transform_technical investigations

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Stig Bang Krogh

Rikke Winding Madsen

Maria Claire Pedersen

Supervisors:
Architectural: Peter Lind Bonderup
Technical: Peter V. Nielsen

table of content

introduction

During the design process different technical aspects have been investigated to ensure an integrated project with coherence between the architectural expression and the technical requirements and parameters involved in the design. The different aspects have been investigated and implemented in relation to the different quandaries occuring during the process.

The aim of the project has been to fulfil low energy building class 1 that prescribe an energy frame of 50 kW/m^2 per year + 1100/A (A being heated floor area) why preliminary programs as 24 h average and monthly average have been introduced to present an estimation of internal temperatures and energy consumption early in the process to create an understanding of the different parameters and their rules according to the design.

Here window sizes and orientation, different materials and their thermal capacity, weather conditions and solar radiations have been examined to determine the optimal conditions for each component, which have been considered during the design process.

BSim and BE06 have been used to verify the final solution however the outcome has been adjusted retroactively.

In addition other simulation programs have been introduced to the project to verify other challenges that have occured during the process. Here acoustic examination of the auditorium, light studies in the offices and structural investigations of the hanging café can be mentioned among others.

The different investigations have had great influence upon the discisions made during the process however the values have always been evaluated in relation to the architectural expression and the different possibilities of implementations.

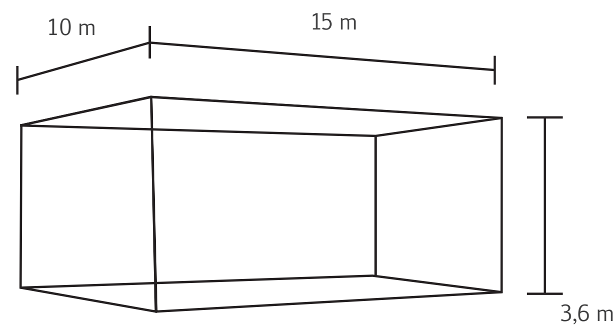
24H average & Month average

To ensure a minimum energy consumption, buildings, wall constructions and window areas have been investigated through the spreadsheet applications; Month average and 24-hour average developed by Aalborg University for the department of architectural engineering. Month average giving an idea of the energy consumption for a given space, determined by dimensions, occupancy, ventilation, materials and window areas, while 24 h average gives an idea of the internal mean- and max temperatures and their variation.

silo 03_energy consumption

The function in Silo 03, being mainly offices, introduced the idea of a double glazing facade towards North and West to create an unheated area with a higher temperature than outside, hence lowering the heat transmission loss from the offices, resulting in possibilities for larger areas of glazing towards North. Apart from the sustainable solution within the double facade of the building the expression of the tower being constructed as an outer shell with an inner core of functions rising above the existing building volume has been of big importance. To obtain a light expression of the inner wall and through that a contrast to the existing wall construction of Silo 03 the walls are constructed from either glass or polycarbonate. To determine the possibility for this solution and the amount of needed window areas in the office spaces, investigations are made through the use of Month average and 24-hour average spreadsheets.

the box



Overall dimensions of the box;

Floor area: 150 m^2

Roof area: 150 m^2

Walls;

- **South**: 54 m^2
- **North**: 54 m^2
- **East**: 36 m^2
- **West**: 36 m^2

Volume: 540 m^3

Ventilation for the office occupied by 10 persons: 1,85 h^{-1}

Working hour: 08:00 – 20:00

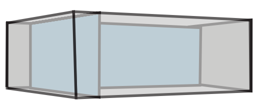
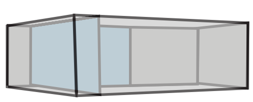
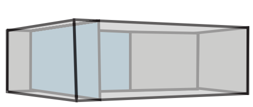
Lux level: 200 lux.

the procedure

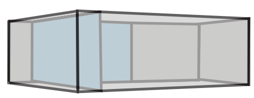
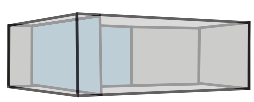
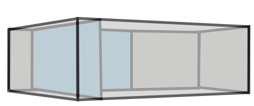
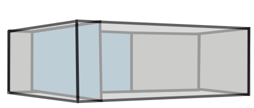
The office space is initially investigated regarding the use of a material with a relatively high U-value (1,1 W/m^{2}K) located on the North and West facade. To be able to compare the results and to get a realistic idea of them, certain parameters have been held as constants through this investigation. These parameters are the amount of windows, which have been determined by the guiding 22% of the floor area as in the Danish building regulation (BR08) with the majority of the windows positioned towards South. Also the U-values have been determined by BR08. (00 + 01)

The following investigations concern the size of the windows, which will mainly affect the southern facade of the building. The two possibilities have also been evaluated in terms of the architecture.(01 + 02)

The last investigations concern the possible amount of windows towards North and West in the two previous scenarios. (01A-B + 02A-B) silo 03_results

	24-hour average	month average	
[00]  **U-values;** north/west: 1,1 W/m^2 K south/east: 0,2 W/m^2 K floor/ceiling: 0,2 W/m^2K Windows: 1,1 W/m^2K **Window areas;** south: (4*(1,6m*3,6m)) 23m^2 east: 0 m^2 west: 8 m^2 north: 2 m^2	july: 24- hour average temp: 22,4 °C 24-hour temp. variation: 3,2 °C 24-hour max. temp: 24,1 °C	49,0 kWh/m^2 year used for heating.	Amount of polycarbonate vs. concrete in the North facade
[01]  **U-values;** north/west: 0,65 W/m^2 K * south/east: 0,2 W/m^2 K floor/ceiling: 0,2 W/m^2K Windows: 1,1 W/m^2K **Window areas;** south: (4x(1,6mx3,6m)) 23m^2 east: 0 m^2 west: 8 m^2 north: 2 m^2 * 50/50 concrete/polycarbonate; ((27m^2 ;x 0,2 W/m^2K) + (27 m^2 x 1,1 W/m^2K)) /54m^2 = 0,65 W/m^2K	july: 24- hour average temp: 22,5 °C 24-hour temp. variation: 3,3 °C 24-hour max. temp: 24,2 °C	28, 5 kWh/m^2 year used for heating. 1,0 kWh/m^2 year used for cooling.	Amount of polycarbonate vs. concrete in the North facade
[02]  **U-values;** north/west: 0,65 W/m^2 K south/east: 0,2 W/m^2 K floor/ceiling: 0,2 W/m^2K Windows: 1,1 W/m^2K **Window areas;** south: (4x(2,4mx3,6m)) 31m^2 ** east: 0 m^2 west: 8 m^2 north: 2 m^2 ** wider window bands; 1,6 m --> 2,4 m	july: 24- hour average temp: 22,8 °C 24-hour temp. variation: 3,5 °C 24-hour max. temp: 24,5 °C	27,7 kWh/m^2 year used for heating.	Window areas towards South

Possible window areas towards West and North
Two scenarios according to window areas towards South, 0 towards East.

U-values; north/west: 0,65 W/m^2 K south/east: 0,2 W/m^2 K floor/ceiling: 0,2 W/m^2K Windows: 1,1 W/m^2K	24-hour average	month average
[01A]  **Window areas;** south: (4x(1,6mx3,6m)) 23 m^2 east: 0 m^2 west: 10 m^2 north: 5 m^2	july: 24- hour average temp: 22,6 °C 24-hour temp. variation: 3,3 °C 24-hour max. temp: 24,3 °C	30,3 kWh/m^2 year used for heating.
[01B]  **Window areas;** south: (4x(1,6mx3,6m)) 23 m^2 east: 0 m^2 west: 15 m^2 north: 10 m^2	july: 24- hour average temp: 22,6 °C 24-hour temp. variation: 3,4 °C 24-hour max. temp: 24,3 °C	29,5 kWh/m^2 year used for heating.
[02A]  **Window areas;** south: (4x(2,4mx3,6m)) 31 m^2 east: 0 m^2 west: 10 m^2 north: 5 m^2	july: 24- hour average temp: 22,8 °C 24-hour temp. variation: 3,6 °C 24-hour max. temp: 24,6 °C	27,6 kWh/m^2 year used for heating.
[02B]  **Window areas;** south: (4x(2,4mx3,6m)) 31 m^2 east: 0 m^2 west: 15 m^2 north: 10 m^2	july: 24- hour average temp: 22,8 °C 24-hour temp. variation: 3,6 °C 24-hour max. temp: 24,6 °C	27,4 kWh/m^2 year used for heating.

conclusion:

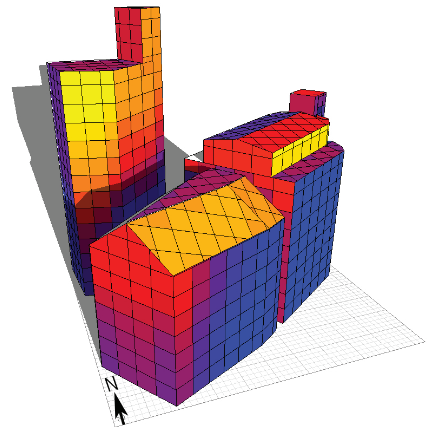
In the final design of the North-West facade the amount of polycarbonate combined with a more heat accumulating material, as concrete, can be very important to obtain the demand for energy consumption in energy class 1, as seen in investigation [00] and [01].

The amount of window area towards South in the two scenarios [01] and [02] do not create an outstanding difference in the energy consumption, why the architectural expression of the facades will be the determining factor in the final result of the design.

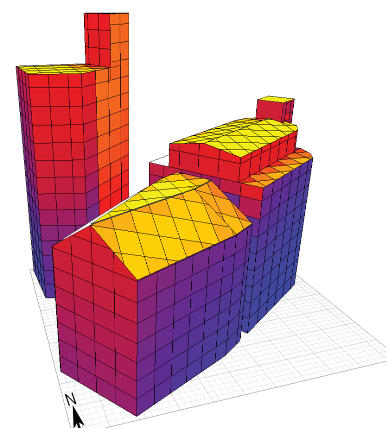
silo 04_window orientation

introduction

A large part of the facades towards South of the existing buildings are not, as shown through the application Ecotect, exposed to direct sunlight, as a large construction will be build close to the southern facade of Silo 02 and 04. To determine the impact of the construction the facades of Silo 04 have been investigated through the use of Month average and 24-hour average spreadsheet regarding energy consumption and temperature differences.



DIrect solar radiation



Diffuse solar radiation

Input

The Box:
Width: 25 m
Depth: 20 m
Height: 4 m
Volume: 2000 m3

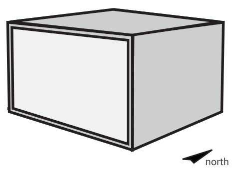
Facade areas:
North - South: 100 m2
East - West: 80 m2
Floor: 500 m2
Roof: 500 m2

U-values:
Outer walls: 0,2 W/m2 K
Ceilings: 0,15 W/m2 K
Floor: 0,12 W/m2 K
Windows: 1,1 W/m2 K
g-value: 0,6 [-]

Input:
Min. temp: 21 C
Max. temp: 26 C
Max. window area: 110 m2
Occupants: 170 pax

Ventilation Input:
Infiltration: 0,9 h-1
Airchange - peak: 5,03 h-1
Airchange - off-peak: 1,20 h-1

[01] 100 % open South facade - shadow from construction on site

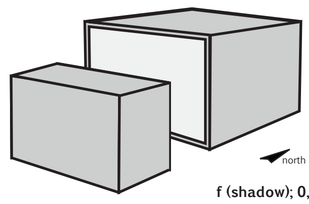


f (shadow); 0,9

Window area: 100 m^2 - south

24-hour average;
Average temperatures: 24,1 C
Temp variation: 7,2 C
Max. temperature: 27,7 C

Month average; [kWh/m^2 year]
Energy consump. for heating: 11,00

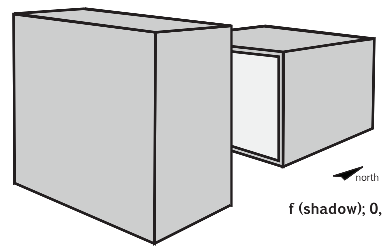


f (shadow); 0,7

Window area: 100 m^2 - south

24-hour average;
Average temperatures: 23,8 C
Temp variation: 6,8 C
Max. temperature: 27,2 C

Month average; [kWh/m^2 year]
Energy consump. for heating: 13,50



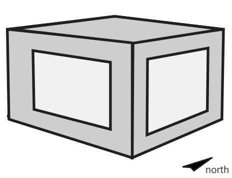
f (shadow); 0,5

Window area: 100 m^2 - south

24-hour average;
Average temperatures: 23,5 C
Temp variation: 6,4 C
Max. temperature: 26,8 C

Month average; [kWh/m^2 year]
Energy consump. for heating: 16,70

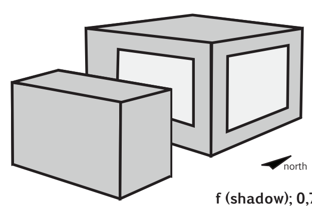
[02] 50/50 East and Sourh - shadow from construction on site



f (shadow); 0,9

Window area: 55 m^2 - south
55 m^2 - east

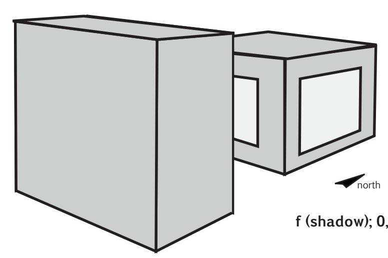
24-hour average;
Average temperatures: 23,9 C
Temp variation: 7,2 C
Max. temperature: 27,6 C



f (shadow); 0,7

Window area: 55 m^2 - south
55 m^2 - east

24-hour average;
Average temperatures: 24,1 C
Temp variation: 7,4 C
Max. temperature: 27,8 C

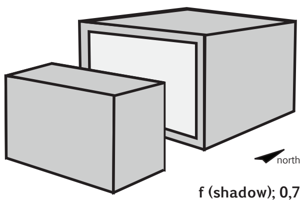


f (shadow); 0,5

Window area: 55 m^2 - south
55 m^2 - east

24-hour average;
Average temperatures: 23,9 C
Temp variation: 7,2 C
Max. temperature: 27,6 C

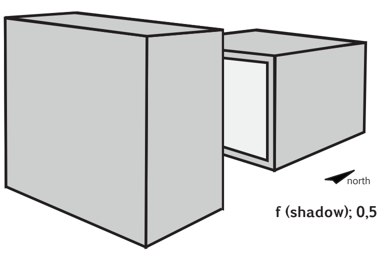
[03]



Window area: 90 m² - south
20 m² - north

24-hour average;
Average temperatures: 23,9 C
Temp variation: 6,8 C
Max. temperature: 27,3 C

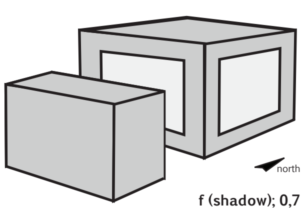
Month average; [kWh/m² year]
Energy consump. for heating: 15,00



Window area: 90 m² - south
20 m² - north

24-hour average;
Average temperatures: 23,6 C
Temp variation: 6,5 C
Max. temperature: 26,9 C

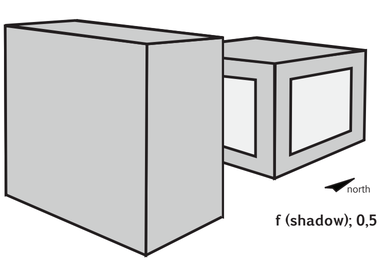
Month average; [kWh/m² year]
Energy consump. for heating: 18,10



Window area: 45 m² - south
45 m² - east
20 m² - north

24-hour average;
Average temperatures: 24,0C
Temp variation: 7,2 C
Max. temperature: 27,6 C

Month average; [kWh/m² year]
Energy consump. for heating: 17,00



Window area: 45 m² - south
45 m² - east
20 m² - north

24-hour average;
Average temperatures: 23,9 C
Temp variation: 7,0 C
Max. temperature: 27,4 C

Month average; [kWh/m² year]
Energy consump. for heating: 18,60

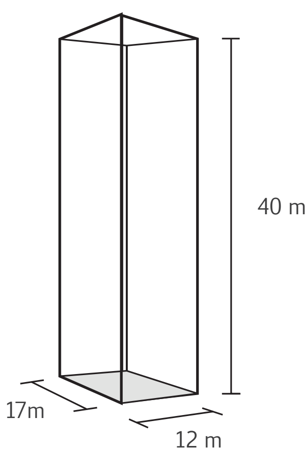
conclusion

The large construction on the southern façade of the buildings means a reduction of the solar gain from South, why the eastern facade can provide as much solar gain as the southern facade under these circumstances.

the atrium_overheating

Designing an atrium means large attention upon the risk of overheating, as the large glass panels in the design, that ensure natural daylight and a light and translucent expression of the architecture, also create a risk for seriously overheating inside the construction. The following investigations deal with the right amount of windows vs. wall construction to ensure more realistic temperatures inside, which can be further reduced by parameters such as; deep window holes, U-values, g-values, ventilation, shade devices and the use of thermal mass for heat accumulation.

the box



To simplify the investigations the atrium in question is seen as a box with the dimensions; 12m x 17m x 40m.

Floor: 204 m^2
Ceiling: 204 m^2
Walls;
North: 480 m^2
South: 480 m^2
East: 680 m^2
West: 680 m^2
Volume: 8160 m^3

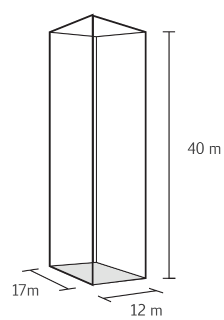
The use of the atrium is mainly for flow between the different functions in the silo buildings, but also small casual open spaces with informal activities, why the occupancy is specified to 30 persons using the area in the period of 7 am to 9 pm. Outside service hours the occupancy will be 0. Furthermore the atrium is ventilated with 0,5 h^{-1} and a light amount of 100 lux around the clock.

Specified U-values for;
Walls: 0,2 W/m^2K
Ceiling: 0,2 W/m^2K
Floor: 0,2 W/m^2K
Windows: varies

atrium investigations

Scenarios	24-hour average results

[01] glass box



Window areas;
South: 480 m²
North: 480 m²
West: 680 m²
East: 680 m²

glass panels U-value: 0,5 W/m²K

July:

24- hour average temp:
46,3 °C

24-hour temp. variation:
66,6 °C

24-hour max. temp:
74,7 °C

[02] Construction in context

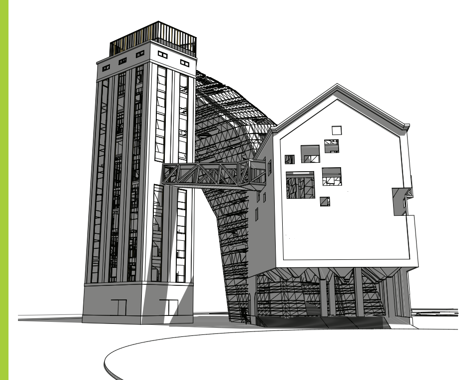
Context;
South: 100 % free facade
North: 90 % free facade
West: 90 % free facade
East: 35 % free facade

Shadow from construction on site;
South: 0,7
North: 0,5
West: 0,7
East: 0,8

Window areas; (20% of surface for construction)

	wall	windows
South	96 m²	384 m²
North	134,4 m²	345,6m²
West	190,4 m²	489,5 m²
East	489,6 m²	190,4 m²
Ceiling	40,8 m²	163,2 m²

glass panels U-value: 0,5 W/m²K



july:

24- hour average temp:
40,1°C

24-hour temp. variation:
55,9°C

24-hour max. temp:
68,0 °C

wall / window ratio

Scenarios Following scenarios deal with the amount of window area vs. amount of wall construction	24-hour average results
[03] reduction of South facade - 50 % glass panels U-value: 0,5 W/m²K	July: 24- hour average temp: 38,1 °C 24-hour temp. variation: 50,7 °C 24-hour max. temp: 63,4 °C
[04] reduction of North facade - 50 % glass panels U-value: 0,5 W/m²K	July: 24- hour average temp: 39,4 °C 24-hour temp. variation: 54,8 °C 24-hour max. temp: 66,8 °C
[05] reduction of West facade - 50 % glass panels U-value: 0,5 W/m²K	July: 24- hour average temp: 38,3 °C 24-hour temp. variation: 49,8 °C 24-hour max. temp: 63,3 °C
[06] reduction of South, North and West facade - 50 % glass panels U-value: 0,5 W/m²K	July: 24- hour average temp: 34,7 °C 24-hour temp. variation: 40,6 °C 24-hour max. temp: 55,0 °C
[07] reduction of South, West facade and skylight - 50 % north facade - 80 % glass panels U-value: 0,5 W/m²K	July: 24- hour average temp: 32,6 °C 24-hour temp. variation: 36,7 °C 24-hour max. temp: 50,9 °C

additional parameters

Scenarios	24-hour average results
Following scenarios deal with the most realistic suggestion for the atrium, as a result of previous investigations regarding wall/window ratio. Additional parameters are taken into consideration.	

[08] optimisation of wall / window ratio

Context;	shadow
South: 100 % free facade	0,7
North: 90 % free facade	0,5
West: 90 % free facade	0,7
East: 35 % free facade	0,8

	wall	windows
South	288 m^2	192 m^2
North	410,88 m^2	69,12 m^2
West	435,6 m^2	244,75 m^2
East	489,6 m^2	190,4 m^2
Ceiling	122,4m^2	81,6 m^2

glass panels U-value: 0,5 W/m^2K

July:

24- hour average temp:
32,9 °C

24-hour temp. variation:
38,4 °C

24-hour max. temp:
52,1 °C

[09] additional parameters; deep window holes, small overhang, U-value to 1,1 W/m^2K and 20 % skylight

July:
24- hour average temp:
27,8 °C

24-hour temp. variation:
26,6 °C

24-hour max. temp:
41,1 °C

[09] A
extermal shading - 0,35

July:
24- hour average temp:
23,5 °C

24-hour temp. variation:
14,4 °C

24-hour max. temp:
30,7 °C

[09] B
reduction of the g-value; 0,2 [-]

July:
24- hour average temp:
23,4 °C

24-hour temp. variation:
14,1 °C

24-hour max. temp:
30,5 °C

[09] C
increasing ventilation rate; 5 h^{-1}

July:
24- hour average temp:
22,7 °C

24-hour temp. variation:
16,6 °C

24-hour max. temp:
30,9 °C

results_conclusion

Scenarios

The atrium will be the flow area of the building, why stairs and slabs for common rooms will be implemented in the final design and contribute with a larger amount of heat accumulating material, which is added in the following scenario.

[10] g-value 04 [-], Vent. 3 h^{-1} and reduction of heat accumulating area - 1200 m^2

glass panels U-value: 1,1 W/m^2K

Context;	**shadow**
South: 100 % free facade	0,7
North: 90 % free facade	0,5
West: 90 % free facade	0,7
East: 35 % free facade	0,8

	wall	windows
South	288 m^2	192 m^2
North	410,88 m^2	69,12 m^2
West	435,6 m^2	244,75 m^2
East	489,6 m^2	190,4 m^2
Ceiling	171,36 m^2	32,64 m^2

24-hour average;

July:
24- hour average temp:
22,7 °C

24-hour temp. variation:
8,2 °C

24-hour max. temp:
26,8 °C

Month-average;

Heating: **22,2 kWh/m^2 year**

Cooling: 7,9 kWh/m^2 year

Total: 30,1 kWh/m^2 year

Conclusion;

The use of a larger amount of wall in the facades together with additional parameters such as; deeper window holes, shading devices, small overhang, ventilation, reduced g- and u-values and the use of heat accumulation materials have made it possible to create an atrium with acceptable temperatures during the day without too large temperature variations in the space.

To ensure a reasonable energy consumption for the building volume the final inputs from 24-hour have also been investigated in Month-average to be used as a guideline for the further design process.

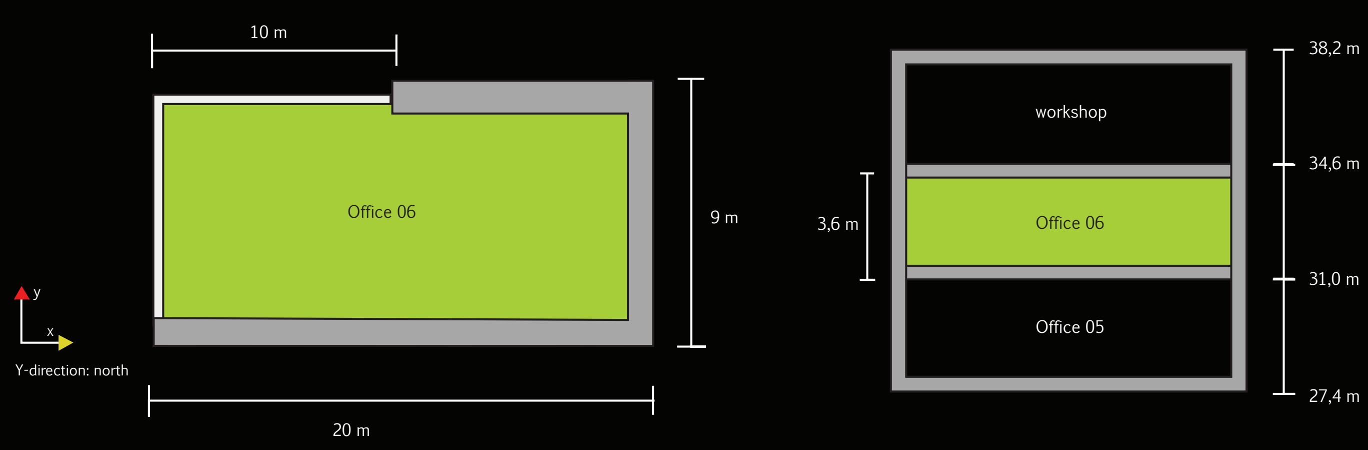
BSim - office 06

scenario 01

To ensure an acceptable indoor climate in the office building the application BSim has been used to optimize the design according to the different parameters. One of the offices is the chosen room for calculation, as these rooms have a large wall construction made from Polycarbonate towards North and West, which needs among others, to be investigated regarding temperature variations. Also the large internal heat loads from equipment, light and people together with the large amount of hours spent in these spaces are the reason for choosing this room as a reference room.

The office has been modelled in two different ways to see the effiency of the adjacent sunspaces on the North and West facades. The first model is made as a box with the following dimensions to see the indoor climate with the window areas in question. The second model is as the box with the corresponding values, with two additional adjacent zones on the North and West facades, being categorized as unheated, as the existing wall construction will be remained as an outer climate shell. (See CD for further information regarding the two scenarios)

geometry



ill. 01 Simplification of the floor plan and section

Area: 180,0 m^2

Volume: 648,0 m^3

input - materials

		R-values;	U-values;
Optimized concrete wall			
	180 mm reinforced concrete (existing)	5,26 m^2K/W	0,16 W/m^2K
	190 mm insulation		
	100 mm concrete inner wall		
Polycarbonate			
	2 layers of carbonate with Nanogel insulation in between – 16 mm	3,33 m^2K/W	0,3 W/m^2K
Slabs			
	50 mm rubber, black, hard	0,367 m^2K/W	2,72 W/m^2K
	350 mm concrete slab		
Windows			
	Climate Stop N Diamante	2,00 m^2K/W	0,5 W/m^2K

window areas

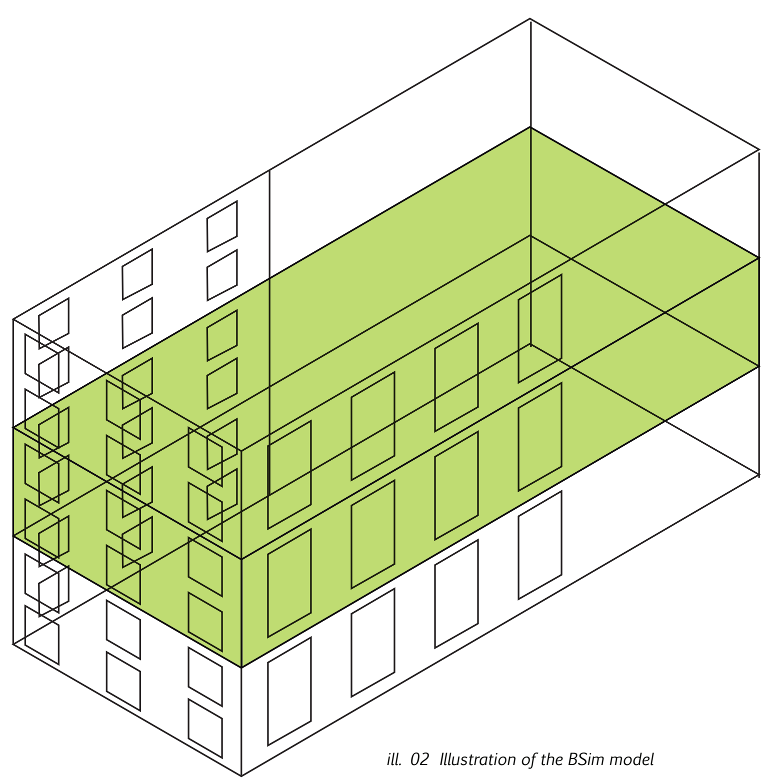
South: 4 x 5,28 m^2 - 21 m^2

North: 6 x 1,28 m^2 - 7,68 m^2

West 6 x 1,69 m^2 - 10,14 m^2

East: 0 m^2 - 0 m^2

All recessed 5 cm into the facades and with a frame of 13 mm.
Openable areas of: A_{frac}: 0,6



ill. 02 Illustration of the BSim model

input

The model is build as three equal offices on top of each other. Office 06 (the reference room) has its own thermal zone defined in the program with the following values.

The site of the project relates to the danish weather informations, DRY.

Thermal Zone: **Office 06**;

People Load: 10 persons, standard, with working hours from 08.00-21:00 all year except Sundays and July.

Equipment: 10 laptops (270W), 1 printer (110W) – 0,37kW, turned on during working hours (08:00-21:00).

Lighting: 10 architect lights (0,18kW) and general lighting (0,346kW), switched on during working hours.

Ventilation: Air change rate according to sensory pollution: 1,75 h^{-1} – 0,5 m^3/s, with a heat recovery of 85%. Switched on during the heating period.
Pressure input: 1200 Pa, Pressure output: 600 Pa.
Set point for heating: 22,0 C [CR1752]
Set point for cooling: 26,0 C [CR1752]

Venting: Basic air change: 1,75 h^{-1} for the sensory pollution
Windfactor: 0,4 (high buildings, semi-exposed)
Venting set point: 24,5 C [CR1752]

Infiltration: Basic air change: 0,2 h^{-1}, Full Load, Always.

results

The results are to be found according to the indoor climate concerning temperatures (overheating), CO_2 emission and infiltration.
The calculations are made with automatical mechanical ventilation for the office, which means that BSim choose the optimal ventilation strategy depending on the geometry of the space.

The results illustrates that the building is very stable all year round according to temperatures and that there is no overheating during summer.

Mean temperature: 22,07 C Hours under 21 C; 7.977,00 h Hours above 27 C; 11,00 h Hours above 26 C; 84,00 h Hours under 18 C; 0,00 h Infiltration, mean; 0,18 h^{-1} CO_2 - emission; 554,10 ppm	Temperature; 21,00 - 26, 00 C Hours permitted; Above 27 C; 25 h Above 26 C; 100 h Infiltration; 0,5 h^{-1} CO_2 emission; 810,00 ppm

2009	Min	Mean	Max	1	2	3	4	5
TopMean(offices)°C	19,03	22,07	27,43	21,74	21,75	21,89	21,96	21,97
AirChange(offices)/h	0,20	2,53	7,09	3,77	3,74	3,76	3,74	1,49
ExtTmp([Outdoor])°C	-21,10	7,76	32,10	-0,53	-1,02	1,70	5,59	11,32
Co2(offices)ppm	350,0	554,1	2226,3	412,8	412,2	410,3	412,3	759,3
Infilt(offices)m³/s	0,0240	0,0506	0,1483	0,0544	0,0510	0,0535	0,0517	0,0490

2009	6	7	8	9	10	11	12
TopMean(offices)°C	23,05	21,78	23,16	22,06	21,91	21,84	21,69
AirChange(offices)/h	0,41	0,39	0,39	1,53	3,74	3,74	3,76
ExtTmp([Outdoor])°C	14,95	16,37	16,18	12,48	9,12	4,82	1,47
Co2(offices)ppm	981,5	352,4	938,3	730,2	413,0	410,5	413,1
Infilt(offices)m³/s	0,0471	0,0476	0,0456	0,0506	0,0517	0,0516	0,0538

With the chosen ventilation strategy the CO_2 emission in the building will not be removed with the set air change, why the same iteration has been done with the needed ventilation rate for the CO_2 emission found through calculations of the air change rate according to internal load and room dimensions. (1,78 h^{-1}) (See appendix, Air change rate.)
(See CD for further information)

Mean temperature: 22,00 C Hours under 21 C; 8,359,00 h Hours above 27 C; 0,00 h Hours above 26 C; 0,00 h Hours under 18 C; 0,00 h Infiltration, mean; 0,18 h^{-1} CO_2 - emission; 466,50 ppm	Temperature; 21,00 - 26, 00 C Hours permitted; Above 27 C; 25 h Above 26 C; 100 h Infiltration; 0,5 h^{-1} CO_2 emission; 810,00 ppm

2009	Min	Mean	Max	1	2	3	4	5
TopMean(offices)°C	19,86	22,00	25,73	21,74	21,75	21,89	21,96	21,80
AirChange(offices)/h	0,20	2,61	7,08	3,77	3,74	3,76	3,74	1,66
ExtTmp([Outdoor])°C	-21,10	7,76	32,10	-0,53	-1,02	1,70	5,59	11,32
Co2(offices)ppm	350,0	466,5	979,7	412,8	412,2	410,3	412,3	560,0
Infilt(offices)m³/s	0,0241	0,0506	0,1483	0,0544	0,0510	0,0535	0,0517	0,0490

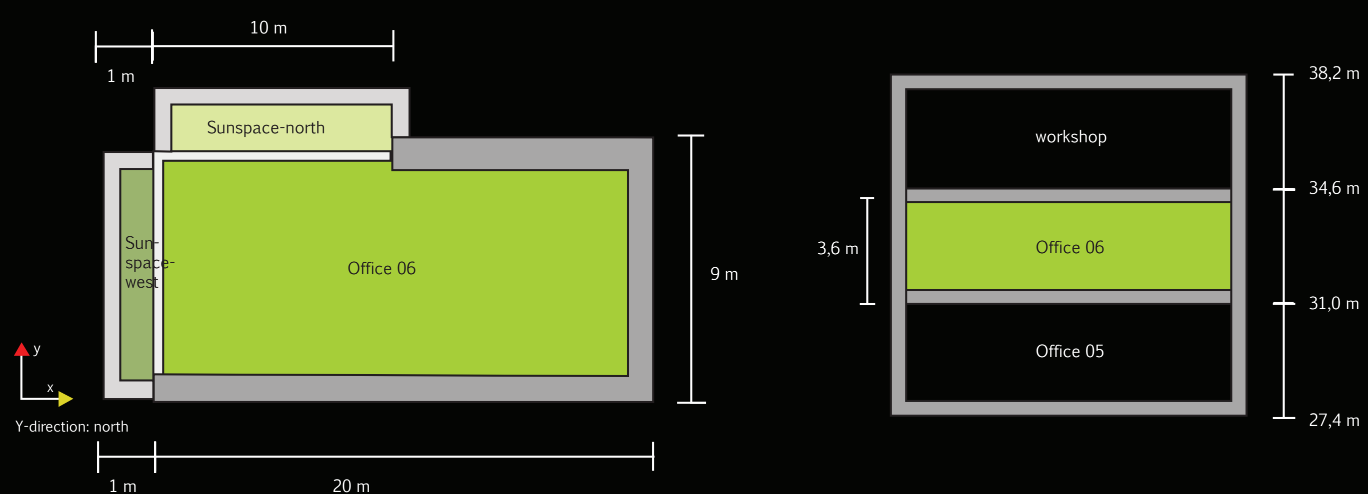
2009	6	7	8	9	10	11	12
TopMean(offices)°C	22,58	21,90	22,77	21,89	21,99	21,95	21,80
AirChange(offices)/h	0,74	0,39	0,70	1,68	3,74	3,74	3,76
ExtTmp([Outdoor])°C	14,95	16,37	16,18	12,48	9,12	4,82	1,47
Co2(offices)ppm	625,0	351,0	620,4	556,3	413,0	410,5	413,3
Infilt(offices)m³/s	0,0471	0,0476	0,0456	0,0506	0,0517	0,0516	0,0538

scenario 02

The offices will be embraced by an outdoor space on the North and West facade of the buildings, creating a double facade with a translucent material for the inner wall constructions to let in as much natural daylight as possible. The meaning of these addtional open spaces has also been investigated through the use of BSim.

The box being the same as in previous iteration with the same window to floor ratio and choice of materials for construction.

the geometry



ill. 03 Simplification of the floor plan and section

Area: 180,0 m^2

Volume: 648,0 m^3

input - materials

	R-values;	U-values;
Existing concrete wall		
180 mm Reinforced concrete	0,18 m^2K/W	5,5 W/m^2K
Optimized concrete wall		
180 mm reinforced concrete (existing) 190 mm insulation 100 mm concrete inner wall	5,26 m^2K/W	0,16 W/m^2K
Polycarbonate		
2 layers of carbonate with Nanogel insulation in between – 16 mm	3,33 m^2K/W	0,3 W/m^2K
Slabs		
50 mm rubber, black, hard 350 mm concrete slab	0,367 m^2K/W	2,72 W/m^2K
Windows		
Climate Stop N Diamante	2,00 m^2K/W	0,5 W/m^2K

window areas

South: 4 x 5,28 m^2 - 21 m^2

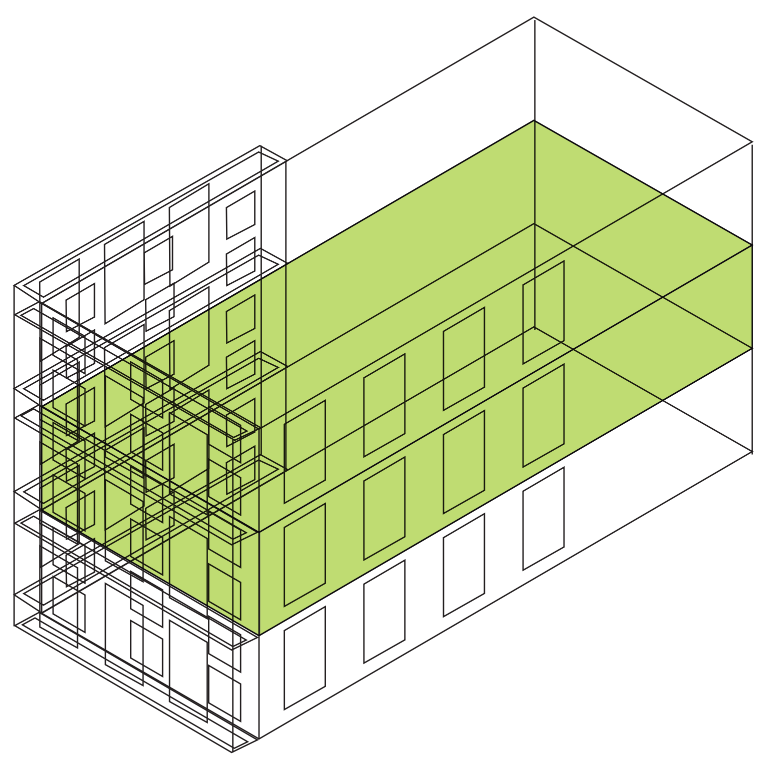
North: 6 x 1,28 m^2 - 7,68 m^2

West 6 x 1,69 m^2 - 10,14 m^2

East: 0 m^2 - 0 m^2

Sunspaces - each floor:
3 x 5,28 m^2 - 15,84 m^2

All recessed 5 cm into the facades and with a frame of 13 mm.
Openable areas of: $A_{frac:}$ 0,6



ill. 04 Illustration of the BSim model

input

The model is build as three equal offices on top of each other, with adjacent spaces on the West and North facade. The susnspaces are each in therir own thermal zone while Office 06 (the reference room) has its own thermal zone defined in the program.

The site of the project relates to the danish weather informations, DRY.

Thermal Zone; Sunspace West:
The only selected system is "infiltration", which deals with heat loss through leaks in the construction. An infiltration of 0,2 h^{-1} is added and set to be the case "Always" and "FullLoad"

Thermal Zone; Sunspace North:
The only selected system is "infiltration", which deals with heat loss through leaks in the construction. An infiltration of 0,2 h^{-1} is added and set to be the case "Always" and "FullLoad"

Thermal Zone: **Office 06;**
People Load: 10 persons, standard, with working hours from 08.00-21:00 all year except Sundays and July.

Equipment: 10 laptops (270W), 1 printer (110W) – 0,37kW, turned on during working hours (08:00-21:00).

Lighting: 10 architect lights (0,18kW) and general lighting (0,346kW), switched on during working hours.

Ventilation: Air change rate according to sensory pollution: 1,75 h^{-1} – 0,5 m^3/s, with a heat recovery of 85%. Switched on during the heating period.
Pressure input: 1200 Pa, Pressure output: 600 Pa.
Set point for heating: 22,0 C [CR1752]
Set point for cooling: 26,0 C [CR1752]

Venting: Basic air change: 1,75 h^{-1} for the sensory pollution
Windfactor: 0,4 (high buildings, semi-exposed)
Venting set point: 24,5 C [CR1752]

Infiltration: Basic air change: 0,2 h^{-1}, Full Load, Always.

results

The results from the last iteration with the outer sunspaces on the North and West facades show the contribution from these spaces. The risk for overheating is lower when the sunspaces are introduced as less direct solar radiation from West is gained through the window panels. At the same time the inlet air from the northern sunspace is colder during night and early morning hours, why this can be used for cooling down the offices outside working hours.
The first calculation are made with automatical mechanical ventilation for the office, which means that BSim choose the optimal ventilation strategy depending on the geometry of the space.

Mean temperature: 21,96 C	Temperature; 21,00 - 26, 00 C
Hours under 21 C; 8.198,00 h Hours above 27 C; 0,00 h Hours above 26 C; 0,00 h Hours under 18 C; 0,00 h	Hours permitted; Above 27 C; 25 h Above 26 C; 100 h
Infiltration, mean; 0,18 h^{-1}	Infiltration; 0,5 h^{-1}
CO_2 - emission; 531,80 ppm	CO_2 emission; 810,00 ppm

2009	Min	Mean	Max	1	2	3	4	5
Co2(offices)ppm	350,0	531,8	2180,0	412,8	412,2	410,3	412,3	718,4
TopMean(offices)°C	19,99	21,96	25,03	21,96	21,96	21,97	21,97	21,70
ExtTmp([Outdoor])°C	-21,10	7,76	32,10	-0,53	-1,02	1,70	5,59	11,32
Infilt(offices)m³/s	0,0241	0,0506	0,1482	0,0544	0,0510	0,0535	0,0517	0,0490
AirChange(offices)/h	0,20	2,57	4,55	3,77	3,74	3,76	3,74	1,59

2009	6	7	8	9	10	11	12
Co2(offices)ppm	901,4	352,4	856,9	665,4	413,0	410,6	413,3
TopMean(offices)°C	22,35	21,26	22,56	21,89	21,98	21,97	21,96
ExtTmp([Outdoor])°C	14,95	16,37	16,18	12,48	9,12	4,82	1,47
Infilt(offices)m³/s	0,0471	0,0476	0,0456	0,0506	0,0517	0,0516	0,0538
AirChange(offices)/h	0,54	0,39	0,54	1,65	3,74	3,74	3,76

With the chosen ventilation strategy the CO_2 emission in the building will not be removed through the air change, why the same iteration has been done with the needed ventilation rate for the CO_2 emission found through calculations of the air change rate according to internal load and room dimensions. (1,78 h^{-1}) (see CD for further information)

Mean temperature: 21,88 C	Temperature; 21,00 - 26, 00 C
Hours under 21 C; 7.979,00 h Hours above 27 C; 0,00 h Hours above 26 C; 0,00 h Hours under 18 C; 0,00 h	Hours permitted; Above 27 C; 25 h Above 26 C; 100 h
Infiltration, mean; 0,18 h^{-1}	Infiltration; 0,5 h^{-1}
CO_2 - emission; 468,20 ppm	CO_2 emission; 810,00 ppm

2009	Min	Mean	Max	1	2	3	4	5
Co2(offices)ppm	350,0	468,2	979,6	412,8	412,2	410,3	412,3	563,3
AirChange(offices)/h	0,20	2,60	5,32	3,77	3,74	3,76	3,74	1,65
TopMean(offices)°C	19,71	21,88	25,01	21,96	21,96	21,97	21,97	21,48
ExtTmp([Outdoor])°C	-21,10	7,76	32,10	-0,53	-1,02	1,70	5,59	11,32
Infilt(offices)m³/s	0,0241	0,0506	0,1482	0,0544	0,0510	0,0535	0,0517	0,0490

2009	6	7	8	9	10	11	12
Co2(offices)ppm	634,4	351,0	629,1	555,2	413,0	410,6	413,3
AirChange(offices)/h	0,68	0,39	0,64	1,69	3,74	3,74	3,76
TopMean(offices)°C	22,02	21,22	22,34	21,69	21,98	21,97	21,96
ExtTmp([Outdoor])°C	14,95	16,37	16,18	12,48	9,12	4,82	1,47
Infilt(offices)m³/s	0,0471	0,0476	0,0456	0,0506	0,0517	0,0516	0,0538

BE06

BE06 is used to verify the compliance with the energy demands in the Danish building regulations (BR08) and must be submitted to the municipality when applying for building license. It is also used during the design process to test different compositions of the building, and hereby find the best suited solutions in coherence with the architectural expression.

This project is divided into four different files to ease the identification of solutions to the very different building content:

Silo_03; mainly office building, but with dance studio, workshop, rental and lounge as well.

Silo_02; café and rehearsal room.

Silo_04; mainly physical activities, but also auditorium/cinema and restaurant.

Atrium; handle the flow between the buildings and furthermore contains informal meeting places and small activity areas.

Each of the buildings must comply with the energy demands from BR08. However supplement can be made as the complex is seen as one unit where high heat gains in one department can be used in another areas.

The project aims for a low energy building class 1, which means certain demands needs to be fulfilled:

Max energy consumption
$q_r = 50 + 1100/A$
where,
q_r = annually energy frame [kWh/m^2]
A = heated floor area [m^2]
This concerns heating, cooling, ventilation, hot water and lighting.

Air tightness of 1.5 L/s per m^2 heated floor area at a pressure difference of 50 Pa

Maximum U-values and line loss as defined in BR08

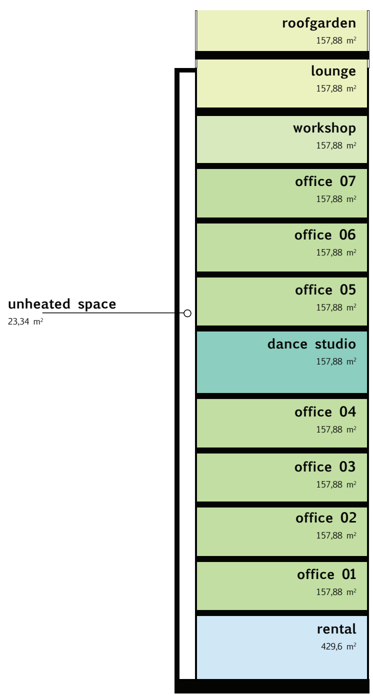
Maximum transmisson loss per m^2
Having buildings higher than three stories, the project needs to comply with maximum 8 W/m^2 external wall
[BR08]

In the following each of the buildings will be evaluated through BE06 to comply with the above mentioned demands.

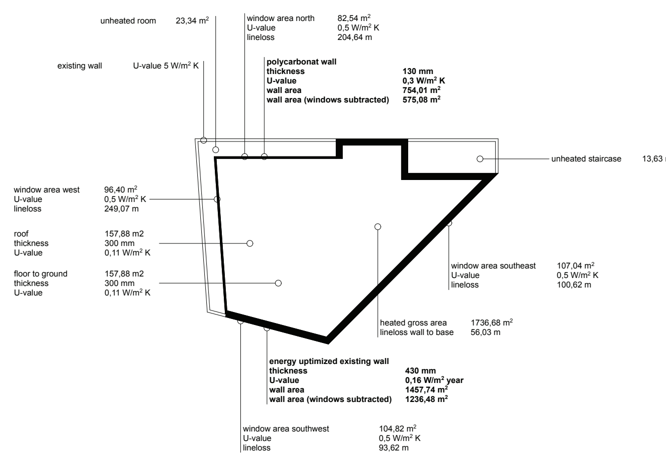
silo_03

Silo 03 is mainly an office building, as can be seen from the building programme illustration. Below is shown a plan with the building data put into BE06.
The most important decisions taken inside BE06 are listed below, as are the results. On the attached cd BE06-files can be found showing all the details.
Considerations during the process with BE06 will be explained afterwards.

Results



ill. 05 Building programme silo_03



ill. 06 Footprint silo_03

Energy frame	49,9 kWh/m² year	Complies with low energy building class 1
Transmission loss	7,1 W/m²	Must be below 8 W/m² for buildings above 3 stories

Input	#	Info
Heat capacity	140 Wh/K m^2	The building has a high heat capacity, external walls and slabs are fabricated from concrete.
Normal usage time	45 hours	Ranging from 8.00 – 17.00. Being mainly an office building, this is seen as a realistic schedule.
Heat supply	District Heating	
Heat pump	-	Heat pump is not chosen, the energy consumption could have been lowered even more with this on, but it is not necessary to comply with the demands. The ventilations system has an effective heat exchanger, which makes it possible to utilise most of the energy stored in the outlet air.
External walls	Polycarbonate 0,3 W/m^2 K	Chosen for its high transparency, and low U-value together with lightness in the expression. The U-value and lack of thermal mass of this material means that the remaining walls needs even higher values to counterbalance. The polycarbonate wall faces an unheated area, to comply with this a temperature factor of 0,7 is chosen.
	Optimized walls 0,16 W/m^2 K	These walls consists of the existing 180 mm concrete walls, which has been optimized with 190 mm isolation and a 100 mm concrete inner wall.
Roof/floor	300 mm concrete 0,11 W/m^2 K	Concrete slabs are chosen as roof/floor elements mainly because of its high thermal mass and low U-value. The floor is on ground, therefore a temperature factor of 0,7 is applied.

Line losses	Windows 0,03 W/mK Wall to base 0,15 W/mK	The length of line losses are as described on the illustration. A temperature factor of 0,7 is chosen for those elements, which faces an unheated area.
Windows and outer doors	0,5 W/m² K	Windows and doors have a g-value of 0,65 to allow a high degree of solar heat to enter the building, at the same time a low U-value will reduce the transmission loss.
	Temperature factors	The windows are given temperature factors corresponding to whether they are facing the outdoor (1,0) or an unheated room (0,7).
	Shading	Shading factors are given that correspond to the significant shading from surrounding buildings and from the remaining existing wall.
	Shadow	There is no shadowing on the windows since this has proven unnecessary because of the efficiency of the shading.
Ventilation	Zoning	Offices, workshop and rental are collected as one zone, since they have similar loads and requirements. Lounge, dance studio and toilets are individual zones.
	Air flow	The air flows are determined by the sensory- and CO_2 pollution defined for the different zones through a spreadsheet calculation seen elsewhere in this appendix.

	Heat recovery	A system with a high heat recovery is chosen, 85% efficiency. This has proven necessary to comply with the energy frame.
Internal heat supply	Entire building	Load from people is set to 4 W/m^2 and 6 W/m^2 for equipment, as a standard measure for offices.
	Dance studio	The people loads in the dance studio are significantly higher reasoning the function of the zone, with 10,3 W/m^2 and 5 W/m^2 for equipment.
Lighting	Zone near facade	A zone near the facade has been selected at having very good daylight conditions, aiming for a daylight factor of 5% and 200 lux.
	Middle of room	Less daylight factor, 2%, but still with the aim of 200 lux.
	Toilet/lift	Both zones aims for a daylight factor of 2% and 100/50 lux, this being rooms with less need of daylight.
	Control	All zones have automatic control of artificial light according to current daylight conditions.

Considerations

It has proven possible to extend the window sizes towards North and West, and still cope with the energy demands, by adjusting the U-values for the remaining construction. U-values have changed as shown below:

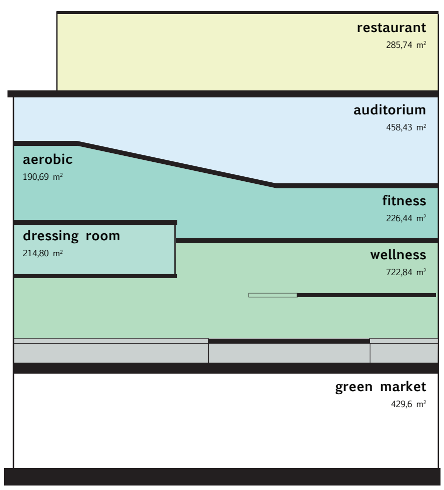
Element	**1st iteration**	**2nd iteration**
Average North/West window area per story	12 m^2	21 m^2
Polycarbonate wall	0,3 W/m^2 K	0,3 W/m^2 K
Optimized existing wall	0,19 W/m^2 K	0,16 W/m^2 K
Floor/roof	0,15 W/m^2 K	0,11 W/m^2 K
Glazing	0,5 W/m^2 K	0,5 W/m^2 K

By implementing an unheated room towards North and West, heat loss can be significantly reduced, together with creating an outdoor area for people to step out and have an open view towards the water front. The effect on the result can be seen below. For more detailed information, see the two attached files on the cd.

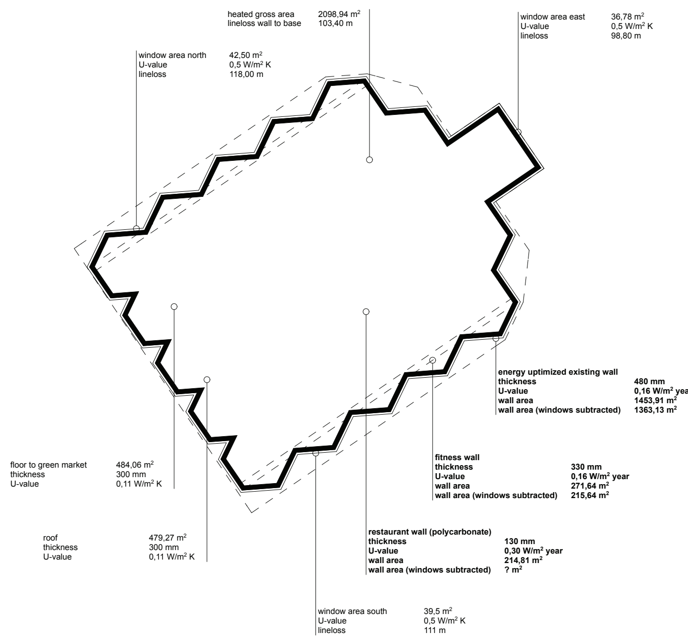
Results without unheated space		
Energy frame	53,2 kWh/m^2 year	Complies with low energy building class 2
Results with unheated space		
Energy frame	**49,9 kWh/m^2 year**	**Complies with low energy building class 1**
Transmission loss	7,1 W/m^2	Must be below 8 W/m^2 for buildings above 3 stories

silo 04

Silo 04 has a great diversity in the function distribution as seen in the building programme illustrated below. Furthermore a plan with the building data input to BE06 is displayed. The most important decisions taken inside BE06 are listed below as are the results.



ill. 07 Building programme silo_04



ill. 08 Footprint silo_04

Results		
Energy frame	45,7 kWh/m² year	Complies with low energy building class 1
Transmission loss	4,0 W/m²	Must be below 8 W/m² for buildings above 3 stories

Input	#	Info
Heat capacity	100 Wh/K m	The building has a high heat capacity, where the external walls and slabs are fabricated from concrete. However in the fitness area concrete and Swissfiber is used why the total heat capacity is reduced.
Normal usage time	112 hours	The usage time is listed from 08-24 every day of the week however the different functions have been adjusted according to their utilisations (f_0 value)
Heat supply	District Heating	
Heat pump	-	Heat pump is not chosen, the energy consumption could have been lowered even more with this on, but it is not necessary to comply with the demands. The ventilations system has an effective heat exchanger, which makes it possible to utilise most of the energy stored in the outlet air.
External walls	Optimized walls 0,16 W/m^2 K	The walls in the wellness section consists of the existing 180 mm concrete walls, which have been optimized with 190 mm isolation and a 100 mm inner concrete wall. Internal cladding of 20 mm wood has been added.
	Optimized walls 0,16 W/m^2 K	The fitness, changing rooms, reception and aerobic have a facade consisting of 20 mm Swissfiber, 100 mm concrete, 175 mm isolation and 20 mm Swissfiber

Roof/floor	300 mm concrete 0,11 W/m² K	Concrete slabs are chosen as roof/floor elements mainly because of its high thermal mass and low U-value. The floor is towards the unheated green market, therefore a temperature factor of 0,7 is applied.
Line losses	Windows 0,03 W/mK Wall to base 0,15 W/mK	The length of line losses are as described on the illustration.
Windows and outer doors	0,5 W/m² K	Windows and doors have a g-value of 0,65 to allow a high degree of solar heat to enter the building, at the same time a low U-value will reduce the transmission loss.
	Shading	Shading factors are given that correspond to the significant shading from surrounding buildings and from the remaining existing wall.
	Shadow	There is no shadowing on the windows since this has proven unnecessary because of the efficiency of the shading.
Ventilation	Zoning	Wellness, changing room, reception, auditorium and restaurant are seen as individual zones whereas fitness and aerobic are collected as one zone as they have similar loads and requirements.
	Air flow	The air flows are determined by the sensory- and CO_2 pollution defined for the different zones through a spreadsheet calculation seen elsewhere in this appendix.
	Heat recovery	A system with a high heat recovery is chosen, 85% efficiency.

Internal heat supply [CR1752]	Wellness	Load from people is set to 2,7 W/m² and 20 W/m² for equipment.
	Fitness + Aerobic	Here the people loads are high heat supply due to the function of the zone, with 25,8/20,4 W/m² and 1 W/m² for equipment.
	Auditorium	Load from people is set to 12,7 W/m² and 1 W/m² for equipment
	Restaurant + Kitchen	Here people loads of 8,9/7.8 W/m² is applied and 2/7 W/m² for equipment
Lighting	Wellness	100 lux - daylight factor(DF) 2 %
	Fitness/aerobic	200 lux - DF 5%
	Auditorium/Cinema	200 lux - DF 2%
	Changing rooms	100 lux - DF 2%
	Restaurant + Kitchen	100/200 lux - DF : 5/2 %
	Control	All zones have automatic control of artificial light according to current daylight conditions.

Considerations

It has proven that the preliminary investigations in Month Average have been a good guideline to follow in the further development. In scenario 01[silo 04_scenario01] the airchanges have been listed according to the sensory- and CO_2 pollution defined for each zone. It has proven difficult to fulfill the energy consumption because of high airchange rate due to the activity level of the different functions, why in scenario 02 [silo 04_scenario02] the ventilation rates have been changed in relation to the requirements listed in BR08 [6.3.1.3,stk 2]. Where the ventilation is calculated as 5 l/s per person and 0,4 l/s pr m² floor. Scenario 03[silo 04_scenario03] the usage time has been changed to 45 hours/week which reduces the energy consumption significantly.

This can be adjusted because in buildings with extra high ventilation rates, high usage of water or long service life the energy frame will be raised with an addition corresponding the extra energy consumption.

In every scenario the internal heat gains from the people load at the different activities have been added to the calculation however the energy consumption to maintain the requirements for e.g. wellness have not been included, which also will be given a supplement.
Through the investigations the window area towards North have been examined where it has proven possible to raise the amount in relation to the calculation done in month average. Why more window areas have been implemented in the final design. This will also help fulfill the high ventilation rates required through natural ventilation during summer.

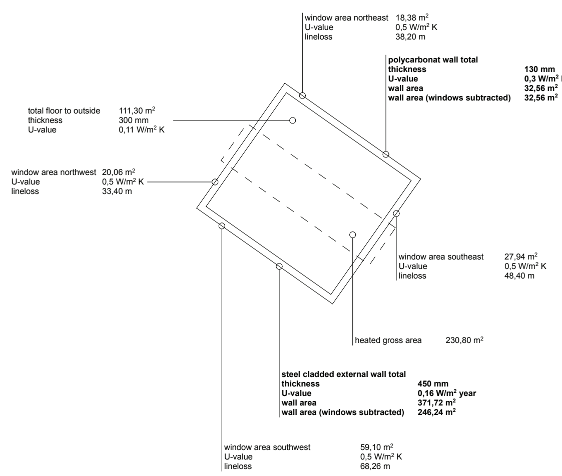
This low energy consumption for silo 04 can help some of the other functions that do not have a high internal heat load in relation to their volume for example the atrium.

Results

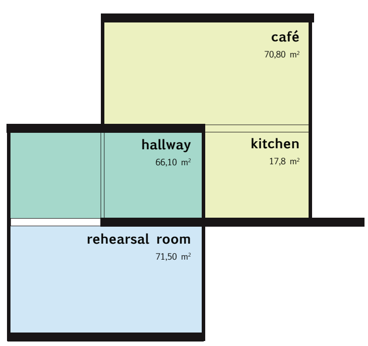
Scenario 01		
Energy frame	85,9 kWh/m² year	Complies with normal energy class
Scenario 02		
Energy frame	**44,9 kWh/m² year**	**Complies with low energy building class 1**
Scenario 03		
Energy frame	25,7 kWh/m² year	Complies with low energy building class 1
In all scenarios:		
Transmission loss	5,6 W/m²	Must be below 8 W/m² for buildings above 3 stories.

silo_02

Silo 02 is mainly an outdoor space however a café and a rehersal room have been incorporated above the outdoor space. Below is shown a section and plan with the building data put into BE06.
The most important decisions taken inside BE06 are listed below, as are the results.



ill. 10 Footprint silo_02



ill. 09 Building programme silo_02

Results

Energy frame	kWh/m² year	Complies with low energy building class 1
Transmission loss	5,5 W/m²	Must be below 8 W/m² for buildings above 3 stories

Input	#	Info
Heat capacity	100 Wh/K m^2	The building has a high heat capacity, external walls and slabs are fabricated from concrete.
Normal usage time	91 hours	Ranging from 09.00 – 22.00 every day at the week.
Heat supply	District Heating	
Heat pump	-	Heat pump is not chosen, the energy consumption could have been lowered even more with this on, but it is not necessary to comply with the demands. The ventilations system has an effective heat exchanger, which makes it possible to utilise most of the energy stored in the outlet air.
External walls	Steel cladded external wall	0,16 W/m^2 K Chosen for its rough expression.
	Polycarbonate 0,3 W/m^2 K	Chosen for its high transparency, and low U-value together with lightness in the expression.
Roof/floor	300 mm concrete 0,11 W/m^2 K	Concrete slabs are chosen as roof/floor elements mainly because of its high thermal mass and low U-value.
Line losses	Windows 0,03 W/mK Wall to base 0,15 W/mK	The length of line losses are as described on the illustration.

Windows and outer doors	0,5 W/m^2 K	Windows and doors have a g-value of 0,65 to allow a high degree of solar heat to enter the building, at the same time a low U-value will reduce the transmission loss.
	Shading	Shading factors are given that correspond to the significant shading from the existing wall and the atrium.
	Shadow	There is no shadowing on the windows since this has proven unnecessary because of the efficiency of the shading.
Ventilation	Zoning	The café and rehearsal room are given individual room because of the different requirements.
	Air flow	The air flows are determined by the sensory- and CO_2 pollution defined for the different zones through a spreadsheet calculation seen elsewhere in this appendix.
	Heat recovery	A system with a high heat recovery is chosen, 85% efficiency.
Internal heat supply	Café / Kitchen	Load from people is set to 16,2 / 10,3 W/m^2 and 6/10 W/m^2 for equipment.
	Rehearsal room	Here people load 8,7 W/m^2 and 6 W/m^2 for equipment are applied.
	Hallway	People load of 5,4 W/m^2 and equipment load of 6 W/m^2 is applied.
Lighting	Café	The café has been selected to have very good daylight conditions, aiming for a daylight factor of 5% and 100 lux.

Rehearsal room	Less daylight factor, 2%, but with the aim of 200 lux.
Hallway	Daylight factor of 2 % and 50 lux.
Control	All zones have automatic control of artificial light according to current daylight conditions.

Considerations

The ventilation rates are corrected according to the requirement listed in BR08 [6.3.1.3, stk 2]. Here the ventilation rate is calculated as 5 l/s per person and 0,4 l/s pr m^2 floor. The opening hours for the café, kitchen and rehearsal room varies during the day why the opening hour of the building is from 8.00 a.m. to 9 p.m. However the individual opening hours for the different functions is corrected according to the ventilation and lighting.
Due to the position surrounded by the existing facade the building will primary be in shade however the high position and implementation of the polycarbonate material at the top of the building allow sunlight into the café why the shading factor is set to 70°.

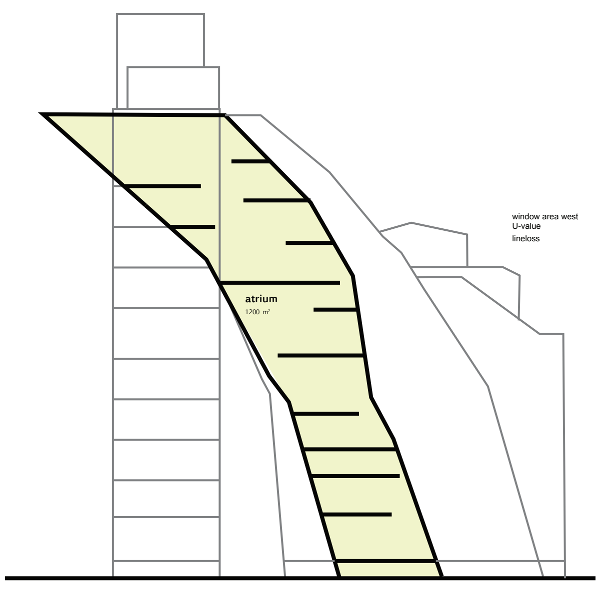
Results

Scenario 01 **Energy frame**	**49,2 kWh/m^2 year**	**Complies with low energy building class 1**
Transmission loss	5,1 W/m^2	Must be below 8 W/m^2 for buildings above 3 stories.

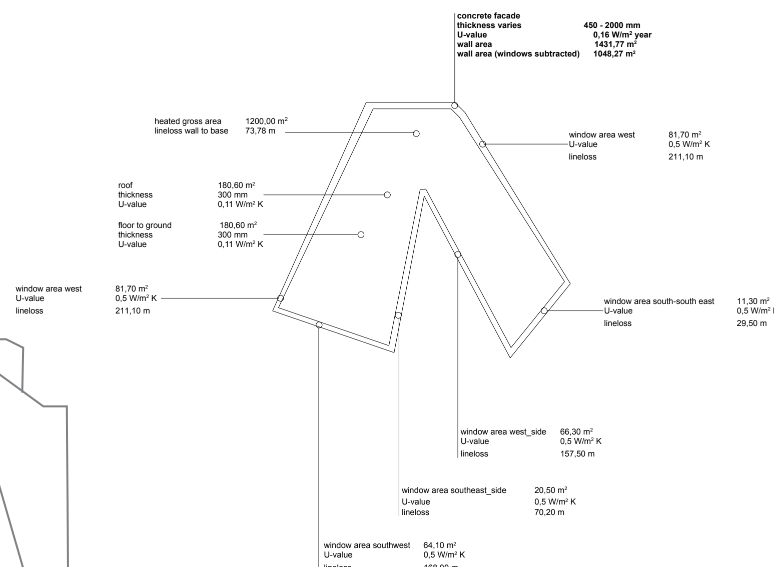
the atrium

The atrium connects three buildings together and service as flow system to create an open and visible connection among the functions. The footprint of the atrium connects silo 02 and 04, from here it spins to the top floors in silo 03. This means that a great part of the facades are either located in shade or inside a heated area in the existing buildings. In BE06 the values in shade has been specified and given a shade corresponding to the shadow angle however the facades creating a division to other functions have not been included because the temperatures here are seen as the same as in the atrium.
Below is shown a plan with the building data put into BE06.
The most important decisions taken inside BE06 are listed below, as are the results.

Results



ill. 11 Building programme_atrium



ill. 12 Footprint_atrium

Energy frame	49,0 kWh/m² year	Complies with low energy building class 1
Transmission loss	7,1 W/m²	Must be below 8 W/m² for buildings above 3 stories

Input	#	Info
Heat capacity	140 Wh/K m^2	The building has a high heat capacity, where external walls, slabs and stairs are fabricated from concrete.
Normal usage time	112 hours	Ranging from 8.00 – 24.00 every day at the week.
Heat supply	District Heating	
Heat pump	-	Heat pump is not chosen, the energy consumption could have been lowered even more with this on, but it is not necessary to comply with the demands. The ventilations system has an effective heat exchanger, which makes it possible to utilise most of the energy stored in the outlet air.
External walls	Concrete 0,16 W/m^2 K	Here concrete has been chosen..
Roof		
Floor	300 mm concrete 0,11 W/m^2 K	Concrete slabs are chosen as floor elements mainly because of its high thermal mass and low U-value. The floor is on ground, therefore a temperature factor of 0,7 is applied.
Line losses	Windows 0,03 W/mK Wall to base 0,15 W/mK	The length of line losses are as described on the illustration. A temperature factor of 0,7 is chosen for those elements, which faces an unheated area.

Windows and outer doors	0,5 W/m² K	Windows and doors have a g-value of 0,65 to allow a high degree of solar heat to enter the building, at the same time a low U-value will reduce the transmission loss.
	Shading	Shading factors are given that correspond to the significant shading from surrounding buildings.
	Shadow	There is no shadowing on the windows since this has proven unnecessary because of the efficiency of the shading.
Ventilation	Zoning	The atrim is seen as one large zone eventhough different spaces for interaction have been arranged through out the atrium.
	Air flow	The air flows are determined by the sensory- and CO_2 pollution defined for the different zones through a spreadsheet calculation seen elsewhere in this appendix.
	Heat recovery	A system with a high heat recovery is chosen, 85% efficiency.
Internal heat supply		The person load is 4 W/m2 for people and 6 W/m² for equipment
Lighting		The daylight factor and lux vary in the atrium depending on the activity and zone.
Control		All zones have automatic control of artificial light according to current daylight conditions.

Considerations
Through preliminary calculations in 24 h average and month average the amount of window areas and their orientation have been found in relation to maximum temperatures and energy consumption. These figures have created the guideline for the further development of the facades. The different meeting points and pathways consist of concrete which has a high heat capacity that assists equalisation of the temperature variations.

Calculation of the required ventilation rate in relation to the people load and volume showed a rate of 2,75 l/s m^2 [Atrium_scenario 01] however according to the Danish building regulation a minimum air change of 0,5 h^{-1} is required. This signifies an air change of 6 l/s m^2 of the atrium because of the high volume and small footprint. This raises the energy consumption but still fulfill the energy frame for low energy class 1 [Atrium_scenario 02].

Results

Scenario 01		
Energy frame	46,5 kWh/m^2 year	Complies with low energy building class 1
Scenario 02		
Energy frame	**47,7 kWh/m^2 year**	**Complies with low energy building class 1**
Transmission loss	7,1 W/m^2	Must be below 8 W/m^2 for buildings above 3 stories.

conclusion

BE06 has been used to verify that the complex meets the demand of a low energy building class 1. Each building fulfil the requirements to the energy consumption. The program has been used both for verification however different iterations have also been tested through the process and changes architectural implemented in the final solution ensuring an integrated output.

ventilation strategies

introduction

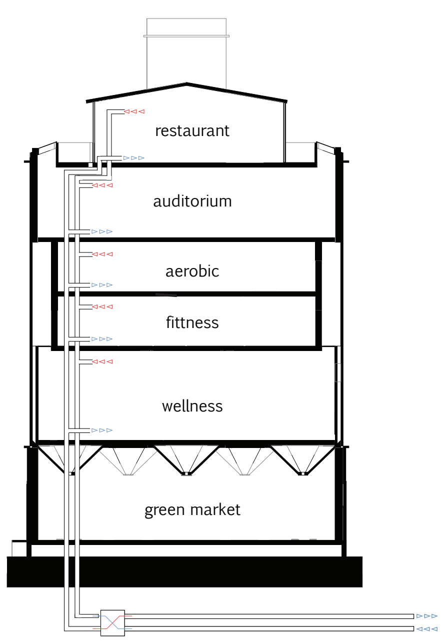
The building complex operates with different strategies for natural ventilation where both thermal buoyancy and wind driven strategies are in use. The strategy depends on the function, orientation, adjacent elements and wind velocities. When dealing with natural ventilation it can be difficult to predict the affect of the changes in weather conditions. In order to predict the details of the natural airflow in the complex, numerical computational fluid mechanics models(CFM) can be used. These computer simulations create an accurate analyse of the airflow in relation to the buildings. However, in the following paragraphs feasible concepts are described for each building component.

The buildings operate with hybrid ventilation, which exploits the benefits from both natural and mechanical ventilation. Hybrid ventilation is a two-mode system that adjusts the ventilation mode according to the weather conditions. The mechanical system has a heat recover efficiency of 85 % where a counter-flow heat exchanger is located between the inbound and outbound air flow minimising the heat loss. The equipment for the mechanical ventilation is located at the bottom of the atrium creating a minimum length of ducts to the different spaces.

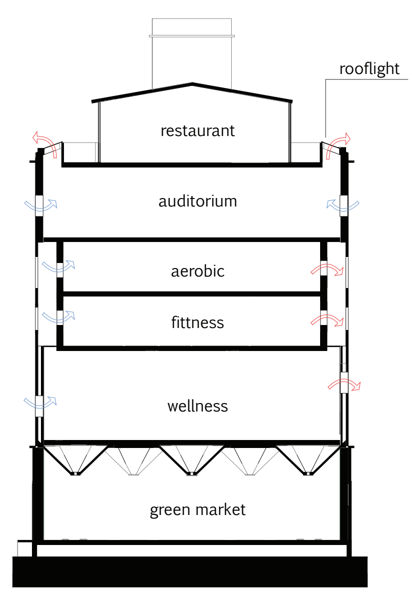
silo 04

In silo 04 wellness, fitness and aerobic is located, which cause that the natural ventilation mode only is seen as a supplement to the mechanical for fresh air because of the high physical activity level which affects the humidity and the sensory pollution in the rooms.

The auditorium utilises the openings in the facade as inlets where as the roof lights serve as outlets illustrated on the section diagram.



ill. 13 Mechanical ventilation system



ill. 14 Natural ventilation is only seen as a supplement to the mechanical .

silo 03

The adjacent space between the office space and the existing facade has been introduced to perform as a double facade creating both an architectural quality for the offices as well as reduce the heat transmission through the northern facade. Furthermore the space can assist the natural ventilation during periods with low wind velocities. The ventilation strategies have been developed according to the adjacent unheated area and the connection to the atrium.

ventilation strategies

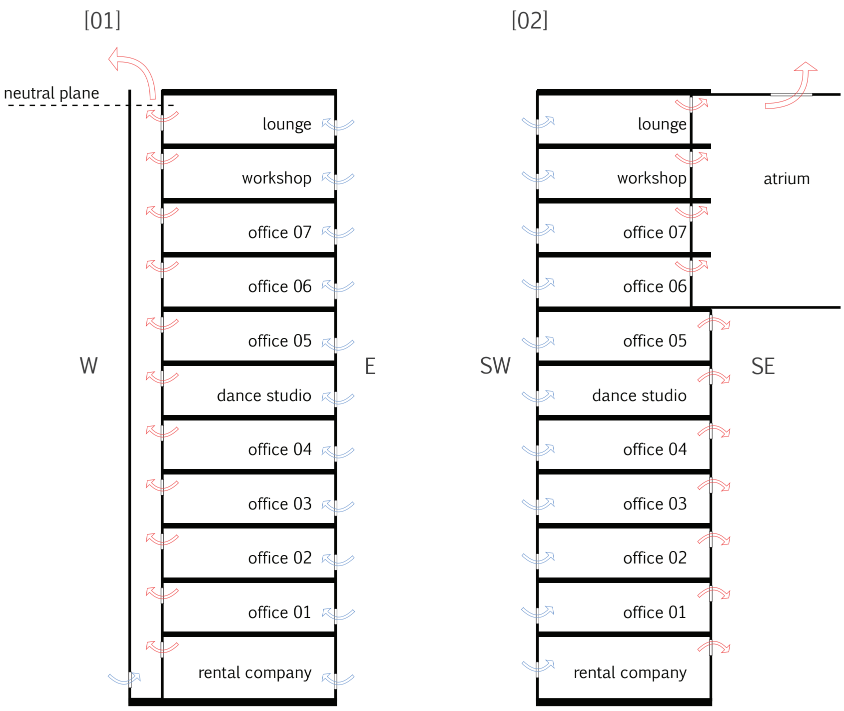
Summer strategy
The ventilation strategy during summer is to a great extent affected by the surrounding climatic conditions. On the opposite page two different scenarios are illustrated.

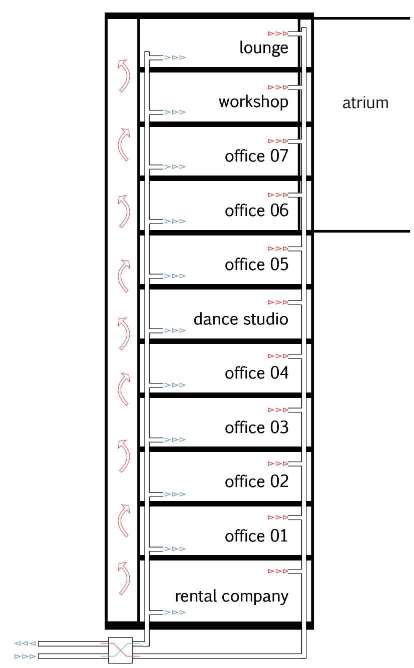
The first exemplifies the exploitation of the unheated area utilising the difference in density between cold and warm air. It is important to design the sizes of the openings so the neutral plane is located high in the adjacent space to ensure that the situation is not reversed, where polluted air from the offices at the bottom is let into the offices located above the neutral plane. This scenario is used during days with low wind velocities.

The other scenario take advantage of the prevailing wind direction exposure creating cross ventilation through the office spaces. The unheated area creates a shelter for the wind why the fresh air enters the spaces from Southwest and exhaust through the Southeast facade. In this scenario the top floors take advantage of the connected to the atrium, where the temperature differences between the atrium and offices assist the air change. This scenario is very efficient during days with high wind velocities.

Winter strategy
In winter the unheated space adjacent to the offices will be enclosed, which will result in higher temperatures here than the outdoor temperature which then will reduce the transmission loss from the northern facade. The offices will be mechanical ventilated using a system with a high heat recovery.

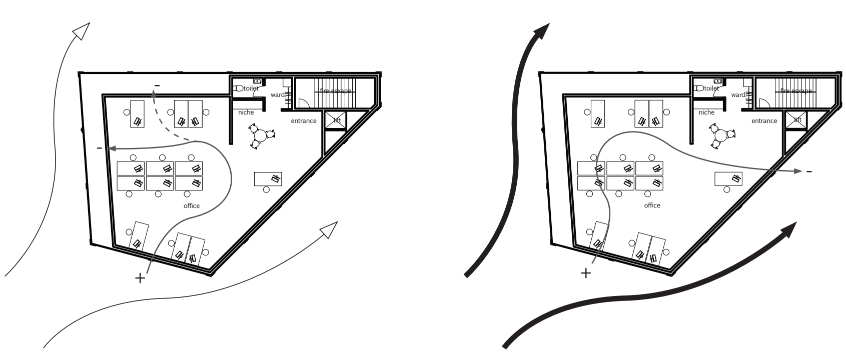
In the transition periods between summer and winter hybrid ventilation will be used. This strategy exploits the benefits from both natural and mechanical systems.

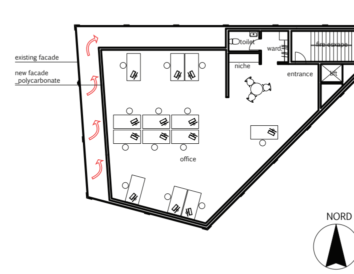




ill. 15 Summer strategies.
[01] illustrate the exploitation of the unheated area for stack ventilation.
[02] display the utilisation of wind driven ventilation

ill. 16 During winter, mechanical ventilation is used. Here the unheated space helps reduce the transmission loss through the facades towards this space.





ill. 17 Plan illustration of the offices and the air flow in the unheated area.

ill. 18 Plan illustration of the offices and the air flow in the unheated area. The western facade will be heated by the sun, which then will flow towards the colder areas.

atrium

Natural ventilation strategies

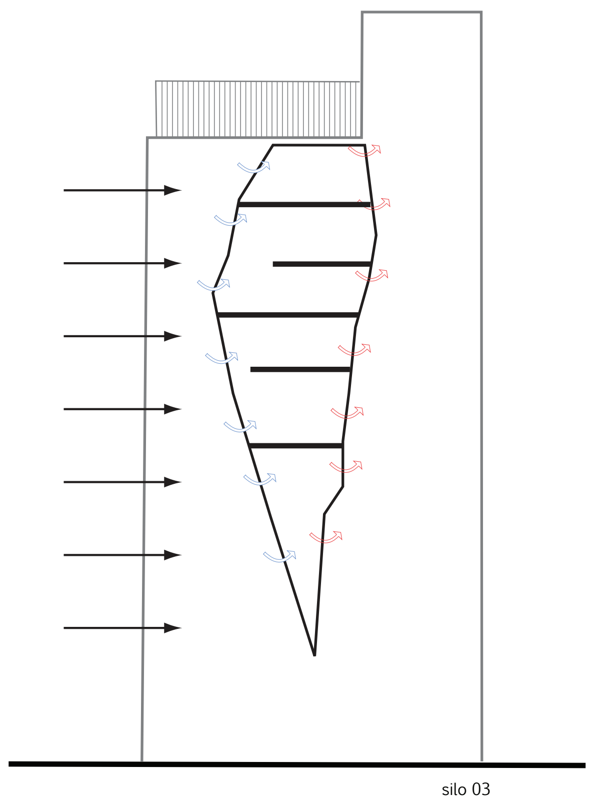
Summer strategy
In summertime the buoyancy forces are small, why the natural ventilation requires openings in opposing pressure zones. The arrangement of the atrium between the existing buildings is in a West-South direction, which is optimal in relation to the prevailing wind direction during summer. In summer the ventilation rely on the wind, where the wind velocity increases in relation to the height of the building inducing an increasing airflow rate through the windward openings of the top floors and higher suction at the lee walls. The openings in the atrium are distributed at both sides ensuring good possibility for cross ventilation. The air will move upward in the atrium creating stack airflow. However, this effect is only efficient when the wind flow is weak. This will always occur because the height of the atrium creates pressure differences.

The height of the atrium can provide high difference in temperature and air density at peak summer days which can be difficult to ventilate by passive means. To assist the air flow rate in these situations, a fire ventilator located at the roof of the atrium can be used for these purposes as well.

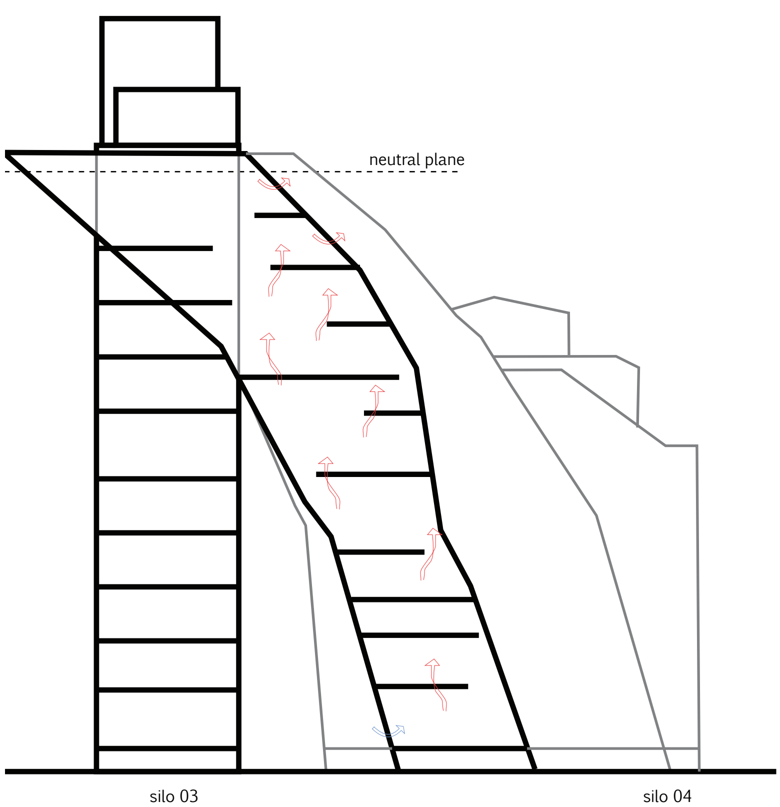
Transition strategy
In transition periods, autumn and spring, natural ventilation is used, when the conditions suit this mode. The ventilation principle will be dominated by the stack effect in the atrium induced by the internal heat sources and solar heat gain. The fresh air is provided to the atrium through inlets located at the bottom of the atrium. The strategy takes advantages of the difference in density between warm and cold air. At the top of the atrium air exhaust points are placed. The effectiveness of the stack ventilation is ensured by designing the stack outlets on the wind-induced negative pressure. The locations of the outlets are located on Southeast to secure that the polluted air does not extend to the office zones.

Night cooling
The lower air temperature during the night is used to remove the heat from the atrium. The interior of the atrium consists of concrete which has a high thermal storage mass. The mass store heat during the day and releases it through night ensuring stable temperatures, avoiding high mean and maximum temperature and high temperature variations. Night cooling provides with an effective method of cooling without additional operating costs.

Mechanical ventilation
The mechanical ventilation operates with mixing ventilation where the inlets are placed in a vertical direction to ensure fresh air throughout the height of the atrium and an outlet at the top of the atrium. Mixing ventilation is chosen because it can be difficult to maintain a satisfied air quality at the top of the atrium by displacement ventilation.



ill. 19 Diagram illustrating the strategy for natural ventilation during summer for the atrium



ill. 20 Diagram illustrating the strategy for natural ventilation for the transission periods for the atrium

natural light analysis

An office has been selected for light analysis, mainly to validate that it can fulfil the requirements of daylight factor and required illuminance level as listed below.

Measured 0,85 m above floor surface

Continues read/write	*500 lux*
Other	*200 lux*
Meeting room	*200 lux*
Hallways	*50 lux*

Daylight factor of minimum 2%
[DS 700 – kunstig belysning i arbejdslokaler]

Illuminance is defined as the amount of light actually falling on a surface given in lux.

Daylight factor is defined as the ratio between the light strength of a surface inside the room compared to that of a horizontal surface outside with an overcast sky and no shadowing elements.
[DS 700 – kunstig belysning I arbejdslokaler]

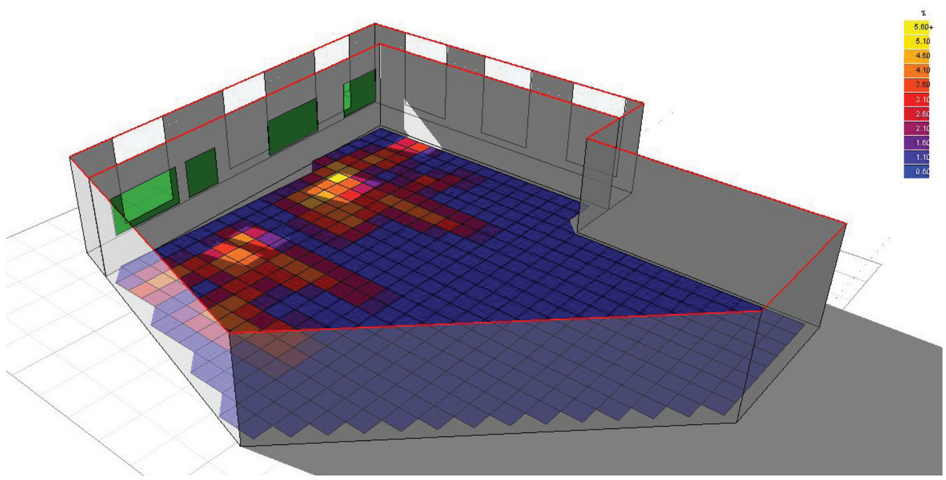
The investigations are modelled in Ecotect [www.ecotect.com] and exported to Radiance [http://radsite.lbl.gov/] for calculations. Both iterations are carried out on the 21st of December with an overcast sky to illustrate worst case scenario.

Iteration 01 – height of windows

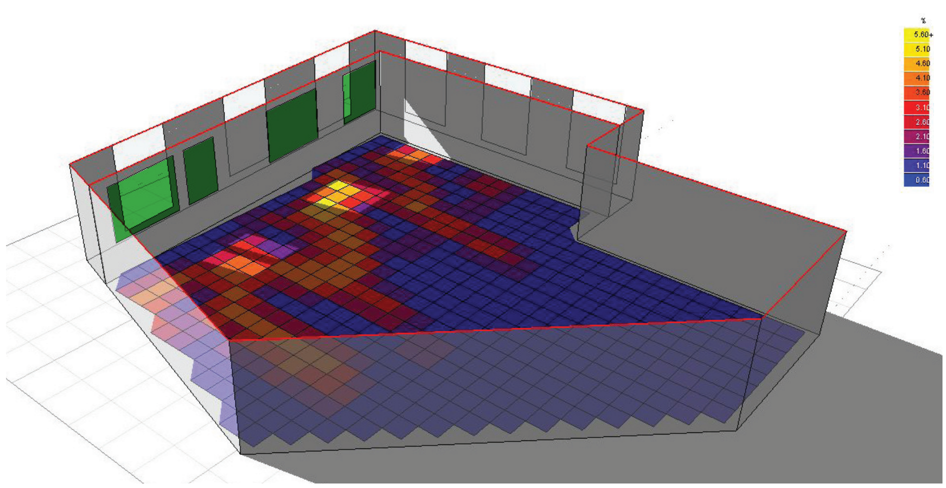
Given the room depth of the offices, it seems reasonable to determine how high the windows must be to give a satisfying natural light level. In this iteration the remaining windows have been deleted to ease the identification of improvements. The calculations are carried out as daylight factor analysis on the 21st of June at 4 pm, when the sun hits the windows. The windows are highlighted in green.
Two scenarios have been set up;

Window height of 1000 mm

Window height of 1500 mm



ill. 21 Window size iteration - height 1000 mm (daylight factor)



ill. 22 Window size iteration - height 1500 mm (daylight factor)

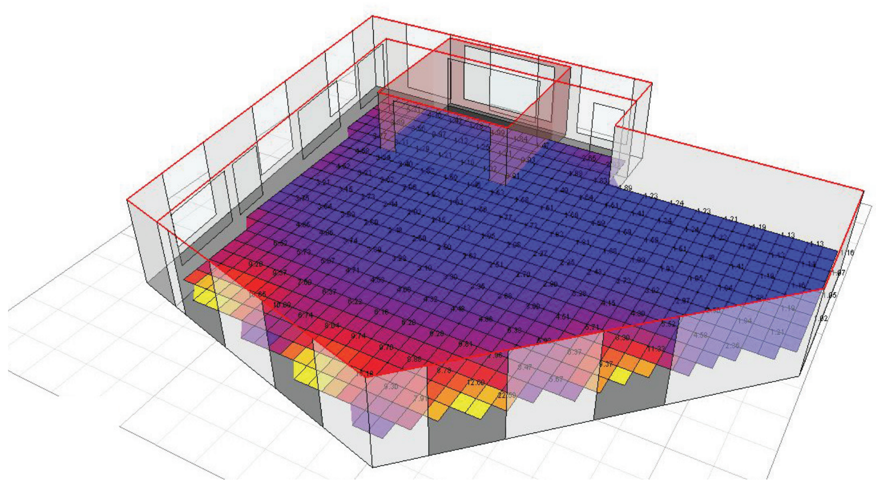
By adjusting the window height from 1000 mm to 1500 mm it is possible to get a better distribution of light deep into the room. Other aspects are more favourable views out both when standing and sitting. This result is taken to the next iteration.

ill. 23 Example of office interior with window heigh of 1500 mm

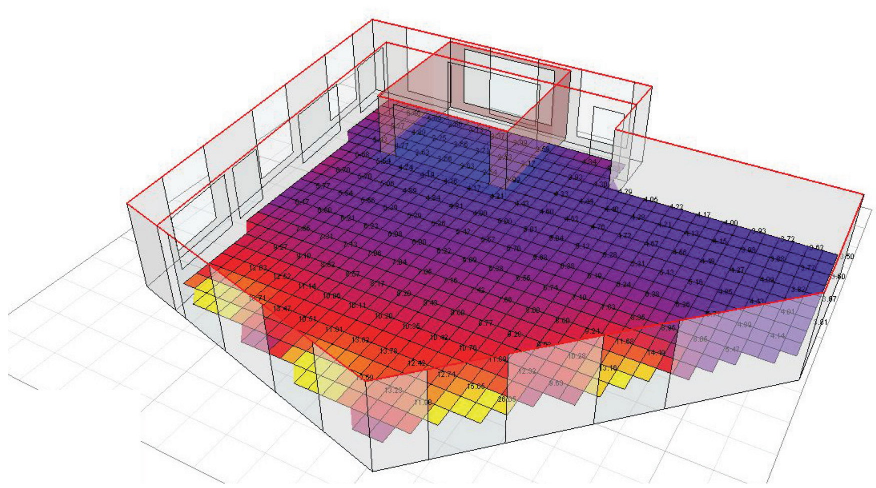
Iteration 02 – colour and reflectance of floor

An early wish in the project was to have a black rubber floor in the offices, the following iteration will show the effect of this. The walls and ceiling have been kept in white throughout the iterations for comparison purposes.

Daylight factor [%]



ill. 24 Dark flooring with daylight factor [%]



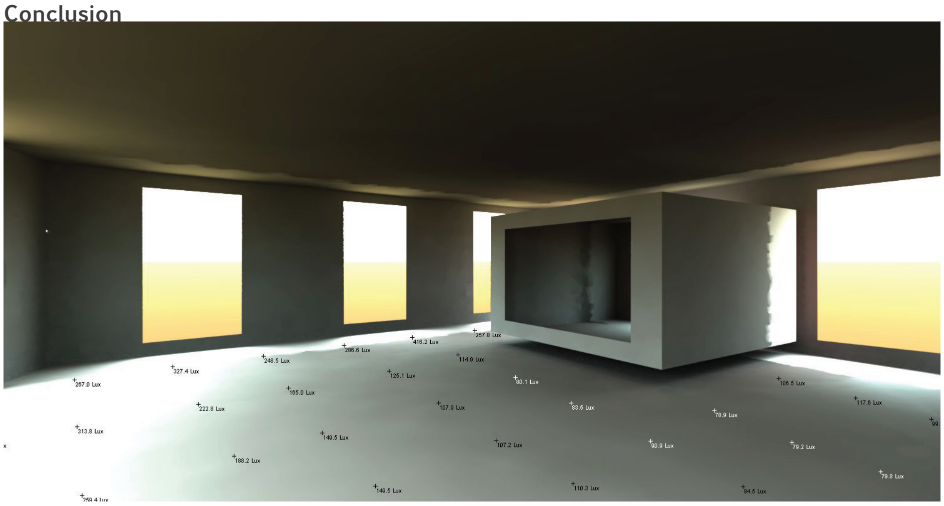
ill. 25 Light flooring with daylight factor [%]

The illustrations above clearly show the impact of the dark floor on the daylight factor, which reduces significantly both in strength and how deep the light is reflected into the room.

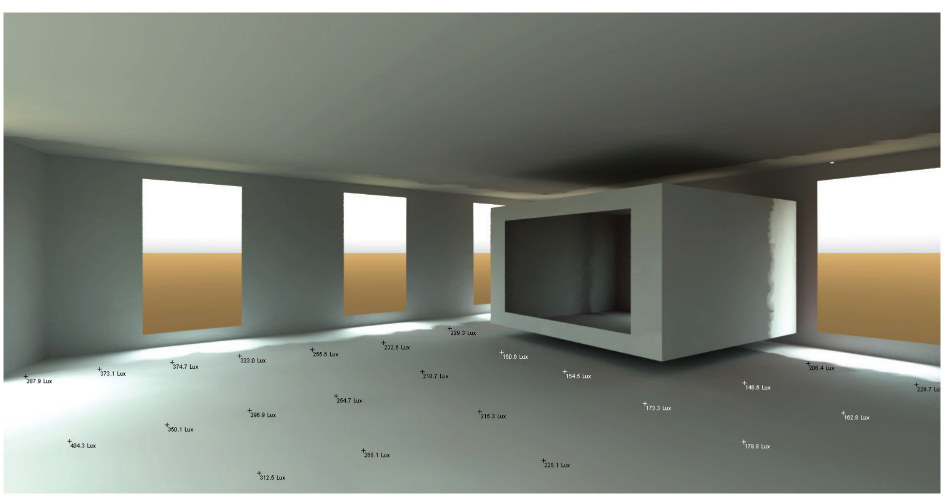
The values achieved are fulfilling the demands set up earlier, both for dark as for light flooring.

Illuminance level [lux]
As with daylight factor, the illuminance level is investigated, shown below. The two images gives an understanding of the necessity of having a bright floor, to achieve satisfying results. The illuminance level is not high enough to fulfil the demands, but taking in mind it is a worst case scenario and that no artificial light is on, this seems to be satisfying for both examples.

Conclusion



ill. 26 Radiance rendering showing different lux levels with dark flooring



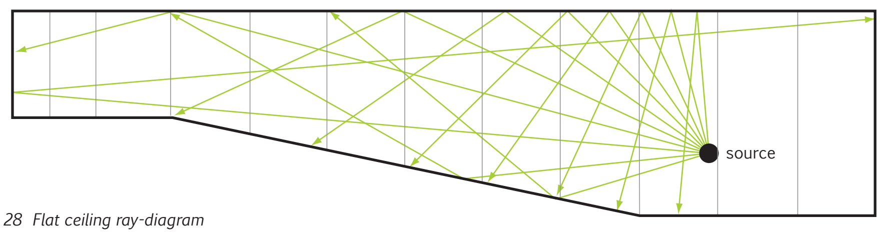
ill. 27 Radiance rendering showing different lux levels with light flooring

The two iterations have been quite helpful to get an understanding of the level of natural light in the offices. The effect of having higher windows is significant in relation to the depth of the room, as have been proved here, why this height is chosen for all windows towards North and West. The effect of having a dark floor is also significant, and caution to comfort and need for artificial light must be taken when choosing this, but by choosing higher windows and given the fact the calculation is carried out for a worst case scenario, this seems to be a satisfying choice for this project. The architectural values must also be considered and weighted against the technical aspects, not only fulfilling one of them.

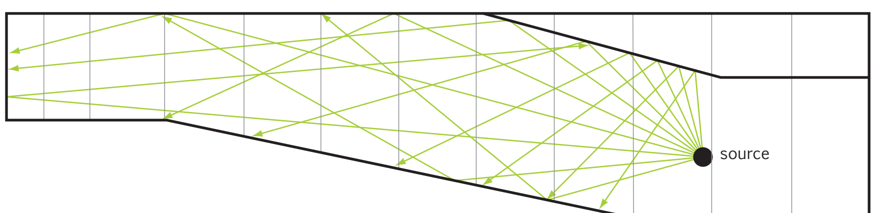
acoustic

auditorium

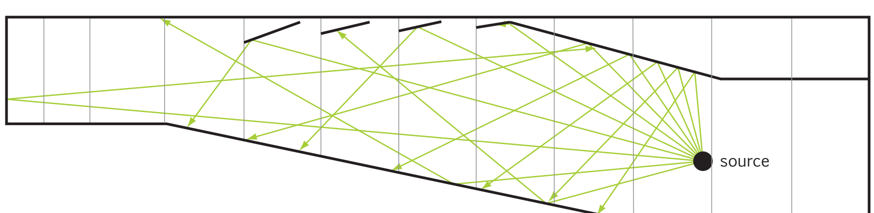
The auditorium is to be used both for speech and small music performances, as for cinema. The criteria's aimed for is primarily a good reverberation time, that can fulfil both speech and music, since a cinema can be controlled by adjusting the sound speakers.
The wanted outcome is simple iterations showing the efficiency of the room shape, and the possibilities for improving this. This is done through ray-diagrams, direct- to reflected sound ratio and reverberation time. All iterations are carried out in Ecotect [www.ecotect.com]



ill. 28 Flat ceiling ray-diagram



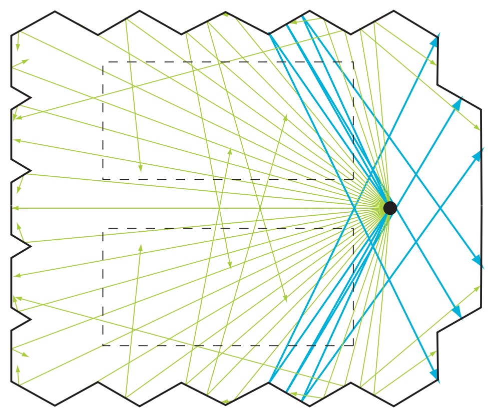
ill. 29 Sloping ceiling ray-diagram



ill. 30 Reflector ceiling ray-diagram

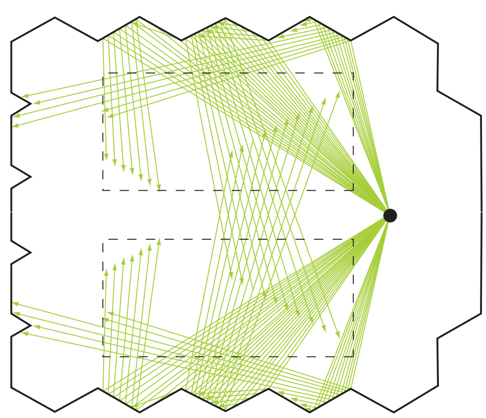
Ray-diagram iterations - vertical
Different solutions have been tried out to investigate the effect of the ceiling according to the sound distribution inside the auditorium, as shown by these vertical sections.
The flat ceiling has a higher risk of producing flutter echoes, simply because of its angle to the source. Another result of this is a poor distribution of sound towards the end of the room.
By implementing a sloping ceiling or reflectors this can be improved as shown. By adjusting the reflectors or slope of the ceiling it is possible to have reflections to the rear of the room from more than one reflector.
The ray-diagrams clearly indicate the need for a highly absorbing material on the rear wall, or a non-vertical shape of the wall, as this will create echoes back into the seating area.

Ray-diagram iterations – horizontal
The layout of the existing walls is examined for the same reason as for the ceiling. As can be seen on the first illustration, there is a problem with sound backfiring at the source position (blue lines), creating a situation with the risk of echo. This illustration has both direct and reflected sound in it.



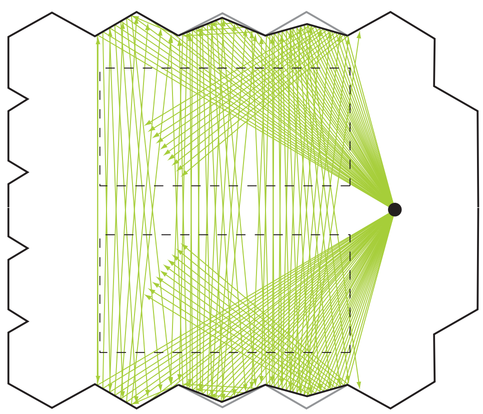
ill. 32 Existing building layout, showing problems with reflected sound towards speaker

The next illustration only contains reflected sound, and the two potential echo-producing walls have been treated to work as absorbing, as have the back wall, due to the risk of echoes from this. The image clearly shows areas with no reflected sound, meaning that these areas will have less clarity and feeling of the room (intimacy).



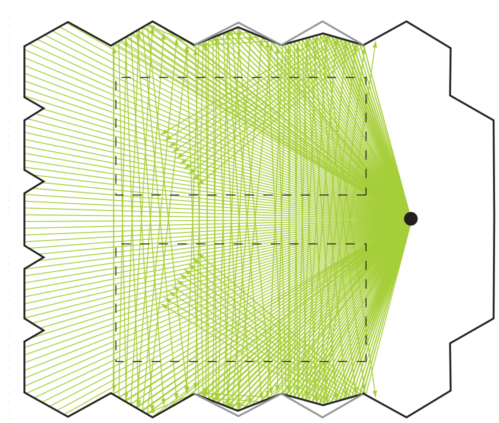
ill. 31 Selected reflective walls only, showing gabs with no reflected sound

To adjust this the third illustration shows a change in the wall angle, creating a better distribution of the sound, eliminating the before mentioned areas with lack of reflected sound. The walls that created an echo risk before, can now be used to distribute sound to the first rows of seating in the room.



ill. 33 Wall adjustment to distribute reflected sound better

Finally the last illustration shows the direct sound together with the reflected sound, creating a satisfying distribution of rays in the room.



ill. 34 Both direct- and reflected sound illustrated

Direct- to reflected sound ratio/initial time delay gab
Beside the distribution of sound, it is evident that the clarity of the sound is good, being used as an auditorium, why the ray-diagrams also are used for checking the initial time delay gab to avoid echoes as a result of to long time delay between direct- and reflected sound.
The human ear can not hear a time delay less than 50 ms, which can be directly converted to the difference in travelling length between direct- and reflected sound.

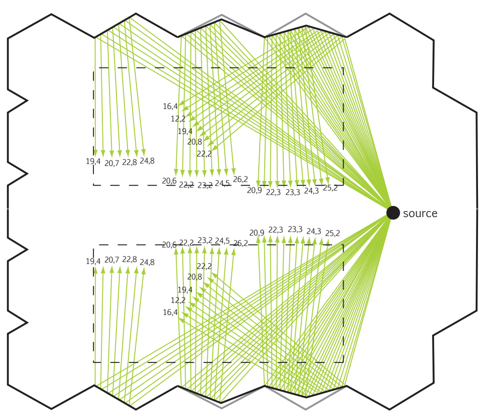
Distance = velocity x time = 343 m/s x 0,05 s = 17,15 m

where, 0,05 = 50 ms / 1000
and 343 m/s = the speed of sound in dry air

A time delay less than 20 ms is seen as excellent for speech and music, why this is aimed for. The travelling length being

343 m/s x 0,02 = 6,86 m

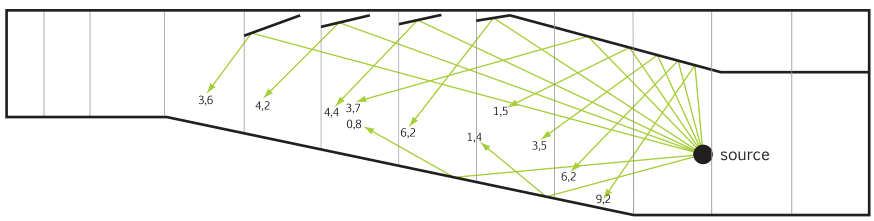
[PDF; Copy from Egan]



ill. 35 Direct- to reflected sound ratio, horizontal [ms]

The illustration shows the difference between direct- and reflected sound in the end point of each arrow. As the aim is to be below 20 ms, this is seen as fulfilled, even though there can be values between 20 – 30 ms in the middle of the room, but since the plan has a corridor here, this is acceptable. With differences up to 30 ms, speech and music still has a good clarity, but is preferably to be max 20 ms.

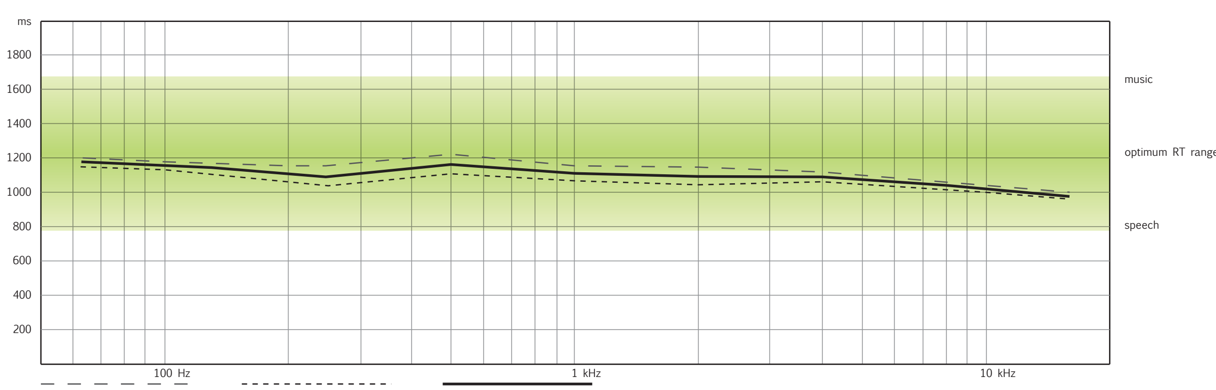
The vertical ray-diagram have no problems with fulfilling the set point for initial time delay gab. The difference in travelling length is very short, meaning that this will improve the feeling of intimacy quite well.



ill. 37 Direct- to reflected sound ratio, vertical [ms]

Reverberation times
Reverberation times for theatres is less than 1.2 second for frequencies between 250 – 4000 Hz, and 0,8 second for classrooms. In general music need longer reverberation times than speech. By aiming for something in between the two, it is possible to achieve an auditorium with good acoustic for both speech and music. [PDF; Copy from Egan]

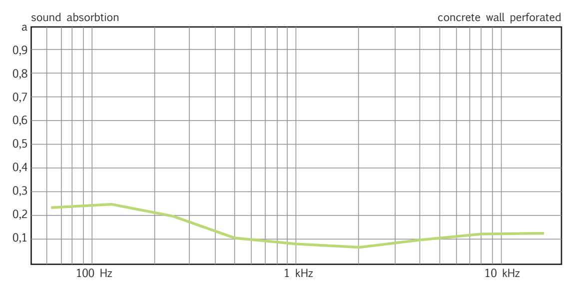
Below is shown a graph of the reverberation time in the auditorium, based on level of occupancy, ranging from empty, over 50% to 100% occupied. The auditorium has seats for 168 persons and a volume of 2251,30 m^{3}.



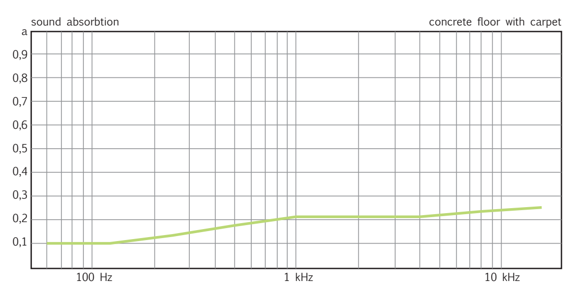
ill. 36 Reverberation times auditorium

The reverberation time depends on the absorbtion coefficient of the materials and the volume of the room.
The materials are chosen to fulfill the wanted absorbtion coefficients, this is only seen as a verification that the room can meet the demands set for it, further work needs to be carried out in this field.

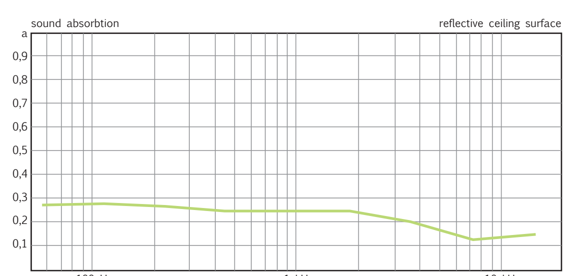
Selected materials
Concrete walls with areas of perforation with airspace and insolating material behind for better absorbtion of low frequencies.
Concrete floor slab with carpet.
A reflective hard ceiling, could be a plastic material, for efficient sound distribution.
The seats are chosen as upholstered.



ill. 38 Absorbtion coefficents, concrete wall perforated



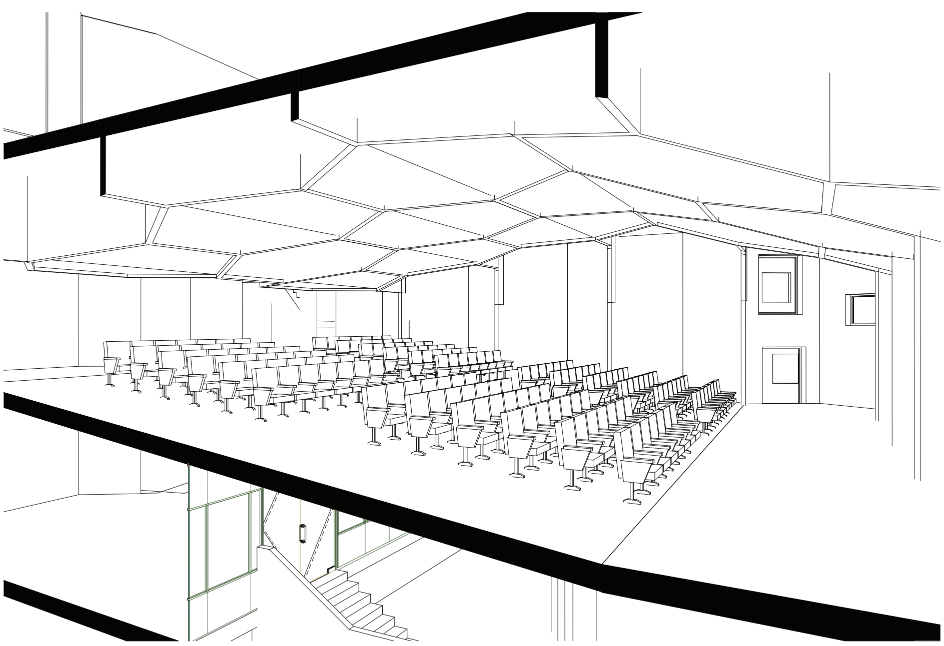
ill. 39 Absorbtion coefficents, concrete floor with carpet



ill. 40 Absorbtion coefficents, reflective ceiling surface

Conclusion

The auditorium showed early on to have certain problems with the layout of the walls, creating risks of echoes, but with small changes through ray-diagrams, it has been possible to use these for acoustic purposes, as goes for the ceiling, that now works as an impressive architectural element as a result of the acoustic investigations.
The auditorium will need further work, but this is seen as outside the project boundaires, the main thing is to verify that it is possible to create an effective auditorium, within the design of these buildings.



ill. 41 Line perspective of the auditorium, showing the adjusted ceiling

STAAD Pro

Through the project process different scenarios appeared that have been interesting to investigate through STAAD Pro to define the structural stability of the proposal.
In the following paragraph different models are presented that have been through STAAD Pro. As the structural system is not the main concern of this project only preliminary investigations are made to create an understanding of dimensions and possible solutions. Here further investigations are necessary to examine in future iterations.

load

Construction load

In STAAD Pro selfweight of the construction is calculated. However the programme only include the weight of the structural elements put into STAAD Pro why the other permanent loads as e.g. floor slabs are added as dead load.

Self weight: Fg = m x g, m = mass; g = gravity acceleration, 9,82 N/m^2

The existing concrete load = 20 kN/m^3
compression tension, f_c = 8 MPa -> f_{ck} = 6 MPa

Service load
Equipment – furniture ect. = 3 kN/m^2
People, q = 5,0 kN/m^2 [DS 410, 3.1.1.7]

load combination

The load combination is based on DS 409 (Tabel 5.2.8)

G = selfweight + dead load
Q = service load + snow load
W = wind load
y = load factor, partial coefficient
¥ = load reduction factor, ¥W = 0,5; ¥Q = 1,0

Serviciability limit state

Load combination 1 - This examination takes place on an individual load basis, e.g.:

Sd ~ Gk Deformation from permanent load / Selfweight
Sd ~Qk Deformation from the variable loads

Where combinations of several loads which act at the same time the following type is often used:

Sd = Gk + Qk,1 + ¥2 x Qk,2 + ¥3 x Qk,3 + ...

1.1	G + Q + W1
1.2	G + Q + W2
1.3	G + Q
1.4	G + W1
1.5	G + W2

Ultimate limit state

Load combination 2.1 - This load combination is relevant when the variable loads is considerable in comparison to the dead load. Usually several cases are examined.

Sd = yfg x G + yfq x Q1 + ¥ x Q2 + ...

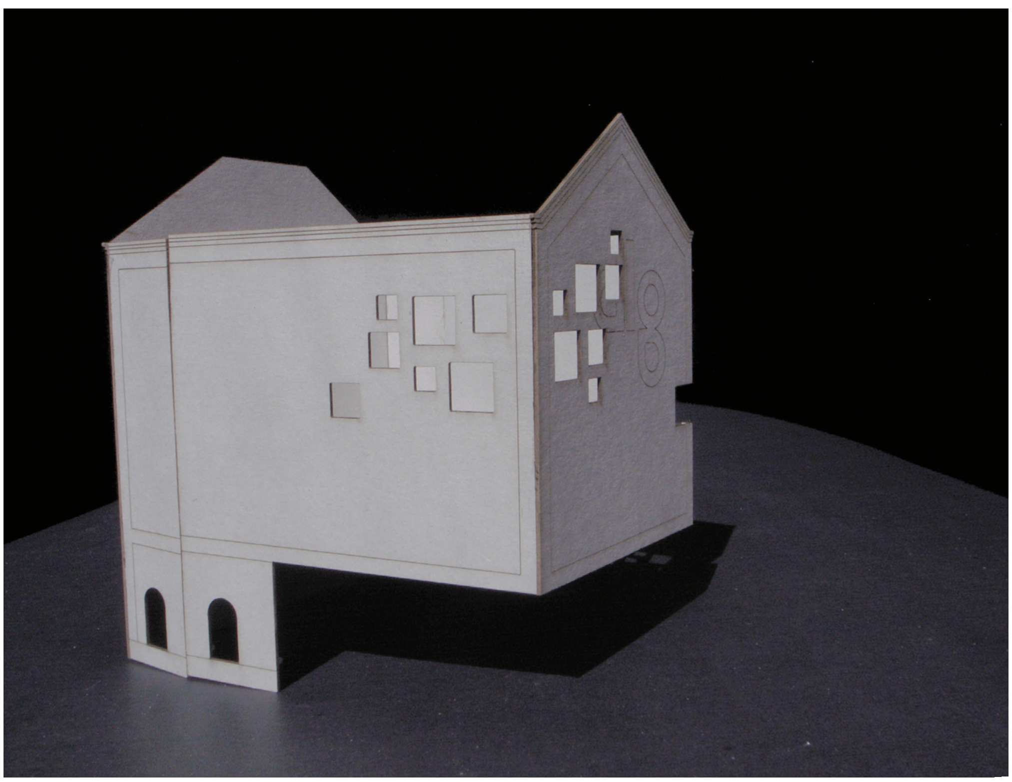
2.1.a	1 x G + 1,3 x Q
2.1.b	1 x G + 1,5 x W1
2.1.c	1 x G + 1,5 x W2
2.1.d	1 x G + 1,3 x Q + 1,0 W1
2.1.e	1 x G + 1,0 x Q + 1,5 W1
2.1.f	1 x G + 1,3 x Q + 1,0 W2
2.1.g	1 x G + 1,0 x Q + 1,5 W2

Load combination 2.2 - This load combination is relevant when the permanent load works in favour and has a conclusive importance for the building, e.g. to lift or push the construction. For high security class the load factors for variable loads are multiplied with 1.1.

2.2.a	0,8 x G + 1,5 x W1
2.2.b	0,8 x G + 1,5 x W2

silo 02_cantilever

During the design process the possibility of having an open ground level occurred when considering the flow from the public square located just West of Silo 02. This entails a large cantilever. In this building the industrial expression has been kept why a system with a rough appearance was preferable. Here inspiration from cranes have influenced the perspective of strategy and system.
The cantilever has been investigated in STAAD Pro to determine the dimension required for structural stability.



Max displacement, Dy_{max} = l/200 = 14000/200 = 70 mm

Concrete, compression tension, f_c = 20 MPa -> f_{cd} = 11,6 MPa
Steel yilding point, f_y = 235 -335 MPa -> f_{yd} = 201-286 MPa
[Data, Teknisk Ståbi, p. 161 & 188]

loads

Permanent load

Additional construction load
Existing concrete load = 20 kN/m³ / Compression tension, f_c = 8 MPa
f_{ck} = 6 MPa

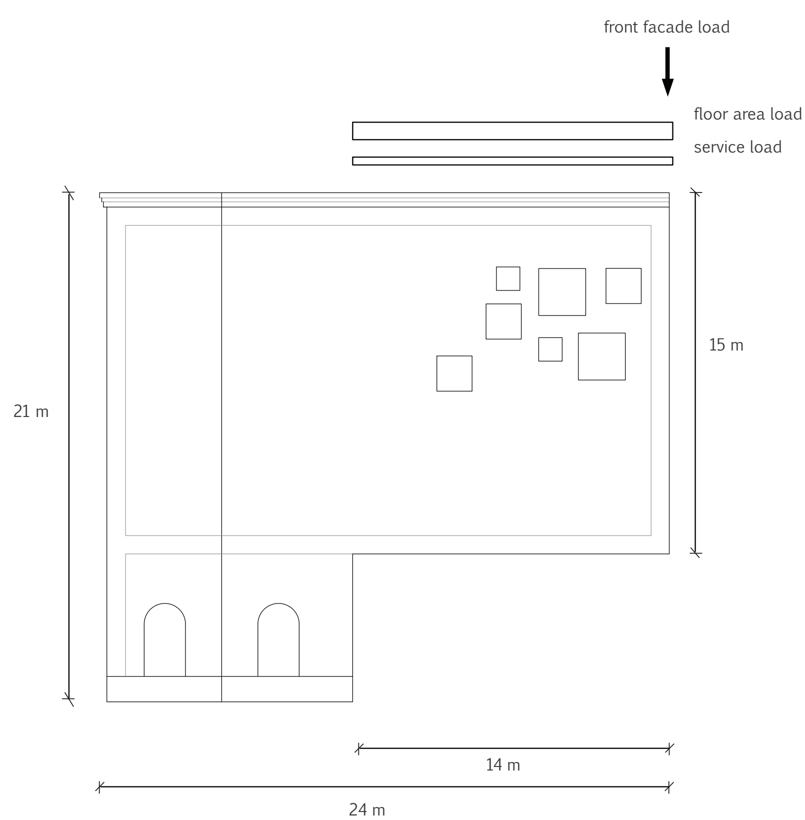
- front facade:	258 m² - 15,5 m² =242,5 m² x 0,18 m = 43,65 m³	
	2,79 m³ x 20 kN/m³ = 873 kN / 2	**= 436,5 kN**
- floor area	219 m² x 0,5 m = 109,5 m³	
	109,5 m³ x 20 kN/m³ = 2190 kN / 2 = 1095 kN	
	1095 kN / 14 m	**= 78,2 kN/m**
- facade load	207 m² - 30,25 m² = 176,75 m² x 0,18 m = 31,8 m³	
	31,8 m³ x 20 kN/m³ = 636 kN	
	636 kN / 14 m	= **45,5 kN/m**

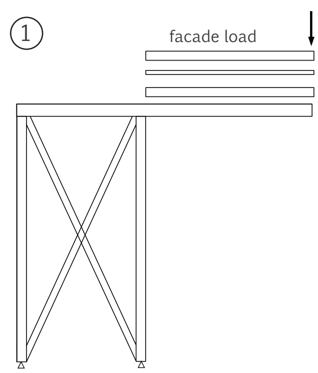
Service load

Equipment – furniture ect. q = 3 kN/m²

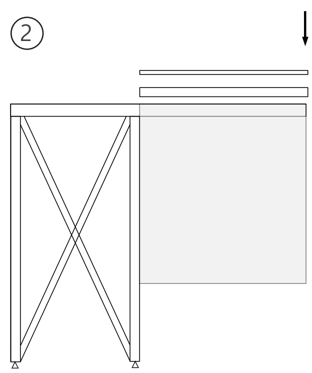
- floor area	219 m2 x 3 kN/m2 = 657 kN / 2 = 328 kN	
	328 kN / 14 m	**= 23,5 kN/m**

People, q = 5,0 kN/m²	, DS 410, 3.1.1.7	
- floor area	219 m2 x 5 kN/m2 = 1095 kN / 2 = 547,5 kN	
	547,5 / 14 m	**= 39,1 kN/m**

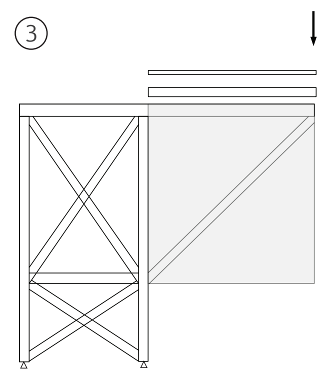




ill. 42 Cantilever01.std



ill. 43 Cantilever_plate.std

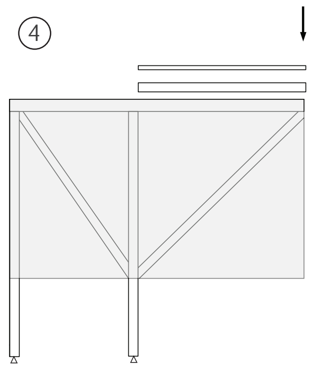


ill. 44 Cantilever_plate02.std

iterations

Here different profiles and geometric systems have been examined. The first iterations concerned the maximum displacement which was difficult to fullfill without increasing in size of beams[1]. Then looking upon the facade this could function as a plate bolted to the structure[02]. This creates a satisfied displacement with relative small profiles however the stresses in the steel beams and in the plate was too high in relation to the compression tension of concrete and steel yilding state. This can be solved by optimising the geometric of the system[3].

3	DY_{max}	$f_{y,max}$	$f_{c,max}$
HE 550 M	31 mm	185 MPa	12 MPa
HE 650 M	29 mm	178 MPa	11,8 MPa
HE 700 M	28 mm	175 MPa	11,7 MPa
HE 800 M	27 mm	168 MPa	11,5 MPa



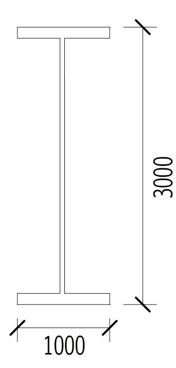
4 HE 800 M	Serviciability limit state	Ultimate limit state
DY_{max}	23 mm	24 mm
$f_{y,max}$	182 MPa	183 MPa
$f_{c,max}$	9,8 MPa	9.8 MPa

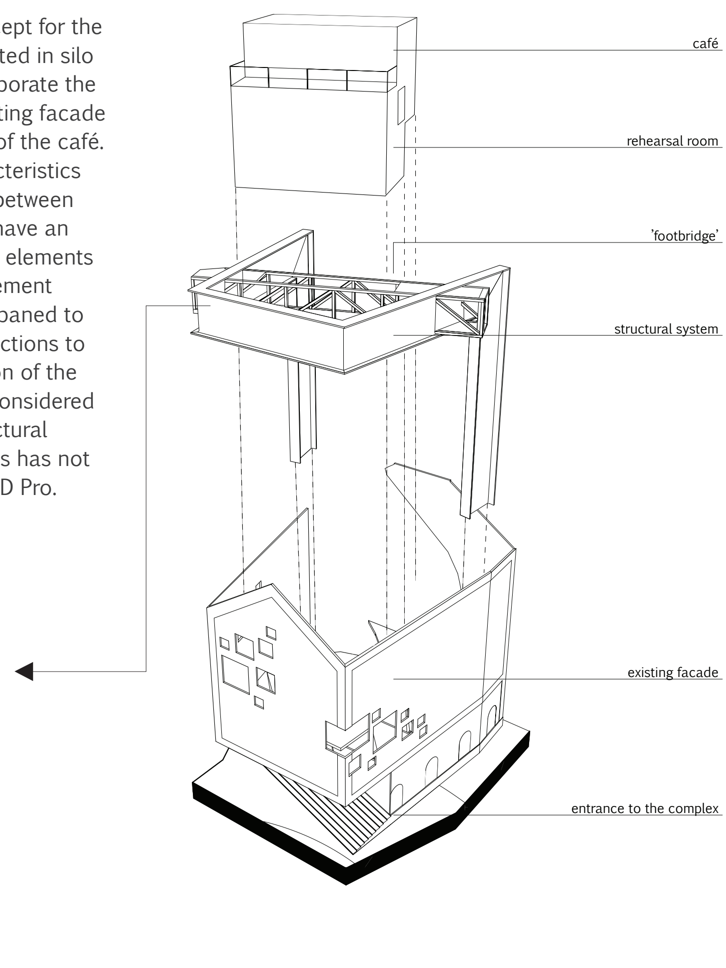
ill. 45 Cantilever_plate03.std

Here the intire facade has been bolted to the profiles this reduces the tension in the concrete. This figure has been further investigated to secure stability in utimate limit state as well.

cantilever with café

This system developed a concept for the café and rehearsal room situated in silo 02. Here the aim was to incorporate the system that stabilises the existing facade of silo 02 into the expression of the café. Furthermore one of the characteristics in the area is the footbridges between the buildings. Both elements have an industrial character why these elements have been connected. The element running through the café is expaned to a size that allows flow and functions to be implemented. The extension of the profiles[see illustration beneath] is considered as enough to sustain the structural stability in the building why this has not been calculated through STAAD Pro.

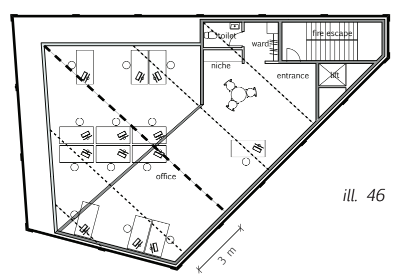




silo 03_slab dimensions

Here the office slabs of silo 03 is investigated due to the fact that the facades of polycarbonate are not the bearing strucutre, it is the wish to create a clean office expression without desturbing elements such as columns or walls that can limit the degree of interior arrangement. This lead to a cantilevered slab that has been investigated to ensure stability and adjusted dimensions.

The elements are examined in relation to the serviceability limit state.

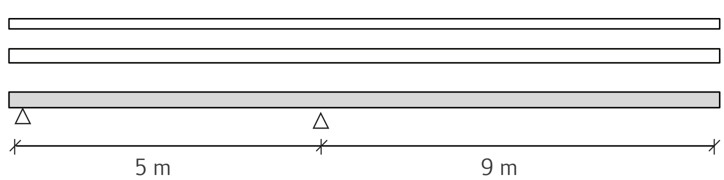


$DY_{max} = l/200$

ill. 46 Office floor plan illustrated with the structural system

structure

Here the structure has been simplyfied in relation to STAAD Pro.



service load = 3 kN/m^2
floor load = 1,5 kN/m^2

	HE300M	HE400M	HE450M
DY_{max} = 45 mm	81 mm	48 mm	37 mm

This indicate that the supporting structure for the cantilevered floor is designed with HE450M.

The profiles can be tapered towards the facade to illustrate the direction of forces however this needs to be investigated in relation to the natural frequency to avoid unpleasant vibrations.

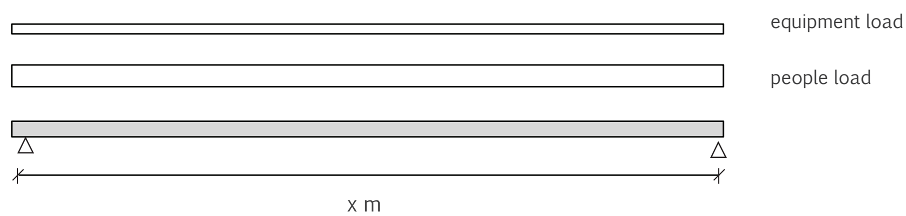
the atrium_path length

The pathways in the atria do in some areas span a long way to connect the different levels and create an interesting flow through the atrium both vertical and horizontal. In the following structural investigations are made to create an idea of the dimension and span needed to avoid unpleasant deflections.

The elements are examined in relation to the serviceability limit state.

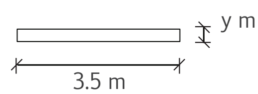
path

Here the dimensions of the footbridge are investigated in relation to the length.
Max displacement, $DY_{max} = x/200$



[01] Concrete path

Cross sections

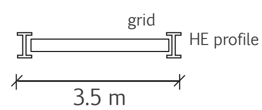


	x = 20 m DY_{max} = 100 mm	x = 18 m DY_{max} = 90 mm	x = 16 m DY_{max} = 80 mm
y = 150 mm	397 mm	260 mm	163 mm
y = 200 mm	202 mm	132 mm	83 mm
y = 250 mm	120 mm	80 mm	50 mm
y = 300 mm	80 mm	53 mm	33 mm

The dimensions need to be relative small so the pathways do not become too dominant in the atria. However the length of the paths is very determaint for the flow between the functions and the combination of path and activities.

[01B] Steel path

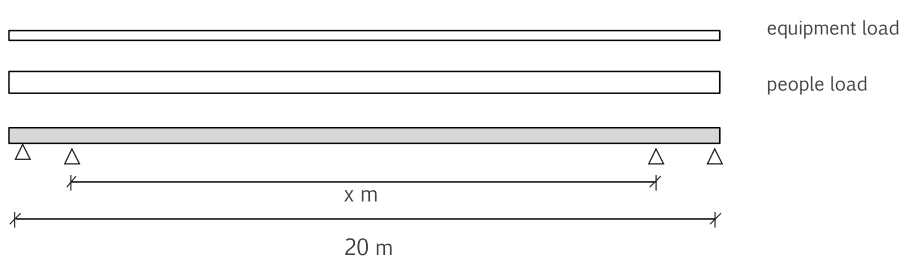
Cross sections



grid = permanent load
3 KN/m^2

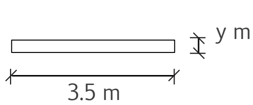
	x = 20 m, DY_{max} = 100 mm	x = 18 m, DY_{max} = 90 mm	x = 16 m, DY_{max} = 80 mm
HE 160 M	483 mm	317 mm	198 mm
HE 200 M	238 mm	156 mm	98 mm
HE 240 M	109 mm	72 mm	45 mm

The use of HE profiles will not reduce the dimensions radically. Furthermore there is a gain in relation to the sustainable principles by introducing thermal mass in the path which can help naturally to control the temperatures.



[02] Concrete footbridge

Cross sections



	x = 19 m, DY_{max} = 100 mm	x = 18 m, DY_{max} = 100 mm
y = 150 mm	260 mm	162 mm
y = 200 mm	132 mm	83 mm
y = 250 mm	80 mm	50 mm

ill. 47 Illustration of flow in the atrium. Here the maximum length of the slabs have through STAAD Pro been determined to 20 m however with supports along the atrium side.

Conclusion

Here the path has a span of 20 meters however there need to be some supporting along the side of the atria to keep the thickness of the slabs at a required level in relation to the expression.

x = 18 m / y = 250 mm DY_{max} = 50 mm $F_{c,max}$ = 11,2 MPa

materials

introduction

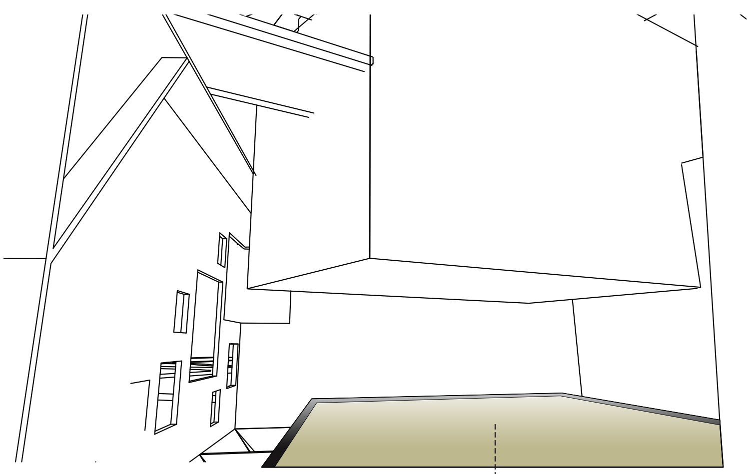
The overall concept for selecting the different materials and the final processing of them in the design has been a very clear definition of old and new. A clear division of the two will ensure an emphasis of them both and make it easy for the observer to perceive the architecture and the story of the past, which has been of big importance throughout the entire project.

The choice of materials has also been evaluated in relation to the more technical aspects such as sustainability, acoustic and daylight distribution within the different spatialities.

The different iterations and selections can be seen in the following.

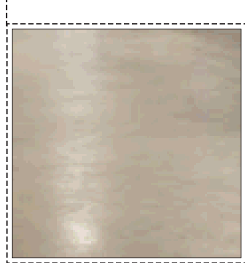
silo 02

The open space in Silo 02 being an embraced outdoor area resulted in aiming for a more rough expression in this part of the complex, why the chosen materials for the cafe and open space slab are inspired by the materials used in urban cityscapes. Also the constructive element in the design that carries the awning of the cantilevered building has been constructed from large I-profiles to obtain a very industrial appearance. The large slab that merges into the silo is the new element of the outdoor area, why the choice of material and finishing of the surface has been investigated.



The construction of the slab in Open space

The open space will be constructed from concrete, with a smooth and polished surface. The edges will be defined through the use of a steel frame to emphasize the element as new in the existing concrete building.



Polished concrete floor

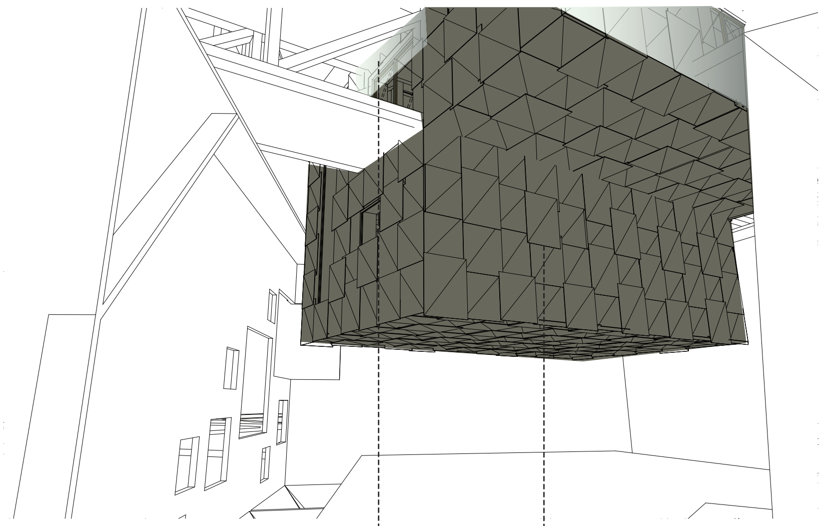
Considerations;

Wood:
A soft material, which is very often used in areas of contact. Wood is perceived as warm because of the colour and the well known expression and feeling of the material. The material is renewable and can be processed under environmentally friendly circumstances, why it would be a reasonable choice regarding sustainability. But as a more rough expression is wanted in this area, the more soft expression of the wooden surface has been deselected.

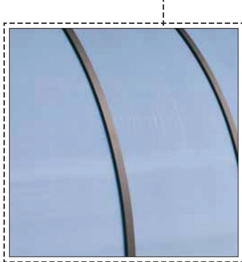
Tiles:
large concrete tiles will give the expression of an outdoor area as these are very often used as pavement. A hard surface that provides the space with the wanted expression, but the rectangular grid in the surface might interfere with the expression of the cladding on the hanging cafe.

Concrete:
Perceived as a raw material and is often used in harsh environments - inside and outside, because of the high durability and small need for maintenance. The same qualities make concrete a sustainable material, because of the relatively low energy consumption after ended construction. The slab will appear as one surface and underlie the more dynamic expression of the cafe.

The large constructive solution for the awning has also been used in the design of the cafe, which gives the hanging volume a more harsh expression in the open silo construction. The facade solution for the cafe has been investigated to ensure the right appearance of this hanging element.



The metal cladding of the cafe



Polycarbonate

Metel cladding

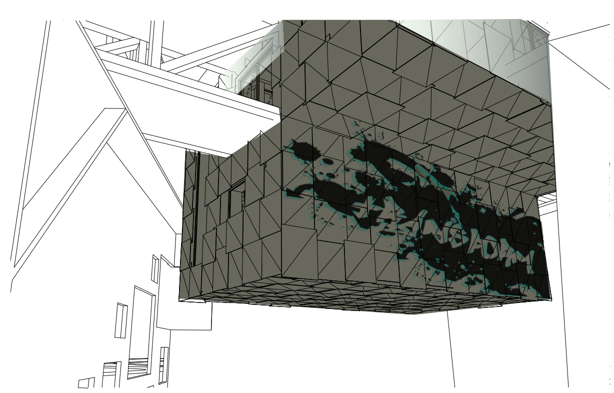
Considerations:

Polycarbonate: Translucent material that provides the internal spaces with large amount of natural daylight through the wall construction and makes it possible to see the ongoing activities inside the cafe and rehearsal room from outside, the atrium and open space. Despite the light and translucent appearance of the material, the properties for insulation are rather high, why it can be used for wall constructions and ensure low energy consumption. But the very light and stringent expression of the polycarbonate as an opposition to the large steel construction seemed as a too large contrast between the two elements.

Wood: Large areas of contact and a larger intimacy in the cafe made wood considerable, because of the very well known perception of the material being soft and warm. The expression of the surface was seen as shingles, that could give the stringent volume a more fragmented and exciting expression on the outside. The material is renewable and can be processed under environmental friendly circumstances, why it would be a reasonable choice regarding sustainability. But the more light expression of the material together with wood not being seen as very industrial in the given context are the reasons for not choosing this material.

Steel: The metal cladding gives certain heaviness to the volume and makes the interaction between the cafe box and the bearing construction more equilibrious. The untreated steel is also perceived as being more industrial and rough compared with polycarbonate and wood. The facades constructed from same principle as shingles creates irregularities in the joints and makes a more dynamic expression in the facades. The maintenance of the material is low and it can be processed to become rather weather resistance.

To break up the closed steel facade and to emphasize the open space as an outdoor area the facade towards the entrance from the atrium will be decorated with street art.



Introduction of street art on the facade towrads the atrium

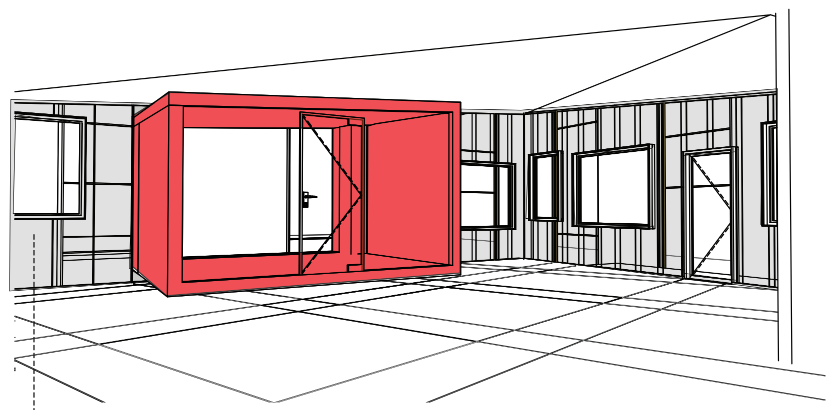
silo 03

The expression of silo 03 has been with largest focus upon the new materials, why optimisation of the existing walls will be mounted directly on the outer wall of concrete and a new wall construction towards North and West have been introduced. The wall should provide the offices with larger amount of daylight through a translucent wall construction. The existing wall will be maintained as outer shell with large window areas to let in as much daylight as possible. The double facade will additionally create possibility for using the void for small balconies with a view, natural ventilation and reduction of the transmission loss towards North giving larger window areas in this direction.

Considerations;

Pilkington Profilit: Translucent U-profile glass panels for wall constructions. The panels can be mounted in a double layer which gives the opportunity to use Nanogel in between and obtain acceptable low u-values in the walls (1,1 kWh/m2). The expression of the material is vertically as a joint appears each 20-30 cm along the wall construction. Even though the material is made out of glass it has a heavier expression than polycarbonate, which is the second opportunity of material for these walls. A very light wall construction is desirable, as the ceiling will be constructed as cantilevers, and the expression of lightness in the material will emphasize the lack of support for the ceiling.

Polycarbonate: a light and translucent material that will emphasize the cantilevered ceiling. With the introduction of Nanogel a very low u-value can be obtained (0,23-0,52 W/m^{2}K) , why it can be used in the design of sustainable architecture.
The transparent expression of the Polycarbonate also ensures an illumination of the silo building in night time, where the inner structure will be seen as a luminous wall behind the shell of the old concrete construction of the silo. At the same time it will create light in the outdoor spaces between the two wall constructions. The acoustic properties for Polycarbonate are also the reason for choosing this material, as Polycarbonate can be produced with a large span in absorption coefficients, which is favourable in the office spaces with a larger amount of concrete surfaces on the adjacent constructions.
[http://www.supersky.com/]



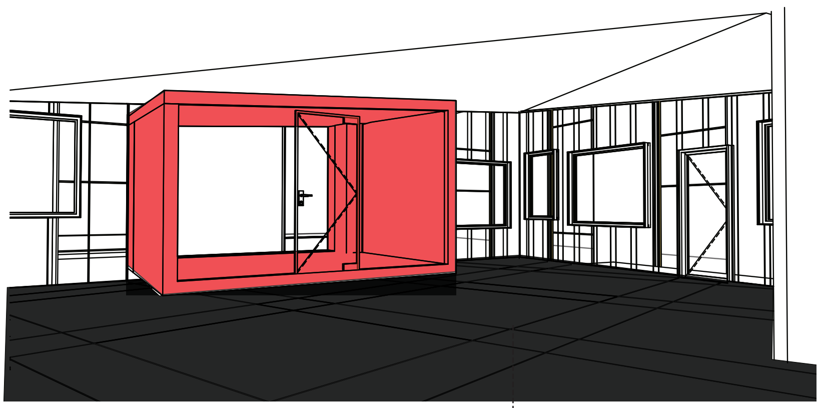
The wall construction in one of the office spaces

Polycarbonate

nanogel

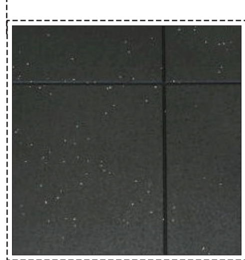
Nanogel (honey-combs)
Constructed from either polycarbonate (PC) or Polymethylmethacrylate (PMMA) in a honeycomb pattern, consisting of small tubes perpendicular to the absorber, so the material allows for solar radiation through the insulation and at the same as a result of the stationary air in these small tubes insulate through lowering of the conductivity. The thickness of the material varies depending on the needed U-value in the construction, but normally around 5 cm. [http://www.supersky.com/]

The angled pattern of the silo walls in the existing building will be projected onto the floor as guidelines for the layout of the flooring to create a remembrance of the historical past of the building, but as the new elements are to be the dominating expression in this building volume the link to the past will become more symbolic and humble.



Flooring in one of the office spaces

The use of light colours in the room will ensure a higher daylight factor in the office space compared with the use of dark colours, but opposite to this will a darker floor reduce the risk of glare and create possibility for heat accumulation in the slabs.



Black rubber floor

Considerations:

Stone tiles: The use of stone tiles in the offices will give a new expression to the slabs, and become the new element in the old Silo building, but at the same time create great coherence with the existing walls and ensure a greater attention towards the new and light wall construction made from Polycarbonate. But the acoustic properties of the hard stone material could cause a hard acoustic environment in the offices together with the heavy weight of the flooring on top of the cantilevered slabs.

Rubber: Even though the surface is hard the expression and properties of the material are softer and can ensure a better indoor climate in the office spaces. The material still contributes with a more industrial look to the room and creates a great coherence with the optimised concrete walls. Here the colour of the flooring has been highly considered according to utilization of the daylight into the space.

silo 04

The concrete construction from the existing building, where the optimisation of the facades regarding the demand for low energy consumption will be implemented on the inside of the wall construction. The window holes in the inner wall will differentiate from the window holes in the outer construction in size and layout and create a tension between old and new where the existing wall construction can be seen from the inside through the windows and the new material depending on the functions inside can be se from the outside. The meeting between old and new will be emphasized in the windows in silo 04, why processing of the materials here has been of big importance. The window frame will be constructed as a smooth concrete surface that stands in contrast to the rougher surface of the existing wall construction.

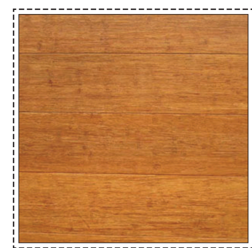
Inside: The material on the inner walls varies depending on the use of the space inside the construction and can be seen outside creating a colourful pattern on the facades.

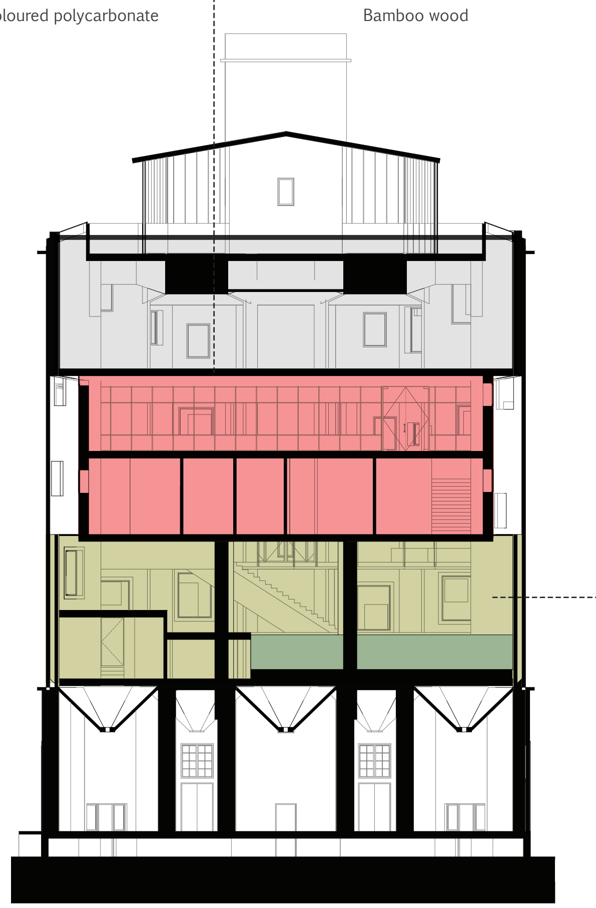
Wellness: Coloured concrete in the external window holes. Inside wood is chosen as cladding because of the perception of the material being soft and warm. Wellness has large areas of contact, why a warmer and well known material is preferable here. Wood is because of its properties in connection with water a good and reasonable material to use in water rooms. Furthermore it has a relatively long lifespan and the need for maintenance is limited depending on the type of wood. At the same time wood is a renewable material and can be processed under sustainable principles. The surface of the material and the possibility for using the material for acoustic solutions are also the reason for choosing wood as an element in wellness.
Fitness/changing room: The same material inside as seen in the window frames. The chosen material is a coloured polycarbonate which allows daylight to enter the building while insights to the room can be controlled.

Auditorium: Constructed from concrete. External window holes painted in a dark colour as black. Internal the material will be painted in a white colour to ensure a better daylight distribution. Furthermore will the walls be perforated to obtain a good acoustic environment for the auditorium. See further details under the acoustic for the auditorium.

The Restaurant: on top of Silo 04 is constructed from Polycarbonate as the wall constructions in the Roof top garden on top of Silo 03. The material is also implemented in the cafe, which will ensure a coherent expression of the three extensions of the silo buildings and at the same time create a light and luminous expression of the new elements compared with the more massive and darker silos.


Coloured polycarbonate


Bamboo wood



atrium

The atrium is the new element of the complex, why it needs to separate itself from the rest of the complex in its architectural expression. The way of distinguishing the atrium has been through a lot of iterations regarding the wanted expression. How should the atrium be seen in the context. Should the construction be a completely new element, a parasite to the existing building volumes, dominating or should the two elements appear as equal – as one unit.

White concrete with coating

Transform

Considerations:

Glass and steel: Large glass panels to let in as much daylight as possible and to ensure a light expression in the facades compared with the existing silos. The lightness of the structure will emphasize the new part of the complex and pay large attention towards the old building volumes. The large transparency in the facades will contribute with life and diversity to the surroundings, as it is possible to see the ongoing functions inside the atrium. A hugh risk for overheating and/or a larger amount of needed shading devices in the facades to obtain an acceptable indoor climate made this facade solution unwanted for the final design.

Metal cladding: Possibility to open the facades according to the sun and window areas. A rougher expression of the material could contribute with a larger coherence with the silos and the story of the site. However introduction of colours in the metal-cladding facade created an expression of the atrium being more a parasite on the silos, as it distinguished itself quite obvious from the existing buildings.

Concrete: The atrium constructed from concrete will give a certain heaviness to the volume and create a larger coherence with the existing concrete buildings. The different buildings in the complex are all seen as one unit, but through the work with the facade solutions and different processing methods a differentiating of the surfaces on the two shapes will occur and ensure a clear tension between old and new for the observer. The use of concrete also contributes with smaller temperature variations in the space because of high heat accumulation.

fire regulation

application category

The complex is divided into different sections corrected in relation to the application.

Offices located in silo 03 will be in application category 1 as the users are familiar with the building and thereby with the fire escapes and routes, while the café and rehearsal rooms arranged in silo 02 are application category 2 where the maximum people load does not exceed 50 people. Furthermore the functions placed in silo 04 (wellness, fitness, aerobic and auditorium) as well as the atrium between the buildings are application category 3 which are functions with a people load of more than 50 persons and where the people do not know the subdivision of the building in relation to fire. [BR95, 6.1.1]

fire escapes

The offices are divided into fire cells where the fire can not disperse. Each office zone is provided with two of each other independent exit, through the main external fire escape located at the north or through the atrium which is seen as an enclosed fire section. Furthermore is each floor provided with rescue openings [*].

Looking upon silo 04 the atrium serves as a fire escape which has access to the outdoor furthermore is an external stair located on the east facade opposite the atrium ensuring that the maximum distance between the openings does not exceed 25 m [BR95, 6.2.6]. Here it is important to create wide openings and corridors for a smooth evacuation. The different functions act as an independent fire section where the fire can not diffuse to other building section during the time necessary for evacuation.

The café and rehearsal room located in silo 02 are connected to the atrium and furthermore the footbridge running through the volume is seen as a fire escape route that either directs the occupants to a secure place as the location of the café and rehearsal room do not exceed 22 m the bridge can be reached by the stairs of the fire department. Another possibility is to follow the bridge to silo 03 where a secure fire stair is located.

The atrium is seen as an independent fire section which indicates that the fire can not diffuse to other building sections during the time necessary for evacuation. The atrium is connected to the other building volumes which have individual fire escapes that also can be used for the atrium in instance of fire.

In case of fire fans are located on the roof to ensure the venting of the smoke and warm air. This system is constructed on the basis of fire technical configuration. These ventilators can furthermore be used during the week to help fulfil the ventilation rate if the wind pressure or thermal buoyancy are not enough to secure a comfortable indoor climate.

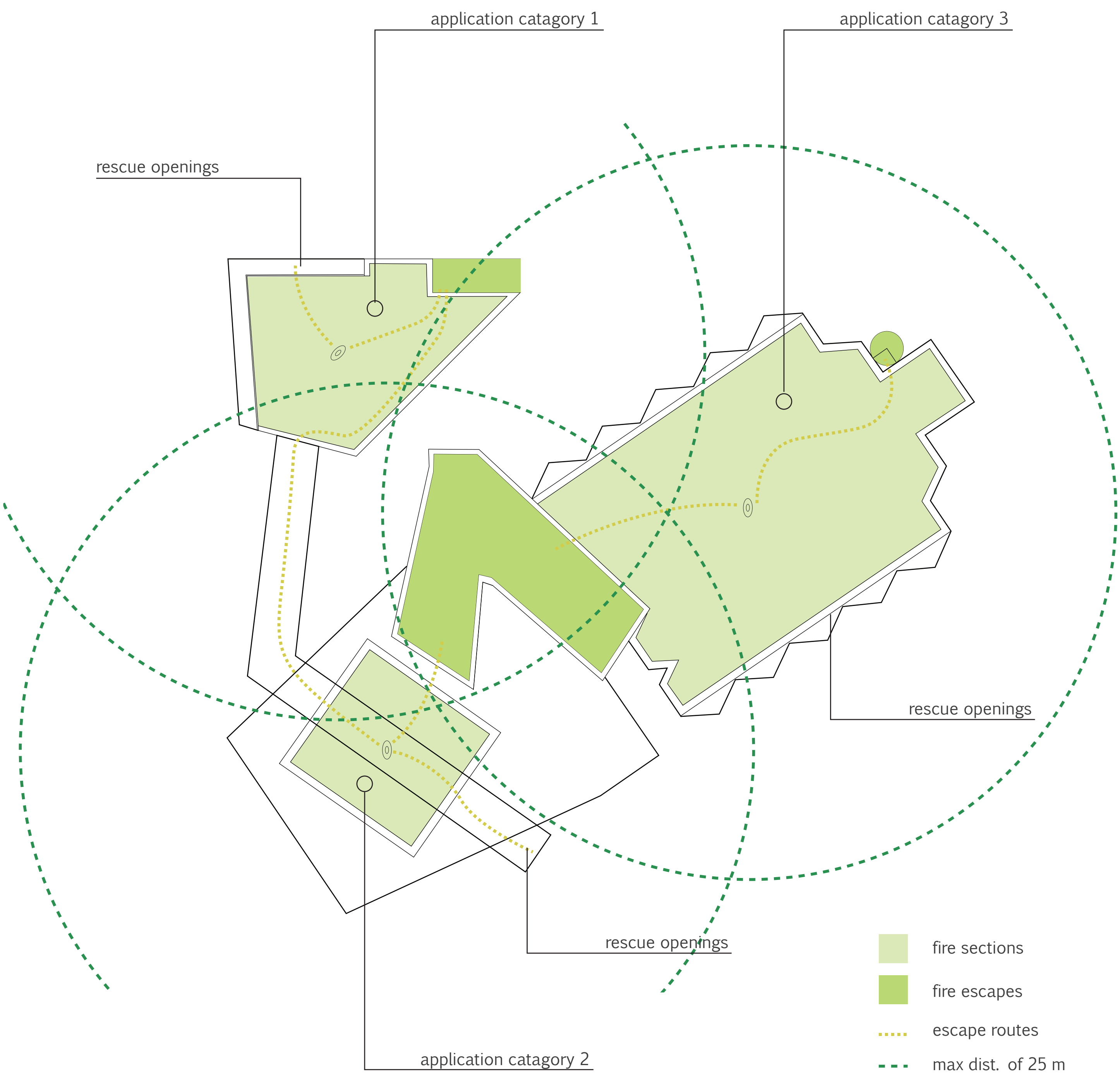
* Rescue openings have to have a free height and width of 1,5 m altogether, where the height has to be at least 0,6 m and the width 0,5 m. The position of a rescue opening has to be in a distance from the floor to the lower level of the rescue opening of max 1,2 m. One rescue opening is enough for a fire unit with a person load of 10 people.

materials

Installations shafts, stairways, lift shafts are classified in individual fire sections separated from other building parts.

Ceiling, walls and facades are corrected in relation to their ability to resistance fire. The materials are denoted REI where R classify the load capacity of the material, E for the integrity and I for the isolation.

Since the building exceed 12 m above terrain the horizontal divisions between the floors are building class R 120 A2-s1,d0 where the vertical divisions are building class REI/EI 30 A2-s1,d0. Here A2 signifies that the material participation to fire is very limited, s1 indicates that there are a minimum smoke formation and d0 signifies no burning drop or particles. Fire escape doors belong to building class EI2 60-C secured with a ABDL-system.
[PDF; Eksempelsamling, om brandsikring af bygninger]



ill. 48 Diagram indicating the different fire escapes, division of fire units and escape routes

air change rate

introduction

The sensory polution and the CO_2 polution load in a room indicate airchange rate in a building in relation to the specific space, people load and activity. These values have been calculated through a spreed sheet throughout the project creating an understanding of the necessary ventilation rate in relation to the perceived air quality. These figures have been important in relation to BE06 and BSim to find the optimal ventilation rate according to the specific space, the people load and activity.

sensory polution

The sensory polution load is found by adding the loads of the pollution sources in the space. Pollution sources can be occupants, the building, furnishings, machines, carpeting and ventilation systems. ccupants produce and emits carbon dioxide, carbon onoxide and water vapur[CR1752, p.25]

CO_2 pollution load

The CO_2 load from persons is calculated to see whether the demand for ventilation should be higher than the values from the sensory pollution load. The highest demand will determine the required air change for achieving a PD(percent dissatisfied) of max 20 % as stated in CR1752.

Function	Occupants	Room volume m^2	Air change rate acc. to sensory pollution h^{-1}	Air change rate acc. to CO_2 pollution h^{-1}
Meeting place	30	8772	0,23	0,15
Café	30	270	5,8	4,12
Restaurant	60	1142	3,87	2,34
Lounge	30	474	3,10	3,10
Workshop	15	450	8,67	3,39
Rehearsal room	16	215	14,06	5,93
Lecture room	15	450	1,78	0,47
Auditorium/cinema	150	2250	3,49	1,2
Wellness	40	2530	4,0	1,6
Fitness	30	747	0,69	0,13
Aerobic	20	820	2,67	1,2
Dance studio	10	436	2,25	1,02
Office A	10	436	1,42	0,84
Office B	17	900	8,74	3,61
Rental company	3	1015	1,44	0,84

Ventilation rate

The results from the sensory and CO_2 pollution are compared and as shown in the spreadsheet the sensory pollution requires the highest air change which have been implemented in 24 H average, BE06 and BSim.