam between two slab elements, 1:10

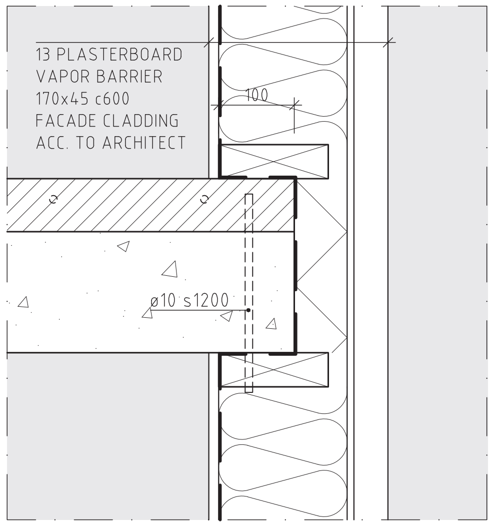


Fig. 17, Connection slab and exterior wall, 1:10

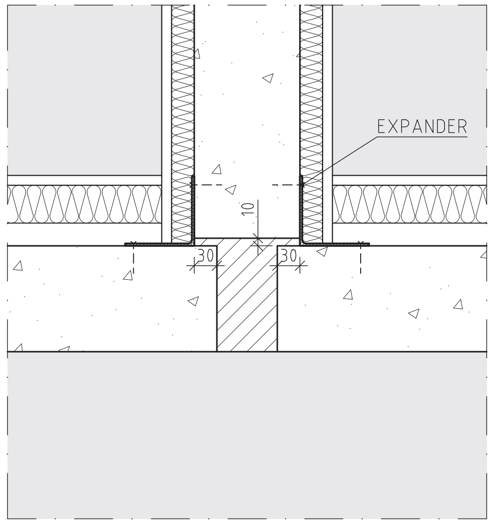


Fig. 18, Connection separation wall and corridor wall, 1:10

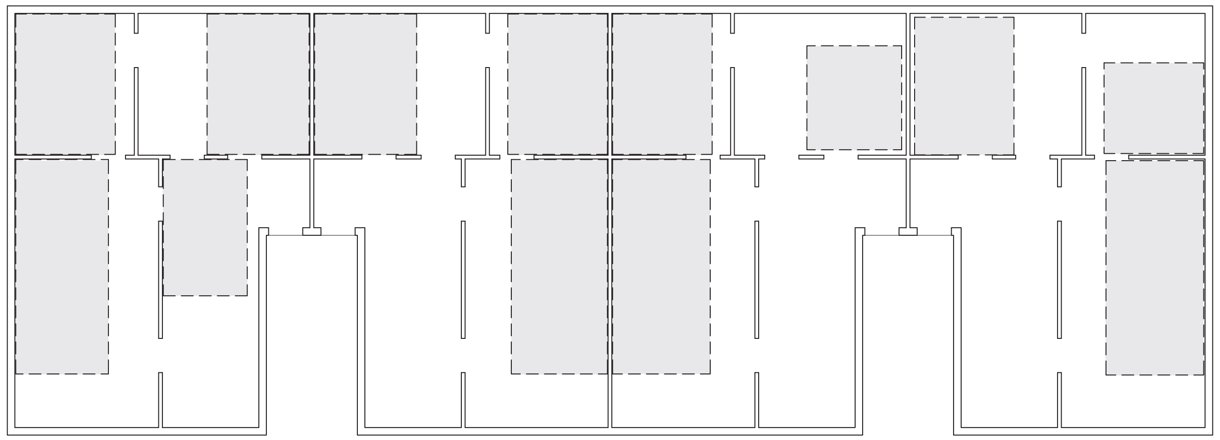


Fig. 19, Example of sawn out slab elements from Finspång, 1:200

and effective way to avoid storing of any kind, since storing is expensive. (P. Carlfjord, personal communication, 16 February 2022) It was a crane standing both at the demolition site and the construction site and as soon as a concrete element were sawn out it was lifted onto a truck for transport. When a load arrived in Linköping the elements were directly lifted of and put into the right place in the new house. In this way storing was never needed and it also worked out well without any trouble. (G. Sundbaum, personal communication, 7 February 2022)

New construction: Since the 1960's standards had changed, all elements needed to be updated to meet current regulations. Slabs needed to be thicker as well as walls between apartments and walls between apartment and corridor. Even though the sawn out slabs had different dimensions than the original layout (fig. 19) they could be used as prefab elements in the new construction, joined together with extra reinforcement and add-on casting (fig. 15-17). The sawn out walls instead got an extra layer of insulation covered with plasterboard on the inside of the apartments to meet current standards. This layer was also suitable for hiding installations and keeping the surface inside the apartments clean. (fig. 18) (P. Carlfjord, personal communication, 16 February 2022)

As we can see, all these solutions remind of, and clearly relate to, conventional building techniques and do not suggest any special measures in the construction. Since the project was relatively small there were no room for developing new methods or techniques and instead the focus was on finding simple solutions that made the technical difficulties limited and easy to solve. (Alén et al., 1999)

ARCHITECTURAL QUALITIES

According to Falk there was a discussion going on about if it was a quality to show that the house was built of old elements and components. In a sustainable perspective, it would be enough to just build a house of old materials, but if the old parts also are shown off, it could give an extra quality to see that even the toilets, for instance, are old. (A. Falk, personal communication, 16 February 2022)

When visiting the house today this quality is clearly visual. From distance it looks as typical a 90's house as it can be. But when you look again you recognize many details that are typical for 60's architecture. These details are not hidden, they blend in in the design and tell their story at the same time. This is a perfect example of modern spolia that takes advantage of that it a house of different visible older building elemnts. The mix gives a unique feeling of both heritage and modernity.

ENVIRONMENTAL IMPACT

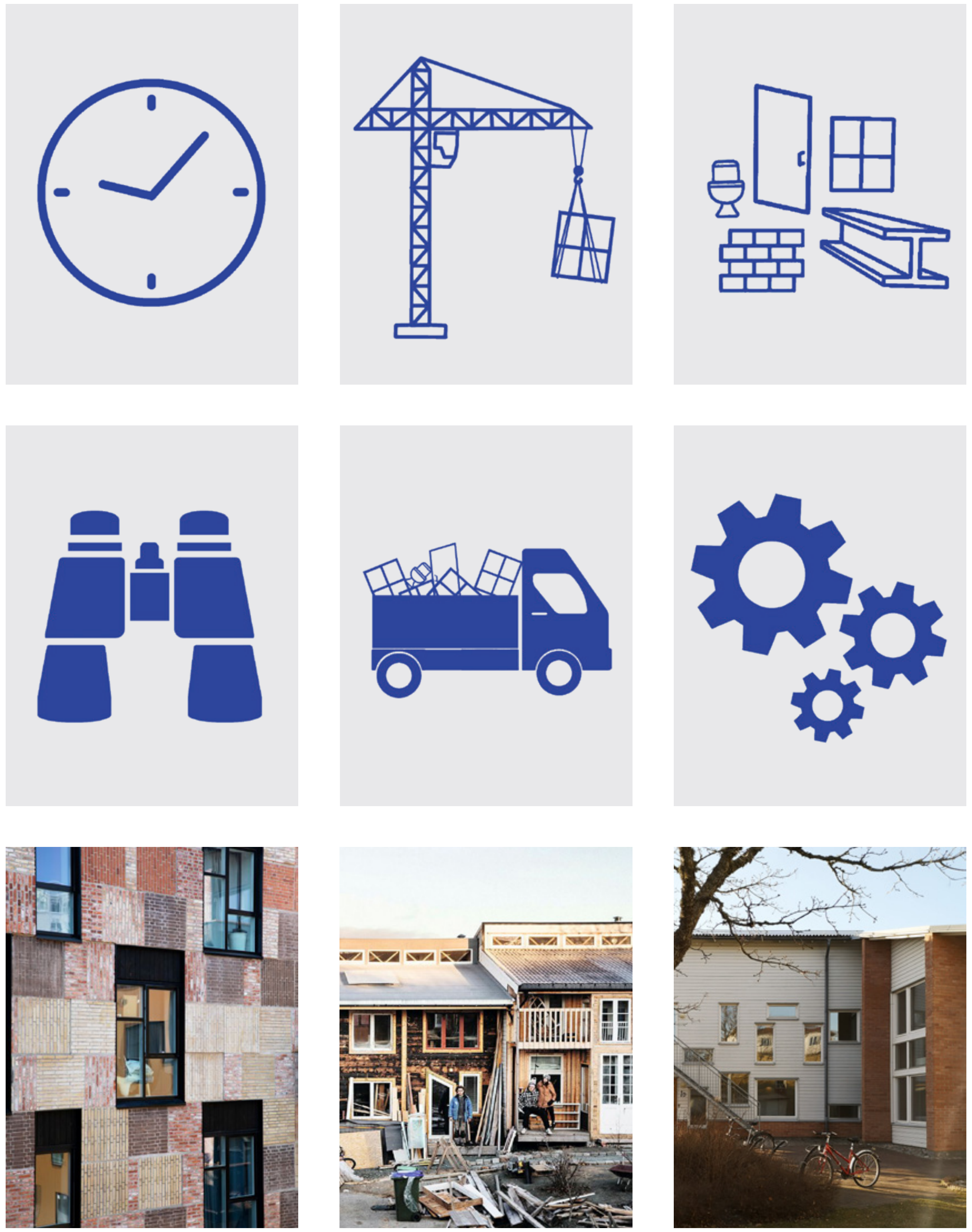
To analyse the environmental impact of Udden researchers at Linköping University made LCA on the project and compared it to if the house was built with 100% virgin raw material. The focus for the LCA was the structural concrete elements and not other salvaged products used in the new building. The LCA gives numbers on carbon dioxide (CO2) emissions, nitrogen oxide (NO) emissions and energy demand. (Roth & Eklund, 2000)

The result shows that Udden saved more than 50% of CO2 emissions and about 40% in energy demand compared to if the same building had been built in a conventional way. The NO emissions was on the other hand almost similar in both cases, which has to do with the longer transport distance of the reused concrete. (Roth, 1999)

What turned out to have the biggest influence on the total environmental impact when using reused concrete was the transport distance. Both the CO2 emissions, the NO emissions and the energy demand would have been substantially lowered if the distance between the deconstruction site and building site was shorter. If the distance instead was longer than 140km round trip the NO emissions of the project would have been higher than if virgin raw concrete had been used. (Eklund et al., 2003)

FINANCIAL ASPECTS

As described earlier all results and analysis gave positive numbers except the economical one. The cost for the project was 15-20% higher than if it would have been built as conventional new construction with cast-in-situ concrete. This is due to higher labour related costs such as sawing, transporting, and assembling of the concrete elements. Since Udden was a pilot project it qualified for founding from the municipality and the government to cover the extra cost that made the project realizable. (Roth, 1999)



CONCLUSIONS PART TWO

There are different aspects you need to relate to when practicing reuse in a new construction. The hardest one is the reliability of the resources and the amount of labour that is needed to ensure it. This depends on a variety of reasons and tend to lead to a higher cost of reuse projects than conventional new construction. It is both hard to know what resources will be available when you need them, and it is difficult to ensure its technical aspects. Storing is often needed when working with reuse, which also contributes to the higher cost.

To be able to practice a reuse at an industrial scale the most important aspect to solve is the reliability of the reused material, both in supply and in technical aspects. When we do, also economical savings compared to conventional new construction will be possible.

The main driving force for working with reuse in the construction of new buildings are the major positive results on environmental impact, but also the aesthetics gain positive effects when working with reuse. Through the old building components new buildings are given a history.

HOW COULD BUILDING ELEMENTS FROM THE DEMOLITION STOCK IN SWEDEN BE TURNED INTO RESOURCES SUITABLE TO USE IN NEW CONSTRUCTION IN A SYSTEMATIC WAY?

PART THREE - DESIGN PROPOSAL

BUILDING WITH BUILDINGS

We have now investigated what type of buildings that are being demolished in Sweden for one year. We have also investigated what are the aspects of reuse that could enable a systematic and industrial reuse of building elements. In this part the findings from these two investigations are combined into a design proposal showing one way of practicing an industrial reuse of the demolition stock, showing how we could build buildings with buildings.

This is done firstly with a general design concept that later is applied for a redesign of a multifamily building in Gamlestan, Gothenburg where the concept gets tested.

AN INDUSTRIAL REUSE

The term ‘industrial reuse’ implies that the reuse is to be made in a way that it can be done repeatedly, and systematically, without the need for project specific solutions. That it should be as similar to conventional new construction as possible.

What is found earlier in the thesis to be the biggest difference in designing with reuse contra conventional new construction design is the reliability on the resources. In conventional new construction you do not have to ask yourself if the wanted resource is available or not, you order it and it arrive just in time, with the prescribed technical aspects. In reuse projects it is instead a great uncertainty regarding what resources that are available and it is hard to ensure its technical aspects.

An industrial reuse asks for a design solution that skips the extra need for scouting, planning and inventory. A solution that does not need the reuse to be project specific until it is time for construction, and that does not rely on the timing aspect of demolition and construction. Hence, it does not have any other requirements of the reuse than that it will carry itself.

To reach these goals the design proposal is based on three design strategies that are explained on the right page.

WOODEN LOADBEARING CONSTRUCTION

To avoid the need of ensuring technical aspects of reused building parts the skeleton of the design concept is a wooden loadbearing construction. It is a post and beam structure of glulam, with CLT boards as separation walls. The best would have been to make use of old concrete walls as separation walls as well, leaving the wood to only be a skeleton but that would make the detail solutions a bit trickier, and the separation walls could be so thick that it would not be reasonable.

REUSE AS INFILL

Reused building elements are used to fill out the wooden structure, an old wall as a new wall, and an old slab as a new slab. Through the investigations made in part one we now know what resources we can count on finding in the demolition stock. We know enough about it to be able to design with it as long as the requirements of technical aspects do not rely on the reused building elements. Suitable elements for this reuse are concrete slabs and facade elements, but also smaller components such as doors and furnishings are reused. Both part one and two tells me that reuse is a local business and for this concept I have focused on the demolition stock in Gothenburg.

SPOLIA

The principles of spolia are also used based on the notion that they come with qualities to the building that intrigues both viewers and inhabitants. Through spolia the unconscious heritage of an area can be saved in an efficient way telling its stories for future generations. Spolia also suggests that you do not have to use elements from a multifamily building in a multifamily building again, which can lead to unexpected combinations that makes people engage with architecture.

REUSED FACDE ELEMENT

The sawn out facade elements get a wooden frame wrapped around them to keep the insulation in its place. The wooden frame also makes it easier to mount the element into the construction. See construction details on next spread.

Since the idea with an industrial reuse is that these modules can be used anywhere without constraints to have exact placement or measures of windows, it could happen that the element needs to end at half a window and leave a whole. When that happens, the whole can be filled with either a new narrow window, or insulation covered with a contrasting sheet on the outside. Here the principles of spolia are used again, telling the story of old and new.

The facade elements also need upgrading to meet modern standards regarding insulation. In this thesis a typical wall construction from the 80's has been used for the design. This type of wall seems to be the most common one among the demolition stock in Gothenburg and therefore also what you can count on using in a reuse project. To upgrade it for modern standards it needs to get one layer of additional insulation and a vapour barrier. See construction details on next spread. (p.66)

But what happens when the module ends with a half window?

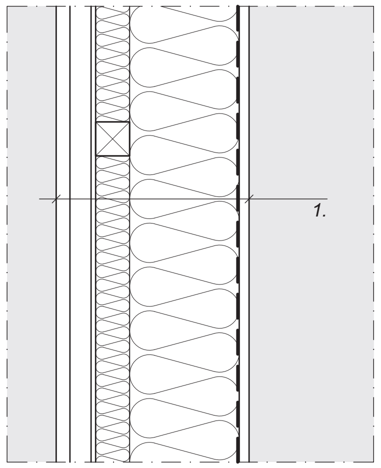
The whole can either be filled with a new narrow window or...

...insulation covered with a contrasting sheet e.g. plywood.

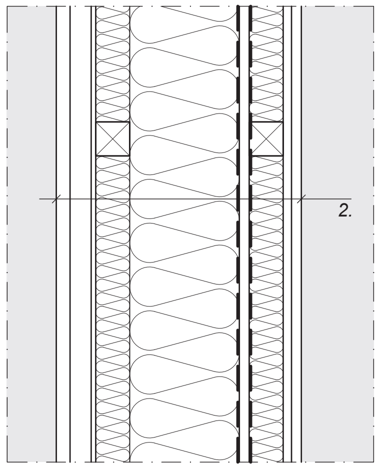
UPGRADING REUSED FACADE ELEMENTS

1.
20 CORRUGATED METAL SHEET
28x70 LATH
WIND PROTECTOR
45x45 STUD/INSULATION
45x145 STUD/INSULATION
VAPOUR BARRIER
13 PLASTERBOARD

2.
18 CORRUGATED METAL SHEET
28x70 LATH
WIND PROTECTOR
45x45 STUD/INSULATION
45x145 STUD/INSULATION
VAPOUR BARRIER
13 PLASTERBOARD
VAPOUR BARRIER
11 OSB
13 PLATSERBOARD



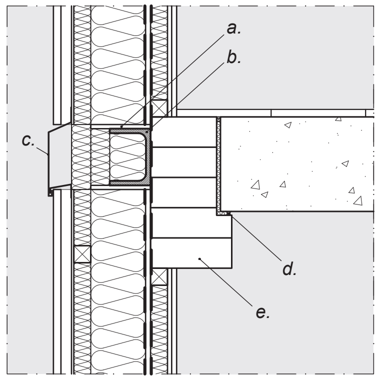
A1: Common construction of reused facade element in Gothenburg, 1:10



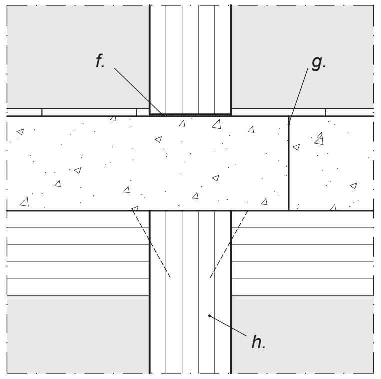
A1+A2: Reused facade element + additional interior insulation, 1:10

CONSTRUCTION DETAILS

a. TIMBER FRAME HOLDING REUSED FACADE ELEMENT
b. U ANGLE IRON BRACKET
c. COVERING METAL SHEET
d. EDGE LIST AND INSULATION
e. 215x400 GLULAM BEAM
f. EDGE LIST
g. JOINTS BETWEEN CONCRETE ELEMENTS CAN BE ANYWHERE
h. 215x215 GLULAM POST
i. EDGE LIST
j. ADDITIONAL CASTING
k. 115x225 GLULAM BEAM



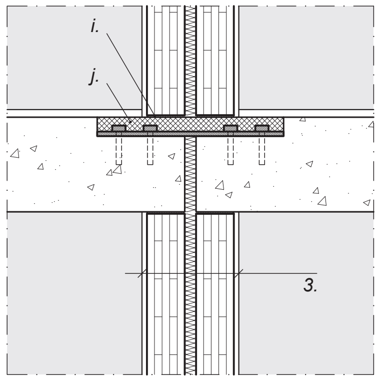
B1: Connection slab and reused facade elements, 1:20



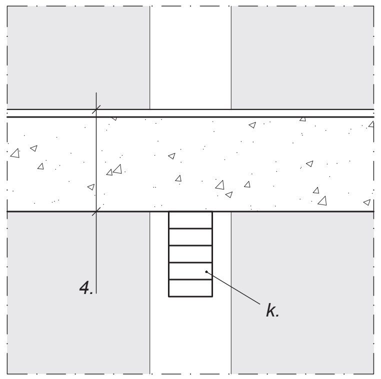
B2: Connection slab and glulam post, 1:20

3.
13 PLASTERBOARD
100 CLT
30 INSULATION
100 CLT
13 PLASTERBOARD

4.
20 PARQUET FLOOR
STEP SOUND DAMPING
~250 REUSED CONCRETE ELEMENT



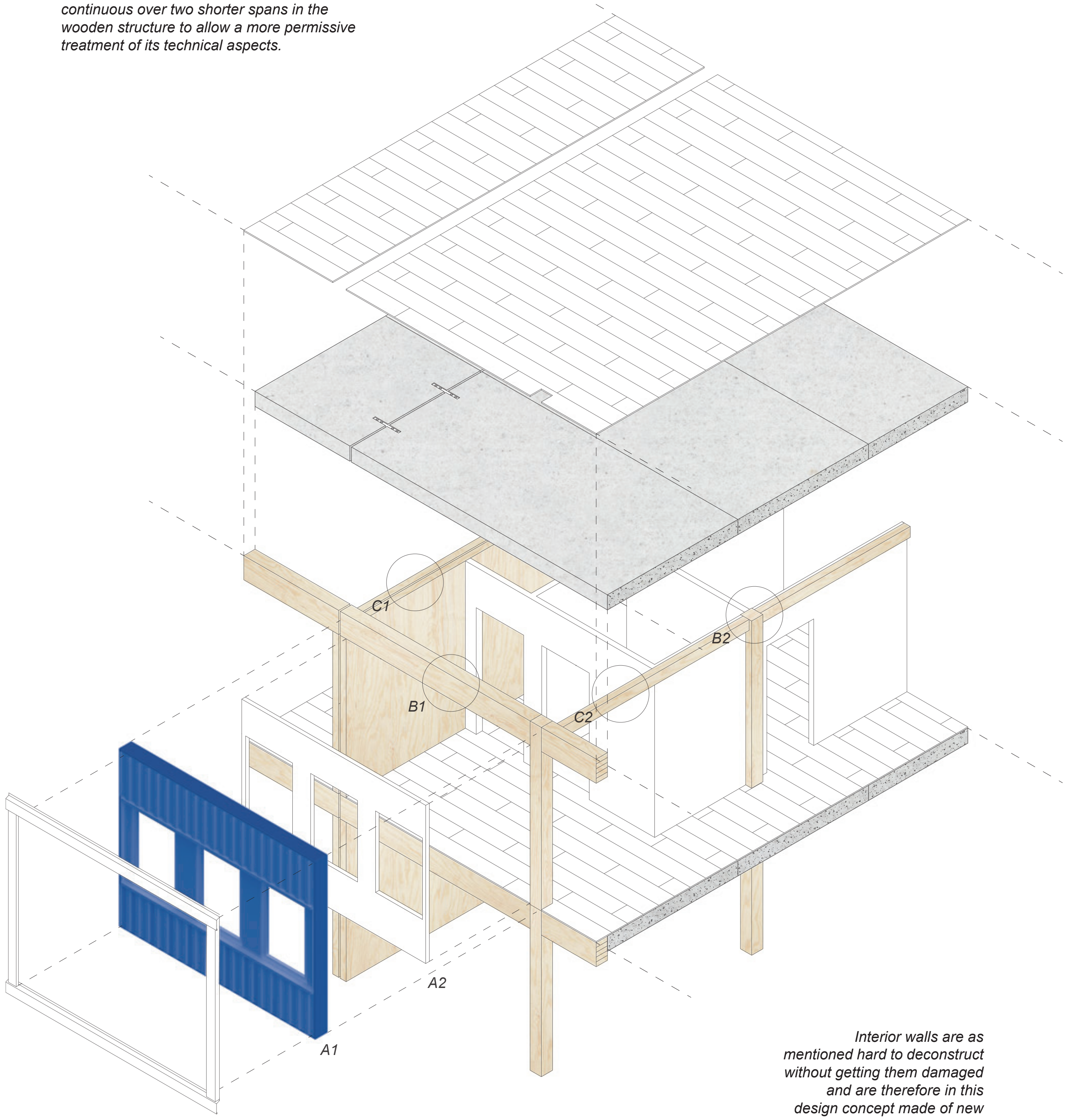
C1: Connection reused slab elements and separation wall, 1:20



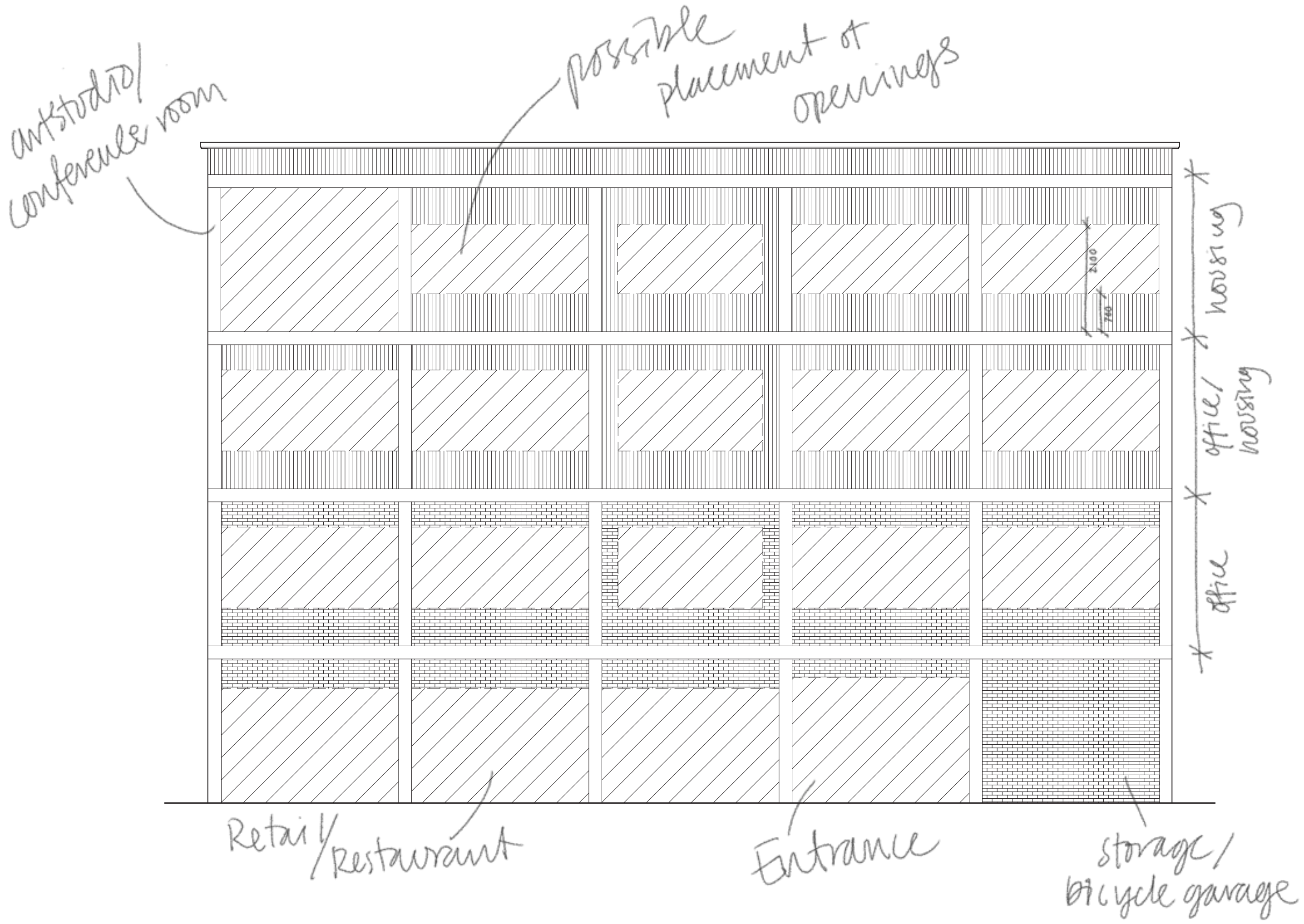
C2: Connection slab and glulam beam, 1:20

ASSEMBLING THE STRUCTURE

Since all the loads are concentrated in the wooden construction, the facade elements have no other requirement than to carry themselves. The slab elements still need to carry live loads and are therefore placed continuous over two shorter spans in the wooden structure to allow a more permissive treatment of its technical aspects.



Interior walls are as mentioned hard to deconstruct without getting them damaged and are therefore in this design concept made of new material.



DESIGNING WITH UNCERTAINTY

Even though we know enough about the reused elements to be able to design the overall layout of a building, there will still be uncertainties regarding placement of windows and exterior doors until it is time for construction. This can be solved by setting rules for where possible window openings can be placed, based on the floorplans and the planned usage of the building.

Above shows a hypothetical Gothenburg building in the middle of the planning process. The floorplan is set and also the materials of the facade, which are decided based on the demolition stock.

Hatched surfaces represent possible placement of windows. These surfaces could be specified with a percentage of required window coverage e.g., 50-100%. They are a result of different rules for the windows, for instance: lowest acceptable sill height, interior wall placements, and that the upper edge of windows preferably matches the door height inside.

Later, right before it is time for construction, the final design is getting into shape. If this building were to be built in 2020 it could have turned out looking like the illustration shown to the right.

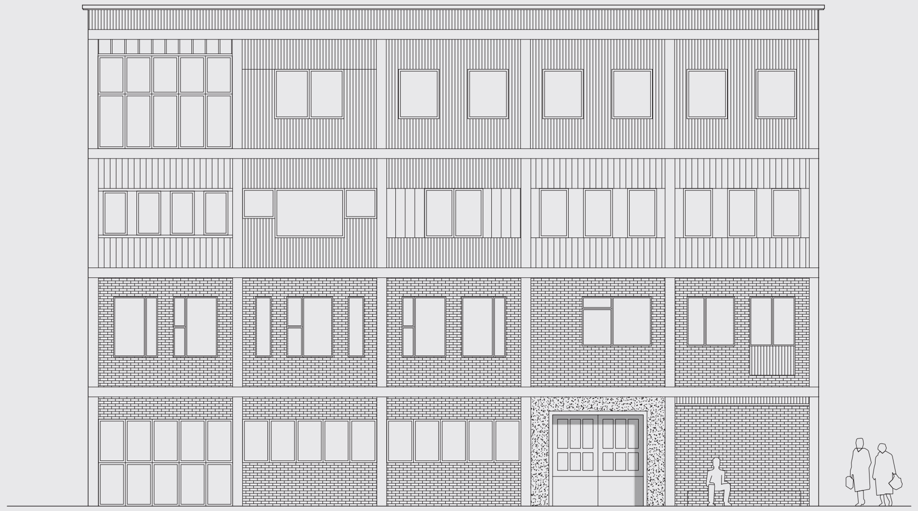


Fig. 20, Kv. Makrillen

WHAT HAPPENS IN PRACTICE?

To test the design concept a redesign of a conventional new construction in Gothenburg have been made. The chosen building is located in Gamlestan in Gothenburg and contains housing apartments in four stories, with commercial spaces on ground floor. It is part of a bigger block called Makrillen.

The focus of the redesign has been two typical apartments on the fourth floor and the facade facing Artillerigatan. To do the redesign everything from the concept is implemented. The original concrete structure is changed to the new wooden structure, while the slabs and the facades are being exchanged for reused elements.

The result shows that nothing from the original floorplan of the apartments needed to be changed, except that the separation walls got 50 mm thicker with the CLT instead of concrete, and that the freezer was moved in order to allow a more flexible window placement. (see p. 74-75)

Also the height between slabs is kept the same with the exception of where the beam supporting the reused concrete elements is located. Here the free height is 2275 mm instead of the original 2500.

The grid on the facade is the same as the wooden structure. They both follow the loadbearing grid of the original design, but with an extra divider where the added posts and beams supporting the reused slabs meet the facade.

It has been an important comparison to see if there would be any big changes in the layout of the house when building with a combination of new wood and reused elements instead of prefabricated concrete. The comparison is also valid for the aesthetics of the building since the redesign contains buildings that got approved for demolition in Gothenburg the same year as Makrillen was built. Hence the redesign shows a possibility of how the building could have been built and could have looked like if buildings from the demolition stock had been used in the construction instead of virgin raw concrete.

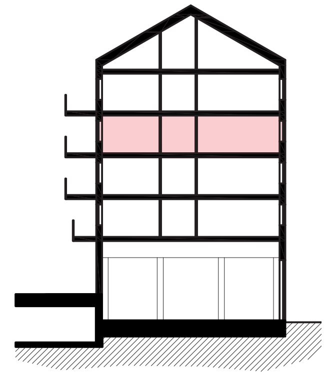


Fig. 21, Section of Kv Makrillen, 1:500

Fig. 22, Site plan and typical floorplan of Kv Makrillen, 1:500

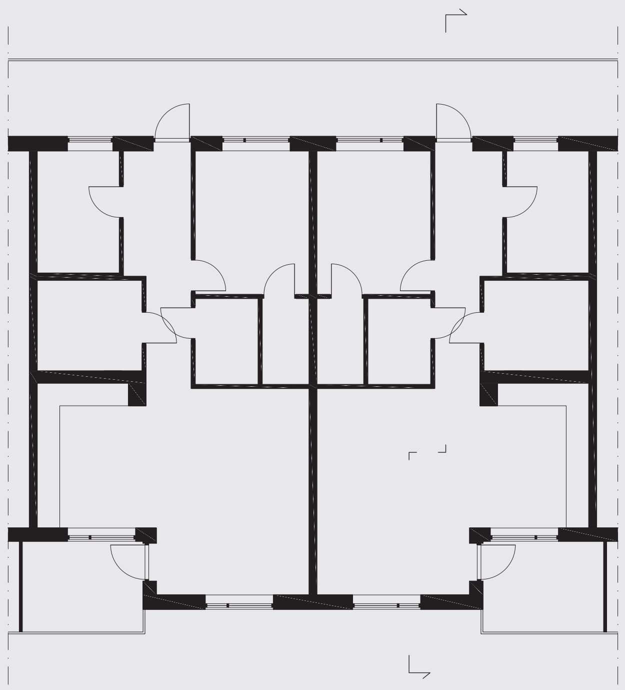
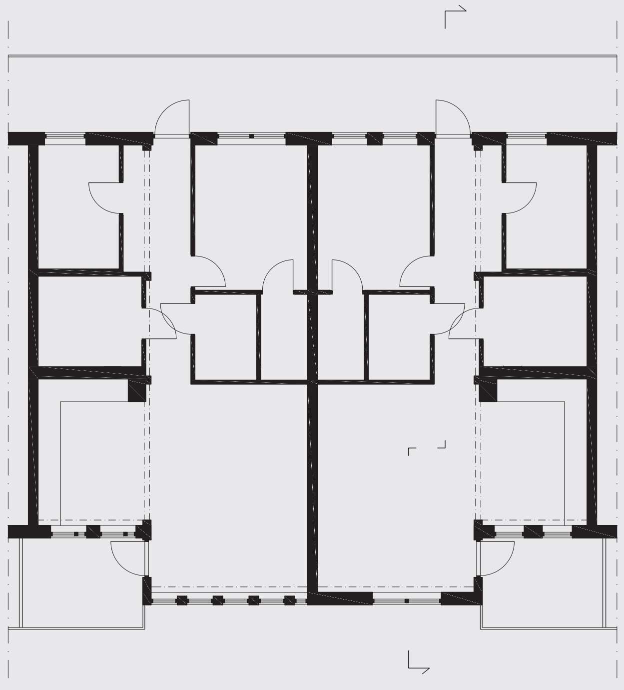


Fig. 23, Original Floorplan, 1:200

Fig. 24, Original Facade of Kv Makrillen, 1:200



Floorplan w. reused elements, 1:200

Facade w. reused elements, 1:200

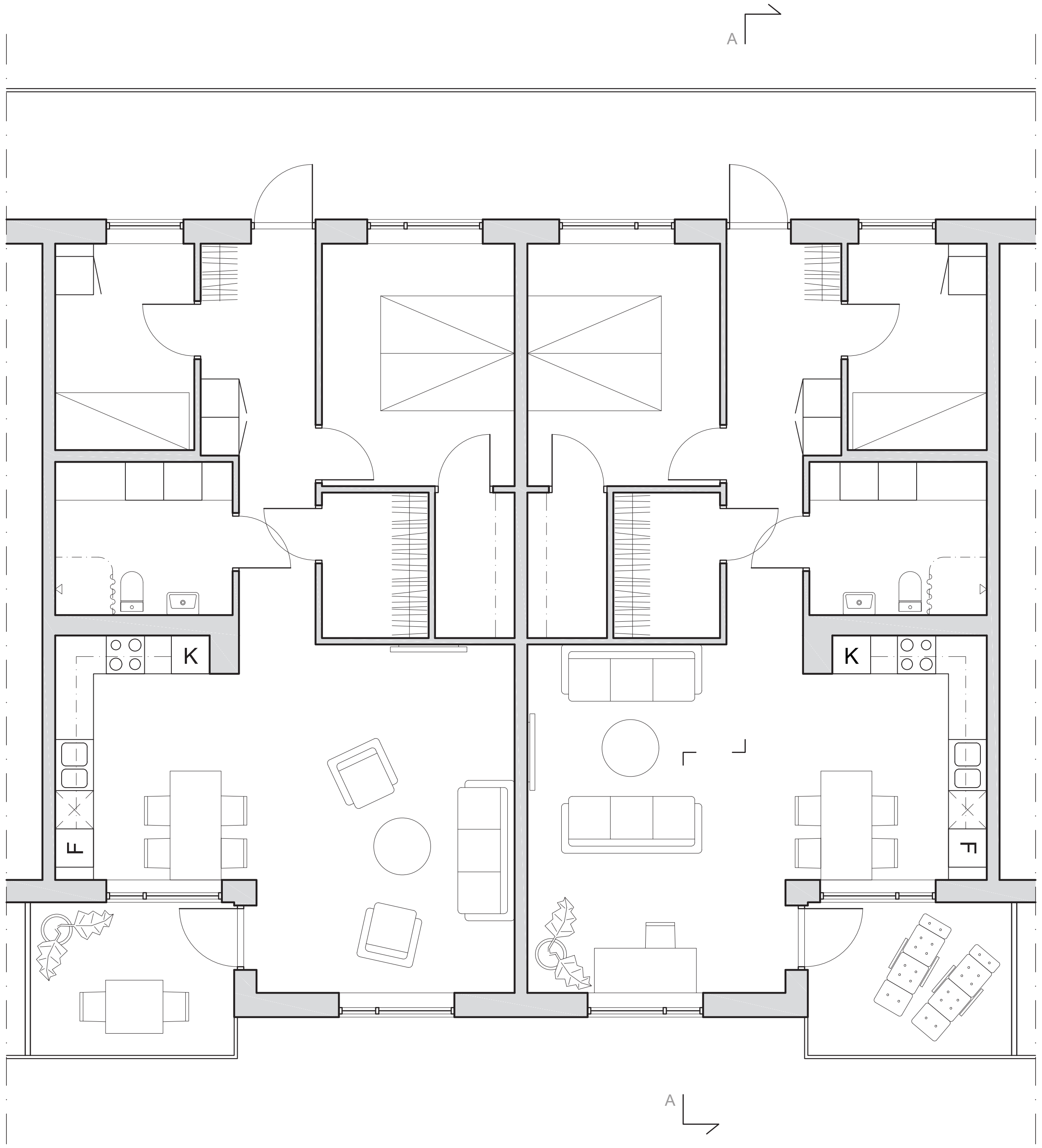
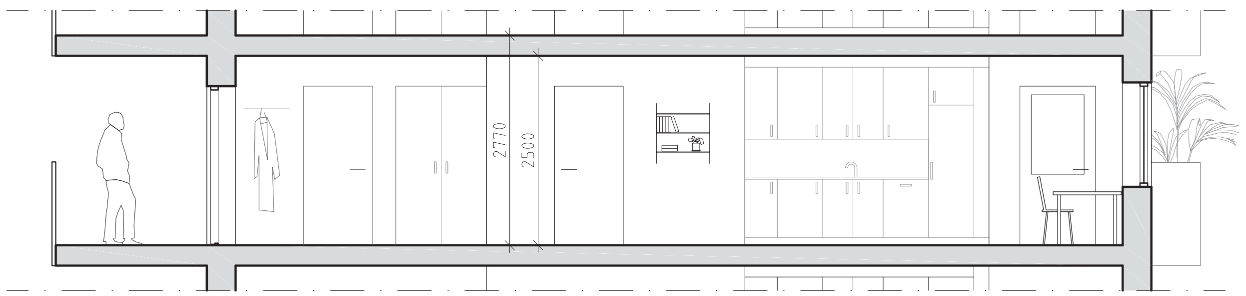
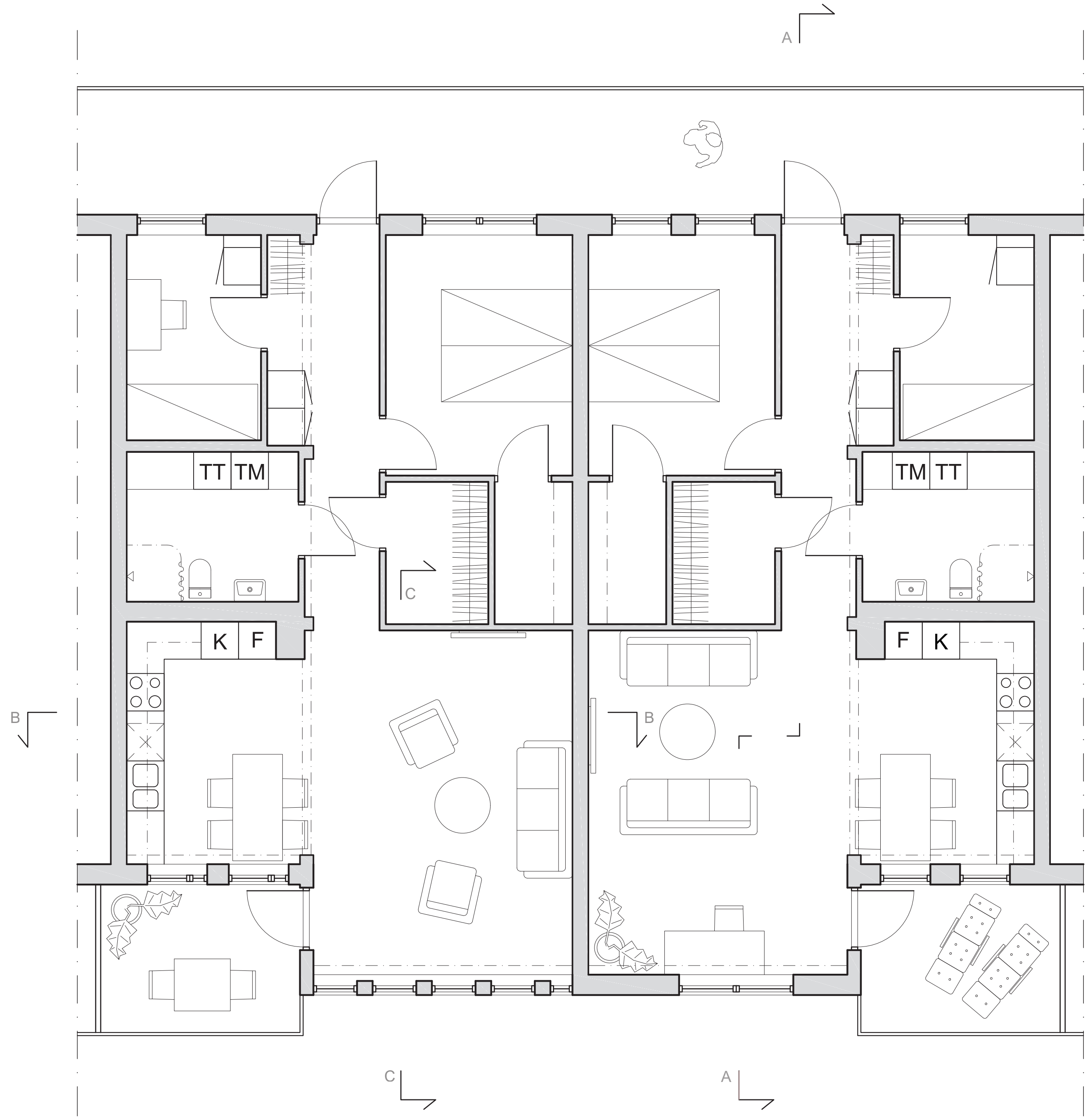


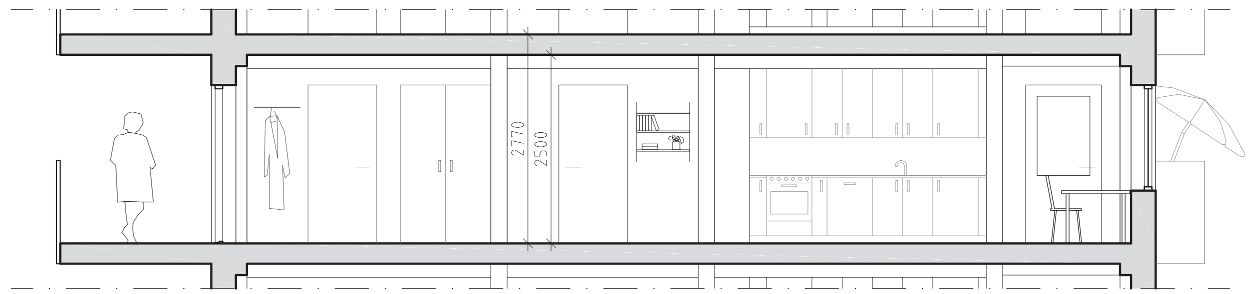
Fig. 25, Orginal floorplan 1:100



Orginal section A-A 1:100

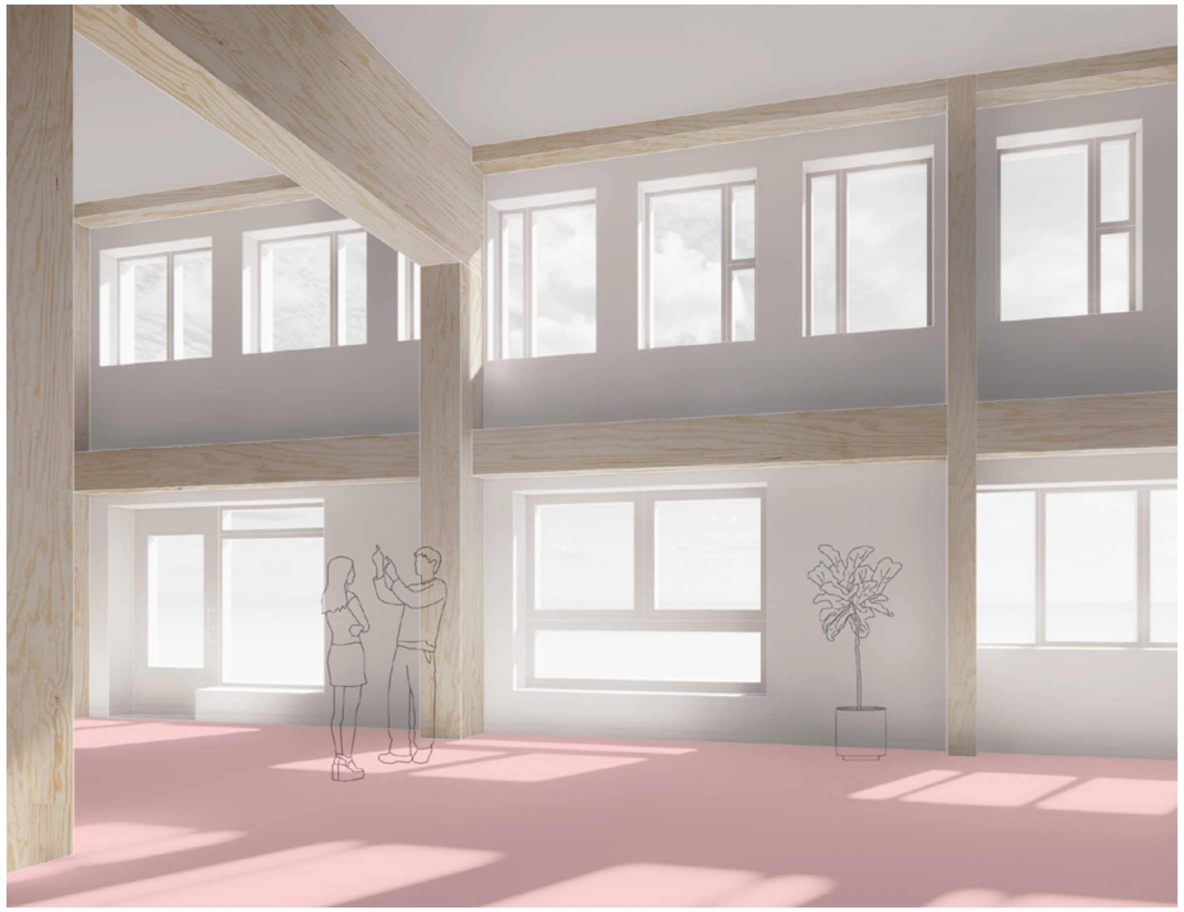


Floorplan w. Reused elements 1:100

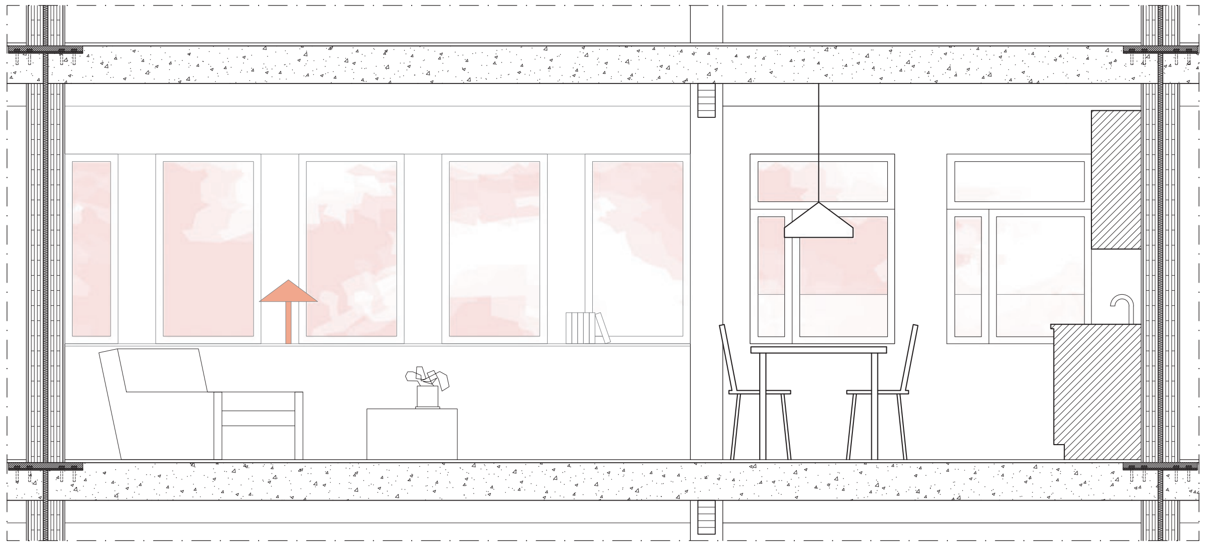


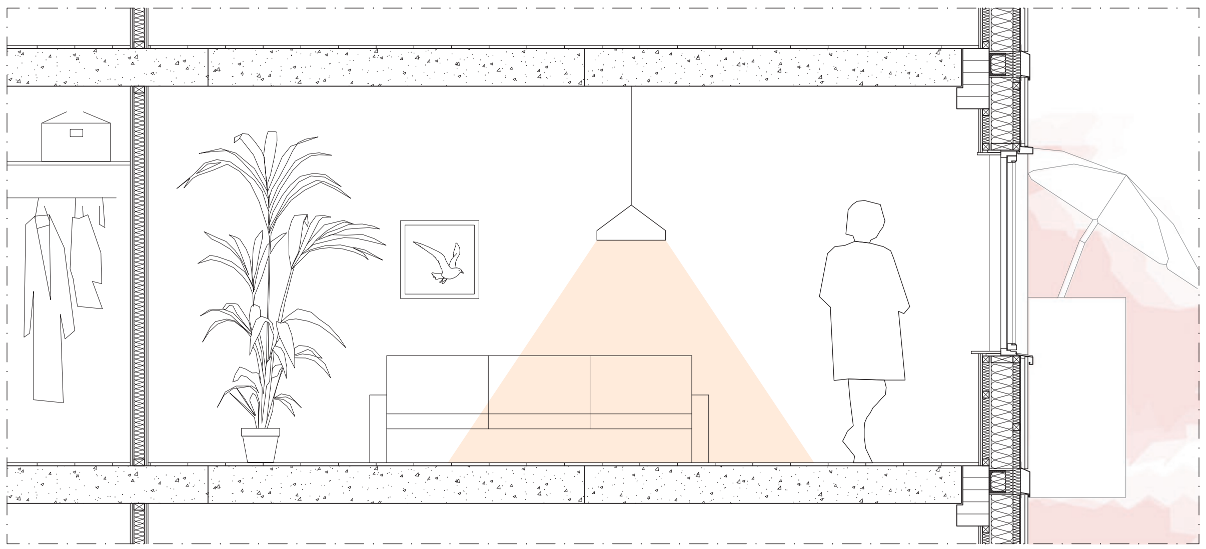
Section w. Reused elemnts A-A 1:100


Interior perspective of an apartment


Interior perspective of commercial space on ground floor


Part of facade w. reused elemnts, 1:50


Section w. reused elemnts, B-B, 1:50


Section w. reused elemnts, C-C, 1:50


Huge office building at Personalvägen
The office of a metal business at Stålverksgatan
Office- and retail building at Lantvärnsgatan
Busgarage + office at Karl Johansgatan
Another huge office building at Personalvägen
Lundby gymnasium at Blackevägen 1
Carserviceshop at Gamlestadsvägen
Officebuilding at Kryddgårds-gatan
Building at Fjärde Långgatan

DISCUSSION & CONCLUSIONS

It has turned out to be two themes regarding reuse in this thesis, one that counts the environmental benefits and one that focuses on the cultural/unconscious heritage of our built environment.

DEMOLITION AS A RESOURCE

The problems stated in the background are that the building industry is one of Sweden's main waste producer, resource extractor and producer of GHG emissions, and yet do not make use of the resources that already are in the industry. To utilize old buildings for new construction when they are not wanted anymore would have a major effect on the whole industry's climate impact. For that impact to happen the reuse must reach an industrial scale that can be a comparable alternative to conventional new construction. In an attempt to propose a solution for these problems the thesis investigates the possibilities of an industrial reuse through following questions:

Q1: What type of buildings are being demolished in Sweden?

Q2: What are the aspects of reuse that could enable an industrial reuse of building elements in new construction?

Q3: How could building elements from the demolition stock in Sweden be turned into resources suitable to use as elements in new construction in a systematic way?

The biggest difference in a reuse project and a conventional new construction is the reliability on the resources and the amount of labor that is needed to ensure it. This depends on a variety of aspects but are related to the difficulties in timing between demolition and construction projects, and to knowing what will be demolished in the first place since the documentation on demolition is scarce. When you eventually know what resources you can use, it is hard to ensure the found resources' technical aspects.

To enable an industrial reuse out of these difficult preconditions a shortcut is needed that makes it possible to get around the reliability problems of reuse. In the thesis this is proposed as a design concept using a loadbearing wooden construction, and the reused elements have no other requirements than to carry themselves. This shortcut means though that a project using this concept cannot take full advantage of the reused elements capacities, but it opens for a more systematic and permissive treatment of the reused resources that is a lot better than that they do not get used at all.

Based on the first investigation we know in enough rough measures what resources we can count on finding to proceed with a reuse project with this shortcut. This is based on hypothesizes that the demolition stock is about the same every year and that it therefore can be a cohesive and reliable material bank to pick from. For this to be possible in reality it is crucial that the documentation about demolition gets guidelines on how to file and archive the information that already is there.

The treatment of demolition permits confirms the principles of the linear economy. It is clear that what has become waste no longer have any value and therefore not need a proper documentation, it should just be disposed of and forgotten as fast as possible. By starting to save the information about the demolition stock in a structured way, the perceived value of it would increase by itself, and maybe be the start for the industry to think of all these unwanted houses as resources instead of as waste.

That said, the industry needs a shift starting to discuss value in a broader sense than just economical profit. That is though a slow-going development, and the need for incitement from municipalities and governments is crucial for a change to happen that could make the practice of reuse in the building industry reach beyond pilot projects and environmental enthusiasts.

OUR UNCONSCIOUS HERITAGE

What struck me when doing the investigation of the demolition stock in Sweden was that there are so many buildings that disappears without no one noticing it. I have in previous works investigated the collagemaking as a tool for visual investigations, and even in this thesis it has shown me how powerful it is. Through the collages of the demolition stocks' different local characters the unconscious heritage of these not noticeable buildings appeared in a clear shape, and as something that I have not thought of (or noticed) before.

These everyday buildings are by themselves not that important for the heritage and character of a place but when you put them together in a uniform demolition stock, they leave a cavity that echoes empty when they disappear, even though it is hard to pinpoint what is missing.

There are sad stories of buildings with a high cultural and historical value that get demolished even though it causes reactions from the society. They are part of a heritage that we are conscious of and feel when they disappear. But for most of the roughly 5500 demolition objects that gets approved for demolition each year this is not the case. No one reacts on it, nor notices it. They are buildings that not many people even think of before or after they are gone.

To save this heritage we can look for inspiration in medieval spolia. As far as we know, they did not have any goals on telling the story of old roman culture in their buildings, they just thought that it was better to use the old blocks than to letting them lay on the ground useless. But even so, these buildings are amongst the most intriguing ones in history with their odd combinations of building parts that all tell their stories at the same time.

I have heard many people in Gothenburg say that the character of the new construction happening in the city do not feel like Gothenburg. When they walk in these areas they feel as if the city is a stranger with no identity, something that Gothenburg always have had so much of. Could it be due to that our unconscious heritage, the everyday buildings that no one seems to care about, has started to disappear?

BIBLIOGRAPHY

Alén, C., Roth, L., Dahlgren, S., Östberg, G., & Andersson, M. (1999) *Rapport Profilen-Ryd. A pilot project reusing concrete frames.* (In Swedish).

Andersson, M., Nilsson, E. (2020). *The Rehouse Project*. Göteborg: Chalmers University of Technology (SWE).

Bertino, G., Kisser, J., Zeilinger, J., Langergraber, G., Fischer, T., & Österreicher, D. (2021). Fundamentals of Building Deconstruction as a Circular Economy Strategy for the Reuse of Construction Materials. *Applied Sciences volym , 11*(3). https://doi.org/10.3390/app11030939

Björklund, A., Lindborg, M. (2021). *Reuse is the New Use*. Göteborg: Chalmers University of Technology (SWE).

Eklund, M., Dahlgren, S., Dagersten, A., & Sundbaum, G. (2003). The conditions and constraints for using reused materials in building projects. *Deconstruction and Materials Reuse, CIB Publication*, 287, 248-259.

Gunne, N. (2021, 18, Oct). Nya grepp krävs för återbruk i industriell skala. *Arkitekten*. https://arkitekten.se/nyheter/nya-grepp-kravs-for-aterbruk-i-industriell-skala/

Johansson, E. (2021). *Cheaper but Better*. Göteborg: Chalmers University of Technology (SWE).

Erlandsson, M., & Larsson, M. (2016). *Byggandets klimat-påverkan för ett flerbostadshus med yttervägg och stomme av korslimmat trä–kvarteret Strandparken*. IVL Svenska Miljöinstitutet.

Minunno, R., O'Grady, T., Morrison, G. M., & Gruner, R. L. (2020). Exploring environmental benefits of reuse and recycle practices: A circular economy case study of a modular building. *Resources, Conservation and Recycling, 160*(104855). https://doi.org/10.1016/j.resconrec.2020.104855

Moberg, F., Roupé, J. & Haeggman, M. (2021) *Betong och Burgare - Analys av strategiska flöden inom bygg- och livsmedelssektorn viktiga för svenskt material- och resursnyttjande inom planetens gränser*. Re:Source

Naturvårdsverket. (2020a). Statistikblad Avfall - Bygg och rivningsavfall

Naturvårdsverket. (2020b). Avfall i Sverige 2018 - Uppkomst och behandling.

Roth, L., & Eklund, M. (2000). Environmental analysis of reuse of cast-in-situ concrete in the building sector.

Schoof, J. (2021, june). Who Will Run the Urban Mines of the Future?. *Detail, 2021*(6), 60-64

WEBPAGES

Organisation/Myndighet/Efternamn, A. A. (År/publiceringsdatum). *Titel*. Webbsidans namn. Hämtad år-månad-datum från URL

Cambridge Dictionary. (n.d.). Waste. In Cambridge Dictionary. Retrieved 2022, 3 May from https://dictionary.cambridge.org/dictionary/english/waste

Earth Overshoot Day. (n.d. a) *About Earth Overshoot Day*. Retrieved 2022, 3 May from https://www.overshootday.org/about-earth-overshoot-day/

Earth Overshoot Day. (n.d. b) *Country Overshoot Days*. Retrieved 2022, 3 May from https://www.overshootday.org/newsroom/country-overshoot-days/

Ellen MacArthur Foundation. (n.d.) *Circular Economy Introduction*. Retrieved 2022, 4 May from https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Nøysom arkitekter. (2022), *Experimental Housing at Svartlamon*. Retrieved 2022, 11 May from https://www.noysomarkitekter.no/eksperimentboliger-pa-svartlamon

Lendager Group. (2020), *Sustainability - Upcycle Studios & The Resource Rows*. Retrieved 2022, 6 May from https://nrep.com/wp-content/uploads/2020/11/200923_Upcycle-Studios-RR-LCALCC_NREP.pdf

Miljödepartementet. (2016, 5 july), *Miljöbalken och EU:s kemikalielagstiftning*. Retrieved 2022, 24 May from https://www.regeringen.se/artiklar/2016/07/regelandringar-beslutade-den-22-juni-2016/

UNCTAD. (n.d.) *Circular Economy*. Retrieved 2022, 4 May from https://unctad.org/topic/trade-and-environment/circular-economy

Waste. (2022, 11 April). In *Wikipedia*. Retrieved 2022, 3 May from https://en.wikipedia.org/wiki/Waste

FIGURES

Fig. 1, A Fall of Ordinariness and Light. Graphite drawing by Jessie Brennan. Retrieved from http://www.jessiebrennan.co.uk/a-fall-of-ordinariness-and-light

Fig. 2, Construction and Demolition Waste. Photograph taken by Mankukuku. Retrieved from https://se.depositphotos.com/portfolio-1473684.html?content=photo

Fig. 3, Waste treatment of CDW in Sweden during 2018. Bar shart redrawn by author. Original chart retrieved from Naturvårdsverket. (2020a). Statistikblad Avfall - Bygg och rivningsavfall

Fig. 4, Demolition. Photograph taken by Photomat. Retrieved from https://pixabay.com/es/photos/arquitectura-cielo-edificio-3173357/

Fig. 5, Demolition. Photograph taken by Joakim Kröger. Retrieved from https://codesign.se/cotalk-20-maj-webinar-aterhus-att-bygga-hus-av-hus/

Fig. 6, Spolia at the clocktower of Santa Maria Maggiore della Pietrasanta, Naples. Photograph taken by Vincenzo Lerro. Retrieved from https://www.flickr.com/photos/14747125@N08/5575026558/in/photostream/

Fig. 7, Details of the base. Photographer unknown. Retrieved from Bertino, G., Kisser, J., Zeilinger, J., Langergraber, G., Fischer, T., & Österreicher, D. (2021). Fundamentals of Building Deconstruction as a Circular Economy Strategy for the Reuse of Construction Materials. *Applied Sciences volym , 11*(3). https://doi.org/10.3390/app11030939

Fig. 8, Genius Loci / Kiruna. Collage by Anastasia Savinova. Retrieved from http://www.anastasiasavinova.com/genius-loci.html

Fig. 9, Mass demolition of 15 unfinished skyscrapers in Kunming, China 2021. Photograph taken by Long Yudan. Retrieved from https://www.chinadaily.com.cn/a/202109/03/WS6131506ea310efa1bd66cfda_5.html

Fig. 10, The reused brickwork facade of the Resource rows. Photograph taken by Mikkel Strange. Retrieved from https://www.theguardian.com/cities/2020/jan/13/the-case-for-never-demolishing-another-building

Fig. 11, The Resource rows. Photograph taken by Rasmus Hjortshøj. Retrieved from https://dac.dk/en/knowledgebase/architecture/resource-rows-a-gem-of-upcycling-nestled-between-newbuilds-and-nature/#gallery-4

Fig. 12, Sawing out brick modules from the old Carlsberg brewey in Copenhagen. Photographer unknown. Retrieved from https://lendager.com/arkitektur/ressourceraekkerne/

Fig. 13, The construction of Svartlamon townhouses. Photograph taken by Jimmy Linus. Retrieved from https://www.dn.no/d2/arkitektur/stavanger/siv-helene-stangeland/sissel-leire/na-bygges-det-eksperimentelle-fellesboliger/2-1-230291

Fig. 14, Wall arriving at the construction site. Photographer unknown. Retrieved from Eklund, M., Dahlgren, S., Dagersten, A., & Sundbaum, G. (2003). The conditions and constraints for using reused materials in building projects. *Deconstruction and Materials Reuse, CIB Publication*, 287, 248-259.

Fig. 15-19, Construction details from Udden. Redrawn and translated by the author. Original drawings retreived from Alén, C., Roth, L., Dahlgren, S., Östberg, G., & Andersson, M. (1999) *Rapport Profilen-Ryd. A pilot project reusing concrete frames.* (In Swedish).

Fig. 20, Kv. Makrillen. Print screen from Google streetview. Retrieved from https://www.google.se/maps/@57.7297537,12.0153517,3a,75y,25.15h,105.78t/data=!3m7!1e1!3m5!1sj9I2nk01NS4dm-hMShIwVg!2e0!5s20210901T000000!7i16384!8i8192

Fig. 21, Section of Kv Makrillen, 1:500. Redrawn by the author. Original drawings retreived from the building permit, SBK Gothenburg municipality.

Fig. 22, Site plan and typical floorplan of Kv Makrillen, 1:500. Redrawn by the author. Original drawings retreived from the building permit, SBK Gothenburg municipality.

Fig. 23, Original Floorplan of Kv Makrillen, 1:200. Redrawn by the author. Original drawings retreived from the building permit, SBK Gothenburg municipality.

Fig. 24, Original Facade of Kv Makrillen, 1:200. Redrawn by the author. Original drawings retreived from Arkitekthuset.

Fig. 25, Original Floorplan of Kv Makrillen, 1:100. Redrawn by the author. Original drawings retreived from the building permit, SBK Gothenburg municipality.

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ÖSTERGÖTLANDS