CO OPERATIVE DESIGN PROCESS - FROM URBAN STRATEGY TO DETAIL

COOPERATIVE THESIS PROJECT BY AN ARCHITECT OLOF PHILIPSON AND AN ARCHITECTURAL ENGINEER PÅR THUNBERG
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This project is a collaborative master thesis project between Pär Thunberg at the Department of the Civil and Architectural engineering and Olof Philipson at the Department of Architecture, both at the Royal Institute of Technology in Stockholm.

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Stockholm 19 Mars 2009

Pär Thunberg and Olof Philipson
This project investigates the cooperation between architect and engineer. The context of the investigation is the design of buildings for a sustainable society. The goal of the project is to further the development of the sustainable built society by increasing the knowledge of the interdisciplinary cooperation between these two fields. The focus is a close cooperation already from the start of a project. By involving both fields in the early design stages it is thought that the knowledge and skills of each field is better utilized. With both parts working side by side, helping and learning from each others work, a more creative and innovative environment may be achieved.

The project method consists of two parts. The first part is a research study investigating different forms of close interdisciplinary cooperation and different methods for sustainable design. This research study forms the foundation of the second part of the project, an experimental case design. By documenting and then evaluating the cooperation during the design process certain conclusions can be drawn about the investigated design method.

The most important aspect of a close cooperation studied is the informal communication paths. It is essential that these are acknowledged and not limited by rigid formal communication plans. Nevertheless, it is important to include both the architect and engineer in all the major design choices, which may require a general approach to the design process. A design approach similar to a common prototype loop was developed and tested.

The case design experiment is a large office building in a suburb south of Stockholm called Flemmingsberg. The documentation of the design process shows a close involvement of both the architect and engineer in all the major design choices. It is presented by short graphical summaries of the process leading up to a design choice.

The concluding discussion promotes the close cooperation by arguing that it creates a better design process with a higher knowledge input. It is also suggested that the design process promotes innovation, because it forces the members of the design team to widen their view and include new aspects in their design tasks.

SAMMANFATTNING (ABSTRACT IN SWEDISH)


Den avslutande diskussionen argumenterar för ett nära samarbete genom att säga att det skapar en bättre designprocess med ett högre kunskapsinnehåll. Det är också föreslaget att samarbetet gynnar innovation, eftersom det tvingar parterna att vidga deras vyer och inkludera nya aspekter i deras designprocess.
A process chart of the projects progression is presented below. It is placed on each page to illustrate the contents placement in the process. The page content is marked with a pink dotted square. The presentation method of this thesis project differs from the common, therefore a project outline is written below to guide and introduce the chapters and order of the paper.

**PROJECT OUTLINE**

**INTRODUCTION**
The first chapter introduces the project by giving a brief background, goal, method, and scope of the paper.

**RESEARCH**
The chapters within the research strand summarize and formalize the important technical and theoretical ideas that were studied within the fields of interdisciplinary cooperation and sustainable design.

**CASE**
The case project, an office building in Flemmingsberg, is introduced. A brief formalization of the goal and method is stated.

**FINDING FORM**
The pages named Finding Form present the initial ideas about how to approach building design from the start by both the engineer and the architect. The cooperation method of informal communication within a frame of a “design loop” (that was discussed in the research section) is begun. The first loop introduces the idea of a cluster of smaller buildings within a larger climate shell.

**INTERNAL SPACE**
As the design continues, the internal relationships within the building are studied. As a result from previous loops, different ways of zoning the building are investigated in order to find an effective and low energy climate system. A two-zone system is introduced. Some ideas of how natural light can enter the building, as well as the relationship between the atrium and floors are also illustrated.

**FIRST PROPOSAL**
A first proposal of the final building was proposed to bring together the ideas and studies carried out in the first chapters. The proposal suggests five separate building masses with an irregular floor-atrium plan.

**DEVELOPMENT OF STRANDS**
Carrying on from the first proposal a couple of design paths where chosen to be developed in more detail. They were chosen because they were interesting from the perspective of the project goals.

**REVISION / REFORM**
Further ideas about the building shape, climate system, internal space, and more are illustrated in this last development section of the case project. An idea about local energy production integrated with a climate system is also illustrated.

**FINAL PROPOSAL**
The final building proposal is presented with floor plans, sections, and figures showing its energy use.

**CONCLUSION**
Last chapter of the paper revisits and discusses the goals and hypothesis written in the introduction.
**INTRODUCTION**

**BACKGROUND**
The development of society entails the gaining of knowledge and specialization of education and profession. A hundred years ago it was feasible to believe that one person could have the skill to fully design a functional building. As technology increases and more knowledge is produced it is natural to divide a profession into more specific skills. When this is done it is of course essential that the cooperation between the professions work well.

In the context of creating a sustainable society it is important that all aspects of the built environment is studied and improved. This project focuses on the cooperation between architects and architectural/environmental engineers.

**HYPOTHESIS**
Remodelling the design process by integrating the environmental engineer and the architect from the start of a project will create a better building for a sustainable society.

The engineer and architect hold unique skills and interests when designing a building but share common design tasks. A distant cooperation and a separation of each field's design tasks do not utilize the full skill set of the engineer nor architect. When the skills of both the engineer and the architect are applied to a design task the goal of a building for a sustainable society is easier to reach.

A close cooperation will create greater knowledge between the fields and their respective parameters of design. This understanding will be essential for creating and reaching a shared design goal for the building.

**METHOD**
The project will contain two parallel parts:

1. A research study investigating different methods of interdisciplinary cooperation and sustainable design.
2. A case project.

The aim of the case is to experiment with the working methods investigated in the study.

By gaining knowledge in the study and evaluating the project process in the case, a conclusion on the hypothesis can be drawn. There are a couple of significant indicators that will be studied and discussed in order to draw this conclusion, for example:

- The finding of methods for sustainable and interdisciplinary design that are practiced successfully.
- During design of the case project there is significant input from both engineer and architect in most design tasks.
- There is an understanding by engineer and architect of the different values and parameters that the respective fields investigate during the design of the case project.
- The case project building showcases elements of a well-integrated building aimed for a sustainable society.

**SCOPE**
The most important aspect of the project is to study a close cooperation between engineer and architect. Sustainable design methodology is a well-researched field and the study of the subject will therefore be limited to the methods of most important.

Time constraints will also be a variable defining the scope. Subjective decisions will direct what elements will be designed in the case project building. The decisions will be based on the assessed importance of the elements in regard to the project objectives.

The chosen case project is an office building. The design of office buildings will therefore be in focus.

**GOAL**
The goal of the project is to further the development of the sustainable built society by increasing the knowledge of the interdisciplinary cooperation between engineers and architects in the field.

**PRESENTATION**
To demonstrate the project findings, documenting the cooperative design process of the case study is important. This will be achieved by formalizing and summarizing the different ideas and investigations that take place. The summaries are presented as chapters in this booklet.
COOPERATION

As the field of building design has evolved the need for separation of skills and education has been apparent. Building design now involves many professions, like the architect, the interior designer, the structural engineer, environmental engineer and many more. Each profession bring different set of skills for the design of a building. However, the design tasks that can benefit from the involvement of each profession may still be shared. It is therefore important that the cooperation in the design team works well.

Historically, the area with close interdisciplinary cooperation is that between the architect and structural engineer. An architect has a vision of a structure and needs the immediate help of a structural engineer to achieve this vision. Recently the issue of climate change has pushed architects to build more sustainable buildings. To achieve this they now need the help of an environmental engineer to, for example, simulate the designs resource use already in the early design stages. However, examples and research on this type of cooperation are few.

A very broad investigation of the traditional process compared to the investigated cooperative process is summarized to the right.

INFORMAL COMMUNICATION

Informal communication paths are proven to be of great importance in project management. In a close collaboration, such as working side by side, the informal communication between the architect and engineer will be the central way to communicate. Investigating means and methods of formal communication patterns, such as setting up weekly meetings, should be totally unnecessary. Such formalization might constrain the exchange of ideas and the continues discussion that promote the involvement of both parts in all aspects of development. It is vital to recognize the importance and benefits of the informal and not limit the collaboration by searching for a rigid and over structured process plan.

TRADITIONAL PROCESS (very simplified)

Architect formulates the goal and drives the process. The Engineer interweens and solves problems. Likely the engineer takes over the finalization of the design.

COOPERATIVE PROCESS (very simplified)

Both Architect and Engineer does contextual analysis, together they formulate the goal. The design process is more like a ongoing ping pong game with informal exchange of ideas and rapid test-loops of ideas.

CONTEXTUAL ANALYSIS

FORMULATING GOAL

The architect's context is based on the "facts" delivered by the architect.

DESIGN PROCESS

"the engineer comes in and destroys the cool design" 
"the architect doesn't understand budget and technical needs"

COMMUNICATION

The idea is to use formal communication, usually the informal communication has to solve the problems.

ACCUMULATION OF KNOWLEDGE

The engineer gains knowledge through his problem solving. The architect does the cool design but doesn't know how it works.
THE CREATIVE COOPERATIVE PROCESS

The core of the collaboration is that both the architect and engineer take part in the creative process. To allow this to happen there needs to be a strive for idea generation, both collaboratively and individually. Finding inspiration is essential.

Generated ideas need to be discussed and matched. The ideas will reflect each respective fields interests and skills. In order for the process to progress there should to be a shared understanding of the driving parameters of each field. This will allow ideas to be chosen. They can then be explored further by studying them by testing them from the perspective of each field. Informed decision can be drawn from the feedbacks of these tests. Decisions will create a new context for idea generation.

The process can be described as a loop with four main sections; idea generation, matching, testing, and feedback. Each time the loop passes the project progresses and new knowledge has been created.

STARTING POINT

Analysing the project context is a good starting point for the collaboration. Engineer and architect will search and find different aspects of the site. If understood by both fields, they will serve as the perfect ground for collaborative and individual idea sketching.
THE VISION
A society that can meet the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland Commission, 1987).

THE CURRENT SITUATION
Our planets resources are being used at a rate at which they can not be replenished. A broad effort is needed to return the use of natural resources to sustainable limits. The human consumption of energy, food, materials and water are all important contributors. Perhaps the most urgent of these is the consumption of energy.

Our need for energy is largely met by the burning of fossil fuels. This is warming our planet. It is caused by changes in the gas content of our air, which keeps more solar energy inside the earth’s atmosphere and makes the planet warmer. Excess emissions of greenhouse gases (for example CO₂) by the burning of fossil fuels has caused an increase in the natural levels. At the same time we are removing some of the planets natural absorption resources, such as rainforests. The consequences of global warming can be catastrophic to the human population worldwide. It has already been observed that sea level has risen due to the melting of glaciers.

THE STRATEGY
The use of natural resources will be returned to sustainable limits. This will be achieved in two main ways:

1. Efficient consumption. Minimizing our need for energy, food, materials, and water. This can be achieved by example minimizing waste, changing habits, or finding more efficient technologies.

2. Using renewable supplies. Using resources for our consumption that has a low impact on the environment. For example using wind for generating energy instead of burning fossil fuels.

Basically all life on our planet together makes up a sustainable ecological system. This system supplies energy, food, materials, and water to its inhabitants. Nature itself is therefore the perfect reference in sustainable design.

However, it is necessary to consider the driving forces of change in the modern human society. Efficient consumption will always be restricted to needs of the today's lifestyle. Naturally, it is important to consider social and economical factors in the strategy for sustainable design.

THE SUSTAINABLE BUILDING
An important contributor to our current unsustainable society is the buildings that we live in. They consume a large part of our total need for energy and materials. Sustainable building design should thereby be defined as the process to design our buildings as a part of our sustainable society.

This will be achieved by using energy and material efficiently, by, for example, minimizing its need for heating or cooling.

In order to make decisions during the design of a sustainable building, there need to be truthful knowledge of how these decisions influence the resulting resource consumption. It is therefore necessary to find an appropriate measurement.

Almost all processes, both energy and material, in the life of a building can be traced to the release of CO₂ into our atmosphere. As described previously, CO₂ is the significant factor in global warming. It can therefore be appropriate to use this gas as a measurement or indicator of the buildings sustainability.

Several different rating systems have been developed worldwide in order to help and promote sustainable building design. Examples of such assessment systems are LEED (USA) and BREEAM (UK).

The burning of fossil fuels and annual average temperature anomaly between the years 1850 and 2003.

The traditional three circles of sustainability.

Energy use by sector.
Sustainable design
This chapter describes the concept of sustainability and tries to draw conclusions that will guide the search for a design method.

TECHNICAL COMPONENTS
The goal of having a sustainable approach to designing a building is in broad terms to minimize its impact on our environment and its climate. It is therefore important that in order to know how to build sustainable to start by defining how a building uses our natural resources. Use and location of a building are obviously key influencing factors that need to be considered in this definition. A building in, for example, southern Spain has different impact patterns compared to one in Sweden. Likewise, an office building has different impact patterns compared to a residential building at the same location.

An attempt at evaluating the sustainability of a building has to be started by first finding its general components and their functions. Three main component groups can be characterized out of a very basic definition of a building's functional requirements (fig 1). Both architects and engineers should have a solid understanding of these components. Many sustainable designs and methods used today and in the past fail to recognize them. For example, one can insulate a building to a degree where it uses energy for heating extremely efficiently, however, this can result in a huge amount of material that needs to be manufactured, transported, and later disposed of.

It has been decided that an indicator that can be used for measuring the buildings sustainability will be its total release of CO2. Minimizing this release is consequently a main objective of sustainable design. From the functional disposition the major processes that release CO2 can be characterized (fig 2).

1. Structure of the essential technical functions of a building.

2. Technical processes that contribute to global warming; A buildings environmental impact.

Heating & Cooling
Ventilating
Supplying and warming water
Electricity for lighting
Gen. electricity

During life time
Disposal / Recycling
Land use
Manufacturing (mining, transporting etc)
Wasted material
Transport & machine use

During construction

Resource use
Material use

Land use

During lifetime

Material use

Manufacturing (mining, transporting etc)
Wasted material
Transport & machine use
INTRODUCTION
The general components of a building’s resource use have been defined in the previous chapter. In order to design a sustainable building, that minimizes this resource use, there needs to be effective methods to predict the performance of a building already from the start of the design process. From the components of the resource use some important types of simulations can be categorized. Different tools and methods within these categories will be investigated in this chapter.

Simulation methods and tools used in the early design stages have different requirements compared to tools used in the final stages (for example when choosing pipe sizes for the ventilation system). In the early stages, the final building is not known, and the studies conducted consist of comparing different design alternatives. In the final stages, the simulation needs to accurately predict one certain scenario. This difference can be significant in the choice of simulation tool.

The aspect of time is also important when discussing simulation tools in the early design stages. The shorter time a simulation study can be performed, the better and more direct the communication between the design team will be. The need for accuracy versus time always needs to be taken into account when performing a simulation study. In the early stages of design, when the final building is still just an idea, the availability of input data may also limit the accuracy of a simulation, but the output is still very useful when making early design choices.

SIMULATION

1. SIMULATING ENERGY USE
Perhaps the component with the highest impact on the resource consumption of a building is its use of energy to maintain a comfortable interior climate. The models to calculate and estimate this energy use can range from very complex to rather simple. The general components of the energy flows of a full building are seen below.

Considering the need for a constant internal temperature, a simple heat balance model can be set up:

\[ \Phi_T + \Phi_{TB} + \Phi_V + \Phi_n + \Phi_P + \Phi_C = 0 \]

The thermal energy use can be described as the energy flow \( \Phi_T \), cool or heat, that need to be added in order to maintain this heat balance. To accurately predict this balance and its components, a good prediction of the outside climate, such as temperature, cloud cover, etc, need to be made.

There are several methods to estimate the yearly energy use of a building. Usually two main types are recognized, steady state calculations and dynamic calculation methods.

Steady state methods often use material coefficients, such as envelope U-values, to estimate an overall building loss coefficient. This value is then multiplied by statistical data (like degree day figures) to estimate a total heat gains/losses without having to use equations where the temperature varies with time.

- \( \Phi_T \): Heat flow from solar radiation through windows
- \( \Phi_{TB} \): Transmission heat flow
- \( \Phi_n \): Transmission heat flow through thermal bridges
- \( \Phi_V \): Heat flow from ventilation system
- \( \Phi_P \): Heat flow from leaked air
- \( \Phi_C \): Heat flow from a capacitive heat storage
- \( \Phi_{HE} \): Heat flow generated from heating/cooling system
- \( \Phi_{EL} \): Heat flow from appliances, persons etc

Dynamic or non-steady state calculation methods are basically methods that considers a changing temperature with time. Both analytical simplifications and numerical methods, sometimes hybrids, are used. As computer power increases, numerical methods are becoming more widely used.

Analytical methods may simplify the temperature variations by, for example, expressing it as a sinus function to make it easier to derive the total energy use from a time derivative.

Numerical methods estimate the energy flows in small time steps and then solves incrementally as conditions change to finally find a total energy use. A common time step used is one hour.

Due to the high number of iterations the numerical methods often need high computer power. Hybrid solutions are therefore common. There are a number of computer software available to simulate building energy use. Most use numerical methods to dynamically estimate the yearly energy use.

These methods are often comparatively inaccurate since they do not take into account several important factors, such as the dynamic effects of thermal mass.
A popular simulation software is called Autodesk Ecotect. It uses a method called the Admittance Method. This thermal algorithm is very flexible and has no restrictions on building geometry or the number of thermal zones that can be simultaneously analysed. Most importantly, with only a few pre-calculations for shading and overshadowing, it is very quick to calculate and can be used to display a wide range of very useful design information. The underlying assumption of the Admittance Method is that the internal temperature of any building will always tend towards the local mean outdoor temperature. Any fluctuations in outside temperature or solar load will cause the internal air temperature to fluctuate in a similar way, though delayed and dampened somewhat by thermal capacitance and resistance within the building fabric. When the total of all heat losses become equal to the total of all gains, then internal temperatures stabilise. (Ecotect HELP, 2008)

The main reason for Ecotect’s success is its ease of use and graphical 3d modelling interface.

Ecotect also has a very good representation of the result. A wide range of graphs can be produced with the click of a button. The downside to Ecotect is that the fast and easy use limit the simulations accuracy. However, the software is a perfect option for early stages design development, where comparative studies is the main requirement.

A software with a totally different approach is Consolis EnergyPlus, made by Gudni Jóhannesson. This software is Microsoft Excell based and has both a steady state method and dynamic calculation method. The dynamic method calculates three typical days each month, one with clear skies, one partially cloudy, and one cloudy. From these three days and weather data, full monthly energy loads are estimated. This method might be more accurate compared to the admittance method in Ecotect. The downside is the user interface which is all text based.

In order to estimate the electricity use of a building, an accurate prediction of the natural light conditions in the building need to be made. Calculating the light levels by hand is often time consuming and requires a lot of simplifications. Computer software that simulates light levels from a 3d model is a common tools used today. One such tool is, again, Autodesk Ecotect. It is very simple to generate a 3d model and then analyse its light levels.

2. SIMULATING NATURAL LIGHT LEVELS

Material consumption accounts for a significant amount of a buildings resource consumption. During the design stage it can be time consuming to calculate the material use. Using computer modelling software the quantities of different components can be calculated quickly. Some also attempts to, from a 3d model and material data, output CO2 life-cycle data automatically.

Popular 3d-modelling tools include, Autodesk Autocad, Autodesk Revit, Microstation, Rhino 3d, and SolidWorks. Models from all of these can, often with a few modifications, be exported to range of energy simulation, like for example Ecotect.

3. MASSING
GOAL
The goal of the case project is to design a sustainable office building. The target of a sustainable office building will follow the definition and principles discussed in the research chapters.

As part of the broader project, the goal of the case contains the ambition to achieve a significant input from both the engineer and architect in the important design tasks.

METHOD
The design method will be guided by the findings in the study. Both the methods of cooperative and sustainable design will be carefully investigated. The starting point of the design will be the functional disposition of office buildings in regard to the site.

An approach that ideas and guiding principles can change during the process is important in order to achieve the projects objectives.

LOCATION
A piece of land in the Stockholm suburb of Flemingsberg has been chosen as the location of the office building. The region has an extensive municipal plan and the likelihood of future development is high. There was also a potential of improvement in the social structures of the area. Proximity to renewable energy resources was not considered when choosing the location.
An introduction to our case project.

The residential houses are clad with colorful metal panels. Elevation along Huddingevägen.

Grantorp habitat Large scale colorful residential buildings with tenants-ownership.

Södertörn University Sunfeather shape with certain adaptations to topology, centred round a plaza.


Site Situated between Huddingevägen and Terapivägen. The Municipal plan proposes a set off six lamellas with mainly offices. Approximately 45-55.000 sqm.
Cross section through site. Planned deck over railway with buildings on the sides of the tracks. Exposed bedrock. Noisy area. Green and forested areas are not well kept. Residential buildings, with a backside towards Terapivägen. Parking underneath.

Elevation along Huddingevägen. The residential houses are clad with colorful metal panels.
INTRODUCTION

RESEARCH SUSTAINABLE DESIGN

COOPERATION

METHOD

SIMULATION

METHODS

LEARNING

THE GROUND

POINT-LINE-FIELD

BORDER VACUUM

RESOURCE USE

FIRST PROPOSAL

PLAN

SECTION

ROCK

AXIO

(SMHI, 2008)
PROGRAM AND SUSTAINABILITY

The brief needs to be analyzed and decomposed:
- Are there ways of having shared use, pools.
- Can objects and spaces have several functions.
- Can the function of the same space vary over the day (and night).

BRIEF
45-55,000 sqm

USE
Offices as a part of a new regional center in greater Stockholm.

RESOURCES ON SITE
Higher education.
Researchers and students.
Transport.
Different kinds of dwellings in adjacent areas.
Close to recreation (nature preserves and lake Mälaren).

Comparison of two offices and the use of pools in relation to sqm/WS

2 offices with fixed places. Not including areas for transportation, reception and larger conference room. (330x2)/48=13,8 m²/WS

2 offices with half of the WS and a few functions in a pool. Not including areas for transportation, reception and larger conference room. (130x2+230)/48=10,2 m²/WS

LACK
Connectivity. There is great diversity in the area with dwellings, research etc but these fields do not connect and make use of their possibilities to create a very creative region.

According to Richard Florida a region needs Tolerance, Talent and Technique to become a creative region. Tolerance is attained by offering many different kinds of dwellings, meeting places closely knit to the workplaces and a wide range of recreation. Ref. R Florida: Rise of the Creative Class.

POOL
Services such as parking, restaurant and areas for recreation and conferences can be used by more people than just the office tenants. This multiple use will also help to integrate the building as a present part of Flemingsberg. Larger conference rooms can be rented out to Södertörns University, the sports hall used for larger conferences. Existing parking places in Granortorp will daytime be used by office tenants and night time by residents. Facilities such as team rooms and hot desks, are in a pool to be rented when needed. This idea of pools and mixed use is not merely a question about money we think that this mixed use will open up for a better use of the areas diversity.

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<tr>
<td>Changing area</td>
<td>160</td>
<td>1</td>
<td>2000</td>
<td>3.0</td>
</tr>
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</table>

TOTAL

| Total          | 1 698 | 54 246 |

This example shows the use of pools in relation to sqm/WS.
Night rendering of the final proposal.
REFERENCE STUDY
In order to guide the decision making during the design process, there needs to be an understanding of the overall environmental impact of an office building during its entire lifetime. The different aspects of a building’s resource consumption and how they relate to each other is essential to understand. With a sufficient understanding of the typical impact pattern of a building at the proposed site and with similar context, the design process can be focused on the most significant factors. This estimate also enables a general comparison of different design paths that may stand in contrast.

TOTAL CONSUMPTION
An estimate of the general resource consumption of a typical concrete office building in Sweden can be grouped in three main categories:

- Construction 5%
- Material 12%
- Services (Energy) 83%

MATERIAL CONSUMPTION
Roughly 10% of a building’s overall resource consumption can be traced to material use in the building. A reference study has been conducted to find its components: A typical concrete office building has been used.

(1) Energianvändning teori och praktik (2) Energy manual
ENERGY CONSUMPTION

The services provided by a building, such as temperature control and ventilation, represent the largest part of the buildings total resource consumption. However, even these patterns vary greatly with the chosen design. For example, a solid, low window area building will have a much lower cooling requirement compared to a glass facade building. Two buildings have been studied to exemplify the difference.

TYPICAL BUILDING

A large but compact office building with a brick and glass facade. Mostly hidden concrete core structure.
- Envelope area/ floor area = 0.72
- Area towards ground/envelope area = 20%
- Height = 5 floors (ca 20m)
- Window area = 55%
- Windows towards south = 225 m²
- U-value windows = 1.7
- Floor area = 14000 m²

GLASS FACADE BUILDING

A concrete core structure with a glass facade. The concrete is exposed directly to sunlight. The short sides of the building face north and south.
- Envelope area/ floor area = 1.02
- Area towards ground/envelope area = 20%
- Height = 5 floors (ca 20m)
- Window area = 100%
- Windows towards south = 333 m² (10%)
- U-value windows = 1.0
- Floor area = 5500 m²

Typical compact building, Stockholm.

Glass facade building, Stockholm.

(1) Energianvändigsteori och praktik (2) Whites nya kontorsbyggnad i kv Katsan, Stockholm
OBJECTS AND FIELDS OF ATTRACTION
Different attitudes towards flows and connections.

POINT - the strip. The site stretches out along the main road Huddingevägen. Offers good possibilities for exposing ongoing activities. Comparison is the old village road with a good interchange between different users.

Today Flemingsberg consists of several points of attraction without a clear hierarchy in between them. A new travel center is being planned close to the north railway entrance.

FIELD Today the site can be seen as a rough field. The plans are to level the functionally separated roads, bicycle and walking paths. This leveling of the ground will add to the character of a field.

FUSION The site acting as a point, line and field. How can buildings on this site add to this idea of fusion?!

Flemingsberg is divided by the areas different functions. Higher education, dwellings, health care, research. Each area has a boundary, a back side, the inactivated zones between the border turns in to barriers. Some of these back sides are treated in a nice way close to the building but not integrate on an urban level.

Ref. Jane Jacobs' chapter on "Borderside Vacum"

TAKING CARE OF TERAPIVÄGEN

LINE E - the strip. The site stretches out along the main road Huddingevägen. Offers good possibilities for exposing ongoing activities. Comparison is the old village road with a good interchange between different users.

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Ref. Jane Jacobs' chapter on "Borderside Vacum"
Axiometric drawing of the final building proposal, showing its placement on the site.
FLOWS Short flows within each unit.

To generalize, a field condition could be any formal or spatial capable of unifying diverse elements while respecting the identity of each. Field configurations are loosely bound aggregates characterized by porosity and local interconnectivity. Overall shape and extent are highly fluid and less important than the internal relationships of parts, which determine the behaviour of the field. Field conditions are bottom-up phenomena, defined not be overarching geometrical schemas but by intricate local connections. Interval, repetition, and seriality are key concepts. Form matters, but not so much the forms of things as the form between things."

- Stan Allen: Field Conditions

ENGINEERING FORM
In this case, engineering form means optimising a building from a resource efficient perspective. Form will have an impact on several different aspects of the office buildings consumption. Studying the reference building in Stockholm, the relevance of the different aspects can be estimated. The most relevant is the energy use during the buildings lifetime. The shape can be formed to minimize the exchange of thermal energy caused by the difference in temperature between the inside and the outside of the building. Other strategies are forming the building to minimize the energy used to run the climate system, for example minimizing electricity use by using natural ventilation instead of mechanical.

In cold climates like Stockholm, minimizing transmission losses will be the best approach to optimising form. The two main parameters for this are the surface area to the outside and the surface area to the ground.

-  SURFACE AREA 16800m²
- GROUND AREA 1200m² (7%)
- AREA 60m x 20m x 30 floors (36000m²)

Transmission losses %

Transmission losses kWh/yr

Energy need kWh/yr
Normal building, ca 10% window

Glass facade building

<table>
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<tr>
<th>A/V</th>
<th>Ground</th>
<th>Transmission kWh/yr</th>
<th>Energy need kWh/yr</th>
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<tr>
<td>0.70</td>
<td>2.6%</td>
<td>+43%</td>
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</tr>
</tbody>
</table>

We decided that a good starting point in the design process would be the general shape and massing of the building.

"We decided that a good starting point in the design process would be the general shape and massing of the building."

CLIMATE SYSTEM
High surface area, low energy efficiency.

RELATION TO SITE
Building creates its context rather than the other way around. Urbanism and landscape planning is a good idea!

Clusters of buildings inside a climate shell / envelope is a good idea!

A compact close to the ground / in ground, good spatial qualities.

MASSING FINDINGS / CONCLUSION
FINDING FORM
In cold climates like Stockholm, minimizing transmission of thermal energy is crucial for the building's lifetime. The shape can be formed to minimize the energy used to run the climate system, for example, by reducing the surface area to volume ratio. The most relevant aspect is the energy use during the building's lifetime. Studying the reference building in Stockholm helps to estimate the relevance of the different aspects.

ENGINEERING FORM
In cold climates like Stockholm, the exchange of thermal energy caused by the difference in temperature between the inside and the outside of the building is a significant factor. Other strategies are forming the building to respect the identity of each. Field configurations can be estimated, but not so much the forms of things as the internal relationships of parts, which determine the extent are highly fluid and less important than the phenomena, defined not be overarching geometrical porosity and local interconnectivity. Overall shape and or spatial capable of unifying diverse elements while or spatial capable of unifying diverse elements while respecting the identity of each. Field configurations matters, but not so much the forms of things as the internal relationships of parts, which determine the extent are highly fluid and less important than the phenomena, defined not be overarching geometrical porosity and local interconnectivity.

MASSING STUDY
(1368m² / 1944m³)

TOTAL HEAT
0,70

(1080m² / 1944m³)

2,6%

INTRODUCTION
(324m²)

2,6%

1,00

TRANSMISSION(1) kWh/yr

(12474)

30,0%

MUNICIPAL PLAN
(36m²)

100%

Normal building, ca 30% window

52271      18298     33973

Glass facade building

52271      18298     33973

ENERGY CONCEPT
(157970, V 91831, K 66138)

(176111, V 120907, K 55205)

COOPERATE
(176111, V 120907, K 55205)

100%

(157970, V 91831, K 66138)

(65204, V 31489, K 33716)

FLOWS Short flows within each unit. Cold

FLOWS Short flows within each unit. Cold

FLOWS Fast but long vertical flows. Concentrated point, can act as point of gathering.

RELATION PRIVATE / PUBLIC Bottom floor usually public, while others strictly private.

RELATION TO SITE Building creates its own context rather then adapting to the site. Risk of becoming another area of backside and borders.

SKYSCRAPER
- AREA 60m x 20m x 30 floors (36000m²)
- SURFACE AREA 16800m²
- GROUND AREA 1200m² (7%)

GROUNDSCRAPER
- AREA 60m x 60m x 1,5 floors (36000m²)
- SURFACE AREA 21400m²
- GROUND AREA 2400m² (46%)

GROUNDSCRAPER
FLOWS Long sweeping horizontal movements dominate, crossed with short vertical between floor levels. The long distances can influence user interaction negatively.

RELATION PRIVATE / PUBLIC A close relationship between outside and inside due to the closeness to the ground.

RELATION TO SITE Uses full site. Bends with the topography, can lead to variations in form. Can be used to join the adjacent communities.

CLUSTER
- AREA 16m x 15m x 3 floors x 50 buildings (36000m²)
- SURFACE AREA 9000m²
- YTA NOT MARK: 12000m³ (23%)

FLOWS Short flows within each unit. Demands many stairs and lifts. Several ways to move to, from and between the units.

RELATION PRIVATE / PUBLIC Very good possibilities to create a close relation to the surroundings.

RELATION TO SITE Easily adaptable to the topography of the site. The units can spread into surrounding areas and help to unite the separated communities.

A compact shape with good overall energy efficiency.

Very high surface area towards the outside. The ground cover saves a lot of energy loss.

High surface area, low energy efficiency.
INHABITING THE GROUND

To create a room underneath the earth is a common method among animals to protect themselves from heat or cold. Just a few meters of earth can be enough buffer to keep an even temperature the year around. To dig down buildings certainly have architectural problems but it is interesting to study how efficient this method is. The study can motivate that parts or sections of the building is placed in the ground.

MASSING FINDINGS / CONCLUSION
A small scale cluster of buildings will have good spatial qualities.

A compact close to the ground / in ground, will be good for energy efficiency.

A cluster of buildings inside a climate shell / envelope is a good idea!

This very approximate study was made using a typical building envelope and simulated in Ecotect. See appendix 1 for a description on how these studies were carried out.
Rendering of the final building proposal showing the clusters within a shell.
SOLAR DIAGRAM AND SHADING

Solar positions corresponding to the time where cooling needs are higher than heating. Shading is important during these times.

A good indicator of the times of day and time of year that shading is important can be derived from the reference buildings heating and cooling curves. The decline in heating needs and the incline of the reference buildings heating and cooling curves. A good indicator of the times of day and time of year that shading is important can be derived from the reference buildings heating and cooling curves.

Solar radiation influences the cooling needs more than it reduces the heating loads in the winter. Shading is therefore an essential component of office design, even in colder climates.

In this study we investigate a box-building that has windows facing one side only. Our goal was to get an understanding of how much solar energy matters in Stockholm.
Solar positions corresponding to the time where cooling needs are higher than heating. Shading is important during these times.

A good indicator of the times of day and time of year that shading is important can be derived from the reference buildings heating and cooling curves. The decline in heating needs and the incline of cooling is fairly rapid, so the angles of shading becomes quite apparent.

**Solar Radiation**

Solar radiation is the main energy supply for life on our planet. In building design it enters our buildings and heats them up. It can also be harvested by integrating solar panels in the facade systems. However, in a climate like Stockholm, where we have a high need for heat, the sun will still not be of much help. Obviously, the times when heating is needed correspond to the time when the sun is low. In the summer when cooling loads are high, the sun is high and gives a high radiation. Studying the consumption patterns of an office building in Stockholm, and its influence of solar radiation, it is quite clear that solar radiation influences the cooling needs more than it reduces the heating loads in the winter. Shading is therefore an essential component of office design, even in colder climates.
HARVEST & HIDE
A concept derived from the massing of the site was developed in relation to solar radiation. The general idea is to slope the entire building generating two sides, one that harvests the solar radiation, and the other that hides from the solar radiation. The harvest area can be used for both direct energy generation (like using solar panels for thermal heat generation), but also harvesting in the sense of using it as recreational area.

SOLAR RADIATION
Solar radiation is the main energy supply for life on our planet. In building design it enters our buildings through the windows and heats them up. It can also be harvested by integrating solar panels in the facade systems. The harvest area can be used for both direct energy generation (like using solar panels for thermal heat generation), but also harvesting in the sense of using it as recreational area.
INTRODUCTION

RESEARCH SUSTAINABLE DESIGN
COOPERATION
METHOD
SIMULATION
METHODS
LEARNING TO COOPERATE

CASE INTRODUCTION
MUNICIPAL PLAN CONTEXT
PROGRAM

SKETCHING TYPOGRAPHY
FINDING FORM
TYPOLOGY
FEEDBACK

SOLAR DESIGN
SOLAR FORM
CONCEPT

INTERNAL SPACE CLUSTER WITH SHELL
DAYLIGHT & ATRIUM
INTERNAL RELATIONS VIEW

FIRST "FLOWCHART"
DEVELOPMENT OF STRANDS
ROOF COMPONENT
INTERNAL
URBAN SWEEP
ROOF SCAPE
ROOF COMPONENT
FACADES

CONCLUSION / DISCUSSION
REVISION OF PROCESS
REVISION / REFORM
REFORM
PUBLIC SPACE
ENERGY CONCEPT
STRUCTURE
CLIMATE SYSTEM
FLOOR SLABS
ZONES

INHABITING THE GROUND
POINT-LINE-FIELD
BORDER VACUUM
RESOURCE USE
FIRST PROPOSAL
PLAN
SECTION
ROCK
AXIO

Sketch of interior effects.
INTERNAL SPACE

SMALL SCALE
Unique qualities
Variation in flows and visual connections.
Divided.
Many meeting places

DYNAMIC TENSION
The quest is how to make a set of buildings which have the qualities of both the small and large scale systems. We think that the dynamic tension between these two can create strong spatial qualities.

LARGE SCALE
Easy to orientate
Efficient flows and easily made suitable for the disabled.
Joined together

ADJUSTMENT OF INTERIOR CLIMATE TO PROGRAMMATIC NEEDS

100% of volume is kept at highest comfort level.
+ All volumes can be used for all program needs.
- Large volume to heat and cool.

80% of volume is kept at highest comfort level.
20% is atrium, not heated.
+ Low energy use.
- Atrium spaces can not be used

55% consists of work stations and meeting rooms, 20-23 degrees C.
45% can have a higher tolerance, 18-26 degrees C. Designated for informal meeting places, hot desks, lounge, café, copy.

Potential energy saving by limiting comfort.
ATRIUM & DAYLIGHT

A compact building needs to have voids, atriums, to let daylight into the floors inside. A cluster of smaller buildings inside a compact envelope will create a dispersed and decentralized atrium volume. How does this compare to a more common atrium plan?

Small dispersed atriums are preferable over larger centralized. At a certain floor width and height there is an optimal atrium size.

Minimum daylight level: 540 lux.

Minimum daylight level: 540 lux.

Minimum daylight level: 530 lux.

ATRIUM

Finding form of the atriums. How can they let in light, open up to views and avoid direct sunlight.

Centred atrium.

North - South direction.

Atriums which opens up against south. They reduce the amount of floor area which is hit by the direct sun nad on the same time open up for better views to the exterior.

The overlaps permits interior walls from floor to ceiling. These can be used to create different climate zones.

Shifting around the floors to create atriums that have more the qualities of double height spaces rather than deep light shafts.

Minimum daylight level: 540 lux.

Minimum daylight level: 640 lux.

Minimum daylight level: 530 lux.

North - South direction.

The overlaps permits interior walls from floor to ceiling. These can be used to create different climate zones.
DEVELOPMENT OF FLOOR PLANS

Two lamellas with atrium between. Adjustment to suns direction Combination Developed in to clusters

By looping the plan and the section there are more ways to both divide and connect parts of the building.

The varying overlaps and connections add to the creation of three dimensional clusters. High comfort zones are in the overlaps and more informal meetingplaces in the double height spaces which also are more visually connected to the building as a whole.
Sketch of interior space.
HARVEST
- Solar panels, terraces, plants
- Skylights for direct solar intake

INTERNAL ENVELOPE
- Only sound and safety, no climate protection (wind, rain). Possibly climatic boundary.

ROCK
- Cool and heat storage, both seasonal and daily.

FLOOR PLAN
- Width of 1.2m

OUTER ENVELOPE
- Limiting the envelope size. Different temperature zones within inner and outer envelopes.

URBAN LINK
- Passage, services and meeting places for office tenants, local inhabitants, students and researchers.

HIDING ROOF
- Skylights, reflective glass

ATRIUM
- North to south orientation

COMMUNICATIONS
- Long staircase, tilted elevator or vertical staircases and elevators.

HIDING FACADE
- Forward-tilting facade hiding from the sun.

17 NOVEMBER
After the initial studies a first proposal of the final building was produced.
ROOFSCAPE DEVELOPMENT

SOLAR DRIVEN DESIGN OF ROOF

“Traditional” roof
Facades letting in the sun

Industrial roof
Blocks the sun, lets in the light.

Industrial roof as section of the building.

SOLAR DRIVEN DESIGN OF ROOF COMPONENTS

The same type of components spread over the roof. Components must be adopted to the roof’s angle relative the sun and desirable views.

Components change according to roofs angle and opens up to create views. The parts exposed to the sun can be used for harvesting solar radiation.

ROOFSCAPE ADAPTED TO SITE

Industrial type section placed on site

Placement of massing on site, enabling passage inbetween and with possibilities to use the bedrock as thermal mass. Connecting the two building masses with a roofscape. The lower part hosts a public sports hall.

Site conditions

TOPOGRAPHY, EXPOSED BEDROCK
LOWER GROUND

ROAD CROSSING THE SITE

SITE CONDITIONS
LOWER GROUND
EXPOSED BEDROCK
TOPOGRAPHY
PLACEMENT OF MASSING
ENABLING PASSAGE INBETWEEN AND WITH POSSIBILITIES TO USE THE BEDROCK AS THERMAL MASS.
CONNECTING THE TWO BUILDING MASSES WITH A ROOFSCAPE. THE LOWER PART HOSTS A PUBLIC SPORTS HALL.
POTENTIAL USE

The proposed scale of the roof focuses the attention on the possible use of its different components. Besides shielding from the exterior climate, the components can have several other uses.

SOLAR HARVEST SYSTEMS
Potential for harvesting solar energy. Solar panels to heat water for tap water needs and perhaps for long term heat storage. Possible placement of photovoltaic panels generating electricity. There might also be a potential for harvesting cold during clear winter nights for long term cold storage.

REFLECTIVE SURFACE
Potential for a reflecting surface that will increase the natural light passing into the glass/void components.

WALK ON SURFACE
The roof component can be used for leisure or transportation of people. Terrace.

ACTIVE CLIMATE COMPONENTS
Components can be used as a component in a climate system. By opening and closing the climate shield it can help an active natural cooling or ventilation system.

GLASS/VOID
Letting natural light into the interior space. Enables views from the office desks out to the surrounding environment.
ROOF COMPONENTS

Local individual transformation of triangular element by changing centrepoints altitude and relative distance from borders.

Global transformation in relation to solar angle. Local transformation for light (atrium) and dark areas.

Variations
Altitude, scale, assembly
Interior view of the footscape and rear view of the final building proposal.
PROPOSAL: URBAN SWEEP

20 DECEMBER
A roof that turns according to the site topography and building massing. Between the building masses, the roof meets the ground and make up a ground cover with the same pattern as the triangular components on the roof. The building opens up towards Huddingevägen as well as towards the backside areas.
When revising the parameters of design, certain problems with the proposed shape clarified. For example, the slope of the hide surface of the roof was not steep enough to be shadowed from the sun during the important summer days. Another problem was the large surface area of the building envelope. The steep sloping facades create problems with unused space.

The rethinking of form rationalized the building shape and massing. The result was two building masses with a more rational shape, similar to the first proposal.
FACADE SYSTEM
The facades facing south east have scales. These scales protect the glazed parts from the sun, the scales vary in opening angle and shape. The surface not shaded by the scales is dense and insulated. The test from Ecotect show the different versions efficiency as shading devices. The aesthetic considerations of this facade system is that it will change in appearance depending on the spectators viewing angle both from the in- and outside.

The facades facing north west are glazed.

Inside view towards south

Inside view towards east

Outsideview from south

Outsideview from east
INTRODUCTION
RESEARCH SUSTAINABLE DESIGN COOPERATION METHOD SIMULATION METHODS LEARNING TO COOPERATE CASE INTRODUCTION MUNICIPAL PLAN CONTEXT PROGRAM SKETCHING TYPOGRAPHY FINDING FORM TYPOLOGY FEEDBACK SOLAR DESIGN SOLAR FORM CONCEPT INTERNAL SPACE CLUSTER WITH SHELL DAYLIGHT & ATRIUM INTERNAL RELATIONS VIEW INTERNAL CLIMATE FIRST "FLOWCHART" DEVELOPMENT OF STRANDS ROOF COMPONENT INTERNAL URBAN SWEEP ROOF SCAPE ROOF SCAPE ROOF COMPONENT PROPOSAL PLANN REVISION PUBLIC IMAGE ROOF SCAPE ROOF COMPONENT PROPOSAL STRUCTURE CLIMATE SYSTEM FLOOR SLABS ZONES CONCLUSION / DISCUSSION REVISION / REFORM PUBLIC IMAGE ROOF SCAPE PROPOSAL REVISION / REFORM PUBLIC SPACE ENERGY CONCEPT STRUCTURE CLIMATE SYSTEM FLOOR SLABS ZONES CONCLUSION / DISCUSSION REVISION / REFORM PUBLIC SPACE ENERGY CONCEPT STRUCTURE CLIMATE SYSTEM FLOOR SLABS ZONES CONCLUSION / DISCUSSION
MATERIAL IN STRUCTURE
The choice of material in the buildings structure has a large influence on the overall resource consumption. There are two main aspects to consider. First, the structure accounts for around 60% of the total material use in the building. The environmental impact on producing and transporting these materials represents a large share of the buildings total consumption. In this aspect, using wood is much more efficient then for ex concrete or steel.

Secondly, the heat storage capacity of the structural material also influences the overall consumption. A heavy material like concrete, will store thermal energy and even out temperature differences, reducing energy needs.

Hence, a decision on structural material should therefore include both a consideration for material consumption and its impact on energy consumption. In our building, the high level height allows us to use wood as a well as steel or concrete in the structure. Comparing the benefits of thermal mass with the decreased material consumption will be an important factor when deciding structural material.

WOOD VS. CONCRETE
How much can the buildings resource consumption be cut by using a wooden structure instead of a concrete?

MATERIAL CONSUMPTION

- Building services 10%
- Fitting out 20%
- Envelope 14%
- Structure 56%

A wooden structure saves 77% of the structures material consumption (compared to concrete)\(^1\).\(^2\)

ENERGY CONSUMPTION

- Warm water 13%
- Electricity 29%
- Heating 45%
- Cooling 13%

A concrete structure cuts 6% of yearly thermal energy consumption compared to wood\(^2\).

CONCLUSION
The pie-charts show the consumption pattern for an average modern office building in Stockholm. If it was built in wood a rough estimate gives:

-4% (Material savings)
-3% (Thermal mass losses)
-1% (Overall savings)

Considering the material savings and the losses due to lower thermal mass, wood is the better choice for the structure (by 1% of overall resource consumption). However, it should also be known that the accuracy of the study is low. Several factors contribute to the lack of accuracy, for example, the total impact of the heating energy consumption varies greatly with the choice of energy supply source. The 1% is, in comparison to an estimated accuracy, very low.

In conclusion, it should rather be said that the choice between wood and concrete, when looking at thermal mass and material consumption of the building structure, is roughly even.
ENERGY SUPPLY & CLIMATE SYSTEM

Energy supply can have an impact on the efficiency of a climate system. There also needs to be a flexibility that allows different and future potential energy supply sources.

On our site we have access to two local sources of energy, direct solar and stored solar in rock. The harvesting of these sources needs to be compared to the use of more centralized energy supplies, like "fjärrvärme".

An idea of thermal energy supply has been developed that fits the site and the buildings potential. With an appropriate low exergy distribution system, the need for heating and cooling should be able to be supplied all locally. The idea utilizes the harvesting roof surface by strategic placement of solar panels. The solar energy is then stored in the rock below the building. During the winter a similar storage on the other side of the building is used to store cold that can be used in the summer for cooling.

Schematic views of the seasonal heat and cold storage.

STRUCTURE & CLIMATE SYSTEM

The material in the structure will also influence the choice of climate distribution system. The possibility of an efficient low exergy system is harder to achieve with a wooden structure. A heavy structure will act as a thermal mass and reduce energy needs significantly.

High exergy system. "Good" energy source, large temperature difference, and centralized distribution.

Low exergy system. "Bad" energy source, small temperature difference, and need for a large surface area for distribution.

STRUCTURE & INTERIOR APPEARANCE

Aesthetic ambitions in relation to the building's structure. A clean and calm appearance in contrast to the lively roof. A readable structure and so easily accessible that it allows for transformation over time. Electrical and data cables from the floor, to avoid suspended cables. Avoiding overall covering acoustic ceilings. A system which can function in the two comfort zones.

Wood: Gives a sense of warmth, which can add to the feeling of small houses in a shell. A wooden structure does not need a form work.

Concrete: Has a surface which can be treated in many ways. If cast in situ it needs a form, while we want to use the thermal mass of concrete this form can not be left. A surface material. Precast it can be provided with a very smooth surface. By using a whiter cement it will reflect light in a good way.

Structure 56%

Building services 10%

Electricity 29%

Warm water 13%

Cooling 13%

The pie-charts show the consumption pattern for an estimated accuracy, very low.
CLIMATE SETUPS

Heating and cooling from ceiling (for example pipes).
+ Large surface area, low temperature needs. Good for cold circulation.
- Heat will have difficulties reaching floor.

Heating from floor, cooling from ceiling (pipes).
+ Large surface area, low temperature needs. Good for both cold and heat circulation.
- Large system with high material input.

Radiators for space heating and air cooling.
+ Low material requirement. Easy to manage.
- Low surface area of heat distribution, needs high temperature source. Air cooling not very efficient.

Activated floor slab, thermodeck. Floor slab heated and cooled with ventilation air.
+ Very large surface area. Potential for low exergy energy source. Integrated systems means less material use. No need for a distribution pump.
- System complexity (built in structure).

THERMODECK

Thermodeck is an application of prefabricated hollow concrete slabs. By running air through the hollow core the slab can be thermally activated and used as distributor for heating and cooling. The thermal lag reduces energy needs by utilizing the daily temperature differences inside and outside the building. For example, outside temperature may drop significantly during night, by pushing air into the slabs they will cool down. Due to thermal lag they will remain cold until next the day and can then be used for cooling. It is important that the concrete is fully exposed to the air in the room.

Usually the air is inserted in the centre of the slabs (figure A) with an air duct running below the ceiling. A possibility with our 12m interior floor plan, is to move the air duct to the side of the floor slab, thus creating a flat, fully exposed ceiling (figure B).
The resulting idea is to make our 12 meter floor slabs out of hollow concrete slabs. The slabs will be used for all distribution of heat, cold and ventilation in the building.
Energy use estimated with Consolis Energy+ (with the dynamic method). The result was validated in VIP+ (fan power was also estimated using VIP+). Calculation excludes the buildings local energy supply (seasonal bedrock storage).

Cooling and heating needs:
- Cooling zone 1: 52 kWh/m²yr
- Cooling zone 2: 13 kWh/m²yr

Fan power (if no natural vent):
- Heating zone 1: 100 kWh/m²yr
- Heating zone 2: 120 kWh/m²yr

Total building energy (for comfort):
- Heating zone 1: 80 kWh/m²yr
- Heating zone 2: 60 kWh/m²yr

Including an estimate for the energy concept, the total energy demand is calculated to:
- 18 kWh/m²yr

Energy losses:
- Transmission 36%
- Air leakage 6%
- Ventilation losses 58%

Energy use breakdown:
- Fans 18%
- Electricity 30%
- Heating 20%
- Cooling 32%

With energy concept:
- BBR (kWh/m²yr): - 35%
- - 82%

Compared to BBR (kWh/m²yr):
- Coolin zone 1: - 82%
- Coolin zone 2: - 82%
- Heating zone 1: - 82%
- Heating zone 2: - 82%

INTRODUCTION

RESEARCH SUSTAINABLE DESIGN COOPERATION METHOD SIMULATION METHODS LEARNING TO COOPERATE CASE INTRODUCTION

MUNICIPAL PLAN CONTEXT PROGRAM SKETCHING TYPOGRAPHY FINDING FORM TYPOLOGY FEEDBACK

SOLAR DESIGN SOLAR FORM CONCEPT INTERNAL SPACE CLUSTER WITH SHELL DAYLIGHT & ATRIUM INTERNAL RELATIONS VIEW

FIRST "FLOWCHART" DEVELOPMENT OF STRANDS ROOF COMPONENT INTERNAL URBAN SWEEP ROOF SCAPE ROOF COMPONENT FASADE

REVISION OF PROCESS REVISION / REFORM REFORM PUBLIC SPACE ENERGY CONCEPT STRUCTURE CLIMATE SYSTEM FLOOR SLABS ZONES

CONCLUSION / DISCUSSION

INHABITING THE GROUND POINT-LINE-FIELD BORDER VACUUM RESOURCE USE FIRST PROPOSAL PLAN SECTION ROCK AXIO
INTRODUCTION
RESEARCH SUSTAINABLE DESIGN COOPERATION METHOD SIMULATION METHODS LEARNING TO COOPERATE

CASE INTRODUCTION MUNICIPAL PLAN CONTEXT PROGRAM SKETCHING TYPOGRAPHY FINDING FORM TYPOLOGY FEEDBACK

SOLAR DESIGN SOLAR FORM CONCEPT

INTERNAL SPACE INHABITING THE GROUND POINT-LINE-FIELD BORDER VACUUM RESOURCE USE

SITE PLAN

56
INTRODUCTION

RESEARCH

SUSTAINABLE DESIGN

COOPERATION

METHOD

SIMULATION

METHODS

LEARNING TO COOPERATE

CASE INTRODUCTION

MUNICIPAL PLAN CONTEXT

PROGRAM

SKETCHING TYPOGRAPHY

FINDING FORM

TYPOLOGY

FEEDBACK

SOLAR DESIGN

SOLAR FORM

CONCEPT

INTERNAL SPACE

CLUSTER WITH SHELL

DAYLIGHT & ATRIUM

INTERNAL RELATIONS

VIEW

INTERNAL CLIMATE

FIRST "FLOWCHART"

DEVELOPMENT OF STRANDS

ROOF COMPONENT

INTERNAL

URBAN SWEEP

ROOF SCAPE

FINAL PROPOSAL

REVISION OF PROCESS

REVISION / REFORM

REFORM

PUBLIC SPACE

ENERGY CONCEPT

STRUCTURE

CLIMATE SYSTEM

FLOOR SLABS

ZONES

CONCLUSION /

DISCUSSION

ROOF SCAPE

ROOF COMPONENT

FACADES

INHABITING THE GROUND

POINT-LINE-FIELD

BORDER VACUUM

RESOURCE USE

FIRST PROPOSAL

PLAN

SECTION

ROCK

AXIO

LEGEND FLOOR PLANS

High comfort zone

Medium comfort zone

Void

SCALE 1:200

0 10 20 30m

SCALE 1:400

0 10 20 30m

SCALE 1:2000

0 100 200m

SCALE 1:1000

0 50 100m

LEGEND FLOOR PLANS
INTRODUCTION
RESEARCH
SUSTAINABLE DESIGN
COOPERATION
METHOD
SIMULATION
METHODS
LEARNING TO COOPERATE
CASE
MUNICIPAL PLAN CONTEXT
PROGRAM
SKETCHING TYPOGRAPHY
FINDING FORM TYPOLOGY
FEEDBACK
SOLAR DESIGN SOLAR FORM CONCEPT
INTERNAL SPACE CLUSTER WITH SHELL
DAYLIGHT & ATRIUM
INTERNAL RELATIONS VIEW
INTERNAL CLIMATE

FIRST "FLOWCHART" DEVELOPMENT OF STRANDS ROOF COMPONENT INTERNAL
URBAN SWEEP ROOF SCAPE

FINAL PROPOSAL REVISION OF PROCESS REVISION / REFORM PUBLIC SPACE
ENERGY CONCEPT STRUCTURE CLIMATE SYSTEM FLOOR SLABS ZONES

CONCLUSION / DISCUSSION

INHABITING THE GROUND
POINT-LINE-FIELD
BORDER VACUUM RESOURCE USE
FIRST PROPOSAL PLAN SECTION
ROCK AXIO
INTRODUCTION

RESEARCH

SUSTAINABLE DESIGN

COOPERATION

METHOD

SIMULATION

METHODS

LEARNING TO COOPERATE

CASE

MUNICIPAL PLAN CONTEXT

PROGRAM

SKETCHING

TYPOGRAPHY

FINDING FORM

TYPOLOGY

FEEDBACK

SOLAR DESIGN

SOLAR FORM

CONCEPT

INTERNAL SPACE

CLUSTER WITH SHELL

DAYLIGHT & ATRIUM

INTERNAL RELATIONS VIEW

INTERNAL CLIMATE

FIRST "FLOWCHART"

DEVELOPMENT OF STRANDS

ROOF COMPONENT

INTERNAL

URBAN SWEEP

ROOF SCAPE

ROOF COMPONENT

FACADES

INHABITING THE GROUND

POINT-LINE-FIELD

BORDER VACUUM

RESOURCE USE

FIRST PROPOSAL

PLAN

SECTION

ROCK

AXIO

LEGEND FLOOR PLANS

- High comfort zone
- Medium comfort zone
- Void
Looking back at the study and the lessons learned during the case project, conclusions can be drawn on the importance and the benefits of a close cooperation in the field of sustainable building design. To the extent possible by the scope of the project, it is clear that the cooperation exemplified during the case project promotes the design of better buildings for a sustainable society.

IN VolvEmEN
The early cooperation in the design process has led to a rewarding result. Both architect and engineer have to cross new borders and watch the case/problem their findings from a new point of view.

AccUMuLATION OF KNOWLEDGE
Throughout the process both parts gained knowledge about each other’s fields of work and reached an understanding for each other's ambitions. This knowledge helps to translate between the architect and the engineer.

Promotes innovation
We do not argue for a merging of practices. What we want to promote is a close cooperation where the different forces and views are used to create a dynamic climate where innovations can take place.

Informal communication
Ping-Pong. In our process we used a very informal way of communicating ideas, we sat around the same table and could directly ask a question or test an idea. We think that this informal and fast communication has been useful.

iterative and/or parametric process
We worked with a more iterative design process to achieve a fast output. By looking on parts of the building in their specific context we could keep the process quite fast all the time. But if some findings argued that we needed to remodel larger parts it took time to redraw.

This is a speculative idea about two different design processes: Iterative, where a few models are made, tested and evaluated against each other. This process can have a quite fast output in the beginning but as the project develops and the models become more and more complex it risks to slow down due to the time it takes to remodel the project. Parametric, a parametric model is set up and can then be used to create wide array of models. This process can take a long time in the beginning till that the parametric model is set up, but when running it can easily be adjusted.
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Appendix 1

Ecotect is a tool by Autodesk made to help architects and engineers simulate buildings from early stages of designs. During the project Ecotect was used to perform many of the initial studies in the beginning of the case project. This appendix will show how to recreate these studies and show how Ecotect is used to perform early stage building analysis.

1. The software user interface.

2. Setting site and location.
   Location is set on a map and specific and up-to-date weather data can be imported to the program (.wea files).

3. Building a 3d model.
   Ecotect has a built in 3d-modelling software. Models can also be imported from other software.
4. Setting material and zone data.
Set the materials in the building envelope. It is possible to create your own materials as well as selecting standard wall types / materials from a list. Settings for internal zones are also defined. Here you choose, for example, the desired internal temperature range, number of people in the zone, and type of use.

5. Running analysis.
Several different calculations can now be made by simply pressing a button. These include monthly and hourly loads, solar gains, internal gains etc.

6. Exporting data
The data from the calculations can be exported to a file to be used in other software (.txt file)

7. Changing one parameter
During the case project, a couple of studies were performed to investigate an impact of a particular parameter. It is easy to do these tests in Ecotect as you can simply alter the 3d-model to achieve, for example, a different angle towards the sun.

Typical values used in the case project initial studies:

\[ A_\text{vol} = 648 \text{m}^2 \]
\[ V = 648 \text{m}^2 \times 3 \text{m} = 1944 \text{m}^3 \]
\[ U_{\text{wall}} = 0.2 \text{W/m/°C} \]
\[ U_{\text{window}} = 1.3 \text{W/m/°C} \]
\[ T_{\text{int}} = 20-23 \text{°C} \]
\[ q_{\text{int}} = \text{Climate data Stockholm} \]
\[ N_{\text{people}} = 36 \text{ persons (1 per 18m}^2) \]
\[ q = 30 \text{ W/m}^2 \text{ (Lamps, computers etc)} \]
\[ V = 25 \text{ oms/h} \]

Materials:
- Wall: Concrete with insulation U=0.2
- Windows 3-glas aluminium frame U=1.9 reflectance=0.8
- Roof: U=0.2
- Floor slab: U=0.2