POLITECNICO DI MILANO
SCHOOL OF AUIC

POLITECNICO
MILANO 1863

MASTER OF SCIENCE IN BUILDING AND ARCHITECTURAL ENGINEERING

MASTER'S THESIS

CONVERSION OF A RENOVATED BUILDING INTO NEARLY ZERO ENERGY BUILDING

MASTER THESIS OF
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Table of Content:

0.

ABSTRACT

City of Iron was the name that Lecco used to be famous of, but after the crisis of the metallurgical industry many factories were closed and kept abounded for years, that made the municipality of Lecco plan an intervention for these type of buildings.

The mountain hub is the new project for a renovated paper mill that is located in the Northern part of Lecco, the site is characterized by; the Caldone river streaming beside the old paper mill, mountains and forests surrounding the site, making the site in a valley.

The main architectural concept of the mountain hub based on the type of users which are; families and athletes (Peace and Power). So the mountain hub contains recreational functions in the ground floor, athletic functions in the second floor and a small motel in the first floor as a mixed use between the two different categories.

The mountain hub kept the original style of the old paper mill and added a new building with a different style to represent this era. The coverage of the new building is intersecting angled panels made of opaque aluminum for roofing and perforated aluminum for screening with perforation 60% that defined according to the day light analysis (U-value 0.12W/m^{2}K). The exterior and interior walls made of wooden wall with insulation (U-value 0.21W/m^{2}K) and triple window glazing (U-value 0.90 W/m^{2}K).

The external walls and the slabs of the old building were retrofitted to reach the best percentage of energy consumption. The baseline for the old and new building of EUI (Energy Use Intensity) 403 kWh/m^2/yr and the final result is 60.5 kWh/m^2/yr. The use of PV panels , depending on the natural ventilation as an assistant factor with the selected HVAC system, and focusing on the use of natural light supported the decrease of energy consumption.

The paper mill is a 3 storey building, structurally; the oldest part -built in 1700- was removed because the deteriorated condition of the structure, and the main structure is external load bearing stone and brick walls with some internal load bearing walls made of concrete. The new building is made of simple system of steel structure with inclined roofing of corrugated sheet and the central isle in the second floor is continuous steel frames, and the new building is completely independent from the existing building.

In conclusion, the mountain hub project is a renovated project respecting the architectural aspects and focusing on the solutions related to energy consumption based on variable analysis and repetitive simulations.

RIASSUNTO

Città del Ferro era il nome con cui Lecco era famosa, ma dopo la crisi dell'industria metallurgica molte fabbriche furono chiuse e rimasero abbandonate per anni, ciò fece sì che il comune di Lecco progettasse un intervento per questo tipo di edifici.

Il polo montano è il nuovo progetto per una cartiera ristrutturata che si trova nella parte nord di Lecco, il sito è caratterizzato da; il fiume Caldone che scorre accanto alla vecchia cartiera, montagne e boschi che circondano il sito, rendendo il sito in una valle.

Il concetto architettonico principale del polo montano si basa sul tipo di utenti che sono: famiglie e atleti (Peace and Power). Così l'hub di montagna contiene funzioni ricreative al piano terra, funzioni atletiche al secondo piano e un piccolo motel al primo piano come uso misto tra le due diverse categorie.

L'hub di montagna ha mantenuto lo stile originale della vecchia cartiera e ha aggiunto un nuovo edificio con uno stile diverso per rappresentare quest'epoca. La copertura del nuovo edificio è costituita da pannelli angolari intersecanti in alluminio opaco per la copertura e in alluminio perforato per la schermatura con una perforazione del 60% definita in base all'analisi della luce del giorno (valore U 0,12W/m2K). Le pareti esterne e interne in legno con isolamento (valore U 0,21W/m2K) e tripla vetrata (valore U 0,90 W/m2K).

Le pareti esterne e le lastre del vecchio edificio sono state adattate per raggiungere la migliore percentuale di consumo energetico. La linea di base per il vecchio e il nuovo edificio di EUI (Energy Use Intensity) 403 kWh/m2/anno e il risultato finale è 60,5 kWh/m2/anno. L'uso di pannelli fotovoltaici, dipendendo dalla ventilazione naturale come fattore di aiuto con il sistema HVAC selezionato, e concentrandosi sull'uso della luce naturale ha sostenuto la diminuzione del consumo energetico.

La cartiera è un edificio a 3 piani, strutturalmente; la parte più vecchia -costruita nel 1700- è stata rimossa a causa delle condizioni deteriorate della struttura, e la struttura principale è costituita da muri portanti esterni in pietra e mattoni con alcuni muri portanti interni in cemento. Il nuovo edificio è costituito da un semplice sistema di struttura in acciaio con copertura inclinata in lamiera ondulata e l'isola centrale del secondo piano è costituita da telai continui in acciaio, e il nuovo edificio è completamente indipendente dall'edificio esistente.

In conclusione, il progetto dell'hub di montagna è un progetto rinnovato rispettando gli aspetti architettonici e concentrandosi sulle soluzioni relative al consumo energetico basate su analisi variabili e simulazioni ripetitive.

1.

INTRODUCTION

1.1 History of Lecco

Lecco, Lombardia (Lombardy) region is a city located Northern Italy, it lies South-East Lake Como at the outflow of the Adda River.
In the 11th century Lecco was granted to the bishops of Como, and passed to Milan in the 12th century (eccoLecco, 2020).

Lecco was not always a city, in the past it was a fortified village belonged to the Visconti family, in the 14th century Azzone Visconti built a castle by the lack (figure 1).
The castle was enclosed by thick walls of which few visible traces remain nowadays; the Viscontea Tower, the Wall of the Wall, bell tower of the Basilica San Nicolo (figures 2, 3, 4)
(eccoLecco, 2020).

Figure 1 The castle surrounded by the village

Figure 2 The wall remains - 1

Figure 3 The wall remains - 2

Figure 4 The wall remains - 3

The castle with its walls was part of a defensive system with a triangle shape (figure 3,4);
(A,3): Visconti Tower
(B): The castle
(C,1): Porta di Vianova (Wall of the Wall)
(D,5): bell tower of the Basilica San Nicolo
(E): Door of San Stefano
(F): Porta di Milano
In the same period Azzone built Ponte Vecchio which is called Azzone Visconti Bridge. The bridge is built at the end of lake Como where it connects with Adda River (figure 5). This bridge is near the fortified village (figure 6).

In 1782 the walls and the castle was eliminated by an order from the Austrian Emperor Joseph II as shown in the map, since then Lecco expanded and became officially a city (figure 7) (eccoLecco, 2020).

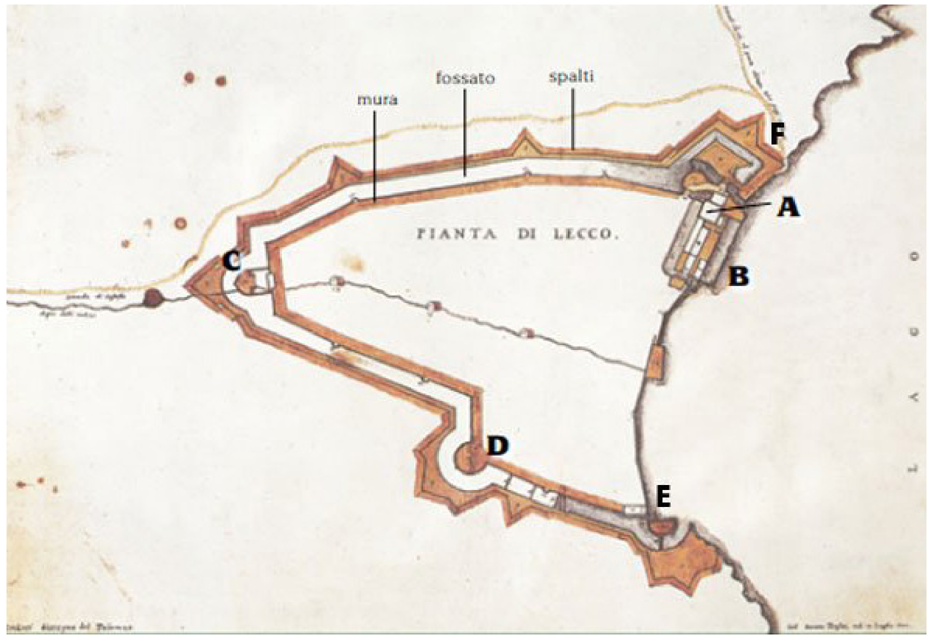


Figure 5 Elaboration of the Plan of Lecco, design by Giacomo Tensini 1642

Figure 6 Map of Historical center

In the 2nd half of the 19th century Lecco has been developed industrially, new buildings and infrastructure have built; the railway and the train station, steel and iron factories, construction of new streets and bridges, Lecco called in that time "City of iron" (Colucci, 2017).

From 1973-1975 all factories closed because of the crisis of the metallurgical industry, leaving Lecco for years between the decision of demolish these factories or re-plan a new idea for urban development and architectural renovation (Colucci, 2017).

Nowadays, there are number of industrial buildings in Lecco with great potentials in location, structural aspect, or architectural view that left unused and abandoned for years, that the Municipality of lecco is planning to be transformed into vital public spaces (Colucci, 2017).


Figure 7 Azzone Visconti Bridge nowadays

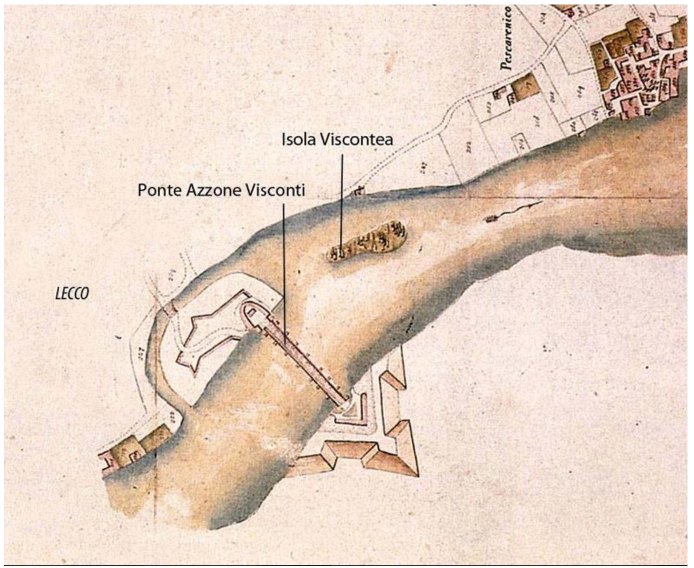


Figure 8 The relation between the bridge and the castle

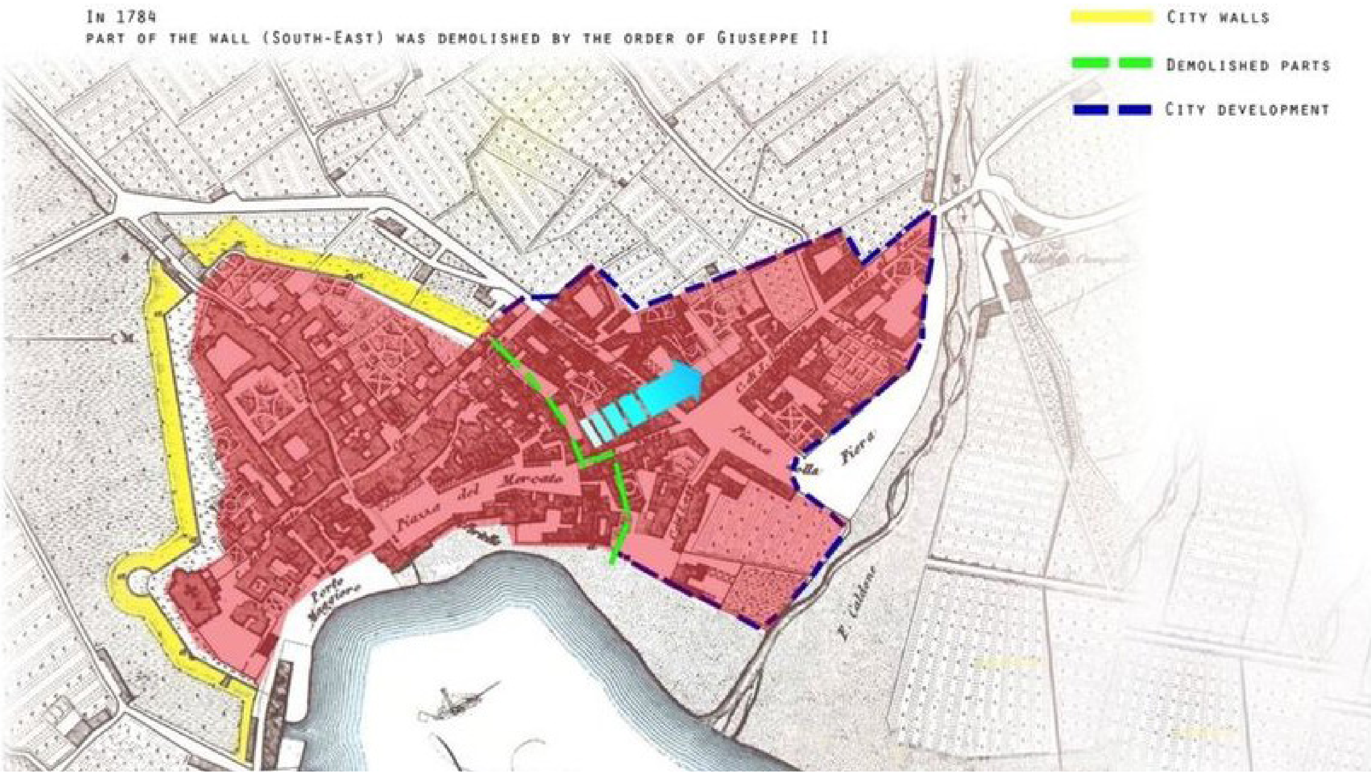


Figure 9 Old Map of Lecco showing the historical city expansion 1782

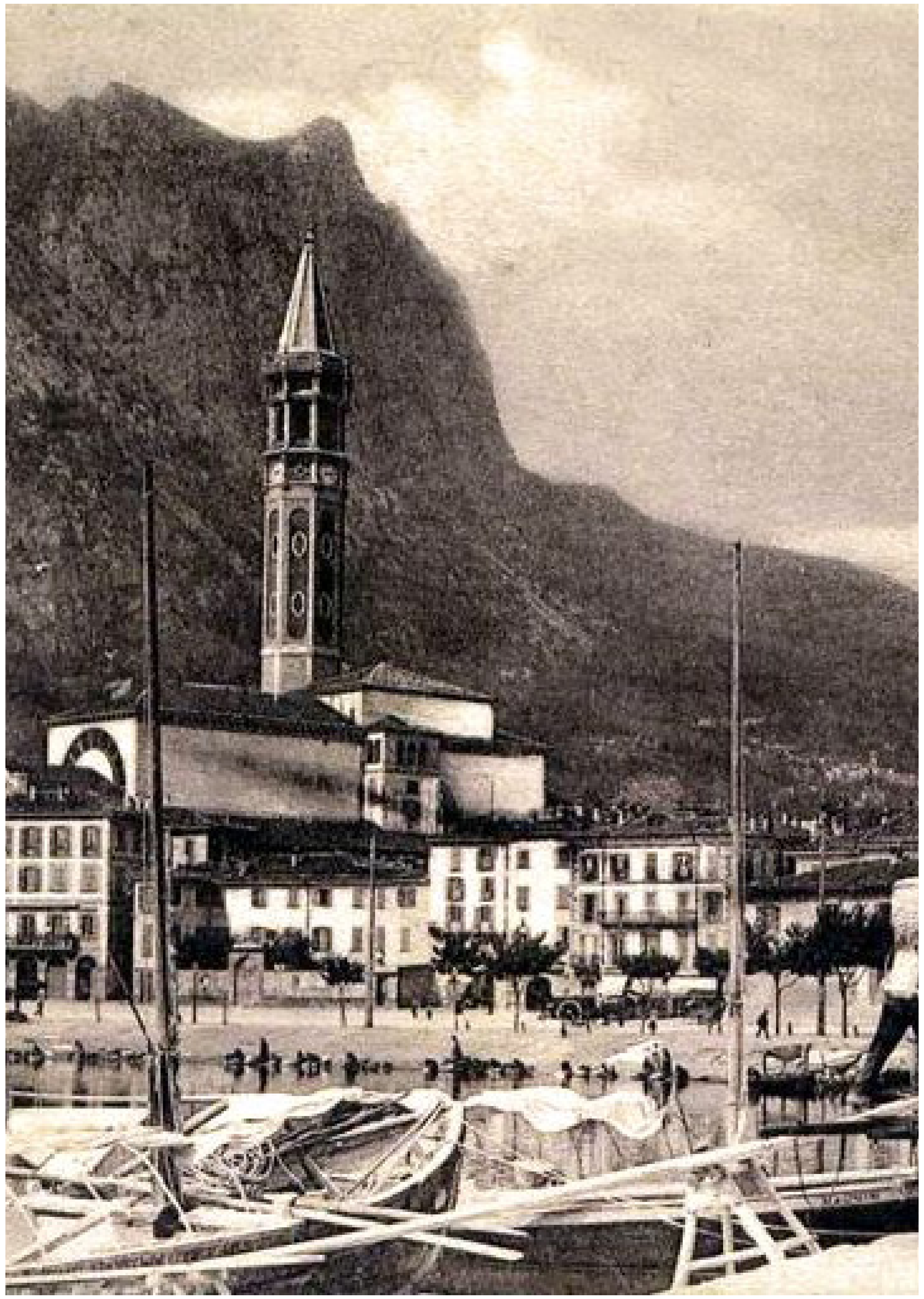


Figure 10 Old photo of Lecco

1.2 Innovative Development

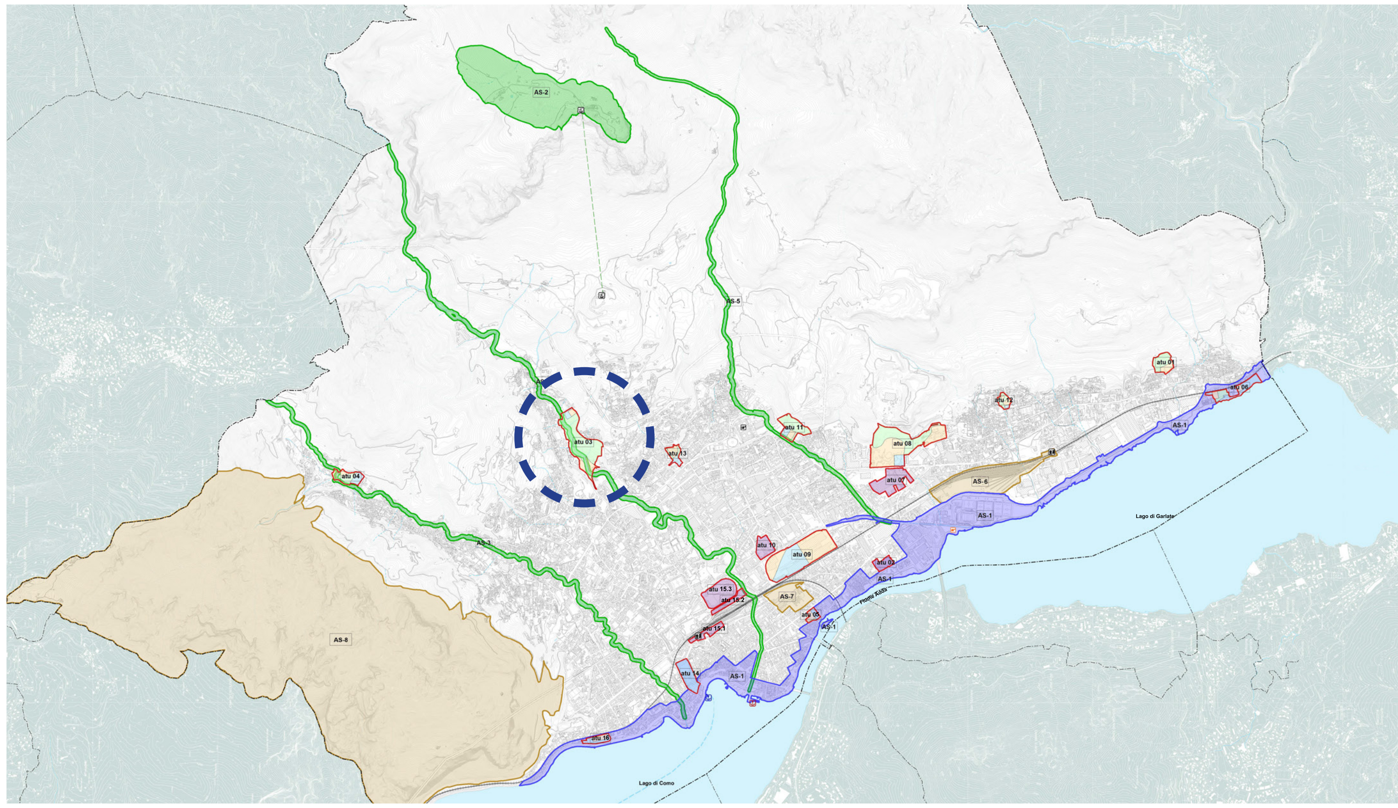


Figure 11 map for the zones of interventions in Lecco

Each area has its features and future planned project according to its typology, location, services, etc. The selected area to be discussed is atu 03 Torrente Caldone-Garabuso Bonacina.

The aim of the urban development is promoting the transformation of the territories with a potential to create a framework for upcoming synergistic plans. The strategic project aims to undertake the future actions with a cooperation between the municipality, different companies and including the individual citizens (Cassin, 2011).

The framework that built the strategic plan was created by the knowledge and research, accurate planning, participatory a long the plan and the guidelines. The plan is identification of areas priorities considering shared purposes: The Urban Transformation Environments and The Territorial Strategic Areas (Cassin, 2011).

The of Urban Transformation (ATU) and the Strategic Territorial Areas (AS) condense the major development strategies of this Territory Governance Plan. The areas in concern are considered full of opportunities and high-leveled potentials in both local and territorial scales, serving the development of the city in terms of competitiveness and quality of life for the city users, not mentioning respecting the sustainable approach, ecological and environmental aspects, and enhancing the landscape (Cassin, 2011).
The (ATU) is responsible of transforming urban environment by negotiating and planning, on the other hand the (AS) through the coherent interweaving of different intervention strategies specifically provided for in the plan of the rules and in the service plan (Cassin, 2011).

Each transformed area is part of the overall design that includes the implementation of the service network of Lecco, infrastructural network of mobility, also the development includes the inter-city, protection of environmental and ecological components (Cassin, 2011).

Areas of urban transformation are:
atu 01 Chiuso—area ex cava
atu 02 Pescarenico
atu 03 Torrente Caldone-Garabuso Bonacina
atu 04 Torrente Gerenzone-Laorca Pomedo
atu 05 Corso Martiri
atu 06 Rivabella
atu 07 Via Pergola
atu 08 Via Valsugana-Unicalce
atu 09 Arlenico
atu 10 Via Fiandra
atu 11 Torrente Bione- Belledo
atu 12 Cava Maggianico
atu 13 Logaglio
atu 14 Area San Nicolo-Ex Faini
atu 15 CALEOTTO Stazione Ferroviaria-Caleotto
atu 16 Caviate

The area is located beside the Caldone river, which unifies and organize the elements, besides it connects areas with settlement, environmental and characteristics different infrastructural.
The Caldone river is deeply engraved in a narrow and steep valley surrounded by mountains and forests, it connects between the areas located in the highest point in Lecco and Lake Como, in these two locations various of building can be found; residential, industrial, and historical, on the other hand the river also stream beside isolated and abandoned buildings (Cassin, 2011).

The selected area includes different natural elements that needs to be protected, enhanced and used in that intervention. Also, there are existing buildings that are abandoned for years, surrounded by residential buildings, which is part of the urban fabric and well connected to the center down near Lake Como (Cassin, 2011).

The unique location of this site proposes an Eco-friendly touristic recreational potential; green areas, external agricultural parks, recreational free time activities foothills where embraced by the mountains and the trees.
The aims of the project in that area are; respecting the natural elements and use it, respect the surrounded heights of the buildings which is 3 floors maximum, highlighting Via Garabuso road which is the main road that connects between the site and the center, connecting the foothill path with the existing buildings, and considering the Caldone river as it is the main element in the site (Cassin, 2011).

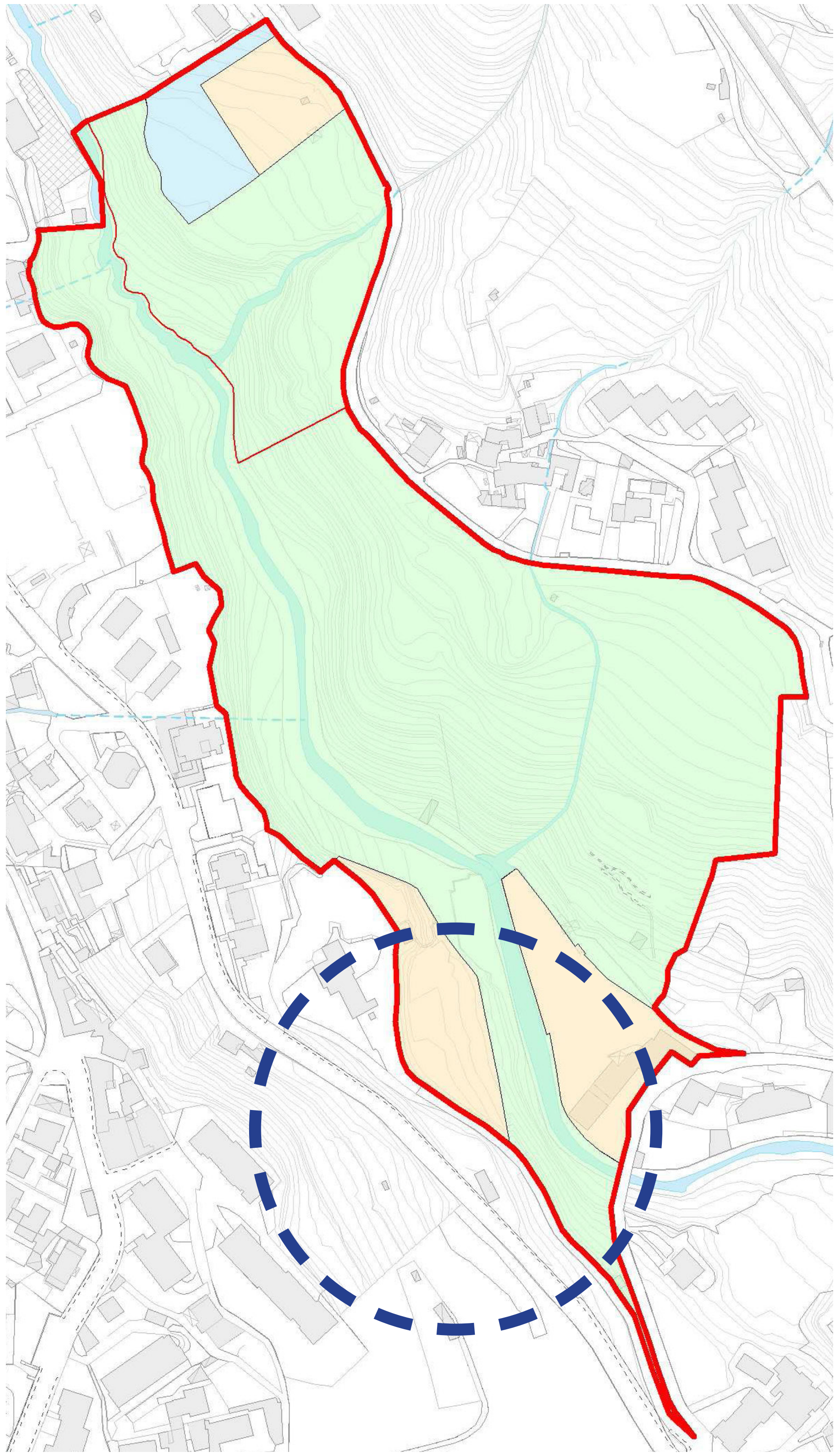


Figure 12 The selected site in atu 03 Torrente Caldone-Garabuso Bonacino is the site on Via Garabuso.

1.3 Brief objective

Lecco as mentioned in the previous chapter is a city with a unique history resulted different areas with high potentials for urban planning development. After an investigation about these areas, the selected area is Via Garabuso site.

Via Garabuso site is located in the upper part of Lecco away from the lake in the middle of the mountains and forests, connected with Caldone river that stream beside the site. In the site there is an old factory of paper mill that built in 1700 and kept unused for a long period of time.

Paper mill building is traditional building in a site that is planned to be a recreational destination for tourists to highlight the importance of the environmental element in that place. So, as a result the selected project for Via Garabuso site is renovating the paper mill to be a mountain hub including different functions that serves the goals and the plans of the municipality.

Renovating paper mill into a mountain hub is the first step in the project. The working process focused on preserving the existing building, demolishing the oldst and weakest part of the paper mill and additions of new building, besides solving the interior spaces architecturally to serve the new functions; recreational functions, athletic functions and shared functions.

These functions was determined according to the users of the building; families and athletes, which the site serves both. Also, this step considered the general appearance of the building, the landscape and the structure.

The second step of this project is transforming the renovated building into nearly zero building energy, considering the existing conditions as a baseline of the optineering analysis and developing during the process for the best energy consumption results.

This step considered the materials used in the building according to the simulations related to the opaque and glazing analysis, details related to the construction of the existing building and the new addition, daylight analysis and comfort zones.

So, by the end of the second step, a new layer of renovation has been added to the paper mill that exists since 18th century. A layer that represents the current time and style, this new layer respects and use the nature to be more included with it not excluded.

1.4 Methodology

"The concept of completing the monuments in modern style is right, but there are no real possibilities of artistic stability and harmony required by a monument while it is necessary and right that the style of our period appears, even in forms inherent to tradition, in the themes of the building municipality. It can not yet have right of citizenship in monuments alongside the expressions of art of the past, until it has proved so stable that it truly represents our century " (Gustavo Giovannoni).

Renovating the paper mill is based on Giovannoni scientific restoration that enhance that the addition of a new building should be representing the modern style of the current time. The mountain hub preserve the style of the old building and the new addition covered with aluminum perforated metal sheets in the roofing and the screen facades.

Why nearly zero building energy? The European Directive on the energy performance of buildings (EPBD) already announced that from 31st of December 2020 all the new buildings will follow the standards of nZEB. So, renovating a potential building into a usable function that serves the public and respecting the environment is a sustainable approach should be followed.

The methodology of achieving this aim is by understanding the meaning of nZEB first! Nearly Zero Energy Building is a "building that has a very high energy performance that the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (G. Masera, 2019).

In order to do that we need to make site analysis to understand the surrounded natural resources of energy, optimize the envelope of the new building and enhance the insulation layers of the existing building as an approach of passive design, making simulations, understanding what is an active system mean and try to implement in the project if needed.

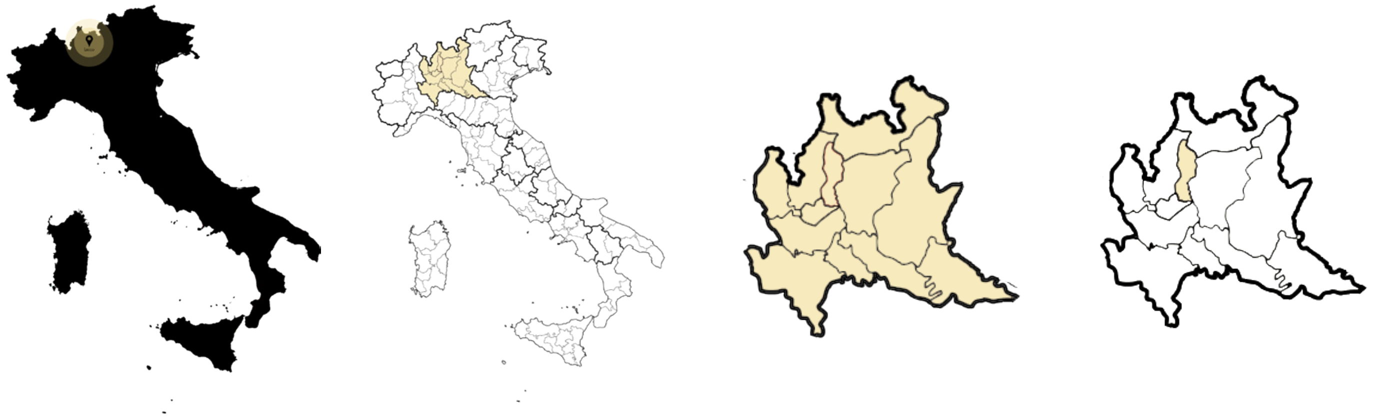
In the process of optimizing the envelope, focusing on the structural details of the new envelope and the relation between the old and the new structure.

In conclusion, the conversion of a renovated building into nZEB, following the strategic steps to achieve that, with focusing on the optimization of the envelope of the new and the old building in terms of passive design and structural design.

2.

ANALYSIS PHASE

1.1.1 Location



Coordinates
Location: Lecco, Italy
Latitude: 45.8566°N
Longitude: 9.3977°E

Climate Zone
Humid subtropical climate
Average temperature: 26°C
Average humidity: 66.58%

Sociological Aspects
Size of Lecco: 45.93 km^2
Population: 48,131
Density: 1,100/km^2

1.1.2 Natural Elements

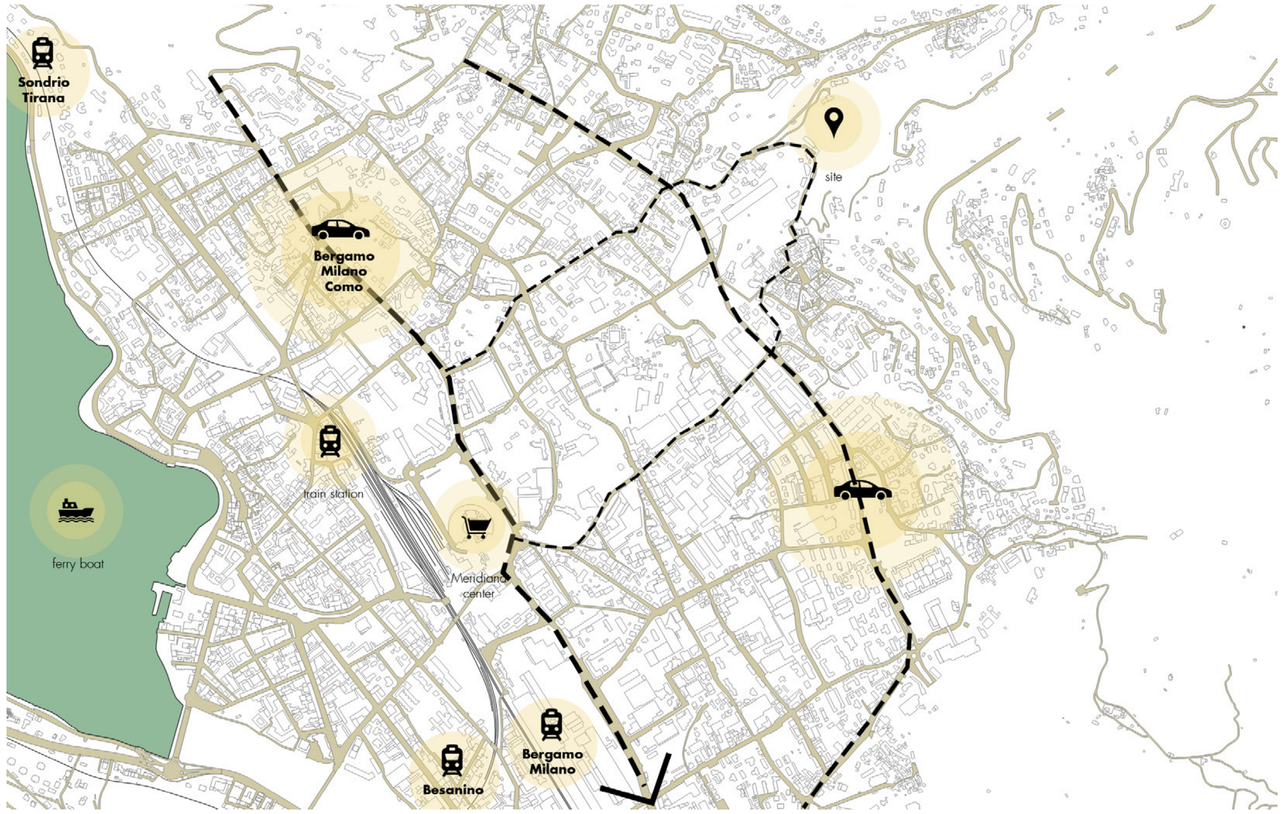
Lecco is a city confronting Lake Como and surrounded by mountains and forests, with two rivers connecting the mountains with the lake; Bione river and Caldone river. Also most of Lecco city green areas; private, semi-private and public.

URBAN & BUILDING ANALYSIS

1.1.3 Solid & Void

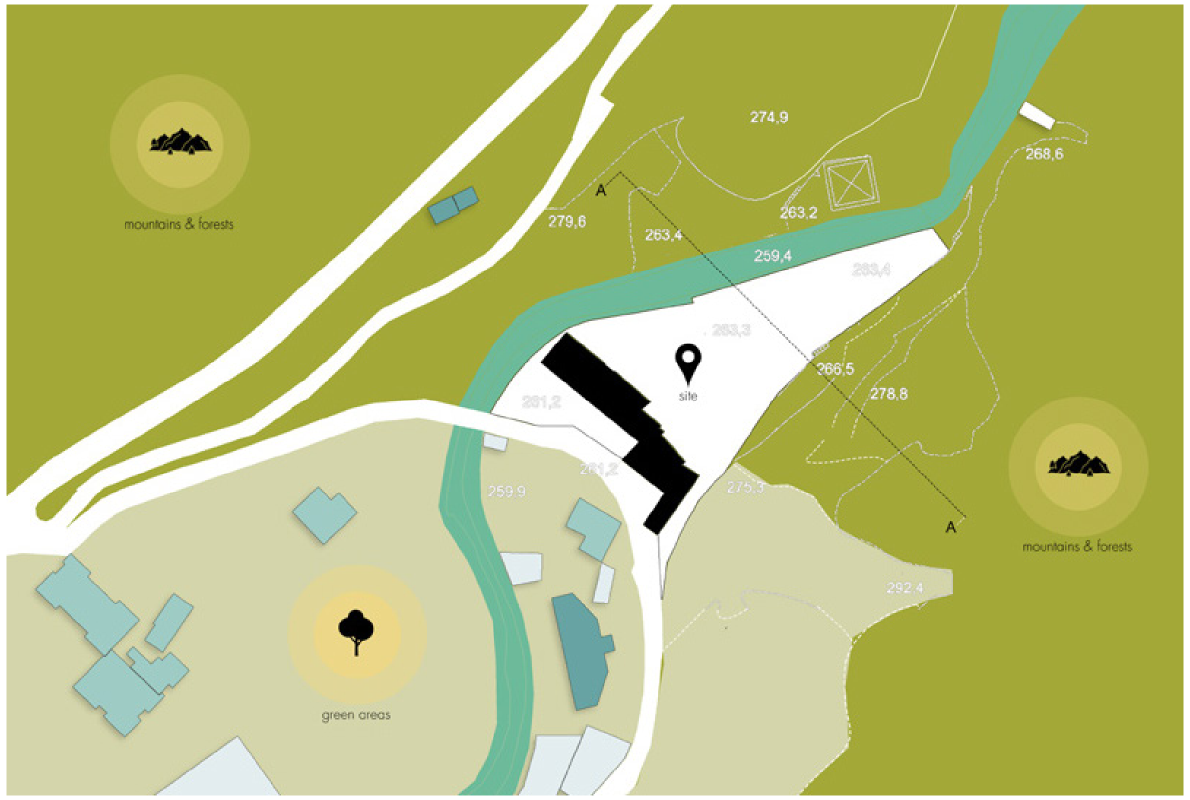
Solid and void map shows condensation of solid near the lake and in the center and the void increases towards the mountains because of the presence of the forests in that part of the city.

1.1.4 Infrastructure



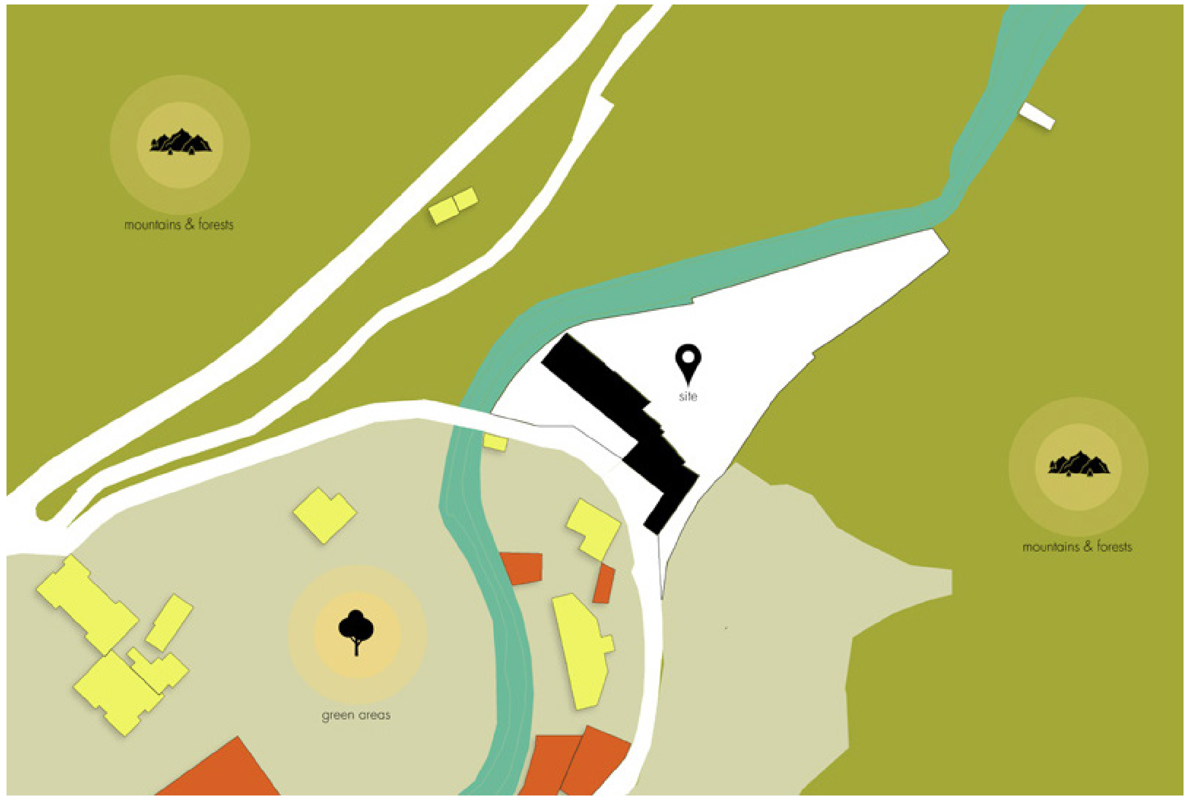
Lecco contains different mobility; trains that reaches stations in Sondrio and Tirana, Bergamo and Milano, and Besanino, and ferry boat. Their are different road hierarchy in Lecco that connects it to the surrounding cities.

1.1.5 Building Heights



Via Garabuso site characterized by its location in the valley embraced by mountains and forests, confronting Caldone river. The existing and surrounding building heights don not exceed 3 floors.

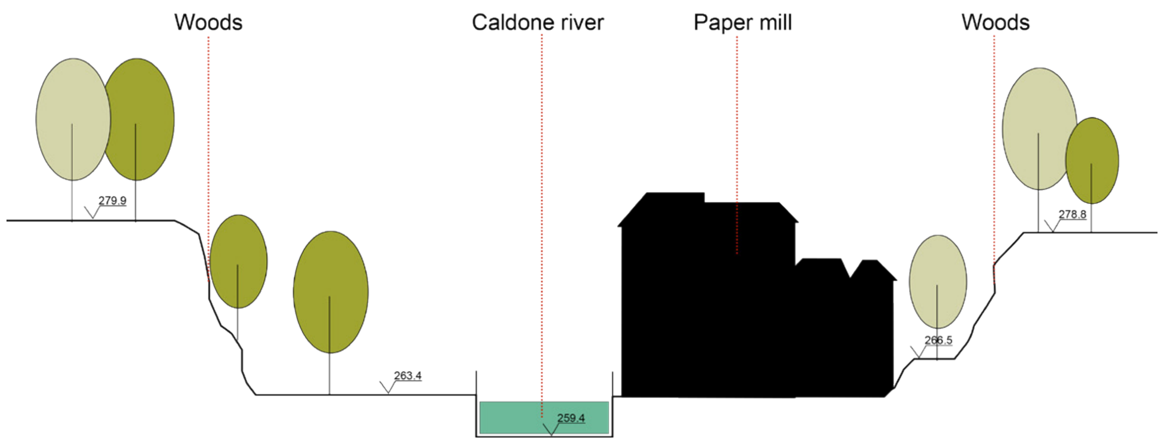
1.1.6 Land-Use



Paper mill was the land use of the existing building in the site, and the surrounded buildings are mainly residential buildings and few warehouses.

URBAN & BUILDING ANALYSIS

1.1.7 Relation with the mountain



The paper mill building scale in relation with the surrounded mountains, that shows that the building is free-standing in the middle of the mountains with a huge scale.

Figure 13 top view for the paper mill site.

1.1.8 Building Survey

VIA GARABUSO - LECCO ANALYSIS Latest update

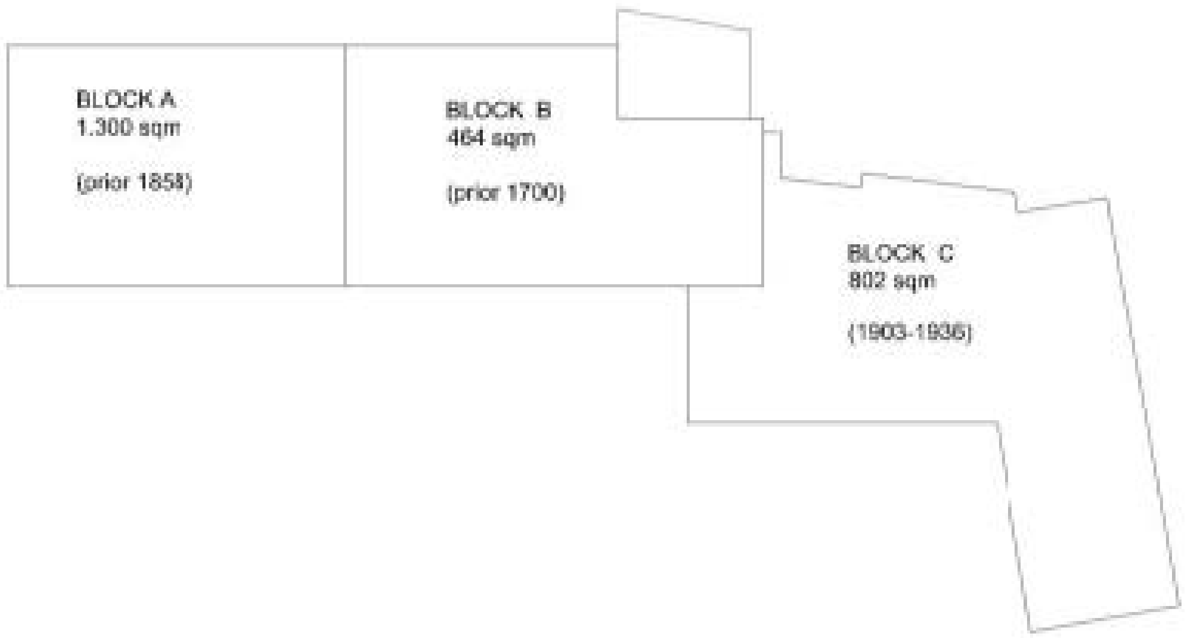
BUILDINGS AND LOTS **25/02/2019**

ID	BUILDING	YEAR OF CONSTRUCTION	MAP N.	LEVEL	NET SURFACE SU sqm	HIGHT H m
A.0		1858		0	146,00	
A.1				1	194,00	
A.2				2	194,00	
A	Tot.				**534,00**	16,00
B.0		1700		0	190,00	
B.1				1	190,00	
B.2				2	137,00	
B	Tot.				**517,00**	15,00
C.0		1903-1936		0	290,00	
C.1				1	256,00	
C.2				2	256,00	
C	Tot.				**802,00**	11,00
	Total				**1.853,00**	

LEVEL 0	0	626,00	
LEVEL 1	1	640,00	
LEVEL 2	2	587,00	
Total		**1.853,00**	

LOT	Free surface (without buildinng's ground floor)	5.154,00
LOT	Global surface	5.780,00

Table 1 paper mill analysis



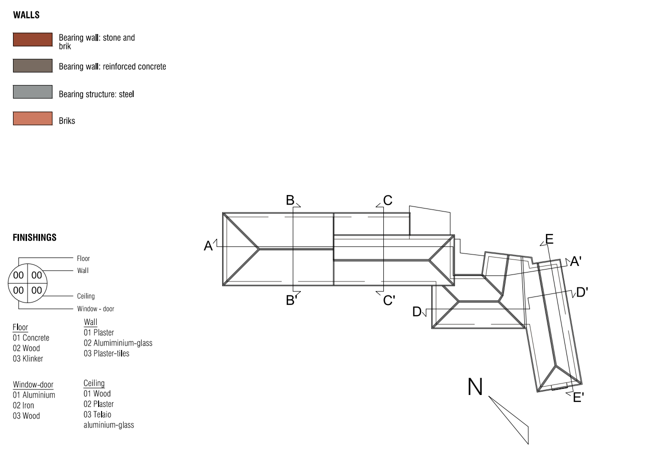
The building in Via Garabuso site is mainly unused abandoned paper mill, which consists of 3 buildings, each building has been constructed on a several times; Building B constructed in 1700, Building A constructed in 1858 and building C constructed in the years between 1903-1936 (Bianchi, 2019).

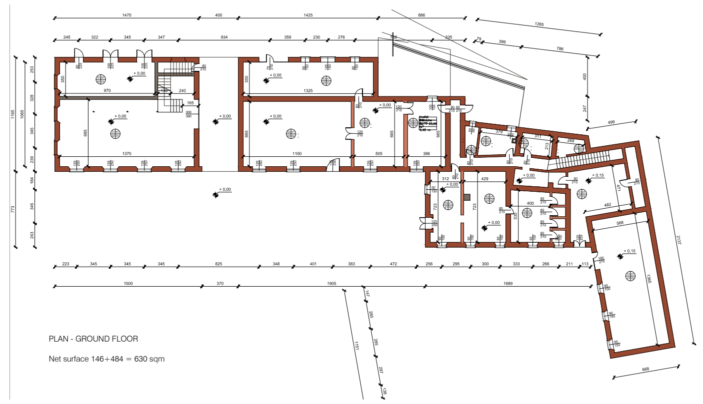
The exterior facade of the paper mill is typical Italian building; almost symmetric facade, long triangle windows, wooden louvers, yellow paint and red pitched roof (figure 8) (Bianchi, 2019).

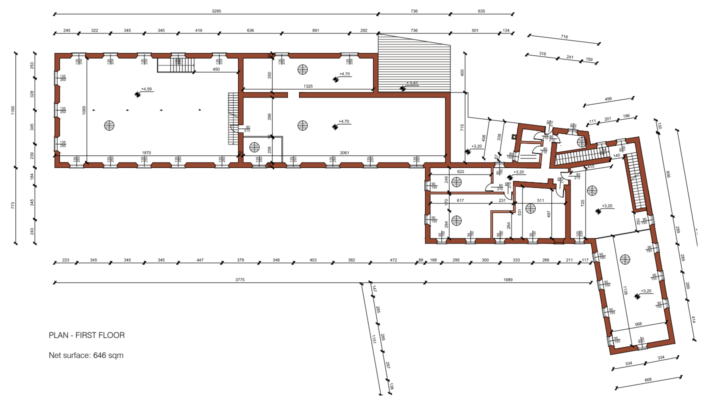
Figure 14 paper mill front view

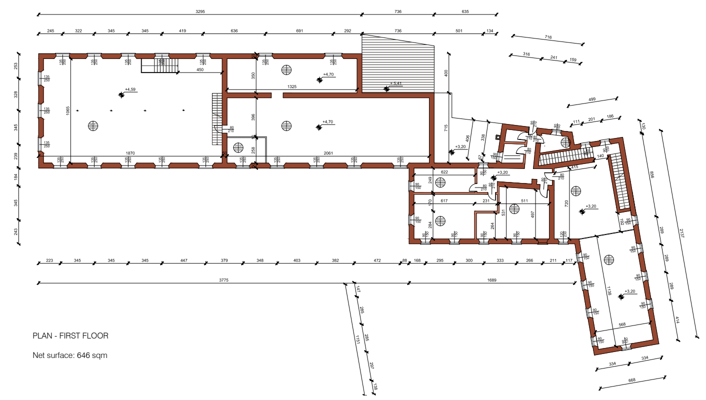
The exterior walls of the 3 buildings are 50cm thick load bearing walls of stone and brick, the interior walls varies between 50cm load bearing walls of stone and brick and 20cm brick walls. The flooring in the buildings varies between concrete, wood and klinker floor. The interior coating also varies but mainly coated by plaster.

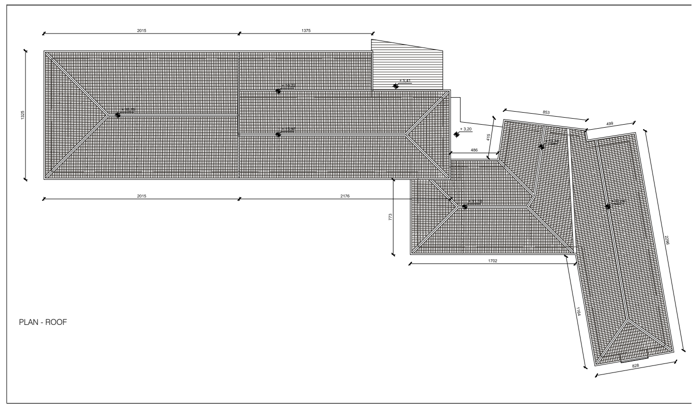
Figure 15 paper mill front view

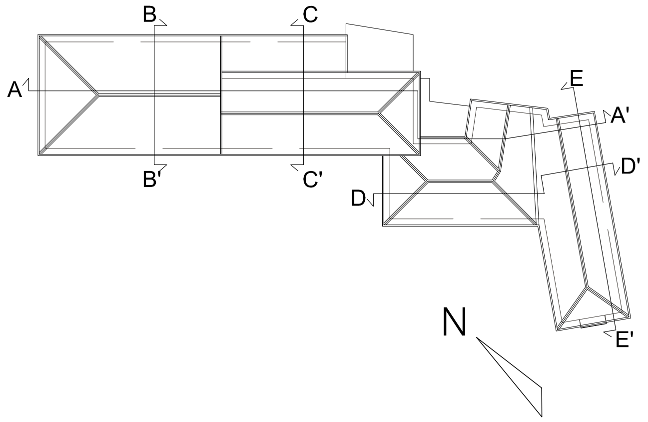


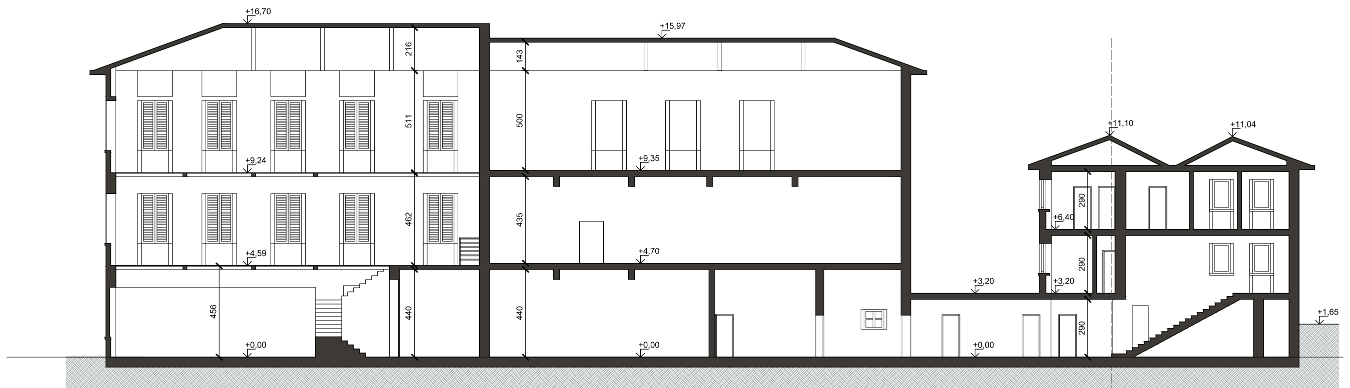




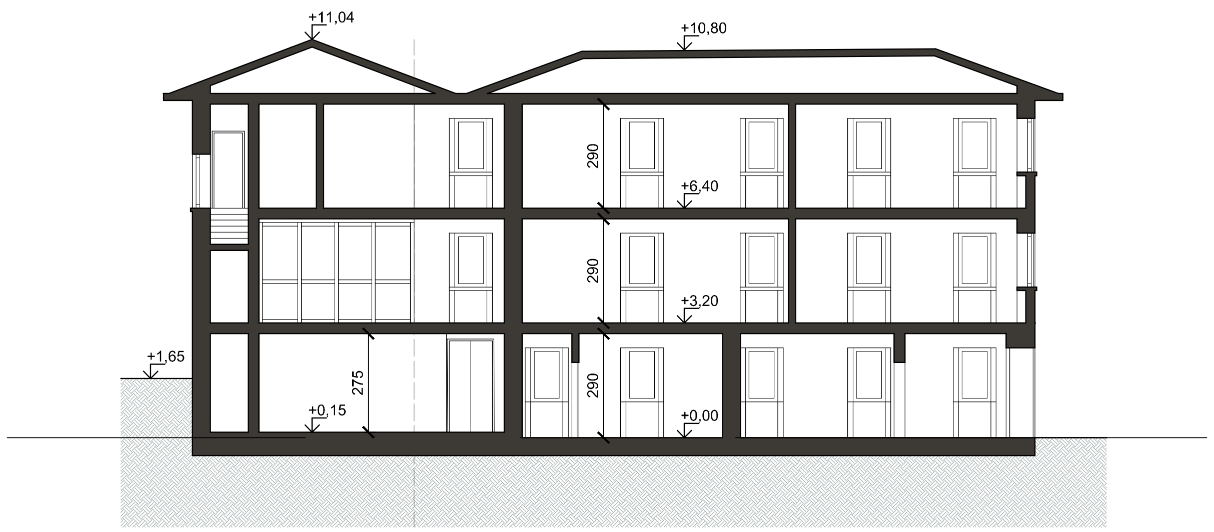






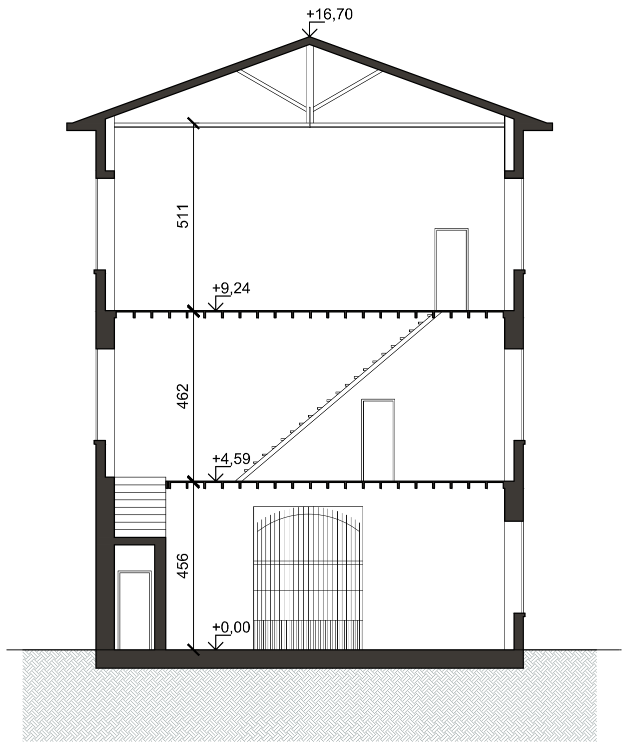


SECTION A-A'

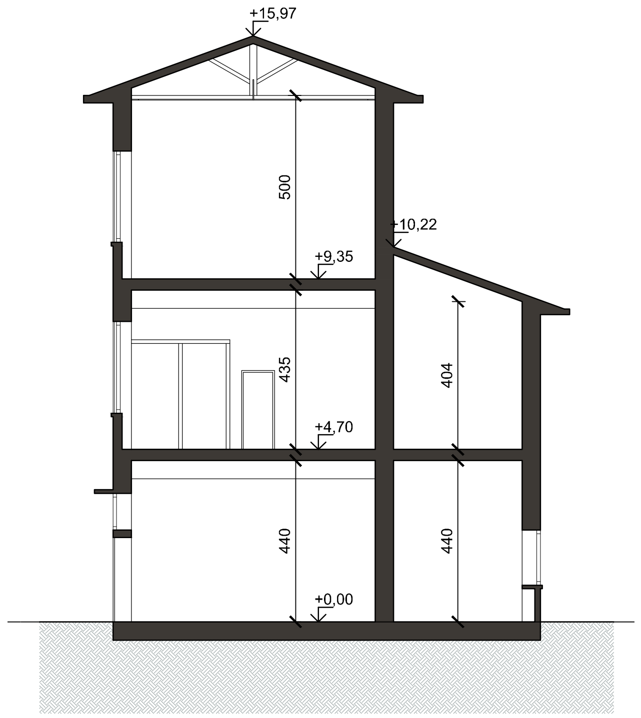


SECTION D-D'

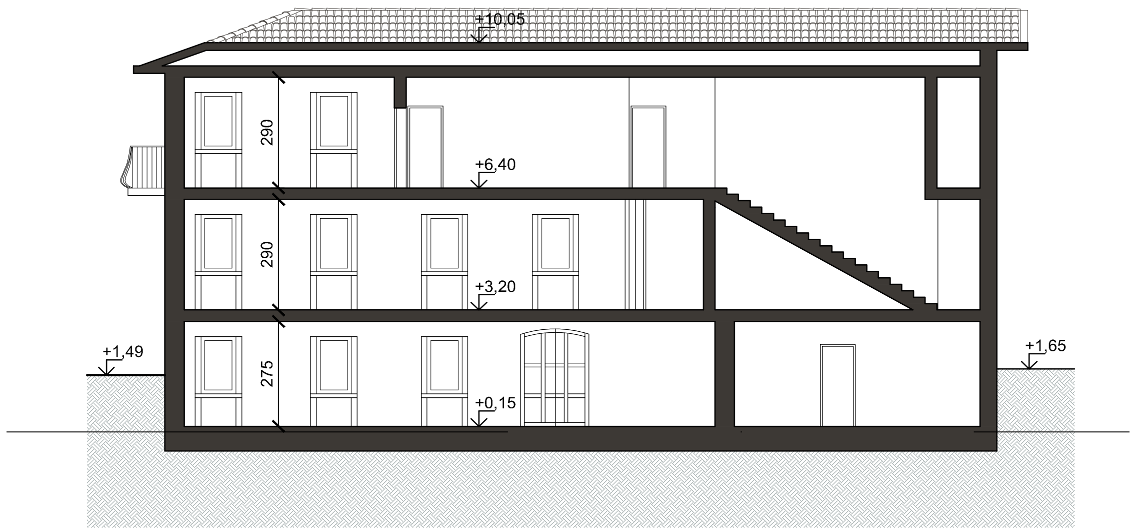
URBAN & BUILDING ANALYSIS



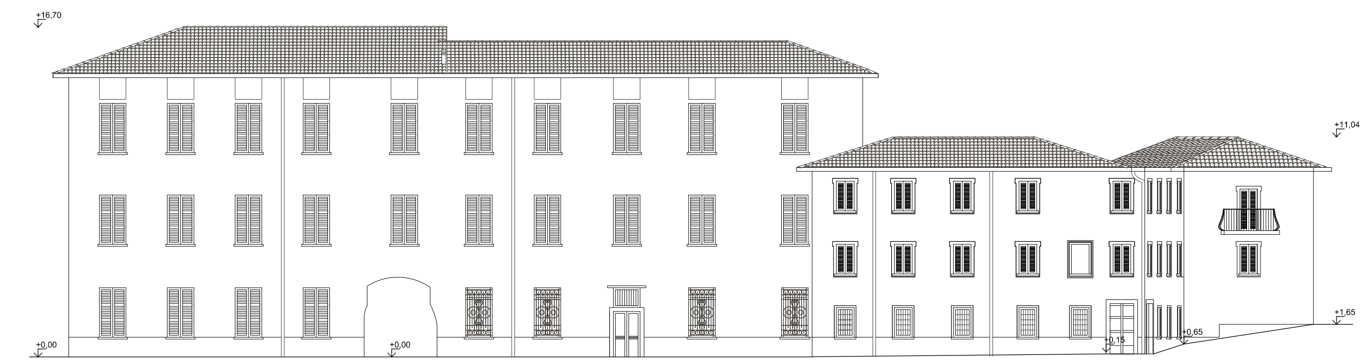
SECTION B-B'



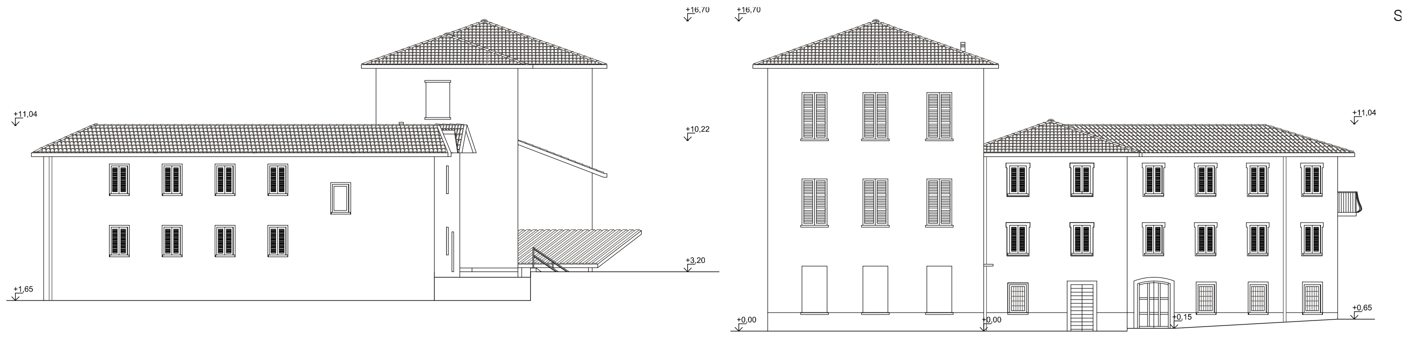
SECTION C-C'

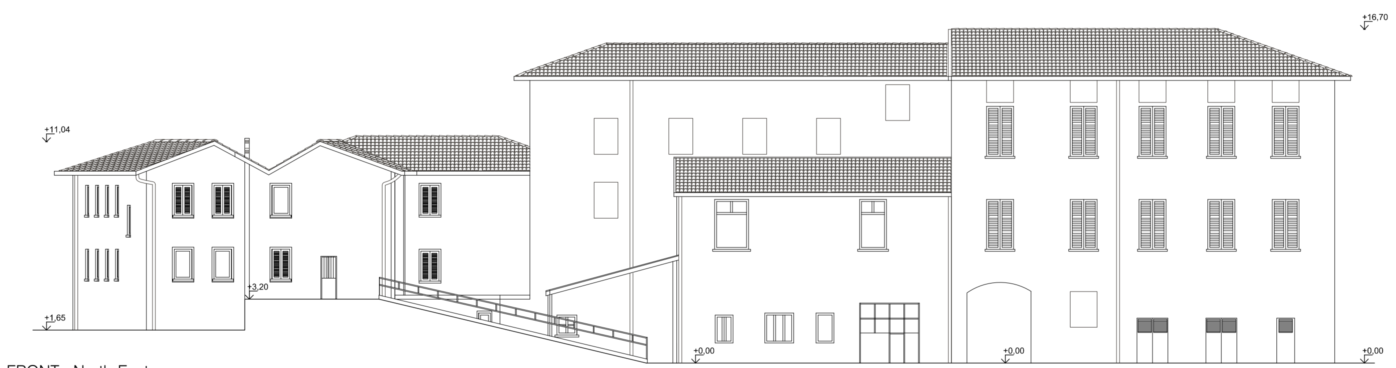


SECTION E-E'



FRONT - South-West





FRONT - North-East

Figure 16 Garabuso road infront of paper mill front view

Figure 17 paper mill main entrance


Figure 18 paper mill


Figure 19 paper mill

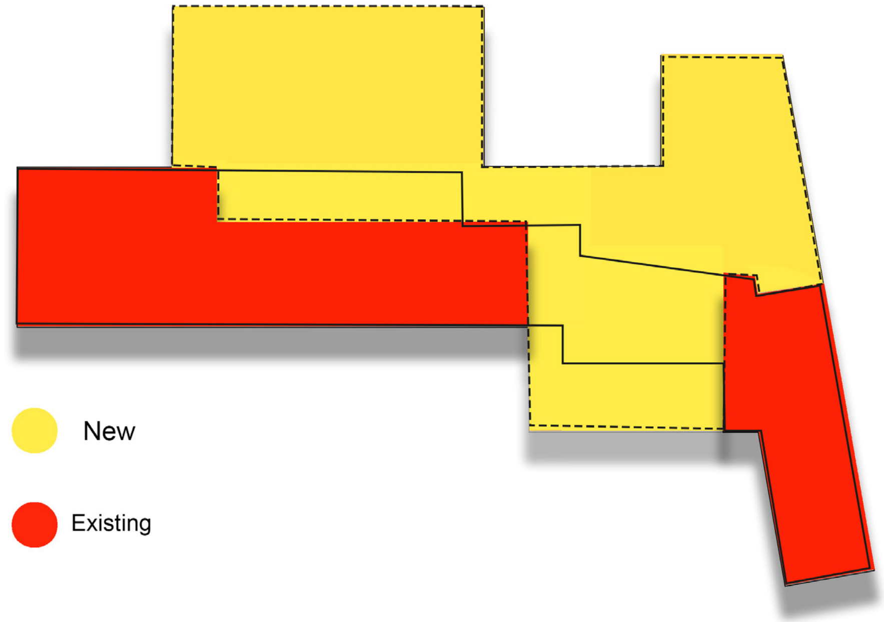
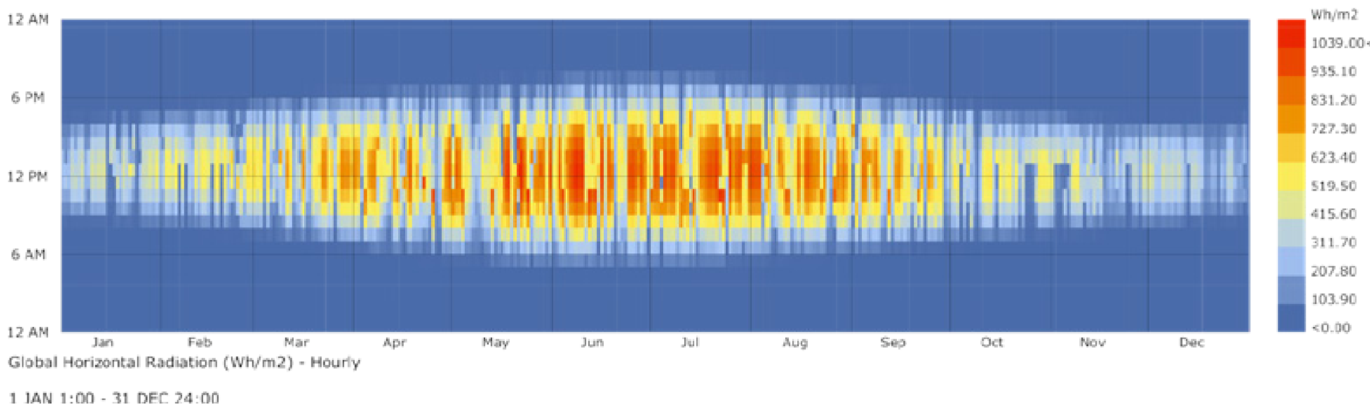


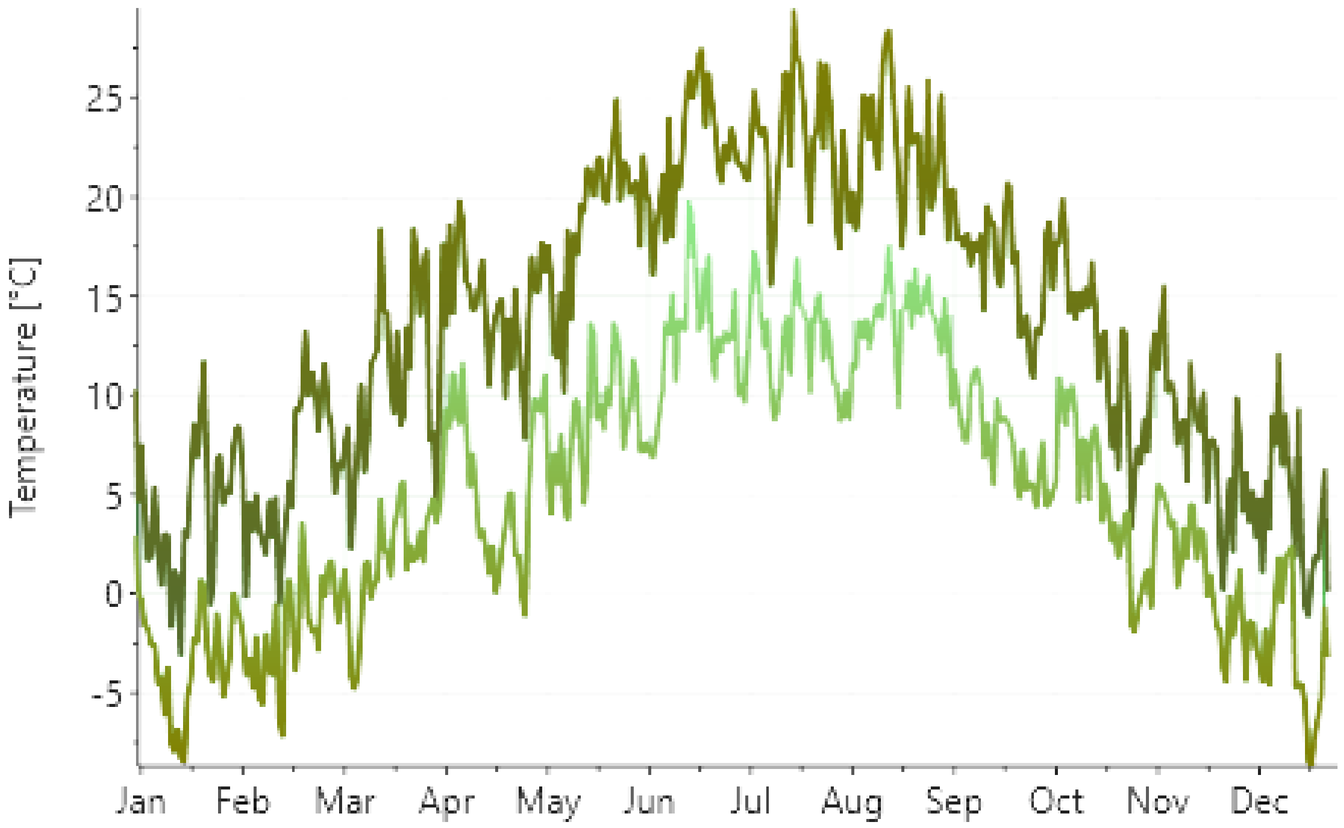
Figure 20 diagram of new and existing building

2.1.1 Global Horizontal Radiation



data from Weather Data and processed with Ladybug plugin of Grasshopper

2.1.2 Dry Bulb Temperature

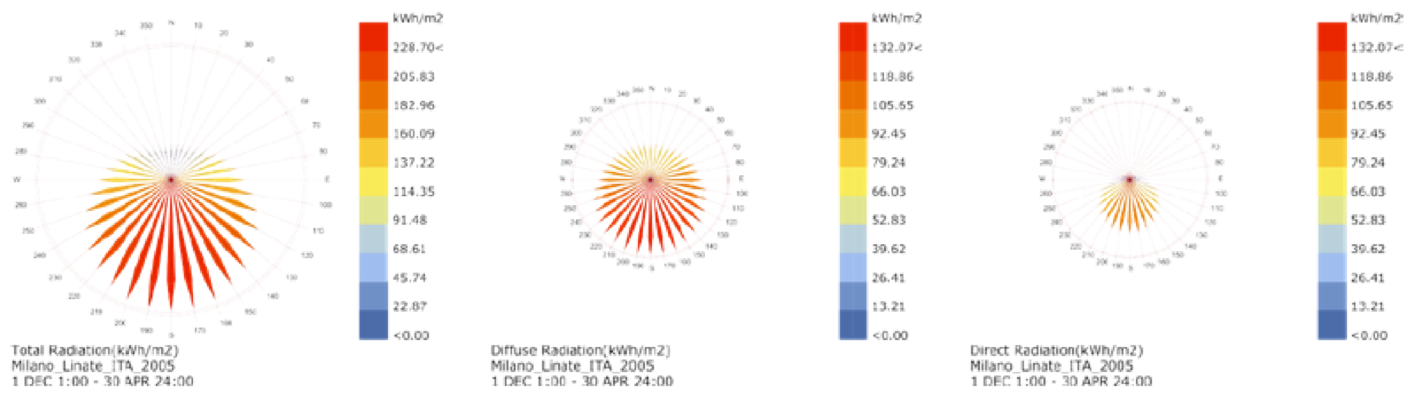


data for via Garabuso, Lecco from Meteonorm 7

Temperature
Maximum temperature during the year: 26°C
Minimum temperature during the year: -5°C

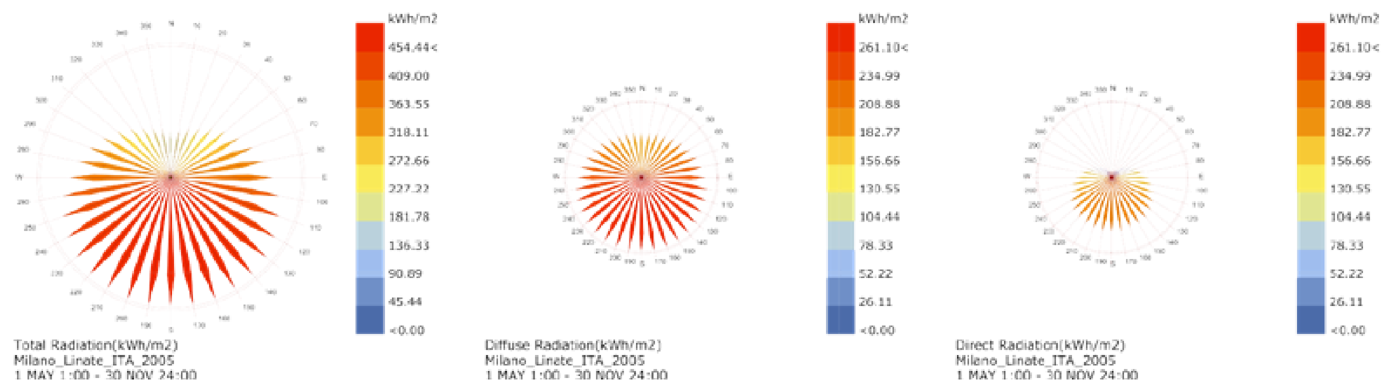
Global Horizontal Radiation
Maximum value during the year: 935.10 Wh/m²
Average value during the year: 156.96 Wh/m²

2.1.3 Summer Radiation



data from Weather Data and processed with Ladybug plugin of Grasshopper

2.1.4 Winter Radiation



data from Weather Data and processed with Ladybug plugin of Grasshopper

The total radiation of the direct and diffuse radiation available in Milan is expressed in kWh/m2 according to the different cardinal directions. It is evaluated in two extreme conditions; summer and winter.

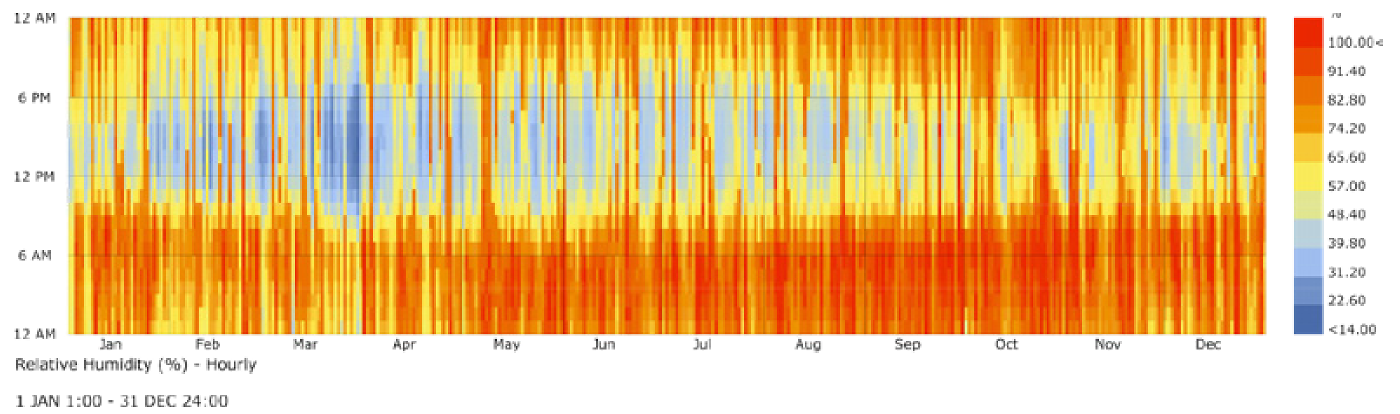
Summer Radiation

Solar radiation should be considered in the South, taking into account South East and South West, which record high value comparing to the Northern direction.

Winter Radiation

Solar radiation is concentrated in the South direction only, but it may have a beneficial effect on the indoor thermal condition.

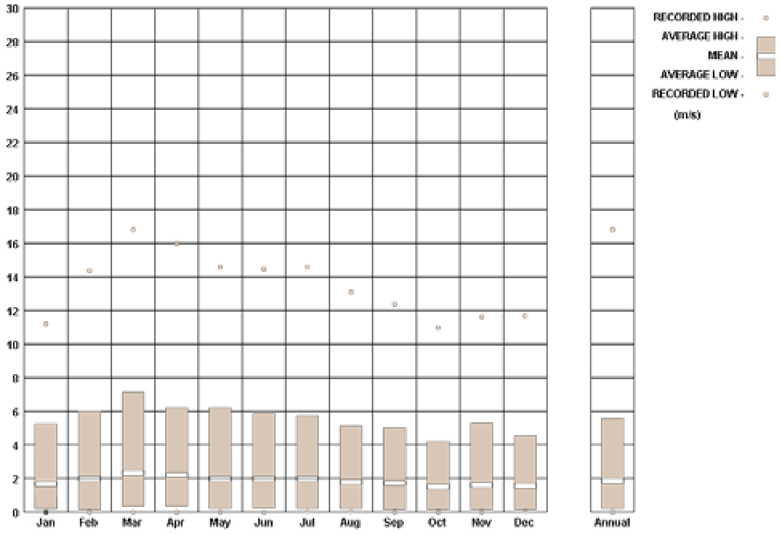
2.1.5 Relative Humidity Map



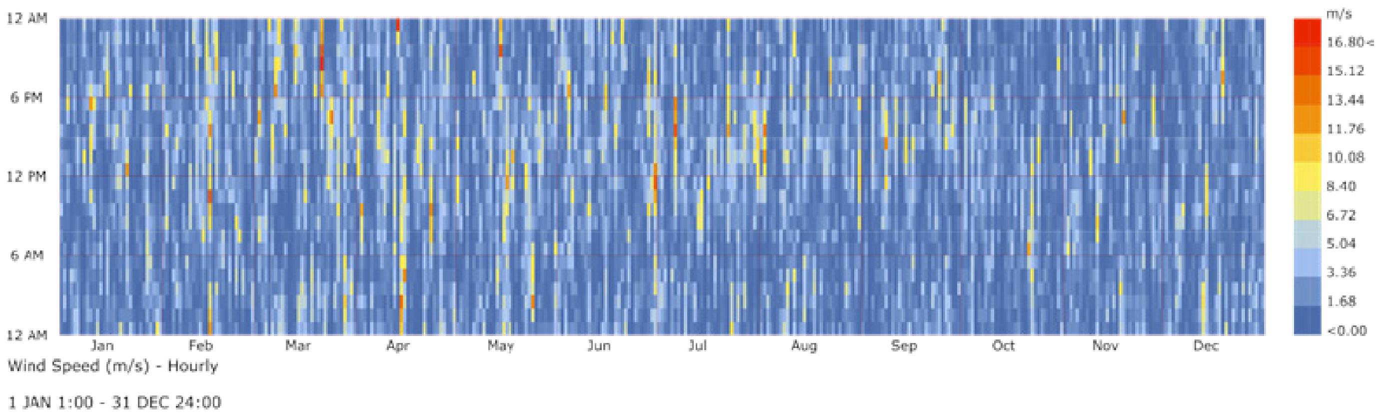
data from Weather Data and processed with Ladybug plugin of Grasshopper

Maximum value during the year: 91.40%
Minimum value during the year: 31.20%
Average value during the year: 66.58%

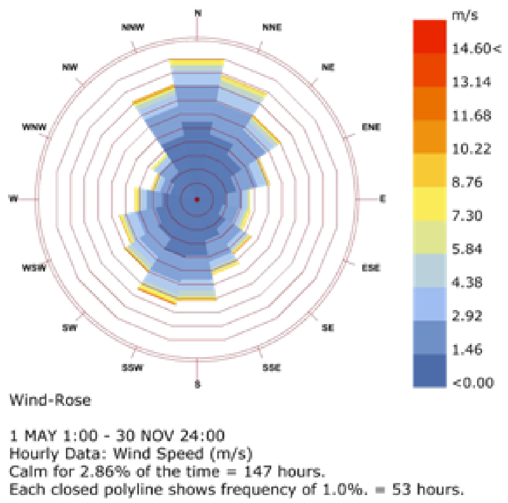
2.1.6 Wind Speed



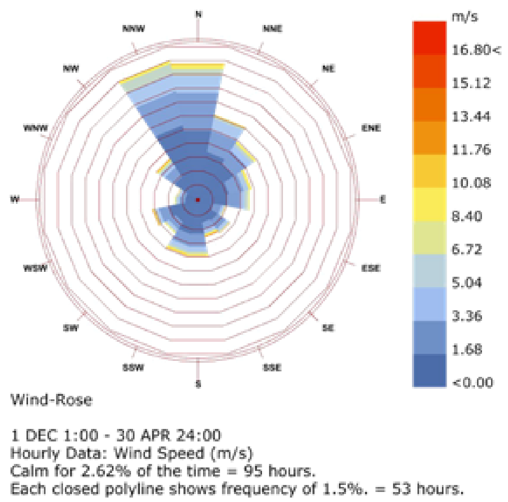
data from Climate Consultant 6.0



data from Weather Data and processed with Ladybug plugin of Grasshopper



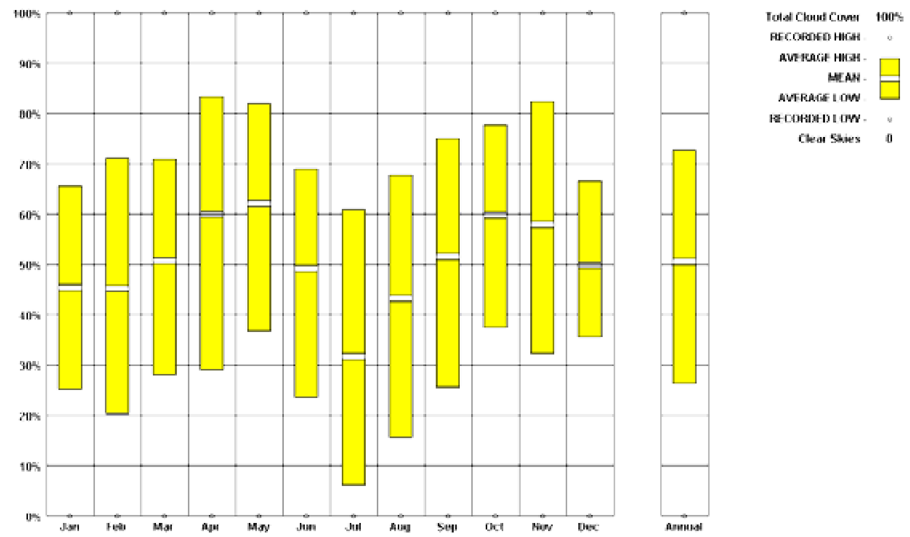
summer wind rose



winter wind rose

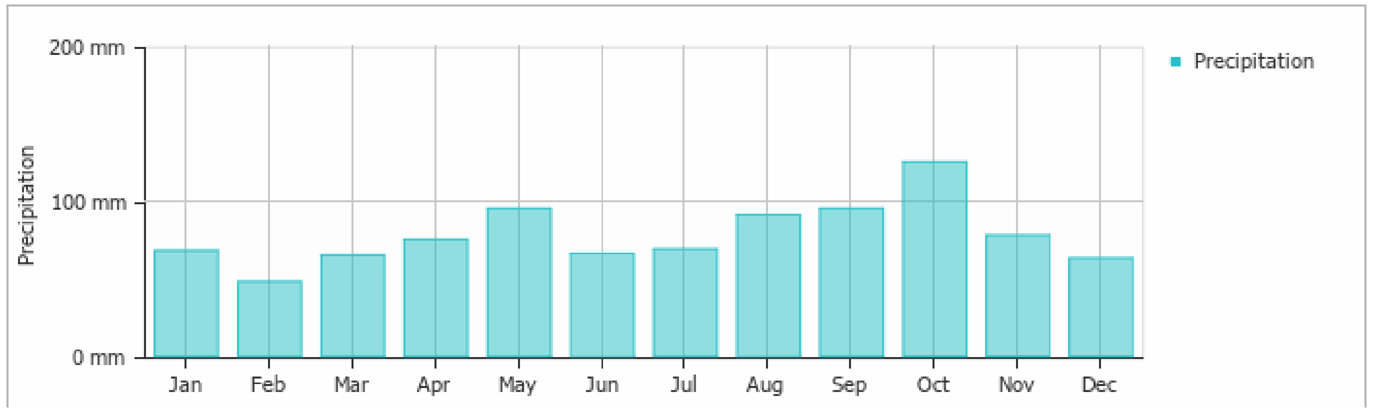
From the wind velocity range graph, the annual wind velocity is almost 6.0 m/s, the highest month is April with wind velocity more than 6.0 m/s.
From the wind rose diagram the wind direction from the North in summer and winter, but in the summer the wind direction also from the South West but not same as the wind coming from the North.

2.1.7 Sky Cover Range



data from Climate Consultant 6.0

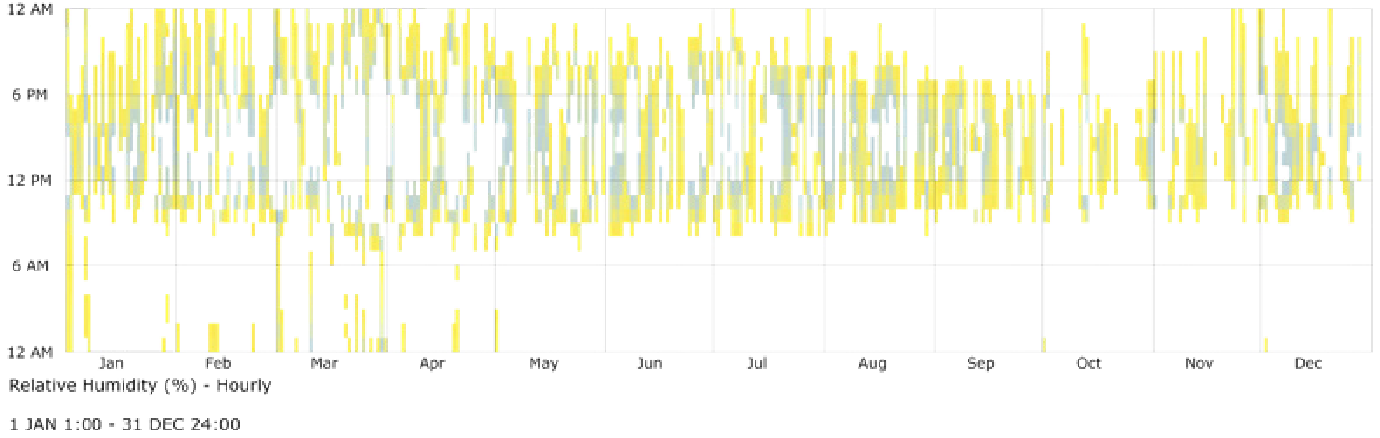
2.1.8 Average Monthly Precipitation



data from weather and climate.com

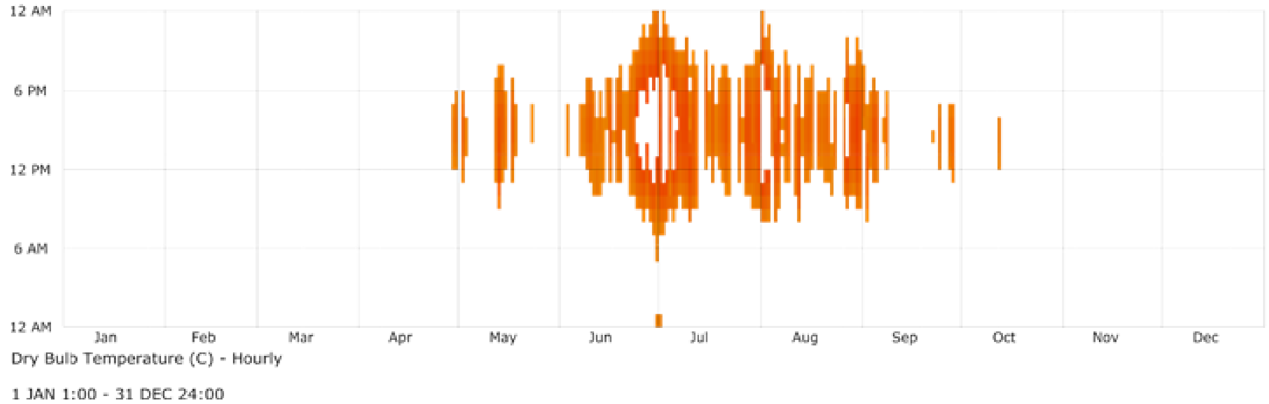
From the sky cover range graph the 100% corresponds to a sky totally covered with clouds, and 0% represents the situation of a clear sky.
From the average monthly precipitation most rainfall (rainy season) is seen in October and the average amount of annual precipitation is: 930.0 mm. (from weather and climate.com)

2.1.9 Dry Bulb Temperature 20°C < T < 26°C



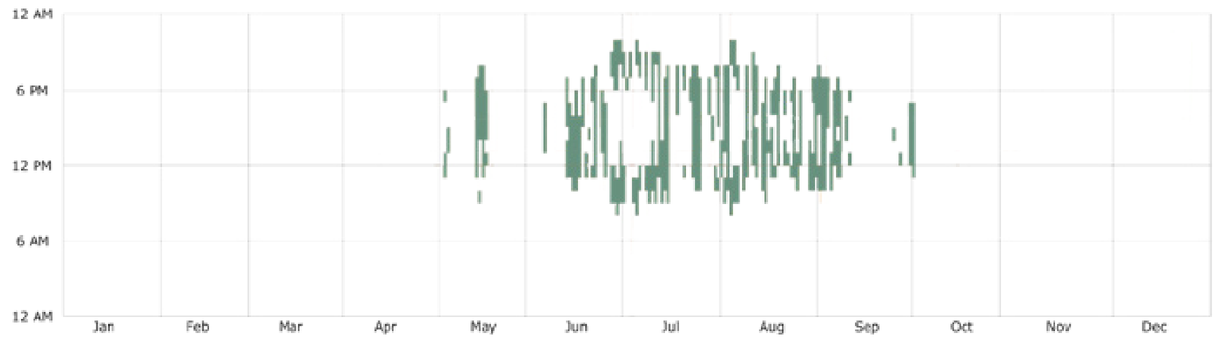
data from Weather Data and processed with Ladybug plugin of Grasshopper

2.1.10 Relative Humidity 4 0 % < R H < 6 0 %



data from Weather Data and processed with Ladybug plugin of Grasshopper

2.1.11 Comfort Map



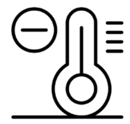
data from Weather Data and processed with Ladybug plugin of Grasshopper

Indoor comfort is guaranteed without using the HVAC system just for 659 hrs./ 8760 hrs.
(Source: Climate Consultant 6.0) when;
Outdoor dry bulb temperature is between 20oC and 26oC
Outdoor relative humidity is between 40% and 60%

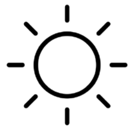
CLIMATIC ANALYSIS

2.1.12 Conclusion & Possible Strategies

Conclusion

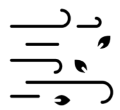


Mild and humid summer, autumn, spring and very cold winter, which requires strategies to control heating and cooling loads.



According to the solar radiation; in summer the facades in the South East, South West and South directions should have particular attention because of the high solar radiation.
On the other hand, the facade in the South direction may be useful as a source of daylight and thermal comfort in winter.

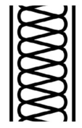
Cloudiness data is useful in daylight design, the annual mean value is 50%.



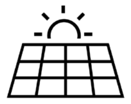
Summer wind direction: North and South West. Winter wind direction: North
Comfort condition is achieved from May to September mainly before 12:00 pm and after 6:00 pm.

Lecco is not considered a rainy city with the highest average around 100mm comparing to Hong Kong the highest average is 400mm. The rainy season is October.

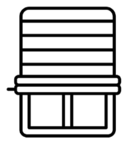
Possible strategies



Insulation for opaque walls and glazing with considering the thickness



The use of photo-voltaic panels on the South facade (Active solar heating strategy).
Provide horizontal shading system to minimize solar gain during summer and allow it during the winter on the South facade.
The use of green walls in summer on the South East, South West and South facades to reduce solar radiation



Strategy to improve daylight for example; louvers and light-shelves.

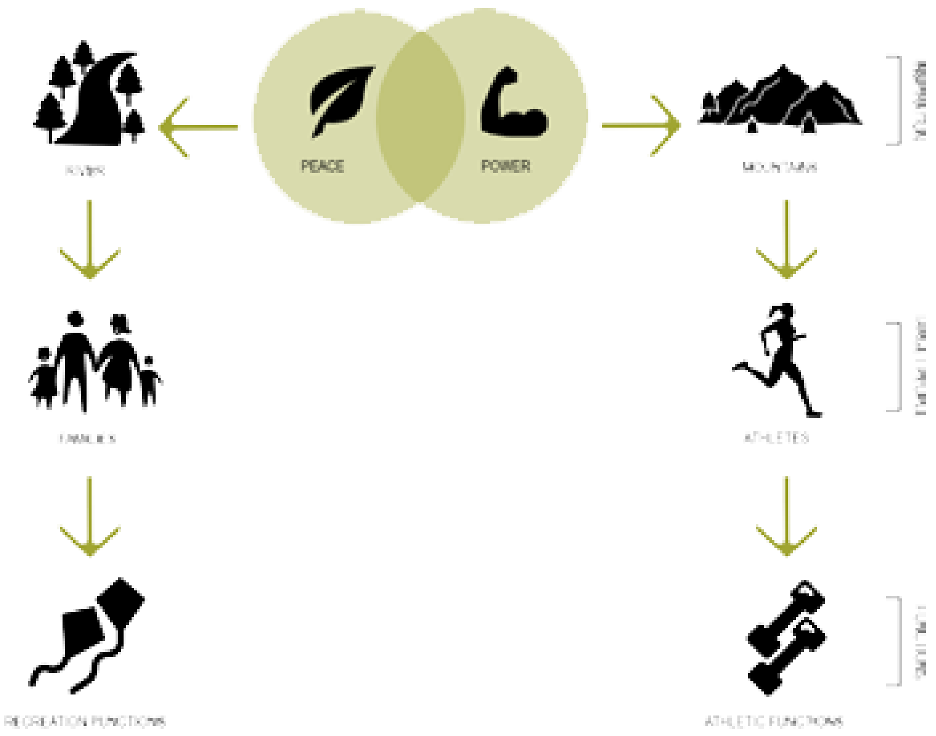
Representing natural ventilation in the comfort situation with respecting the wind direction and speed.

3.

RENOVATION PHASE

3.1 Conceptual Phase

The site analysis illustrated the importance of the natural elements in the site, which made it the dominant aspect in this project. This aspect can not be neglected that are; the huge surrounded mountains, Caldone stream beside the site and the forests. The old paper mill building is the only unique building in that area, since all the surrounding buildings -which are few- are residential building with 3 floor height maximum, as well as this building. The selected new function for the old paper mill is **Mountain Hub** that corresponds with the nature of the site.

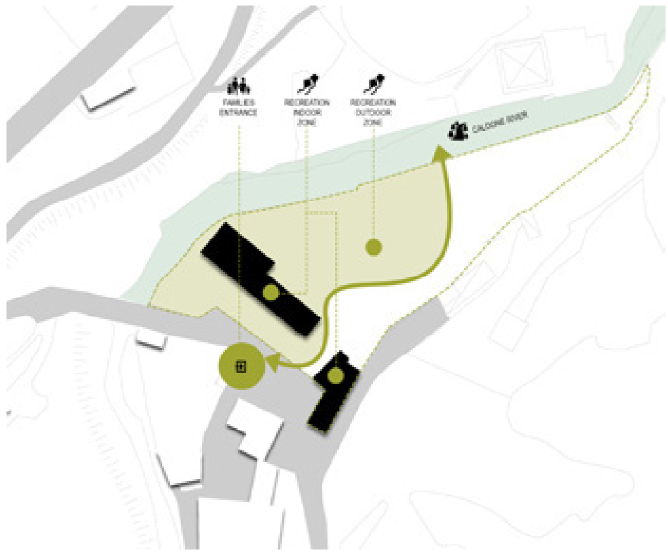


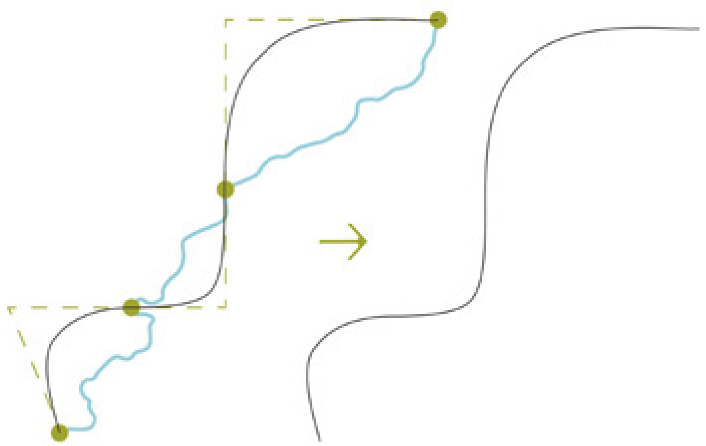
Peace and Power is the main concept in this project. The slogan is inspired from the strong natural elements in the site; mountains, river and trees.

Power represents mountains and peace represents river. The target people in this project defined according to the concept -Peace and Power- they are total different groups. The power (mountains) defines the athletes, and the peace (river) defines the families.

So, our project will serve two different kinds of people, which means it will contain athletic functions and recreational functions.

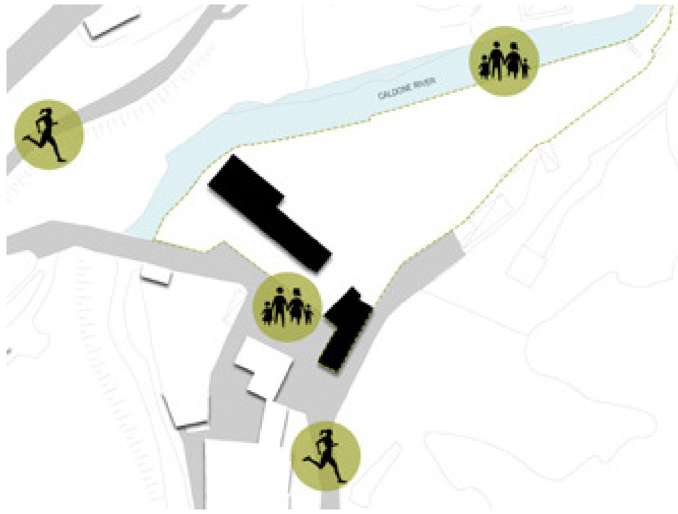
3.2 Caldone's Effect

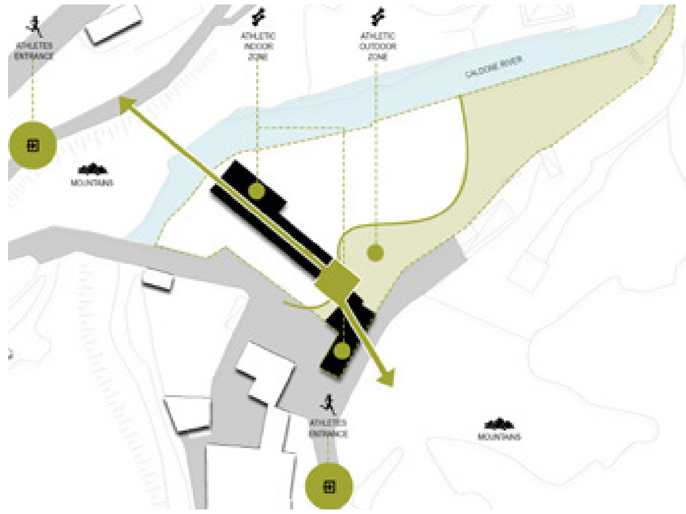




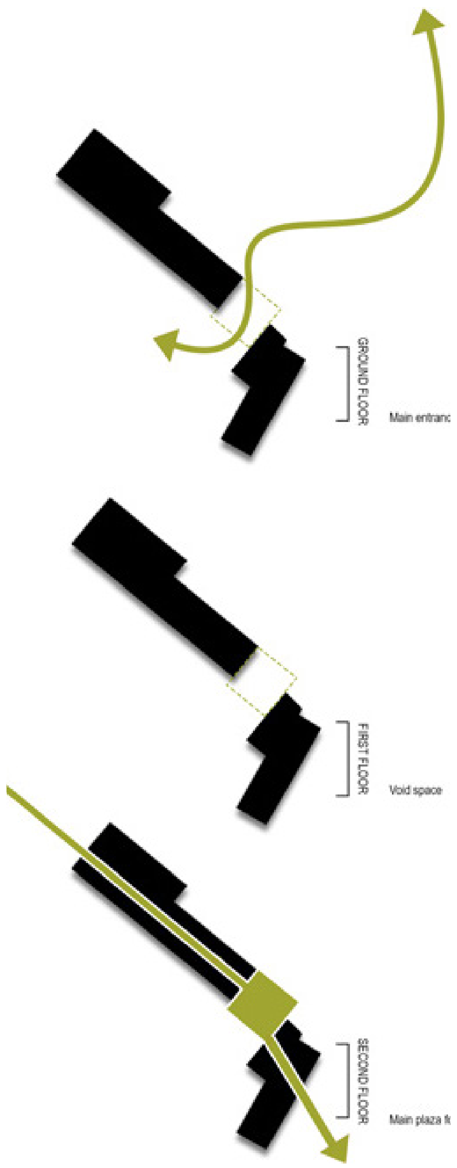
To highlight the importance of the lost Caldone river in the site, this is an illustration of the stream shape and then the selected peeks of the river and connected it with straight lines making the curve that represents the guideline of the families (peace). The families enter the building from the ground floor where the recreational functions are, and the shape of the guideline that connects the entrance with the outdoor activity inspired from the shape of the Caldone river. Also it separates in the landscape the athletic functions and recreational functions

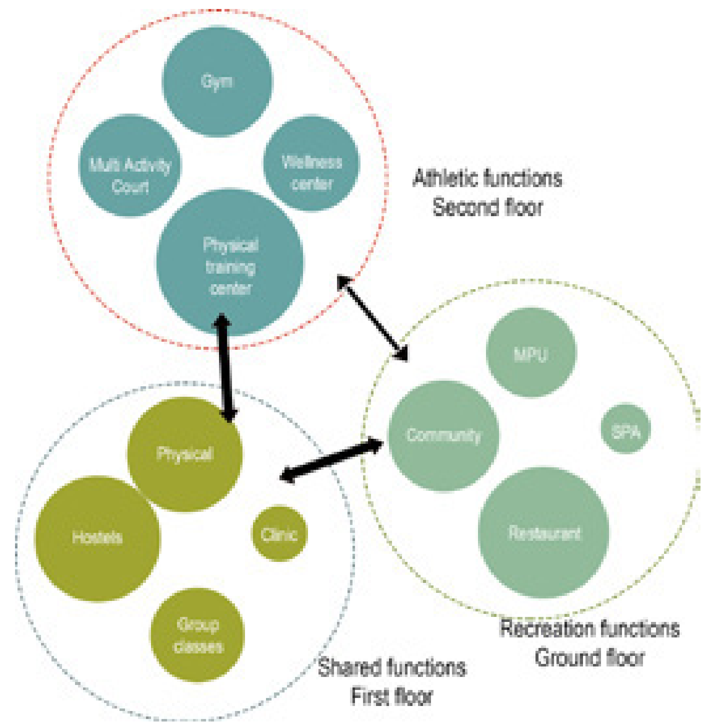
3.3 Functions



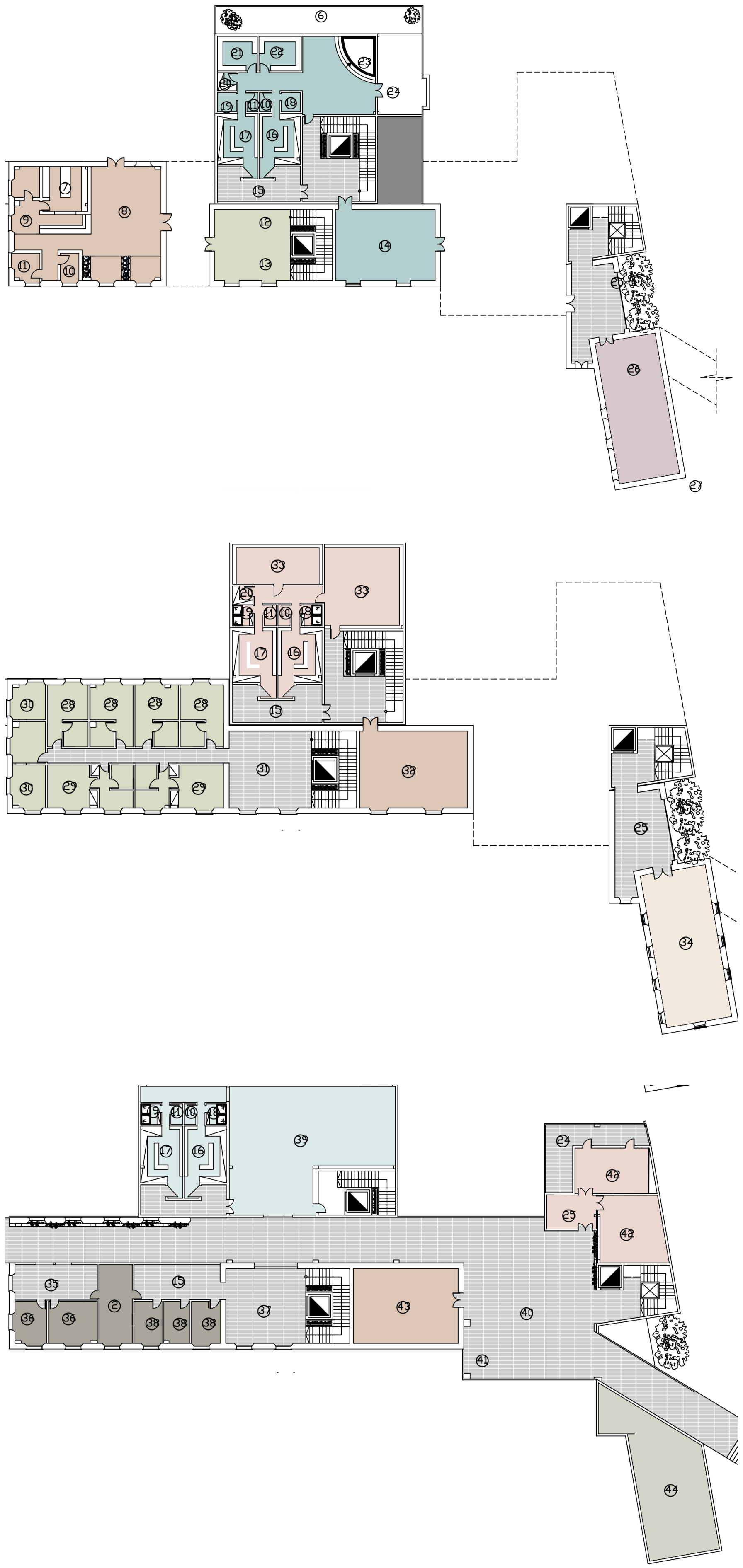


The athletes functions in the second floor, and the arrows are the visual link between the mountains that connects the second floor functions where there is a pathway with a direct visual access to the surrounding mountains, this pathway has a centralized square plaza that acts as a shading element for the ground and first floor. There are different entrances and cores in the building to serve the different functions and people.





3.4 Detailed Functions



1. Massage room
2. Storage
3. Laundry
4. Ironing
5. Waiting area
6. English court
7. Kitchen
8. Cafe' teria
9. Reception
10. Toilet M
11. Toilet F
12. Hostel reception
13. Lobby
14. Spa reception
15. Waiting area
16. Changing room M
17. Changing room F
18. Shower M
19. Shower F
20. Cabinet
21. Sauna
22. Steam room
23. Jacuzzi
24. Terrace
25. Administration
26. Children's activity zone
27. Children's library
28. Twin hostel private room
29. Double room
30. Services
31. Hostel lobby
32. Classes reception and lobby
33. Training class
34. Conference hall
35. Clinic administration
36. Clinic
37. Therapy administration
38. Private room therapy
39. Gym
40. Cafe'
41. Terrace for the cafe
42. Lecture room
43. Mini bar
44. Renting mountain equipment

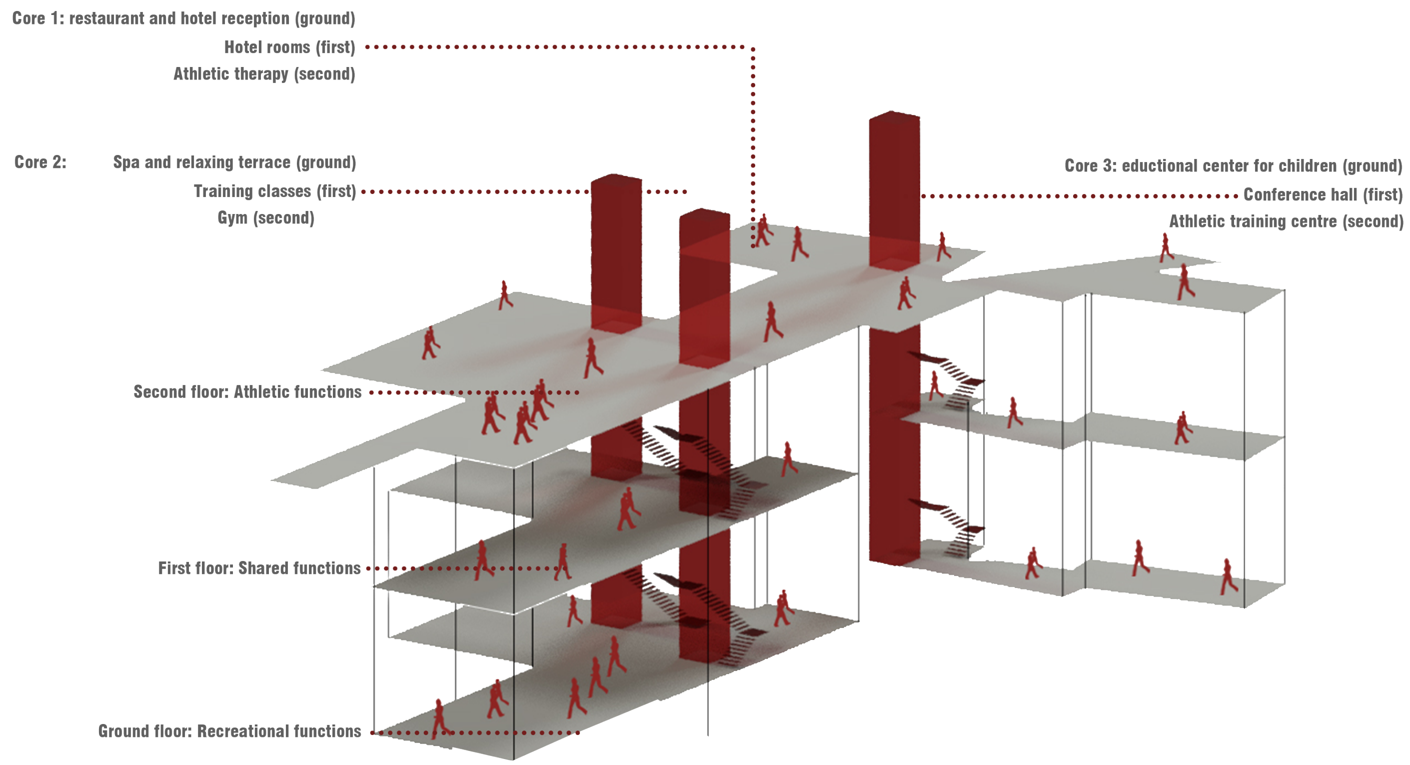
SERVICE
- Spa
- Restaurant
- GYM
- CHILDREN ROOM
- THERAPY AND CLI
- CAFE' AND BAR

WELFARE
- HOSTEL

EDUCATIONAL
- LECTURE ROOM
- Conference hall

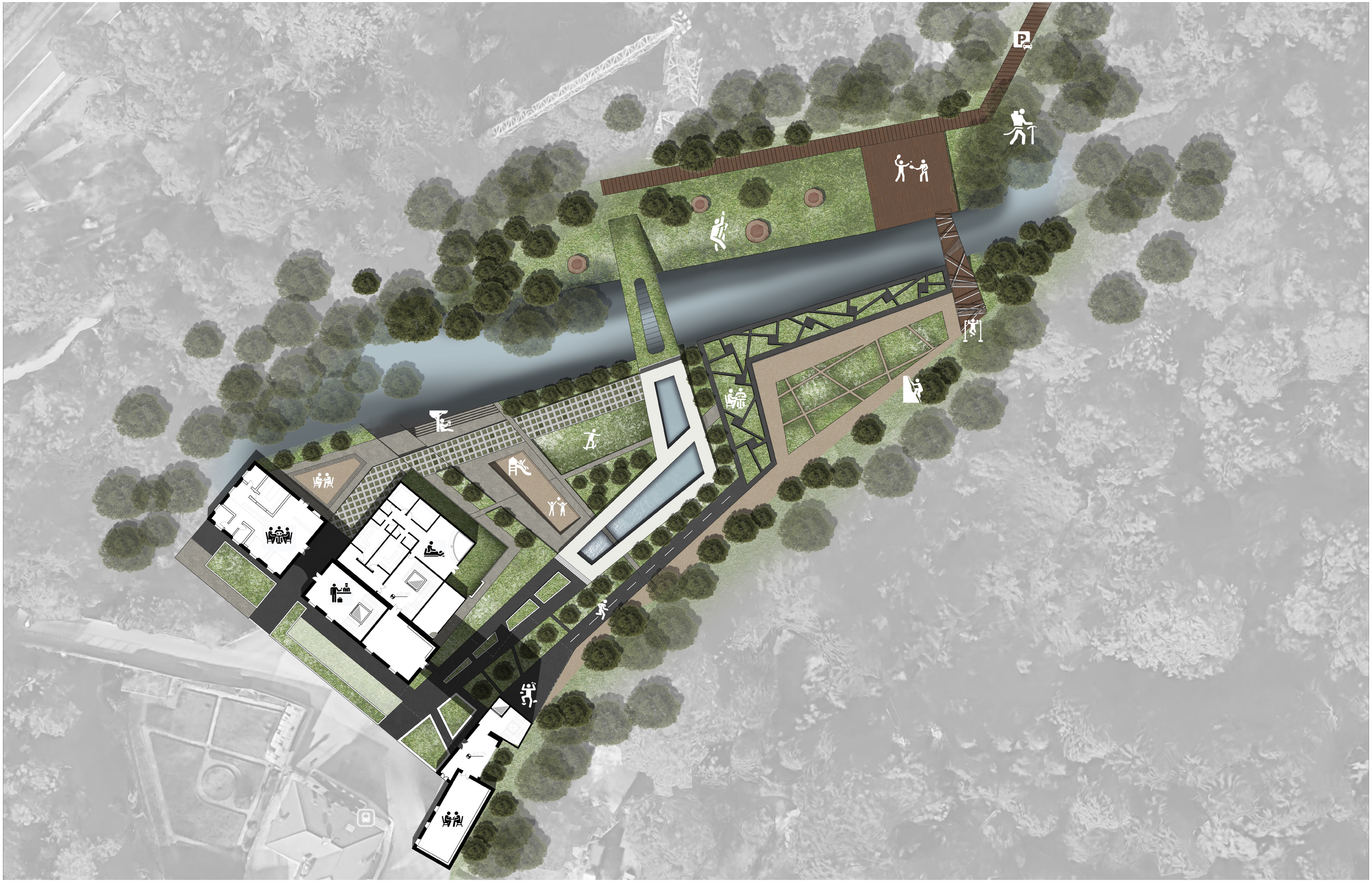
COMMERCIAL
- RENTING SHOP

3.5 Vertical Connections



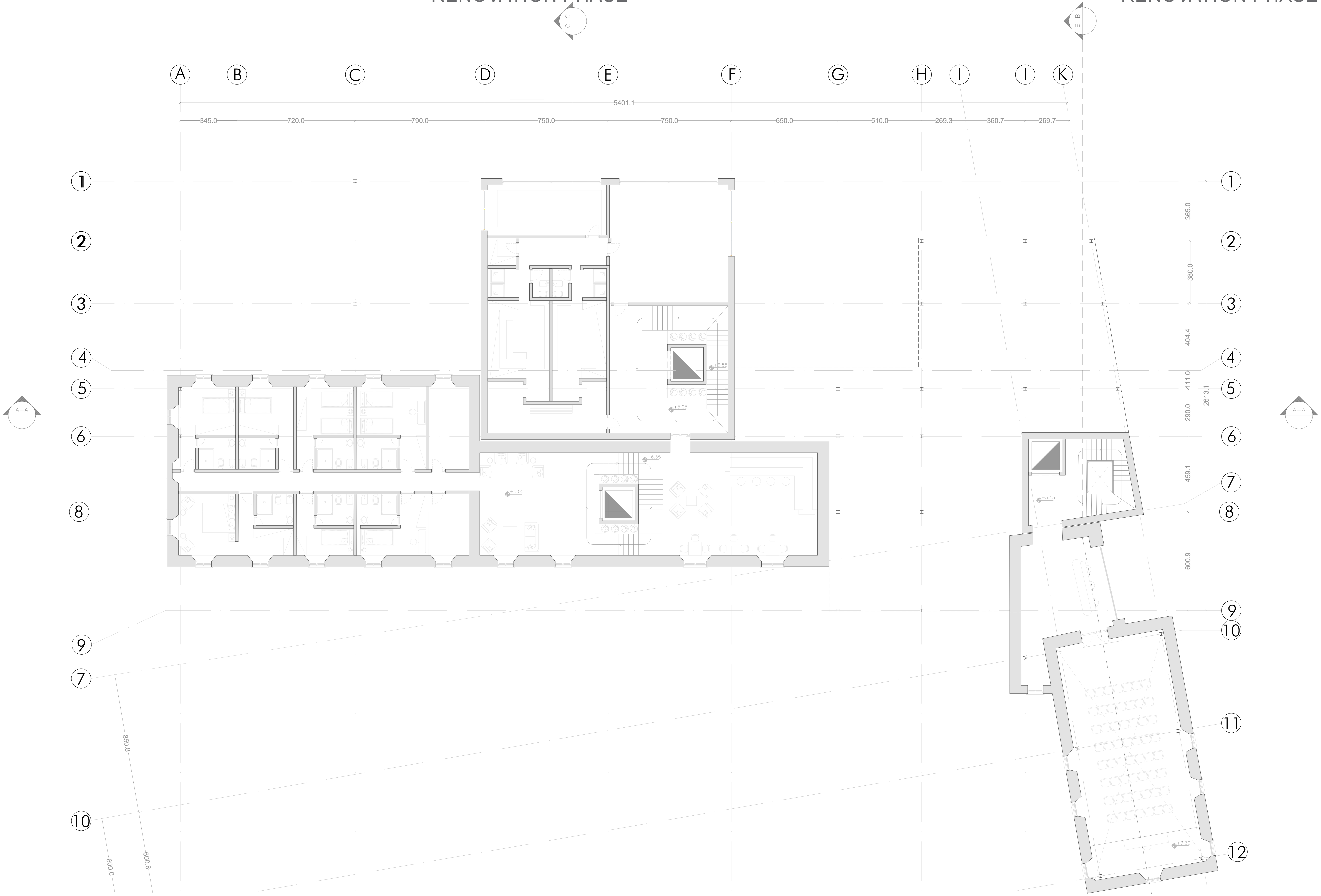
RENOVATION PHASE

3.6 Master Plan

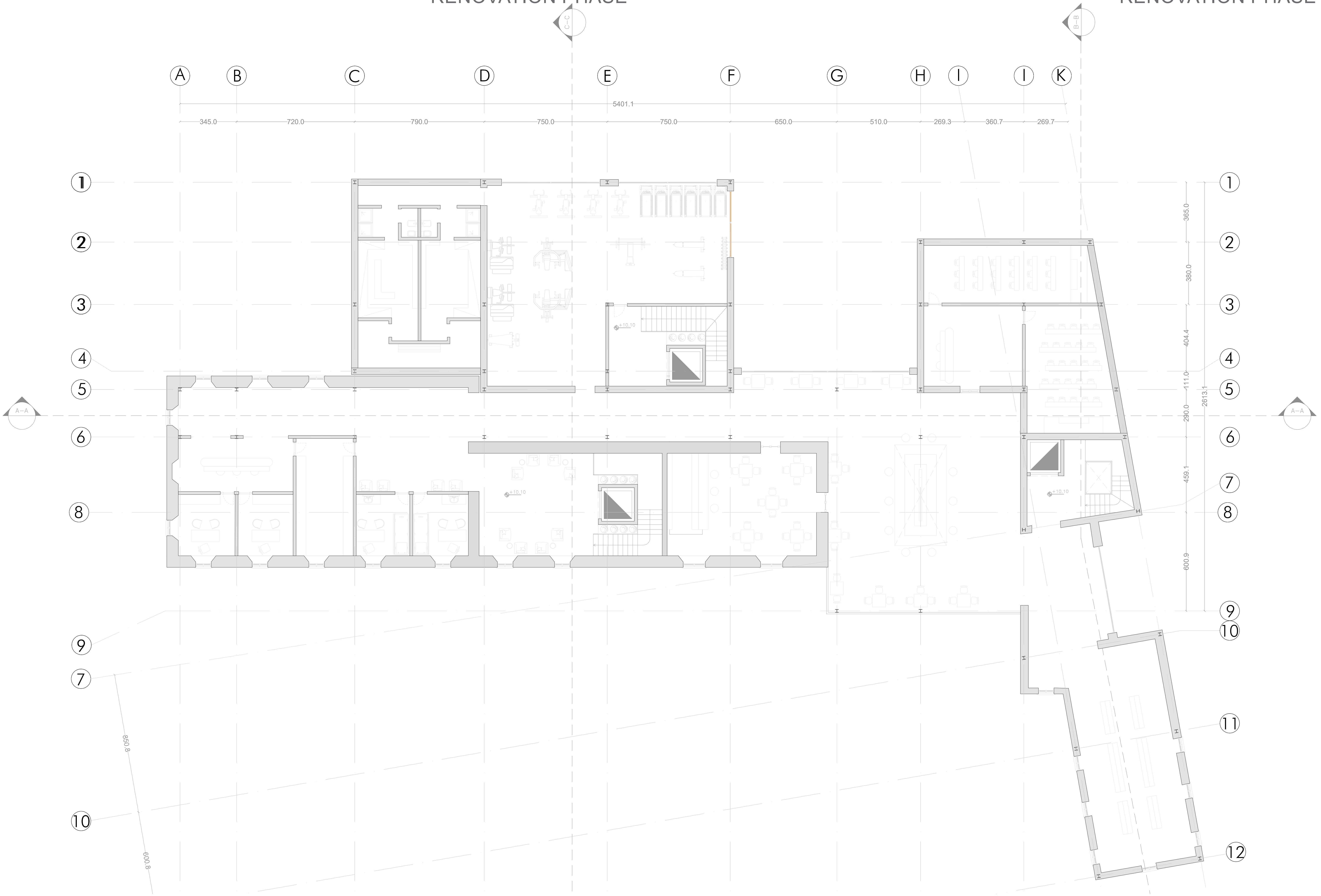


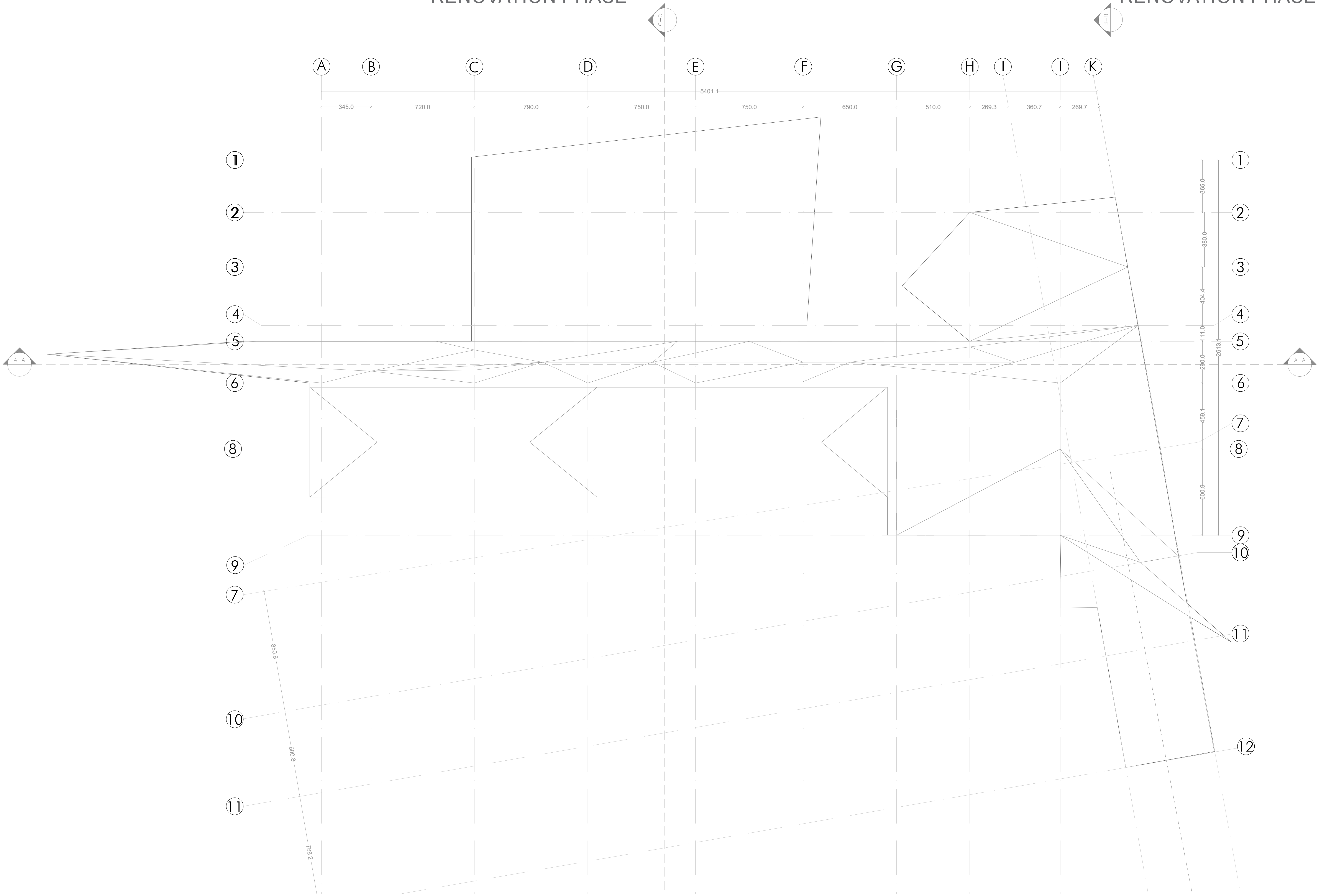
RENOVATION PHASE

3.7 Architectural Drawings


A
B
C
D
E
F
G
H
I
I
K
5401.1
345.0
720.0
790.0
750.0
750.0
650.0
510.0
269.3
360.7
269.7
1
2
3
4
5
6
7
8
9
10
11
12
365.0
380.0
404.4
111.0
290.0
459.1
600.9
2613.1
850.8
600.0
600.8
A-A
B-B
C-C

RENOVATION PHASE




C–C
B–B
A–A
A
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D
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I
K
5401.1
345.0
720.0
790.0
750.0
750.0
650.0
510.0
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1
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11
12
365.0
380.0
404.4
111.0
290.0
459.1
600.9
2613.1
850.8
600.8
788.2

RENOVATION PHASE

RENOVATION PHASE

RENOVATION PHASE

4.

BUILDING TECHNOLOGY - PHASE

4.1.1 U-Value Optioneering

Baseline

Material: stone/ brick wall

Wall weighted average U-value
North: 2.44 W/m^{2}K
South: 2.80 W/m^{2}K
East: 2.47 W/m^{2}K
West: 2.57 W/m^{2}K

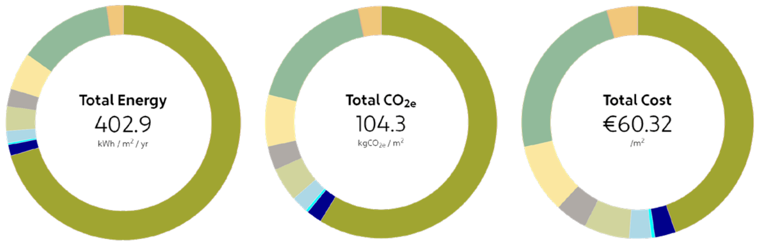
Floor U-value: 0.24 W/m^{2}K

Roof U-value: 3.60 W/m^{2}K

Glazing U-value: 5.80 W/m^{2}K
Solar height gain coefficient SHGC: 0.33

Total energy: 402.9 W/m^{2}K

Segment	kWh / m^2 / yr	% of total use
Heating	**283.8**	**70 %**
AHU	0.1	0 %
Zones	283.7	70 %
Humidification	0.0	0 %
Cooling	**13.9**	**3 %**
AHU	6.2	2 %
Heat Rejection	1.0	0 %
Zones	6.7	2 %
Fans	**23.2**	**6 %**
AHU	13.6	3 %
Zones	9.6	2 %
Interior	**72.7**	**18 %**
Lighting	20.8	5 %
Equipment	51.9	13 %
Pumps	**9.3**	**2 %**



Option 1

Material: ASHARE wall standard

Wall weighted average U-value
North: 0.37 W/m^{2}K
South: 0.37 W/m^{2}K
East: 0.37 W/m^{2}K
West:0.37 W/m^{2}K

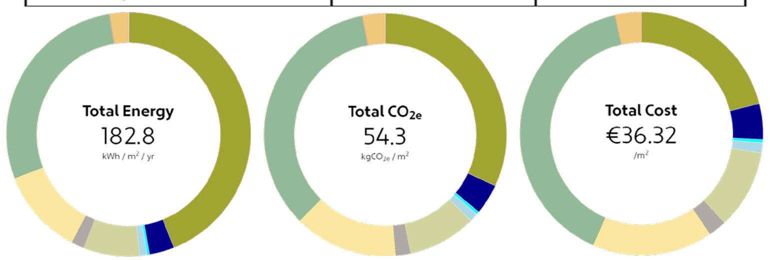
Floor U-value: 0.24 W/m^{2}K

Roof U-value: 0.18 W/m^{2}K

Glazing U-value: 2.56 W/m^{2}K
Solar height gain coefficient SHGC: 0.33

Total energy: 182.8 W/m^{2}K

Segment	kWh / m^2 / yr	% of total use
Heating	**80.3**	**44 %**
AHU	0.1	0 %
Zones	80.2	44 %
Humidification	0.0	0 %
Cooling	**8.5**	**5 %**
AHU	6.1	3 %
Heat Rejection	0.6	0 %
Zones	1.8	1 %
Fans	**16.7**	**9 %**
AHU	13.6	7 %
Zones	3.1	2 %
Interior	**72.7**	**40 %**
Lighting	20.8	11 %
Equipment	51.9	28 %
Pumps	**4.6**	**3 %**



Option 2

Material: ASHARE wall standard and stone/ brick wall

Wall weighted average U-value
North: 1.71 W/m^{2}K
South: 1.30 W/m^{2}K
East: 1.67 W/m^{2}K
West: 1.57 W/m^{2}K

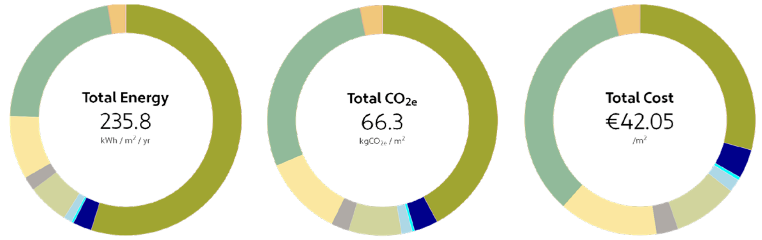
Floor U-value: 0.24 W/m^{2}K

Roof U-value: 0.18 W/m^{2}K

Glazing U-value: 1.20 W/m^{2}K
Solar height gain coefficient SHGC: 0.33

Total energy: 235.8 W/m^{2}K

Segment	kWh / m^2 / yr	% of total use
Heating	**129.3**	**55 %**
AHU	0.1	0 %
Zones	129.2	55 %
Humidification	0.0	0 %
Cooling	**9.7**	**4 %**
AHU	6.2	3 %
Heat Rejection	0.7	0 %
Zones	2.8	1 %
Fans	**18.2**	**8 %**
AHU	13.6	6 %
Zones	4.6	2 %
Interior	**72.7**	**31 %**
Lighting	20.8	9 %
Equipment	51.9	22 %
Pumps	**5.9**	**3 %**



Option 3

Material: Outside wall insulation (wood fiber) Wood fiber insulation board 50mm and stone/ brick wall

Wall weighted average U-value
North: 0.29 W/m^{2}K
South: 0.47 W/m^{2}K
East: 0.31 W/m^{2}K
West:0.35 W/m^{2}K

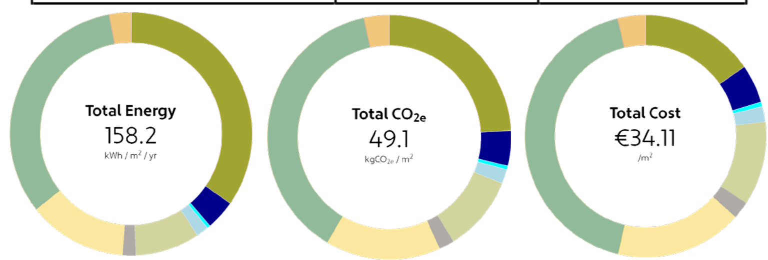
Floor U-value: 0.24 W/m^{2}K

Roof U-value: 0.18 W/m^{2}K

Glazing U-value: 1.20 W/m^{2}K
Solar height gain coefficient SHGC: 0.33

Total energy: 158.2 W/m^{2}K

Segment	kWh / m^2 / yr	% of total use
Heating	**54.9**	**35 %**
AHU	0.1	0 %
Zones	54.8	35 %
Humidification	0.0	0 %
Cooling	**9.6**	**6 %**
AHU	6.3	4 %
Heat Rejection	0.7	0 %
Zones	2.6	2 %
Fans	**16.4**	**10 %**
AHU	13.6	9 %
Zones	2.8	2 %
Interior	**72.7**	**46 %**
Lighting	20.8	13 %
Equipment	51.9	33 %
Pumps	**4.6**	**3 %**



Option 4

Material: Outside wall insulation (wood fiber) Wood fiber insulation board 160mm and stone/ brick wall

Wall weighted average U-value
North: 0.17 W/m²K
South: 0.23 W/m²K
East: 0.18 W/m²K
West:0.19 W/m²K

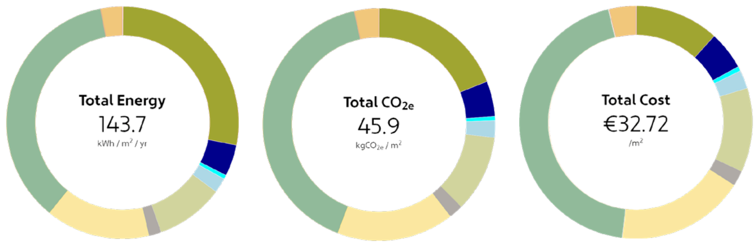
Floor U-value: 0.24 W/m²K

Roof U-value: 0.18 W/m²K

Glazing U-value: 1.20 W/m²K
Solar height gain coefficient SHGC: 0.33

Total energy: 143.7 W/m²K

Segment	kWh / m² / yr	% of total use
Heating	**40.4**	**28 %**
AHU	0.1	0 %
Zones	40.3	28 %
Humidification	0.0	0 %
Cooling	**10.1**	**7 %**
AHU	6.3	4 %
Heat Rejection	0.8	1 %
Zones	3.0	2 %
Fans	**16.1**	**11 %**
AHU	13.6	9 %
Zones	2.5	2 %
Interior	**72.7**	**51 %**
Lighting	20.8	14 %
Equipment	51.9	36 %
Pumps	**4.4**	**3 %**



Option 5

Material: Outside wall insulation (wood fiber) Wood fiber insulation board 160mm and stone/ brick wall

Wall weighted average U-value
North: 0.17 W/m²K
South: 0.23 W/m²K
East: 0.18 W/m²K
West:0.19 W/m²K

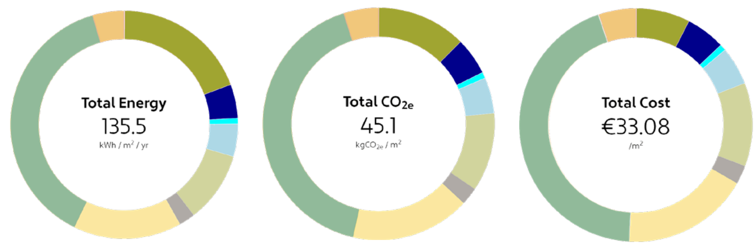
Floor U-value: 0.10 W/m²K

Roof U-value: 0.14 W/m²K

Glazing U-value: 0.90 W/m²K
Solar height gain coefficient SHGC: 0.54

Total energy: 135.5 W/m²K

Segment	kWh / m² / yr	% of total use
Heating	**26.1**	**19 %**
AHU	0.1	0 %
Zones	26.0	19 %
Humidification	0.0	0 %
Cooling	**13.9**	**10 %**
AHU	6.5	5 %
Heat Rejection	1.1	1 %
Zones	6.3	5 %
Fans	**16.7**	**12 %**
AHU	13.6	10 %
Zones	3.1	2 %
Interior	**72.7**	**54 %**
Lighting	20.8	15 %
Equipment	51.9	38 %
Pumps	**6.1**	**5 %**



Option 6

Material: Outside wall insulation (Glasswool) Glasswool insulation layer 160mm and stone/ brick wall

Wall weighted average U-value
North: 0.15 W/m²K
South: 0.18 W/m²K
East: 0.15 W/m²K
West:0.16 W/m²K

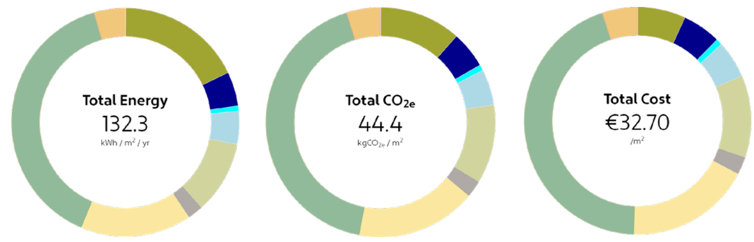
Floor U-value: 0.10 W/m²K

Roof U-value: 0.14 W/m²K

Glazing U-value: 0.90 W/m²K
Solar height gain coefficient SHGC: 0.54

Total energy: 132.3 W/m²K

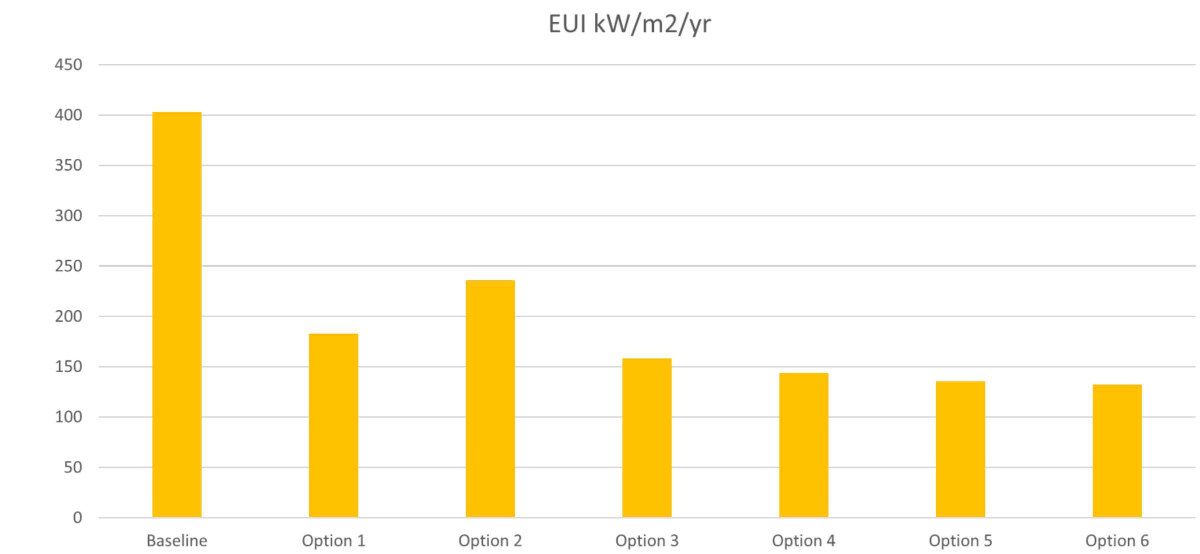
Segment	kWh / m² / yr	% of total use
Heating	**23.6**	**18 %**
AHU	0.1	0 %
Zones	23.5	18 %
Humidification	0.0	0 %
Cooling	**13.6**	**10 %**
AHU	6.4	5 %
Heat Rejection	1.0	1 %
Zones	6.2	5 %
Fans	**16.5**	**12 %**
AHU	13.6	10 %
Zones	2.9	2 %
Interior	**72.7**	**55 %**
Lighting	20.8	16 %
Equipment	51.9	39 %
Pumps	**5.9**	**4 %**



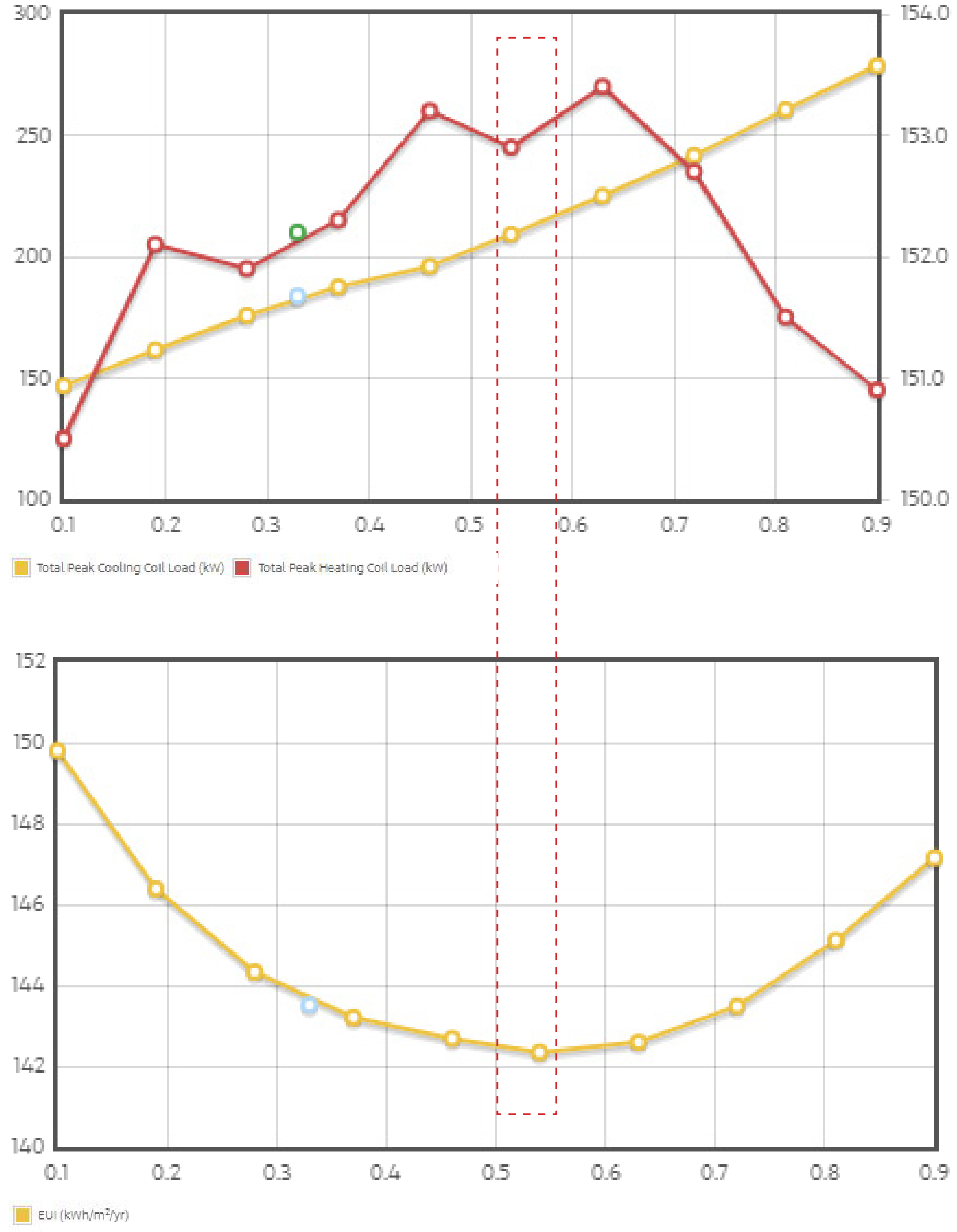
Conclusion

Process	Baseline	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
EUI kW/m2/yr	402.9	182.8	235.8	158.2	143.7	135.5	132.3
Percentace		-55%	29%	-33%	-9%	-6%	-2%

Table 2 u-value optioneerings

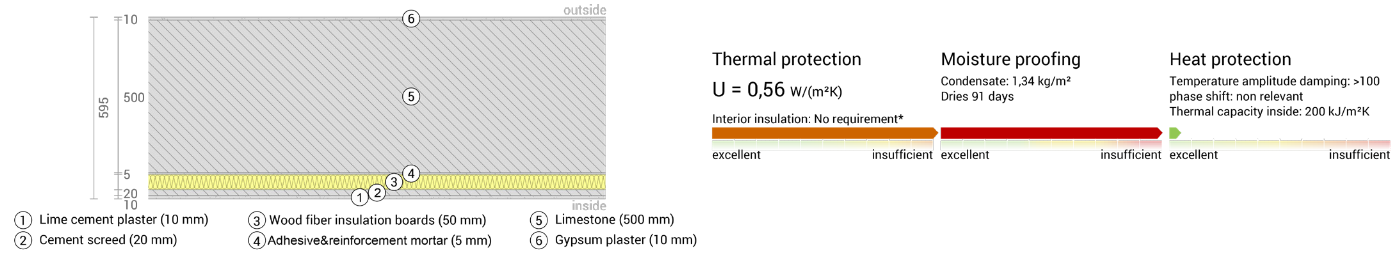


4.1.2 Solar Heat Gain Coefficient (SHGC)

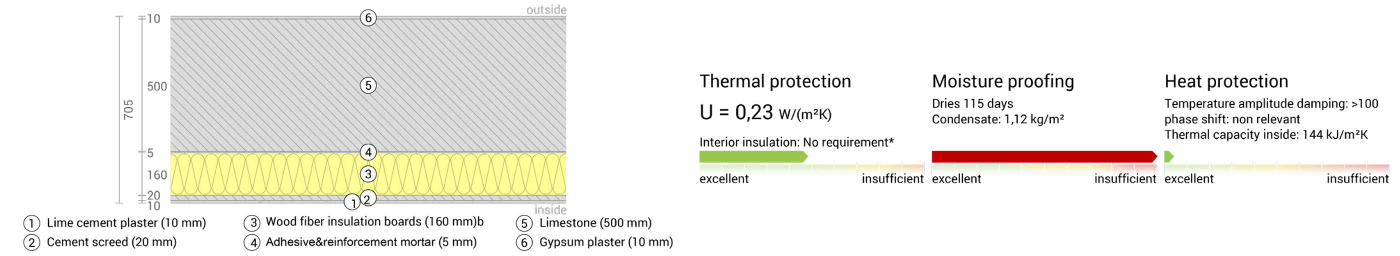


Selected SHGC = 0.54

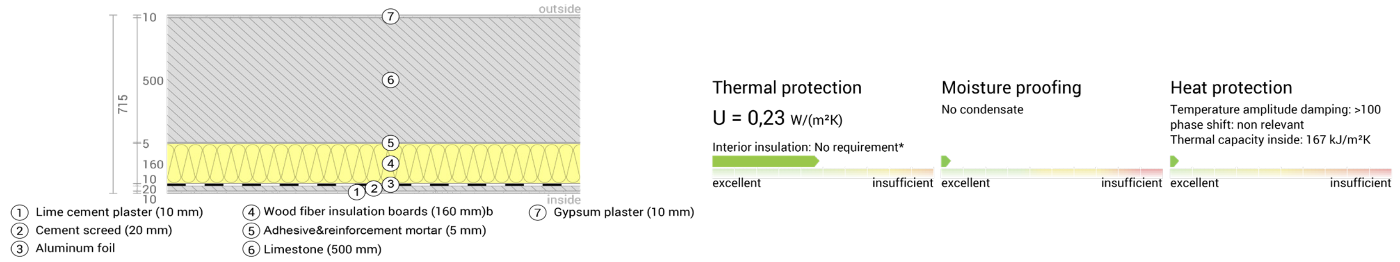
4.1.3 Wall Optioneering



Outside wall insulation (wood fiber)
Wood fiber insulation board 50mm
Not sufficient



Outside wall insulation (wood fiber)
Wood fiber insulation board 160mm
Sufficient but interstitial condensation occurs



Outside wall insulation (wood fiber)
Wood fiber insulation board 160mm
Adding aluminum foil in the warmest side a vapor barrier

Outside wall insulation (Glasswool)
Glasswool insulation layer 160mm
Adding new insulation layer for better results

4.2.1 Existing Building

Outside wall insulation (wood fibre)

Thermal protection

U = 0,18 W/(m²K)

Interior insulation: No requirement*

excellent insufficient

Moisture proofing

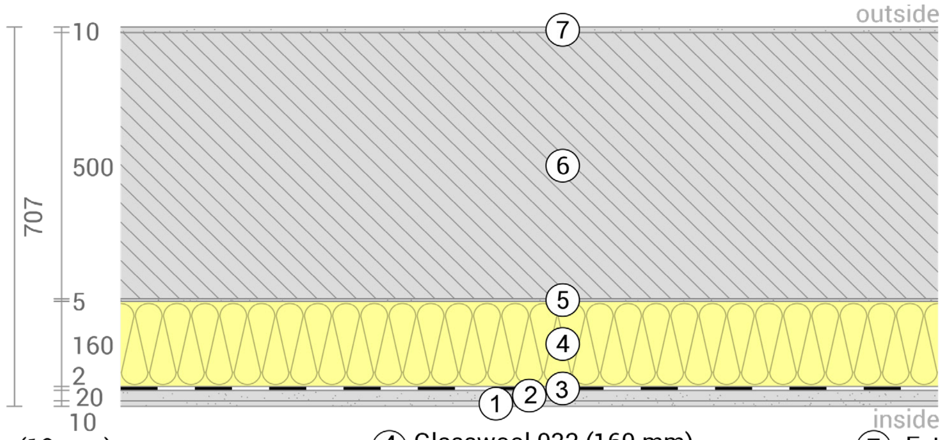
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: >100
phase shift: non relevant
Thermal capacity inside: 88 kJ/m²K

excellent insufficient



1. External plaster (10 mm)
2. Cement screed (20 mm)
3. Aluminum foil
4. Glasswool 032 (160 mm)
5. Adhesive&reinforcement mortar (5 mm)
6. Limestone (500 mm)
7. External plaster (10 mm)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	18,9	20,0	
1	1 cm	External plaster	0,540	0,019	18,8	18,9	14,0
2	2 cm	HASIT 410 Zementleichtestrich	0,420	0,048	18,6	18,8	25,0
3	0,2 cm	Aluminum foil (uncoated)	160,000	0,000	18,6	18,6	5,4
4	16 cm	Glasswool 032	0,032	5,000	-3,1	18,6	4,8
5	0,5 cm	Klebe- und Armiermörtel	0,540	0,009	-3,2	-3,1	7,0
6	50 cm	Limestone	1,400	0,357	-4,7	-3,2	1.000,0
7	1 cm	External plaster	0,540	0,019	-4,8	-4,7	14,0
		Thermal contact resistance*		0,040	-5,0	-4,8	
	70,7 cm	Whole component		5,621			1.070,2

Table 3 material properties

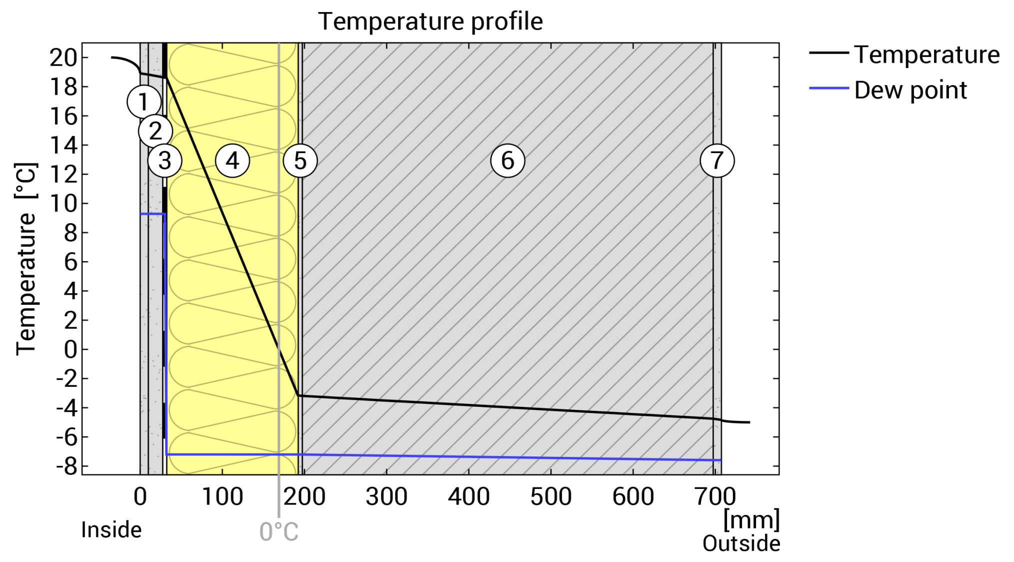
Inside air : 20,0°C / 50%

Outside air: -5,0°C / 50%

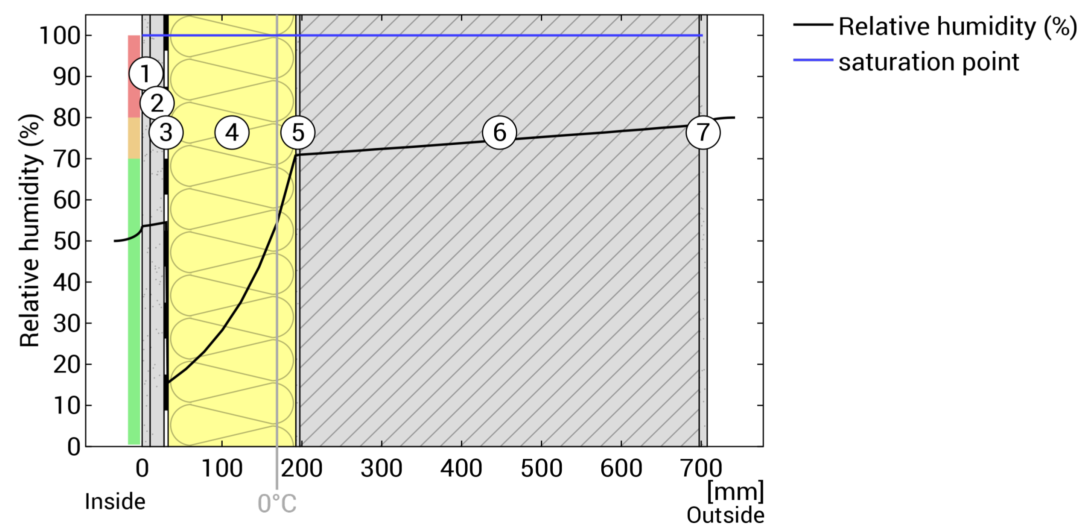
Surface temperature.: 18,9°C / -4,8°C
sd-value: 1520,5 m

Thickness: 70,7 cm
Weight: 1070 kg/m²
Heat capacity: 1069 kJ/m²K

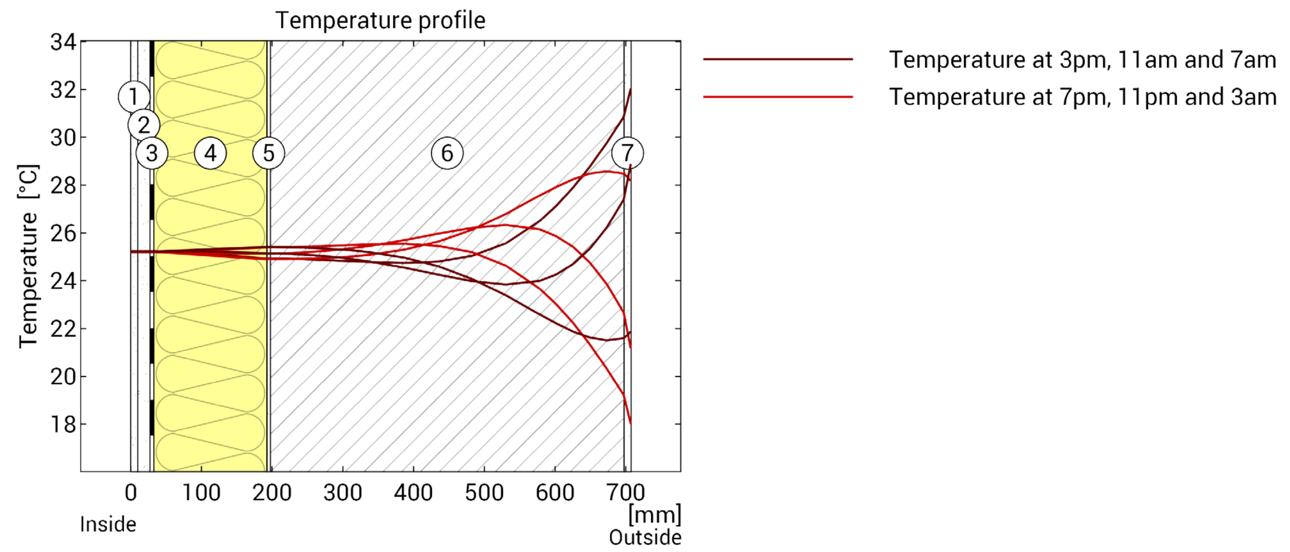
Temperature profile



Humidity



Heat protection



Heating floor for Ground Floor

Thermal protection

U = 0,16 W/(m²K)

EnEV Bestand*: U<0,3 W/(m²K)

excellent insufficient

Moisture proofing

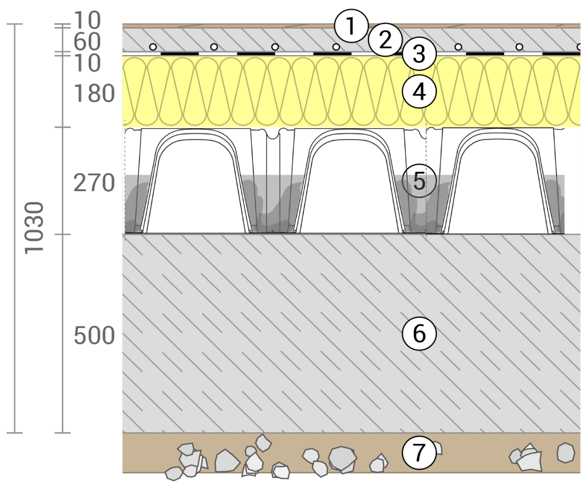
No condensate

excellent insufficient

Heat protection

Component is adjacent to earth:
TAV and phase non relevant
Thermal capacity inside: 293 kJ/m²K

excellent insufficient



(1) Wooden floor (10 mm)
(2) Cement screed (60 mm)
(3) Aluminum foil
(4) Glasswool 032 (180 mm)
(5) Ventilation layer (270 mm)
(6) Reinforced concrete (500 mm)
(7) Soil

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,100	20,0	26,9	
1	1 cm	Pine	0,130	0,077	26,7	29,0	5,2
2	6 cm	Cement screed	1,400	0,043	28,8	30,0	120,0
3	1 cm	Aluminum foil (coated)	160,000	0,000	29,8	29,8	27,0
4	18 cm	Glasswool 032	0,032	5,625	7,0	29,8	5,4
5	27 cm	Stationary air (unventilated)	1,182	0,229	6,0	7,0	0,3
6	50 cm	Reinforced concrete (1%)	2,300	0,217	5,2	6,0	1.150,0
		Thermal contact resistance*		0,000	5,0	5,2	
7		Soil			5,0	5,0	175,1
	103 cm	Whole component		6,292			1.307,9

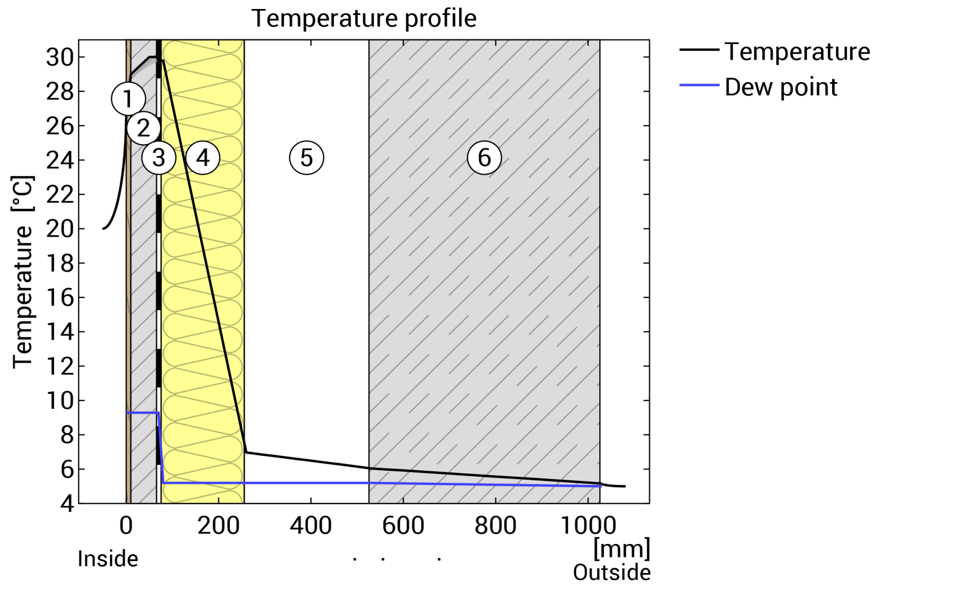
Table 4 material properties

Inside air : 20,0°C / 50%
Ground: 5,0°C / 100%

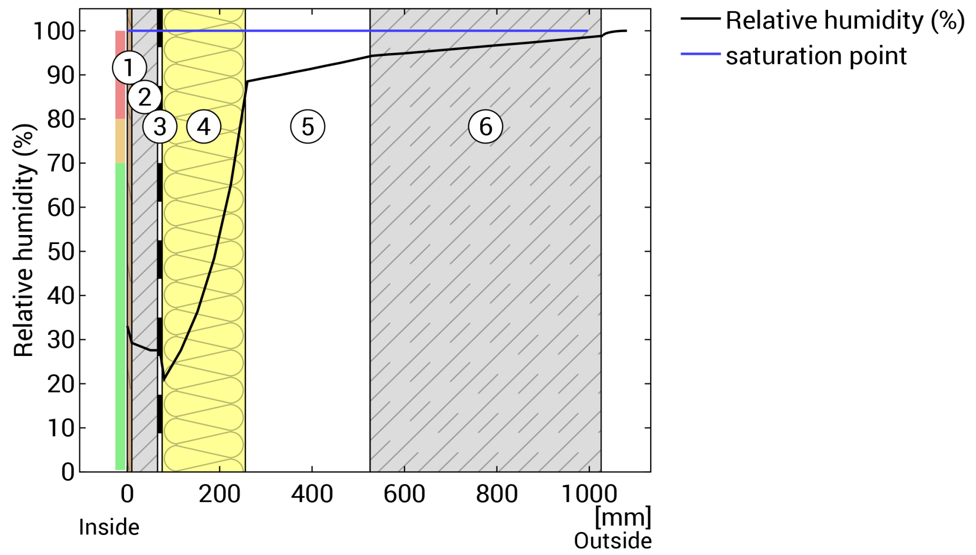
Surface temperature.: 26,7°C / 5,2°C
sd-value: 1566,3 m

Thickness: 103,0 cm
Weight: 1308 kg/m²
Heat capacity: 1169 kJ/m²K

Temperature profile



Humidity



Heating floor for Typical floors

Thermal protection

U = 0,16 W/(m²K)

Heated on both sides: No requirement*

excellent — insufficient

Moisture proofing

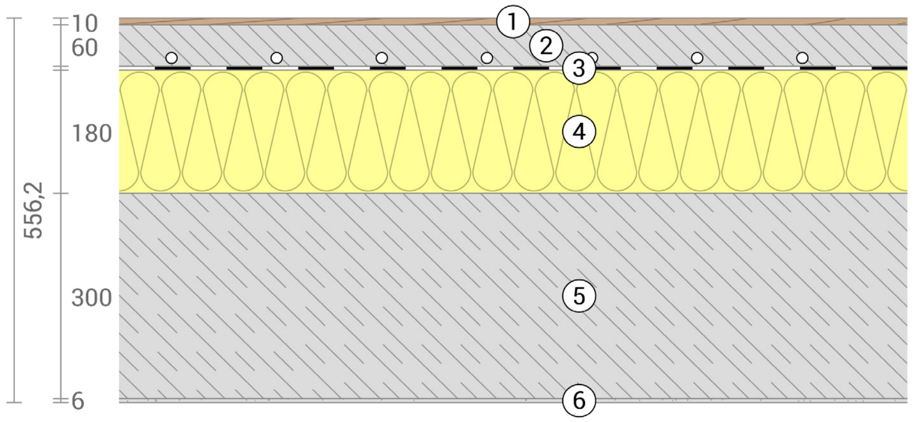
No condensate

excellent — insufficient

Heat protection

Temperature amplitude damping: >100
phase shift: non relevant
Thermal capacity inside: 128455 kJ/m²K

excellent — insufficient



1 Wooden floor (10 mm)
2 Cement screed (60 mm)
3 Foil, PE
4 Glasswool 032 (180 mm)
5 Reinforced concrete (300 mm)
6 StoSilent sound-absorbing systems (6 mm)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,100	20,0	26,7	
1	1 cm	Pine	0,130	0,077	26,5	28,8	5,2
2	6 cm	Cement screed	1,400	0,043	28,4	30,0	120,0
3	0,02 cm	Foil, PE	0,400	0,001	29,0	30,0	0,2
4	18 cm	Glasswool 032	0,032	5,625	20,3	30,0	5,4
5	30 cm	Reinforced concrete (2%)	2,500	0,120	20,1	20,3	720,0
6	0,6 cm	Knauf Gipsmaschinenputz MP 75 L	0,340	0,018	20,1	20,1	5,7
		Thermal contact resistance*		0,100	20,0	20,1	
	55,62 cm	Whole component		6,093			856,5

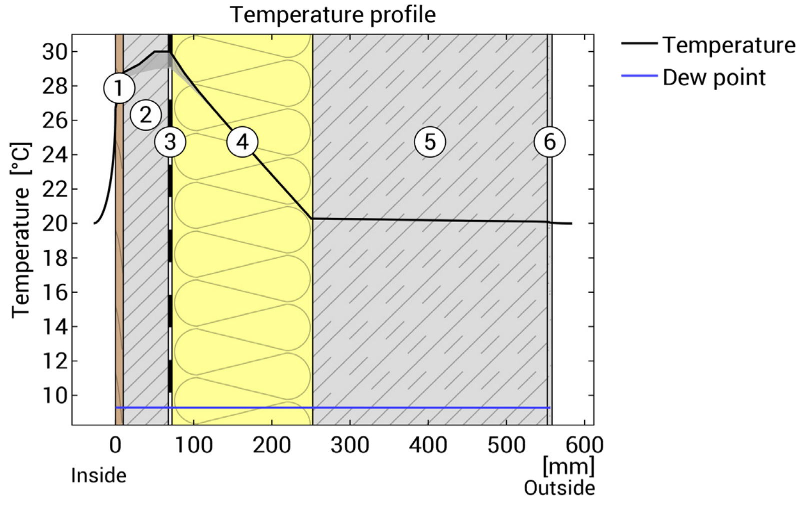
Table 5 material properties

Inside air : 20,0°C / 50%
Inside air 2: 20,0°C / 50%

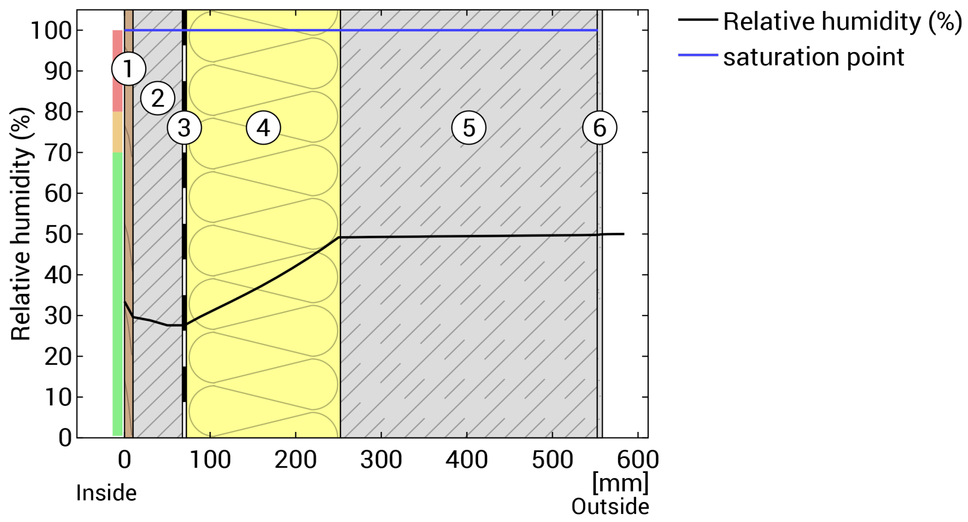
Surface temperature.: 26,5°C / 20,1°C
sd-value: 60,3 m

Thickness: 55,6 cm
Weight: 856 kg/m²
Heat capacity: 773 kJ/m²K

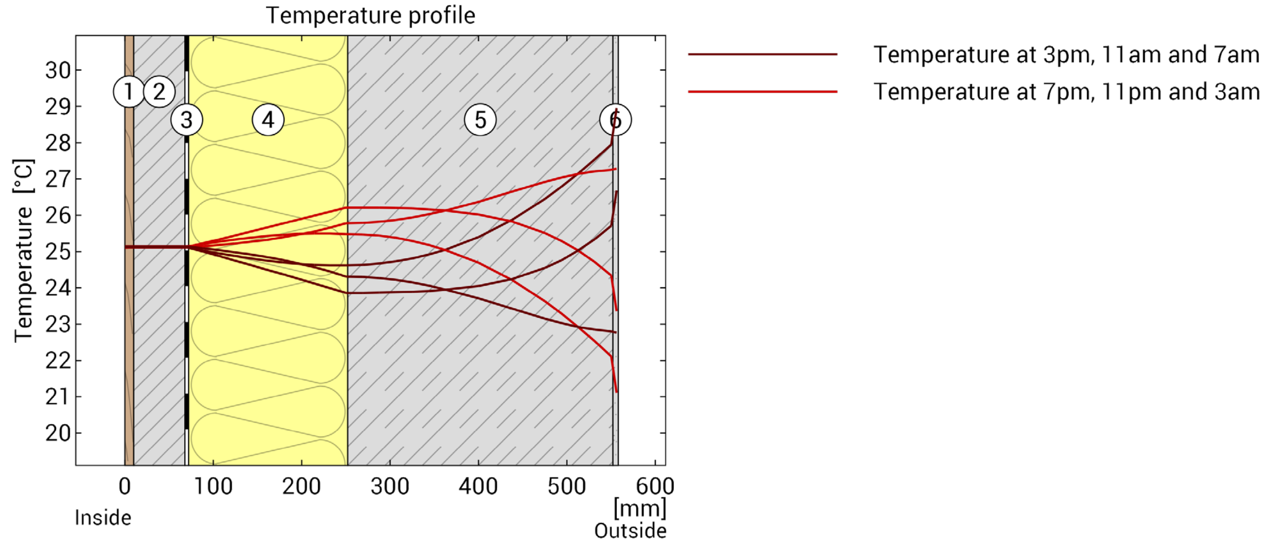
Temperature profile



Humidity



Heat protection



Roof renovation (pavatex)

Thermal protection

U = 0,14 W/(m²K)

KfW Einzelmaßn.*: U<0,14 W/(m²K)

excellent insufficient

Moisture proofing

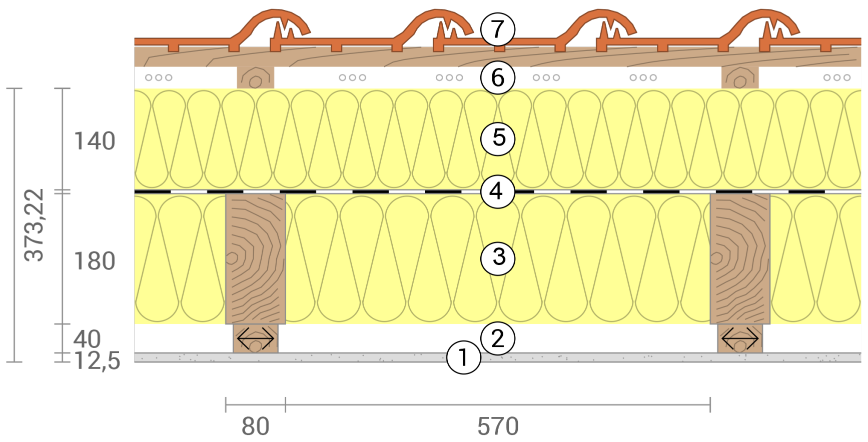
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 60
phase shift: 17,8 h
Thermal capacity inside: 44 kJ/m²K

excellent insufficient



1. Gypsum board (12,5 mm)
2. Installation level (40 mm)
3. PAVATEX PAVAFLEX (180 mm)
4. PAVATEX LDB 0.02
5. PAVATHERM-Plus (140 mm)
6. Rear ventilated level
7. Roofing tiles

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,100	18,9	20,0	
1	1,25 cm	Gypsum board	0,250	0,050	18,6	19,2	8,5
2	4 cm	Installation level	0,250	0,160	17,7	19,1	0,0
	4 cm	Spruce (9,2%)	0,130	0,308			1,7
3	18 cm	PAVATEX PAVAFLEX	0,040	4,500	5,0	18,6	7,9
	18 cm	Spruce (12%)	0,130	1,385	7,8	18,0	10,0
4	0,072 cm	PAVATEX LDB 0.02	0,220	0,003	5,0	8,0	0,2
5	14 cm	PAVATHERM-Plus	0,045	3,111	-4,9	8,0	26,6
		Thermal contact resistance*		0,100	-5,0	-4,8	
6		Rear ventilated level (outside air)			-5,0	-5,0	0,0
7		Roofing tiles (clay)			-5,0	-5,0	51,5
	50,622 cm	Whole component		7,256			106,3

Table 6 material properties

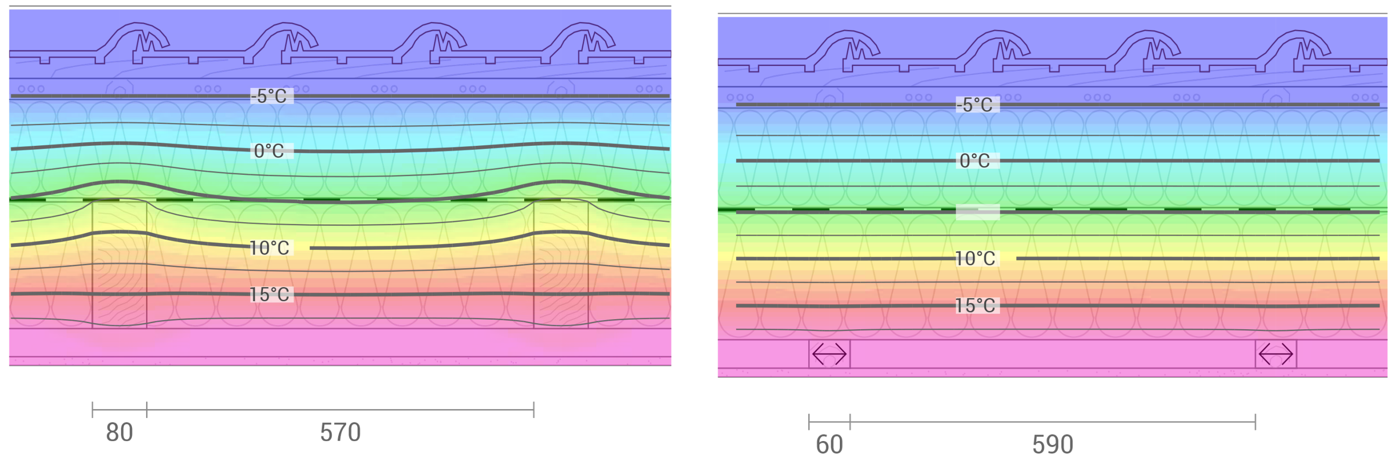
Inside air : 20,0°C / 50%
Outside air: -5,0°C / 50%

Surface temperature.: 18,9°C / -4,9°C

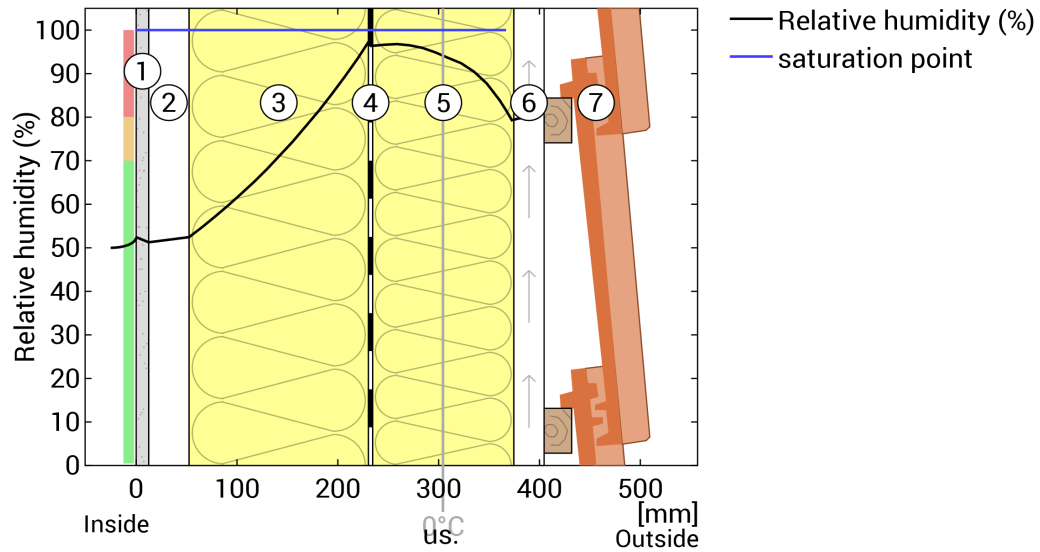
sd-value: 1,2 m

Thickness: 50,6 cm
Weight: 106 kg/m²
Heat capacity: 97 kJ/m²K

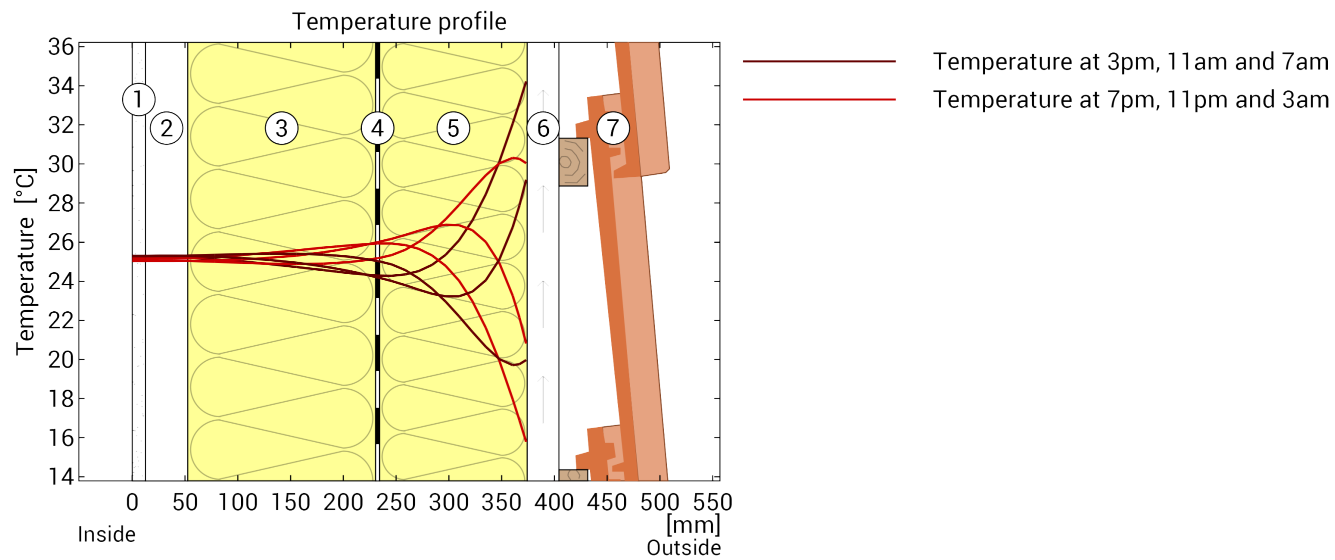
Temperature profile



Humidity



Heat protection



4.2.2 New Building

Wooden wall for passive house (with insulation level) for exterior walls

Thermal protection

U = 0,10 W/(m²K)

EnEV Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

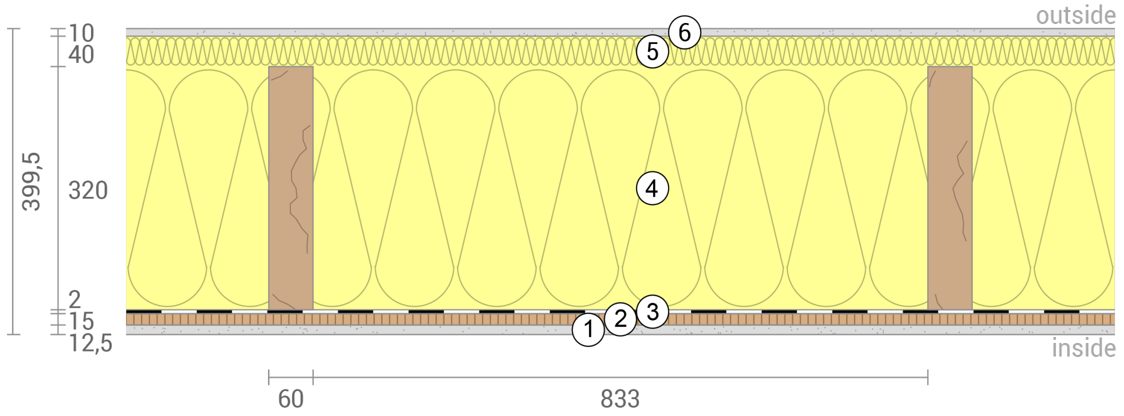
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 32
phase shift: 10,2 h
Thermal capacity inside: 42 kJ/m²K

excellent insufficient



1. Gypsum board (12,5 mm)
2. OSB/3 (15 mm)
3. Aluminum foil
4. Glasswool 032 (320 mm)
5. Glasswool 032 (40 mm)
6. Exterior plaster (10 mm)

Table 6 material properties

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	19,3	20,0	
1	1,25 cm	Gypsum board	0,250	0,050	19,2	19,4	8,5
2	1,5 cm	OSB/3	0,130	0,115	18,9	19,3	9,3
3	0,2 cm	Aluminum foil (coated)	160,000	0,000	18,9	19,0	5,4
4	32 cm	Glasswool 032	0,032	10,000	-2,2	19,0	9,0
	32 cm	Ständer (Brettschichtholz) (6,7%)	0,130	2,462	0,4	18,9	9,7
5	4 cm	Glasswool 032	0,032	1,250	-4,9	0,5	1,2
6	1 cm	Außenputz	1,000	0,010	-4,9	-4,8	18,0
		Thermal contact resistance*		0,040	-5,0	-4,8	
	39,95 cm	Whole component		10,045			61,0

Table 7 material properties

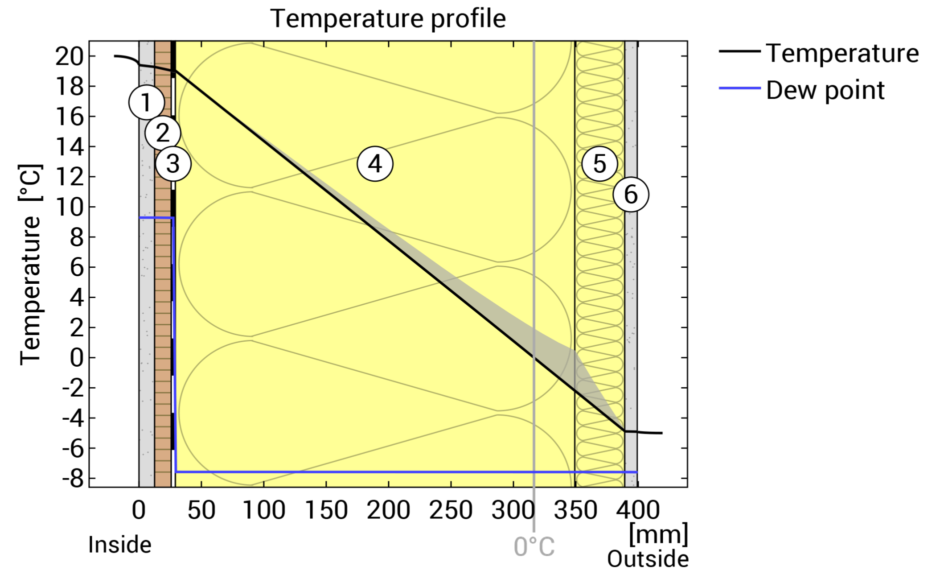
Inside air : 20,0°C / 50%
Outside air: -5,0°C / 80%

Surface temperature.: 19,3°C/-4,9°C
sd-value: 1503,8 m

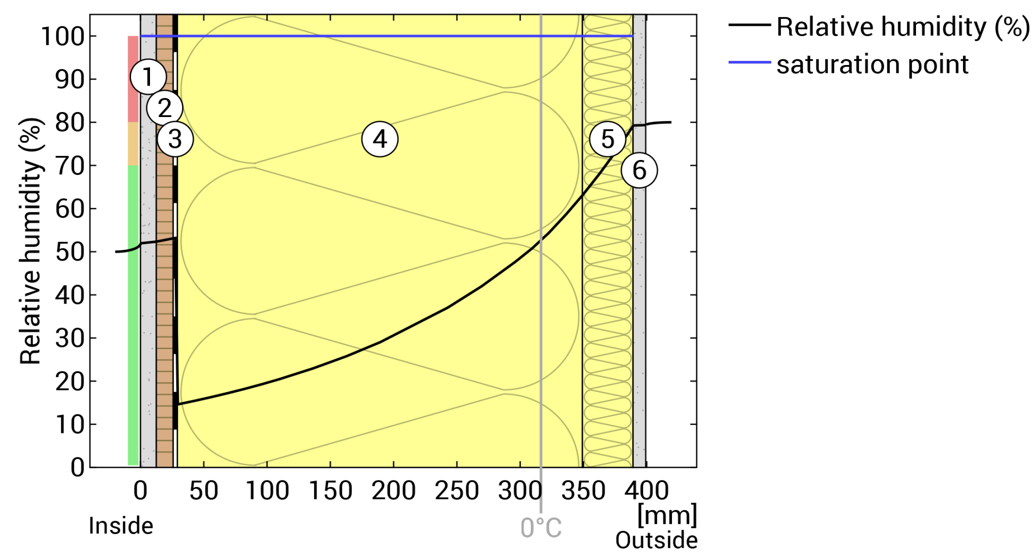
Thickness: 40,0 cm
Weight: 61 kg/m²

Heat capacity: 71 kJ/m²K

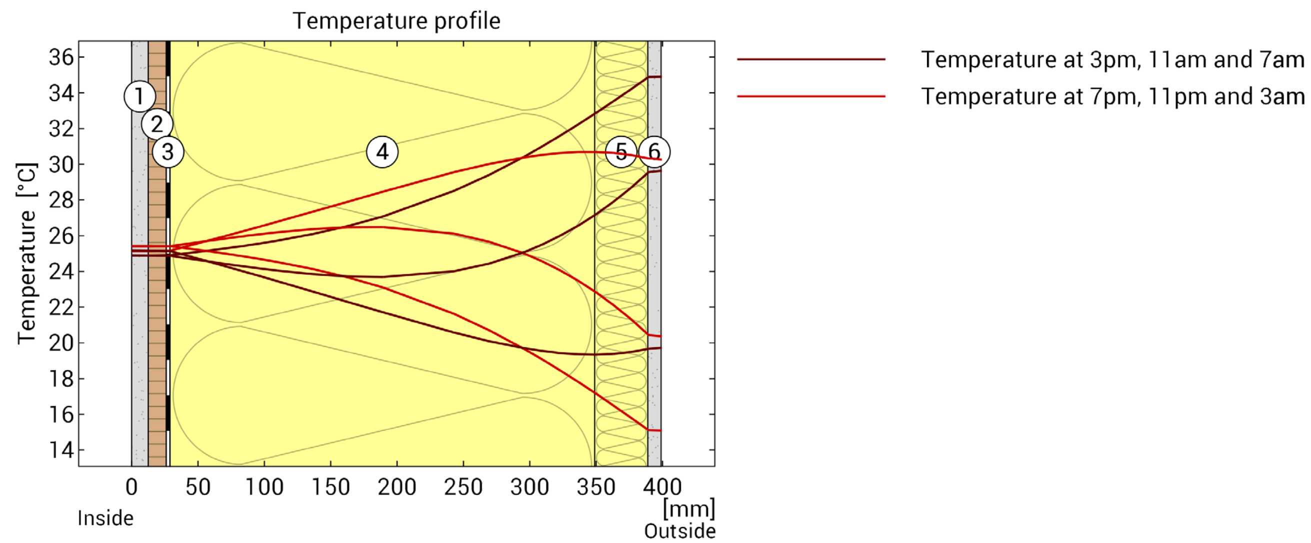
Temperature profile



Humidity



Heat protection



Wooden wall for passive house (with insulation level) for interior walls

Thermal protection

U = 0,21 W/(m²K)

Heated on both sides: No requirement*

excellent insufficient

Moisture proofing

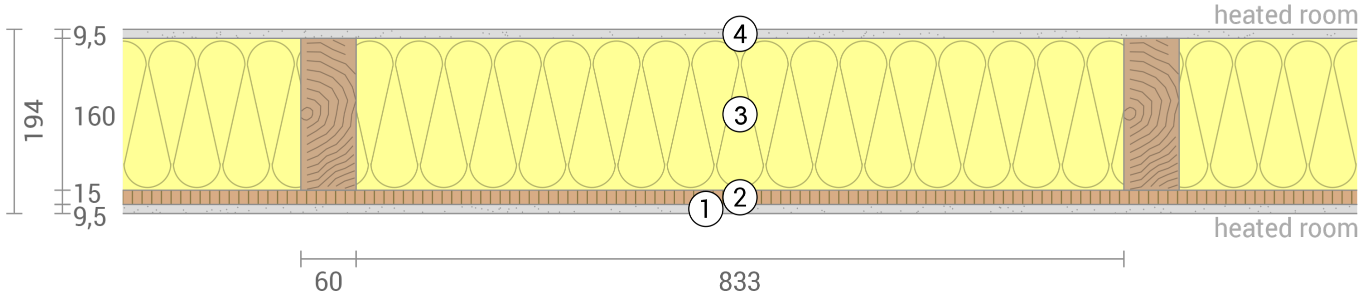
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 8,7
phase shift: 6,7 h
Thermal capacity inside: 26 kJ/m²K

excellent insufficient



① Gypsum board (9,5 mm)
② OSB/3 (15 mm)
③ Glasswool 032 (160 mm)
④ Gypsum board (9,5 mm)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,130	20,0	20,0	
1	0,95 cm	Gypsum board	0,250	0,038	20,0	20,0	6,5
2	1,5 cm	OSB/3	0,130	0,115	20,0	20,0	9,3
3	16 cm	Glasswool 032	0,032	5,000	20,0	20,0	4,5
	16 cm	Ständer (Brettschichtholz) (6,7%)	0,130	1,231	20,0	20,0	4,8
4	0,95 cm	Gypsum board	0,250	0,038	20,0	20,0	6,5
		Thermal contact resistance*		0,130	20,0	20,0	
	19,4 cm	Whole component		4,684			31,5

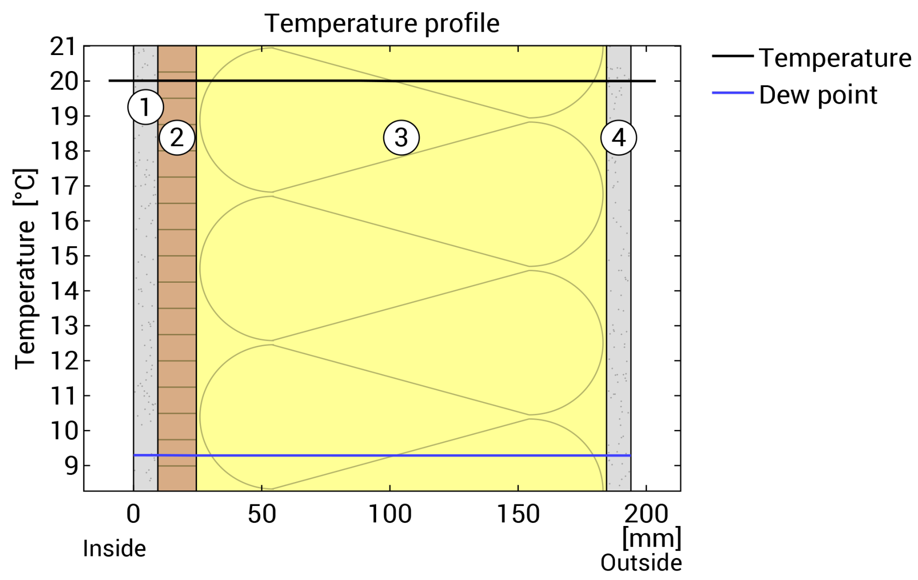
Table 8 material properties

Inside air : 20,0°C / 50%
Inside air 2: 20,0°C / 50%

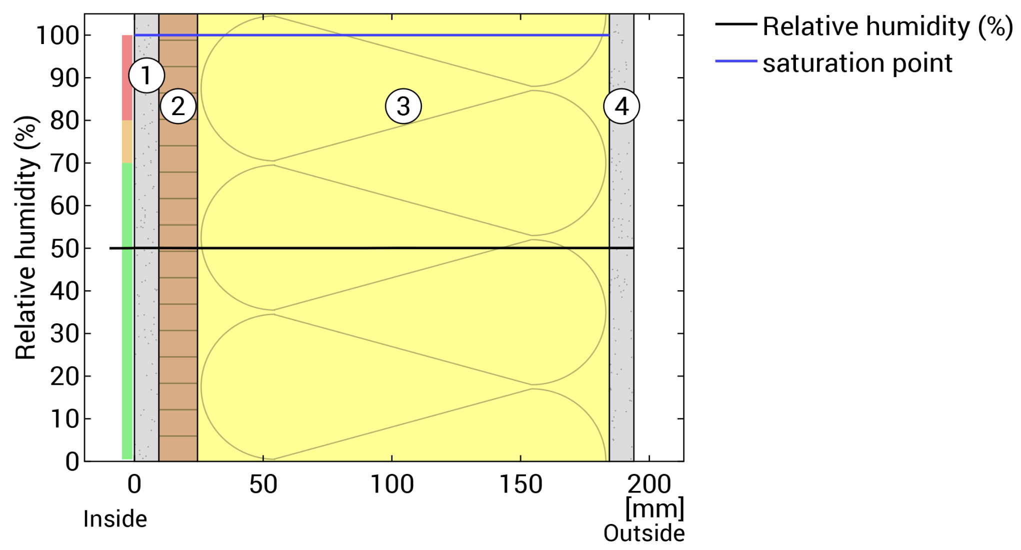
Surface temperature.: 20,0°C / 20,0°C
sd-value: 2,8 m

Thickness: 19,4 cm
Weight: 32 kg/m²
Heat capacity: 40 kJ/m²K

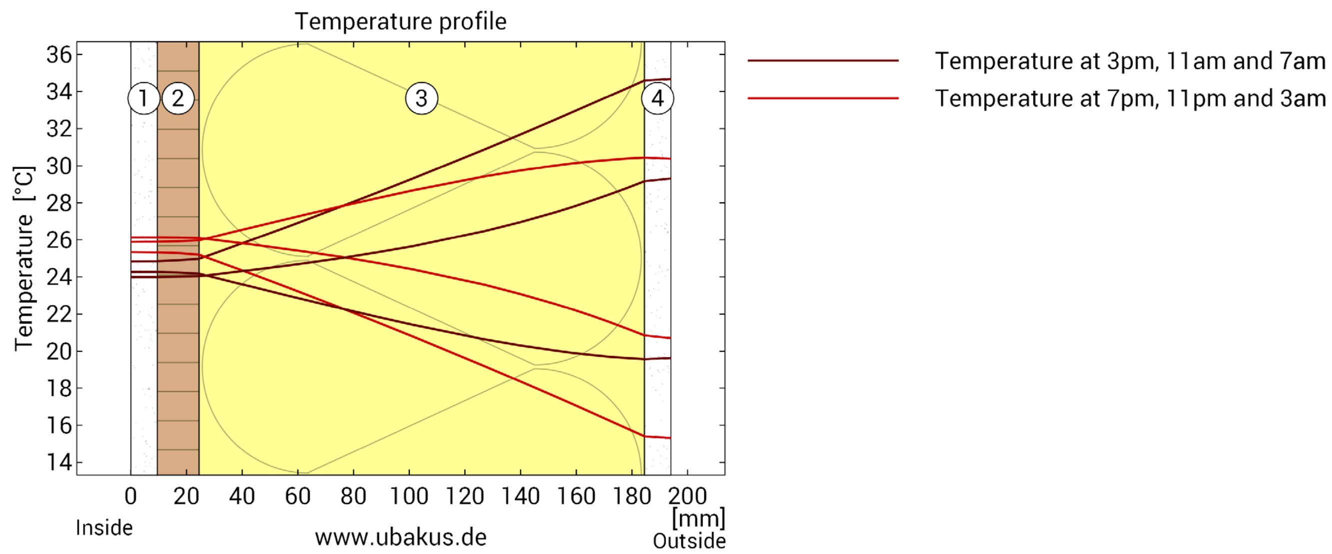
Temperature profile



Humidity



Heat protection



Heating floor for Typical Floors

Thermal protection

U = 0,16 W/(m²K)

Heated on both sides: No requirement*

excellent insufficient

Moisture proofing

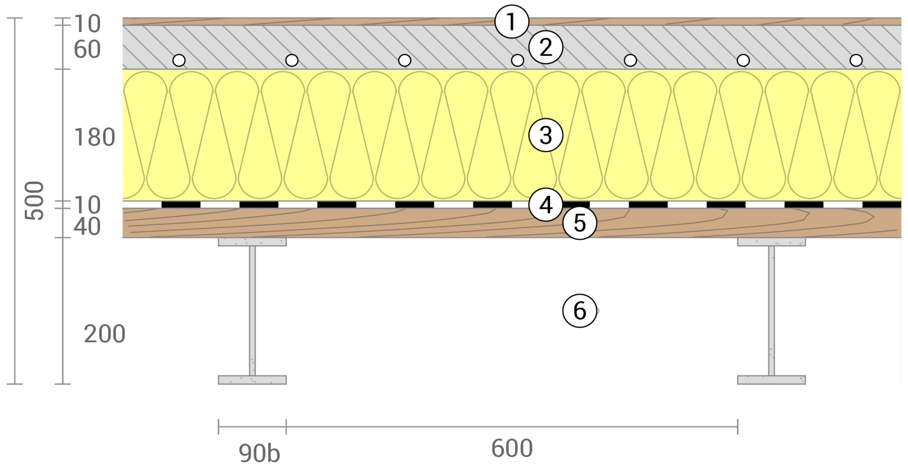
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 68
phase shift: 9,8 h
Thermal capacity inside: 118792 kJ/m²K

excellent insufficient



(1) Wooden floor (10 mm)
(2) Cement screed (60 mm)
(3) Glasswool 032 (180 mm)
(4) Foil, PE
(5) Wooden panel (40 mm)
(6) Steel beam(200 mm)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,100	20,0	26,8	
1	1 cm	Pine	0,130	0,077	26,5	28,9	5,2
2	6 cm	Cement screed	1,400	0,043	28,4	30,0	120,0
3	18 cm	Glasswool 032	0,032	5,625	20,6	30,0	5,4
4	1 cm	Foil, PE	0,400	0,025	20,6	20,7	9,3
5	4 cm	Rafter (spruce)	0,130	0,308	20,0	20,6	18,0
6	20 cm	Outside air			20,0	20,2	
	17,74 cm	Steel (Width: 0,75 cm)	50,000	0,004	20,0	20,0	15,0
	1,13 cm	Steel (Width: 9 cm)	50,000	0,000	20,0	20,0	11,5
	1,13 cm	Steel (Width: 9 cm)	50,000	0,000	20,0	20,0	11,5
		Thermal contact resistance*		0,100	20,0	20,0	
	50 cm	Whole component		6,258			196,2

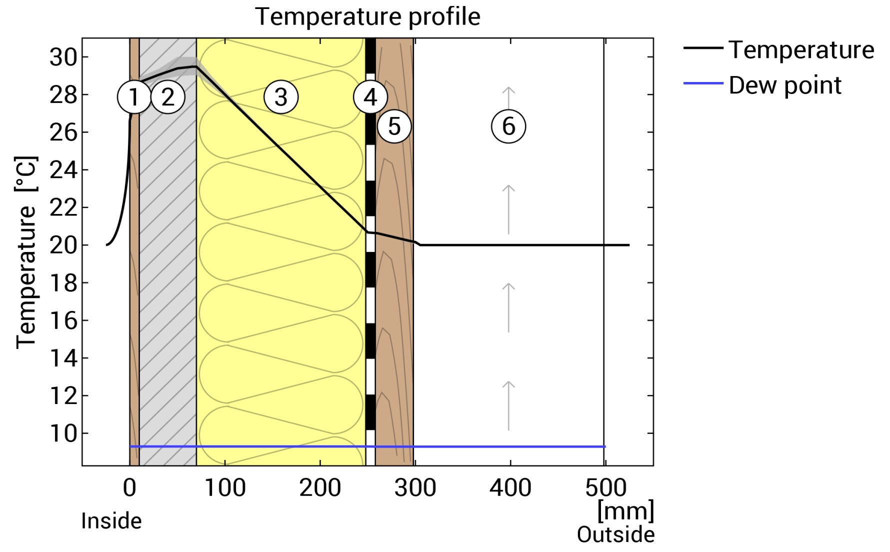
Table 9 material properties

Inside air : 20,0°C / 50%
Inside air 2: 20,0°C / 50%

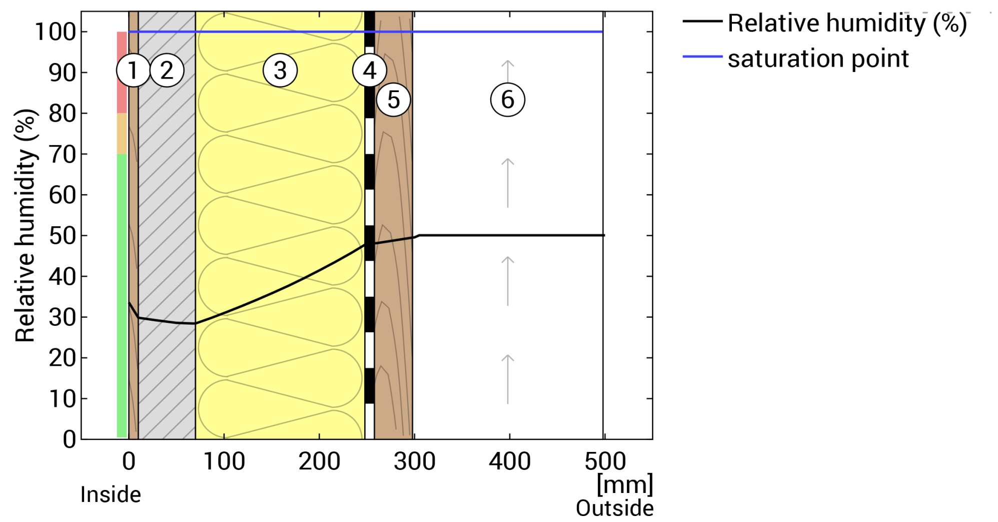
Surface temperature.: 26,5°C / 20,0°C
sd-value: 1083,7 m

Thickness: 50,0 cm
Weight: 196 kg/m²
Heat capacity: 196 kJ/m²K

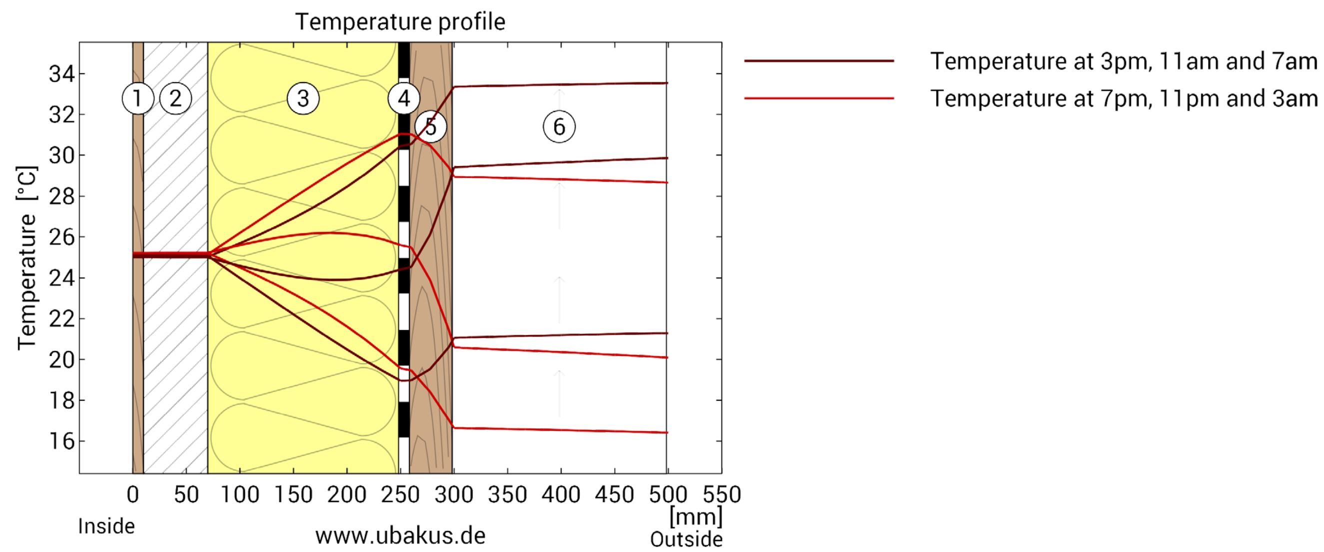
Temperature profile



Humidity



Heat protection



BEMO-soft plus Roof

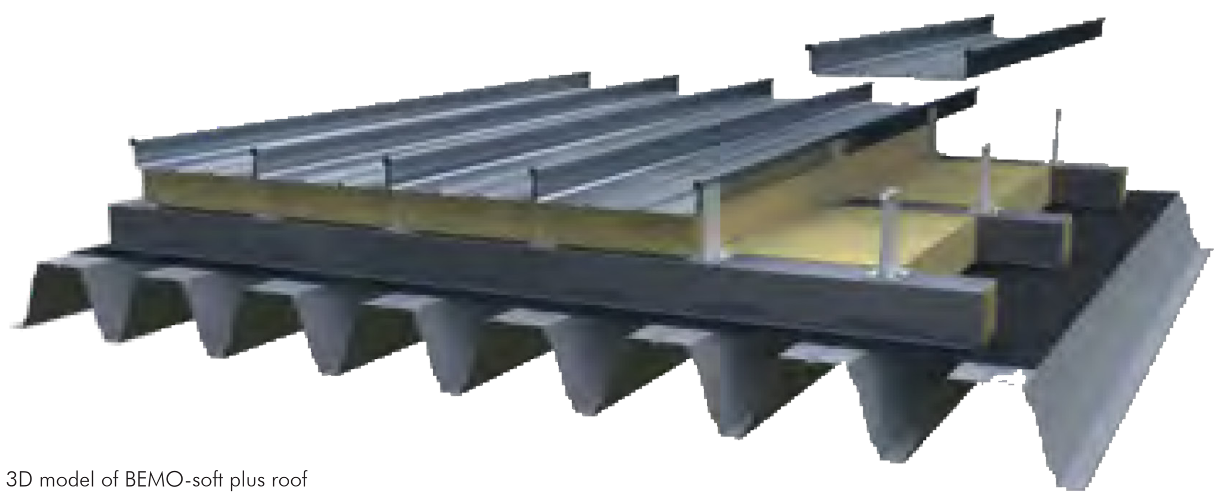


Figure 21 3D model of BEMO-soft plus roof

HEAT PROTECTION

relative halter height in mm:	80	100	120	140	160	180	200	220
Thick insulation layer in mm:	120	140	160	180	200	220	240	260
Total thickness roof construction in mm:	215	235	255	275	295	315	335	355
U-value without considering punctiform thermal bridges:	0.253	0.218	0.192	0.172	0.155	0.141	0.130	0.120
U-value considering punctiform thermal bridges								
Aluminium Halter height:	80+TK5	100+TK5	120+TK5	140+TK5	160+TK5	180+TK5	200+TK5	220+TK5
U-value:	0.467	0.423	0.388	0.360	0.334	0.311	0.292	0.273
GFK Halter height:	85	105	125	145	165	185	205	225
U-value:	0.291	0.253	0.223	0.199	0.178	0.161	0.145	0.131

SOUND PROTECTION

Weight per m² in kg:	17.43	17.83	18.23	18.63	19.03	19.43	19.83	20.23
predictable sound reduction index R in dB:	36.81	37.00	37.20	37.38	37.57	37.75	37.93	38.10
Measures to improve sound insulation: Use of insulating materials with 70kg/m³								
Weight per m² in kg:	23.43	24.83	26.23	27.63	29.03	30.43	31.83	33.23
predictable sound reduction index R in dB:	39.37	39.88	40.36	40.81	41.24	41.65	42.04	42.41
Installation of a layer of gypsum board with 8.5 kg/m²:								
Weight per m² in kg:	25.93	26.33	26.73	27.13	27.53	27.93	28.33	28.73
predictable sound reduction index R in dB:	40.26	40.39	40.52	40.65	40.78	40.90	41.02	41.15
Installation of a soundproofing panel with 17.5kg/m²								
Weight per m² in kg:	34.93	35.33	35.73	36.13	36.53	36.93	37.33	37.73
predictable sound reduction index R in dB:	42.84	42.94	43.04	43.14	43.23	43.33	43.42	43.51

Table 10 material properties

BEMO-soft plus

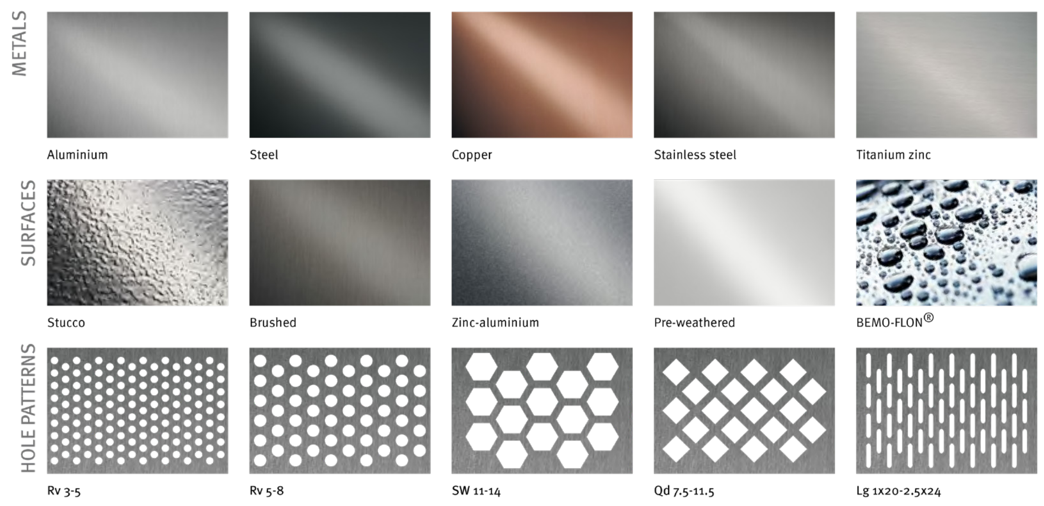


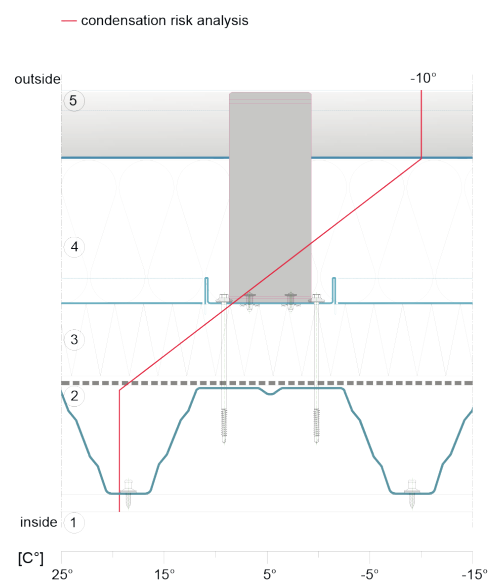
Figure 22 different shapes of BEMO soft plus roof

Figure 23 thermal halter

THERMAL HALTER:

Halters made of fibreglass reinforced plastic are completely free of thermally conductive parts and therefore, are completely thermal bridge-free. As a result, the need for insulation material is reduced considerably. The halters are fire-tested and have passed all frost and damp tests. Their characteristic features have a high level of rigidity and very good load-bearing capacity (BEMO, BEMO roof shapes, 2019).

1. Halters made of high-quality plastic
2. High load-bearing capacity
3. Very good sliding movement of the standing seam tracks
4. Completely thermal bridge-free



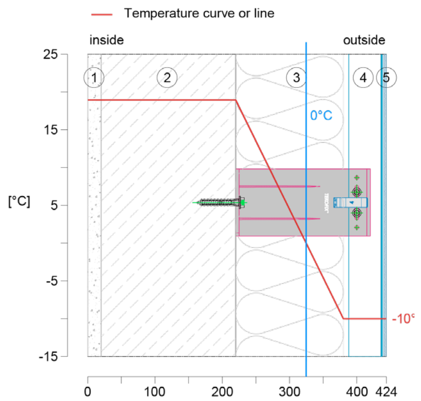
Good soundproofing and thermal and moisture insulation

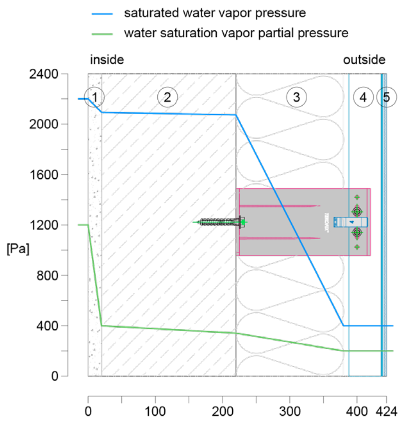
BEMO standing seam Screen Facade

Figure 24 Convention Center, Lausanne, Switzerland

BEMO standing seam					
Profile types	N50		N65		
Profile widths	333 mm, 429 mm, 529 mm, 600 mm		305 mm, 333 mm, 400 mm, 500 mm, 600 mm		
Variable profiles	from 100 mm		from 100 mm		
Materials	Aluminium	Steel	Stainless steel	Copper	Titanium zinc
Material thickness in mm	0.8 – 1.2	0.63 – 0.75	0.6 – 0.7	0.8 – 1.0	0.7 – 1.0
Coatings	BEMO-FLON / PVDF / Polyester				
Surfaces	Stucco / brushed / Aluzinc / pre-weathered / cladded				
Production lengths	factory production up to 38 m, on-site production › 38 m				
Perforation patterns	Rv 3.00 – 5.00	Rv 3.5 – 5.00	Rv 5.00 – 8.00	SW 11-14	
Material	Aluminium				
Material thickness in mm	1.0 – 1.2				

Table 11 material properties





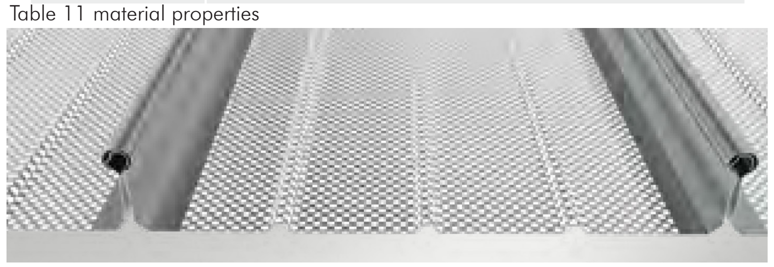


Figure 25 perforated standing seam screen

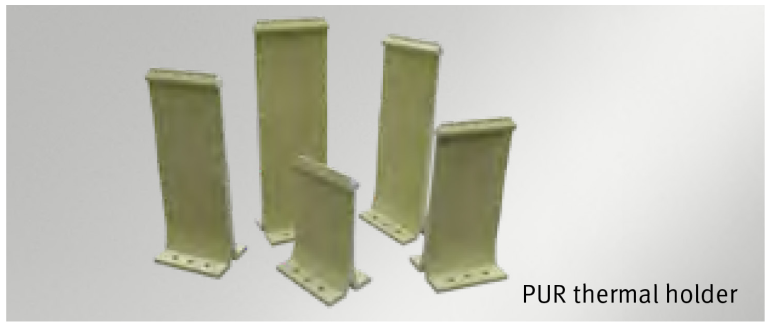


Figure 26 thermal halter

The BEMO standing seam system also offers unimagined possibilities for facade design. Varying profile widths from 100 mm to 800 mm, 2 profile heights, almost endless panel lengths, parallel, conical and "free form" profiles give architects, designers and planners the widest range of options. The materials used are normally aluminum or steel, but can also be stainless steel, zinc or copper. The radii for arched profiles start at 600 mm, depending on the design (BEMO, BEMO Facade Variety, 2019).

UNILUX wooden windows

Figure 27 wooden window 3D section

Figure 28 wooden window section

Thermal insulation without compromises

Every UNILUX window meets today's high standards for energy efficiency. The stable frame catches the outside temperature – reducing heating needs (UNILUX, 2020).

Extra warmth: Triple glazing

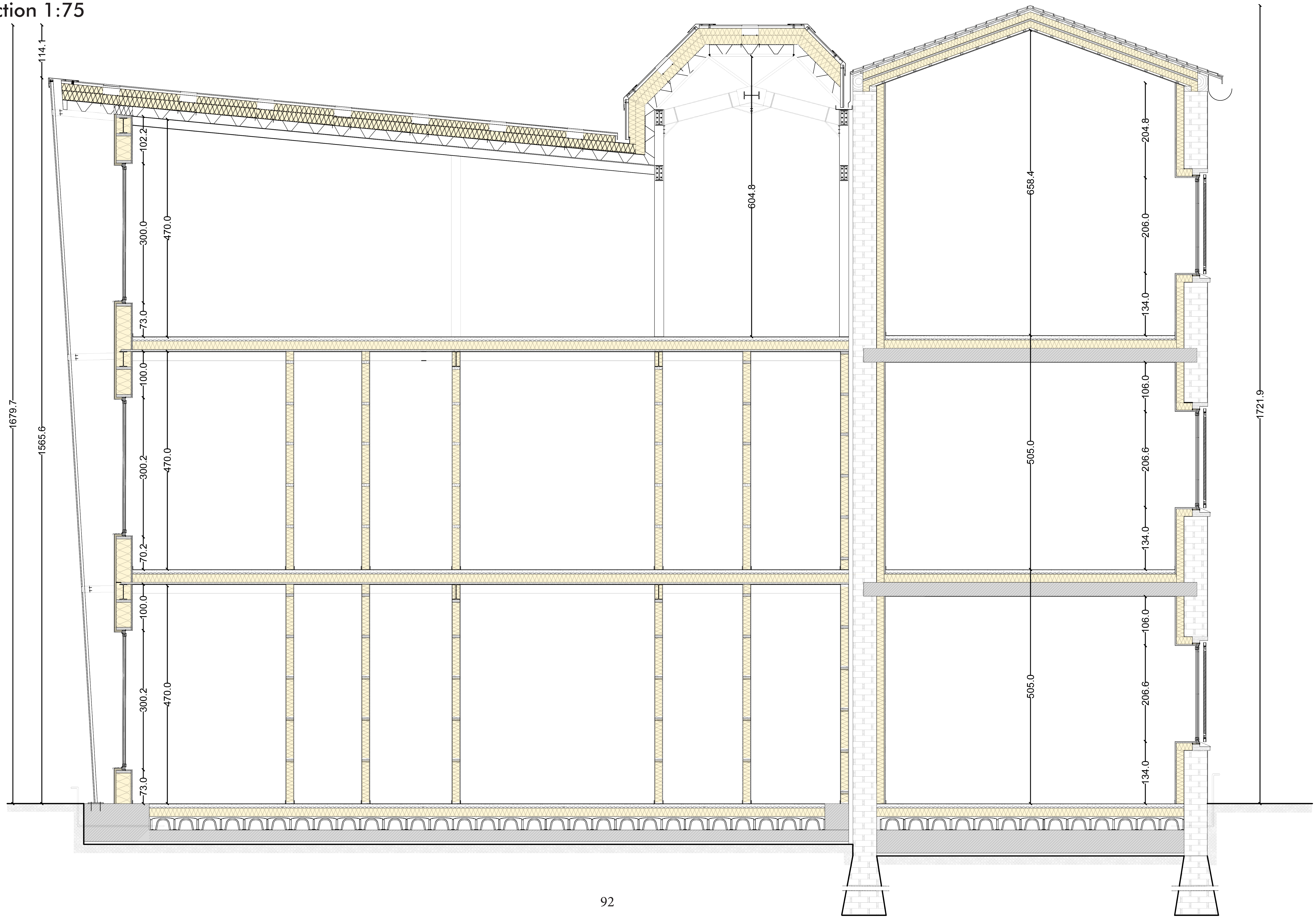
Three panes instead of two. The additional layer of glass provides even better thermal insulation and therefore even lower energy costs. And since the pane itself has a thickness of 40 mm, it can also be efficiently equipped with noise protection (UNILUX, 2020).

Multi-layered wood bonding

Stability guaranteed. Multi-layered bonding equalizes stresses between the solid-wood layers and wood surface, thereby ensuring absolute torsional rigidity (UNILUX, 2020).

BIBLIOGRAPHY

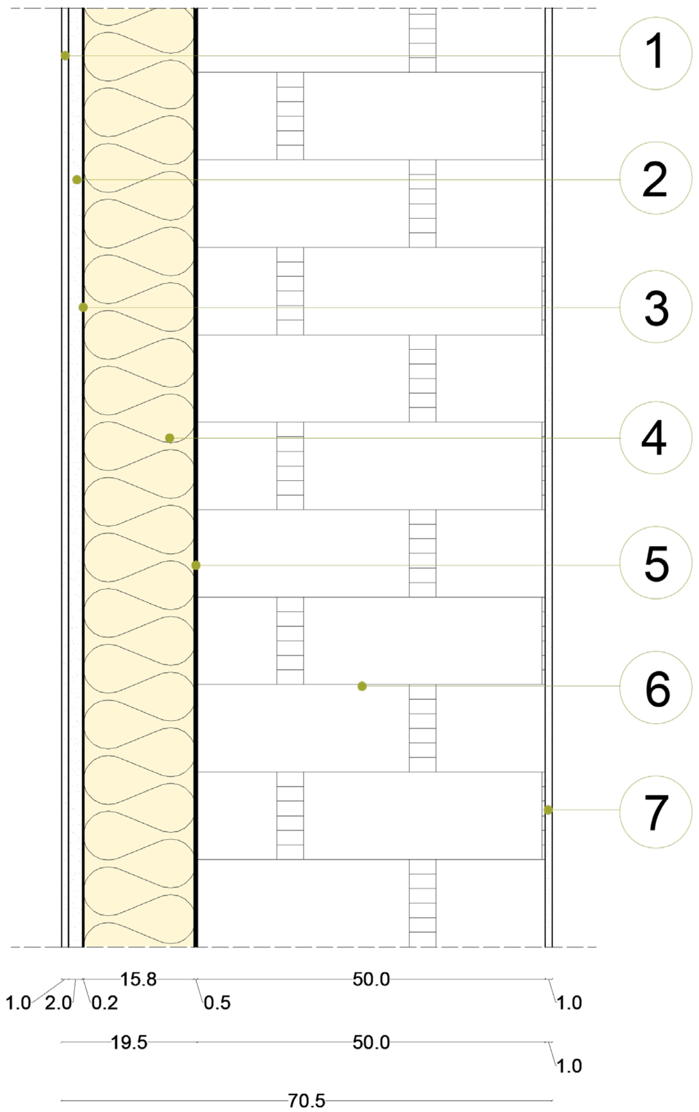
4.3.1 Old Building
Section 1:75



Outside wall insulation (wood fiber) 1:10

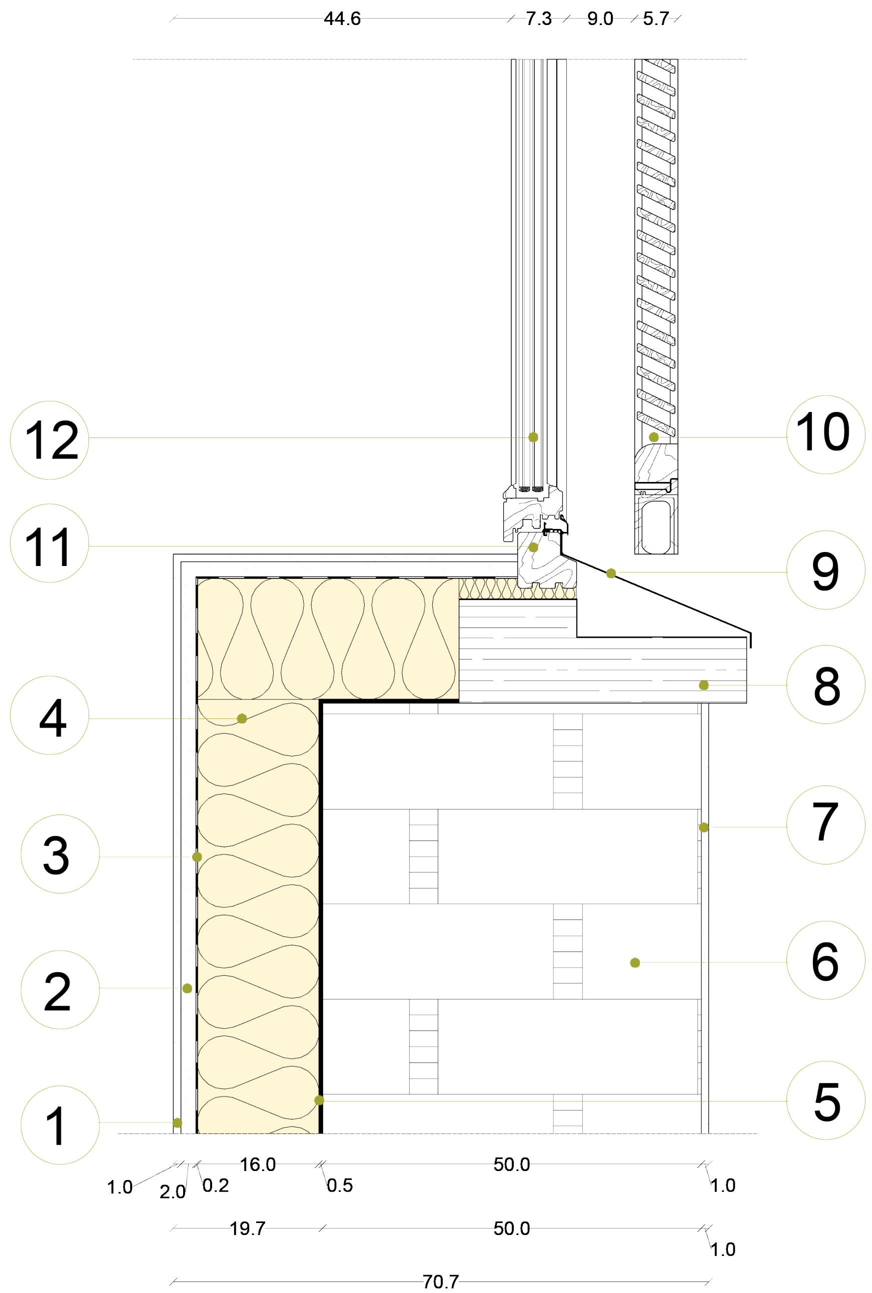
1. **Coating layer**: 1.00cm of internal plaster, its thermal conductivity=0.55W/mK and density= 1900kg/m^3
2. **Screed layer:** 2.00cm of cement screed for external coating, its thermal conductivity=1.40W/mK and density= 2000kg/m^3
3. **Vapor barrier:** 0.20cm of aluminum foil (uncoated) used for prevention of interstitial condensation, its thermal conductivity=160W/mK and density=2700kg/m^3
4. **Thermal insulation:** 16cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m^3
5. **Adhesive and reinforcement mortar:** 0.50cm thickness to hold the insulation layer securely on the substrate and protect against moisture its thermal conductivity=0.054W/mK and density=1400kg/m^3
6. **Existing wall:** 50 cm of brick/stone wall it is the original exterior wall of the existing building its thermal conductivity=1.40W/mK and density=2000kg/m^3
7. **Coating layer**: 1.00cm of external plaster, its thermal conductivity=0.55W/mK and density= 1900kg/m^3

U-Value=0.18W/m^2K



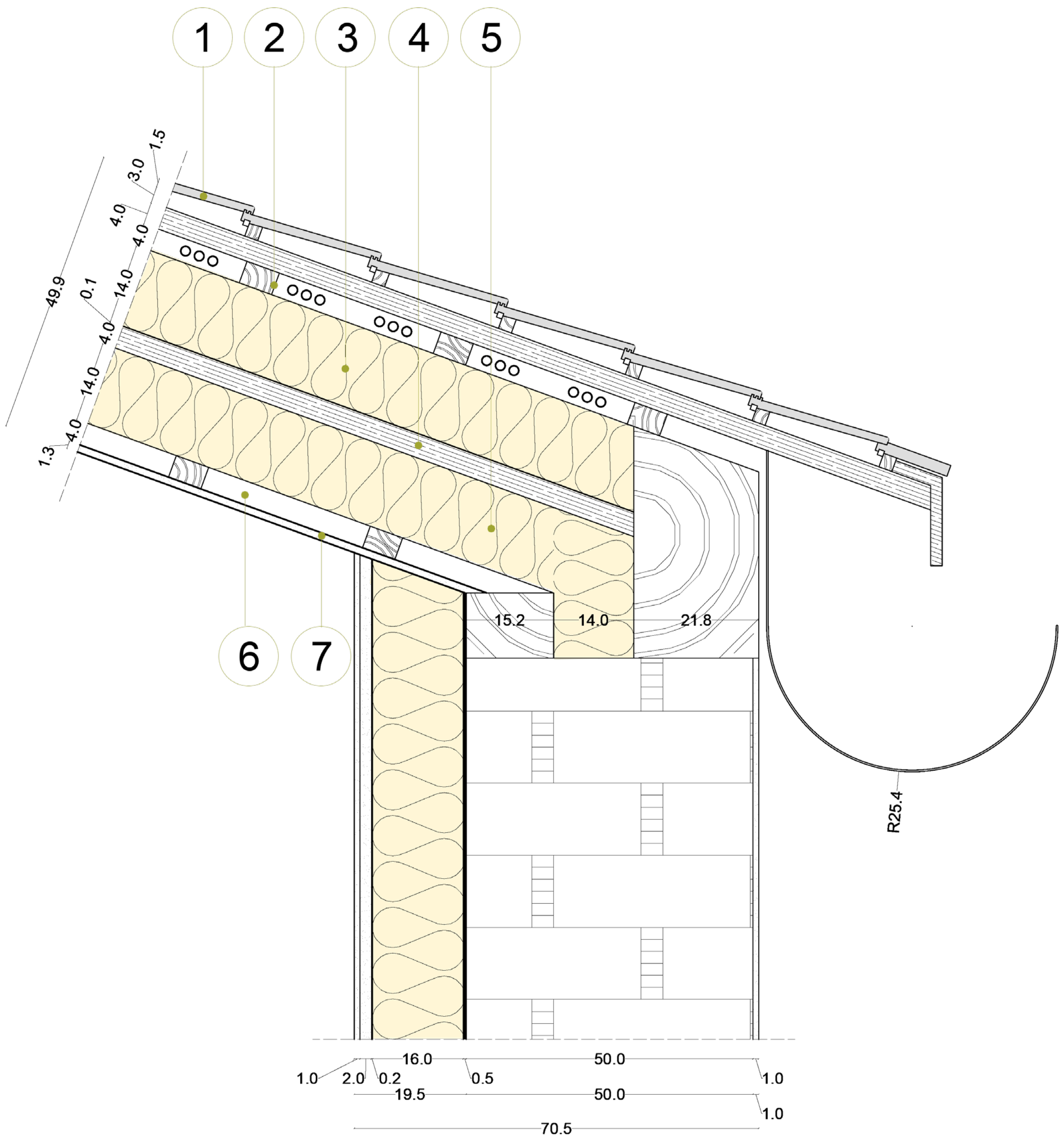
Window and Wall Connection 1:10

1. **Coating layer**: 1.00cm of internal plaster, its thermal conductivity=0.55W/mK and density= 1900kg/m^3
2. **Screed layer:** 2.00cm of cement screed for external coating, its thermal conductivity=1.40W/mK and density= 2000kg/m^3
3. **Vapor barrier:** 0.20cm of aluminium foil (uncoated) used for prevention of interstitial condensation, its thermal conductivity=160W/mK and density=2700kg/m^3
4. **Thermal insulation:** 16cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m^3
5. **Adhesive and reinforcement mortar:** 0.50cm thickness to hold the insulation layer securely on the substrate and protect against moisture its thermal conductivity=0.054W/mK and density=1400kg/m^3
6. **Existing wall:** 50 cm of brick/stone wall it is the original exterior wall of the existing building its thermal conductivity=1.40W/mK and density=2000kg/m^3
7. **Coating layer**: 1.00cm of external plaster, its thermal conductivity=0.55W/mK and density= 1900kg/m^3
8. **Wooden frame**: 8.0cm thickness of wooden frame.
9. **Metal sheet**: 2mm thickness to protect from rain and water
10. **Louver panels**: 5.40cm horizontal louvers
11. **Window frame**: 7.80cm wooden frame holding triple window glazing
12. **Window glazing**: 7.30cm triple glazing U-value=0.90W/m^2K



Wall U-Value=0.18W/m^2K
Window U-Value=0.90W/m^2K

Pitched Roof (PAVATEX) 1:10



1. **Coating layer**: 1.25cm of gypsum board fixed in 8cm width wooden panel, its thermal conductivity=0.25W/mK and density= 680kg/m^3

2. **Insulation gap:** 4 cm gap with wooden panel 8 cm width, the distance between each wooden panel 5.70 cm

3. **Thermal and acoustic insulation:** 18cm of PAVATEX PAVAFLEX its thermal conductivity=0.04W/mK and density=50kg/m^3

4. **Vapor barrier:** 0.10cm of PAVATEX LDB used for prevention of interstitial condensation, its thermal conductivity=0.22W/mK and density=250kg/m^3

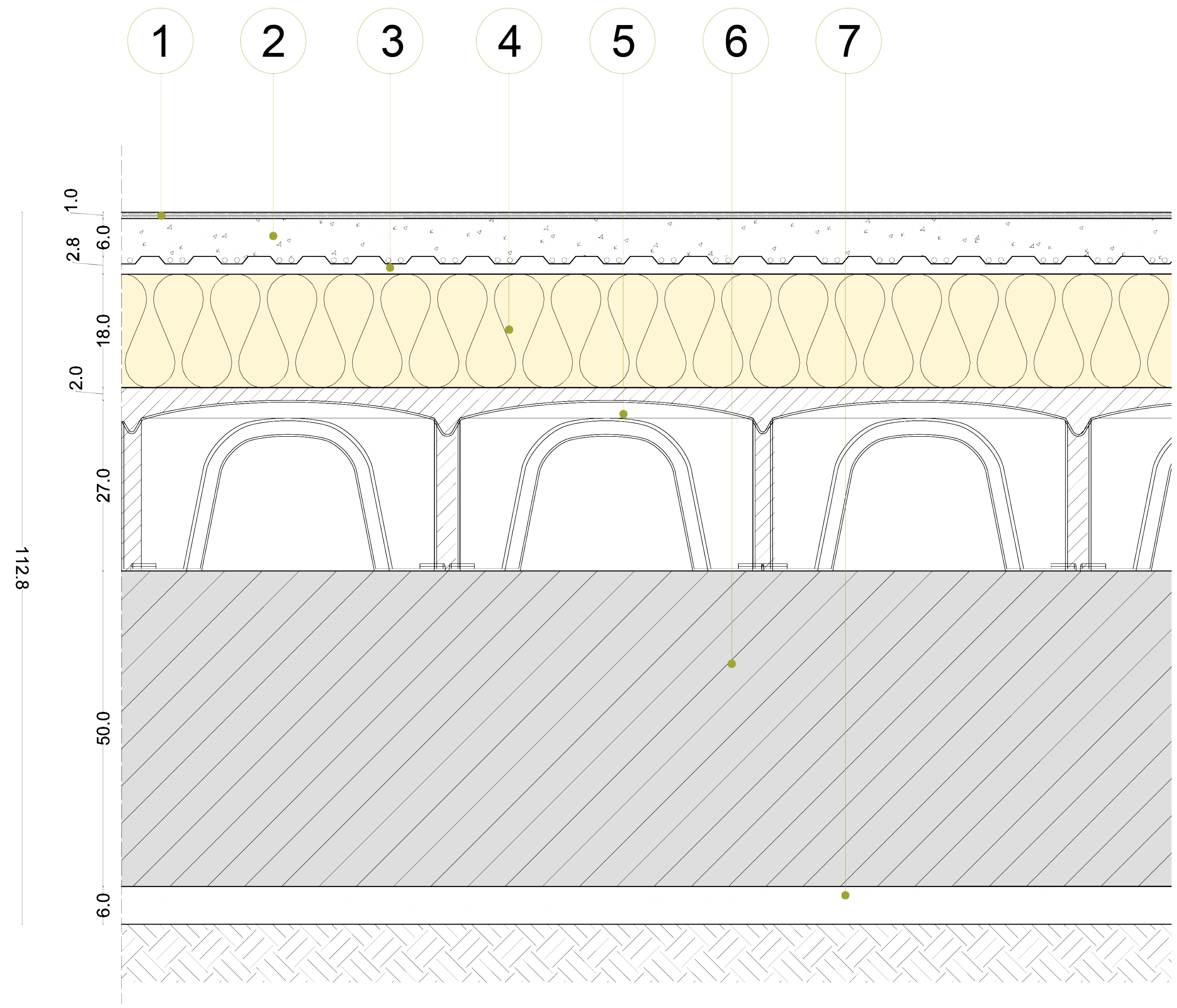
5. **Thermal insulation:** 14cm of PAVATHERM-Plus its thermal conductivity=0.045W/mK and density=190kg/m^3

6. **Insulation gap:** 4 cm with wooden panel 8 cm width, the distance between each wooden panel 5.70 cm

7. **External covering**: Existing wooden rafters

U-Value=0.14W/m^{2}K

Floor Heating 1:10



1. **Flooring layer**: 1.00cm of natural wooden floor its thermal conductivity=0.18W/mK and density= 96kg/m^3

2. **Screed layer:** 6.00cm of cement screed for external coating, its thermal conductivity=1.40W/mK and density= 2000kg/m^3

3. **Rigid panels:** 2.80cm height shaped for heating pipes and covered with cement screed

4. **Thermal insulation:** 16cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m^3

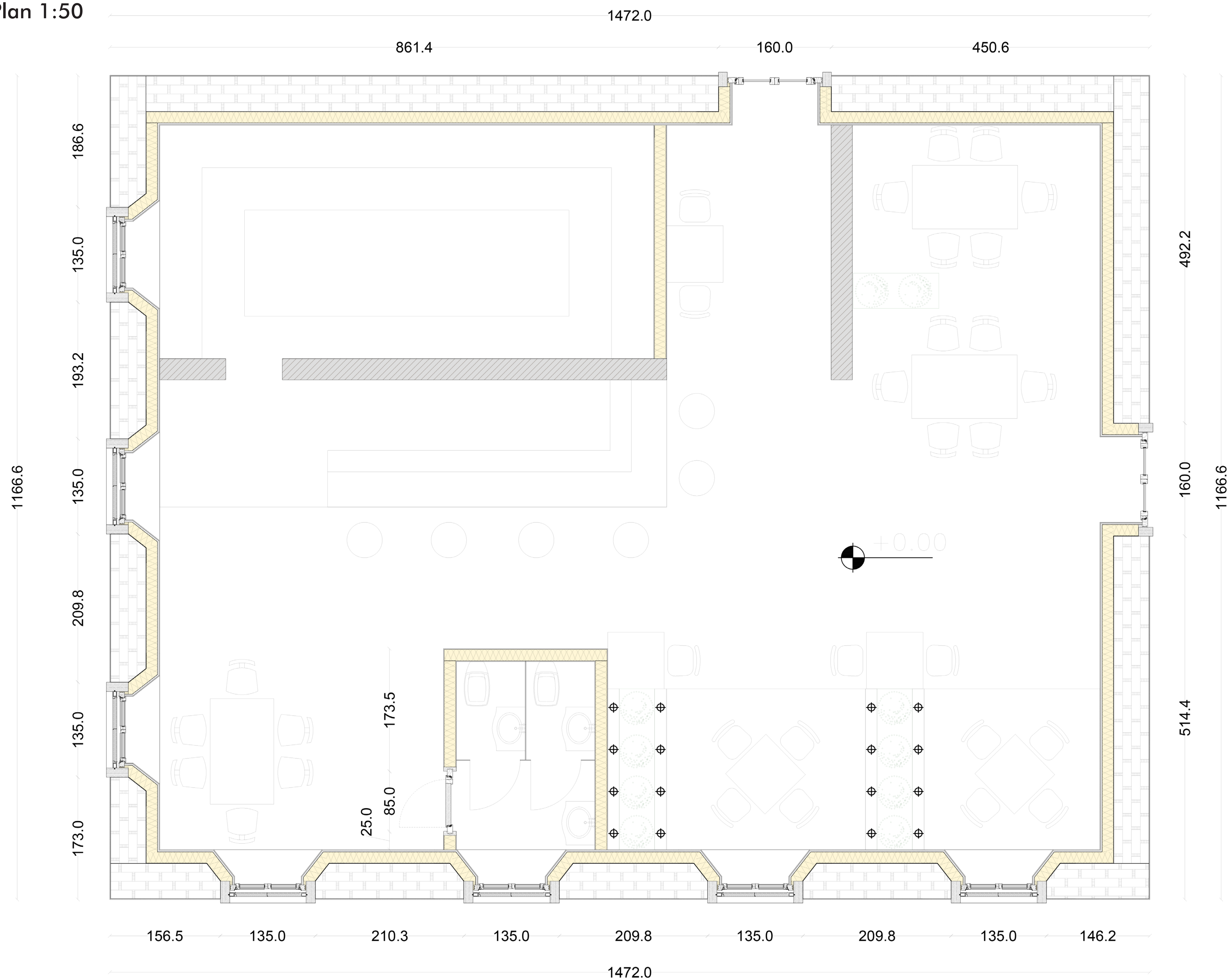
5. **Ventilation layer:** 27cm height for ventilation against humidity and pollution from the soil in the ground floor

6. **Existing ground layer:** 50cm reinforcement concrete for the existing building its thermal conductivity=2.30W/mK and density=2300kg/m^3

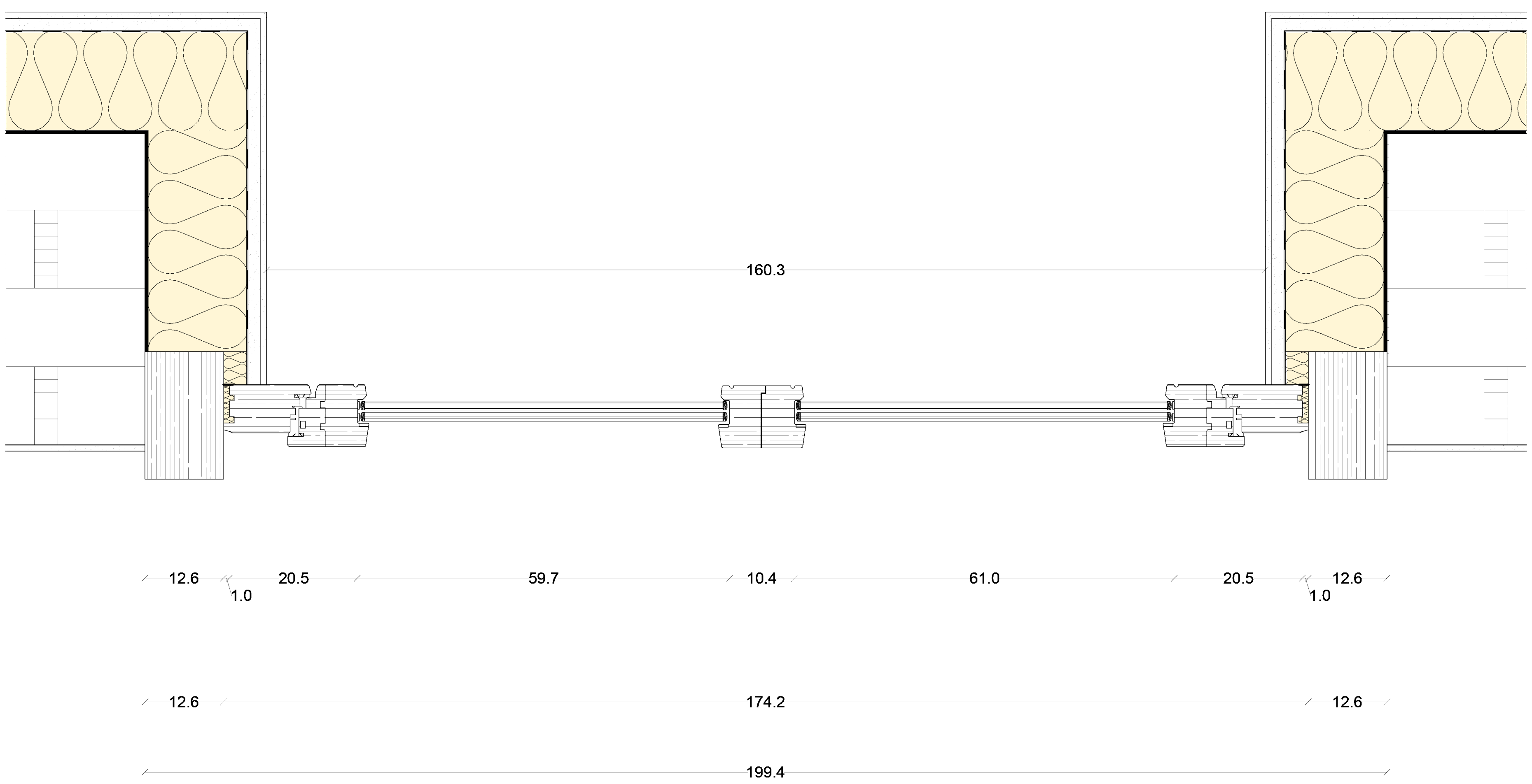
7. **Base sand**: 6.00cm of dry sand its thermal conductivity=0.70W/mK and density=1500kg/m^3

U-Value=0.16W/m^{2}K

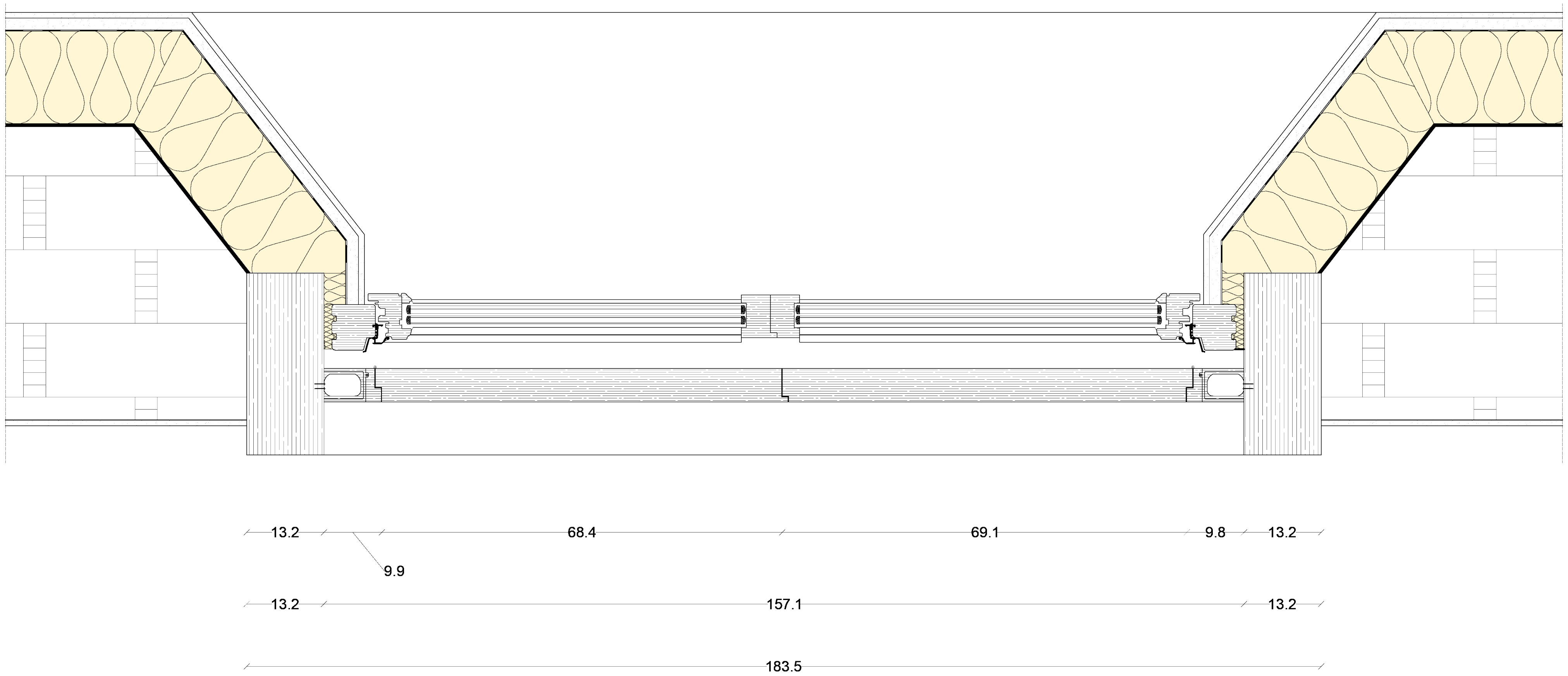
Restaurant Plan 1:50



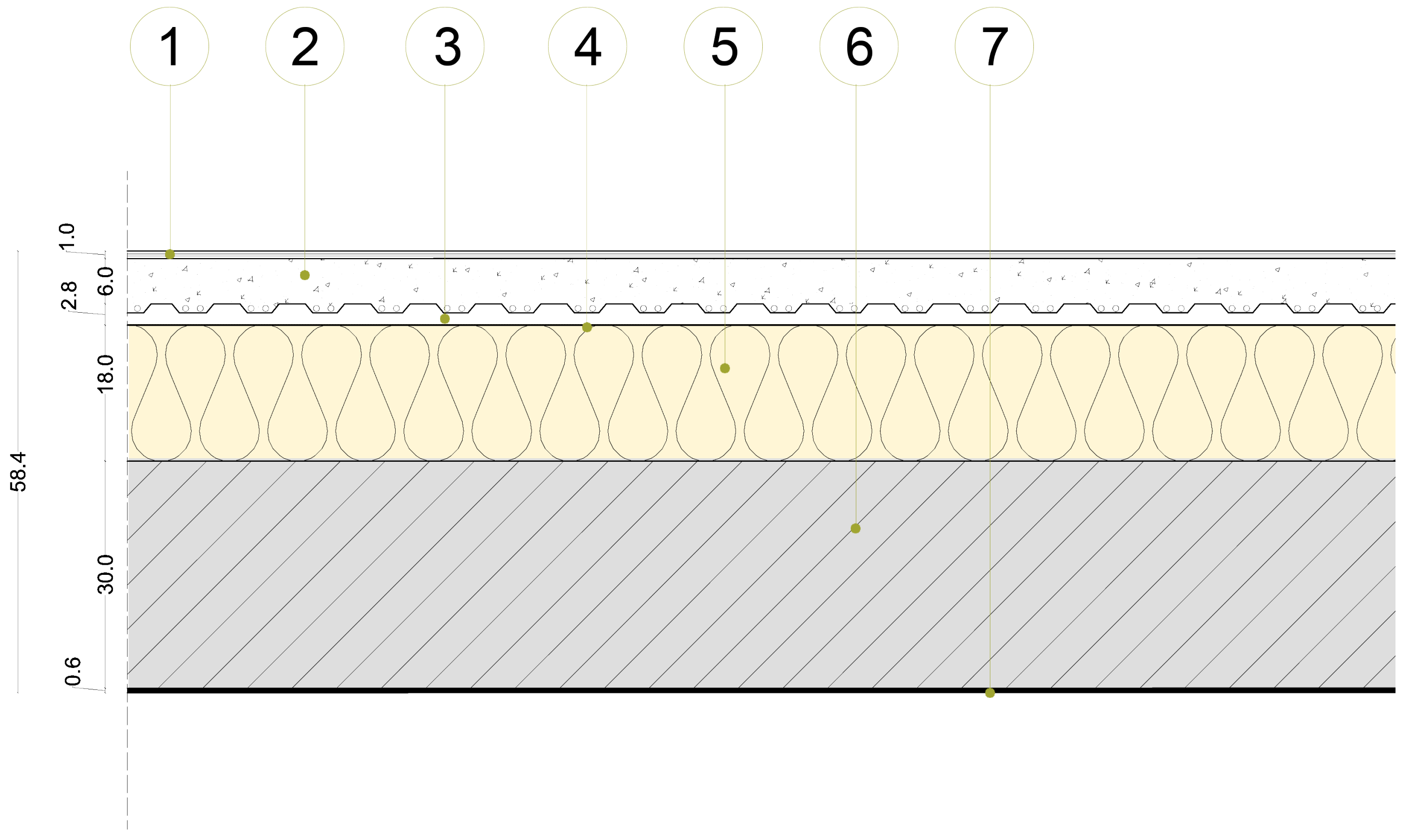
Door Connection Plan 1:20



Window Connection Plan 1:20



Floor Heating 1:10

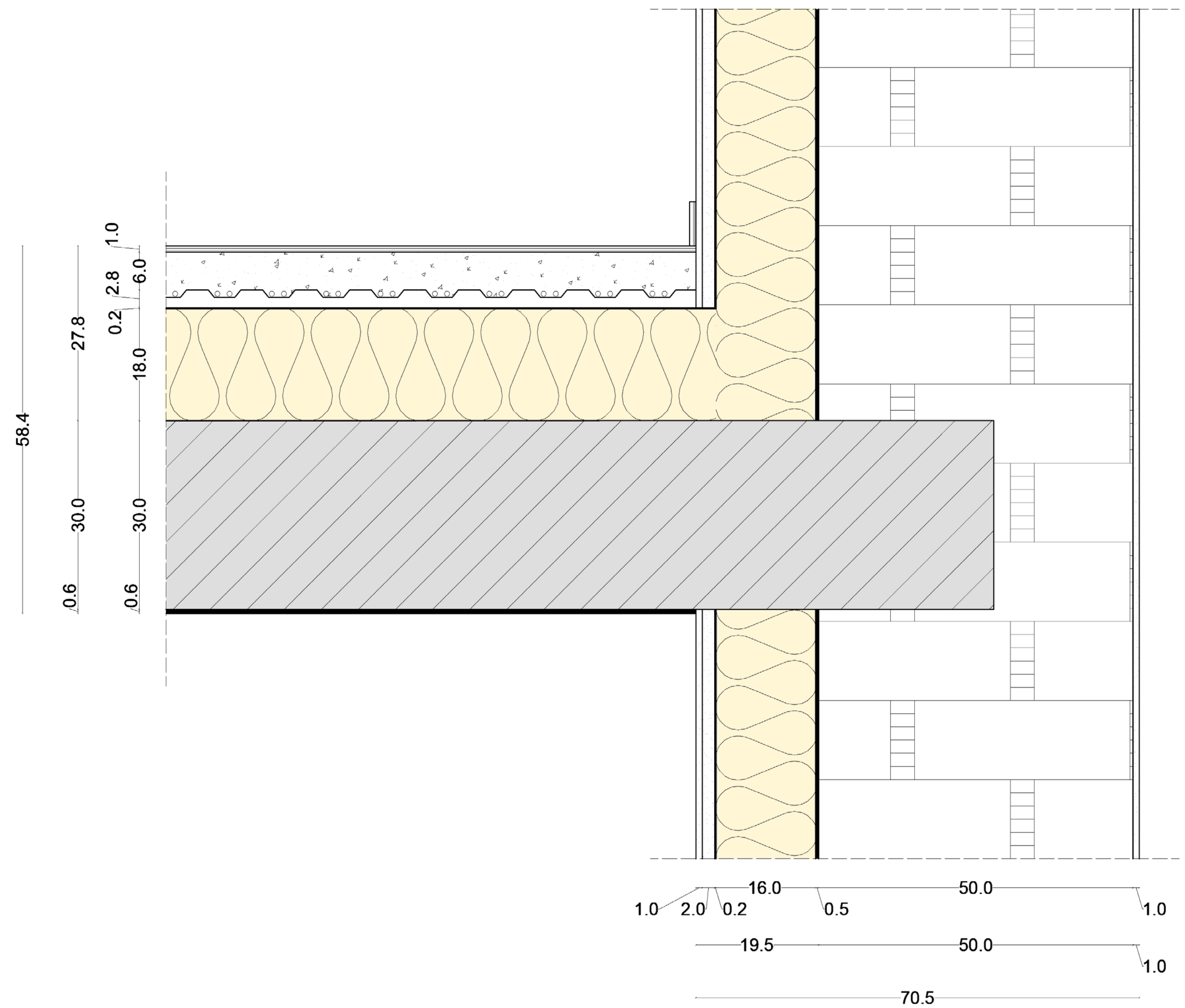


Floor heating

1. **Flooring layer**: 1.00cm of natural wooden floor its thermal conductivity=0.18W/mK and density= 96kg/m^3
2. **Screed layer:** 6.00cm of cement screed for external coating, its thermal conductivity=1.40W/mK and density= 2000kg/m^3
3. **Rigid panels:** 2.80cm height shaped for heating pipes and covered with cement screed
4. **Vapor barrier:** 0.10cm of PAVATEX LDB used for prevention of interstitial condensation, its thermal conductivity=0.22W/mK and density=250kg/m^3
5. **Thermal and acoustic insulation:** 16cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m^3
6. **Existing ground layer:** 30cm reinforcement concrete for the existing building its thermal conductivity=2.30W/mK and density=2300kg/m^3
7. **Sound absorbing plaster**: 0.60cm of StoSilent Compact plaster sound-absorbing systems covered on smooth existing reinforcement concrete layer

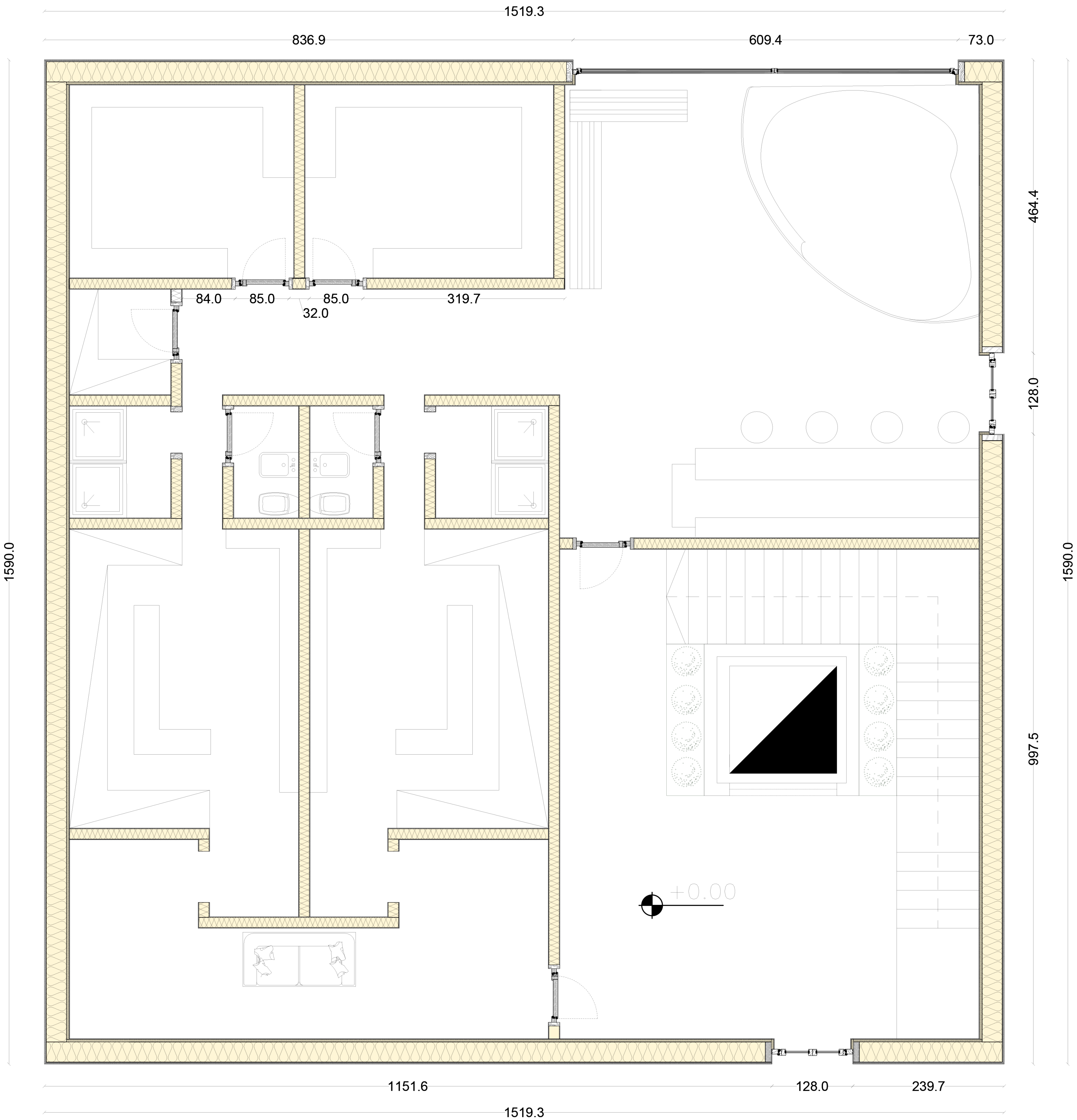
U-Value=0.16W/m^{2}K

Floor and Wall Connection 1:10



4.3.2 New Building

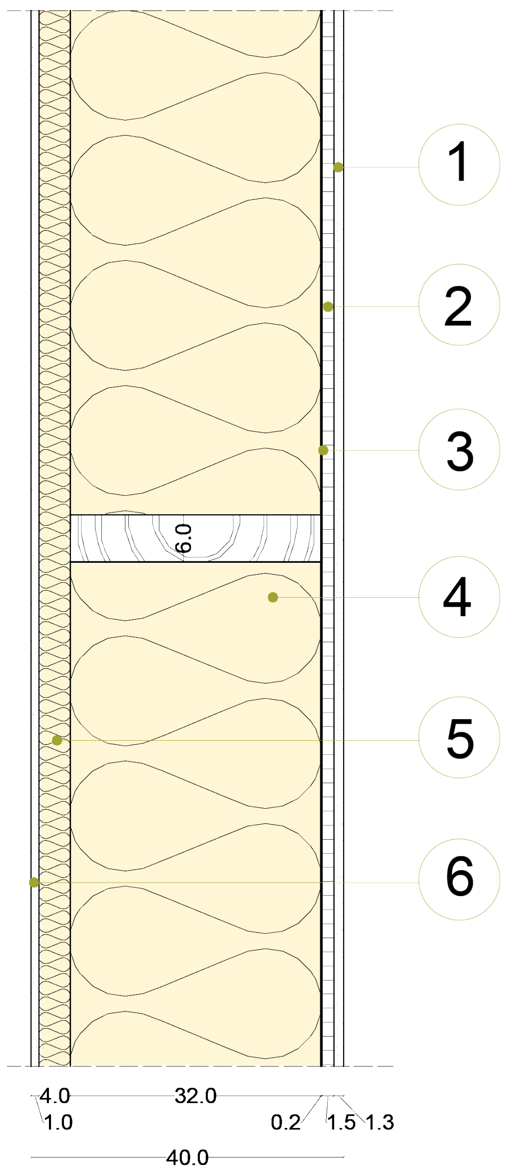
Spa Plan 1:75



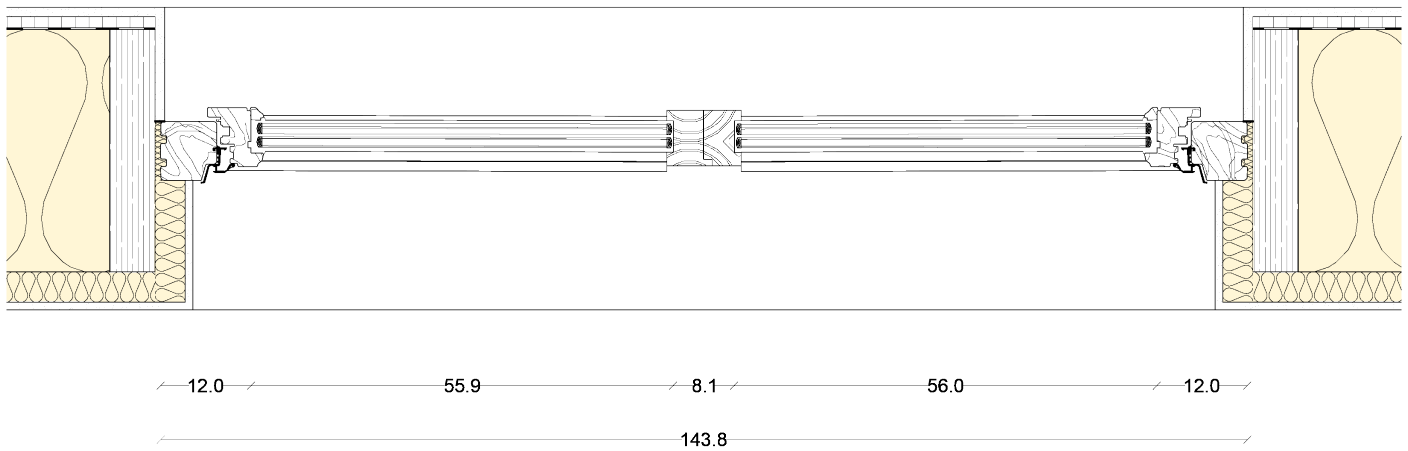
Wooden Wall with insulation 1:10

1. **Coating layer**: 1.25cm of gypsum board fixed in 8cm width wooden panel, its thermal conductivity=0.25W/mK and density= 680kg/m^3
2. **Installation board:** 1.50cm of OSB/3 for load-bearing applications in construction, its thermal conductivity=0.13W/mK and density= 620kg/m^3
3. **Vapor barrier:** 0.20cm of aluminium foil (uncoated) used for prevention of interstitial condensation, its thermal conductivity=160W/mK and density=2700kg/m^3
4. **Thermal insulation:** 32.00cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m^3
5. **Thermal insulation:** 4.00cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m^3
6. **Coating layer:** 1.00cm of external plaster, its thermal conductivity=0.55W/mK and density= 1900kg/m^3

U-Value=0.10W/m^2K



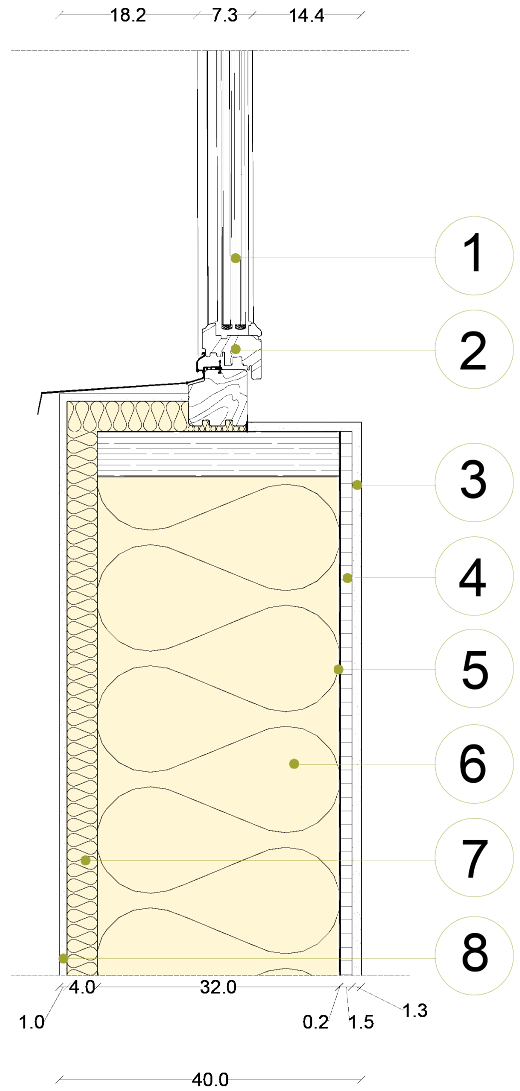
Window Connection Plan 1:20



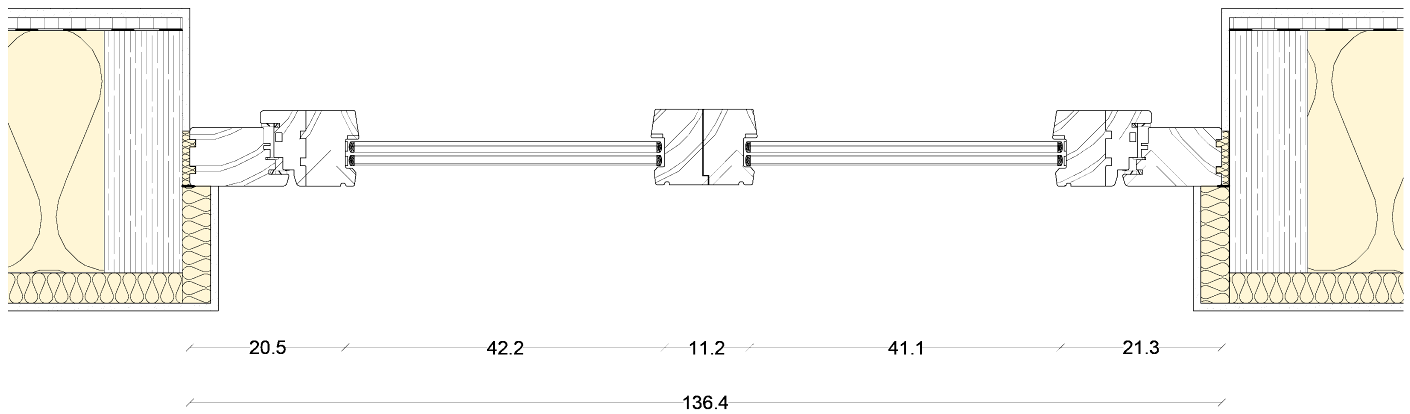
Window and Wall Connection 1:10

1. **Window frame**: 7.80cm wooden frame holding triple window glazing
2. **Window glazing**: 7.30cm triple glazing U-value=0.90W/m^2K
3. **Coating layer**: 1.25cm of gypsum board fixed in 8cm width wooden panel, its thermal conductivity=0.25W/mK and density= 680kg/m^3
4. **Installation board:** 1.50cm of OSB/3 for load-bearing applications in construction, its thermal conductivity=0.13W/mK and density= 620kg/m^3
5. **Vapor barrier:** 0.20cm of aluminium foil (uncoated) used for prevention of interstitial condensation, its thermal conductivity=160W/mK and density=2700kg/m^3
6. **Thermal insulation:** 32.00cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m^3
7. **Thermal insulation:** 4.00cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m^3
8. **Coating layer**: 1.00cm of external plaster, its thermal conductivity=0.55W/mK and density= 1900kg/m^3

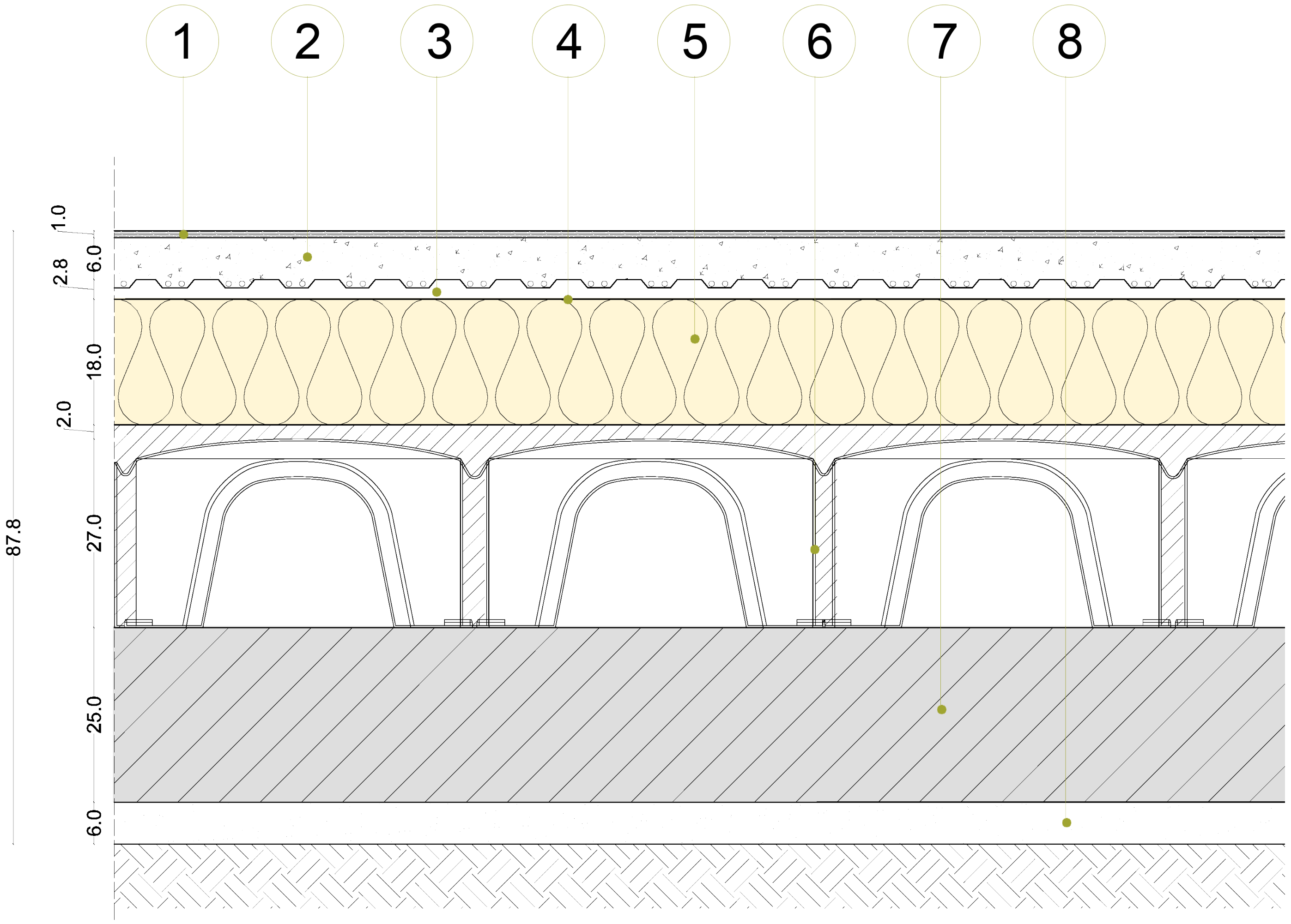
Wall U-Value=0.10W/m^2K
Window U-Value=0.90W/m^2K



Door Connection Plan 1:20



Ground Floor Heating 1:10

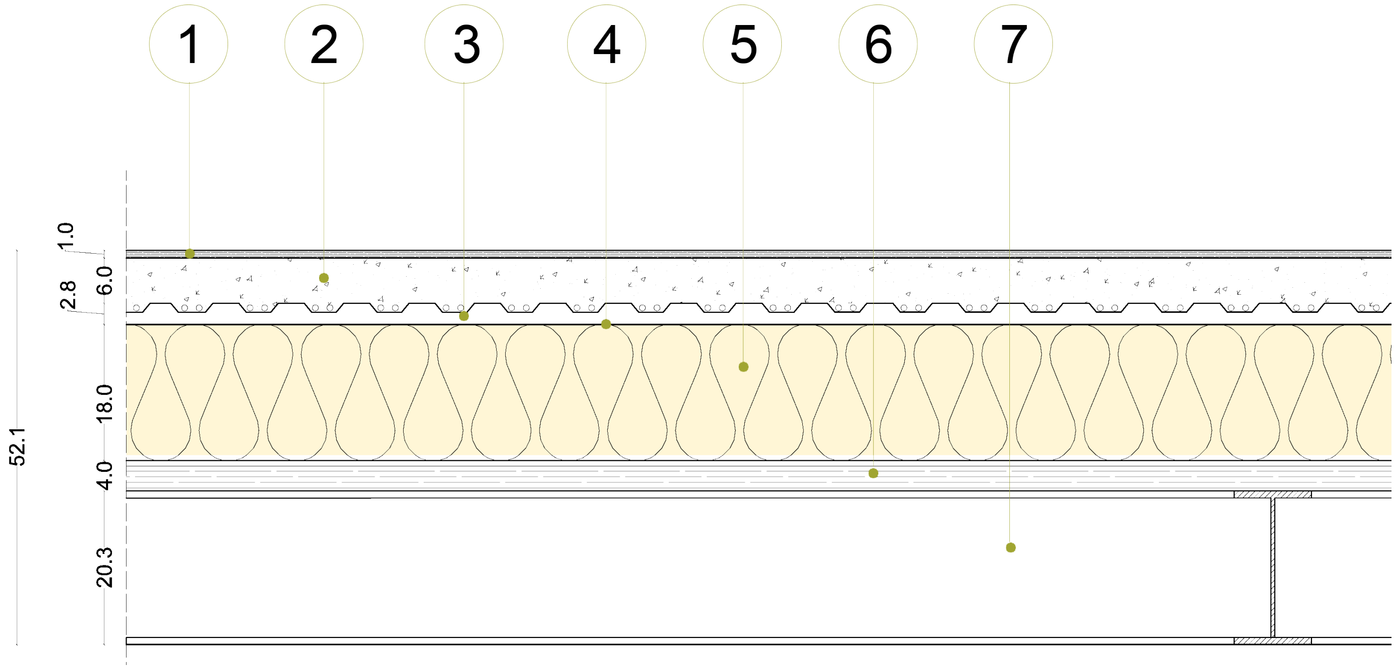


1. **Flooring layer**: 1.00cm of natural wooden floor its thermal conductivity=0.18W/mK and density= 96kg/m³
2. **Screed layer:** 6.00cm of cement screed for external coating, its thermal conductivity=1.40W/mK and density= 2000kg/m³
3. **Rigid panels:** 2.80cm height shaped for heating pipes and covered with cement screed
4. **Vapor barrier:** 0.20cm of aluminum foil (uncoated) used for prevention of interstitial condensation, its thermal conductivity=160W/mK and density=2700kg/m³
5. **Thermal insulation:** 16cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m³
6. **Ventilation layer:** 27cm height for ventilation against humidity and pollution from the soil in the ground floor
7. **Reinforcement concrete:** 25 cm reinforcement concrete for the existing building its thermal conductivity=2.30W/mK and density=2300kg/m³
8. **Base sand**: 6.00cm of dry sand its thermal conductivity=0.70W/mK and density=1500kg/m³

U-Value=0.16W/m²K

BIBLIOGRAPHY

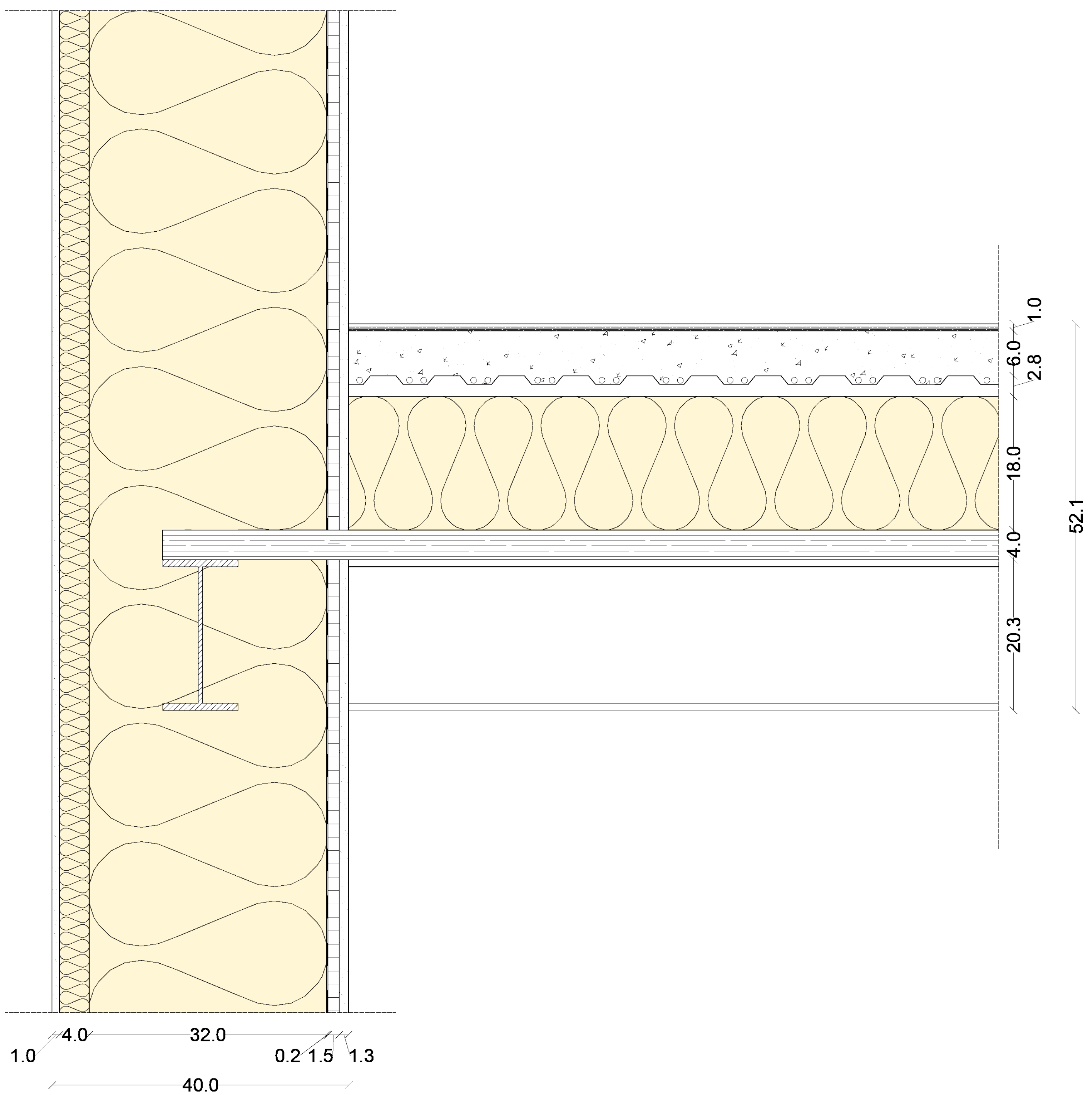
Typical Floor Heating 1:10



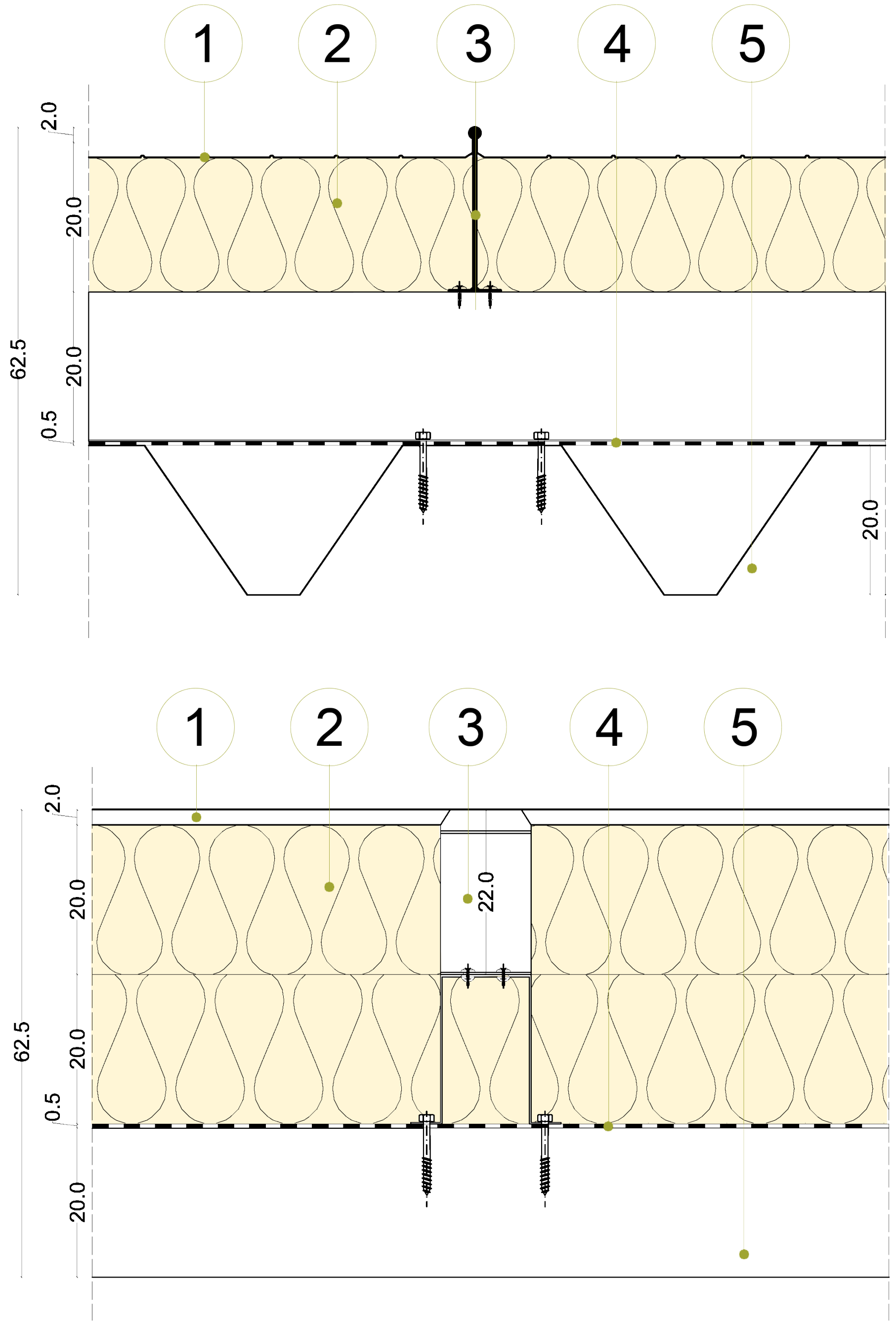
1. **Flooring layer**: 1.00cm of natural wooden floor its thermal conductivity=0.18W/mK and density= 96kg/m³
2. **Screed layer:** 6.00cm of cement screed for external coating, its thermal conductivity=1.40W/mK and density= 2000kg/m³
3. **Rigid panels:** 2.80cm height shaped for heating pipes and covered with cement screed
4. **Vapor barrier:** 0.20cm of aluminum foil (uncoated) used for prevention of interstitial condensation, its thermal conductivity=160W/mK and density=2700kg/m³
5. **Thermal insulation:** 18cm of Glasswool032 insulation layer its thermal conductivity=0.032W/mK and density=30kg/m³
6. **Wood panel:** 4.00cm thickness wood panel
7. **Structural beam**: I beam dimensions; height=20.3cm, width=102cm, dimensions between each beam=400cm

U-Value=0.16W/m²K

Wall and Floor Connection 1:10



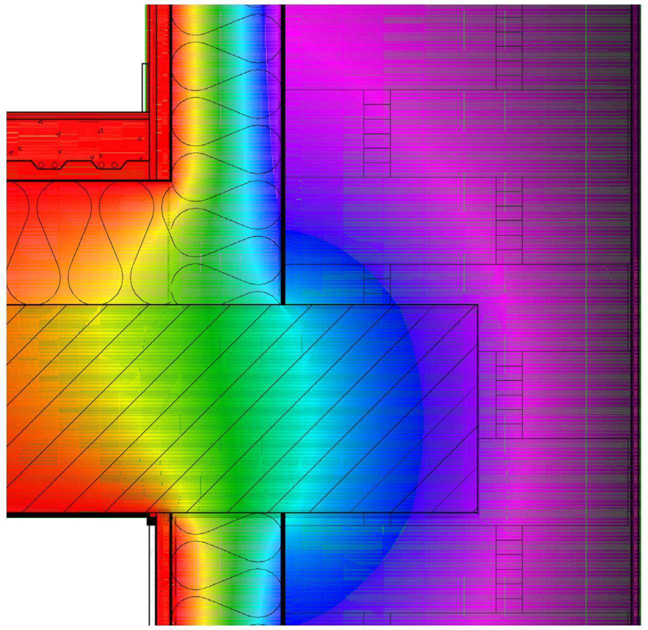
Aluminum Roof Connection 1:10



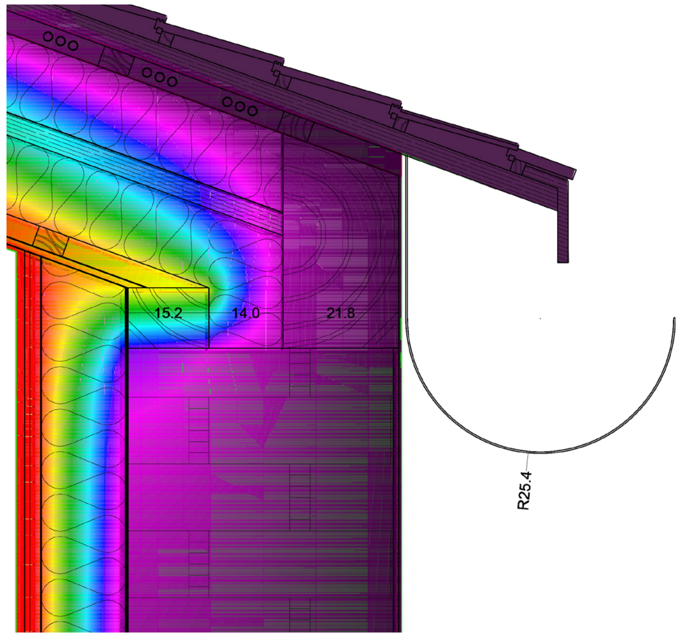
1. **Roofing layer**: 1BEMO standing seam profile 65-400, 0.1cm aluminum
2. **Thermal insulation:** 40cm mineral wool insulation 032, 20 kg/m^3
3. **Halter:** Aluminum halter incl. 0.5cm thermal spacer GFK Halter 1.5 pcs/m^2
4. **Vapor barrier:** 0.50cm of aluminum foil (uncoated) used for prevention of interstitial condensation, its thermal conductivity=160W/mK and density=2700kg/m^3
5. **Corrugated Sheet**

U-Value=0.12W/m^{2}K

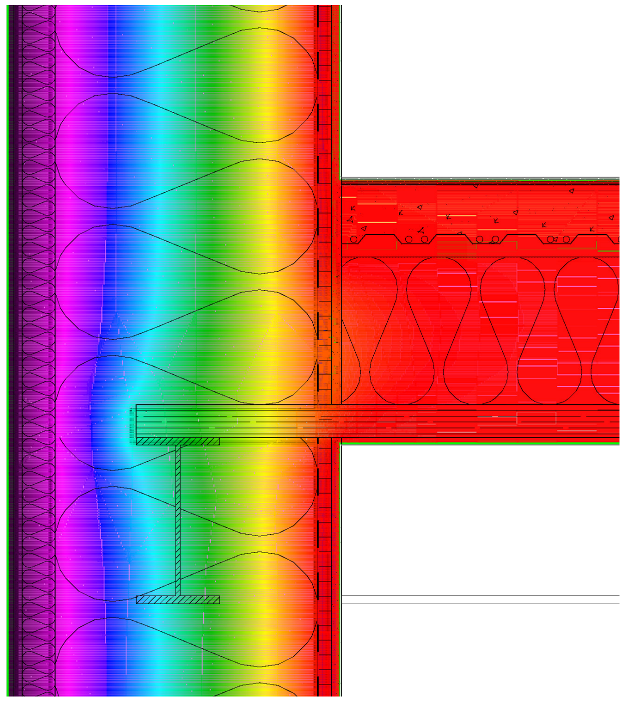
4.4 Thermal Bridge Analysis



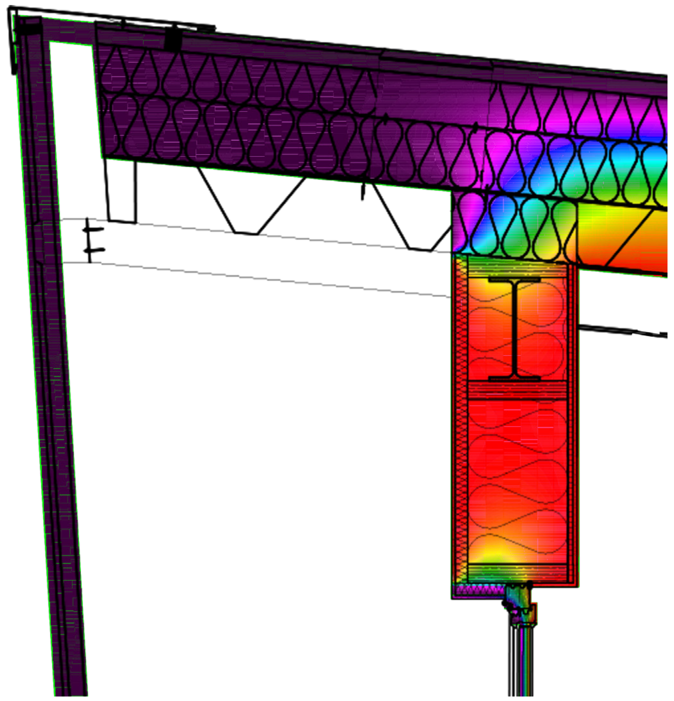
The connection between slab and the wall in the old building.



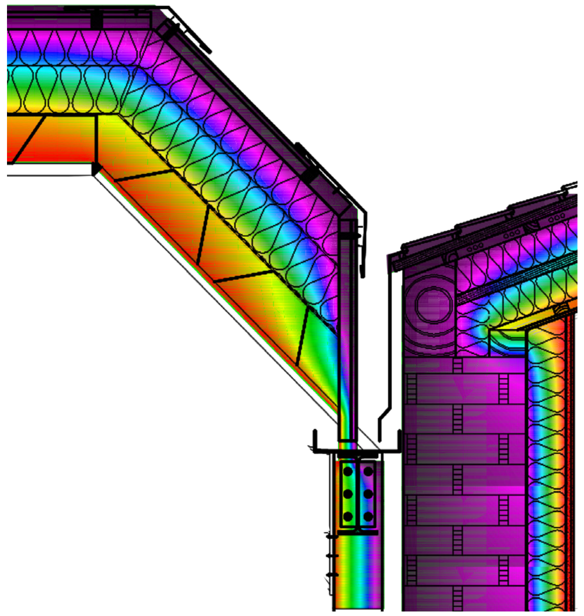
The connection between the roof and the wall in the old building.



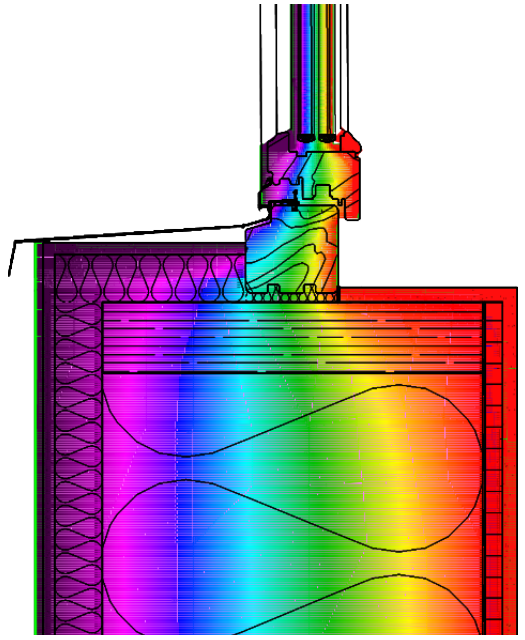
The connection between slab and the wall in the new building.



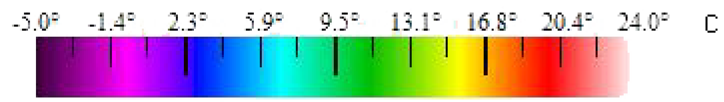
The connection between the roof and the wall in the new building.



The connection between the old and the new building.



The connection between the window and the wall in the new building.



5.

COMFORT STUDIES

5.1.1 Investigated Parameters

Daylight Factor (DF)% — Amount of illumination available indoor in relative to the illumination present outdoor at the same time under overcast sky.

DF% ≥ 2.5%

Spatial Daylight Autonomy (sDA)% — Whether the space receives enough daylight (300lux for at least half of the hours) during standard operation hours (8am - 6pm).

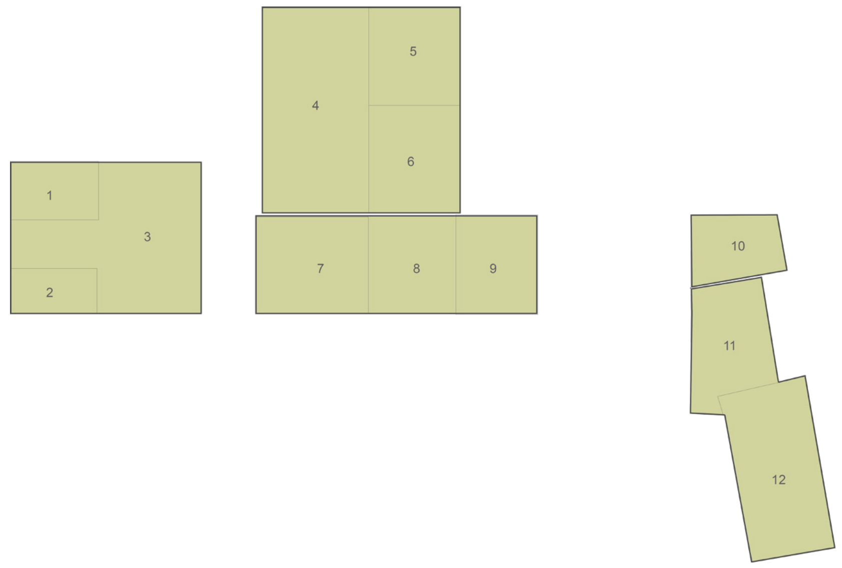
sDA% > 55% Acceptable
sDA% > 75% Preferable

Annual Solar Exposure (ASE)% — It measures the glare phenomena, if the amount of the light exceeds the threshold value of 1000lux for at least 250hr/year.

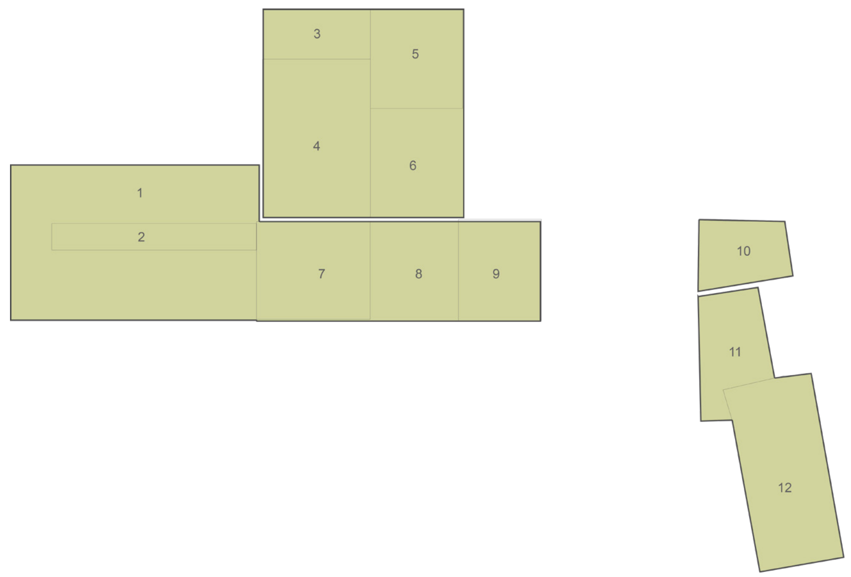
ASE% < 10%

DAYLIGHT ANALYSIS

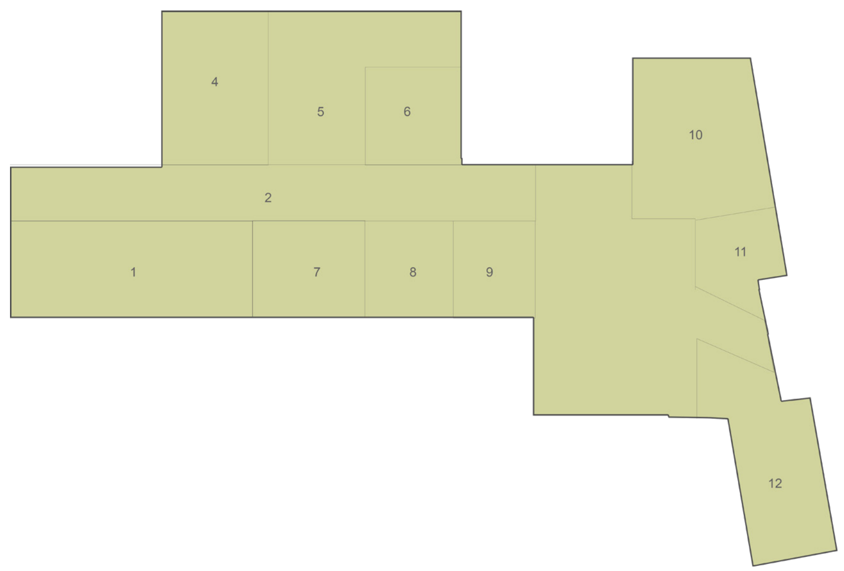
1. Kitchen (restaurant)
2. Toilet (restaurant)
3. Restaurant
4. Changing room (spa)
5. Spa
6. Staircase
7. Reception
8. Staircase
9. Reception
10. Staircase
11. Reception
12. Kindergarten



1. Hotel rooms
2. Corridor
3. Training classes
4. Changing room (classes)
5. Training classes
6. Staircase
7. Reception
8. Staircase
9. Reception
10. Staircase
11. Reception
12. Conference room

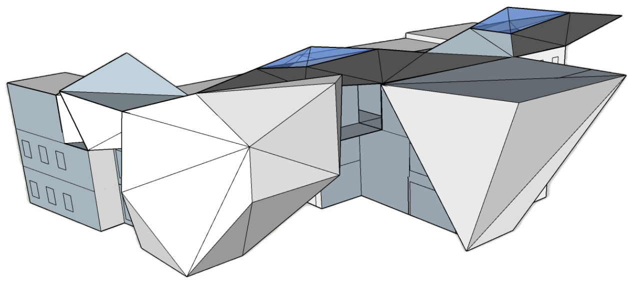


1. Therapy rooms
2. Corridor
3. -
4. Changing room (gym)
5. Gym
6. Staircase
7. Reception
8. Staircase
9. Cafe
10. Training classroom
11. Staircase
12. Climbing equipment store

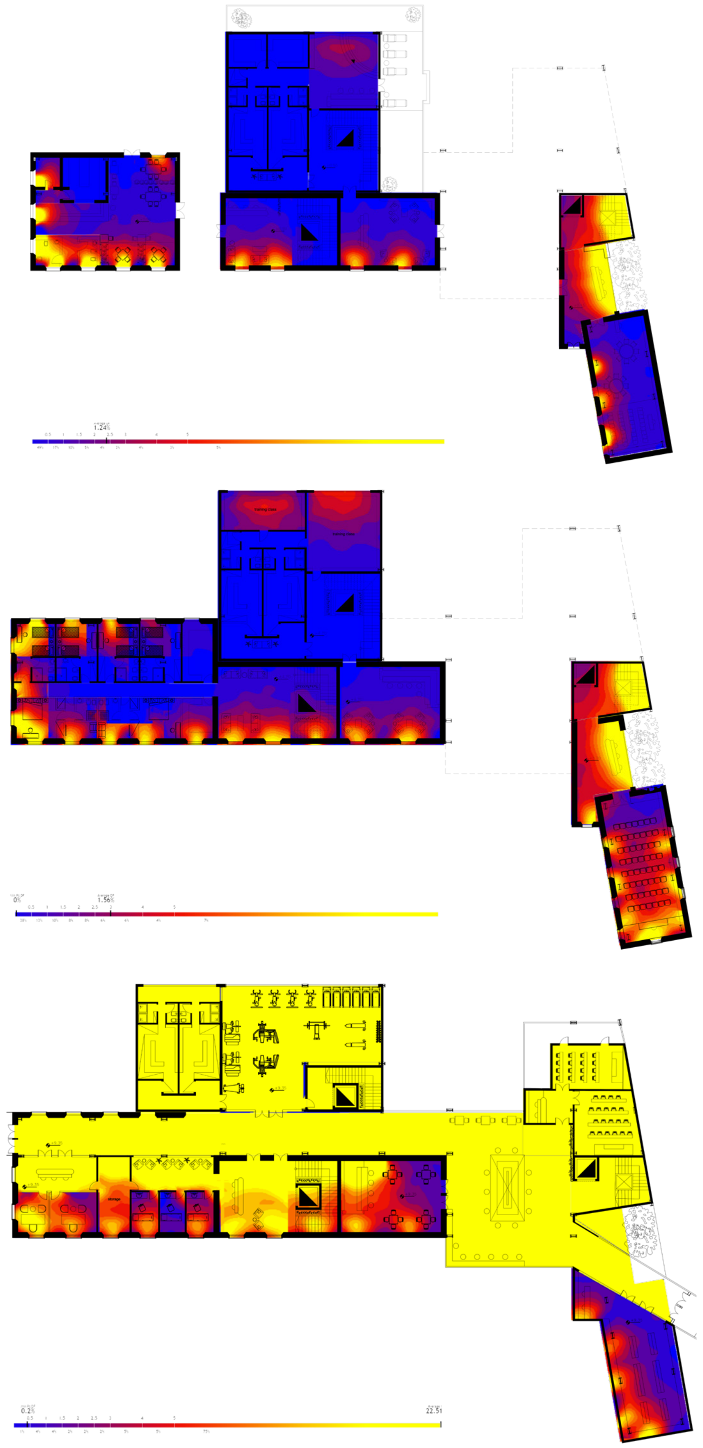


5.1.2 Optioneering

Baseline

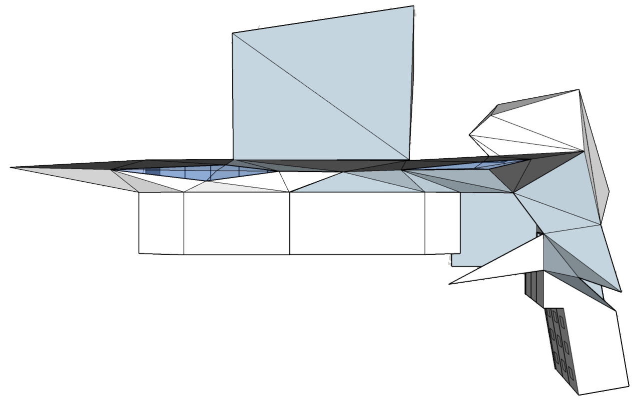


The roof and the screen are opaque with a sky-light.



Baseline DF %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	0.84	4.74	1.46	0.01	0.79	0.02	1.03	0.16	0.83	5.22	3.92	1.16	1.24
first	1.75	0.96	2	0	1.17	0.03	0.96	1.13	1.05	4.91	3.78	2.74	1.56
second	5.51	42.45	-	16.4	26.71	18.2	7.04	6.45	3.45	37.81	26.62	1.7	22.51

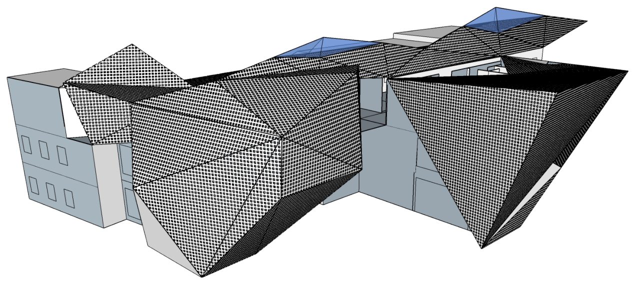
Table 12 daylight analysis

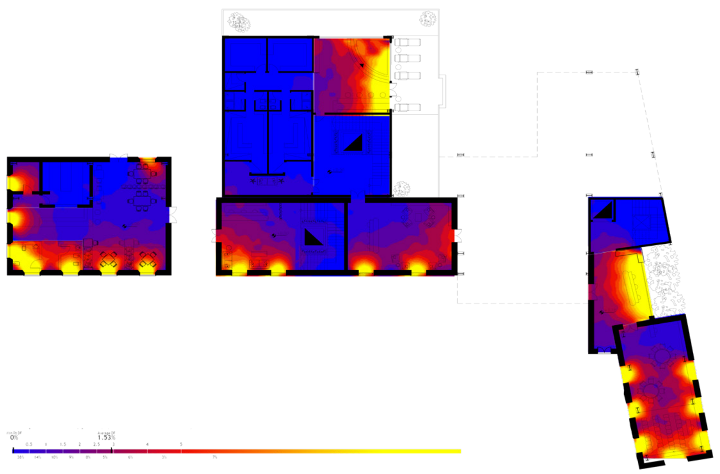


Baseline sDA/ ASE %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	26/1	96/36	33/5	0/0	36526	0/0	33/6	0/0	21/3	100/6	84/0	20/1	26/3
first	42/2	33/2	36/0	0/0	24/0	0/0	33/2	40/1	25/1	100/6	99/0	81/5	39/2
second	89/4	100/24	-	100/11	100/67	100/7	100/3	99/1	74/1	100/100	100/32	51/3	93/40

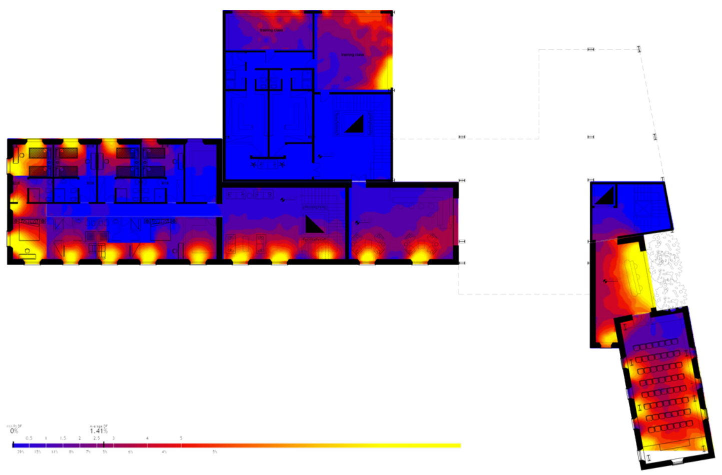
Table 13 sDA and ASE analysis

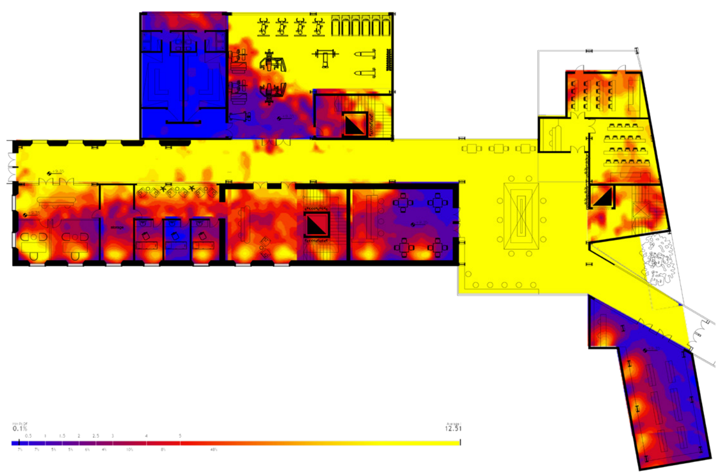
Option 1





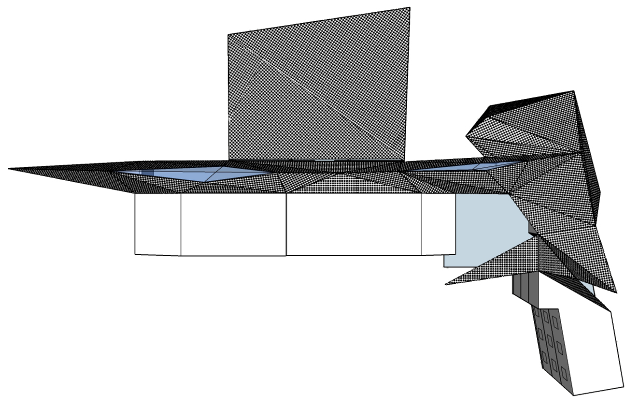
The roof and the screen are completely perforated 50% perforation with a skylight.

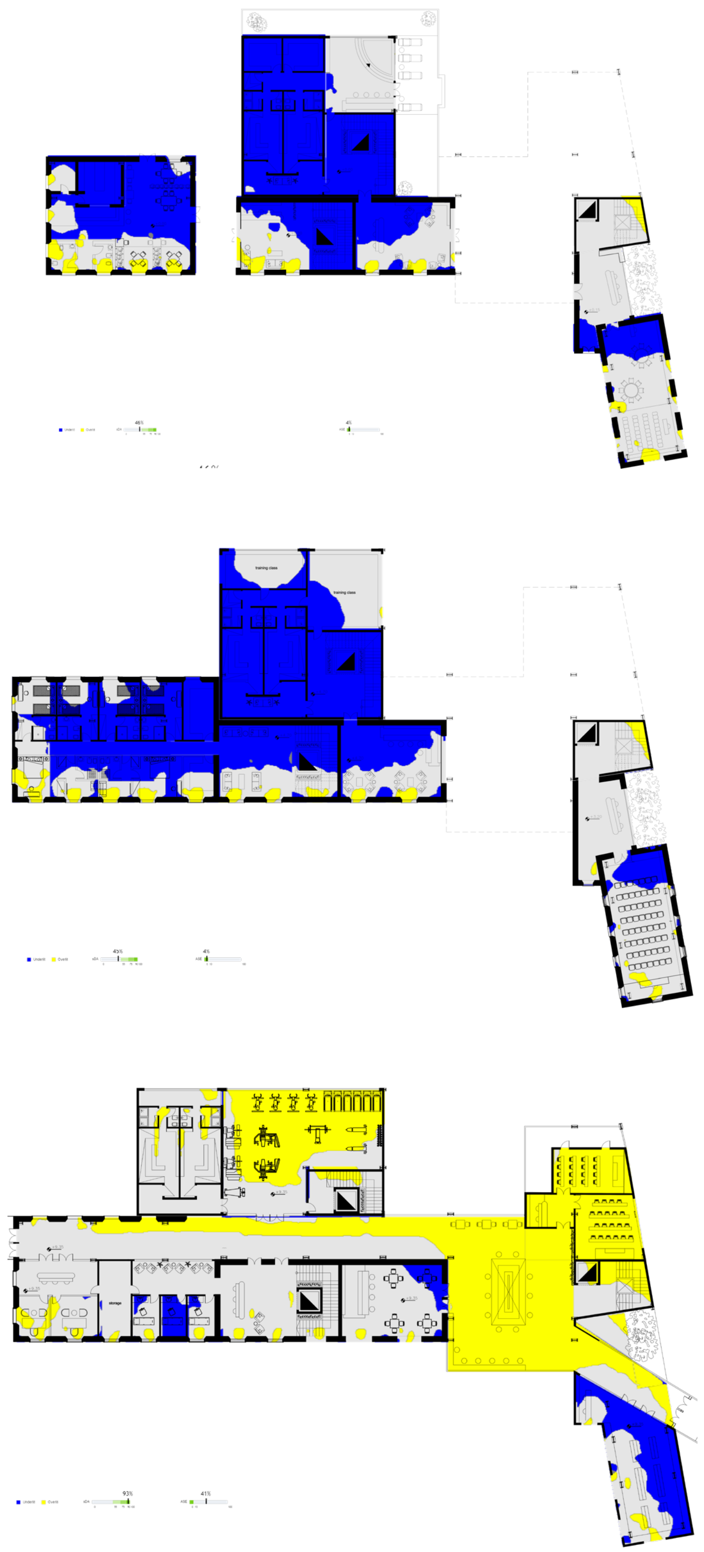




Option 1 DF %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	1	4.74	1.43	0	3.08	0.05	2	0.33	1.63	0.3	3.51	2.54	1.53
first	1.71	1.22	2	0	1.9	0.03	1.22	1.43	1.48	0.37	3.63	2.76	1.41
second	3.03	31.45	-	0.39	7.81	3.6	3.53	3.12	1.84	9.81	7.51	1.8	12.51

Table 14 daylight analysis

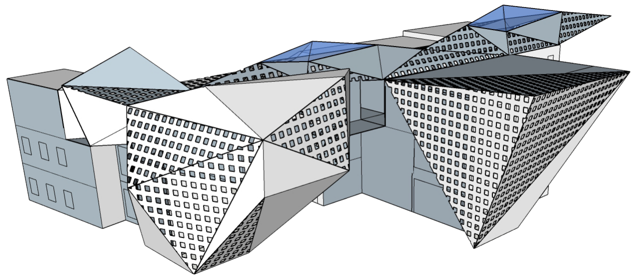




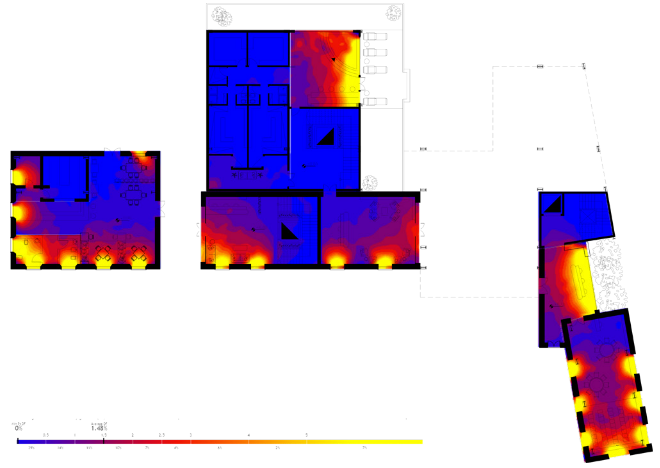
Option 1 sDA/ ASE %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	24/1	96/35	33/5	0/0	97/0	0/0	65/14	0/0	58/3	100/6	88/0	75/6	46/4
first	42/7	31/5	61/0	0/0	78/0	0/0	31/5	40/7	47/5	100/6	99/2	81/4	45/4
second	89/6	100/65	-	100/11	100/68	100/12	100/5	100/2	83/2	100/100	100/33	47/5	93/41

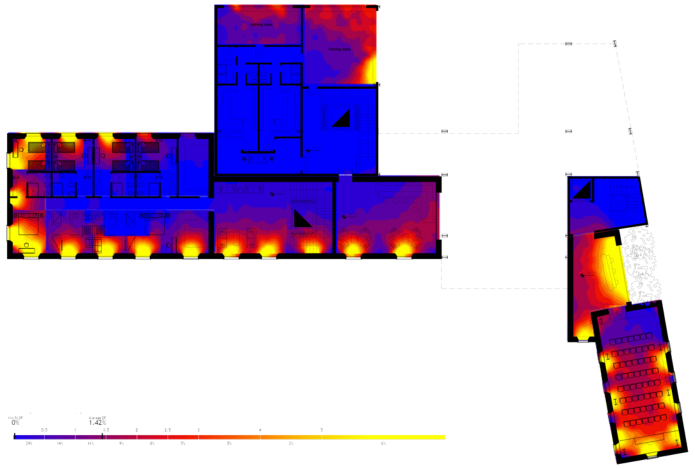
Table 15 sDA and ASE analysis

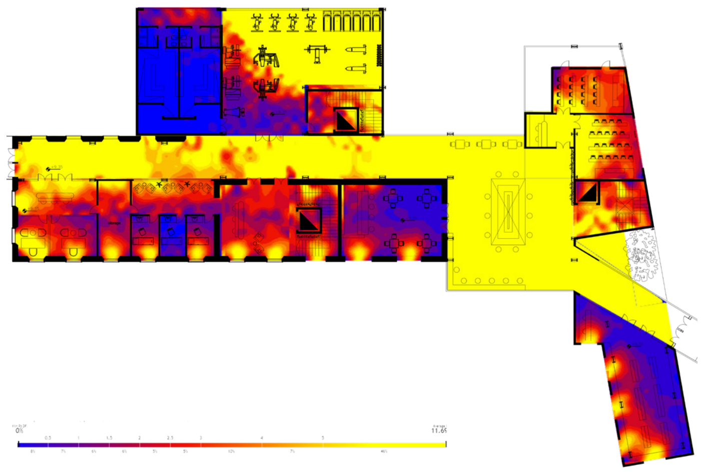
Option 2



The roof and the screen are partially perforated 50% perforation with a skylight.

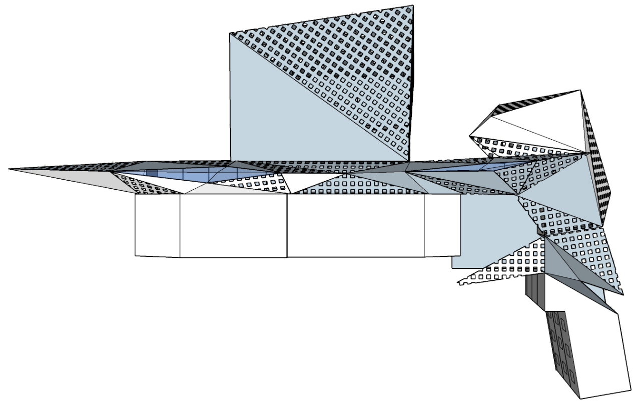


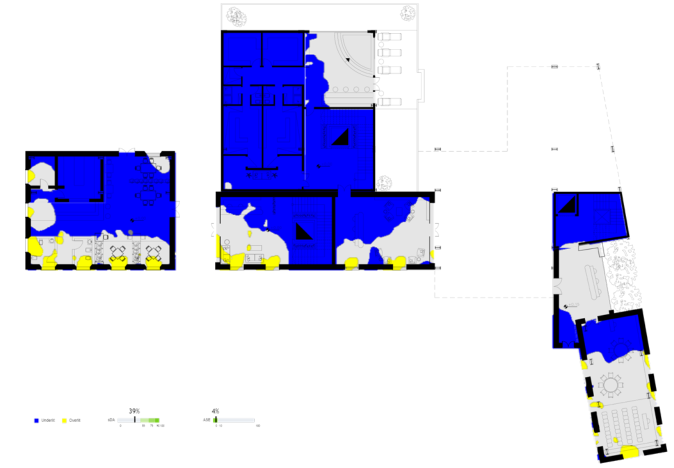


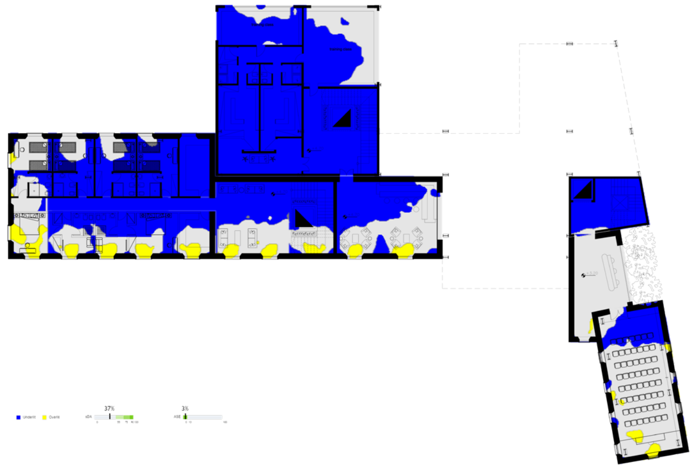


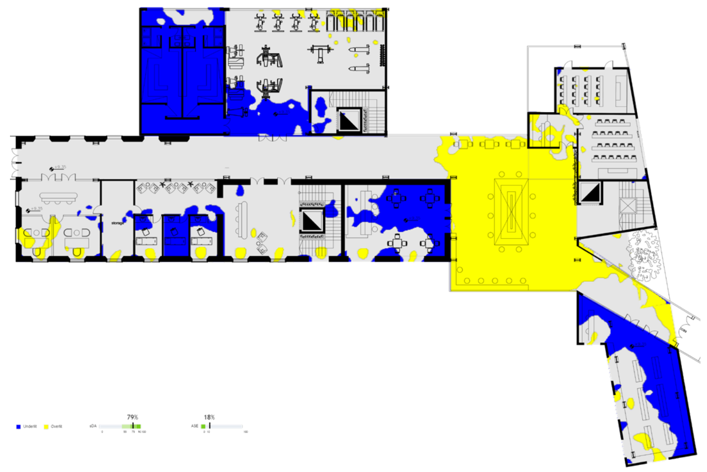
Option 2 DF %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	0.99	4.63	1.38	0.1	2.94	0.05	1.96	0.28	1.56	0.29	3.38	2.42	1.48
first	1.82	1.21	1.24	0	1.8	0.03	1.21	1.4	1.5	0.35	3.57	2.74	1.42
second	2.93	29.1	-	1/0	8.24	3.87	2.92	2.84	1.49	8.54	7.36	1.85	11.7

Table 16 daylight analysis





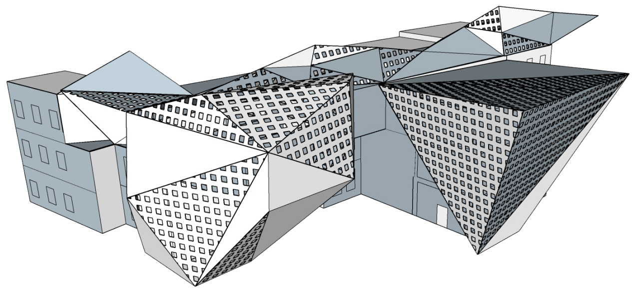


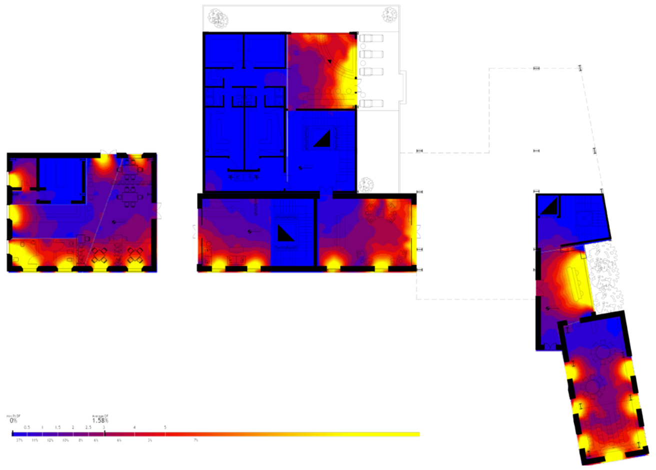


Option 2 sDA/ ASE %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	23/1	96/35	33/5	0/0	78/0	0/0	61/14	0/0	31/3	0/0	85/0	72/5	39/4
first	41/7	33/5	18/0	0/0	51/0	0/0	33/5	36/7	52/5	3/0	99/0	78/5	37/3
second	84/6	100/48	-	6/0	81/5	85/0	96/5	90/2	41/2	100/25	100/0	49/6	79/18

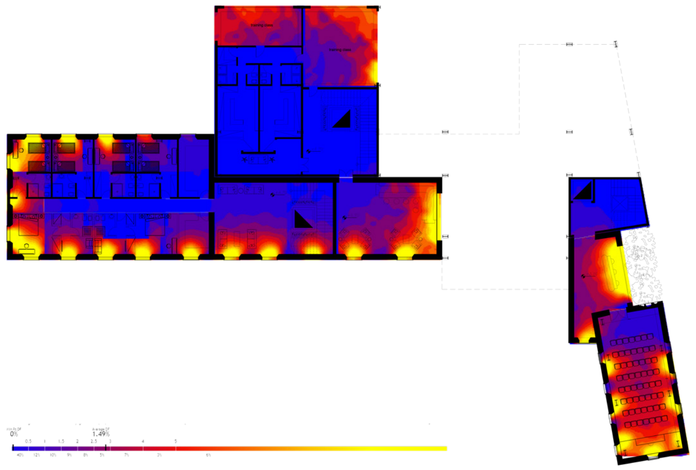
Table 17 sDA and ASE analysis

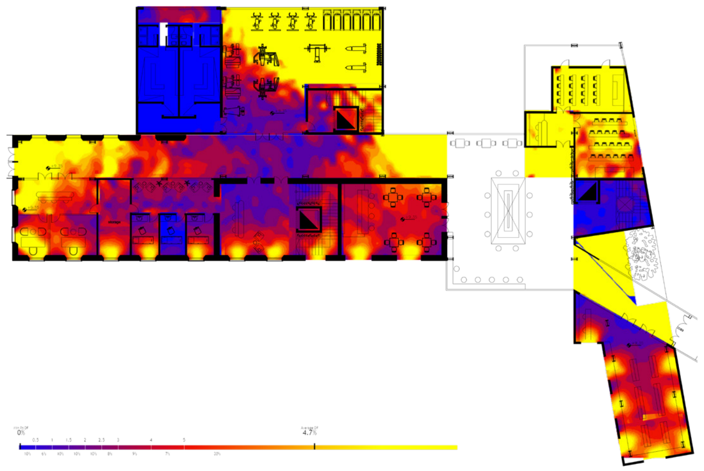
Option 3





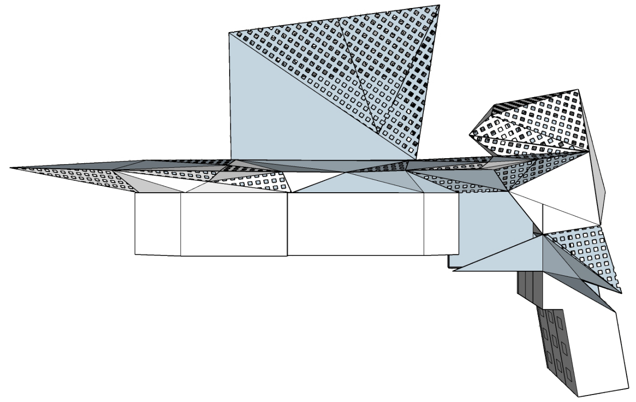
The roof and the screen are partially perforated 50% perforation without a skylight.

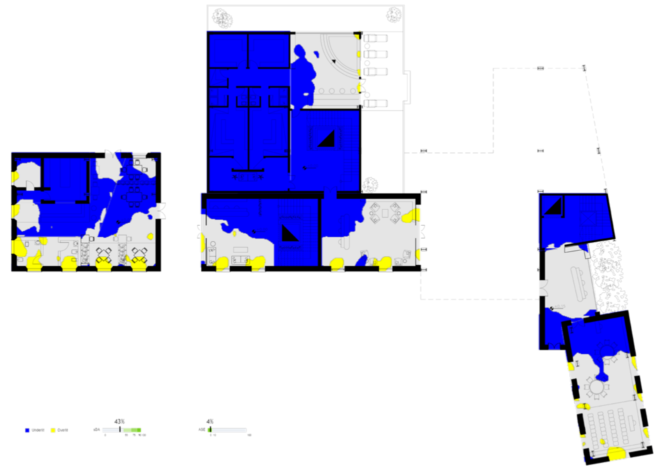


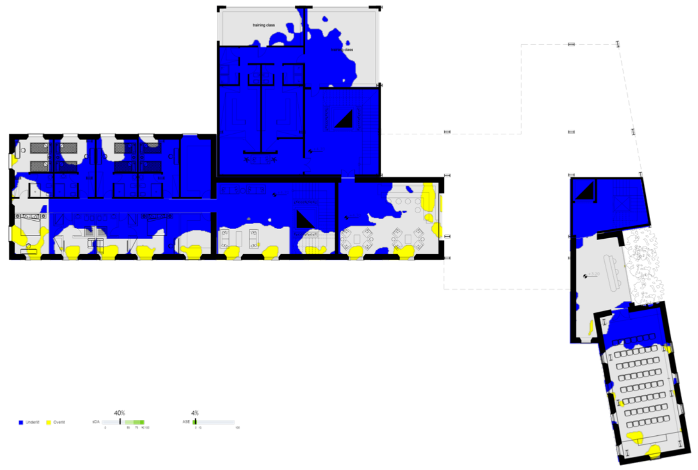


Option 3 DF %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	1.01	4.69	1.95	0	3	0	1.74	0	2.35	0.3	3.49	2.53	1.58
first	1.72	0.18	2.08	0.02	2.06	0.05	1.19	1.14	2.34	0.28	3.13	2.69	1.49
second	2.65	5.06		0.24	8.36	3.14	2.17	2.22	2.9	7.03	0.52	2.9	4.7

Table 18 daylight analysis



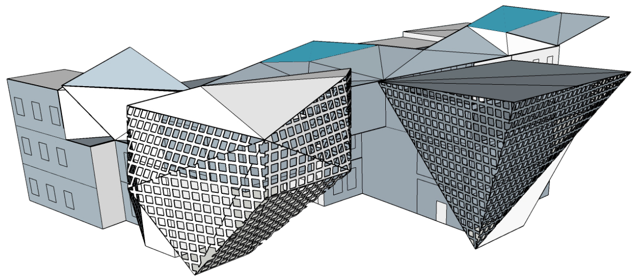


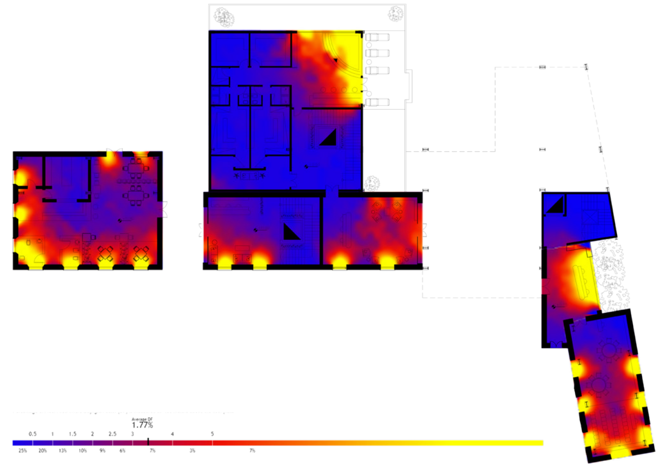


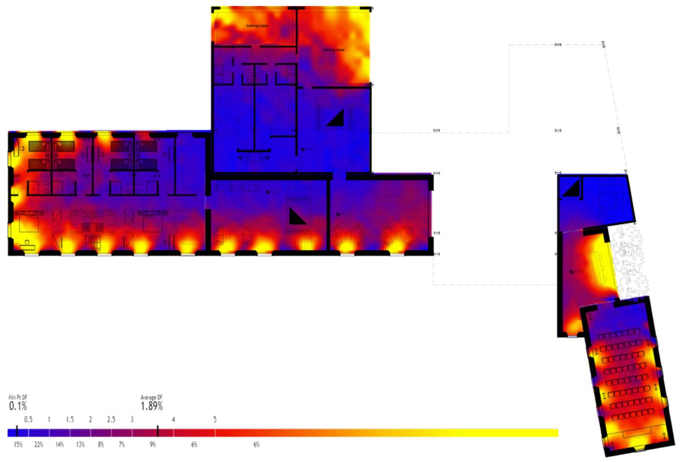
Option 3 sDA/ ASE %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	25/1	96/35	47.5/5	0/0	77/0	0/0	50/8	0/0	77/7	0/0	80/0	71/5	43/4
first	41/7	0/0	80/0	0/0	57/0	0/0	31/5	26/7	70/11	0/0	92/0	77/5	40/4
second	77/6	79/3	-	6/0	80/5	75/0	57/5	82/2	96/2	100/6	0/0	86/7	74/4

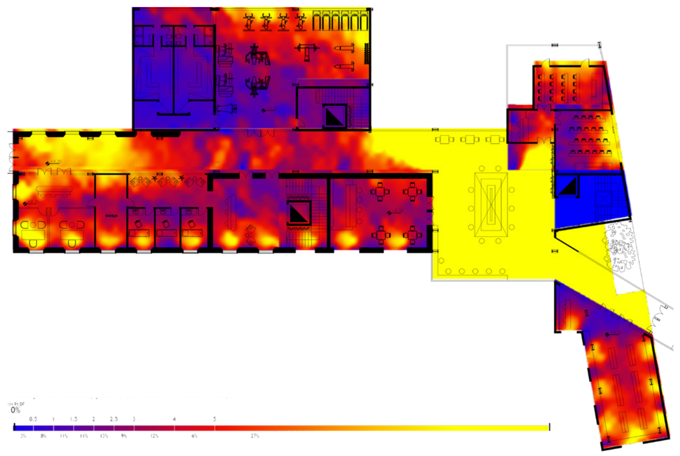
Table 19 sDA and ASE analysis

Option 4





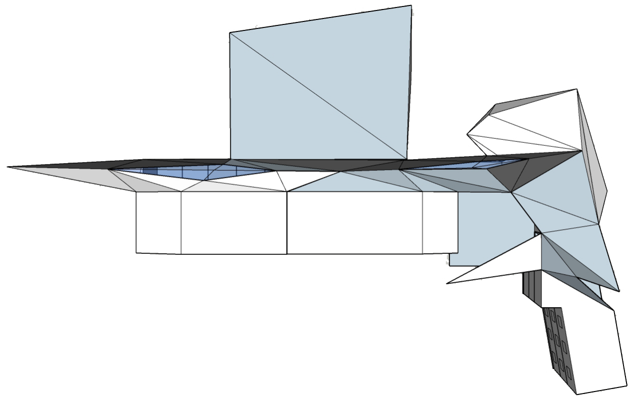


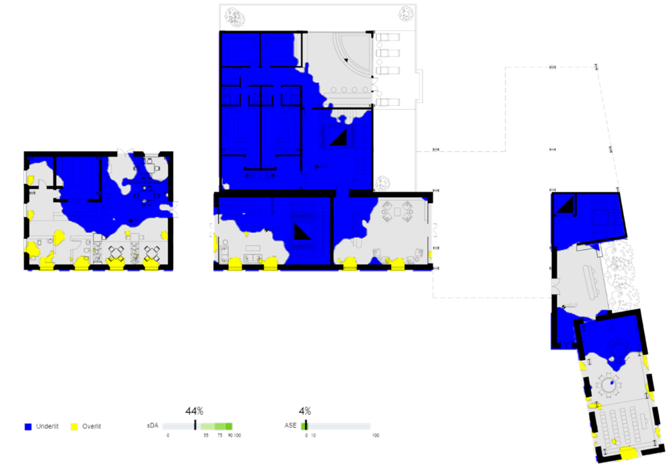


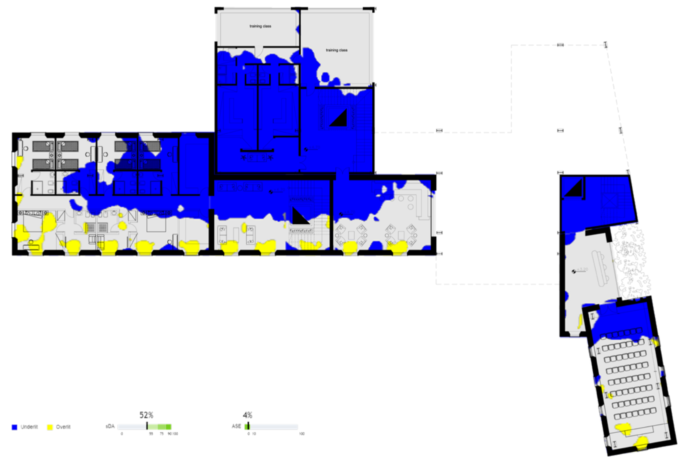
The roof is opaque and the screen is completely perforated 70% perforation with a skylight.

Option 4 DF %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	2.13			1.14			1.73			0.27	3.4	2.4	1.73
first	2.15	0	2.3	0.62	3.08	0.55	1.5	1.57	1.68	0.27	3.12	2.7	1.86
second	2.78	4.25	-	0.92	2.49	1.33	2.19	2.28		3.23	0	11.42	10.12

Table 20 daylight analysis



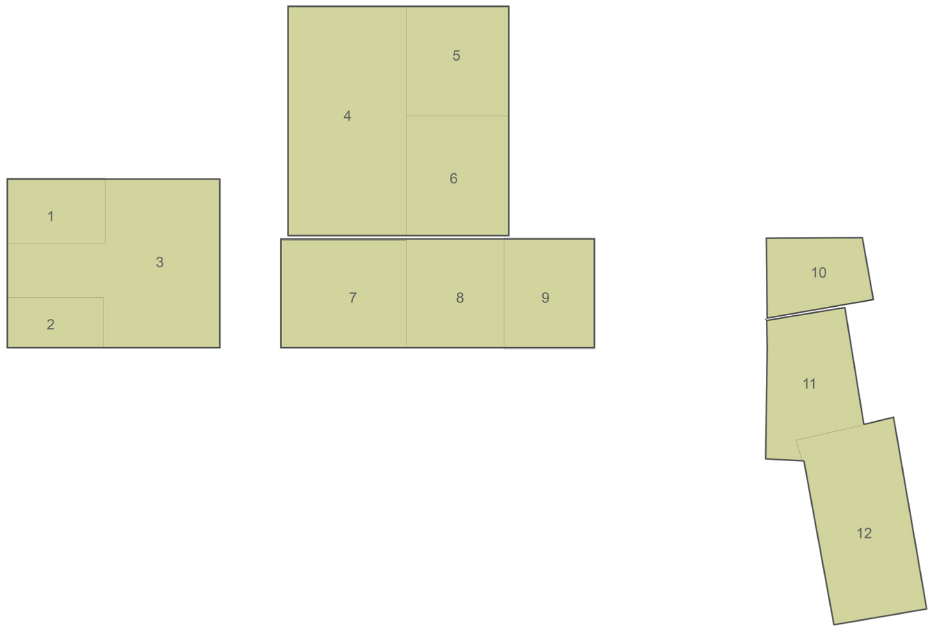


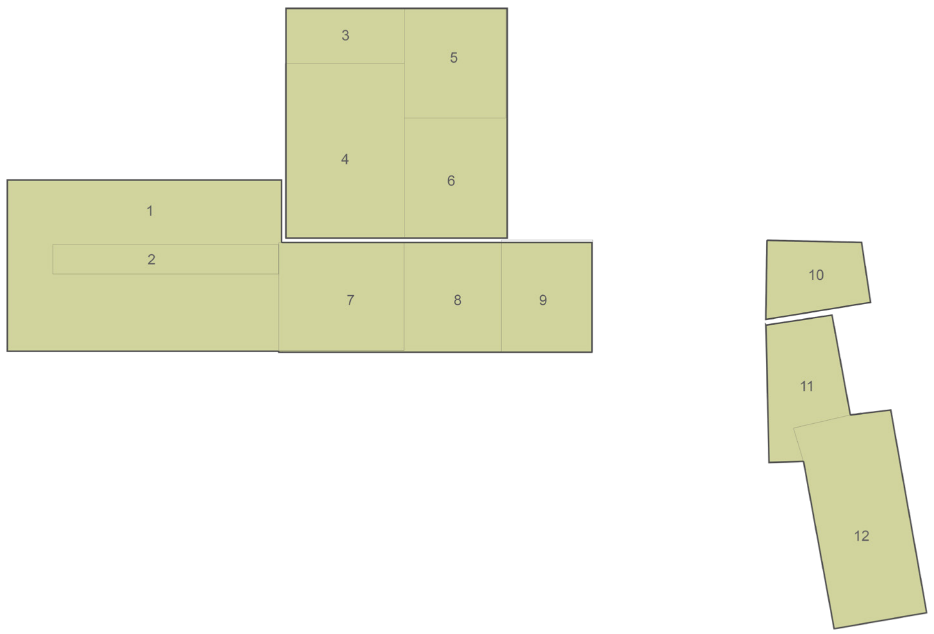


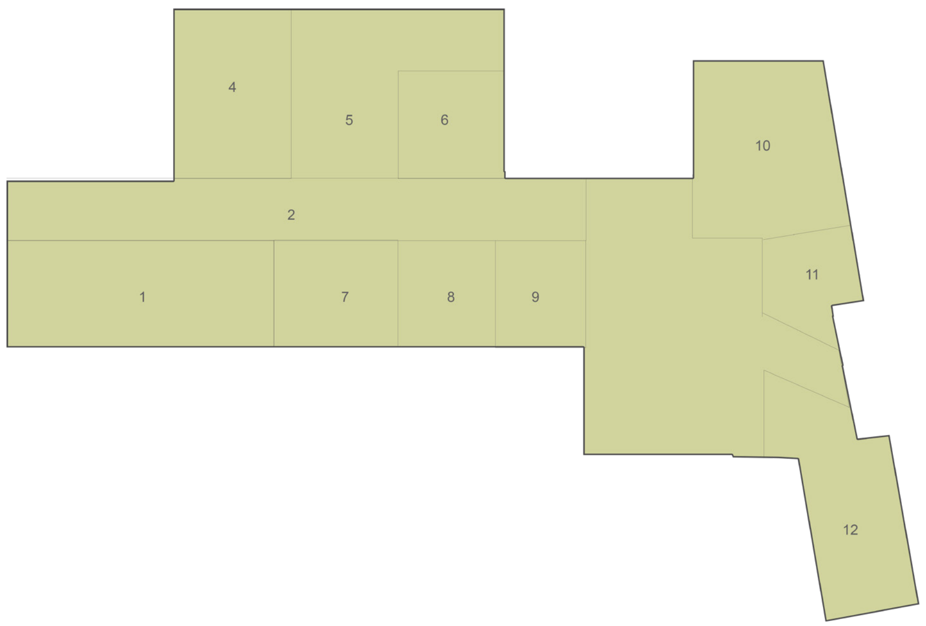
Option 4 sDA/ ASE %													
floors	zones												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
ground	59/8			0/0	21/0	0/0	50/9			0/0	79/0	71/5	44/4
first	59/7	0/0	100/0	6/0	87/0	0/0	45/6	43/8	68/5	0/0	91/0	77/5	52/4
second	93/6	99/0	-	12/0	74/0	45/0	89/2	89/2		87/1	0/0	90/10	81/16

Table 21 sDA and ASE analysis

5.2.1 Zoning in Plan Scheme







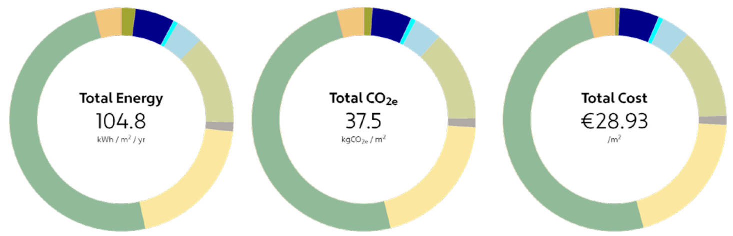
ZONING APPLICATION

5.2.2 Space Use

Before and After Space Use

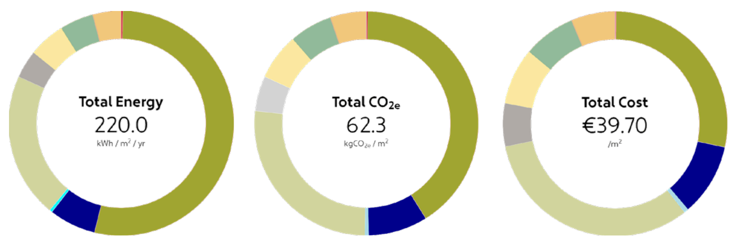
-Occupant density:	10 m^2/person
-Equipment power density:	25 W/m^2
-Light power density:	10 W/m^2
-Outside air rate/ person:	15 L/s-person
-Set-point temperatures:	21°C - 24°C
-Setback temperatures:	12°C - 28°C
-Operating hours:	8am - 6pm
-Setback lo set-point rarnp up time:	1 hrs.
-Internal loads applied:	5 day/week
-HVAC system operating on:	5 day/week

Segment	kWh / m^2 / yr	% of total use
Heating	**23.6**	**18 %**
AHU	0.1	0 %
Zones	23.5	18 %
Humidification	0.0	0 %
Cooling	**13.6**	**10 %**
AHU	6.4	5 %
Heat Rejection	1.0	1 %
Zones	6.2	5 %
Fans	**16.5**	**12 %**
AHU	13.6	10 %
Zones	2.9	2 %
Interior	**72.7**	**55 %**
Lighting	20.8	16 %
Equipment	51.9	39 %
Pumps	**5.9**	**4 %**



-Occupant density:	32 m^2/person
-Equipment power density:	2.8 W/m^2
-Light power density:	3 W/m^2
-Outside air rate/ person:	15 L/s-person
-Set-point temperatures:	21°C - 25°C
-Setback temperatures:	12°C - 25°C
-Operating hours:	9am - 8pm
-Setback lo set-point rarnp up time:	1 hrs.
-Internal loads applied:	7 day/week
-HVAC system operating on:	7 day/week

Segment	kWh / m^2 / yr	% of total use
Heating	**118.4**	**54 %**
AHU	0.5	0 %
Zones	117.9	54 %
Humidification	0.0	0 %
Cooling	**15.7**	**7 %**
AHU	14.8	7 %
Heat Rejection	0.9	0 %
Zones	0.0	0 %
Fans	**54.7**	**25 %**
AHU	45.9	21 %
Zones	8.8	4 %
Interior	**22.2**	**10 %**
Lighting	11.5	5 %
Equipment	10.7	5 %
Pumps	**9.0**	**4 %**



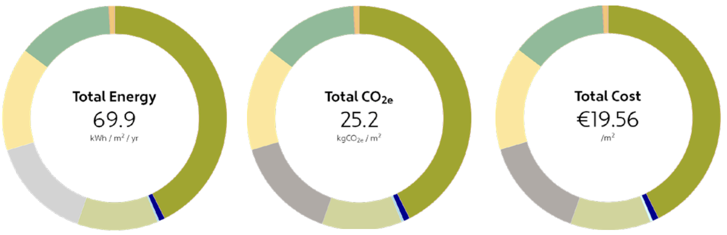
5.3.1 HVAC Integration

The used HVAC system in the project is Fan Coil Units with Central Plant. It's the best HVAC system in energy consumption and thermal comfort. To ensure thermal comfort in the main zones of the project, natural ventilation is insured with the use of cooling and heating unit.

Central Outdoor-Air Handling Unit
-Supply Air Temperature: 17°C

Fan Coil Unit (Each Zone)
-Cooling Design Air Temperature 20°C
-Heating Design Air Temperature: 26°C

Segment	kWh / m² / yr	% of total use
Heating	**29.8**	**43 %**
AHU	0.0	0 %
Zones	29.8	43 %
Humidification	0.0	0 %
Cooling	**0.8**	**1 %**
AHU	0.6	1 %
Heat Rejection	0.0	0 %
Zones	0.2	0 %
Fans	**18.6**	**27 %**
AHU	8.1	12 %
Zones	10.5	15 %
Interior	**20.1**	**29 %**
Lighting	10.4	15 %
Equipment	9.7	14 %
Pumps	**0.6**	**1 %**

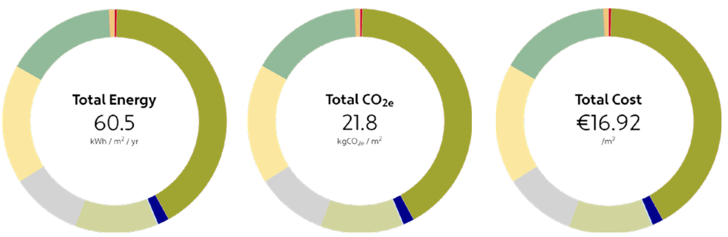


5.3.2 P.V Panels

According to the radiation studies in the climatic analysis. The optimum place for pv panels is on the South direction.

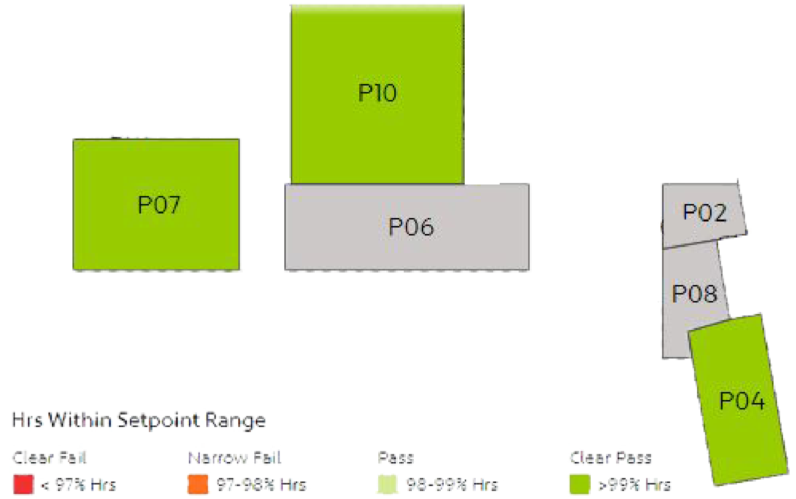
-PV efficiency 20%
-PV panel orientation: 180°
-PV panel tilt: 50°
-PV panel area: 195m²

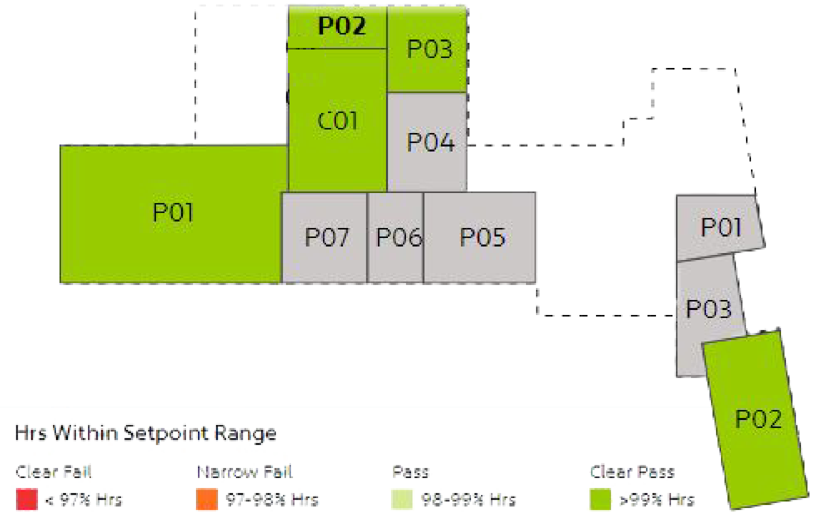
Segment	kWh / m² / yr	% of total use
Heating	**25.4**	**42 %**
AHU	0.2	0 %
Zones	25.2	42 %
Humidification	0.0	0 %
Cooling	**1.1**	**2 %**
AHU	1.0	2 %
Heat Rejection	0.0	0 %
Zones	0.1	0 %
Fans	**13.4**	**22 %**
AHU	7.2	12 %
Zones	6.2	10 %
Interior	**20.1**	**33 %**
Lighting	10.4	17 %
Equipment	9.7	16 %
Pumps	**0.5**	**1 %**



5.4.1 Operative Temperature Criteria

Pass a zone if the Operative Temperature is between **20.0 °C** and **26.0 °C** for more than **98.0 %** of occupied hours.

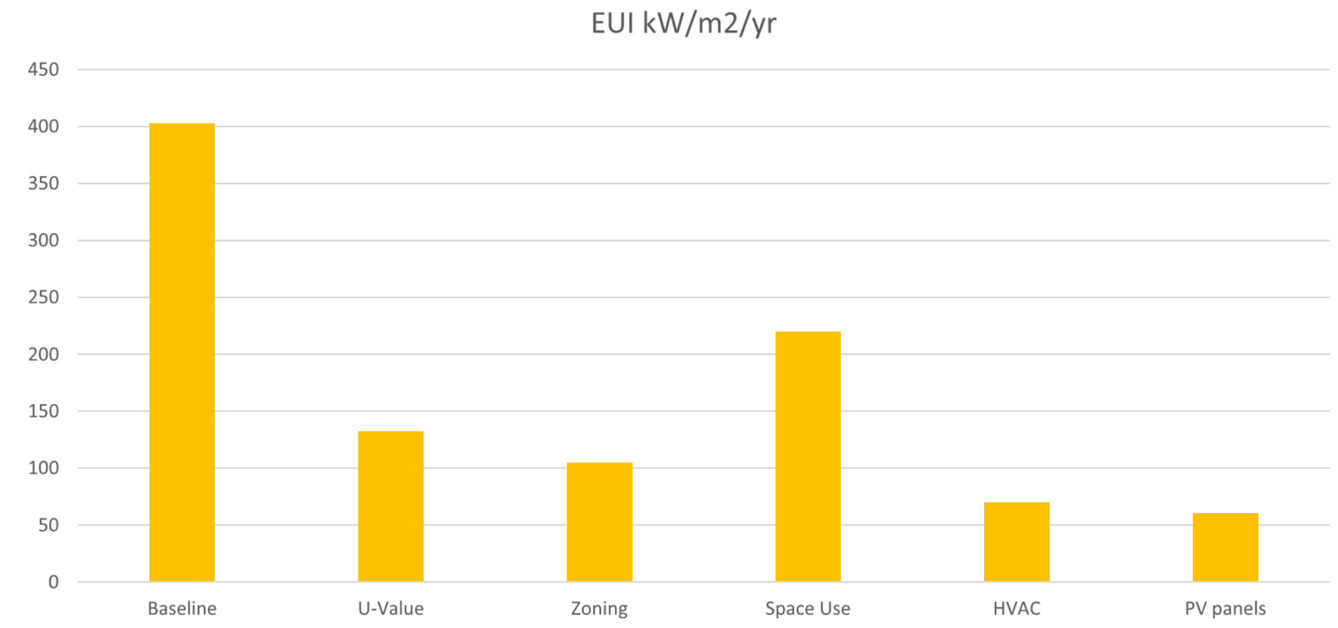




5.5.1 Energy Optimization

Process	Baseline	U-Value	Zoning	Space Use	HVAC	PV panels
EUI kW/m2/yr	402.9	132.3	104.8	220	69.9	60.5
Percentage		-67%	-21%	210%	-68%	-13%

Table 22 energy optimization



-Total Area of the Building: 1749 m^2

-Total Energy Consumption: 60.5 $kW/m^2/yr$

-Total CO2 Emission: 21.8 $kgCO_2/m^2$

-Total Cost: 16.92 m^2

6.

STRUCTURE DESIGN

6.1 Building Description

The Mountain hub is a 3 storey building each storey is 5.5m height. It's a building for public use contains different functions for tourists and athletes. The building is located in the top part of Lecco, Italy. The site is surrounded by mountains which make the building lies in a valley.

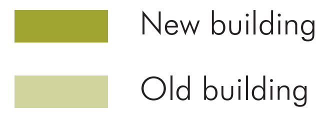
This building is a renovated building, consisting of two parts; the old existing building and the new added building. The existing structure is load bearing walls , which is 50cm thick made of stone and bricks. The added structure is steel beams and columns forms the new skeleton totally independent from the old building.

The studied part is the new steel structure part that contains; spa in the ground floor, training rooms for yoga in the first floor, and a gym with an educational part in the third floor. The gym and educational part are in separated building connecting with a platform that acts as a shading for the ground and first floors.

The exterior walls and the internal partitions are wooden wall with insulation, the one sided inclination roof is covered with aluminum panels with layers of insulation fixed on corrugated sheets that are fixed to the structural beams. The slabs are 4cm wooden panels lies on the main steel beams covered with sound proofing layers.

The selected part to study in the highest point in the building -since the roof is inclined- and the largest span between the columns 7.5m × 6.5m. Steel columns with steel beams covered with 10° inclination made of aluminium.

6.2 Building analysis



Relation between old building and new building - Ground Floor-

Relation between old building and new building - First Floor-

Relation between old building and new building - Second Floor-

6.3.1 Variable loads Calculations (Q)

Analysis of the different variable loads behavior for a service life of 50 years, based in the Norme Tecniche per le Construzioni 2008, Italian standard:

• Q1 – Function
• Q2 – Snow
• Q3 – Wind

Following the code, the nominal values we will consider are; qk, Qk, Hk, from the standard table 3.1. The values are for ordinary dynamics over the structure:

• qk – Vertical Uniform Distributed Loads (kN/m2)
• Qk – Vertical Concentrated Loads (kN)
• Hk – Horizontal Linear Loads (kN/m)

Tabella 3.1.II – *Valori dei carichi d'esercizio per le diverse categorie di edifici*

Cat.	Ambienti	q_k [kN/m²]	Q_k [kN]	H_k [kN/m]
A	**Ambienti ad uso residenziale.** Sono compresi in questa categoria i locali di abitazione e relativi servizi, gli alberghi. (ad esclusione delle aree suscettibili di affollamento)	2,00	2,00	1,00
B	**Uffici.**			
	Cat. B1 Uffici non aperti al pubblico	2,00	2,00	1,00
	Cat. B2 Uffici aperti al pubblico	3,00	2,00	1,00
C	**Ambienti suscettibili di affollamento**			
	Cat. C1 Ospedali, ristoranti, caffè, banche, scuole	3,00	2,00	1,00
	Cat. C2 Balconi, ballatoi e scale comuni, sale convegni, cinema, teatri, chiese, tribune con posti fissi	4,00	4,00	2,00
	Cat. C3 Ambienti privi di ostacoli per il libero movimento delle persone, quali musei, sale per esposizioni, stazioni ferroviarie, sale da ballo, palestre, tribune libere, edifici per eventi pubblici, sale da concerto, palazzetti per lo sport e relative tribune	5,00	5,00	3,00
D	**Ambienti ad uso commerciale.**			
	Cat. D1 Negozi	4,00	4,00	2,00
	Cat. D2 Centri commerciali, mercati, grandi magazzini, librerie…	5,00	5,00	2,00
E	**Biblioteche, archivi, magazzini e ambienti ad uso industriale.**			
	Cat. E1 Biblioteche, archivi, magazzini, depositi, laboratori manifatturieri	≥ 6,00	6,00	1,00*
	Cat. E2 Ambienti ad uso industriale, da valutarsi caso per caso	—	—	—
F-G	**Rimesse e parcheggi.**			
	Cat. F Rimesse e parcheggi per il transito di automezzi di peso a pieno carico fino a 30 kN	2,50	2 x 10,00	1,00**
	Cat. G Rimesse e parcheggi per transito di automezzi di peso a pieno carico superiore a 30 kN: da valutarsi caso per caso	—	—	—
H	**Coperture e sottotetti**			
	Cat. H1 Coperture e sottotetti accessibili per sola manutenzione	0,50	1,20	1,00
	Cat. H2 Coperture praticabili	secondo categoria di appartenenza		
	Cat. H3 Coperture speciali (impianti, eliporti, altri) da valutarsi caso per caso	—	—	—
*	non comprende le azioni orizzontali eventualmente esercitate dai materiali immagazzinati			
**	per i soli parapetti o partizioni nelle zone pedonali. Le azioni sulle barriere esercitate dagli automezzi dovranno essere valutate caso per caso			

Table 23 table 3.1 from the NTC 2008 Italian standard

In this case, because is a mountain hub the category of the building is C, C1:

• qk – 3 (kN/m2)
• Qk – 2 (kN)
• Hk – 1 (kN/m)

Additional with the H, H1 category for only maintenance duties:

• qk – 0.5 (kN/m2)
• Qk – 1.2 (kN)
• Hk – 1 (kN/m)

6.3.2 Snow Load

It is calculated as:

$$qs = \mu i \cdot qsk \cdot CE \cdot Ct$$

Where:

• qs :snow load on the roof
• μi :the shape coefficient of the coverage
• qsk : the reference characteristic value of the snow load on the ground [kN /m2] for a return period of 50 years
• CE : the exposure coefficient
• Ct : the thermal coefficient

Characteristic value for the snow depending of the location:

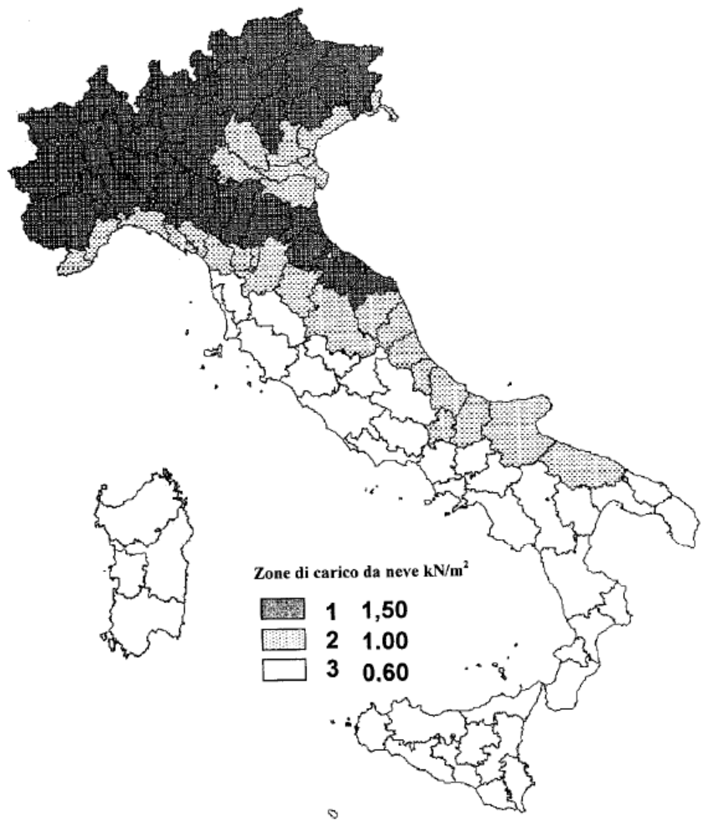


Figura 3.4.1 – *Zone di carico da neve*

6.3.3 Exposure Coefficient C_E

Taking values from the table 3.4 I of the NTC 2008, in function of the specific characteristics of the location:

Topografia	Descrizione	C_E
Battuta dai venti	Aree pianeggianti non ostruite esposte su tutti i lati, senza costruzioni o alberi più alti.	0,9
Normale	Aree in cui non è presente una significativa rimozione di neve sulla costruzione prodotta dal vento, a causa del terreno, altre costruzioni o alberi.	1,0
Riparata	Aree in cui la costruzione considerata è sensibilmente più bassa del circostante terreno o circondata da costruzioni o alberi più alti	1,1

Table 24 snow load table

6.3.4 Roof shape coefficient μi

This project have 3 inclined roof. The inclination not more than 30°, so we will take the first value 0.8 μ_i.

Coefficiente di forma	0° ≤ α ≤ 30°	30° < α < 60°	α ≥ 60°
μ_1	0,8	$0,8 \cdot \frac{(60-\alpha)}{30}$	0,0

Table 25 snow load table

6.3.5 Wind Load

The wind load calculation follows:

Zona	Descrizione	$v_{b,0}$ [m/s]	a_0 [m]	k_a [1/s]
1	Valle d'Aosta, Piemonte, Lombardia, Trentino Alto Adige, Veneto, Friuli Venezia Giulia (con l'eccezione della provincia di Trieste)	25	1000	0,010
2	Emilia Romagna	25	750	0,015
3	Toscana, Marche, Umbria, Lazio, Abruzzo, Molise, Puglia, Campania, Basilicata, Calabria (esclusa la provincia di Reggio Calabria)	27	500	0,020
4	Sicilia e provincia di Reggio Calabria	28	500	0,020
5	Sardegna (zona a oriente della retta congiungente Capo Teulada con l'Isola di Maddalena)	28	750	0,015
6	Sardegna (zona a occidente della retta congiungente Capo Teulada con l'Isola di Maddalena)	28	500	0,020
7	Liguria	28	1000	0,015
8	Provincia di Trieste	30	1500	0,010
9	Isole (con l'eccezione di Sicilia e Sardegna) e mare aperto	31	500	0,020

Table 26 Wind load velocity, distance and flow values

The location of the project is Lombardy, the values considered are:

• Vb,0 (m/s) – 25
• a0 (m) – 1000
• ka (l/s) – 0.010

For as ≤a0 vb =vb,0

For 131m≤1000m vb =25

qs = μi · qsk · CE · Ct

qs = 0.8 × 1.5 × 1.1 × 1 = 1.32kN/m^2

In this case, because is a mountain hub the category of the building is C, C1:

• qk – 3 (kN/m2)
• Qk – 2 (kN)
• Hk – 1 (kN/m)

Additional with the H, H1 category for only maintenance duties:

• qk – 0.5 (kN/m2)
• Qk – 1.2 (kN)
• Hk – 1 (kN/m)

6.3.6 Snow Load

It is calculated as:

$$qs = \mu i \cdot qsk \cdot CE \cdot Ct$$

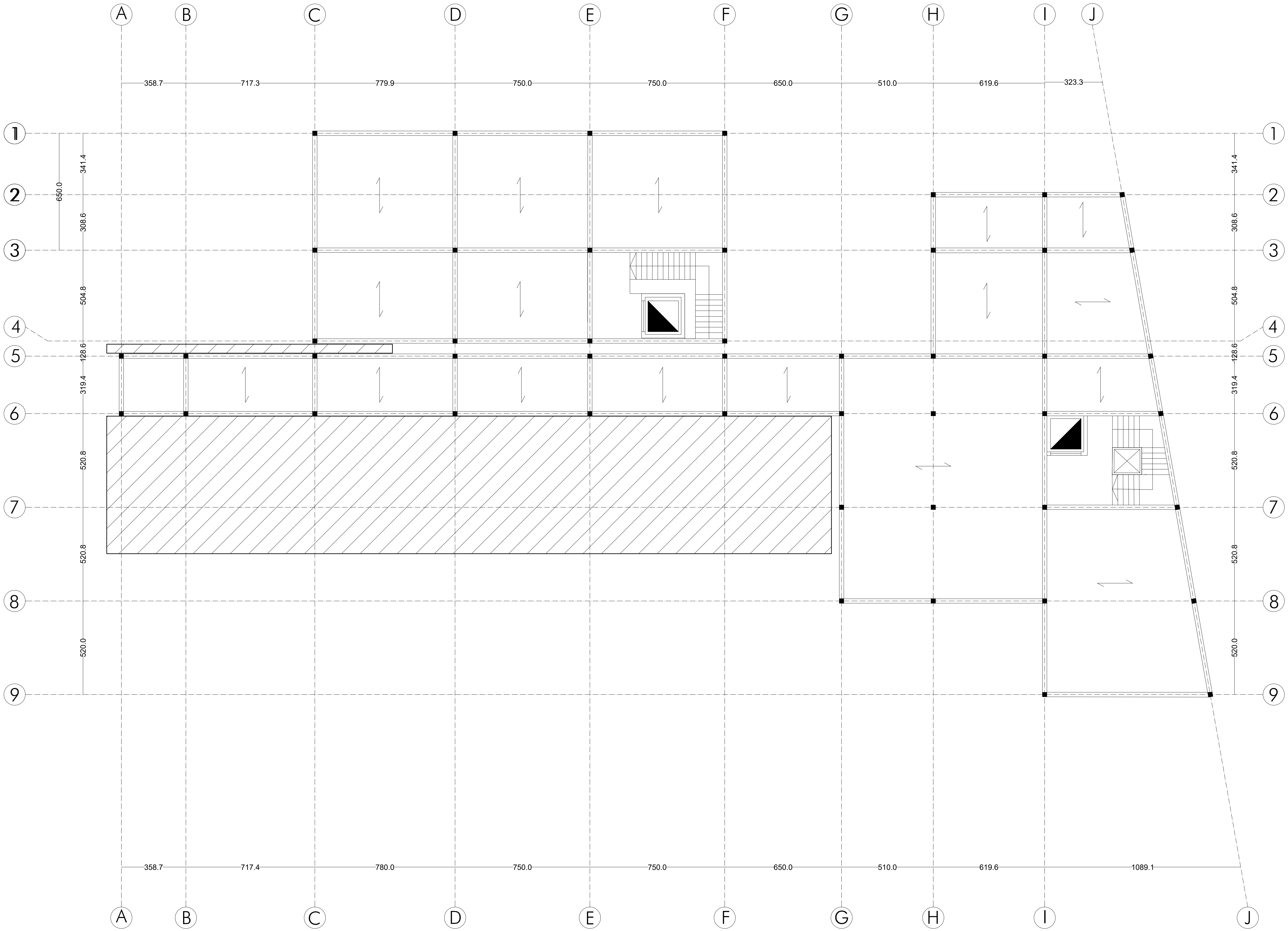
Where:

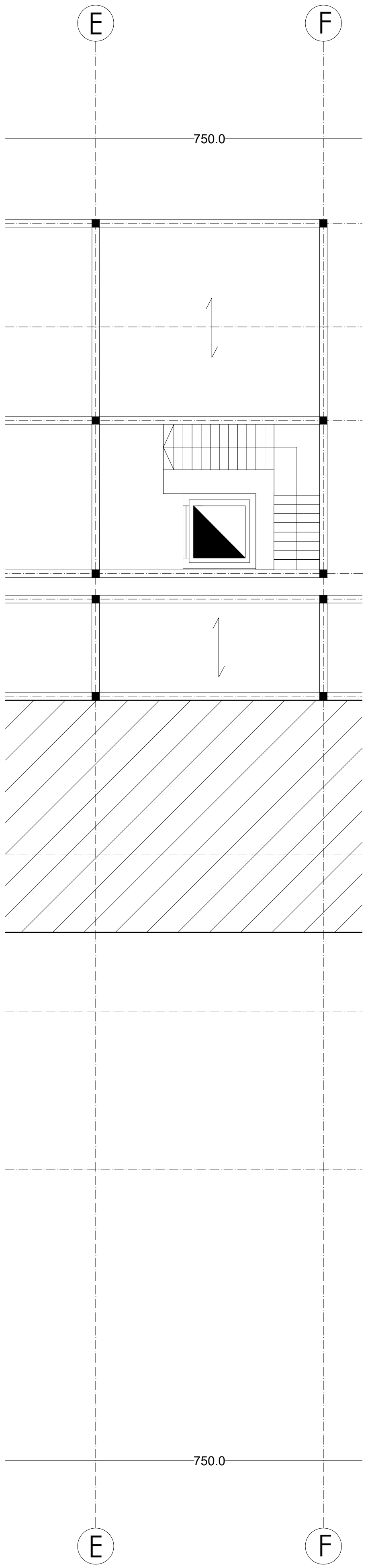
• qs :snow load on the roof
• μi :the shape coefficient of the coverage
• qsk : the reference characteristic value of the snow load on the ground [kN /m2] for a return period of 50 years
• CE : the exposure coefficient
• Ct : the thermal coefficient

Characteristic value for the snow depending of the location:

PERMENANT LOADS

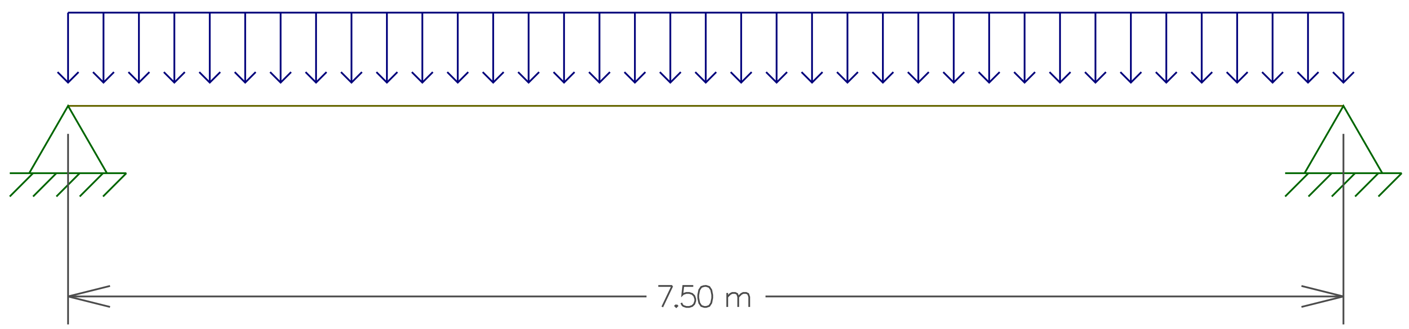
6.4.1 Preliminary Structure Scheme





For a first analysis, the plan shows the distribution of the beams and the slabs, also shows the spans and the direction of the corrugated sheet. The selected part is the largest span in the building 7.50m between 2 columns and 6.50m in the vertical direction. The slab is inclined, so the column is in different heights.

Before analyzing the beam it is necessary to do a full analysis of the types of floor that could be used. For the analysis of the slab, it shall then be considered a static scheme of the support-support type.



6.5.1 Vertical Closure (Walls) Loads

After defining the structural scheme, we need to calculate the loads, permanent and variable, applied on the slab. The loads acting on the structure are as follows:

Vertical closure	Thickness (m)	Weighte per volume	Weight per surface (kN/m2)	Height (m)	Weight per height
Gypsum board	0.0125	14.4	0.18	5	0.9
OSB/3	0.015	6	0.09	5	0.45
Aluminium foil	0.002	25	0.05	5	0.25
Glasswool 032	0.32	0.28	0.09	5	0.45
Glasswool 032	0.04	0.25	0.01	5	0.05
Exterior plaster	0.01	18	0.18	5	0.9
Other elements of vertical closure					
supported wood panel	0.06	1.5	0.09	0.32	0.03
Total			0.69		3.03

Table 27 Vertical closure (walls) loads

6.5.2 Internal Partitions Loads

Internal partitions	Thickness (m)	Weighte per volume (kN/m3)	Weight per surface (kN/m2)	Height (m)	Weight per height (kN/m)
Gypsum board	0.0095	6.3	0.06	4.73	0.28
OSB/3	0.015	6	0.09	4.73	0.42
Glasswool 032	0.16	0.56	0.09	4.73	0.42
Gypsum board	0.0095	6.3	0.06	4.73	0.28
Other elements of vertical closure					
supported wood panel	0.16	0.56	0.09	0.32	0.42
Total			0.39		1.82

Table 28 internal partitions

6.5.3 Internal Storey Loads

Following the code NTC 2008 the uniform distributed load (g), for the vertical partitions, depend in the value G2k of the table:

- per elementi divisori con $G_2 \leq 1,00\ kN/m$: $g_2 = 0,40\ kN/m^2$;
- per elementi divisori con $1,00 < G_2 \leq 2,00\ kN/m$: $g_2 = 0,80\ kN/m^2$;
- per elementi divisori con $2,00 < G_2 \leq 3,00\ kN/m$: $g_2 = 1,20\ kN/m^2$;
- per elementi divisori con $3,00 < G_2 \leq 4,00\ kN/m$: $g_2 = 1,60\ kN/m^2$;
- per elementi divisori con $4,00 < G_2 \leq 5,00\ kN/m$: $g_2 = 2,00\ kN/m^2$.

Loads typology	Loads	Value in (kN/m2)
Permenant loads	G1	1.6
Internal partitions	G2	0.8
Variable of function	Q1	3
Total		5.4

Table 29 internal storey

6.5.4 Roof Covering Loads

Loads typology	Loads	Weight per surface (kN/m2)
Permenant loads	G1	0.37
Variable loads	Q1	3
Snow load	Q2	1.32
Total		4.69

Table 30 roof covering

6.5.5 Typical Flooring Loads

Typical floors	Thickness (m)	Weighte per volume (kN/m3)	Weight per surface (kN/m2)
Oak wooden floor	0.01	7	0.07
Cement screed	0.06	19.7	1.18
Glasswool 032	0.18	0.28	0.05
Aluminium foil	0.002	25	0.05
Wooden panel	0.04	4.5	0.18
Total			1.53

Table 31 Loads of typical floors

6.6.1 Secondary Beams

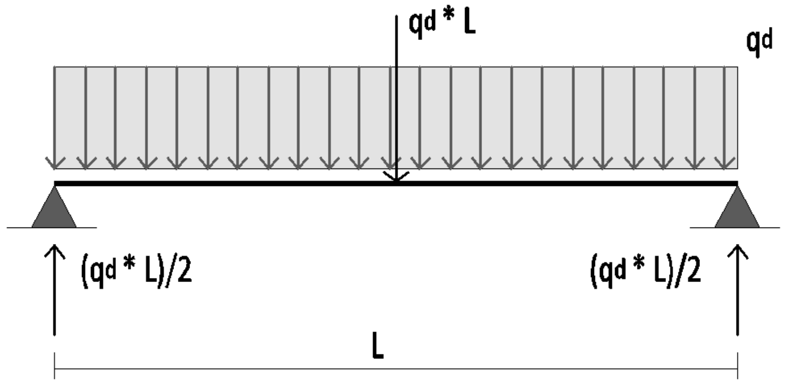
The pre-sizing of the secondary beam, according to legislation, originates with the analysis of the loads acting on the internal storey type and on the roof slab initially neglecting the weight G1, in kN / m, the beam itself. Therefore for the roof of inter-type analysis of the loads previously carried out, the following values:

Loads typology		Loads	Weight per surface (kN/m2)
Permenant loads (G)	Preliminary structure	G1	1.6
	Internal partitions	G2	0.8
Variable loads (Q)	Functions	Q1	3
	Snow load	Q2	1.32

Table 32 Internal and Roof Loads classification.

6.6.2 Load Combination

The static scheme in which it is translated the secondary beam is an auction with straight axis with constant properties, isostatic and constraints at the ends of the supporting-bearing type; as being no horizontal actions the beam is able to transmit, to the main beam or directly to the pillar, only a cutting action. The scheme is the following:



For verification purposes ultimate limit state, the NTC 2008 define the following combination of actions: Essential combination, generally used for the states last ULS limit

$$qd = \gamma G1 \cdot G1 + G2 + \gamma P\, \gamma G2 \cdots P + \gamma Q1 \,.\, QK1 + \gamma Q2\, \Psi 02 \cdots QK2 + \gamma Q3\;\; \Psi 03 \cdot Qk3 + \ldots$$

In the definition of combinations of actions that can act simultaneously, the Qk_i terms represent the variable actions of the combination, with QK1 dominant variable action and QK2, Qk3 ... variable actions that can act simultaneously with that dominant.

Tabella 2.5.I – *Valori dei coefficienti di combinazione*

Categoria/Azione variabile	ψ_{0j}	ψ_{1j}	ψ_{2j}
Categoria A Ambienti ad uso residenziale	0,7	0,5	0,3
Categoria B Uffici	0,7	0,5	0,3
Categoria C Ambienti suscettibili di affollamento	0,7	0,7	0,6
Categoria D Ambienti ad uso commerciale	0,7	0,7	0,6
Categoria E Biblioteche, archivi, magazzini e ambienti ad uso industriale	1,0	0,9	0,8
Categoria F Rimesse e parcheggi (per autoveicoli di peso ≤ 30 kN)	0,7	0,7	0,6
Categoria G Rimesse e parcheggi (per autoveicoli di peso > 30 kN)	0,7	0,5	0,3
Categoria H Coperture	0,0	0,0	0,0
Vento	0,6	0,2	0,0
Neve (a quota ≤ 1000 m s.l.m.)	0,5	0,2	0,0
Neve (a quota > 1000 m s.l.m.)	0,7	0,5	0,2
Variazioni termiche	0,6	0,5	0,0

Table 33 Categories of the variables.

The categories of the project are:

- C – environments susceptible to crowding (Mountain Hub)
- H – Roofing

Tabella 2.6.I – *Coefficienti parziali per le azioni o per l'effetto delle azioni nelle verifiche SLU*

		Coefficiente γ_F	EQU	A1 STR	A2 GEO
Carichi permanenti	favorevoli	γ_{G1}	0,9	1,0	1,0
	sfavorevoli		1,1	1,3	1,0
Carichi permanenti non strutturali(1)	favorevoli	γ_{G2}	0,0	0,0	0,0
	sfavorevoli		1,5	1,5	1,3
Carichi variabili	favorevoli	γ_{Qi}	0,0	0,0	0,0
	sfavorevoli		1,5	1,5	1,3

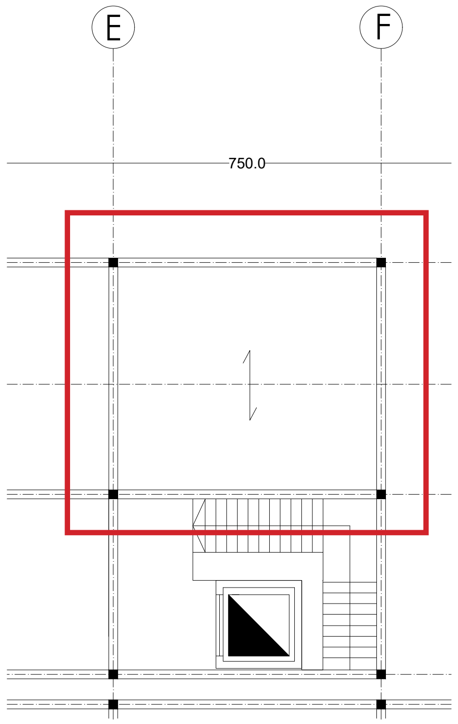
(1)Nel caso in cui i carichi permanenti non strutturali (ad es. carichi permanenti portati) siano compiutamente definiti si potranno adottare per essi gli stessi coefficienti validi per le azioni permanenti.

Table 34 SLU factors

The coefficients introduced for calculating qd regarding the partial factors γGi γQj and safety are as follows:

$$\gamma G1 = 1.3$$
$$\gamma G2 = 1.5$$
$$\gamma Q1 = 1.5$$

In the following structural scheme, it is highlighted the area of influence of the project for the secondary beam:



The beam shown in the figure is characterized by:
Span (L) = 6.5 m
Width (l) = 7.5 m

Steel Profile
As mentioned in the beginning of the design, the steel used is the **S355**

Tabella 11.3.IX – Laminati a caldo con profili a sezione aperta

Norme e qualità degli acciai	Spessore nominale dell'elemento			
	$t \leq 40$ mm		40 mm $< t \leq 80$ mm	
	f_{yk} [N/mm^2]	f_{tk} [N/mm^2]	f_{yk} [N/mm^2]	f_{tk} [N/mm^2]
UNI EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	510	335	470
S 450	440	550	420	550
UNI EN 10025-3				
S 275 N/NL	275	390	255	370
S 355 N/NL	355	490	335	470
S 420 N/NL	420	520	390	520
S 460 N/NL	460	540	430	540
UNI EN 10025-4				
S 275 M/ML	275	370	255	360
S 355 M/ML	355	470	335	450
S 420 M/ML	420	520	390	500
S 460 M/ML	460	540	430	530
UNI EN 10025-5				
S 235 W	235	360	215	340
S 355 W	355	510	335	490

Table 35 steel material characteristics

Tabella 4.2.X *Limiti di deformabilità per gli elementi di impalcato delle costruzioni ordinarie*

Elementi strutturali	Limiti superiori per gli spostamenti verticali	
	$\frac{\delta_{max}}{L}$	$\frac{\delta_2}{L}$
Coperture in generale	$\frac{1}{200}$	$\frac{1}{250}$
Coperture praticabili	$\frac{1}{250}$	$\frac{1}{300}$
Solai in generale	$\frac{1}{250}$	$\frac{1}{300}$
Solai o coperture che reggono intonaco o altro materiale di finitura fragile o tramezzi non flessibili	$\frac{1}{250}$	$\frac{1}{350}$
Solai che supportano colonne	$\frac{1}{400}$	$\frac{1}{500}$
Nei casi in cui lo spostamento può compromettere l'aspetto dell'edificio	$\frac{1}{250}$	
In caso di specifiche esigenze tecniche e/o funzionali tali limiti devono essere opportunamente ridotti.		

Table 36 structure elements limit

Structural element limits used:
- Roof 1/200, 1/250
- Floor 1/250, 1/350

S355 steel with the following characteristics:
- fyk = 355 N / mm2
- ftk = 510 N / mm2

Modulus of elasticity (E) = 210,000 N / mm2m2
We proceed to the calculation of the fundamental combination for pre - sizing, without taking account of its own weight of the secondary beam (G1).

$$qd = \gamma G1 \cdot G1 + G2 + \gamma P\ \gamma G2 \cdots P + \gamma Q1\ QK1 + \gamma Q2\ \Psi 02 \cdots QK2 + \gamma Q3\ \Psi 03 \cdot Qk3 + \ldots$$

Where the partial factors for the actions are as follows:

$$\gamma G1 = 1.3$$
$$\gamma G2 = 1.5$$
$$\gamma Qi = 1.5$$

Loads typology	Loads	Value in (kN/m2)	Value in (kN/m)
Permenant loads	G1	1.53	1.99
Internal partitions	G2	0.8	5.2
Variable of function	Q1	3	19.5
Total		5.33	26.69

Table 37 internal loads

We also assume the coefficient of γp= 1 and the characteristic value of the force P = 0 from which we obtain:

$$Qd = 1.3 * (1.99) + 1.5 * (6.0) + 1.5 * (22.5)$$
$$qd = 45.34 \text{ kN / m}$$

For the verification of the ULS we follow the table of the NTC 2008 standard

Tabella 4.2.V Coefficienti di sicurezza per la resistenza delle membrature e la stabilità

Resistenza delle Sezioni di Classe 1-2-3-4	γ_{M0} = 1,05
Resistenza all'instabilità delle membrature	γ_{M1} = 1,05
Resistenza all'instabilità delle membrature di ponti stradali e ferroviari	γ_{M1} = 1,10
Resistenza, nei riguardi della frattura, delle sezioni tese (indebolite dai fori)	γ_{M2} = 1,25

Table 38 safety values for ULS

Taking the first value γM0= 1.05

6.6.3 ULS Verification

ULS Verification

For the verification of uniaxial bending line must be the following inequality:

$$M_{Ed} / M_{c, Rd} \leq 1$$

Where:

M_{Ed} = resistant design moment (KN.m) M_{Ed} = qd . $(L)^2 / 8$

$M_{c, Rd}$ = resistance moment (KN.m)

Span (m)	6.5
Load qd (kN/m)	45.34

Table 39 Span and Loads of the structure

6.6.4 Profile Selection

The choice of the profile is based on profiles that meet the following requirements:

W> W_{min}

Check the positive plane bending

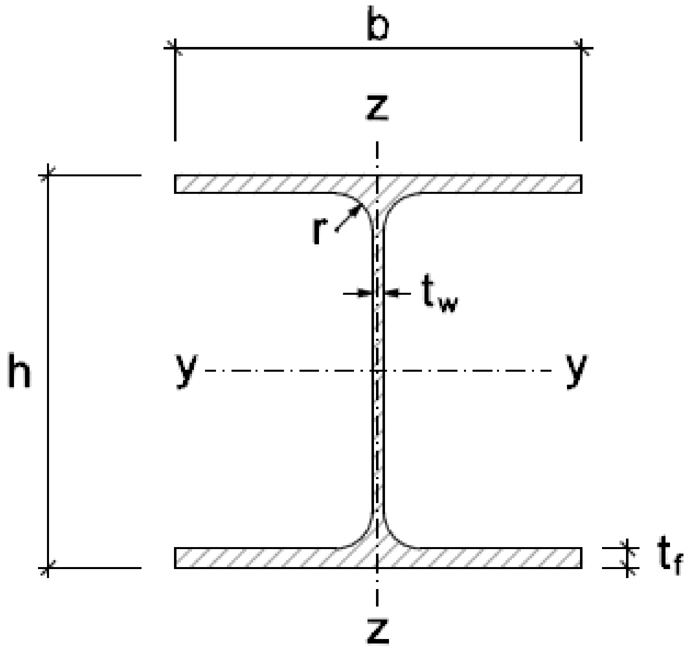
qd also includes the right of the beam weight (G1)

IPE	G1 beam (kg/m)	G1 beam (kN/m)	qd (G1 beam) (kN/m)	L (span) (m)	l (Width) (m)	γM0	fyk (kN/m2)	Med (kN.m)	Wmin (cm3)	Wp (cm3)	MRd (kN.m)	Verification
300	42.24	0.414	45.34	6.5	7.5	1.05	355000	239.45	557	628.3	212.42	1.12
330	49.15	0.482	45.34	6.5	7.5	1.05	355000	239.45	713	804	271.83	0.88
360	57.09	0.56	45.34	6.5	7.5	1.05	355000	239.45	0.45	0.45	325.109	0.73

Table 40 IPE table characteristics and verification calculation

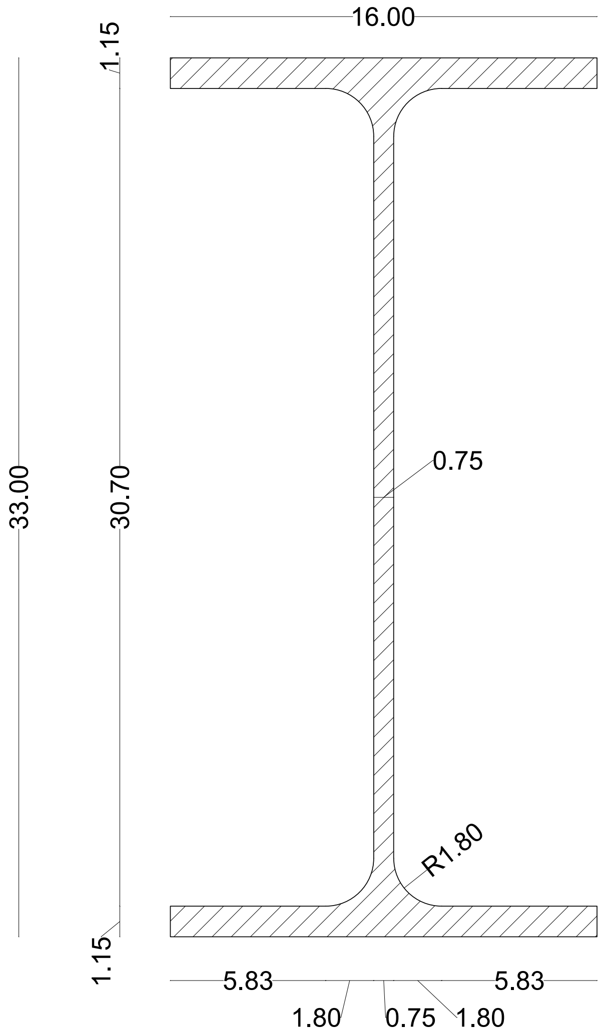
6.6.5 Profile Class

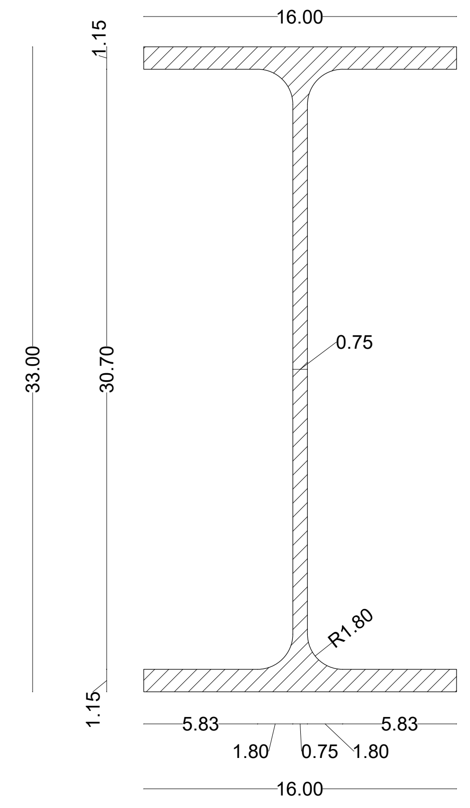
Referring to the section of the beam **IPE 330**, we derive directly the geometric measurements C and t necessary for the calculation of the section of the beam class. Referring as specified above, to a type of steel S355, ε The value of the parameter, is derived from the value of the effort of fyk yield strength, characteristic of the steel making up the beam. The yield strength of the steel value is contained within the legislation.



C =58.30cm

t =11.30cm

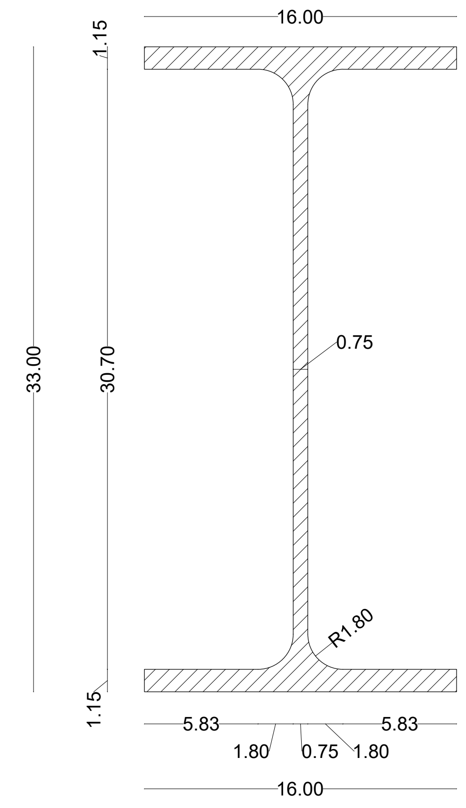


Class	Flange under compression					
Stress distribution in parts (compression positive)						
1	C/t ≤ 9Ɛ					
2	C/t ≤ 10Ɛ					
3	C/t ≤ 9Ɛ					
Ɛ = √235/fyk	fyk	235	275	355	420	460
	Ɛ	1	0.92	0.81	0.75	0.71

$$C/t = 58.30 / 11.5 = 5.06$$

$$9\varepsilon = 9 \times 0.81 = 7.29$$

$$5.06 \leq 7.29$$

Class	Web under compression					
Stress distribution in parts (compression positive)						
1	C/t ≤ 72Ɛ					
2	C/t ≤ 83Ɛ					
3	C/t ≤ 124Ɛ					
Ɛ = √235/fyk	fyk	235	275	355	420	460
	Ɛ	1	0.92	0.81	0.75	0.71

$$C/t = 307 / 7.5 = 40.9$$

$$72\varepsilon = 72 \times 0.81 = 58.32$$

$$40.9 \leq 58.32$$

Profile Class

The results of the profile correspond to **Class 1**.

6.6.6 ULS Shear Verification

$V_{Ed} \ / \ V_{c,Rd} \le 1$

Where $V_{c,Rd} = A_v \ . \ f_{yk} \ / \ \sqrt{\varepsilon} \ . \ \gamma M0$

And $A_v = A - 2b \ . \ t_f + (t_w + 2r) \ . \ t_f$ for profiles with I and H according to the NTC 2008.

For IPE 330: $A_v = A - 2b \ . \ t_f + (t_w + 2r) \ . \ t_f$

$$A_v = 6266 - 2 \times 160 \ . \ 11.5 + (7.5 + 2 \times 18) \ . \ 11.5 = 6398{,}3 \ mm^2$$

$V_{c,Rd}$ in the absence of torsion: $V_{c,Rd} = A_v \ . \ f_{yk} \ / \ \sqrt{\varepsilon} \ . \ \gamma M0$

We now calculate the final value needed to verify, that the shear force V_{Ed} follows:

$$V_{Ed} = q_d \ . \ L/2$$

Then we proceed to check:

$$V_{Ed} \ / \ V_{c,Rd} \le 1$$

The verification summarized in the following table:

IPE	qd (kN/m)	L (span) (m)	l (Width) (m)	γM0	fyk (kN/m2)	Ved (kN.m)	A (m2)	Av (m2)	Vc,Rd (kN)	Verification
330	45.34	6.5	7.5	1.05	355000	147.335	0.006266	0.00639825	1248.93	0.118

Table 41 Choose IPE and verification calculation

6.6.7 SLS Verification

After calculating the load of the project with the rare combination:

$q_d = G1 + G2 + P + + QK1 \ \Psi 02 \cdot QK2 + \Psi 03 \cdot Qk3 + ...$

$q_d = 26.69$ (kN /m) (no weight beam)

The table below shows the verification for the vertical displacement δmax, compared to limits and regulations by using the following formula:

$$\delta max = f = 5/384 \ . \ (q_d \ . \ L^4 \ / \ Iy \ . \ M)$$

IPE	Moment of inertia Iy (m4)	qd (kN/m)	G1 beam (kg/m)	G1 beam (kN/m)	qd (N/m)	L (span) (m)	l (Width) (m)	Modulus of elasticity (N/m2)	Vertical displacement δmax (m)	δmax / L	Vertical displacement limit	Verification
330	0.00011766	26.69	49.15	0.482	2669	6.5	7.5	210×10^9	0.00167	0.000257	0.004	

Table 42 Choose IPE and verification calculation

After calculating the load of the project, considering only variable loads, with the rare combination:

$$qd = P + + QK1 \ \Psi 02 \cdot QK2 + \Psi 03 \cdot Qk3 + ...$$

qd = 5.4 (kN/m) (no weight beam)

The table below shows the verification for the vertical displacement δ2, compared to limits and regulations by using the following formula:

$$\delta max = f = 5/384 \ . \ (q_d \ . \ L^4 \ / \ Iy \ . \ M)$$

IPE	Moment of inertia Iy (m4)	qd (N/m)	L (span) (m)	l (Width) (m)	Modulus of elasticity (N/m2)	Vertical displacement δmax (m)	δmax / L	Vertical displacement limit	Verification
270	0.0000579	54	6.5	7.5	210×10^9				

Table 43 Inferior IPE and verification calculation

The column is subjected to axial load. As mentioned in the building description, horizontal loads were not included in the calculations but were considered in the design, through shear walls and bracings.
The following analysis was based on the chapters 2, 4 and 11 of the NTC 2008 and all 'Eurocode 3- part 1-1.

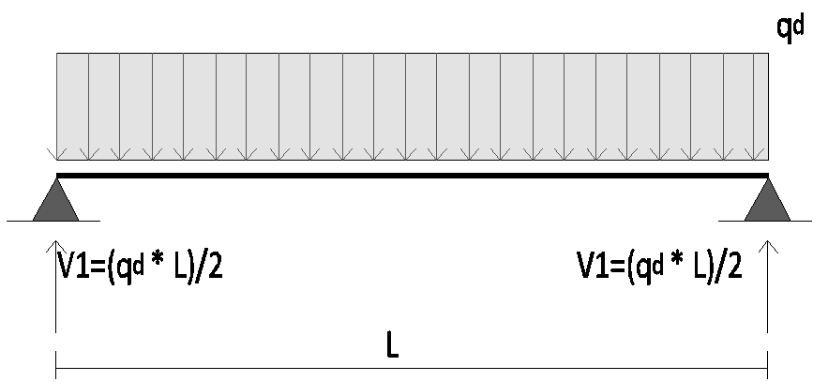
6.7.1 Pre-Dimensioning

The worst situation is found in correspondence of a central pillar of board that receives the load of two secondary edge beams and a main. The same will be analyzed by adopting a static system of hinged pillar to the extreme top and bottom with buckling length equal to the height, with h = 5.0m.

Main beam Lo = 6.50m – influence zone L = 6.50m
Main edge beam Lo = 6.60m - influence zone L = 3.30m

6.7.2 Calculating N_{Ed}

With regard to the roof floor, we proceed with the calculation of the contribution of the secondary edge beam to the left of the column.



Loads transmitted to the column, due to the weight of the main beam only, V3 in kN

Span (m)	6.5
G1 profile weight (kN/m)	0.482
Load qd (kN/m)	0.626
Reaction force transmitted to the column V3a (kN)	2.03

Table 44 Project values.

Calculation of the edge action transmitted to the pillar, due to the concentrated load coming from the secondary beams connected to the main beam, V3b in kN

Considering the structural scheme of the building, you notice that rests on the girder there are four secondary beams; considering the load distribution is evident that each column bears the load of two secondary beams resting on the primary.

Dimensions of beams:
IPE 355 S355
Span L = 6.50m
Distance of I = 750m

Loads typology	Loads	Value in (kN/m2)	Value in (kN/m)
Permenant loads	G1	1.53	1.99
Internal partitions	G2	0.8	5.2
Variable of function	Q1	3	19.5
Total		5.33	26.69

Table 45 Internal Loads values.

We proceed to the calculation of the fundamental combination for pre - sizing, without taking account of its own weight of the main beam (G1).

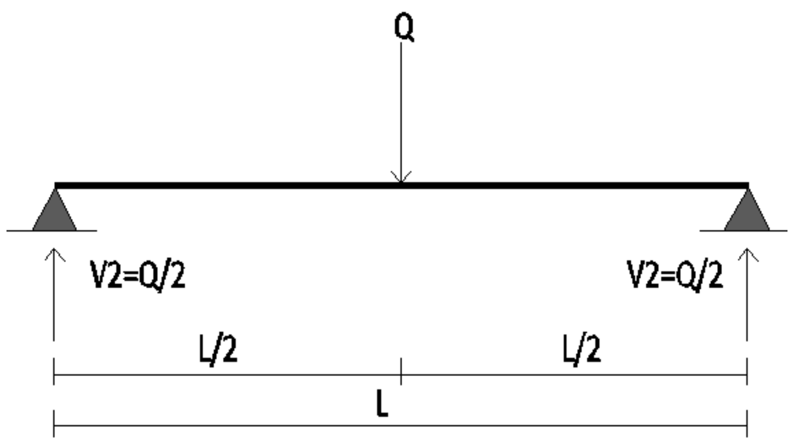
$$q_d = \gamma G1 \cdot G1 + G2 + \gamma P\, \gamma G2 \cdots P + \gamma Q1\, QK1 + \gamma Q2\, \Psi 02 \cdots QK2 + \gamma Q3\, \Psi 03 \cdot Qk3 + \ldots$$

Where the partial factors for the actions are as follows:

$\gamma G1 = 1.3$
$\gamma G2 = 1.5$
$\gamma Q1 = 1.5$

$$q_d = (1.3 \,.\, 1.99) + (1.5 \,.\, 5.2) + (1.5 \,.\, 19.5) = 39.637 \text{ kN/m}$$

We also assume the coefficient of pre-stressing γp = 1 and the characteristic value of the pre-stressing force P = 0.



Span (m)	6.5
Load qd (kN/m)	39.637
Concentrated load Q = qd . L (kN)	257.64
Reaction force transmitted to the column V3a (kN) Q/2	128.82

Table 46 Loads values.

6.7.3 Column Choice

Calculation, the minimum Area from the project. The calculation of the action of the overall cut, the load transmitted from the beam to the column:
For each floor

Reaction of the portion of the main beam on the left side of the column V1a (kN)	64.41
Reaction of the portion of the main beam on the right side of the column V2a (kN)	64.41
Reaction force transmitted to the column V3a (kN)	128.82
Total Vs = V1a + V2a + V3	257.64

Table 47 Loads values in the floor

Since we are still in the pre-sizing of the section, the contribution due to the own weight of the column was not taken into consideration. The sum of the various contributions is N_{Ed}.
Compression action of the pre-sizing:

$$N_{Ed} = Vs \cdot 3 \text{ (horizontal elements)}$$

$$N_{Ed} = 772.92kN$$

We can also assess how the compression force varies on each floor as a function of applied loads:

Zero floor 0F	(0,00 – 5.05m)	= 772.92kN
First floor 1F	(5.05 – 10.10m)	= 515.28kN
Second floor 2F	(10.10 – 15.15m)	= 257.64kN

Knowing the design load (N_{Ed} = 819.3 kN) and the resistance characteristics of the steel yield, it is now possible to calculate the minimum areas of profiles to withstand the design load.

The formula for NEd (extracted from paragraph 4.2.4.1.2 of the NTC 2008):

Compressione

La forza di compressione di calcolo N_{Ed} deve rispettare la seguente condizione:

$$\frac{N_{Ed}}{N_{c,Rd}} \leq 1 \qquad (4.2.10)$$

dove la resistenza di calcolo a compressione della sezione $N_{c,Rd}$ vale:

$$N_{c,Rd} = A\, f_{yk} / \gamma_{M0} \quad \text{per le sezioni di classe 1, 2 e 3,}$$
$$N_{c,Rd} = A_{eff}\, f_{yk} / \gamma_{M0} \quad \text{per le sezioni di classe 4.} \qquad (4.2.11)$$

Non è necessario dedurre l'area dei fori per i collegamenti bullonati o chiodati, purché in tutti i fori siano presenti gli elementi di collegamento e non siano presenti fori sovradimensionati o asolati.

Table 48 NEd validation and calculation values from NTC 2008

The calculation:

$$A = (\gamma M0 \;.\; N_{c,Rd}) \;/\; f_{yk}$$

With $fyk = 355000\ kN/m^2$
$\gamma M0 = 1,05$

Result obtained for minimum Area

$$A_{min} = 0.002423\ m^2 = 24.23\ cm^2$$

6.7.4 Verification Compression Resistance

Verification Compression Resistance

At this point, two types of profiles have been identified; with satisfy the minimum area value.

Steel type	Profile	Area (A) (cm2)	Weight (G1) (kg/m)
S355	HEB 100	26.04	20.4
S355	HEA 120	25.34	19.9

Table 49 steel characteristics with the profiles.

Calculating the contribution N_{Ed} of the column, through the key combination in the following way:

$$N_{Ed,column} = G1_{column} \cdot \gamma G1 \cdot h$$

Where h= total column height=15.15 m

Added to the previously found value, we find the total N_{Ed} and verify that

$$N_{Ed} \leq N_{c,Rd}$$

HEB	Column Weight (kg/m)	Column Weight (kN/m)	Column Height (m)	γG1	Ned column contribution (kN)	Ned beam contribution (kN)	Ned total (kN)	Area (m2)	fyk (kN/m2)	γM0	Compressive strength of the section Nc,rd (kN)	Verification Ned / Nc,rd ≤ 1
100	20.4	0.2	15.15	1.3	4.7268	772.92	777.65	0.002604	355000	1.05	880.4	0.883

HEA	Column Weight (kg/m)	Column Weight (kN/m)	Column Height (m)	γG1	Ned column contribution (kN)	Ned beam contribution (kN)	Ned total (kN)	Area (m2)	fyk (kN/m2)	γM0	Compressive strength of the section Nc,rd (kN)	Verification Ned / Nc,rd ≤ 1
120	19.9	0.195	15.15	1.3	3.840525	772.92	776.76	0.002534	355000	1.05	856.73	0.906

Table 50 Comparison between the HEA and HEB

Verification of compression stability

Following the NTC 2008 Standard

4.2.4.1.3.1 Aste compresse

La verifica di stabilità di un'asta si effettua nell'ipotesi che la sezione trasversale sia uniformemente compressa. Deve essere

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1, \qquad (4.2.42)$$

dove

N_{Ed} è l'azione di compressione di calcolo,

$N_{b,Rd}$ è la resistenza all'instabilità nell'asta compressa, data da

$$N_{b,Rd} = \frac{\chi A f_{yk}}{\gamma_{M1}} \quad \text{per le sezioni di classe 1, 2 e 3,} \qquad (4.2.43)$$

e da

$$N_{b,Rd} = \frac{\chi A_{eff} f_{yk}}{\gamma_{M1}} \quad \text{per le sezioni di classe 4.} \qquad (4.2.44)$$

I coefficienti χ dipendono dal tipo di sezione e dal tipo di acciaio impiegato; essi si desumono, in funzione di appropriati valori della snellezza adimensionale $\bar{\lambda}$, dalla seguente formula

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \leq 1.0 \qquad (4.2.45)$$

dove $\Phi = 0.5\left[1 + \alpha\left(\bar{\lambda} - 0.2\right) + \bar{\lambda}^2\right]$, α è il fattore di imperfezione, ricavato dalla Tab 4.2.VI, e la snellezza adimensionale $\bar{\lambda}$ è pari a

$$\bar{\lambda} = \sqrt{\frac{A \cdot f_{yk}}{N_{cr}}} \quad \text{per le sezioni di classe 1, 2 e 3, e a} \qquad (4.2.46)$$

$$\bar{\lambda} = \sqrt{\frac{A_{eff} \cdot f_{yk}}{N_{cr}}} \quad \text{per le sezioni di classe 4.} \qquad (4.2.47)$$

Table 51 NTC 2008, Compression verification values

$\mathbf{N_{cr}}$ is the elastic critical load based on the properties of the gross section and buckling length l_o, calculated for the failure mode appropriate for instability.

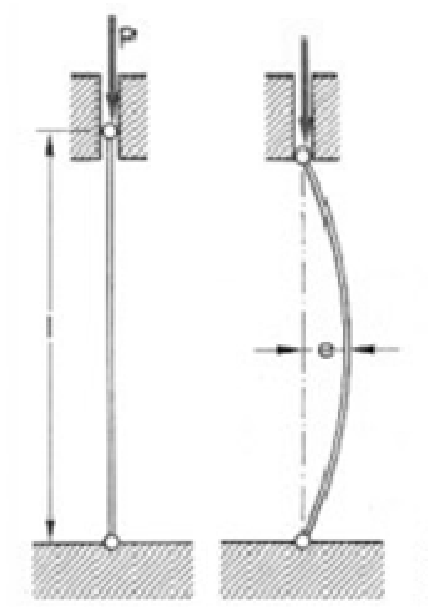
Knowing that the critical load is Eulerian and true:

$$Ncr = \pi^2 \cdot E \cdot I_z / l_0^2$$

Where

l_0 is the inflexion length

I_z is the inertia of the section in the (z–z)



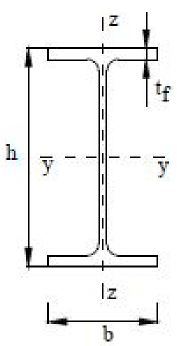
$l_0 = l_i$

In other static scheme:

l_0= Floor height = 5.5m

Following the table to find α .

Tabella 4.2.VI *Curve d'instabilità per varie tipologie di sezioni e classi d'acciaio, per elementi compressi.*

Sezione trasversale		Limiti		Inflessione intorno all'asse	Curva di instabilità S235, S275, S355, S420	Curva di instabilità S460
Sezioni laminate		h/b > 1,2	$t_f \le 40$ mm	y-y z-z	a b	a_0 a_0
			40 mm < $t_f \le 100$ mm	y-y z-z	b c	a a
		h/b ≤ 1,2	$t_f \le 100$ mm	y-y z-z	b c	a a
			$t_f > 100$ mm	y-y z-z	d d	c c

Curva di instabilità	a_0	a	b	c	d
Fattore di imperfezione α	0,13	0,21	0,34	0,49	0,76

Table 52 Limits of steel stability.

Taking from z–z for steel **S355** curve c = α = 0.49 imperfection factor.

As result we obtain the following characteristics:

Characteristics	HEB 100 - S355	HEA 120 - S355
fyk (N/mm²)	355	355
E [N/mm²]	210000	210000
Iz [cm4]	167.3	230.9
l0 [m]	5.5	5.5
Ncr [kN]	114.63	158.2
A [cm2]	26	25.3
λ [adm]	2.32	1.95
h/b	1	1.875
α	0.49	0.49
Ψ	3.72	2.83
χ Verified se ≤ 1	0.15	0.2
Nb,rd [kN]	132.77	175.18
Ned total [kN]	777.65	776.76
Verification Ned / Nb,rd ≤ 1	5.85	4.43

Table 53 Values of HEB and HEA, steel 355

Noticing that, the two profiles don't complete the Verification, lets compare other profiles:

Characteristics	HEB 180 - S355	HEA 200 - S355
fyk (N/mm²)	355	355
E [N/mm²]	210000	210000
Iz [cm4]	1363	1326
l0 [m]	5.5	5.5
Ncr [kN]	933.88	908.53
A [cm2]	65.25	53.83
λ [adm]	1.2	1.2
h/b	1	1.87
α	0.49	0.49
Ψ	1.47	1.34
χ Verified se ≤ 1	0.43	0.48
Nb,rd [kN]	956.93	871.68
Ned total [kN]	782.81	781.09
Verification Ned / Nb,rd ≤ 1	0.82	0.89

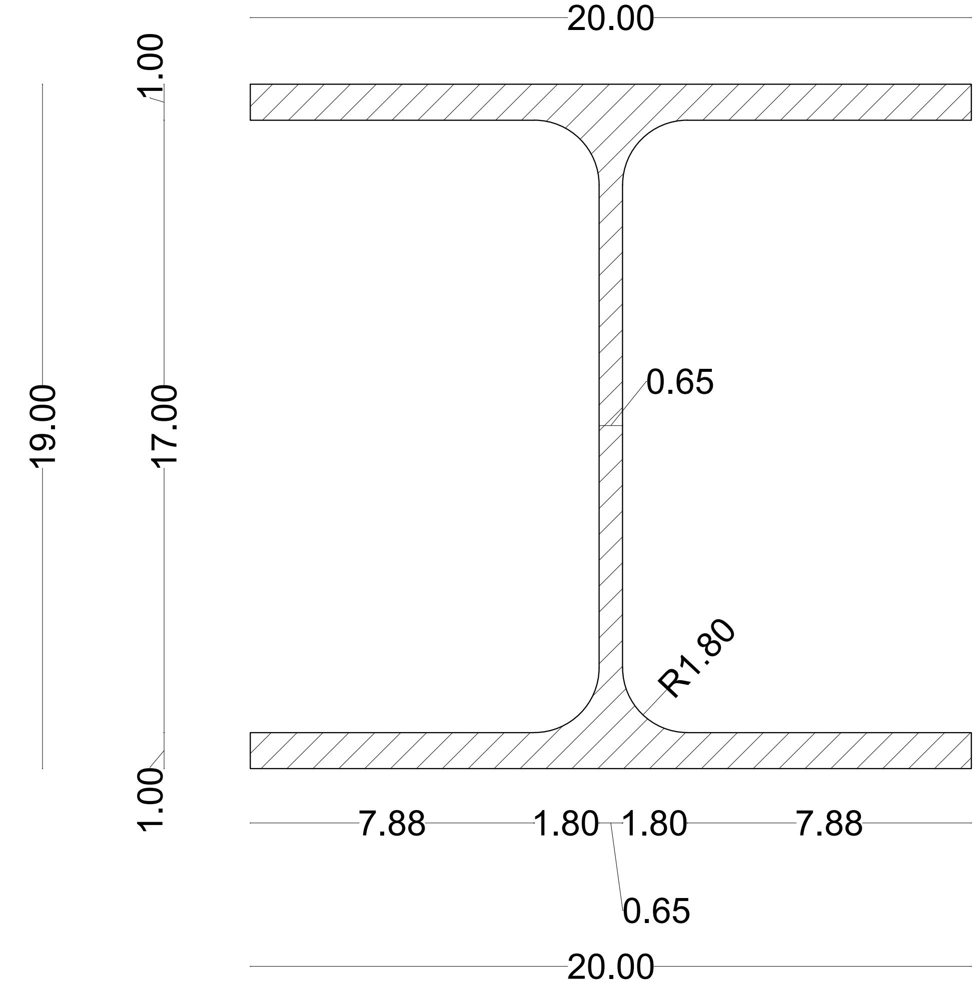
Table 54 Values of HEB and HEA, steel 355

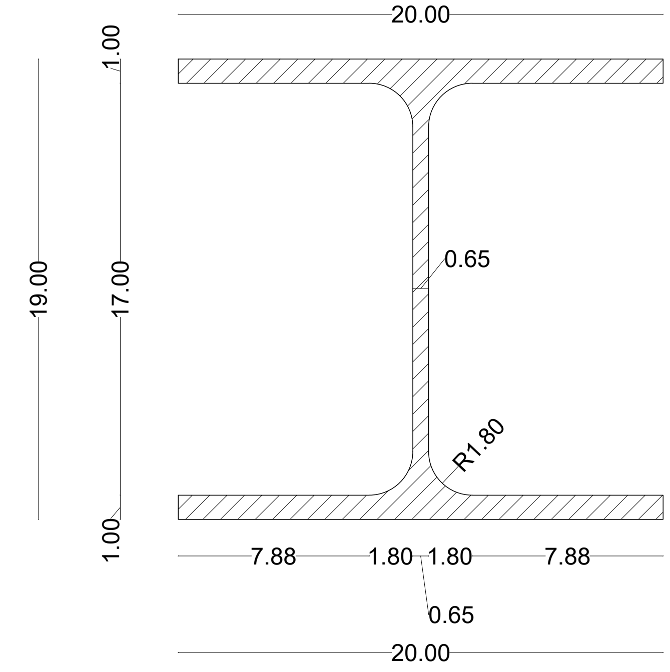
These profiles make valid the Verification, we will continue with **HEA 200–S355**

6.7.5 Profile Class

The formulas written for the compression have been reported to classes 1, 2 and 3: it is therefore necessary to perform verification on the classification of the sections. To determine the profile of the class, we refer to the NTC 2008 chapter 4.2.3.1.

Analyzing the HEA 200

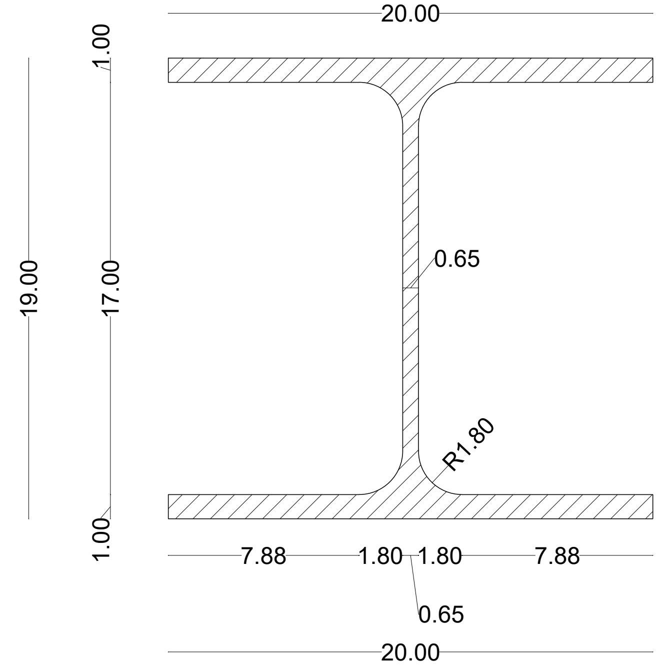


Class	Flange under compresion					
Stress distribution in parts (compression positive)						
1	C/t ≤ 9Ɛ					
2	C/t ≤ 10Ɛ					
3	C/t ≤ 9Ɛ					
Ɛ = √235/fyk	fyk	235	275	355	420	460
	Ɛ	1	0.92	0.81	0.75	0.71

$C/t = 78 / 10 = 7.8$

$10\varepsilon = 10 \times 0.81 = 8.1$

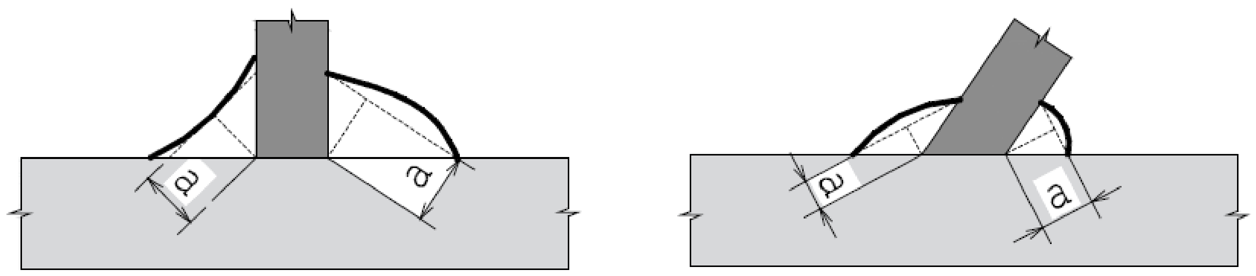
$7.8 \leq 8.1$

Class	Web under compression					
Stress distribution in parts (compression positive)						
1	C/t ≤ 33Ɛ					
2	C/t ≤ 38Ɛ					
3	C/t ≤ 42Ɛ					
Ɛ = √235/fyk	fyk	235	275	355	420	460
	Ɛ	1	0.92	0.81	0.75	0.71

$$C/t = 170 / 6.5 = 26.15$$
$$33\varepsilon = 33 \times 0.81 = 26.73$$
$$26.15 \le 26.73$$

Choosing class 2

Now is possible to create the structural joints welding, which follows the dimension for the connection between the beam and the column.
Following the NTC 2008 standard with the Chap. 4.2.8.2.3, where the resistance is determined by the height of a, of the triangle in the cross section of the cord. Also defined the length L, not having defective ends.



The verification follows the ultimate limit state, when the actions are distributed uniformly in a section. According to the position of a we consider the following resistance conditions:

$$[\sigma\perp^2 + 3\,(\tau\perp^2 + \tau//^2)]^{0.5} \le f_{tk} / (\beta \cdot \gamma_{M2})$$

Where:

σ⊥ Perpendicular to the cord normal tension
τ⊥ Perpendicular to the cord tangential tension
σ// Parallel to the cord normal tension
τ// Parallel to the cord tangential tension
f_{tk} Break resistance (from table) = S 355, 355, 510 (N/mm²)
β 0,90 for Steel S355
γ_{M2} Safety factor = 1,25

Tabella 4.2. XII *Coefficienti di sicurezza per la verifica delle unioni.*

Resistenza dei bulloni	$\gamma_{M2} = 1{,}25$
Resistenza dei chiodi	
Resistenza delle connessioni a perno	
Resistenza delle saldature a parziale penetrazione e a cordone d'angolo	
Resistenza dei piatti a contatto	
Resistenza a scorrimento per SLU per SLE	 $\gamma_{M3} = 1{,}25$ $\gamma_{M3} = 1{,}10$
Resistenza delle connessioni a perno allo stato limite di esercizio	$\gamma_{M6,ser} = 1{,}0$
Precarico di bulloni ad alta resistenza	$\gamma_{M7} = 1{,}10$

Table 55 Safety Factor Table

Tabella 11.3.IX – Laminati a caldo con profili a sezione aperta

Norme e qualità degli acciai	Spessore nominale dell'elemento			
	t ≤ 40 mm		40 mm < t ≤ 80 mm	
	f_{yk} [N/mm^2]	f_{tk} [N/mm^2]	f_{yk} [N/mm^2]	f_{tk} [N/mm^2]
UNI EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	510	335	470
S 450	440	550	420	550
UNI EN 10025-3				
S 275 N/NL	275	390	255	370
S 355 N/NL	355	490	335	470
S 420 N/NL	420	520	390	520
S 460 N/NL	460	540	430	540
UNI EN 10025-4				
S 275 M/ML	275	370	255	360
S 355 M/ML	355	470	335	450
S 420 M/ML	420	520	390	500
S 460 M/ML	460	540	430	530
UNI EN 10025-5				
S 235 W	235	360	215	340
S 355 W	355	510	335	490

Table 56 Steel specifications, Failure resistance

6.8.1 Verification

Main Beam IPE 330
Column HEA 200

For this structure distribution and joint, lets consider the tangential forces from th main beam stress.
For the load lets consider for the ULS
F = 136.5 [kN]

Considering the section a, with the correct angle position, the resistance is:

$$[\sigma\perp^2 + 3\,(\tau\perp^2 + \tau//^2)]^{0.5} \leq f_{tk} / (\beta \cdot \gamma_{M2})$$

From the table we calculate the values applied for steel S355 that is: 510N/mm^2

$f_{tk} / (\beta \cdot \gamma_{M2}) = 510\text{N/mm} / 0.90 \cdot 1.25 = 453{,}33\text{N/mm}^2$

Following the values:
$\sigma// = 0.00\text{N/mm}^2$
$\tau\perp = 0{,}00\text{N/mm}^2$

Considering the joint of the column, its possible to calculate the minimum value of the section a:
$\sigma\perp = M / (2 \cdot a \cdot L^2 / 6)$
$\tau// = F/2 / a \cdot L$

With
L = 100 [mm]; F = 13652 [N] and M = 8560.5 [kNmm]
Results:

$$[\sigma\perp^2 + 3\,(\tau\perp^2 + \tau//^2)]^{0.5} \leq f_{tk} / (\beta \cdot \gamma_{M2})$$

$[\sigma\perp^2 + 3\,(\tau^2 + \tau//^2)]^{0.5} \leq 453{,}33\text{N/mm}^2$
$[\sigma\perp^2 + 3\,(\tau^2 + \tau//^2)] = 453{,}332\ \text{N}^2/\text{mm}^4$

$$[(M / 2 \cdot a \cdot L2) / 6]^2 + [(F/2) / a \cdot L]^2 = 453.332\ \text{N}^2/\text{mm}^4$$

$$a = \frac{\sqrt{\frac{36 * M^2}{4L^4} + \frac{\left(\frac{F}{2}\right)^2}{L^2}}}{453{,}33}$$

From which, the minimum value of the section a is:

$a = 1.506\text{mm}$

The maximum load at the bottom of the column considered is:

$$N = 819.3 \text{ kN}$$

Assuming a rectangular plinth, whose dimensions are (a x b x h) = 2.00m x 1.50m x 1.40m the self weight due to the foundation is

$$G_{plinth} = (2.00 \times 1.50 \times 1.40) \cdot 25 = 105\text{kN}$$

Assuming a gravel soil with internal friction angle equal to ϕ= 35° and density Y= 18 kN/m³, the bearing capacity of the soil is given by the Terzaghi formula, where the pressure due to the lateral soil is not considered.

$$G_{Rd,soil} = s \times N \times \gamma \times b/2$$

$$s = 1 - 0.4\, b/a = 0.7$$

$$N = 2 \cdot [\, e^{\Pi \tan\Phi} \cdot \tan^2(\Pi/4 + \Phi/2) + 1 \,] \cdot \tan\Phi = 20.06$$

The verification implies that $G_{Rd,soil} > G_{Ed,\,soil}$ where
G_{Ed} is **the design pressure on the soil due to loads and foundation self-weight.**

According to the Eurocode 7 [EC7 – 2.4.7.3.4] and the Eurocode 0 [EC0 - A.1.3(5)], the following values for combination coefficients, where γ_F refers to actions, γ_M refers to geotechnical parameters and γ_R refers to the soil resistance after the previous calculations.
The value of γ_F must be averaged from its value for permanent loads ($\gamma_{F,G} = 1.00$) and its value for variable loads ($\gamma_{F,Q} = 1.25$), which yields ($\gamma_F = 1.13$) [EC7 – Table A.3]. We also have the following:

γ_y for the soil density [EC7 – Table A.4]
γ_ϕ which should be applied to $\tan\Phi$ becomes $\tan(\Phi) / 1.25 = 0.560$ [EC7 – Table A.4]
γ_r the global safety factor, which refers to the soil resistance [EC7 – Table A5]

$$N_{Ed} = 1.13\, N + 1.00\, G_{plinth} = (1.13 \times 819.3) + (1.00 \times 105) = 1030.81\text{kN}$$

$$G_{Ed} = N_{Ed} / a \cdot b = 0.34 \text{ N/mm}^2$$

$$G_{Rd,soil} = 0.7 \cdot 20.06 \cdot 18 \cdot (1500/2) / 1.4 = 1.35 \text{ N/mm}^2$$

$$1.35 \text{ N/mm}^2 > 0.34 \text{ N/mm}^2$$

$G_{Rd,soil} > G_{Ed,\,soil}$ the requirement is satisfied

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Table of Figures

Table of Tables