BASEL SCIENCE FORUM

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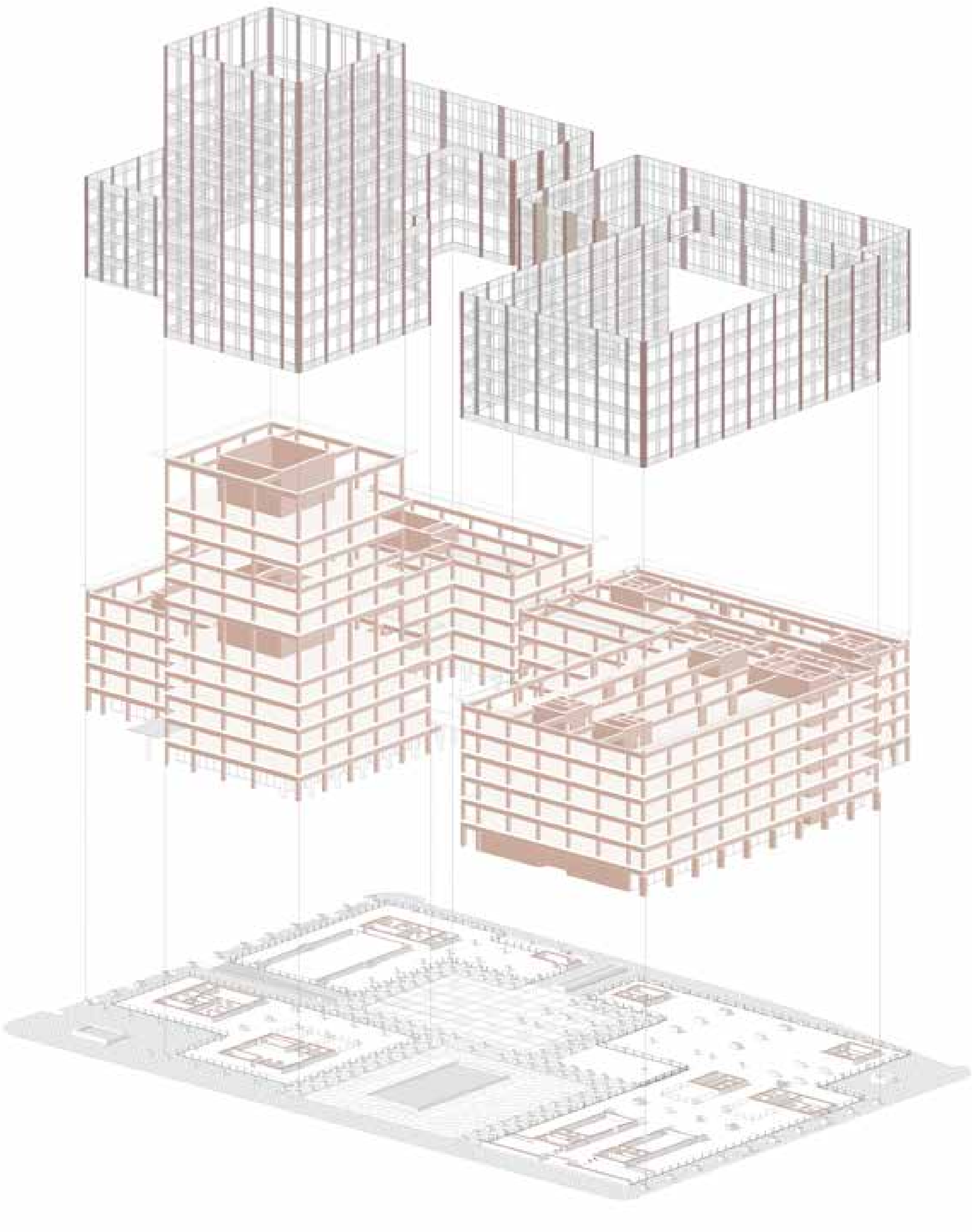
TECHNICAL REPORTS

CEREN BINGÖL & BEATRICE TOSINI



MASTER THESIS IN ARCHITECTURE | BUILDING ARCHITETCURE

A.A. 2019 - 2020

STRUCTURAL DESIGN

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1.

Introduction

INTRODUCTION

This report focuses on the structural design part of Complex Construction Studio II. After a general overview of the design, one structure is selected and parts of it are analyzed and calculated in detail.

After a general description of the project, the complex is described in terms of dimension and internal organization in order to provide information useful for the structural project. Both the complex of building and the selected volume are described by means of structural drawings.
The structural system selected is described also with the comparison of the selected building with similar buildings, based on specific elements, carrying out a comparative analysis.
Such description is carried out in more detail for what concerns the main volume selected for further investigation.

For what concerns deeper analysis, within the main volume, one slab, one beam and one column subjected to peculiar conditions are selected to carry out structural calculations. In this case, the selection starts from the identification of a particularly stressed beam, continuously supported by 4 supports spanning according to an ABA rhythm with A equal to 14.4 meters and B equal to 7,2 meters. One particularly wide continuous slab with two spans is then chosen (having the two spans supported by the identified beam) together with a particularly stressed column supporting the selected beam. For the calculations and the verifications, Eurocode 0 concerning the basis of structural design, Eurocode 1 concerning the external loads on structures and Eurocode 2 concerning the design of concrete structures since the one we focused on is a reinforced concrete columns and beams system.

Finally, the overall system is further investigated as structural system for laboratory buildings, pointing out the stress conditions to which the different members are subjected and drawing observations and conclusions from it.

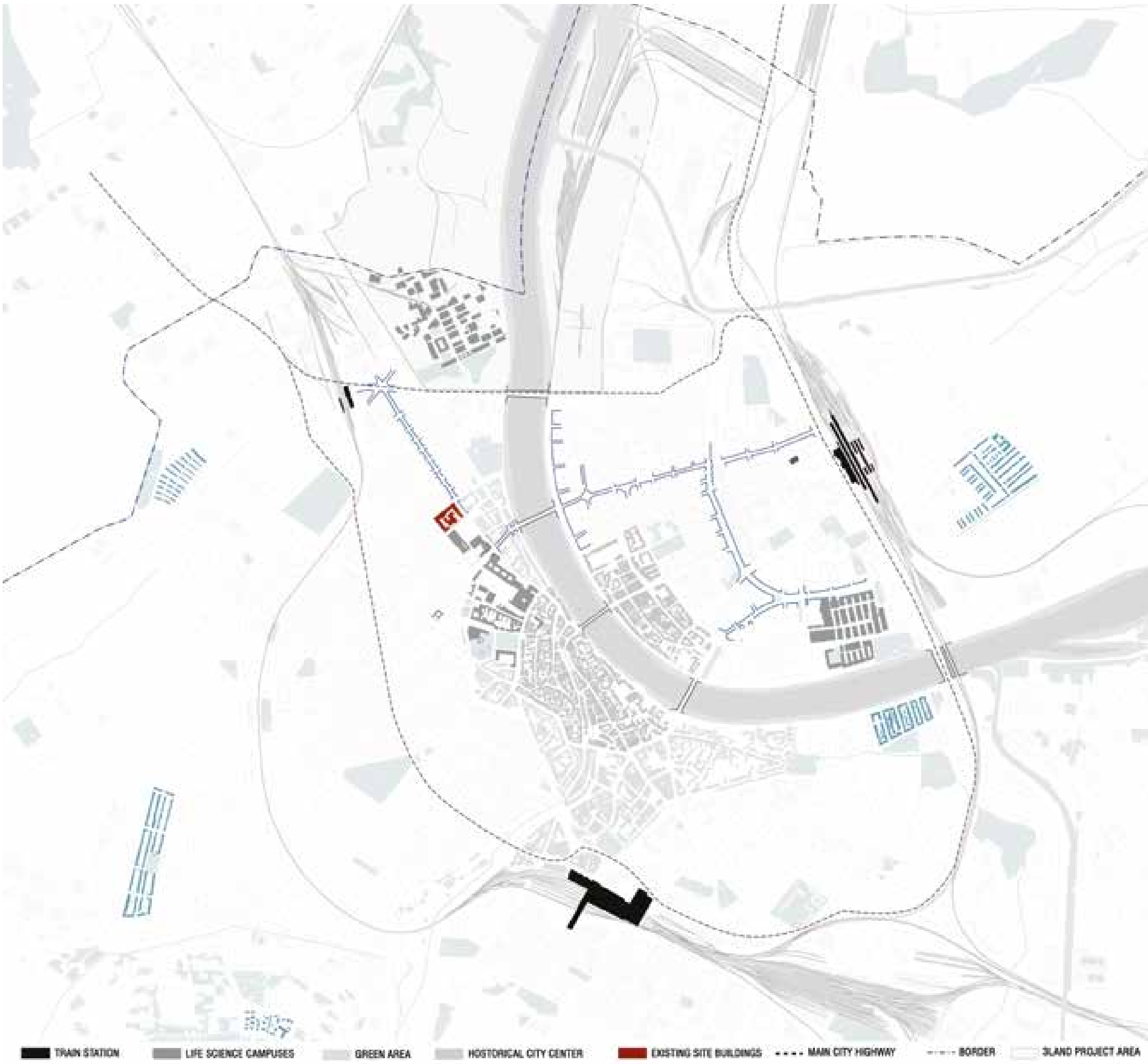
2.

Design

DESIGN

General Description

The following project is in Basel, Switzerland, within the urban Life Science Campus of its University. The University of Basel can be subdivided in different campus areas, and the one concerning our intervention is named Schällemätteli Campus, located at the border of the old city nucleus.

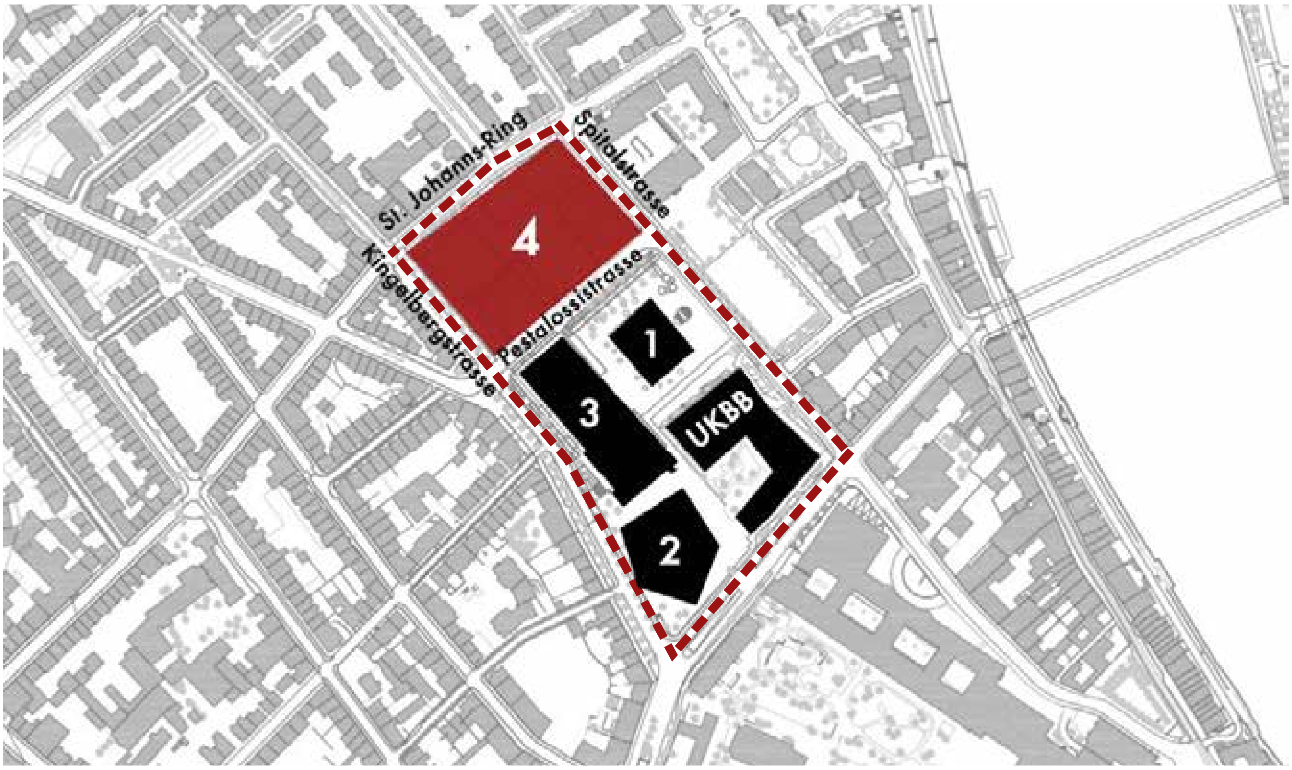


Urban plan of Basel showing the location of the construction site within the city.

The provided plot for the project is identified as Construction Site n°4, which together with the neighbouring sites 1,2 and 3 constitutes the Schällemätteli Campus. The regeneration of the campus was subdivided into two phases: the first stage involved the construction fields 1, 2 and 3, which are now under construction, while the second stage will involve the construction site 4.

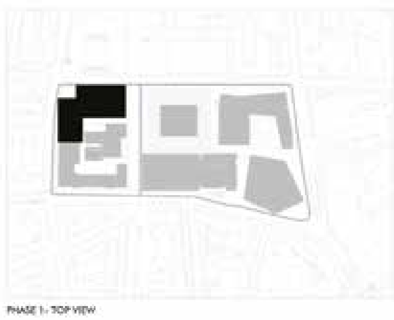
According to the space program of 23 May 2017, a main usable area of 30’402 square meters is planned for construction site 4. Of these, 24,595 square meters are to be arranged above ground, 5,807 square meters are to be provided on the lower floors.

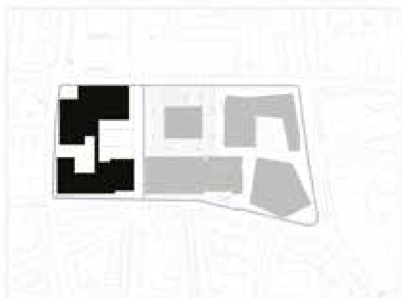
The plot is currently being developed with buildings of the Department of Physics, Chemistry and SNI as well as the Anatomy Department of Biomedicine: all these functions are planned to remain on site with the integration of additional



Plan showing the border of Schällemätteli Campus, with identification of the specific construction sites 1-4.

The design includes a composition of 4 volumes organized paired in two couples, since the construction of Site 4 is meant to be carried out in two phases.





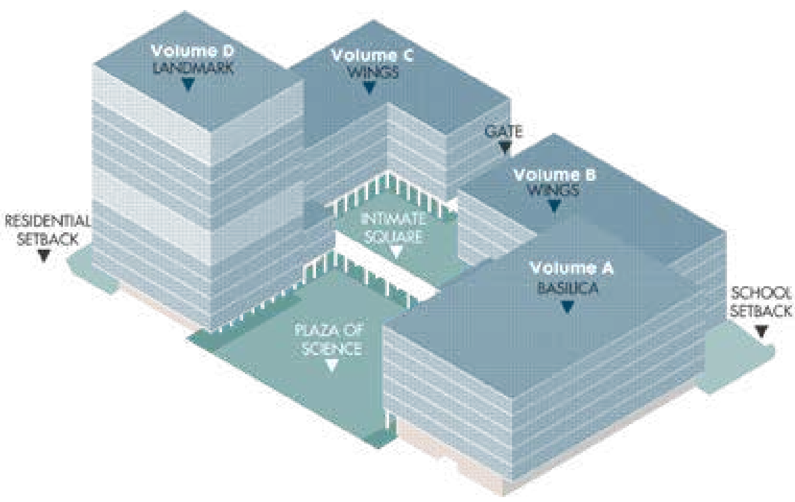
In the first phase, the buildings of organic and inorganic chemistry now located in the north-east side of the plot the will be dismantled, and therefore this side will be developed first, hosting the new Physics, SNI and Anatomy departments, together with new facilities both for the public and for the city. In the second phase all remaining buildings will be dismantled after the buildings of the first phase have been occupied. Parallel to the Klingelbergstrasse, a new building hosting the Chemistry departments, university classrooms, offices and even start-ups spaces will be developed.

The Masterplan

Starting from the idea of developing a complex of buildings as urban catalyser, the design was aimed to create an urban system which could be identified as a part of the city, and therefore characterized by a certain degree of differentiation and variety, yet ensuring a sense of continuity and identity within the system.

Urban plan of Basel showing the location of the construction site within the city.

The built complex, which finally appears to be composed by two macro-buildings, is the result of the elaboration of 4 spatially integrated volumes, defined by taking into account specific reactions to the existing surrounding and urban framework.



The building here indicated as Volume A is the one hosting the physics department as well as many other educational and public facilities.

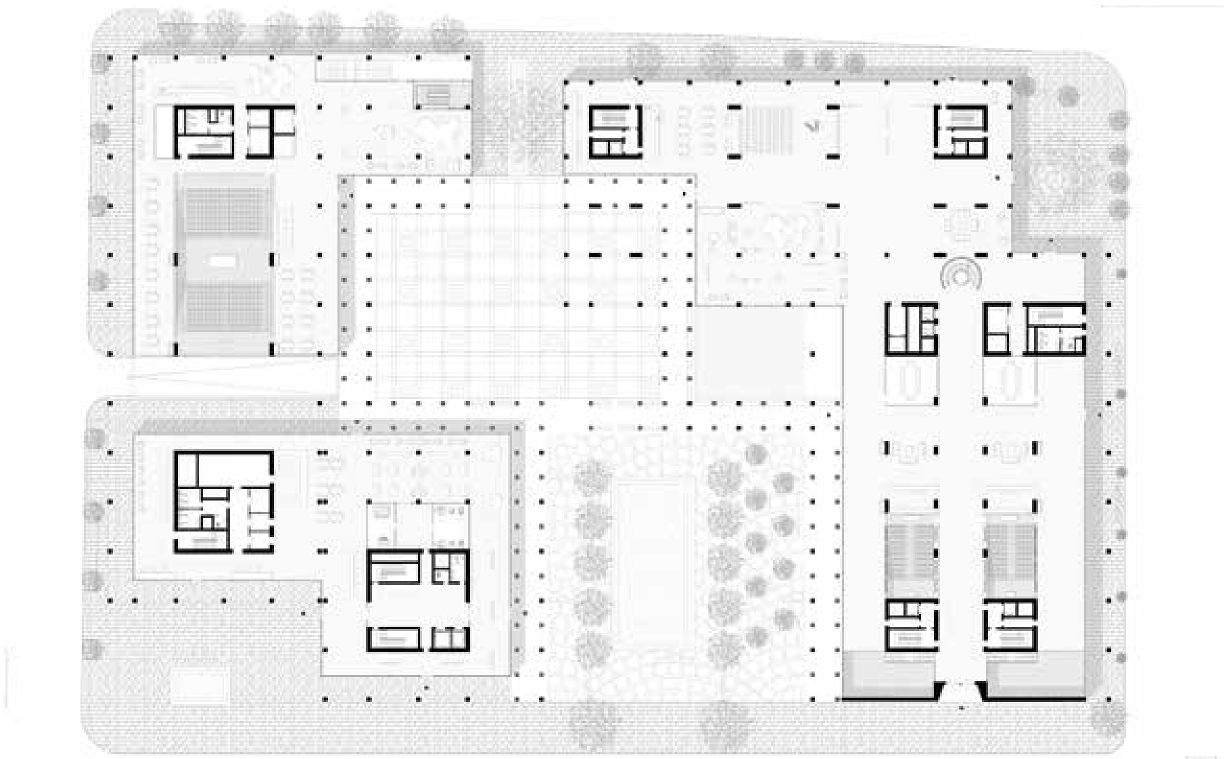
Volume B mainly hosts public facilities at ground floor, the Anatomy museum and the SNI.

Volume C hosts the Chemistry department, partially included also in volume D since the two are linked at some floors.

Volume D mainly hosts public, administrative and educational facilities, especially in the tower.

Variety and Continuity

The sense of variety and complexity defining this elaborated and diversified system derives from its urban role within the city, taking into account the different components that surround the site and that can play a role in the process of innovation and knowledge creation within an urban campus, trying to find suitable spatial solutions to react to each of them. The sense of unity and continuity within the complex, which tried to react not only to the different needs of its numerous users but also to the diversified characteristics of the built surroundings, is researched in different ways.



Architectural ground-floor plan of the project

At ground level is goal is reached through the definition of a continuous public ground marked by a colonnade or portico system, characterizing the facades of the buildings delimiting the "Science Plaza" and its porous borders. Furthermore, this architectural element is also used to defined a sequence of spatial thresholds subdividing the public space into three different spaces, going from a more open to amore intimate space in the axis from the campus towards the residential area.

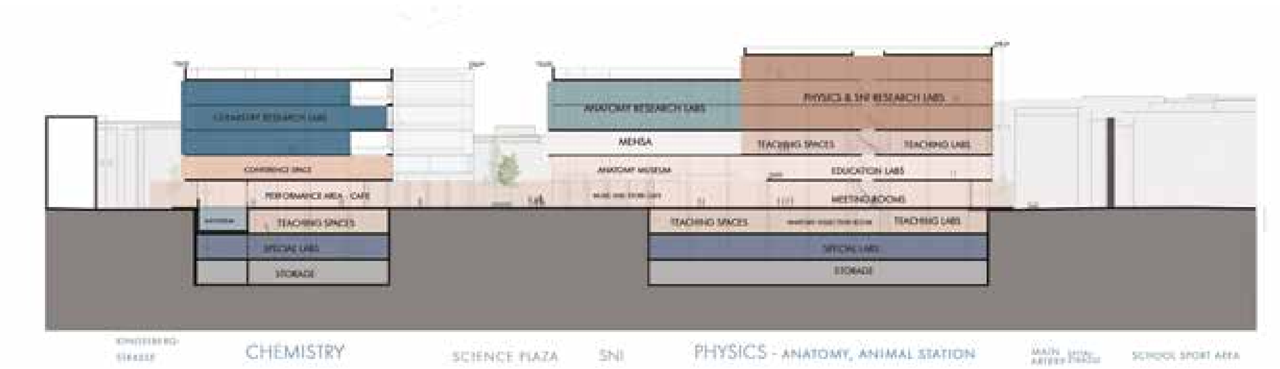
Another element of continuity with the introduction of variations is given by the architectural language chosen in the composition of the facades, which are composed by similar elements clarifying the unique identity, yet such elements are arranged in a series of different compositional schemes.

Finally, the structural system chosen is also homogeneous, including a reinforced concrete columns and beams system supporting solid concrete slabs, organized in a grid with 7.2 meters as main span, with few variations.

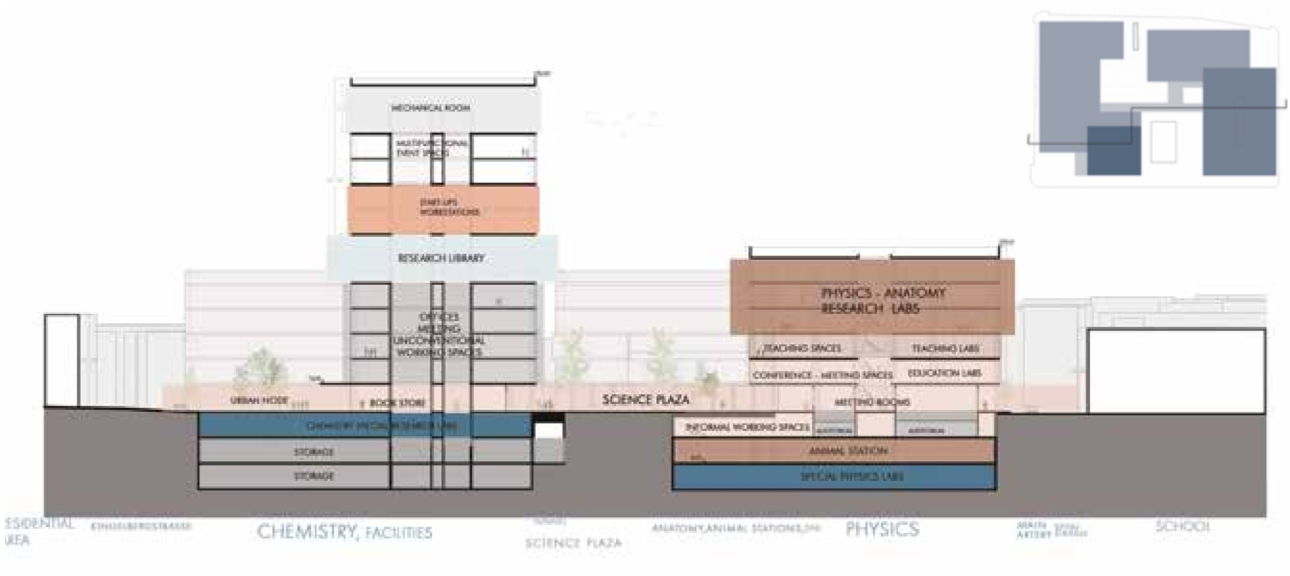
Buildings' layout

For what concerns the layout of interior organization, it is important to say that it was affected by a distribution of the program also in section. The ground-floor of the entire complex, as visible in the ground-floor plan, is kept public, forming a sort of continuous common ground together with the open public space of the Science Plaza.

The first-floor level is also mainly hosting functions accessible by the public, and the same happens to some spaces located in the basement level -1. Ground-floor and first-floor levels then form together a sort of public podium, to which also the second-floor level can be integrated at some degree. Indeed, the second level is mainly dedicated to educational functions, therefore creating a first threshold between spaces open to the public and spaces for students or professors.

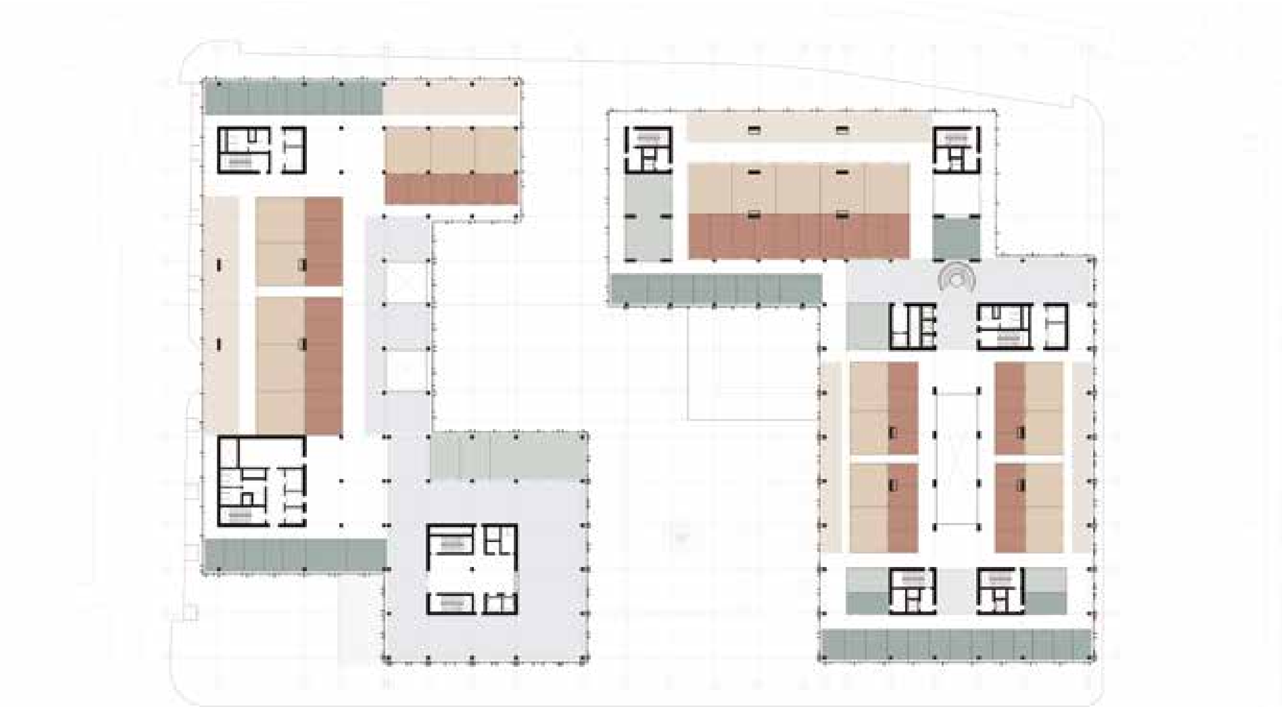


These sections show how the upper floors define another threshold of privacy as they are mainly dedicated to the laboratories of the correspondent departments, and therefore they are accessible only to the people provided with specific badge. The upper floors of the tower host a variety of sections, from offices and meeting rooms up to a library and start-ups spaces. The layout of the tower needs to be quite simple and flexible since has to be adapted to different functions.



Third floor level diagrams

CIRCULATION CORE FACILITIES PREPARATION AREAS



LAB DESKS BENCH LABS SUPPORT LABS FOOD FACILITIES CLASSROOMS MEETING ROOMS OFFICES INFORMAL MEETING AND WORKING SPACES

3.

Main focus structure

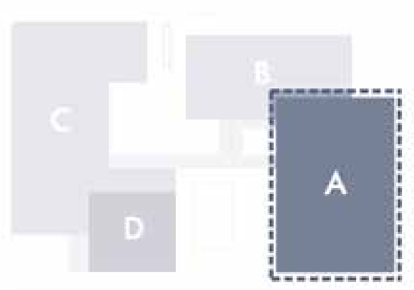
BASILICA BUILDING

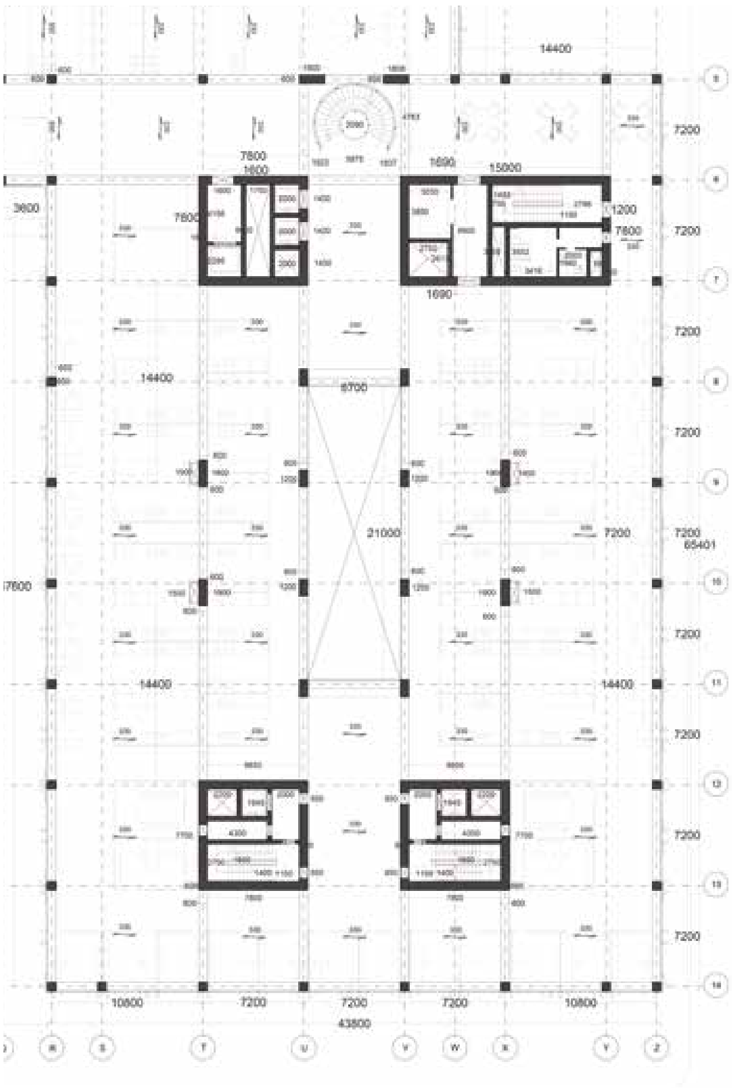
General description

In the further investigation related to structural analysis and design, one of the four volumes is selected. As indicated by the structural drawings, the volumes A and B, characterized by a unique structure, are subjected to greater attention, with focus on volume A.

The structure of volume A is based on a symmetrical grid, in which the span among supports on the longitudinal side is constant and equal to A=7.2 meters.

The supports along the short side are instead symmetrically organized according to an ABBBA rhythm, with B=10.8 meters.





Level +23.20m structural plan overlapped with architectural plan (Laboratory type floor plan)

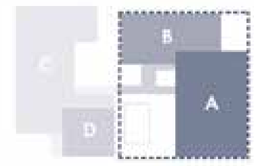
Continuously supported beams are mainly longitudinally laid along the naves of what can be defined as a "Basilica Plan" or a "Lichthof Type" building.

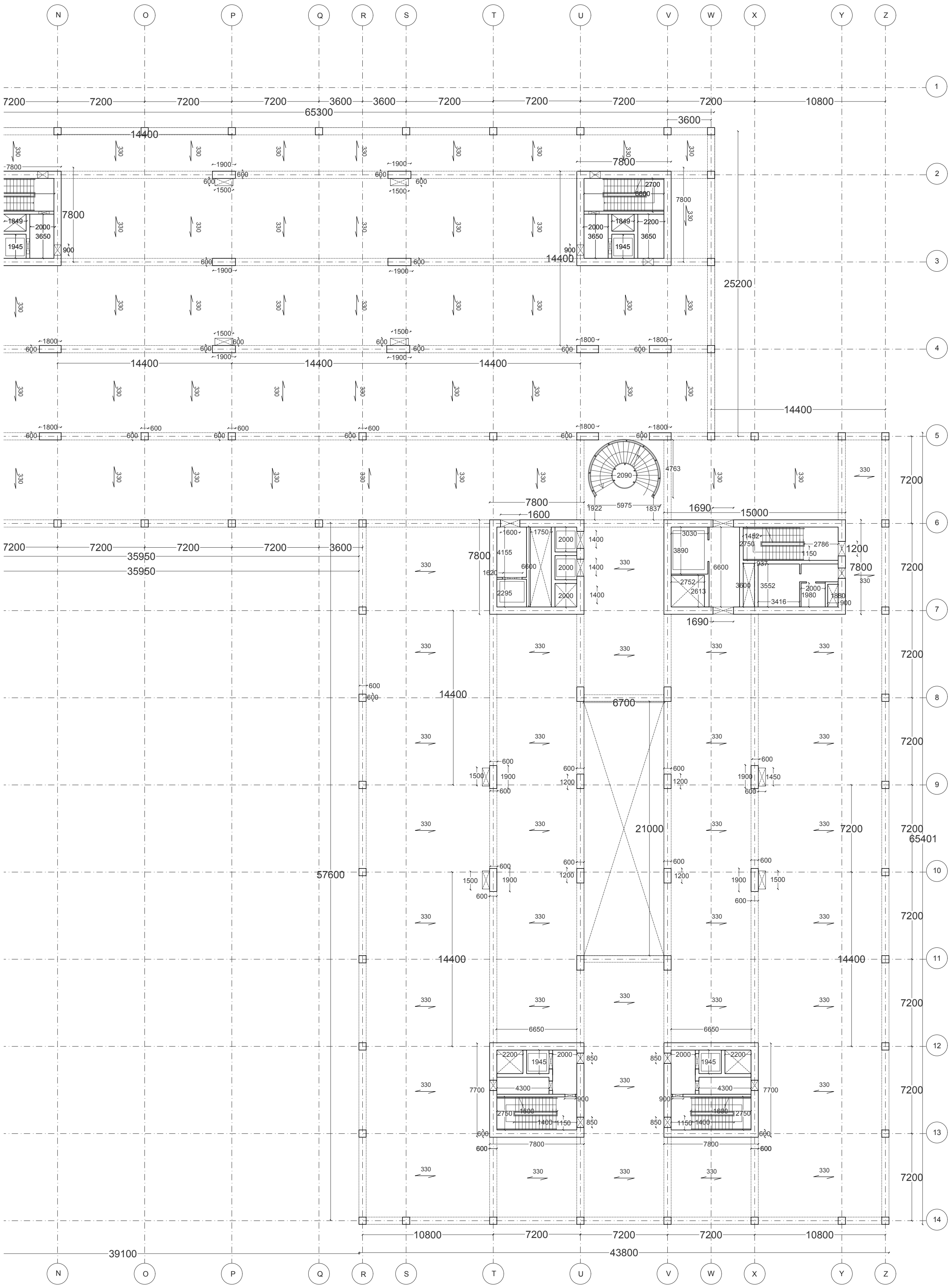
Continuously supported beams are laid transversally along the perimeter and in correspondence of the cores and when double heights are introduced, to create the voids.

Furthermore, one-way reinforced-concrete slabs laid transversally to the longitudinal beams.

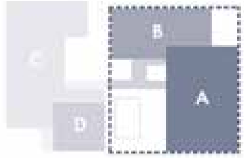
Within the system it is also possible to identify some longitudinal columns, four of which are associated to cavities meant to host the shafts needed to support the laboratories, while the other eight are meant to underline the longitudinal tension characterizing the layout.

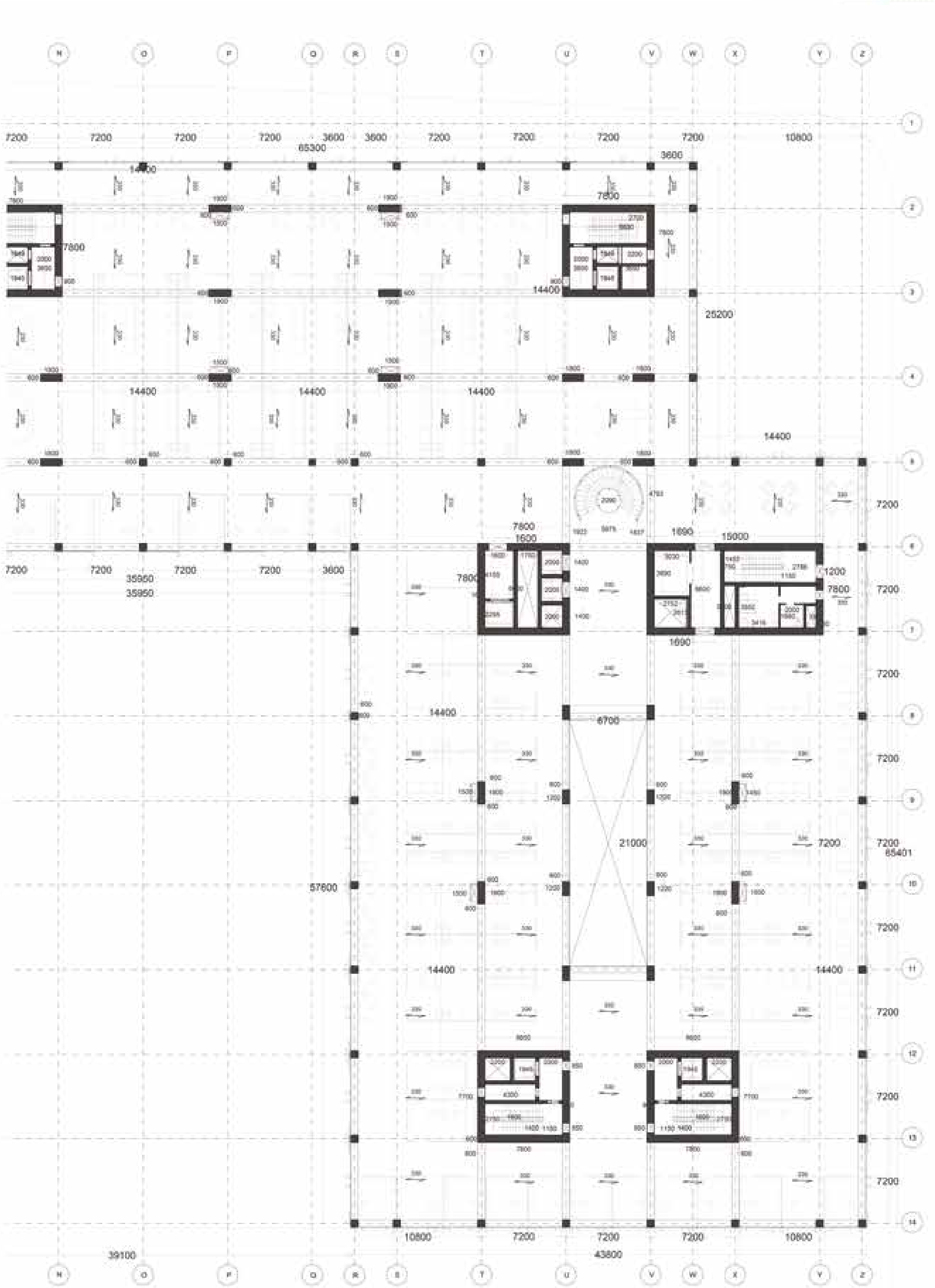
Level +23.20m structural plan overlapped with architectural plan (Laboratory type floor plan)



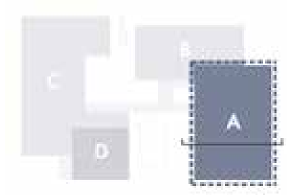


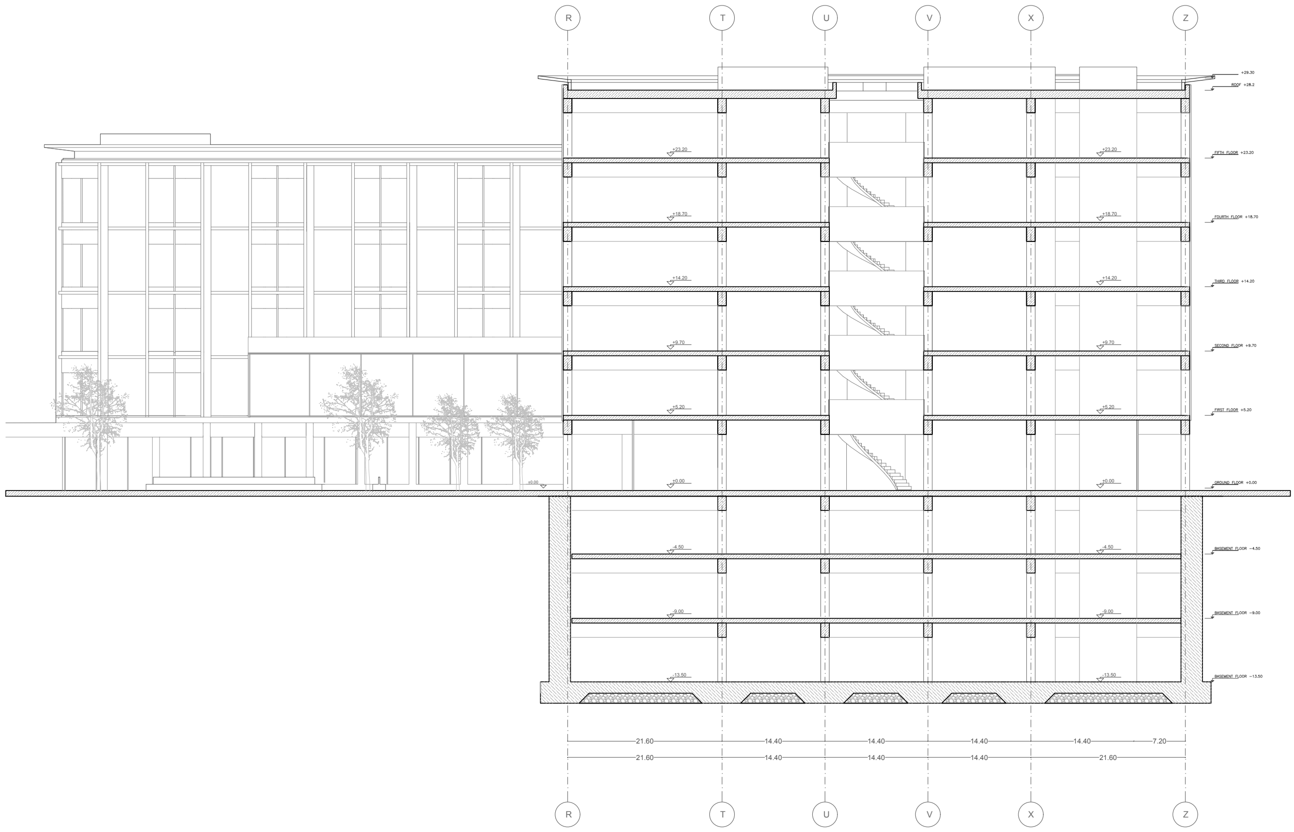
Level +23.20m structural plan overlapped with architectural plan (Laboratory type floor plan)



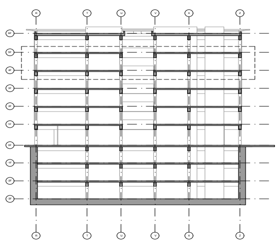


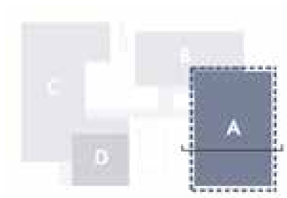
Structural section of volume A (with volume B in view)

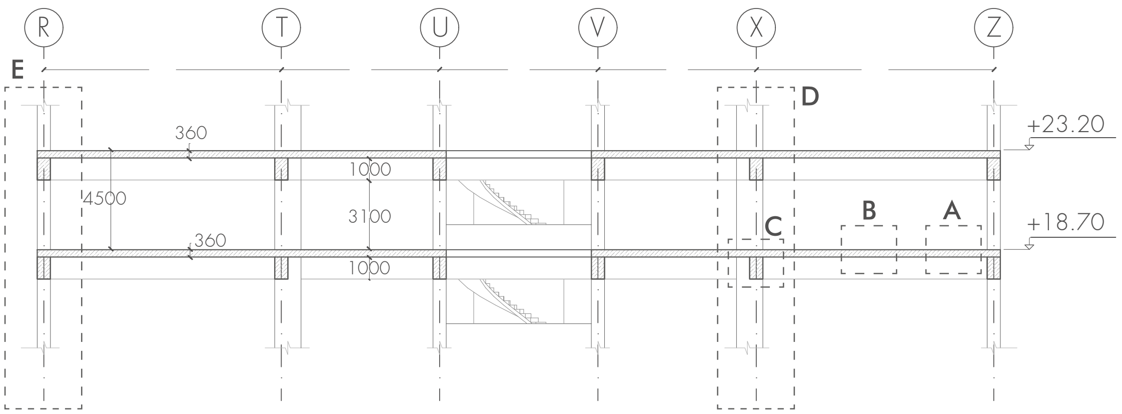




Structural section of volume A (Laboratory type zoom in)



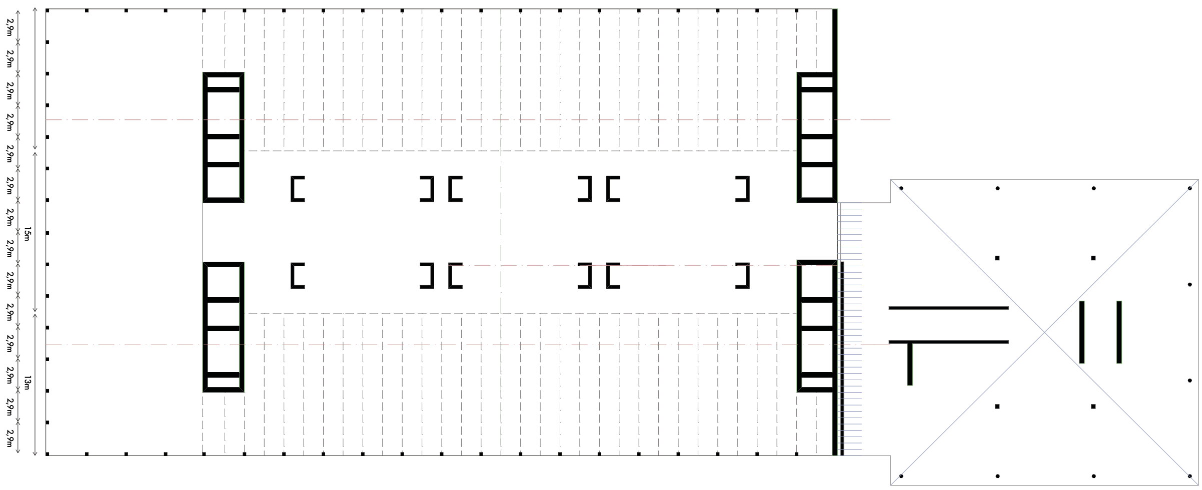


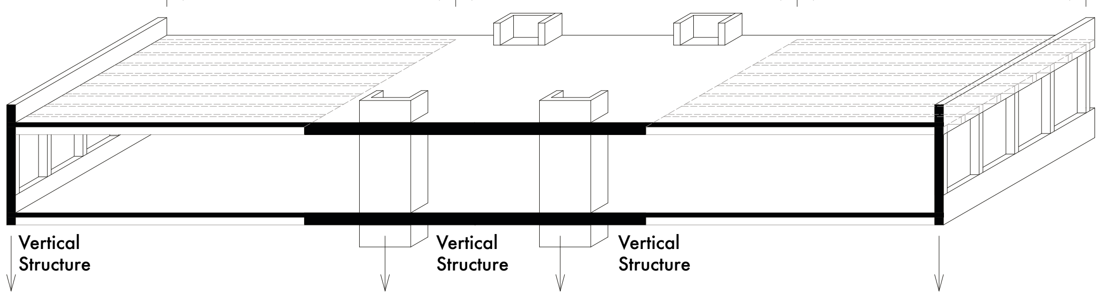


COMPARATIVE ANALYSIS

Structural solutions in similar buildings: Biomedicine Department of Basel, design by Caruso St John Architects

One of the buildings considered by us as a reference for the structural design of the focus building was the design proposal for the new Biomedicine department of Basel. The entire supporting structure of the system is created in concrete, which is particularly typical in the Swiss context. This material is used as a load bearing and space-forming material. The entire structure is constructed as a conventional building structure and follows an orthogonal grid. The prefabricated ribbed panels as light ceilings are connected monolithically with an over-concrete and thereby enable the pane effect for horizontal stabilization.





From this reference we tried to derive basic structural design criteria, starting from its regular orthogonal grid, according to which the structural elements are distributed. Since the University of Basel indicated the basic laboratory units of the Biomedicine department as reference for the organization of the lab modules, we had the goal of defining spans of at least 13 meters free from structural elements in order not to interrupt the laboratory space and obtain a flexible design.

According to such reasoning, we defined a building initially characterized by "five spatial naves", as in the Biomedicine Department, allowing for both central and perimeter circulation paths around the laboratories, yet enriching the initial reference with the opening of a central void.

Due to the large need of shafts and other technical spaces to serve these type of laboratory buildings, we considered to introduce structural elements within the lab areas, combined with technical cavities, always with reference to the Biomedicine department. However, due to the great variety of functions present in the building at the different floors and due to our intention to vary the internal layout within the three more public levels with respect to the lab floors, we introduced less cavities with respect to the reference building.

The design of the cores was eventually designed in such a way to create a balanced layout, also exploiting their location to create sorts of thresholds or "buffer zones" dividing the different programs, similarly to what occurs in Caruso's design.

- *4 service cores of which 2 detached from edges*
- *No internal core*

- *4 service cores detached from edges*
- *Internal core*

Comparison by the Biomedicine Department Design proposal by Caruso St John Architects (left figure) and our design proposal for Schallematteli Campus's Physics Building. (Laboratory type floor plan)

4.

Preliminary dimensions

PRELIMINARY DIMENSIONS

General calculations

The preliminary design of the structural elements was carried out according to the spans underlined by the structural plan. The dimensioning of the height of beams and slabs is based on the biggest span. The biggest span is 10.8 m, hence the height of the slab and the beam are estimated as follows:

Pre-Dimensioning of beam
Since the biggest span is 10.8 m, hence the height of the continuous beam is estimated as:
$h_{beam} = L_{max}/12$; h_{beam} = 10.8/12 [m];
h_{beam} =0.9 m

Pre-Dimensioning of slab
the initial height is calculated by dividing the smaller span by 20;

$h_{slab} = L_{min}/ 20$ = 7.2 /20 [m];
h_{slab} = 0.36 m

Or by dividing the bigger span by 20;
$h_{slab} = L_{max}/ 30$ = 10.8 /30 [m];
h_{slab} = 0.36 m

Pre-Dimensioning of cantilever beam
$h_{cant. beam}$ = L/ 5 = 2.5/5 [m];
$h_{cant. beam}$ = 0.5 m

5.

Materials

MATERIAL SPECIFICS

Initial considerations

The preliminary design of the structural elements was carried out according to the spans underlined by the structural plan. The dimensioning of the height of beams and slabs is based on the biggest span. The biggest span is 10.8 m, hence the height of the slab and the beam are estimated as follows:
The materials used in the calculations could be concrete type C25/30 and steel type B450C. The material specifics for the concrete:

$f_{cd}=\alpha_{cc} \cdot f_{ck}/\gamma_c = 14167$ kN/m^2

With $\alpha_{cc}= 0,85$
$f_{ck}= 25 \cdot 10^3$ kN/m^2
$\gamma_c= 1,5$

$E_c= 22000 \cdot ((f_{ck}+8)/10)^{0,3}=31,476$ GPa$= 31,476 \cdot 10^6$ kN/m^2
With $f_{ck}=25$ N/(mm^2)

$f_{ctm}=2,56 \cdot 10^3$ kN/m^2

$f_{(ctk,0,05)}=1,80 \cdot 10^3$ kN/m^2

The material specifics for the steel:

Class B:

$f_{yk}=500$ MPa
$\gamma_s=1,15$

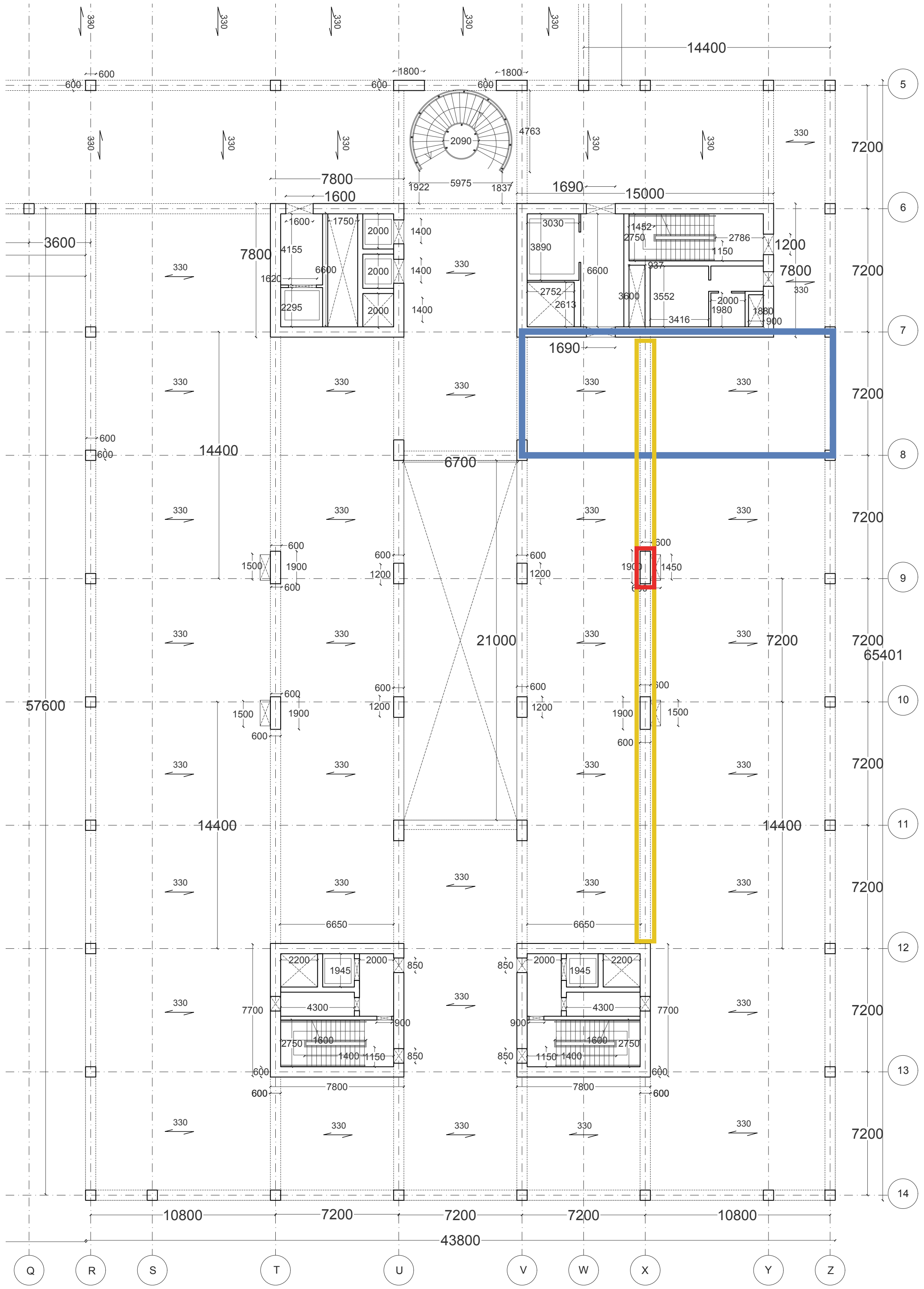
$f_{yd}=f_{yk}/\gamma_s = 391304$ kN/m^2

$E_s=210 \cdot 10^6$ kN/m^2

6.

Interesting components

Selection of one slab, one beam and one column



Level +23.20m structural plan overlapped with architectural plan and identification of interesting elements.
(Laboratory type floor plan)

7.

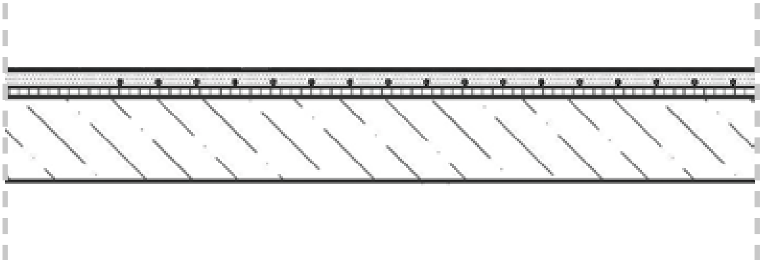
Loads and applied forces

LOADS

Dead Loads

In order to calculate the identified elements, it is necessary to calculate both the dead and live loads acting on the structure. Sine the focus is related to laboratory buildings' structural systems, the selected slab is that located at level +18.70m, constituting one of the ceilings' slabs of the fourth floor, which is a level hosting laboratories and set in between two laboratory floors.

Floor system



1. Epoxy resin coating
2. Cement screed with inserted under floor heating
3. Sound - thermal rock-wool insulation (RW rigid slabs)
4. Solid concrete slab

Index	Material	Specific Weight ɣ [kN/m3]	Thickness d [m]	Formula	Load per unit surface [kN/m2]
1	Epoxy resin coating	/	0,01	/	negligible
2	Cement screed w/ underfloor heating	3,65	0,08	ɣ • d	0,286
3	Impact sound/ thermal rock-wool insulation	1,2	0,4	ɣ • d	0,470
4	Solid Concrete Slab	25	0,36	ɣ • d	9,00
					9,76

The total dead load per unit surface is then $q_{(DL)}=9,76\ kN/m^2$.

Live Loads

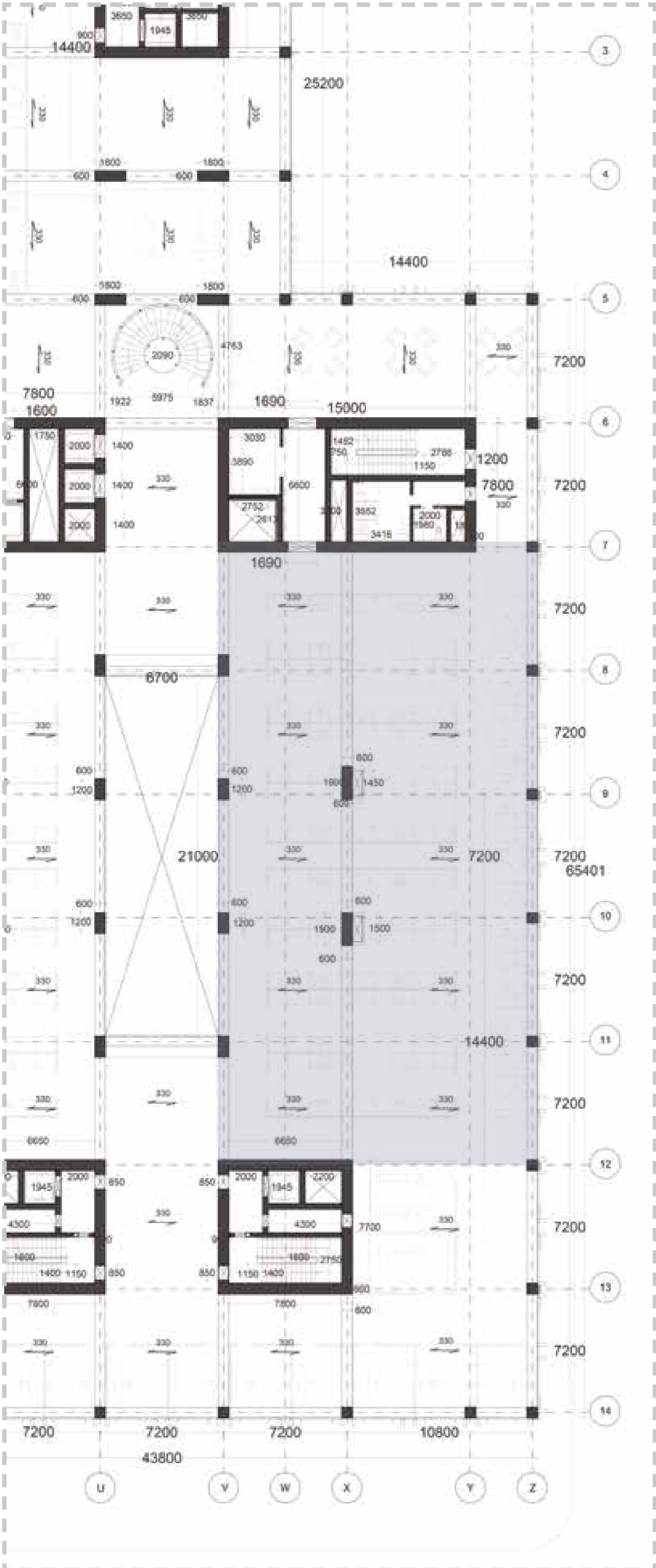
In order to calculate the live load acting on the selected slab it is necessary to refer to the EN-1991 table about building loading in function of the area category.
According to such table, the selected slab, supporting a level hosting physics laboratories, belongs to the category C, which includes areas where people may congregate. In particular, it can be considered in between the Category C1, including for instance schools, since the selected flooring hosts University Laboratories, and the Category C3, including for instance public and administration buildings or hospitals.

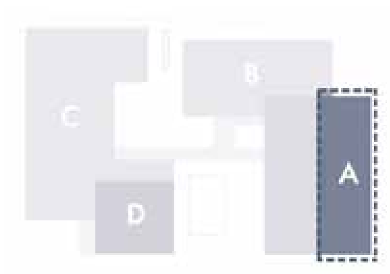
Table 6.1 - Categories of use

Category	Specific Use	Example
A	Areas for domestic and residential activities	Rooms in residential buildings and houses; bedrooms and wards in hospitals; bedrooms in hotels and hostels kitchens and toilets.
B	Office areas	
C	Areas where people may congregate (with the exception of areas defined under category A, B, and D[1])	**C1**: Areas with tables, etc. e.g. areas in schools, cafés, restaurants, dining halls, reading rooms, receptions. **C2**: Areas with fixed seats, e.g. areas in churches, theatres or cinemas, conference rooms, lecture halls, assembly halls, waiting rooms, railway waiting rooms. **C3**: Areas without obstacles for moving people, e.g. areas in museums, exhibition rooms, etc. and access areas in public and administration buildings, hotels, hospitals, railway station forecourts. **C4**: Areas with possible physical activities, e.g. dance halls, gymnastic rooms, stages. **C5**: Areas susceptible to large crowds, e.g. in buildings for public events like concert halls, sports halls including stands, terraces and access areas and railway platforms.
D	Shopping areas	**D1**: Areas in general retail shops **D2**: Areas in department stores

Table 6.2 - Imposed loads on floors, balconies and stairs in buildings

Categories of loaded areas	q_k [kN/m^2]	Q_k [kN]
Category A		
- Floors	1,5 to 2,0	2,0 to 3,0
- Stairs	2,0 to 4,0	2,0 to 4,0
- Balconies	2,5 to 4,0	2,0 to 3,0
Category B	2,0 to 3,0	1,5 to 4,5
Category C		
- C1	2,0 to 3,0	3,0 to 4,0
- C2	3,0 to 4,0	2,5 to 7,0 (4,0)
- C3	3,0 to 5,0	4,0 to 7,0
- C4	4,5 to 5,0	3,5 to 7,0
- C5	5,0 to 7,5	3,5 to 4,5
category D		
- D1	4,0 to 5,0	3,5 to 7,0 (4,0)
- D2	4,0 to 5,0	3,5 to 7,0





Level +18.70m structural plan overlapped with architectural plan-portion of interest.

The area of interest host laboratory units belonging to the Physics department of the University of Basel.

It precisely corresponds to the organization of standard units including layered as:

- Laboratory desks
- Corridor
- Bench Labs
- Support Labs
- Corridor

The choice of the use category for the identification of the applied loads is among the category C1 (Schools) and category C3 (hospitals and administration buildings)

The corresponding loads are:

C1
q_k=2,0 to 3,0 kN/m^2
Q_k=3,0 to 4,0 kN

C3
q_k=3,0 to 5,0 kN/m^2
Q_k=4,0 to 7,0 kN

Therefore, we select as live load per unit of surface an average value of:

q_k=4,0 kN/m^2

Load combination

Various combinations of the characteristic values of permanent Gk, variable actions Qk, wind actions Wk, etc. and their respective partial factors of safety must be considered for the loading of structures.

Permanent and variable actions: $1{,}35\ G_k + 1{,}5\ Q_k$

Considering the following values for the dead loads (g_k) and live loads (q_k), we carry out the load combination:

$g_k = 9{,}76\ \text{kN/m}^2$

$q_k = 4{,}0\ \text{kN/m}^2$

$$w = 1{,}35\, g_k + 1{,}5 q_k = (1{,}35 \cdot 9{,}76\ \text{kN/m}^2) + (1{,}5 \cdot 4{,}00\ \text{kN/m}^2) = 13{,}2\ \text{kN/m}^2 + 6{,}0\ \text{kN/m}^2 = $$
$$= 19{,}2\ \text{kN/m}^2$$

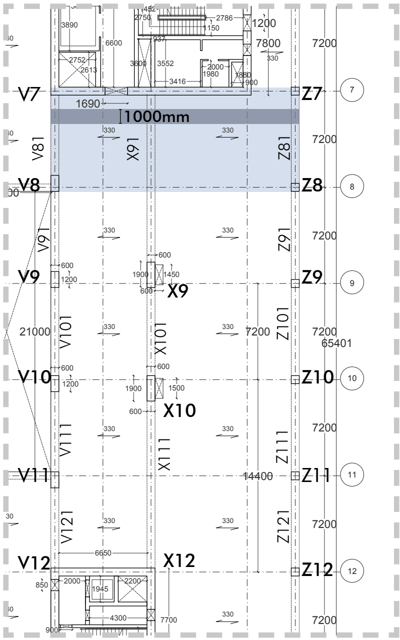
8.

Slab design

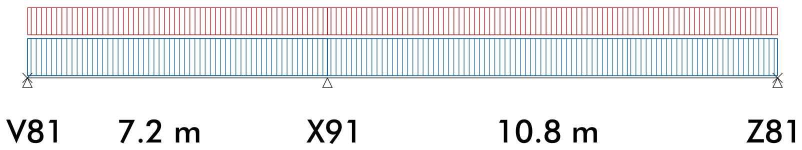
SLAB DESIGN

Load scheme

As next step, we proceed to calculate the RC slab. In order to do so, we consider to take a portion of 1m of slab, and we calculate the internal forces acting in the slab by considering it as a beam with 1 meter of thickness, and thanks to the use of a software for the analysis of continuous beams.
Such software is named **cesdb**, and we used its **cba-continuous beam analysis application**.



In the software we design the two spans of 7.20 meters and 10.8 meters. Two of the three supports, the ones at the extremes, are considered to be fixed, while the one intermediate one is considered to be a simple support.

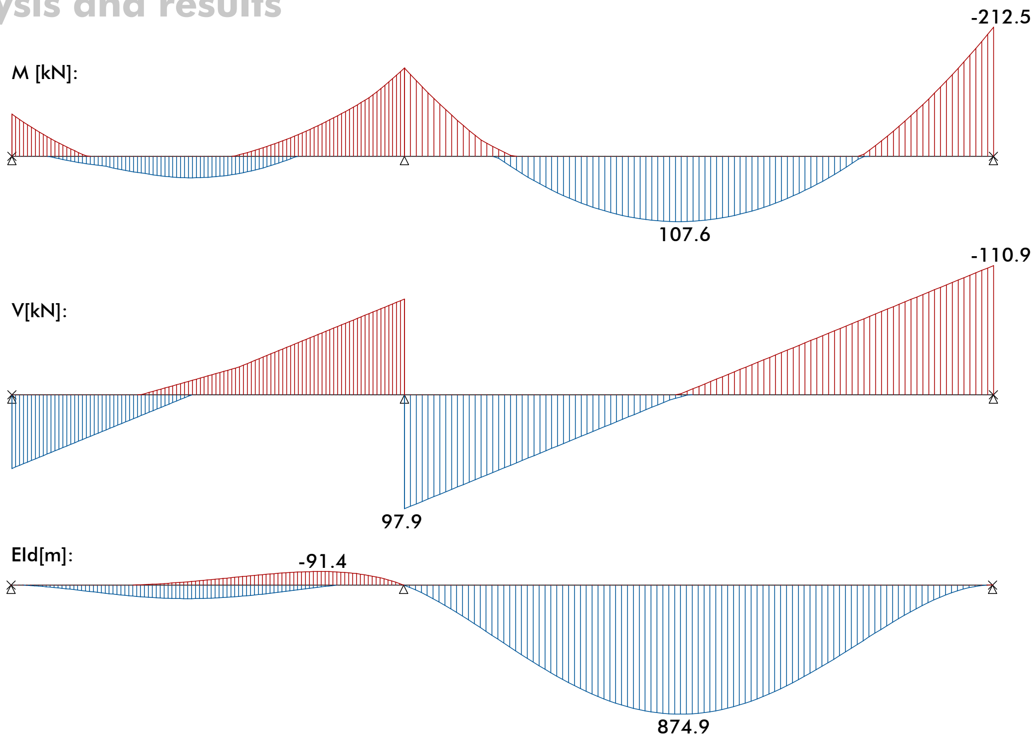


On both span we apply the values of the dead loads and live loads obtained from the previous load combination:

gk= 13,2 kN/m; and qk=6,0 kN/m

With linearly distributed values since we consider a 1m portion of the slab.

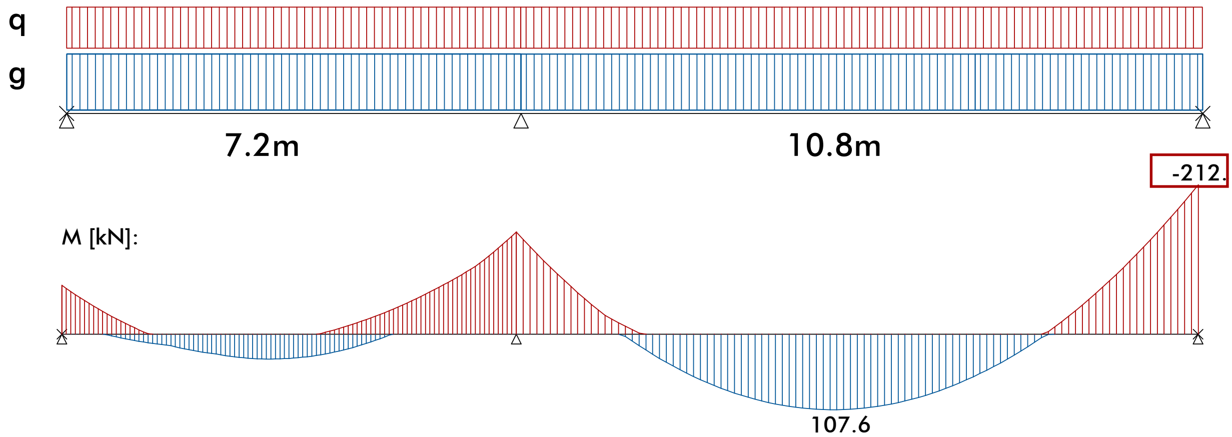
Analysis and results



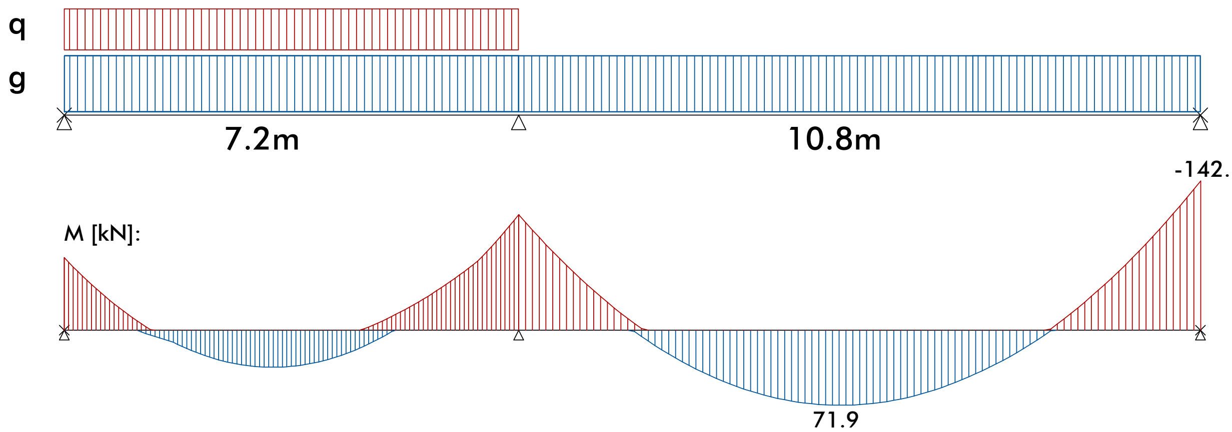
Comparison of different load conditions

Before proceeding with the calculations, different loading conditions were compared trying to vary the distribution of the live loads on the selected slab. However, the maximum values of bending moment is still the one obtained in the initial case, in which the live loads are applied on both spans.

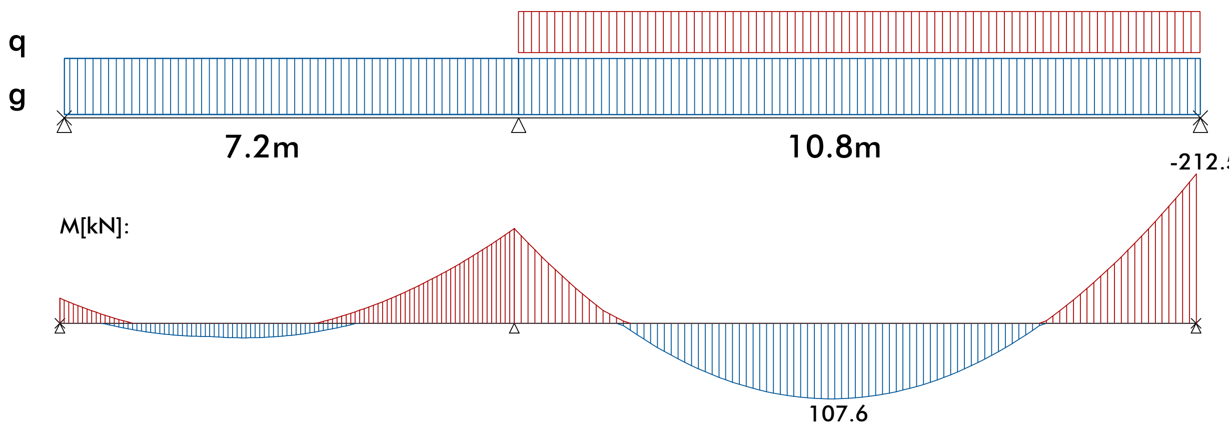
LOAD CONDITION 1: Live loads distributed on both spans



LOAD CONDITION 2: Live loads distributed on the 7.2m span only



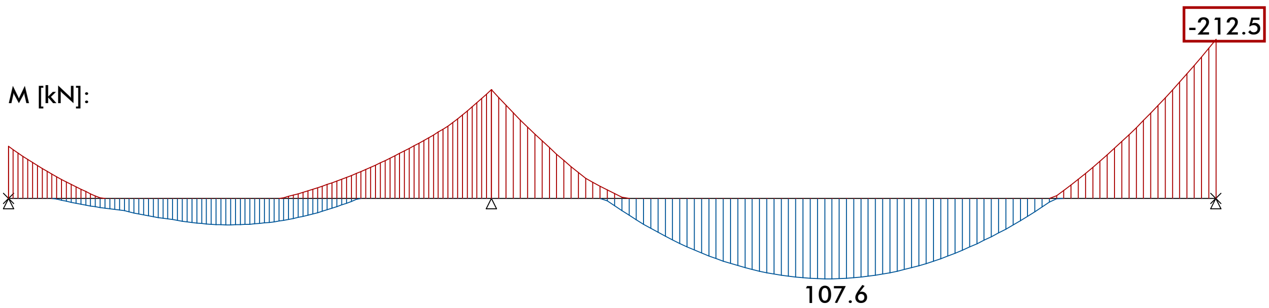
LOAD CONDITION 3: Live loads distributed on the 10.8m span only



SLAB DESIGN CALCULATIONS

Maximum bending moment at support

We design a RC slab with total h=330mm, with effective slab being d=300mm, and with concrete cover=22mm and with φ/2=8mm.



Starting from the results obtained from the Bending Moment diagram in the explicated loading conditions, we obtained that the maximum bending moment at a span is: $\boldsymbol{M_{max,span} = 107.6\ kNm}$,
While the maximum bending moment at a support is: $\boldsymbol{M_{max,supp} = 212.5\ kNm}$.
Starting from the higher value, we proceed with the calculations:

$$\boldsymbol{M_{max,supp} = 212.5\ kNm.}$$

$$\mathbf{1.}\ \boldsymbol{Bending\ Reinforcement}: \quad \boldsymbol{K = \frac{M}{f_{ck}bd^2} = \frac{212.5x10^6\ Nmm}{25Nmm^2x\ 1000mm\ x\ (300mm)^2} = 0.094}$$

We can than verify that $\boldsymbol{K < K_{bal}}$ with $\boldsymbol{K_{bal} = 0.167}$

$$\mathbf{2.}\ \boldsymbol{Lever - arm}: \quad \boldsymbol{z = l_a * d = 0,91 * 300\ mm = 273\ mm}$$

With e $\boldsymbol{l_a = 0.5 + \sqrt{0,25 - \frac{K}{1.134}}}$

$$\mathbf{3.}\ \boldsymbol{Reinforcement}: \quad \boldsymbol{A_s = \frac{M}{0.87f_{yk}z} = \frac{212.5x10^6}{0.87\ x\ 500x\ 273} = 1789\ mm^2/m}$$

$$\mathbf{4.}\ \boldsymbol{Reinforcement\ ratio}: \quad \boldsymbol{\rho = \frac{A_s}{bd} = \frac{1789\ mm^2/m}{1000\ mm\ x\ 300\ mm} = 0.60\%}$$

Tension reinforcement for the slab at supports

Since the area of a **16mm** bar is given by the formula $A_{rebar} = \frac{\pi\varphi^2}{4} = \boldsymbol{201mm^2}$, then we obtain the number of re-bars by calculating $\frac{A_s}{A_{rebar}} =$ **9 ϕ16=1809mm²** every 10cm.

Bar areas and perimeters

Table A.1 Sectional areas of groups of bars (mm²)

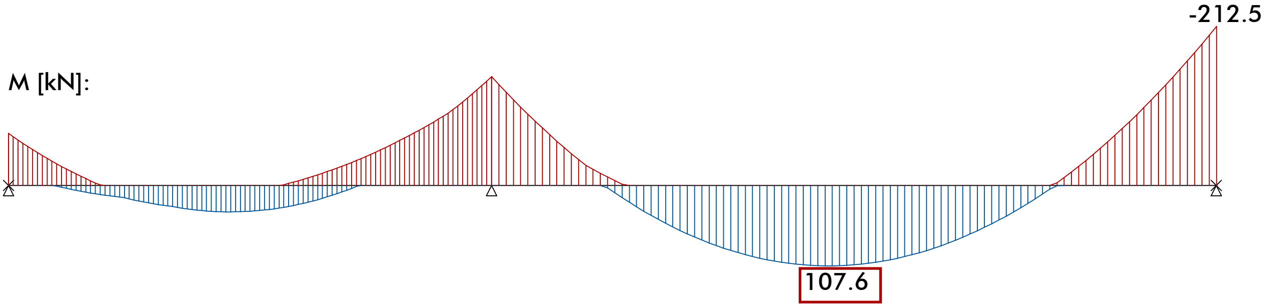
Bar size (mm)	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

Table A.3 Sectional areas per metre width for various bar spacings (mm²)

Bar size (mm)	Spacing of bars								
	50	75	100	125	150	175	200	250	300
6	566	377	283	226	189	162	142	113	94
8	1010	671	503	402	335	287	252	201	168
10	1570	1050	785	628	523	449	393	314	262
12	2260	1510	1130	905	754	646	566	452	377
16	4020	2680	2010	1610	1340	1150	1010	804	670
20	6280	4190	3140	2510	2090	1800	1570	1260	1050
25	9820	6550	4910	3930	3270	2810	2450	1960	1640
32	16100	10700	8040	6430	5360	4600	4020	3220	2680
40	25100	16800	12600	10100	8380	7180	6280	5030	4190

Maximum bending moment at span

We design a RC slab with total h=330mm, with effective slab being d=300mm, and with concrete cover=24mm and with φ/2=6mm.



Calculations are carried out again, considering the maximum span at span:

$$M_{max,span} = 107.6\ kNm.$$

$$1.\ Bending\ Reinforcement: \quad K = \frac{M}{f_{ck}bd^2} = \frac{107.6x10^6\ Nmm}{25Nmm^2 x\ 1000mm\ x\ (300mm)^2} = 0.048$$

We can than verify that $K < K_{bal}$ with $K_{bal} = 0.167$

$$2.\ Lever-arm: \quad z = l_a * d = 0,96 * 300\ mm = 288\ mm$$

With e $l_a = 0.5 + \sqrt{0,25 - \frac{K}{1.134}}$

$$3.\ Reinforcement: \quad A_s = \frac{M}{0.87 f_{yk} z} = \frac{107.6x10^6}{0.87\ x\ 500x\ 288} = 858,9\ mm^2/m$$

$$4.\ Reinforcement\ ratio: \quad \rho = \frac{A_s}{bd} = \frac{858,9\ mm^2/m}{1000\ mm\ x\ 300\ mm} = 0.29\%$$

Tension reinforcement for the slab at span

Since the area of a 12mm bar is given by the formula $A_{rebar} = \frac{\pi\varphi^2}{4} = 113mm^2$, then we obtain the number of re-bars by calculating $\frac{A_s}{A_{rebar}}$ = **8 ф12=904mm²** every 12,5 cm.

Bar areas and perimeters

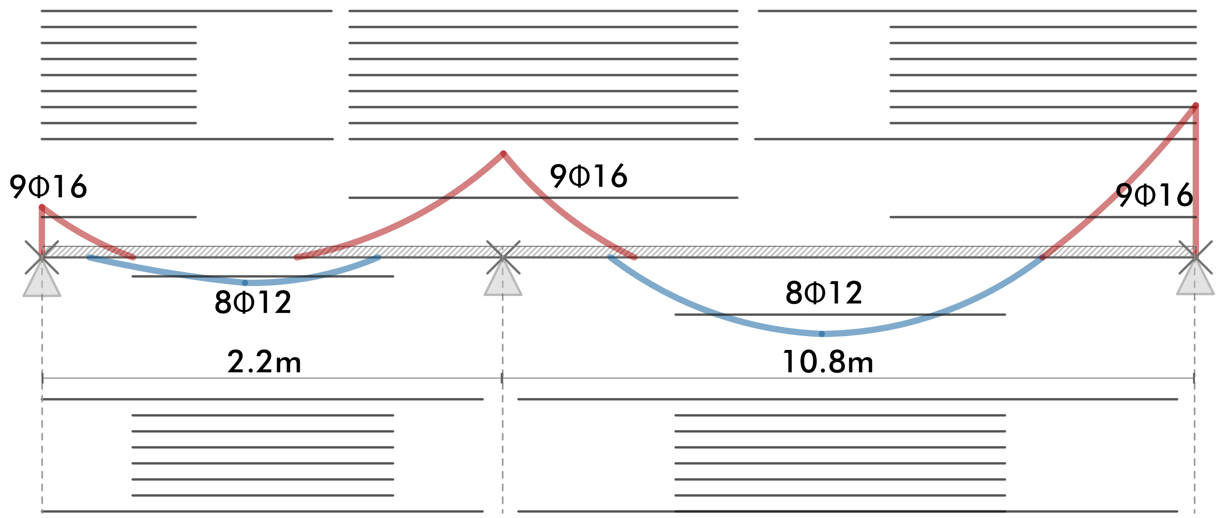
Table A.1 Sectional areas of groups of bars (mm²)

Bar size (mm)	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

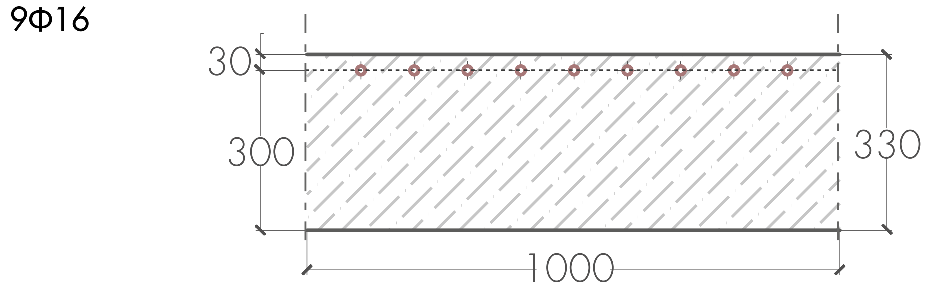
Table A.3 Sectional areas per metre width for various bar spacings (mm²)

Bar size (mm)	Spacing of bars								
	50	75	100	125	150	175	200	250	300
6	566	377	283	226	189	162	142	113	94
8	1010	671	503	402	335	287	252	201	168
10	1570	1050	785	628	523	449	393	314	262
12	2260	1510	1130	905	754	646	566	452	377
16	4020	2680	2010	1610	1340	1150	1010	804	670
20	6280	4190	3140	2510	2090	1800	1570	1260	1050
25	9820	6550	4910	3930	3270	2810	2450	1960	1640
32	16100	10700	8040	6430	5360	4600	4020	3220	2680
40	25100	16800	12600	10100	8380	7180	6280	5030	4190

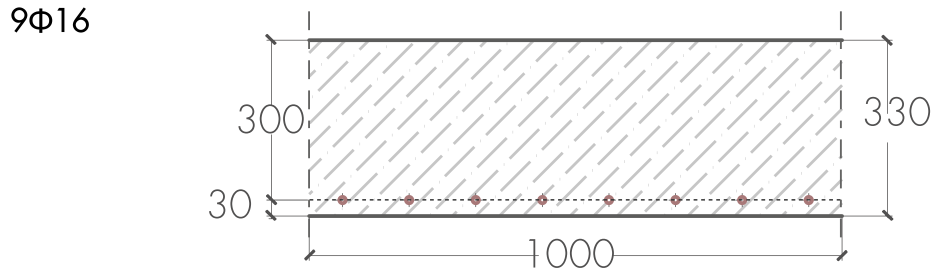
Selected slab cross section and reinforcement design



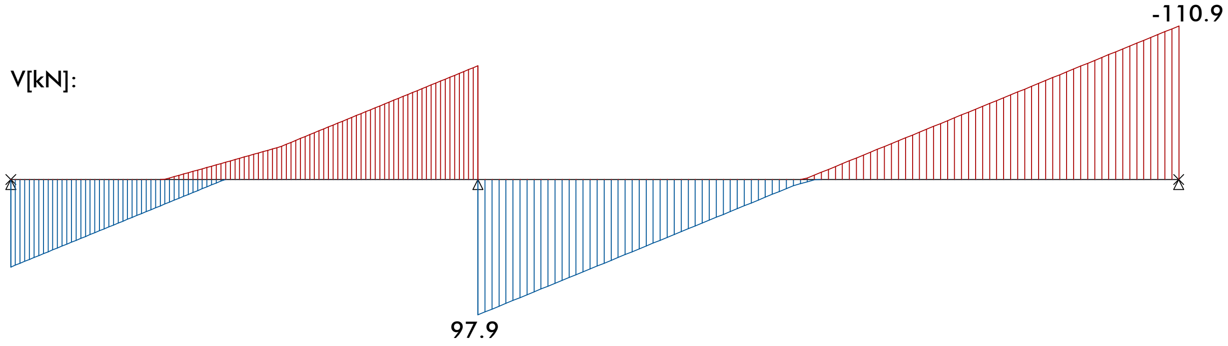
Cross section of the slab near supports



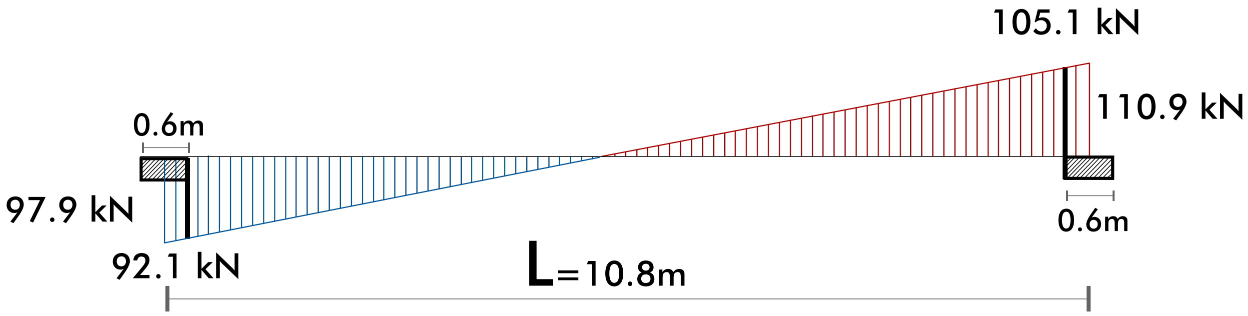
Cross section of the slab at span



Shear reinforcement for the slab at support



The shear force at support is **V_{max}=110,9 kN.** Graphically, it is possible to determine the value of the maximum shear the the inner face of the support, which in this case is **V_{Ed}=105,1 kN.**

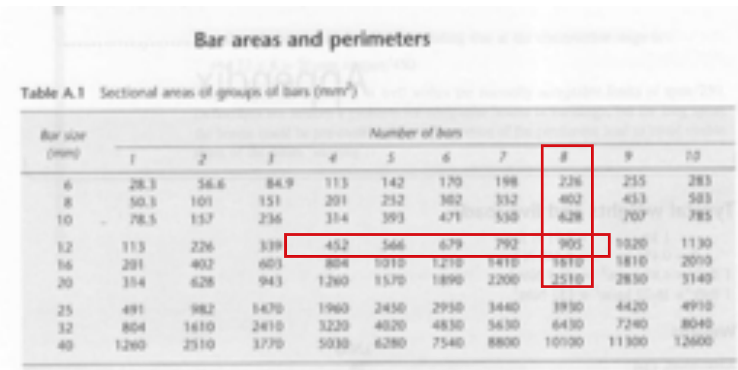


Shear resistance: $V_{(Rd,c)}=v_{(Rd,c)} \cdot b \cdot d$=0,55 N/mm^2 x 1000mm x 300mm=165kN

(With **$v_{(Rd,c)}$= 0,55** being the strength of concrete in shear)

Since **$V_{(Ed)} < V_{(Rd,c)}$,then no reinforcement is needed.**

Therefore, we use only the minimum reinforcement, which in this case is 0,13%
Distribution steel: $A_{(s,distribution)}=0{,}0013 \cdot b \cdot d$=0,0013 x 1000mm x 300mm=390 (mm^2)/m



Bar areas and perimeters

Table A.1 Sectional areas of groups of bars (mm²)

Bar size (mm)	Number of bars 1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

Using the table we decide to provide **4 φ12= 452 mm^2**, every 25cm.

9.

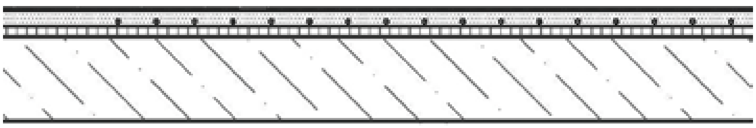
Beam design

LOADS

Dead Loads: calculation considering the updated slab

In order to calculate the identified elements, it is necessary to calculate both the dead and live loads acting on the structure. Sine the focus is related to laboratory buildings' structural systems, the selected slab is that located at level +18.70m, constituting one of the ceilings' slabs of the fourth floor, which is a level hosting laboratories and set in between two laboratory floors.

Floor system



1. Epoxy resin coating
2. Cement screed with inserted under floor heating
3. Sound - thermal rock-wool insulation (RW rigid slabs)
4. Solid concrete slab

Index	Material	Specific Weight ɣ [kN/m3]	Thickness d [m]	Formula	Load per unit surface [kN/m2]
1	Epoxy resin coating	/	0,01	/	negligible
2	Cement screed w/ underfloor heating	3,65	0,08	ɣ • d	0,286
3	Impact sound/ thermal rock-wool insulation	1,2	0,4	ɣ • d	0,470
4	Solid Concrete Slab	25	0,33	ɣ • d	8,25
					9,00

The total dead load per unit surface is then $q_{(DL)}=9{,}00$ kN/m^2 .

Live Loads

The former considerations regarding live loads remain unchanged, therefore, the selected live load per unit of surface has a value of: $q_k=4{,}0$ kN/m^2.

Load combination

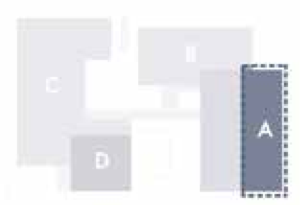
Considering the following values for the dead loads (gk) and live loads (qk), we carry out the load combination:
Permanent and variable actions: 1,35 Gk+1,5 Qk

$g_k = 9{,}00\ \text{kN/m}^2$

$q_k = 4{,}0\ \text{kN/m}^2$

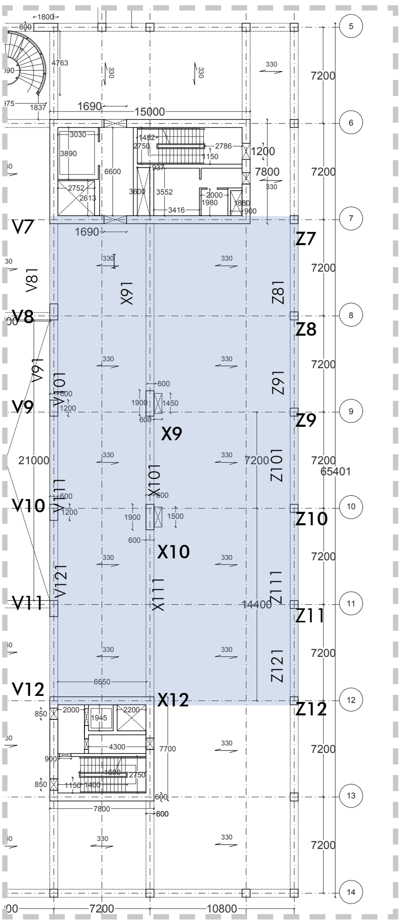
$$w = 1{,}35\, g_k + 1{,}5 q_k = (1{,}35 \cdot 9{,}00\ \text{kN/m}^2) + (1{,}5 \cdot 4{,}00\ \text{kN/m}^2) = 12{,}15\ \text{kN/m}^2 + 6{,}0\ \text{kN/m}^2 =$$
$$= 18{,}15\ \text{kN/m}^2$$

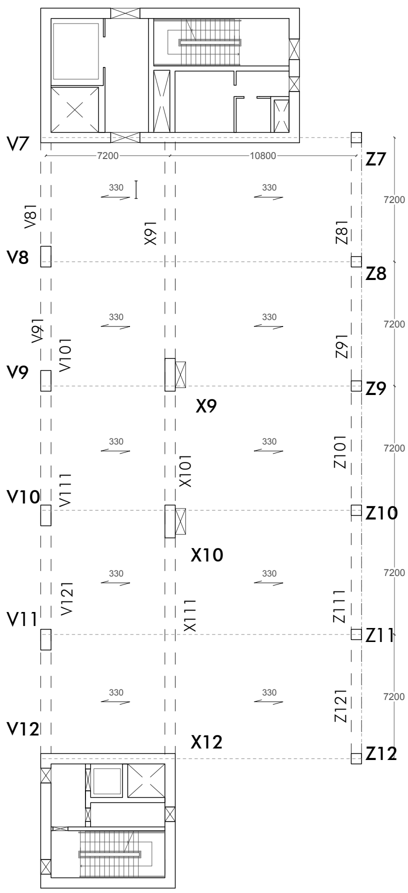
Tributary area

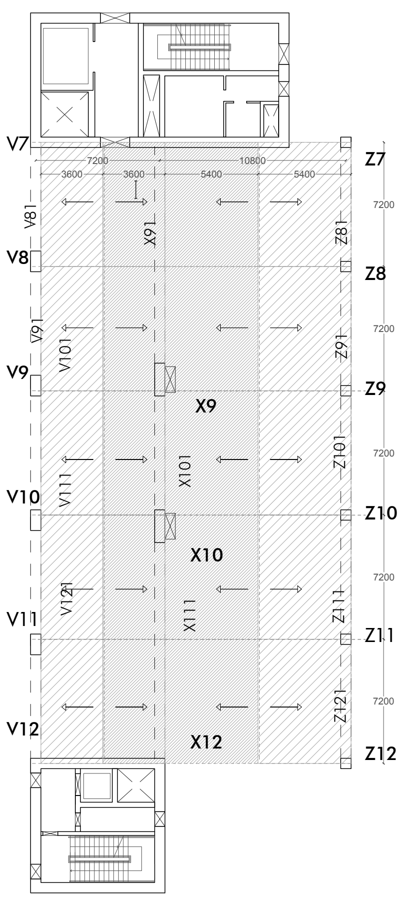


In order to calculate the load acting on one specific beam, in our case the **beam BR** it is necessary to determine calculate the tributary areas transferring the loads on it.

Total load on a beam = floor area supported x magnitude of distributed load on unit surface







Tributary area: [((3,6m+5,4m) x (7.2m x 5))] = **324 m²**
Total load on Beam BR: $G_{k,BR}$= [((3,6m+5,4m) x (7.2m x 5)) x **18.15kN/m²**] = **5880,6 kN**

To go from **kN** to g [**kN/m**] we divide the load by the length.

$$w_{k,BR} = \frac{5880,6\ kN}{(14,4m + 7,2m + 14,4m)} = 163,4\ kN/m$$

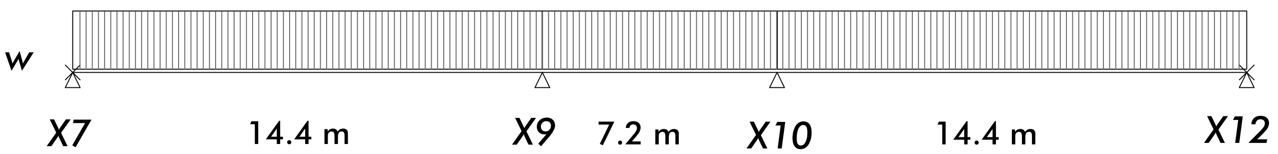
or

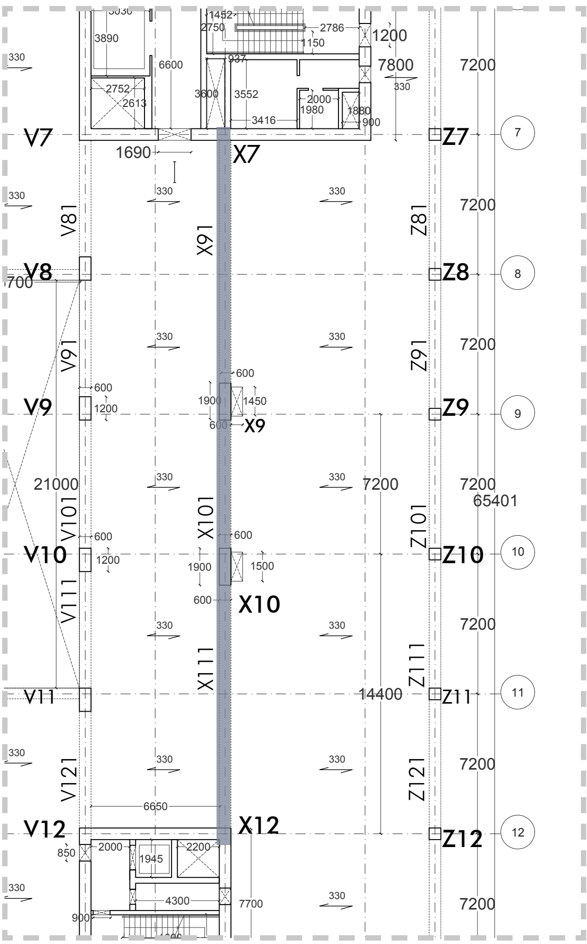
$$w_{k,BR} = 18,15\frac{kN}{m^2 x}\ x\ 9m = 163,4\ kN/m$$

$$g = 12,15\frac{kN}{m^2 x}\ x\ 9m = 109,35\ kN/m$$

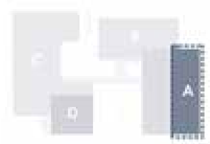
Load scheme

As next step, we proceed to calculate the RC beam, thanks to the use of the cesdb software.





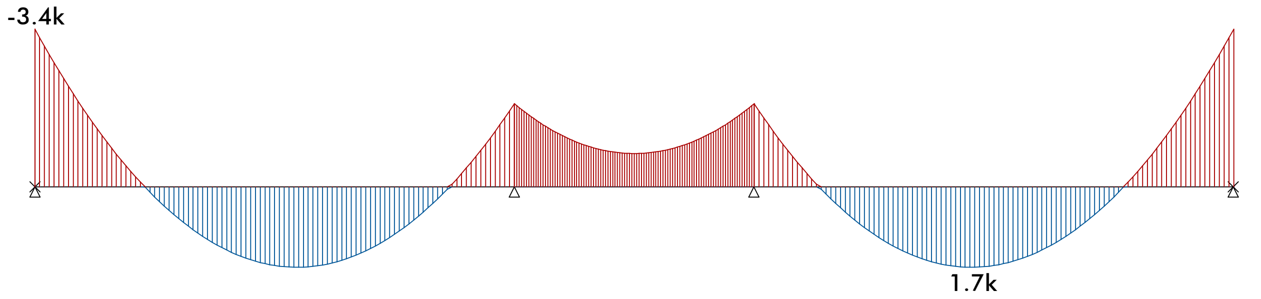
In the software we design the three spans of 14,4 meters, 10.8 meters and 14.4 meters. The two extreme supports are considered to be fixed, while the 2 central supports are not. On both span we apply the value of the loads obtained from the previous load combination:



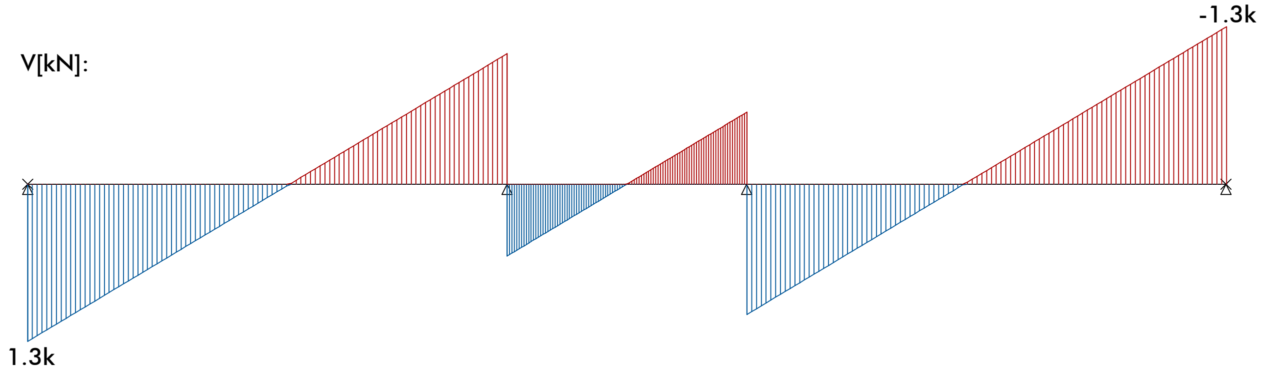
$w_{k,BR}$=163,4 kN/m

Analysis and results

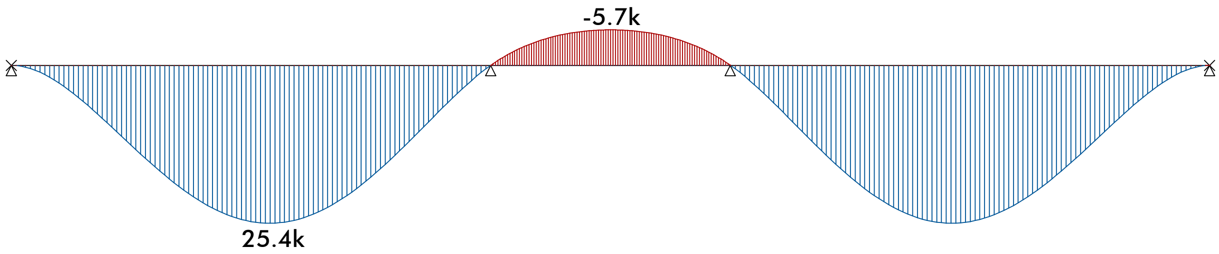
M [kN]:



V[kN]:

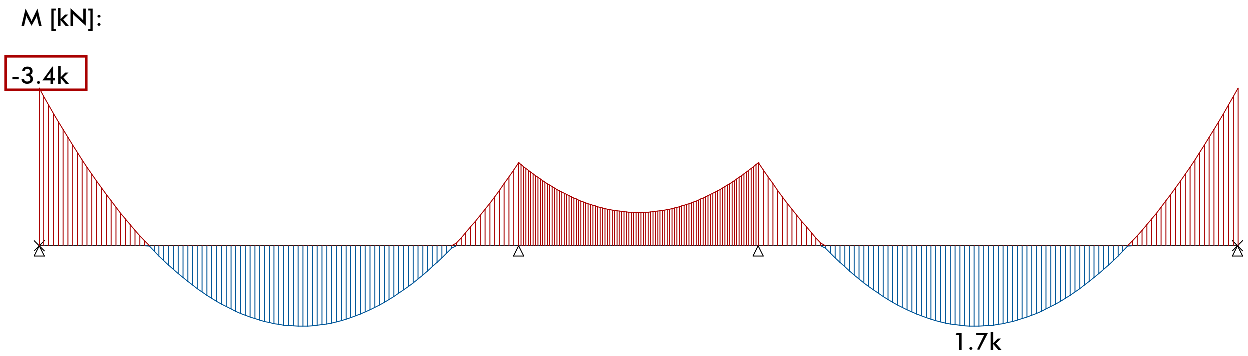


EId[m]:



BEAM DESIGN CALCULATIONS

Maximum bending moment at support



Starting from the results obtained from the Bending Moment diagram in the explicated loading conditions, we obtained that the maximum bending moment at a span is: $M_{max,span} = 1700\ kNm$, While the maximum bending moment at a support is: $M_{max,supp} = 3400\ kNm$.

We consider a double reinforcement RC beam with total **h=1000mm**, with effective beam being **d=885mm**, since the **concrete cover=50mm** and we consider to shape the reinforcement on two rows with tension reinforcement bars having **ϕ/2=20mm and with 50mm** of spacing in between the rows of reinforcement**.**

$M_{max,supp} = 3400\ kNm.$

RC beam = 600*1000 $f_{ck} = 40\ MPa$

RC beam with class of concrete **C40/50, b=600mm** total **h=1000mm**, with effective beam being **d=885mm**, **concrete cover=50 mm** and with **ϕ/2=40mm.**

$$1.\ Bending\ Reinforcement: \quad K = \frac{M}{f_{ck}bd^2} = \frac{3400x10^6}{40x600\ x\ (885)^2} = 0.181$$

We observe that $K > K_{bal}$ with $K_{bal} = 0.167$, **therefore we need to use double reinforcement.**

$2.\ Reinforcement:$

$$Compression\ steel\ area: \ A_{s1} = \frac{M - 0.167 * b * d^2 * f_{ck}}{0.87 f_{yk} * (d - d_1)} = 718\ mm^2 \quad with\ d_1 = 50\ mm$$

$$Being\ the\ arm\ for\ K_{bal}: \quad z_{bal} = 0,82 * d = 0,82 * 885\ mm = 725,7\ mm$$

$$Tension\ steel\ area: \ A_s = \frac{0.167 * b * d^2 * f_{ck}}{0.87 f_{yk} * z_{bal}} + A_{s1} = \frac{0,167x\ 600\ x\ (885)^2 x40}{0.87\ x\ 500x\ 725,7} + 718 = 10662\ mm^2$$

$3.\ Reinforcement\ ratio:$

$$Compression\ reinforcement\ ratio: \ \rho = \frac{A_{s1}}{bd} = \frac{718\ mm^2}{600\ mm\ x\ 885\ mm} = 0,14\% \quad (0,13\% < \rho < 4\%)$$

$$Tension\ reinforcement\ ratio: \ \rho = \frac{A_s}{bd} = \frac{10662\ mm^2}{600\ mm\ x\ 885\ mm} = 2,01\% \quad (0,13\% < \rho < 4\%)$$

Tension reinforcement for the beam at supports

Since the area of a **40mm** bar is given by the formula $A_{rebar} = \frac{\pi\Psi}{4} = \mathbf{1256,6\ mm^2}$, then we obtain the number of tension re-bars by calculating $\frac{A_s}{A_{rebar}} = \frac{10662}{1256,6} = \mathbf{9\ \phi40.}$ However, since we cannot fit all the rebars in one row and we need to have two rows of reinforcement, we prefer to reduce the diameter of the bars in orger to obtain two rows with equal number of bars.

Since the area of a **32mm** bar is given by the formula $A_{rebar} = \frac{\pi\varphi^2}{4} = \mathbf{804,2\ mm^2}$, then we obtain the number of re-bars by calculating $\frac{A_s}{A_{rebar}} = \frac{10662}{804,2} = \mathbf{13,2} \approx \mathbf{14\ \phi32.}$ The 14 bars are organized on two rows having 50 mm of space in between them.

Compression reinforcement for the beam at supports

Since the area of a **32mm** bar is given by the formula $A_{rebar} = \frac{\pi\varphi^2}{4} = \mathbf{804,2\ mm^2}$, then we obtain the number of compression re-bars by calculating $\frac{A_{s1}}{A_{rebar}} = \frac{718}{804,2} = \mathbf{1\ \phi32.}$

Bar areas and perimeters

Table A.1 Sectional areas of groups of bars (mm^2)

Bar size (mm)	Number of bars 1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

However, in order to provide a homogeneous section without introducing bars of different diameters, we consider to insert 2 φ32, one at each corner of the section.

Maximum bending moment at span

$M_{max,supp} = 1700\ kNm.$
RC beam = 600*1000 $f_{ck} = 45\ MPa$

RC beam with class of concrete **C40/55, b=600mm** total **h=1000mm**, with effective beam being **d=950mm**, and with **concrete cover=34mm** and with **ϕ/2=16mm.**

$$1.\ Bending\ Reinforcement: \quad K = \frac{M}{f_{ck}bd^2} = \frac{1700x10^6}{40x600\ x\ (950)^2} = 0.078$$

We observe that $K > K_{bal}$ with $K_{bal} = 0.167$

$$2.\ Lever-arm: \quad z = l_a * d = 0,93 * 950\ mm = 883,5\ mm$$

With e $l_a = 0.5 + \sqrt{0,25 - \frac{K}{1.134}}$

$$3.\ Reinforcement: \quad A_s = \frac{M}{0.87f_{yk}z} = \frac{1700x10^6}{0.87\ x\ 500x\ 883,5} = 4423,37\ mm^2$$

$$4.\ Reinforcement\ ratio: \quad \rho = \frac{A_s}{bd} = \frac{4423,37\ mm^2}{600\ mm\ x\ 950\ mm} = 0,78\% \quad (0,13\% < \rho < 4\%)$$

Tension reinforcement for the beam at span

Since the area of a **32mm** bar is given by the formula $A_{rebar} = \frac{\pi\varphi^2}{4} = \mathbf{804,2\ mm^2}$, then we obtain the number of re-bars by calculating $\frac{A_s}{A_{rebar}} = \mathbf{5,5 \approx 6}$ **ϕ32.** Eventually, we obtain a possible a RC beam with total **h=1000mm**, with effective beam being **d=950mm**, and with **concrete cover=34mm** and with **ϕ/2=6mm, with 6ϕ32.**

Bar areas and perimeters

Table A.1 Sectional areas of groups of bars (mm²)

Bar size (mm)	Number of bars 1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

Compression reinforcement for the beam at span

For the reinforcement of the opposite side of the section we provide the minimum amount of reinforcement, which is the 0,13% of the cross section, which is given by:

$A_{s,min}$ =0,0013 x 600 x 950=741 mm²

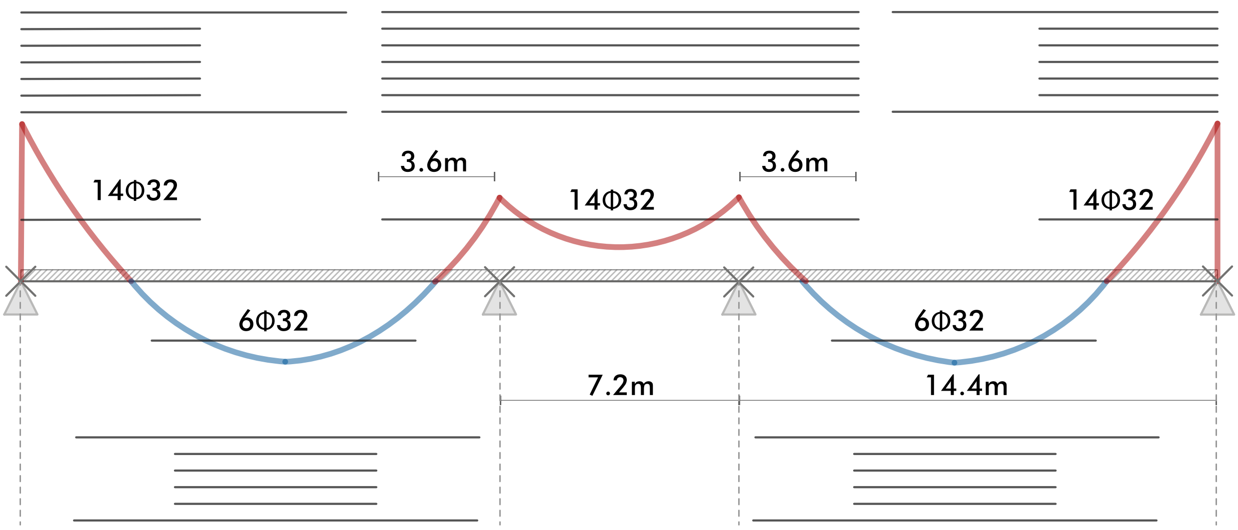
Bar areas and perimeters

Table A.1 Sectional areas of groups of bars (mm²)

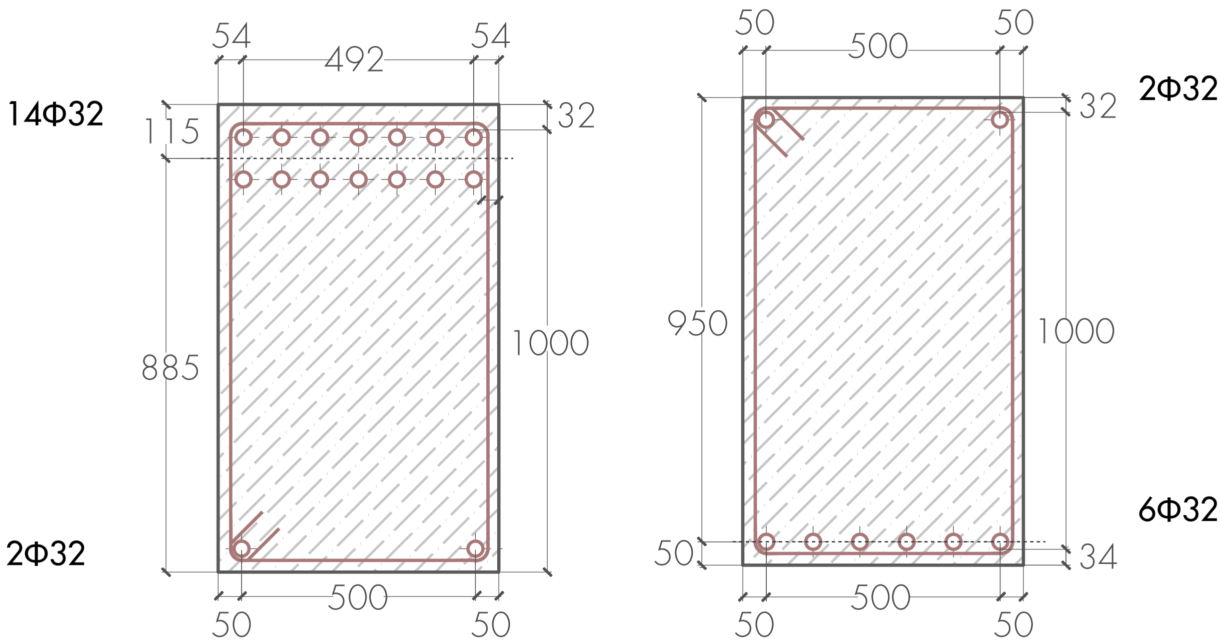
Bar size (mm)	Number of bars 1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

Since the area of a **32mm** bar is given by the formula $A_{rebar} = \frac{\pi\varphi^2}{4} = \mathbf{804,2\ mm^2}$, then we obtain the number of compression re-bars by calculating $\frac{A_{s1}}{A_{rebar}} = \frac{718}{804,2} = \mathbf{1}$ **ϕ32.** However, in order to provide a homogeneous section without introducing bars of different diameters, we consider to insert **2 ϕ32**, one at each corner of the section.

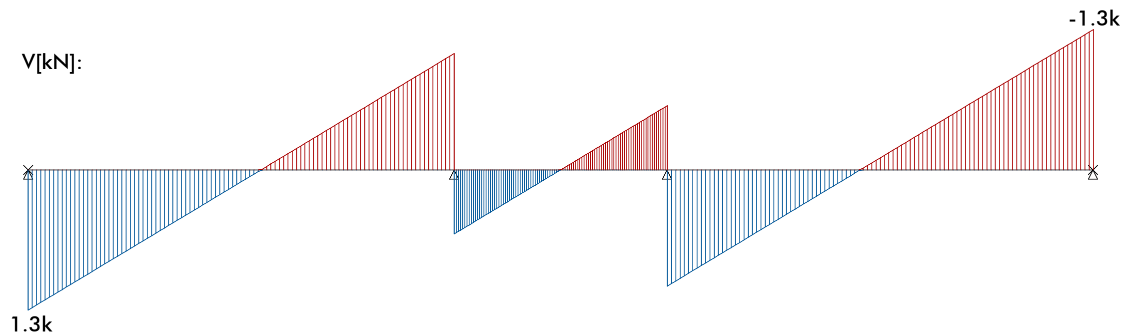
Selected beam cross–section and reinforcement design



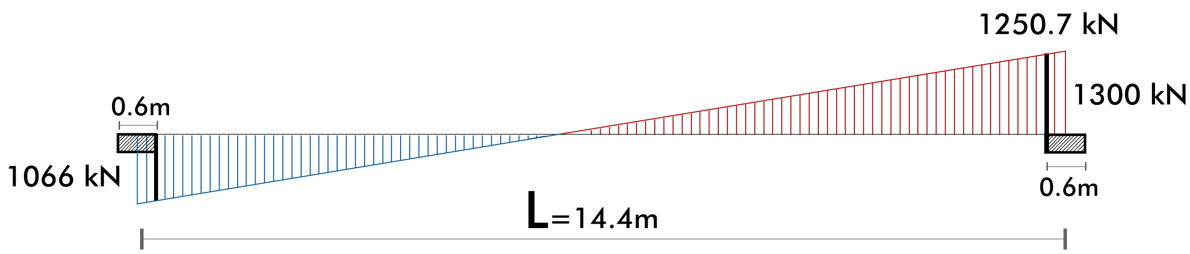
Cross section of the beam close to supports (left) and at span (right)



Shear reinforcement for the beam at support



The shear force at support is **V_{max}=1300 kN.** Graphically, it is possible to determine the value of the maximum shear the the inner face of the support, which in this case is **V_{Ed}=1250,7 kN.**



Shear resistance: $V_{(Rd,c)}=v_{(Rd,c)} \cdot b \cdot d$=0,55 N/mm^2 x 600mm x 950mm=313,5 kN

(With **$v_{(Rd,c)}$ = 0,55** being the strength of concrete in shear)

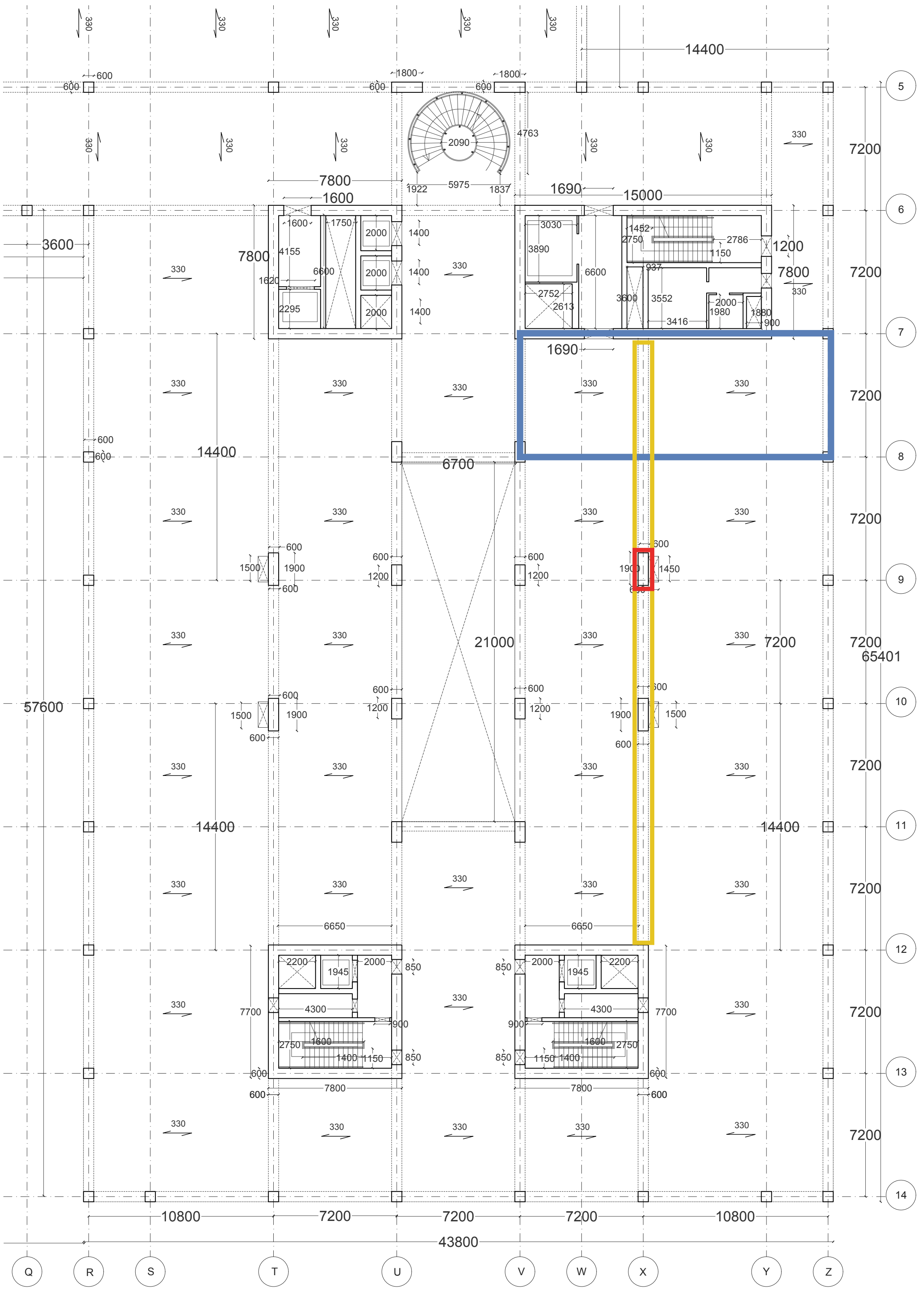
Since $V_{(Ed)} > V_{(Rd,c)}$,then reinforcement is needed.

10.

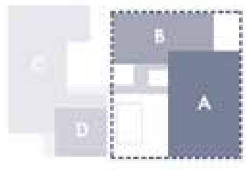
Column design

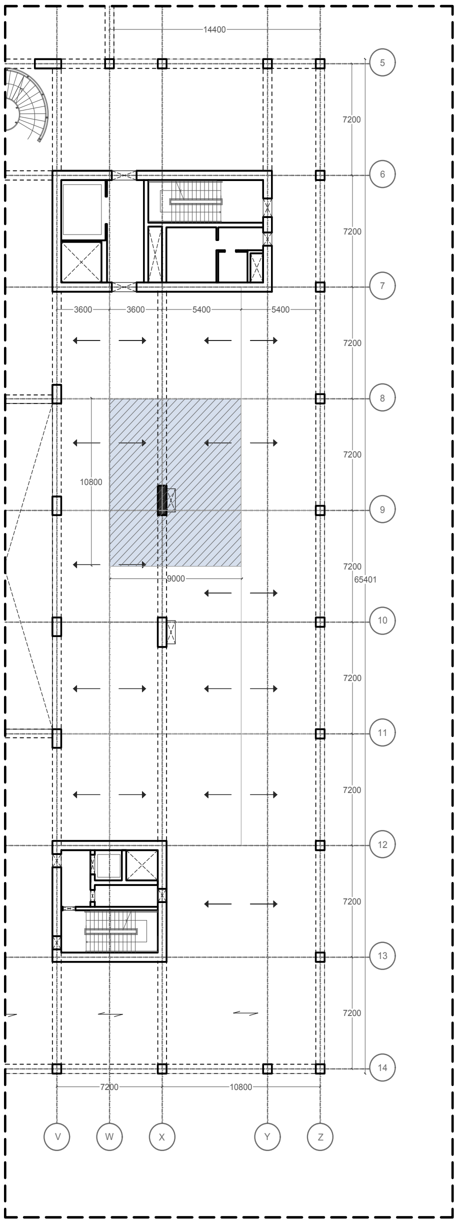
COLUMN DESIGN

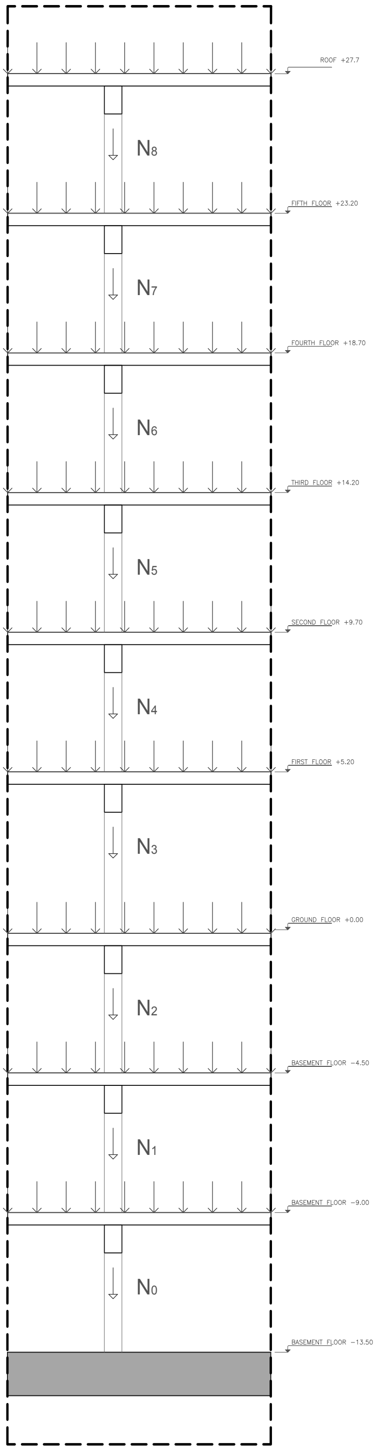
Identification of the selected column

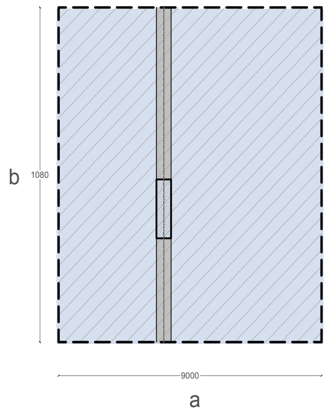


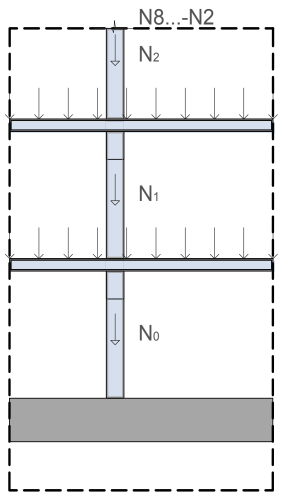
Tributary area and axial load calculation for the selected column (VOLUME A)











In order to calculate the axial weight acting on the column, we determine the influence area of the selected column.

The influence area is
$\boldsymbol{A_{influence} = 9,0\ m\ x\ 10,8\ m = 97,2\ m^2 = 97200\ mm^2}$
Considering that the dead loads and the live loads on the slab are equal to:
$\boldsymbol{g_k = 9\frac{kN}{m^2}}$ **and** $\boldsymbol{q_k = 4\frac{kN}{m^2}}$
and that the combination of loads for the slab is:
$\boldsymbol{w_k = 18,15\ \frac{kN}{m^2}}$
The axial load coming from the slab is equal to:
$\boldsymbol{N_{area\ load} = 1764\ kN}$

Then we must calculate the axial load due to the load of the beam supported by the column. In our case, only one beam is supported by the column and such is characterized by a cross section of **h**=**1000 mm** and **b=600mm** and a length **L=10800mm.** Therefore, it determines an axial load of $\boldsymbol{N_{beam} = 219\ kN}$.
Such value is obtained by multiplying the area of the cross section of the beam $\boldsymbol{A_{beam} = 600000\ mm^2} = \boldsymbol{0,6\ m^2}$ **times the length of the beam (L=10,8m), the unit load per cubic meter of concrete (25 kN/m^3) and the coefficient for dead load 1,35.**

Eventually, we need to consider the self-weight of the column, but since we do not know the exact dimension of the column yet we use an approximation of a column with **h_c=1,9m** and **b_c=0,6m**. Multiplying the cross area of the column **(A_{column}=1,14 m^2) times the floor height (H_{floor}=4,14), times the unit load per cubic meter of concrete (25 kN/m^3) and the coefficient for dead load 1,35, we obtain**$\boldsymbol{N_{column} = 159,2865\ kN}$**.**

Then, we obtain the total axial load for each floor: $\boldsymbol{N_{floor} = 2142\ kN}$.
Such value is multiplied by the total number of floors, which in our case is 9, obtaining a total axial load of $\boldsymbol{N_{tot} = 19279\ kN}$.

Design strength calculation and dimension check for the selected column

In order to check if the column is suitable, we calculate the admissible concrete strength: $\boldsymbol{f_{cd} = \frac{\alpha f_{ck}}{\gamma_c} = 28,3MPa}$ **(with $f_{ck} = 50$ for C50/55, $\gamma_c = 1,5$ and $\alpha = 0,85$)**
Then the area is calculated as $\boldsymbol{A = \frac{N_{tot}}{0,85\ f_{cd}} = 800533\ mm^2}$**. The value 0,85 is the moment coefficient,** which is included in order to consider the effect of bending moment**,** and it can be chosen in a range between 0,45 and 0,85**.**

If we set that one side of the column is **b_c=600mm,** so that it has the same dimension of the beam, then we obtain that the other side of the column is **h_c=1334 mm. Since we dimension the column with a section of 0,6m x 1,9m the column section is then verified.**

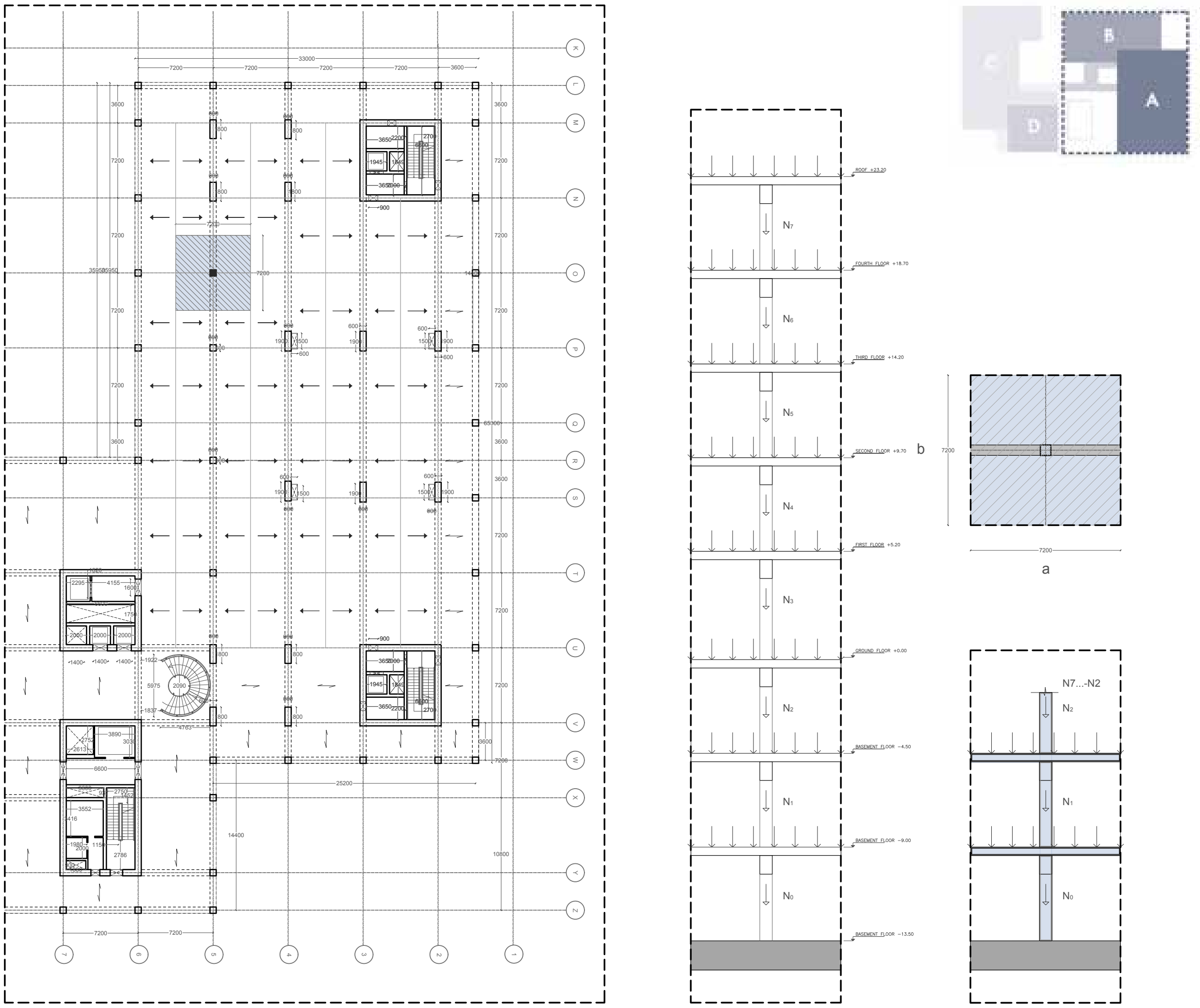
Design of column reinforcement

For the reinforcement of the column we provide an amount equal to **1,5% of the cross section,** which is given by:

$$\boldsymbol{A_{s_{column}} = 0,015\ x\ 600\ x\ 1900 = 17100\ mm^2}$$

Since the area of a **32mm** bar is given by the formula $A_{rebar} = \frac{\pi\varphi^2}{4} = \boldsymbol{804,2\ mm^2}$, then we obtain the number of compression re-bars by calculating $\frac{A_{sc}}{A_{rebar}} = \frac{17100}{804,2} = \boldsymbol{22\ \phi 32}$**.**
Eventually, we obtain a possible a RC column with cross section **600mm x 1900 mm**, with reinforcement equal to **22ϕ32.**

Tributary area and axial load calculation for a sample square column (VOLUME B)



In order to dimension the other squared columns existing in the project, we consider a sample column characterized by a large tributary area.
For this reason, we select a column located in the volume B, hosting the SNI and Anatomy departments.

The influence area is
$$\boldsymbol{A_{influence} = 7,2\ m\ x\ 7,2\ m = 51,84\ m^2 = 51840\ mm^2}$$
Considering that the dead loads and the live loads on the slab are equal to:
$$\boldsymbol{g_k = 9\frac{kN}{m^2}} \text{ and } \boldsymbol{q_k = 4\frac{kN}{m^2}}$$
and that the combination of loads for the slab is:
$$\boldsymbol{w_k = 18,15\ \frac{kN}{m^2}}$$
The axial load coming from the slab is equal to:
$$\boldsymbol{N_{area\ load} = 941\ kN}$$

Then we must calculate the axial load due to the load of the beam supported by the column. In our case, only one beam is supported by the column and such is characterized by a cross section of **h=1000 mm** and **b=600mm** and a length **L=7200mm.** Therefore, it determines an axial load of $\boldsymbol{N_{beam} = 146\ kN}$.
Such value is obtained by multiplying the area of the cross section of the beam $\boldsymbol{A_{beam} = 600000\ mm^2 = 0,6\ m^2}$ **times the length of the beam (L=7,2m), the unit load per cubic meter of concrete (25 kN/m^3) and the coefficient for dead load 1,35.**

Eventually, we need to consider the self-weight of the column, which we approximate as **h_c=0,6m** and **b_c=0,6m**. Multiplying the cross area of the column **(A_{column}=0,36 m^2) times the floor height (H_{floor}=4,14), times the unit load per cubic meter of concrete (25 kN/m^3) and the coefficient for dead load 1,35, we obtain $N_{column} = 50,301\ kN$..**
Then, we obtain the total axial load for each floor: $\boldsymbol{N_{floor} = 1137\ kN}$.
Such value is multiplied by the total number of floors, which in this case is 8, obtaining a total axial load of $\boldsymbol{N_{tot} = 9096\ kN}$.

Design strength calculation and dimension check for the selected column

In order to check if the column is suitable, we calculate the admissible concrete strength: $\boldsymbol{f_{cd} = \frac{\alpha f_{ck}}{\gamma_c} = 28,3MPa}$ **(with $f_{ck} = 50$ for C50/55, $\gamma_c = 1,5$ and $\alpha = 0,85$)**
Then the area is calculated as $\boldsymbol{A = \frac{N_{tot}}{0,85\ f_{cd}} = 377688\ mm^2}$.

If we set that one side of the column is **b_c=600mm,** so that it has the same dimension of the beam, then we obtain that the other side of the column is **h_c=629mm.**

Since we dimension the column with a section of 0,6m x 0,6m, and we are not in the executive design stage, we can approximate the 620mm to 600 mm and the column section can then be verified.

Design of column reinforcement

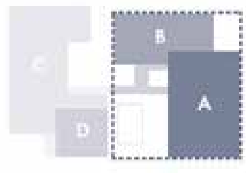
For the reinforcement of the column we provide an amount equal to **1,5% of the cross section,** which is given by:

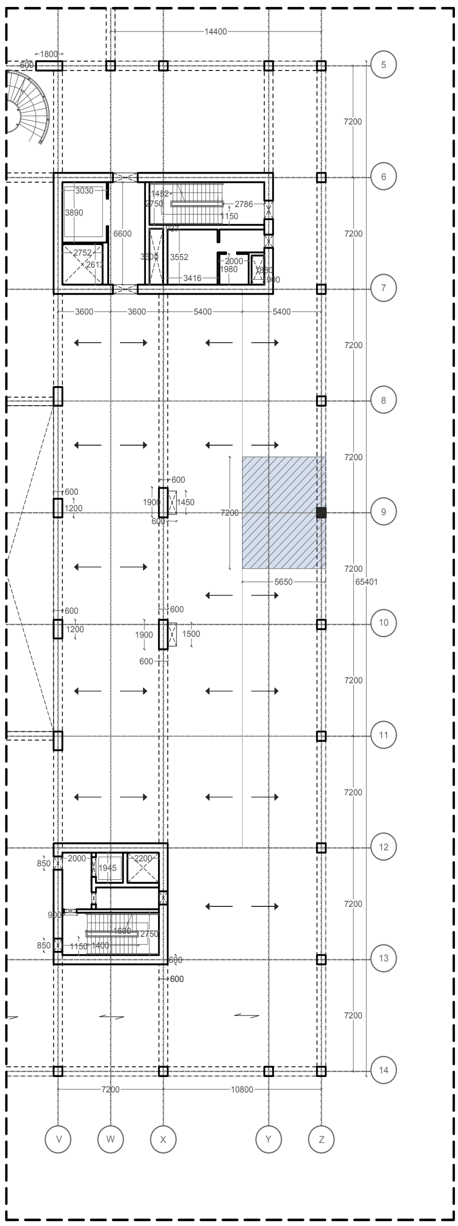
$$\boldsymbol{A_{s_{column}} = 0,015\ x\ 600\ x\ 600 = 5400\ mm^2}$$

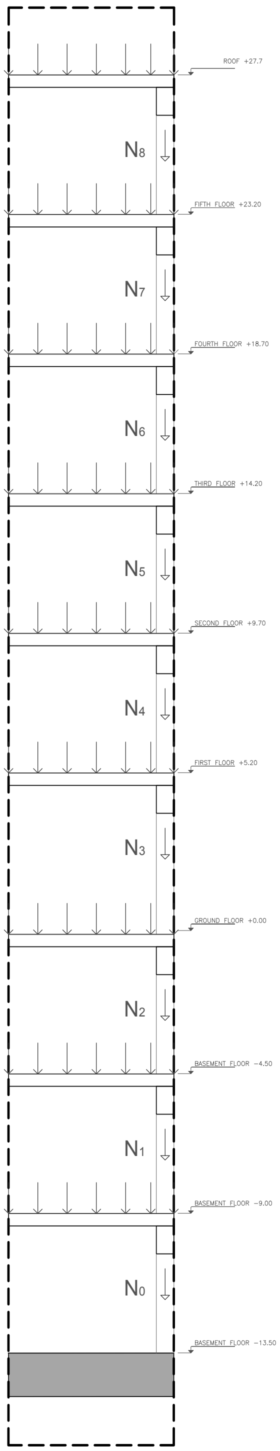
Since the area of a **32mm** bar is given by the formula $A_{rebar} = \frac{\pi\varphi^2}{4} = \boldsymbol{804,2\ mm^2}$, then we obtain the number of compression re-bars by calculating $\frac{A_{sc}}{A_{rebar}} = \frac{5400}{804,2} = \boldsymbol{7\ \phi 32}$. However, since squared columns need reinforcement bars as multiples of 4, we use **8 ϕ32.**

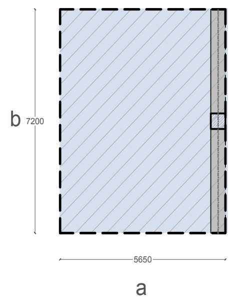
Eventually, we obtain a possible a RC column with cross section **600mm x 600 mm**, with reinforcement equal to **8ϕ32.**

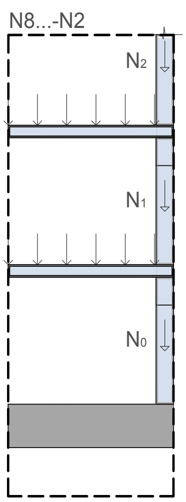
Design strength calculation and dimension check for the selected column (VOLUME A)











In order to dimension the other squared columns existing in the project, we also consider another sample column, which is characterized by a slightly lower tributary area of the tributary area but with one more floor level.
For this reason, we select a column located in the volume A, hosting the Physiscs department.

The influence area is

$A_{influence} = 5,65\ m\ x\ 7,2\ m = 40,68\ m^2 = 40680\ mm^2$

Considering that the dead loads and the live loads on the slab are equal to:

$g_k = 9\frac{kN}{m^2}$ **and** $q_k = 4\frac{kN}{m^2}$

and that the combination of loads for the slab is:

$w_k = 18,15\ \frac{kN}{m^2}$

The axial load coming from the slab is equal to:

$N_{area\ load} = 738\ kN$

Then we must calculate the axial load due to the load of the beam supported by the column. In our case, only one beam is supported by the column and such is characterized by a cross section of **h=1000 mm** and **b=600mm** and a length **L=7200mm.** Therefore, it determines an axial load of $N_{beam} = 146\ kN$.

Such value is obtained by multiplying the area of the cross section of the beam $A_{beam} = 600000\ mm^2 = 0,6\ m^2$ **times the length of the beam (L=7,2m), the unit load per cubic meter of concrete (25 kN/m^3) and the coefficient for dead load 1,35.**

Eventually, we need to consider the self-weight of the column, which we approximate as **h_c=0,6m** and **b_c=0,6m**. Multiplying the cross area of the column **(A_{column}=0,36 m^2) times the floor height (H_{floor}=4,14), times the unit load per cubic meter of concrete (25 kN/m^3) and the coefficient for dead load 1,35, we obtain $N_{column} = 50,301\ kN$..**

Then, we obtain the total axial load for each floor: $N_{floor} = 934\ kN$.

Such value is multiplied by the total number of floors, which in this case is 9, obtaining a total axial load of $N_{tot} = 8410\ kN$.

Design strength calculation and dimension check for the selected column

In order to check if the column is suitable, we calculate the admissible concrete strength: $f_{cd} = \frac{\alpha f_{ck}}{\gamma_c} = 28,3MPa$ **(with $f_{ck} = 50$ for C50/55, $\gamma_c = 1,5$ and $\alpha = 0,85$)**

Then the area is calculated as $A = \frac{N_{tot}}{0,85\ f_{cd}} = 349204\ mm^2$.

If we set that one side of the column is **b_c=600mm,** so that it has the same dimension of the beam, then we obtain that the other side of the column is **h_c=582mm.**

Since we dimension the column with a section of 0,6m x 0,6m the column section is then verified.

Design of column reinforcement

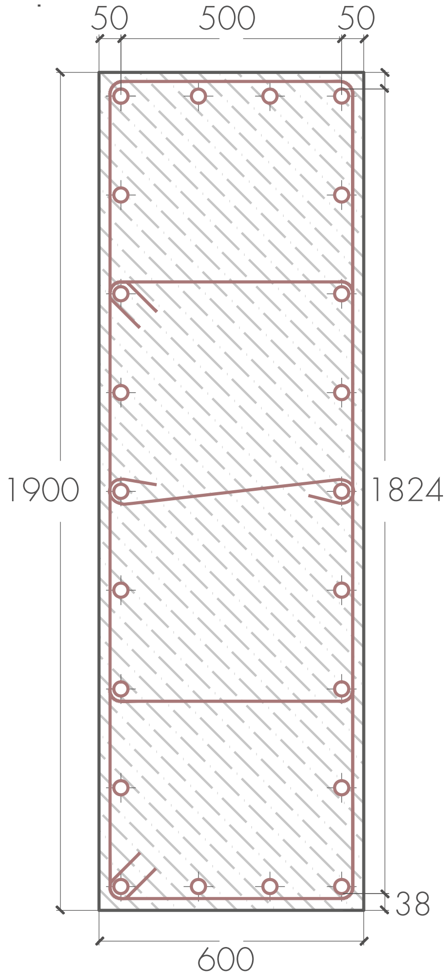
For the reinforcement of the column we provide an amount equal to **1,5% of the cross section,** which is given by: $A_{s_{column}} = 0,015\ x\ 600\ x\ 600 = 5400\ mm^2$

Since the area of a **32mm** bar is given by the formula $A_{rebar} = \frac{\pi\varphi^2}{4} = 804,2\ mm^2$, then we obtain the number of compression re-bars by calculating $\frac{A_{sc}}{A_{rebar}} = \frac{5400}{804,2} = $ **7 ϕ32.** However, since squared columns need reinforcement bars as multiples of 4, we use **8 ϕ32.**

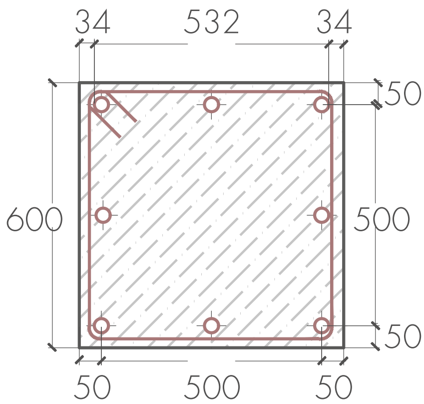
Eventually, we obtain a possible a RC column with cross section **600mm x 600 mm**, with reinforcement equal to **8ϕ32.**

Cross section of standard squared column and of shaft columns

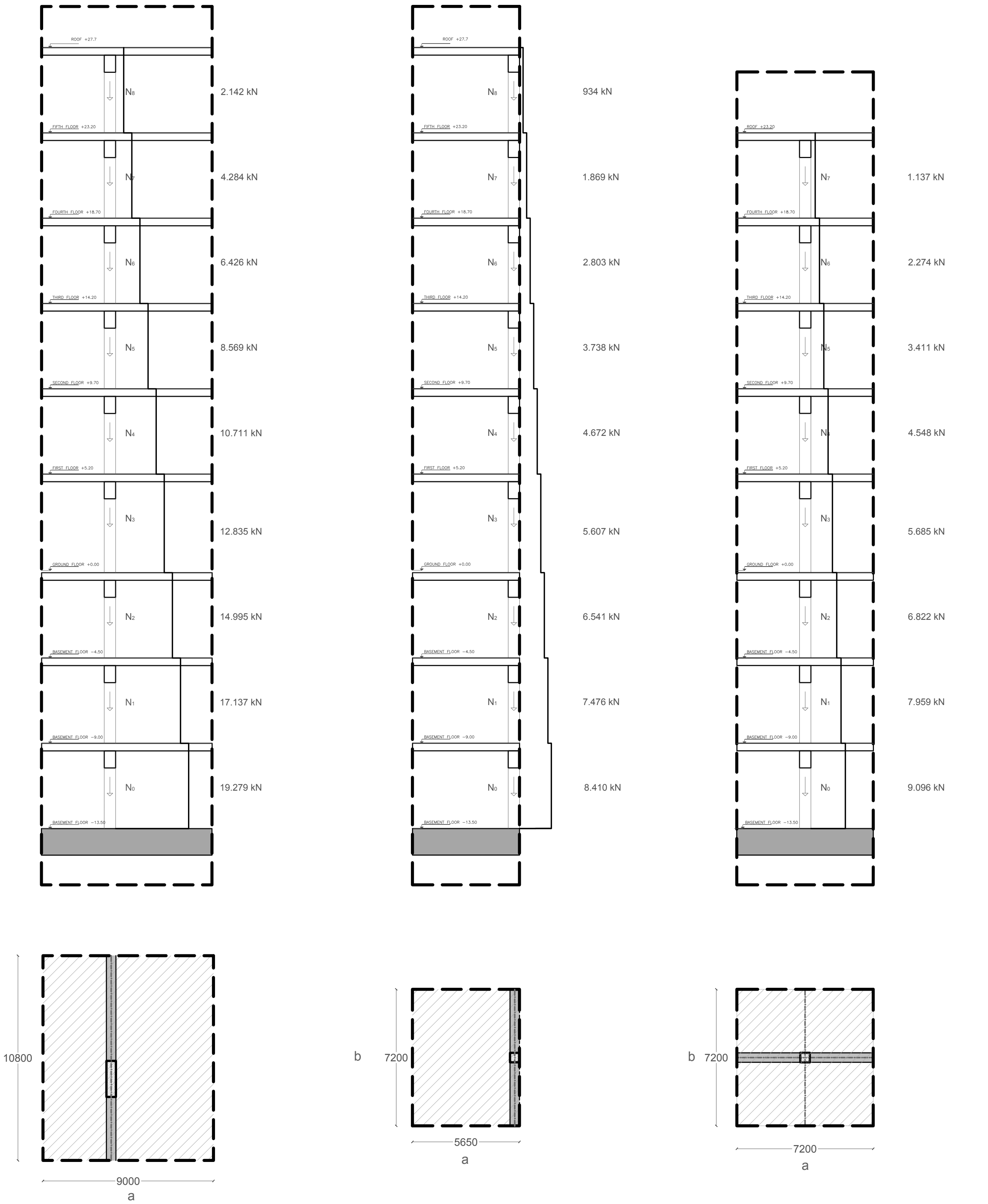
22Φ32



8Φ32



Variation of axial loads



11.

Special Topic

AUDITORIUM DESIGN

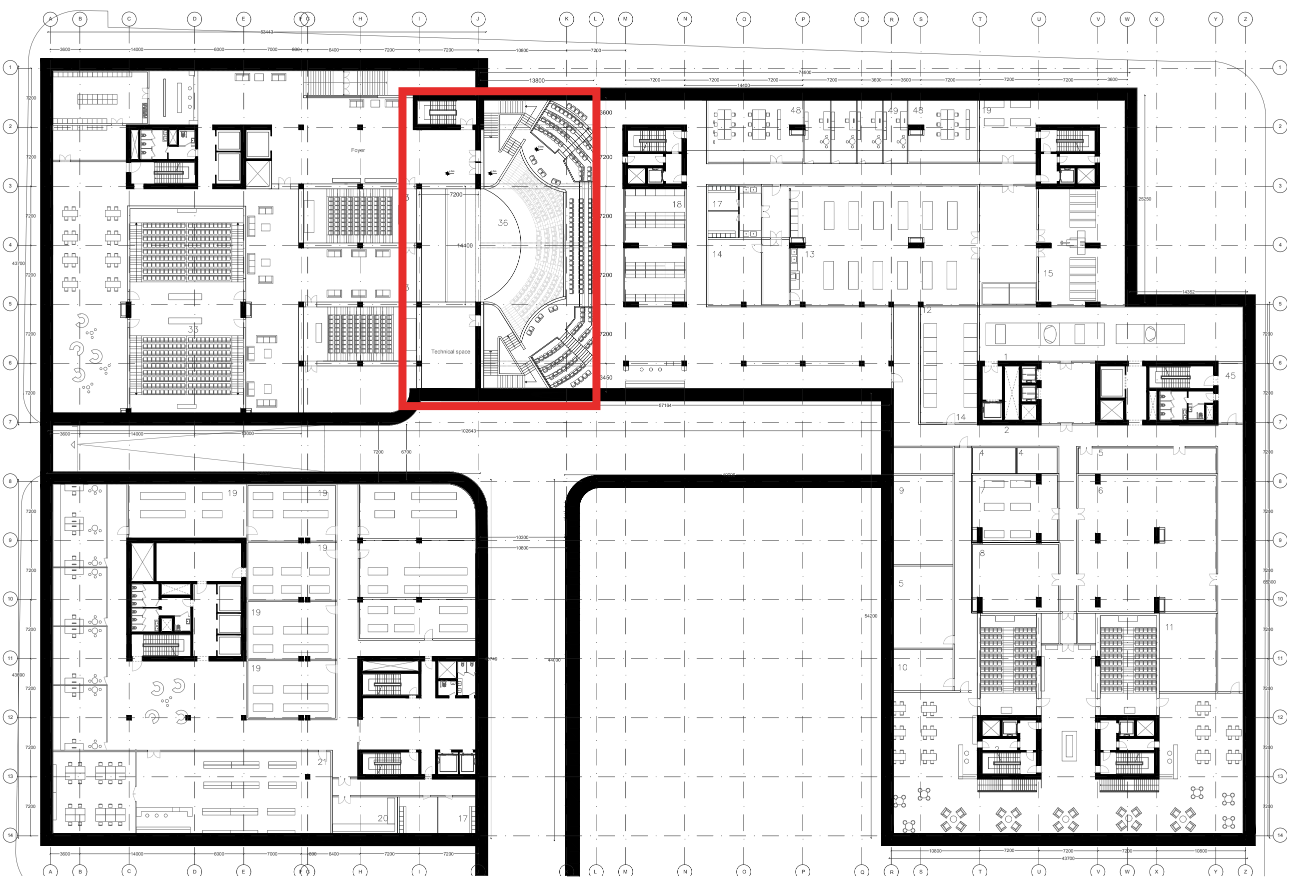
Description of the special design topic

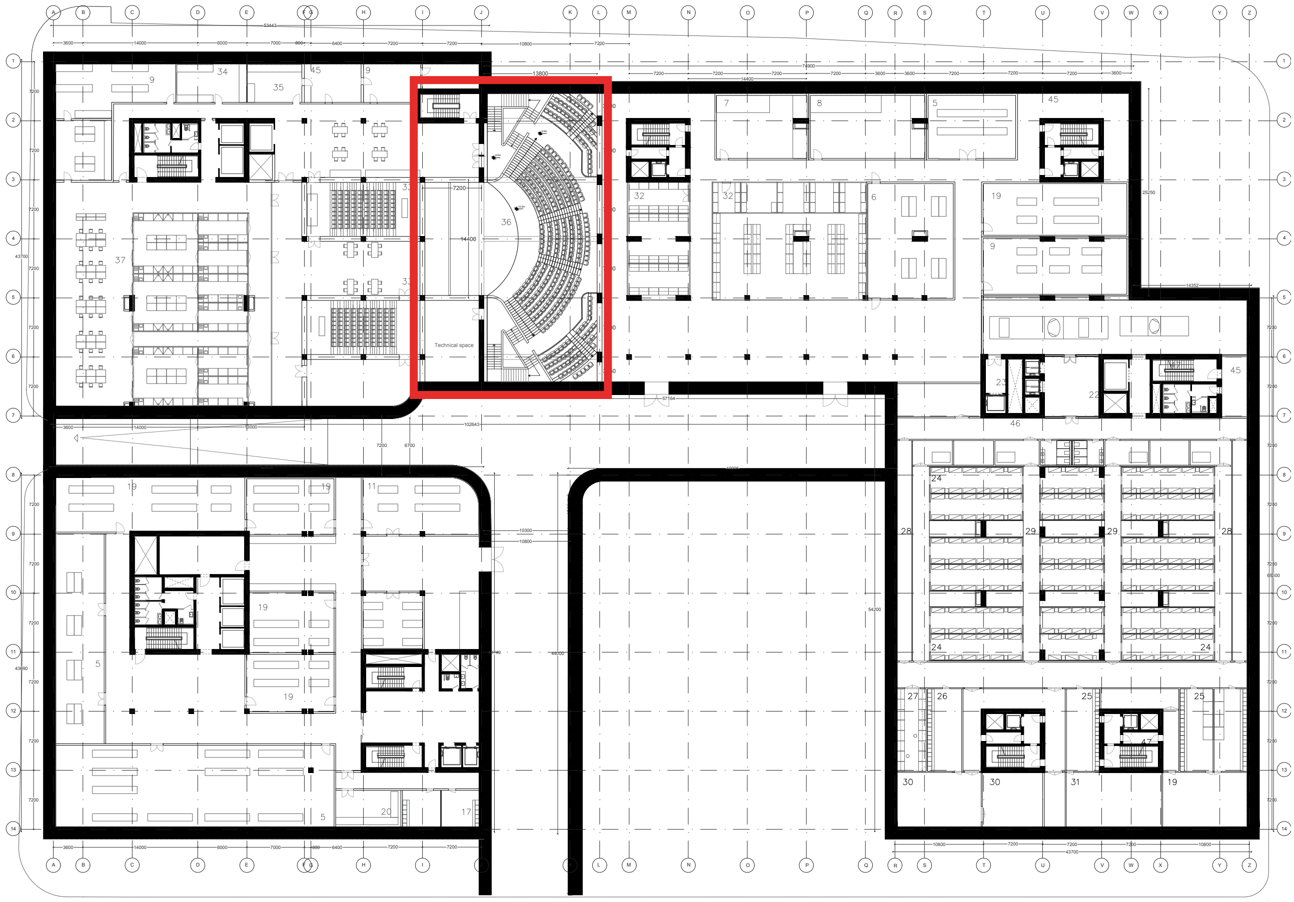
As a special topic, we selected the main auditorium of the complex, open to both university population and to the public. For such reason, an entrance is provided directly from the residential side of volume C, with a stair leading directly from the street to the -1 level (-4.5m) where a broad foyer is located.

The auditorium itself is then fit within a very compressed space located in between volumes C and B: the main room is indeed bordered by the structural border of the two volumes, while the stage area is located under the footprint of the C volume.
The auditorium occupies all the three basement levels below ground, providing an access from each level yet foreseeing a main entrance from -1 level.

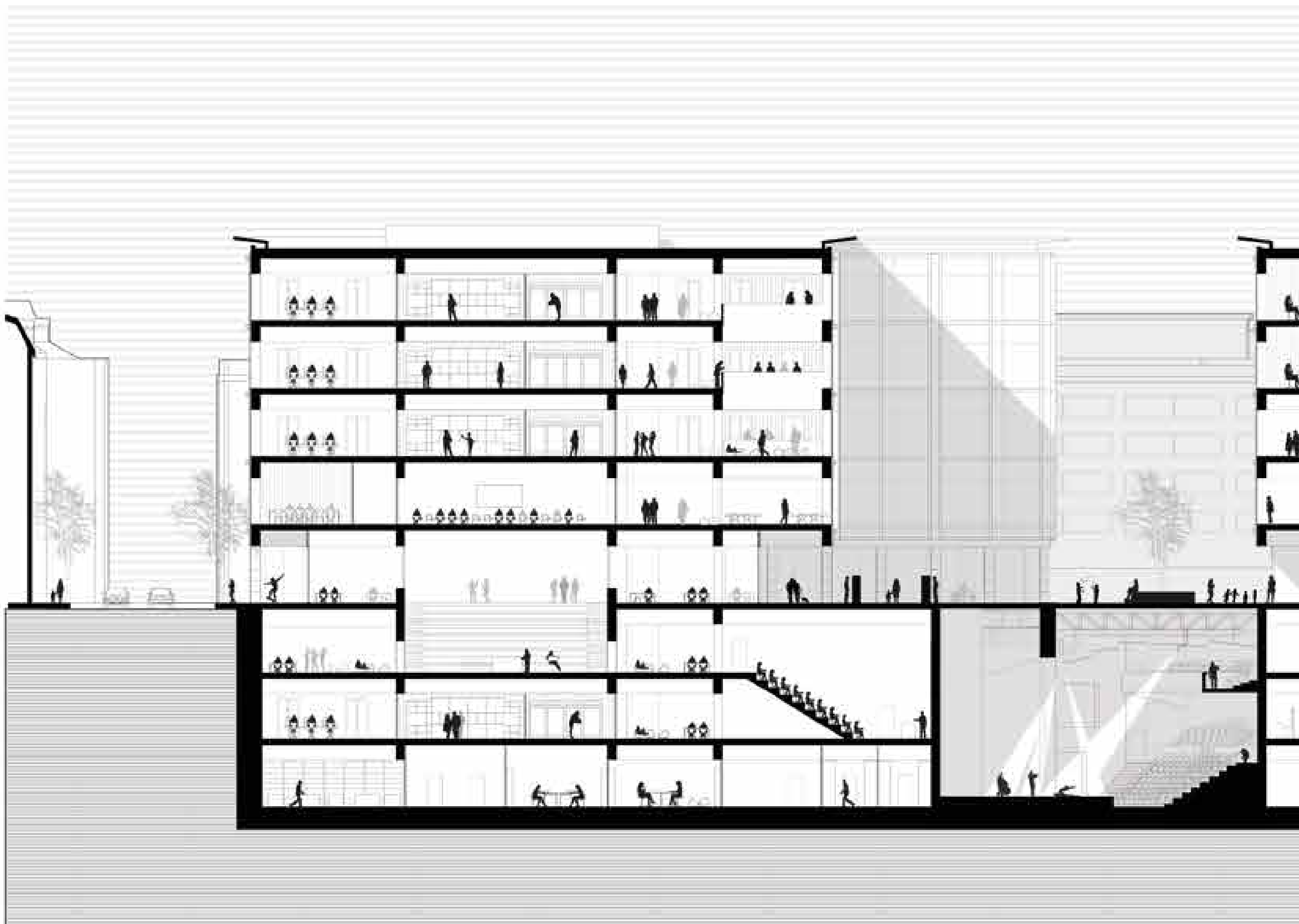
The main room of the auditorium is a rectangular space of **14.4m x 36m**, and it is meant to be spanned by **warren trusses 14.4m long.** The volume hosting the stage is instead a rectangular space with dimensions **7.2m x 14.4m.** In order to free the area of the stage it is necessary to remove one column ending up in the middle of the stage, belonging to volume C: such column is going to be replaced by a reinforced concrete **wall beam, around 1 floor high, and then emptied in the -3 level (or partially in the -2 level as well) in order to free the stage below it.**

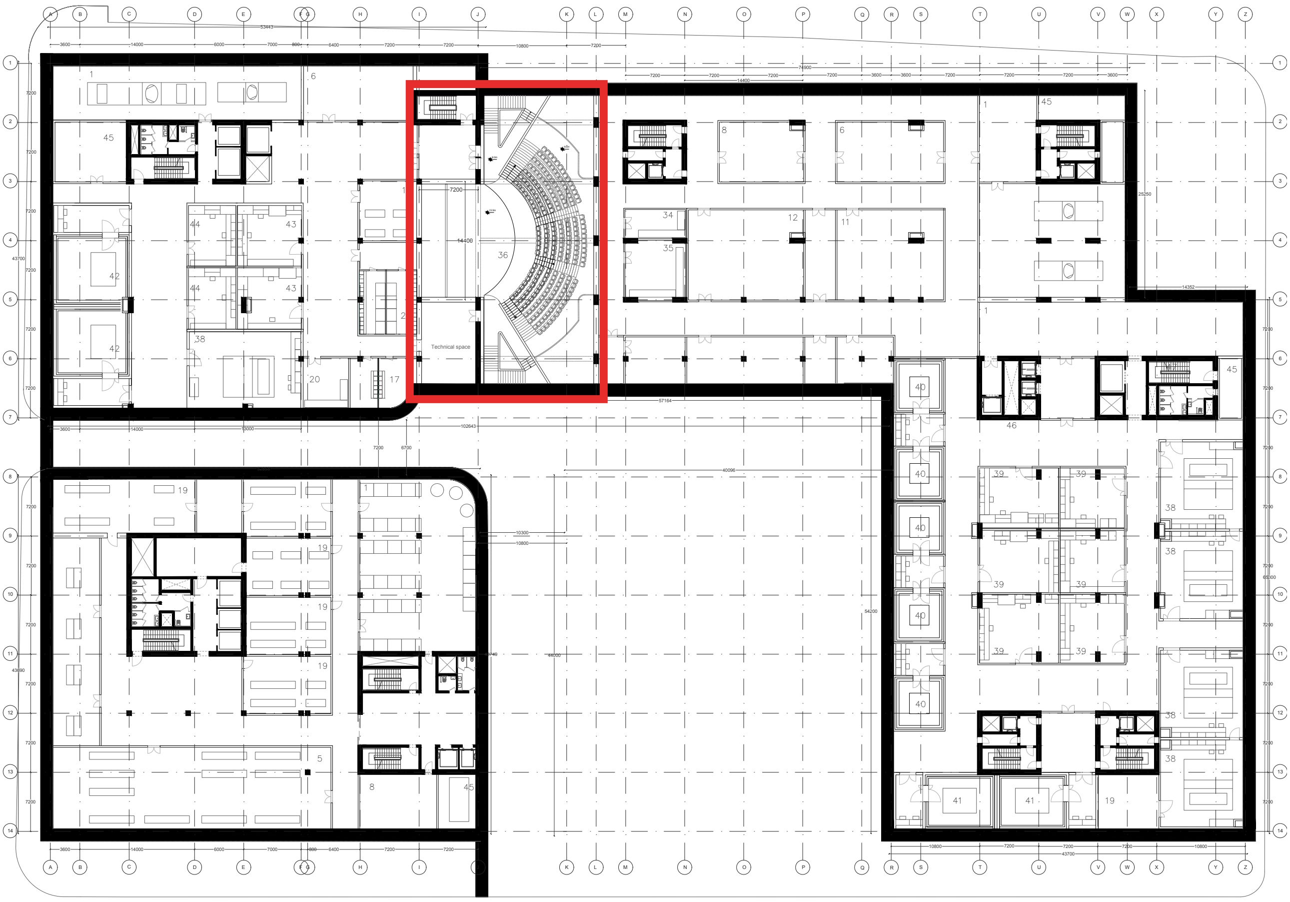
Level -4.50m
(-1 basement level)



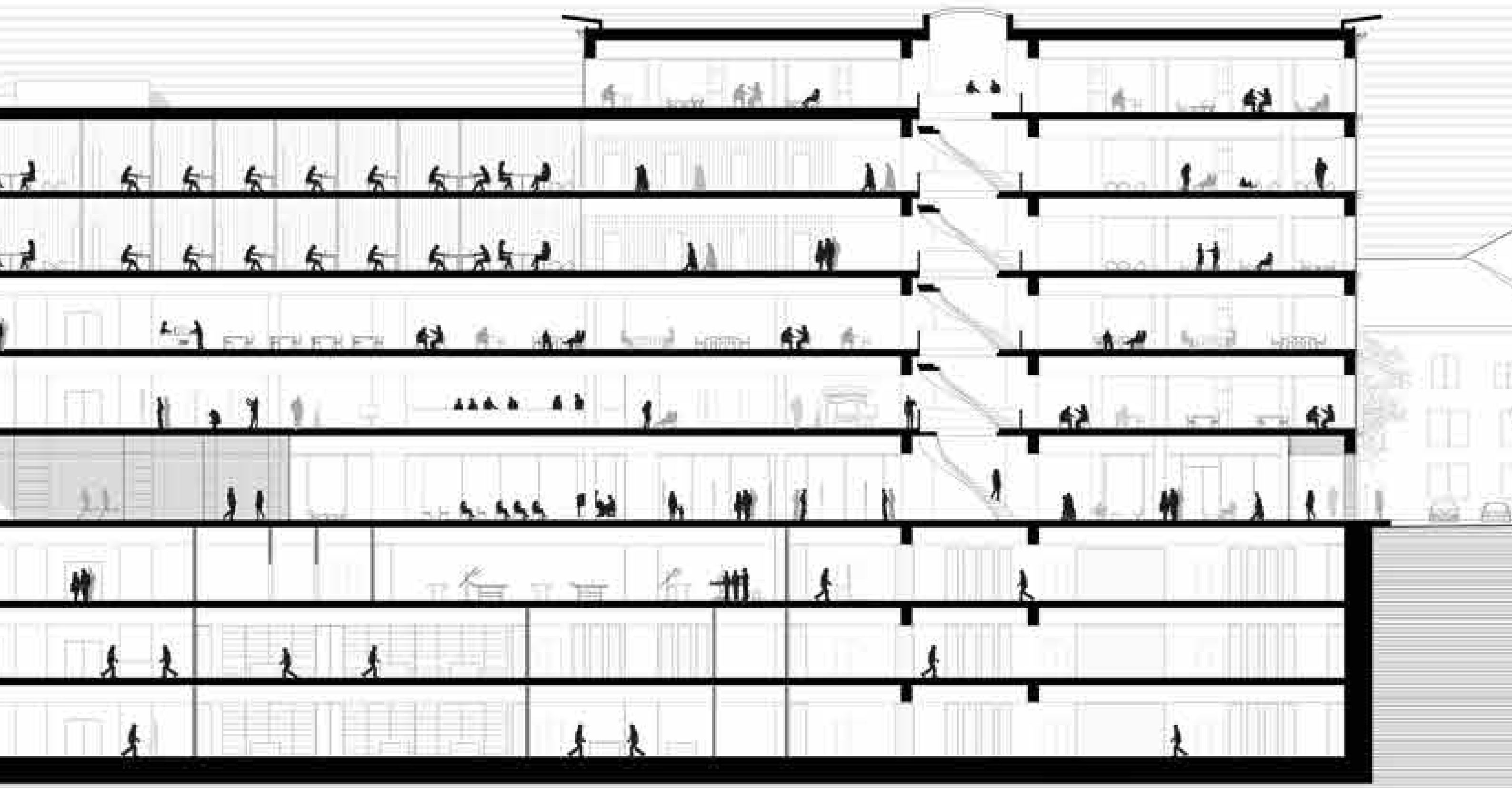


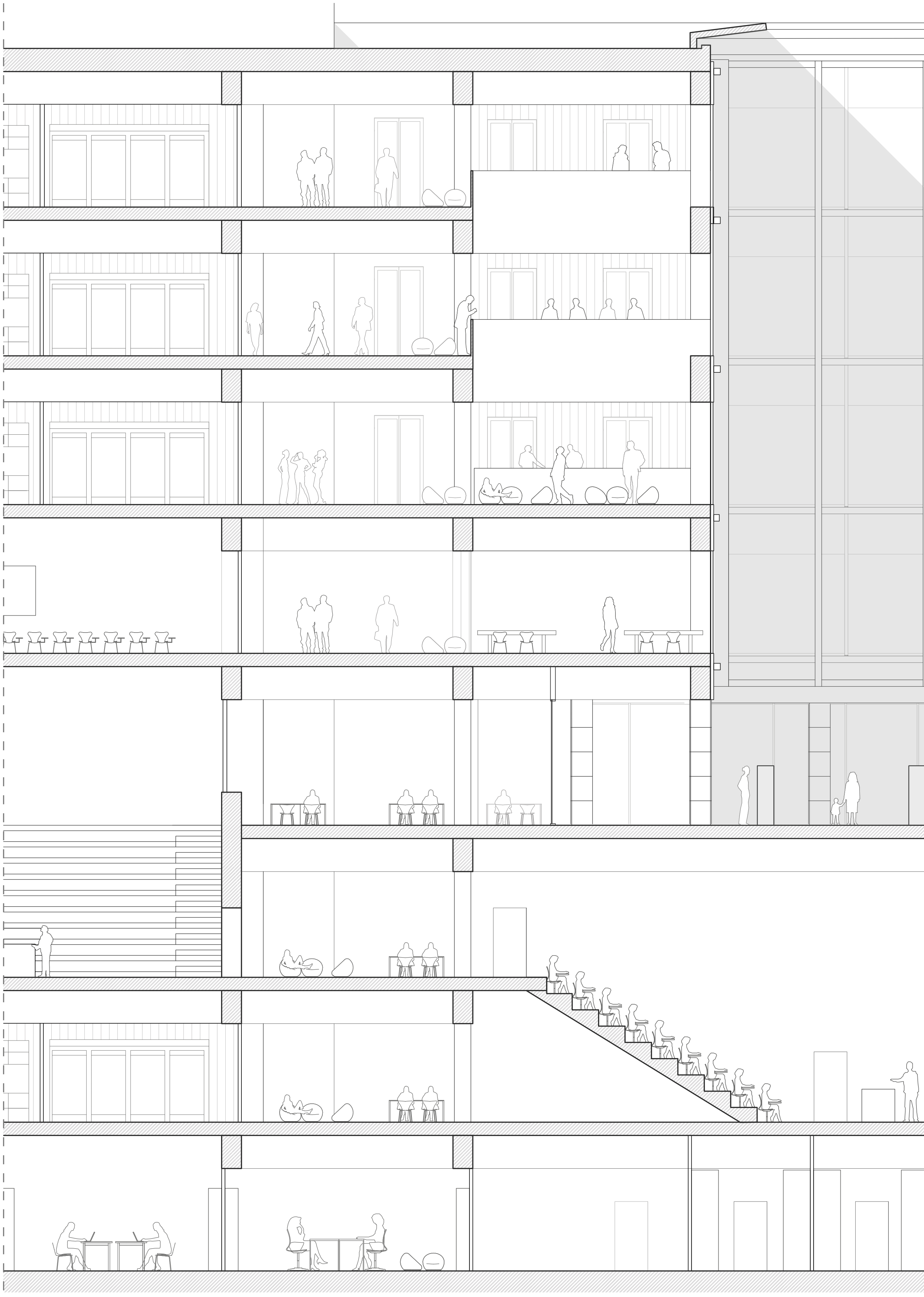
Level -9.00m

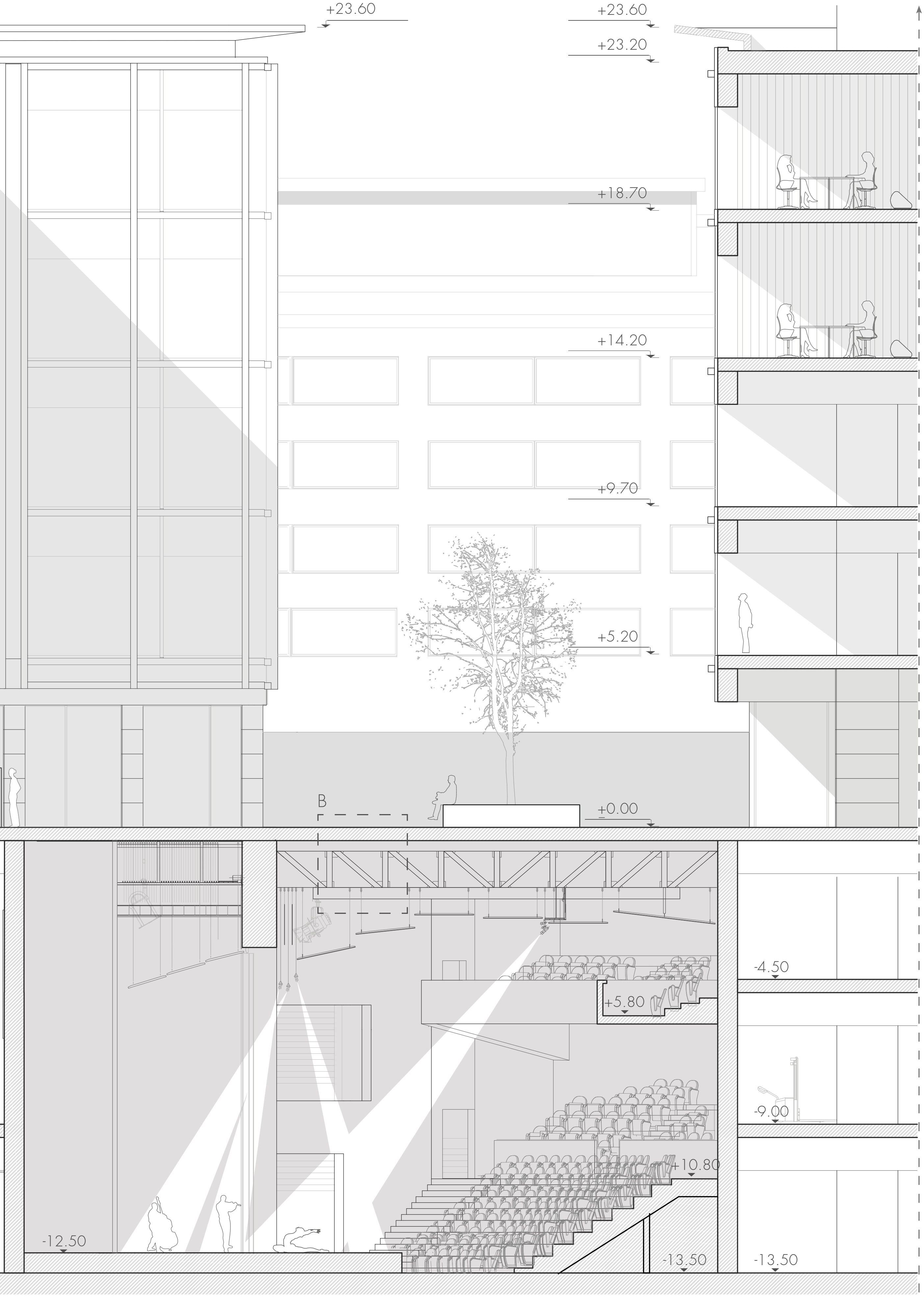




Level -13.50m



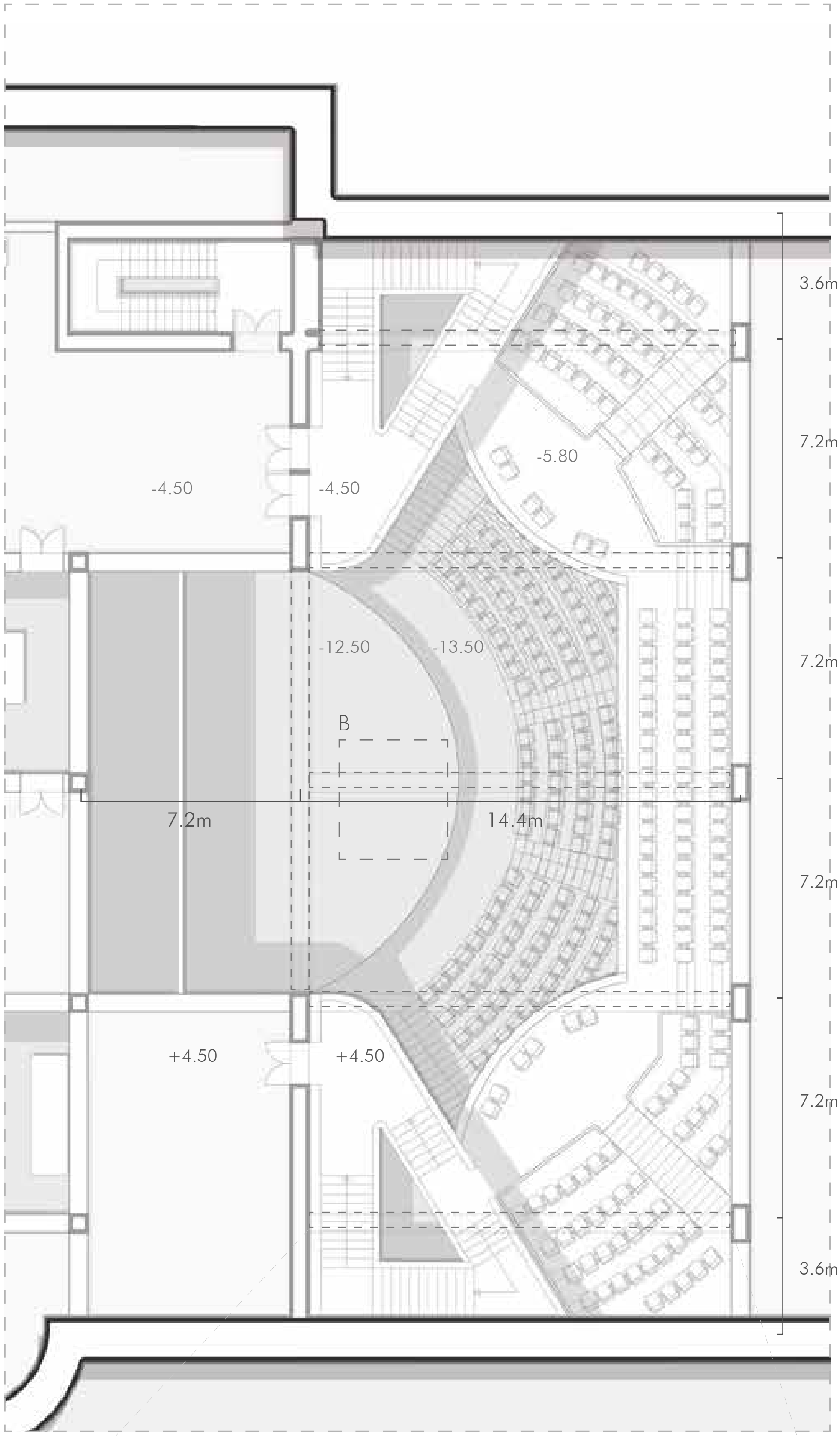




CEREN BİNGÖL I BEATRICE TOSINI

Truss design

The steel trusses are 14.4 meters long, and they are designed as flat Pratt trusses with a height of 1.8 meters and with open ends.

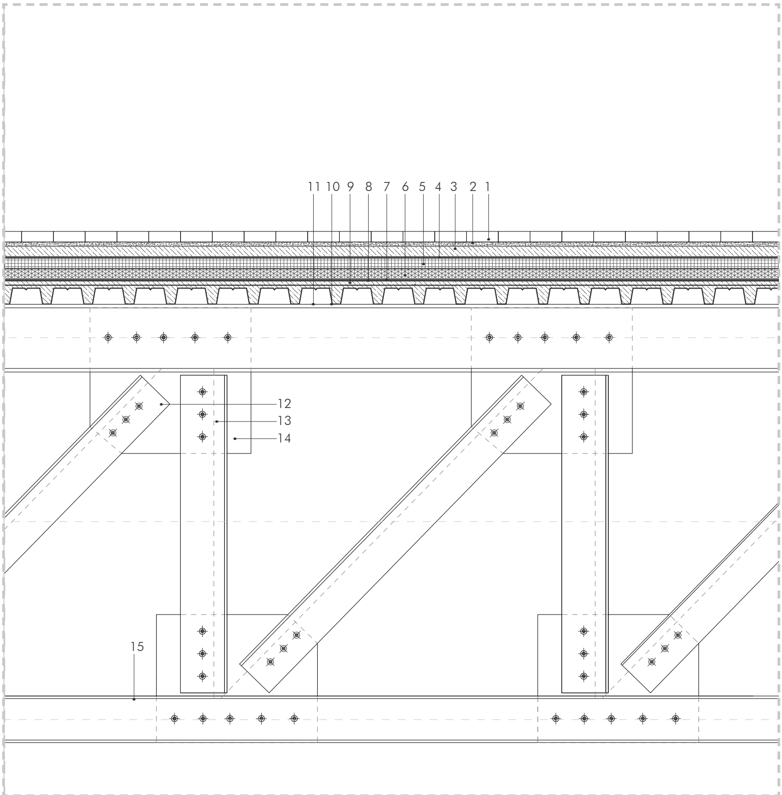


PARTIAL PLAN A - LEVEL -1.00
SCALE 1/100

Dead loads

The truss is supposed to support the insulated composite panels insulating the auditorium room, the composite slabs made of corrugated sheets and reinforced concrete, and the top floors constituting the paving of the public plaza.

Auditorium roof envelope



1 Pavement Stone (50 mm)
2 Mortar (20 mm)
3 Screed (50mm)
4 Moisture Layer (4 mm)
5 XPS thermal insulation layer (50 mm)
6 Impact-sound insulation (EPS) (50mm)
7 Protection mat (4mm)
8 Waterproofing membrane (2mm)
9 Cast concrete (55 mm)
10 Galvanized iron corrugated sheet (3mm)
11 Primary structural stel HEA 400 ?

	NUMBER	MATERIAL	THICKNESS [m]	DENSITY [kN/m3]	WEIGHT [kN/m2]	
Non-Structural self weight G1	1	Pavement Stone	0,05	25	1,25	3,30
	2	Mortar	0,02	21	0,42	
	3	Screed	0,05	17,7	0,885	
	4	Moisture Layer	0,04	13	0,52	
	5	XPS thermal insulation layer	0,05	0,28	0,014	
	6	Impact-sound insulation (EPS)	0,05	4	0,2	
	7	Protection mat	0,004	-	0,004	
	8	Waterproofing membrane	0,002	5	0,01	
Structural self weight G2	9	Cast concrete	0,055	24	1,32	1,52
	10	Galvanized iron corrugated sheet	0,03	0,09	0,0027	
	11	Primary structural stel HEA 400	0.390		0,2	
	TOTAL				4,83	

The total dead load per unit surface is then $q_k = 4,83\,\frac{kN}{m^2}$.

Live loads

In order to calculate the live load acting on the selected area it is necessary to refer to the EN-1991 table about building loading in function of the area category, assuming that a public plaza can be susceptible to large crowds.

According to such table, it is possible to consider the **Category C5 as a feasible live load value for a public square.**

Table 6.1 - Categories of use

Category	Specific Use	Example
A	Areas for domestic and residential activities	Rooms in residential buildings and houses; bedrooms and wards in hospitals; bedrooms in hotels and hostels kitchens and toilets.
B	Office areas	
C	Areas where people may congregate (with the exception of areas defined under category A, B, and D[1])	**C1**: Areas with tables, etc. e.g. areas in schools, cafés, restaurants, dining halls, reading rooms, receptions. **C2**: Areas with fixed seats, e.g. areas in churches, theatres or cinemas, conference rooms, lecture halls, assembly halls, waiting rooms, railway waiting rooms. **C3**: Areas without obstacles for moving people, e.g. areas in museums, exhibition rooms, etc. and access areas in public and administration buildings, hotels, hospitals, railway station forecourts. **C4**: Areas with possible physical activities, e.g. dance halls, gymnastic rooms, stages. **C5**: Areas susceptible to large crowds, e.g. in buildings for public events like concert halls, sports halls including stands, terraces and access areas and railway platforms.
D	Shopping areas	**D1**: Areas in general retail shops **D2**: Areas in department stores

Table 6.2 - Imposed loads on floors, balconies and stairs in buildings

Categories of loaded areas	q_k [kN/m²]	Q_k [kN]
Category A		
- **Floors**	1,5 to 2,0	2,0 to 3,0
- **Stairs**	2,0 to 4,0	2,0 to 4,0
- **Balconies**	2,5 to 4,0	2,0 to 3,0
Category B	2,0 to 3,0	1,5 to 4,5
Category C		
- C1	2,0 to 3,0	3,0 to 4,0
- C2	3,0 to 4,0	2,5 to 7,0 (4,0)
- C3	3,0 to 5,0	4,0 to 7,0
- C4	4,5 to 5,0	3,5 to 7,0
- C5	5,0 to 7,5	3,5 to 4,5
category D		
- D1	4,0 to 5,0	3,5 to 7,0 (4,0)
- D2	4,0 to 5,0	3,5 to 7,0

Therefore, the live load per unit of surface is then: $q_k = 5{,}0\ kN/m^2$

Load combination

Considering the following values for the dead loads (gk) and live loads (qk), we carry out the load combination:
Permanent and variable actions: 1,35 Gk+1,5 Qk

$g_k = 4{,}83\ kN/m^2$

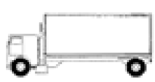
$q_k = 5{,}0\ kN/m^2$

$w = 1{,}35\, g_k + 1{,}5 q_k = (1{,}35 \cdot 4{,}83\ kN/m^2) + (1{,}5 \cdot 5{,}00\ kN/m^2) = 14{,}02\ kN/m^2$

Load due to occasional passag of trucks

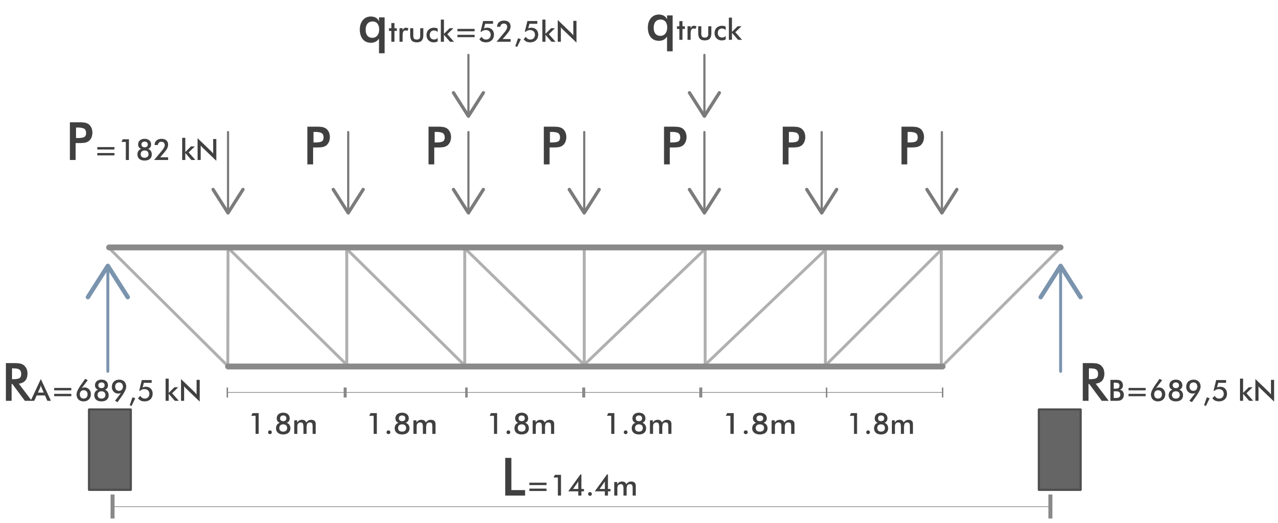
Considering the possibility that, in case of emergency, rescuing trucks need to access the pedestrian plaza, it is necessary to design the floor structure in order to be suitable for occasional passage of vehicles.For such reasons, live loads are considered to be applied as **70 kN applied as two concentrated loads of 35kN, more or less located at 4.5m of distance.**

Table 4.7 - Set of equivalent lorries

VEHICLE TYPE			TRAFFIC TYPE			
1	2	3	4	5	6	7
			Long distance	Medium distance	Local traffic	
LORRY	Axle spacing (m)	Equivalent axle loads (kN)	Lorry percentage	Lorry percentage	Lorry percentage	Wheel type
	4,5	70 130	20,0	40,0	80,0	A B

BS EN 1991-2:2003
EN 1991-2:2003 (E)

Final configuration



$$w_{slab} = \left(4,83\frac{kN}{m^2}\ x\ 1,35\right) + \left(5,00\frac{kN}{m^2}\ x\ 1,5\right) = 14,02\frac{kN}{m^2}$$

$$A_{tributary} = 1,8m\ x\ 7,2m = 13m^2$$

$$P_{1,slab} = 14,02\frac{kN}{m^2}\ x\ 13m^3 = 182\ kN$$

$$P_{track} = 70\ kN\ x\ 1.5 = 105\ kN$$

$$P_{1,track} = \frac{105\ kN}{2} = 52,5\ kN$$

$$P_{1tot} = P_{1,slab} + P_{1,track} = 105kN + 274kN = 379\ kN$$

Design of top and bottom chords

1. $q = \frac{P_{1tot}}{1,8m} = \frac{105kN + 274kN}{1,8m} = 130,3\ kN$

2. $M_{ED} = \frac{qx^2}{8}$ with $x = tributary\ length = 14.4m$

   $M_{ED} = \frac{130,3\ kN\ x\ (14,4m)^2}{8} = 3377,4\ x\ 10^6\ Nmm$

3. $f_{yd} = \frac{f_{yk}}{\Upsilon m} = 338,1\ MPa = 338,1\ \ Nmm^2$

   with $f_{yk} = ultimate\ tensile\ strength = 355\ MPa = 355\ Nmm^2$
   and with $\Upsilon m = partial\ safety\ coefficient = 1,05$

4. $T = \frac{M_{ED}}{H_{truss}} = \frac{3377,4\ x\ 10^6 Nmm}{1800\ mm} = 1,88\ x\ 10^6 N$

5. $A_s = \frac{T}{f_{yd}} = \frac{1,88\ x\ 10^6 N}{338,1\frac{N}{mm^2}} = 5560,5\ mm^2$

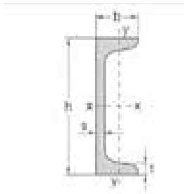
Design of top chords in compression

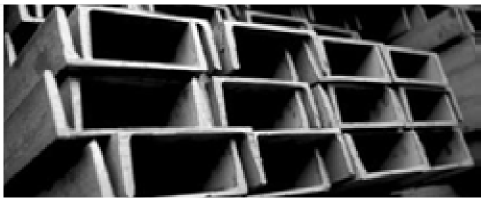
The top chord acts in compression, therefore it needs to have double strength.

$$A_{s,top} = \frac{T}{\frac{1}{2} f_{yd}} = 2\,x\,\frac{1,88\,x\,10^{6} N}{338,1\,\frac{N}{mm^{2}}} = 11121\,mm^{2} = 111,2\,cm^{2}$$

$$\frac{A_{s,top}}{2} = \frac{T}{f_{yd}} = (111,2/2\,)\,cm^{2} = 55,6\,cm^{2}$$

$$A_{UPN320} = 75,8\,cm^{2} > 55,6\,cm^{2}$$





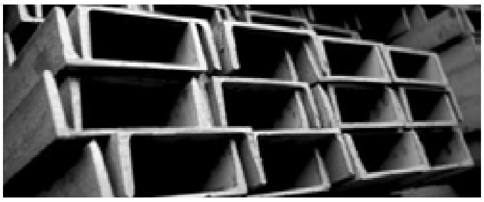
Identification	Nominal weight 1m	Nominal dimensions						Cross-section	Dimensions for detailing				Surface	
UNP		b	h	s	t=R1	R2	e	A	d	Ø	emin	emax	AL	AG
	kg/m	mm						cm2	mm		mm	mm	m2/m	m2/t
UPN 30	4,27	33	30	5,0	7,0	3,5	-	5,4	-	-	-	-	-	-
UPN 40x20	2,86	20	40	5,0	5,5	2,5	-	3,7	-	-	-	-	-	-
UPN 40	4,87	35	40	5,0	3,5	7,0	-	6,2	-	-	-	-	-	-
UPN 50	5,59	38	50	5,0	7,0	3,5	13,7	7,12	21	-	-	-	0,232	42,22
UPN 65	7,09	42	65	5,5	7,5	4,0	14,2	9,03	34	-	-	-	0,273	39,57
UPN 80	8,64	45	80	6,0	8,0	4,0	14,5	11,00	47	-	-	-	0,312	37,10
UPN 100	10,6	50	100	6,0	8,5	4,5	15,5	13,50	64	-	-	-	0,372	35,10
UPN 120	13,4	55	120	7,0	9,0	4,5	16	17,00	82	-	-	-	0,434	32,52
UPN 140	16,0	60	140	7,0	10,0	5,0	17,5	20,40	98	M12	33	37	0,489	30,54
UPN 160	18,8	65	160	7,5	10,5	5,5	18,4	24,00	115	M12	34	42	0,546	28,98
UPN 180	22,0	70	180	8,0	11,0	5,5	19,2	28,00	133	M16	38	41	0,611	27,80
UPN 200	25,3	75	200	8,5	11,5	6,0	20,1	32,20	151	M16	39	46	0,661	26,15
UPN 220	29,4	80	220	9,0	12,5	6,5	21,4	37,40	167	M16	40	51	0,718	24,46
UPN 240	33,2	85	240	9,5	13,0	6,5	22,3	42,30	184	M20	46	50	0,775	23,34
UPN 260	37,9	90	260	10,0	14,0	7,0	23,6	48,30	200	M22	50	52	0,834	22,00
UPN 280	41,8	95	280	10,0	15,0	7,5	25,3	53,30	216	M22	52	57	0,890	21,27
UPN 300	46,2	100	300	10,0	16,0	8,0	27,0	58,80	232	M24	55	59	0,950	20,58
UPN 320	59,5	100	320	14,0	17,5	8,8	-	75,80	246	M22	58	62	0,982	16,50
UPN 350	60,6	100	350	14,0	16,0	8,0	-	77,30	282	M22	56	62	1,05	17,25
UPN 380	63,1	102	380	13,5	16,0	8,0	-	80,40	313	M24	59	60	1,11	17,59
UPN 400	71,8	110	400	14,0	18,0	9,0	-	91,50	324	M27	61	62	1,18	16,46

Design of bottom chords in tension

$$A_{s,bottom} = \frac{T}{f_{yd}} = \frac{1,88\ x\ 10^6 N}{338,1\ \frac{N}{mm^2}} = 5560,5\ mm^2 = 55,6\ cm^3$$

$$\frac{A_{s,bottom}}{2} = 55,6\ cm^2/2 = 27,8\ cm^2$$

$$A_{UPN220} = 37,4\ cm^2 > 27,8\ cm^2$$



Identification	Nominal weight 1m	Nominal dimensions						Cross-section	Dimensions for detailing				Surface	
UNP		b	h	s	t=R1	R2	e	A	d	Ø	emin	emax	AL	AG
	kg/m	mm						cm2	mm		mm	mm	m2/m	m2/t
UPN 30	4,27	33	30	5,0	7,0	3,5	-	5,4	-	-	-	-	-	-
UPN 40x20	2,86	20	40	5,0	5,5	2,5	-	3,7	-	-	-	-	-	-
UPN 40	4,87	35	40	5,0	3,5	7,0	-	6,2	-	-	-	-	-	-
UPN 50	5,59	38	50	5,0	7,0	3,5	13,7	7,12	21	-	-	-	0,232	42,22
UPN 65	7,09	42	65	5,5	7,5	4,0	14,2	9,03	34	-	-	-	0,273	39,57
UPN 80	8,64	45	80	6,0	8,0	4,0	14,5	11,00	47	-	-	-	0,312	37,10
UPN 100	10,6	50	100	6,0	8,5	4,5	15,5	13,50	64	-	-	-	0,372	35,10
UPN 120	13,4	55	120	7,0	9,0	4,5	16	17,00	82	-	-	-	0,434	32,52
UPN 140	16,0	60	140	7,0	10,0	5,0	17,5	20,40	98	M12	33	37	0,489	30,54
UPN 160	18,8	65	160	7,5	10,5	5,5	18,4	24,00	115	M12	34	42	0,546	28,98
UPN 180	22,0	70	180	8,0	11,0	5,5	19,2	28,00	133	M16	38	41	0,611	27,80
UPN 200	25,3	75	200	8,5	11,5	6,0	20,1	32,20	151	M16	39	46	0,661	26,15
UPN 220	29,4	80	220	9,0	12,5	6,5	21,4	37,40	167	M16	40	51	0,718	24,46
UPN 240	33,2	85	240	9,5	13,0	6,5	22,3	42,30	184	M20	46	50	0,775	23,34
UPN 260	37,9	90	260	10,0	14,0	7,0	23,6	48,30	200	M22	50	52	0,834	22,00
UPN 280	41,8	95	280	10,0	15,0	7,5	25,3	53,30	216	M22	52	57	0,890	21,27
UPN 300	46,2	100	300	10,0	16,0	8,0	27,0	58,80	232	M24	55	59	0,950	20,58
UPN 320	59,5	100	320	14,0	17,5	8,8	-	75,80	246	M22	58	62	0,982	16,50
UPN 350	60,6	100	350	14,0	16,0	8,0	-	77,30	282	M22	56	62	1,05	17,25
UPN 380	63,1	102	380	13,5	16,0	8,0	-	80,40	313	M24	59	60	1,11	17,59
UPN 400	71,8	110	400	14,0	18,0	9,0	-	91,50	324	M27	61	62	1,18	16,46

Design of diagonal components

$g_k = 4,83 \frac{kN}{m^2}$; $q_k = 5,00 \frac{kN}{m^2}$

$w_{slab} = \left(4,83 \frac{kN}{m^2} \; x \; 1,35\right) + \left(5,00 \frac{kN}{m^2} \; x \; 1,5\right) = 14,02 \frac{kN}{m^2}$ ULS load combination

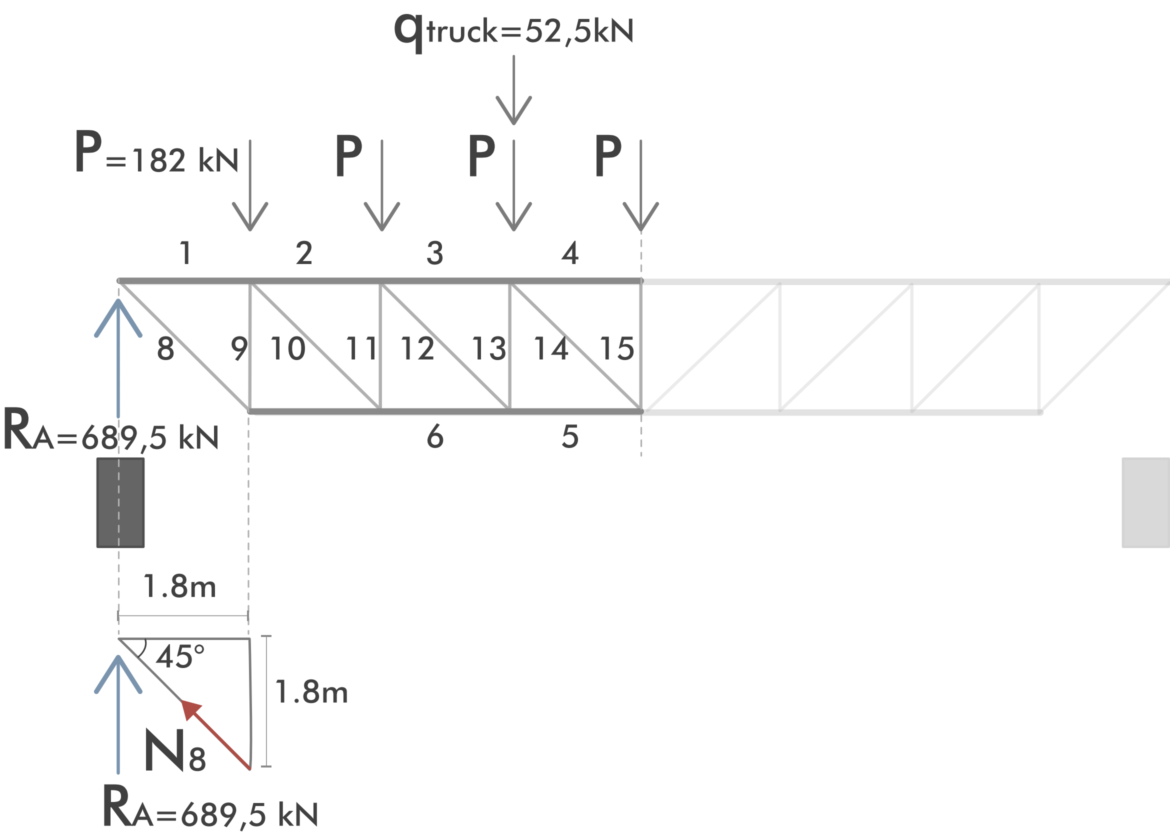
$A_{tributary} = 1,8m \; x \; 7,2m = 13m^2$

$P_{slab} = 14,02 \frac{kN}{m^2} \; x \; 13m^3 = 182 \; kN$; $P_{totslab} = 7P = 7x182 \; kN = 1274 \; kN$

$P_{track} = 70 \; kN \; x \; 1.5 = 105 \; kN$ ULS load combination

$P_{TOTAL} = P_{slab} + P_{track} = 105kN + 274kN = 1379 \; kN$

$R_A = R_B = \frac{P_{TOTAL}}{2} = 1379 \; kN/2 = 689,5 \; kN$

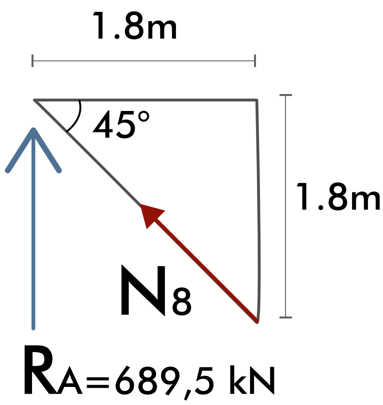


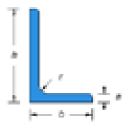
$N_8 = R_A * sin(45°) = 689,5 \; kN \; x \; \frac{\sqrt{2}}{2} = 487,6 \; kN$

$2As_8 = 487,6 \; kN = \frac{487600N}{275 \frac{N}{mm^2}} = 1773 \; mm^2$
$= 17,7cm^2$

$As_8 = 17,7cm^2/2 = 8,87cm^2$

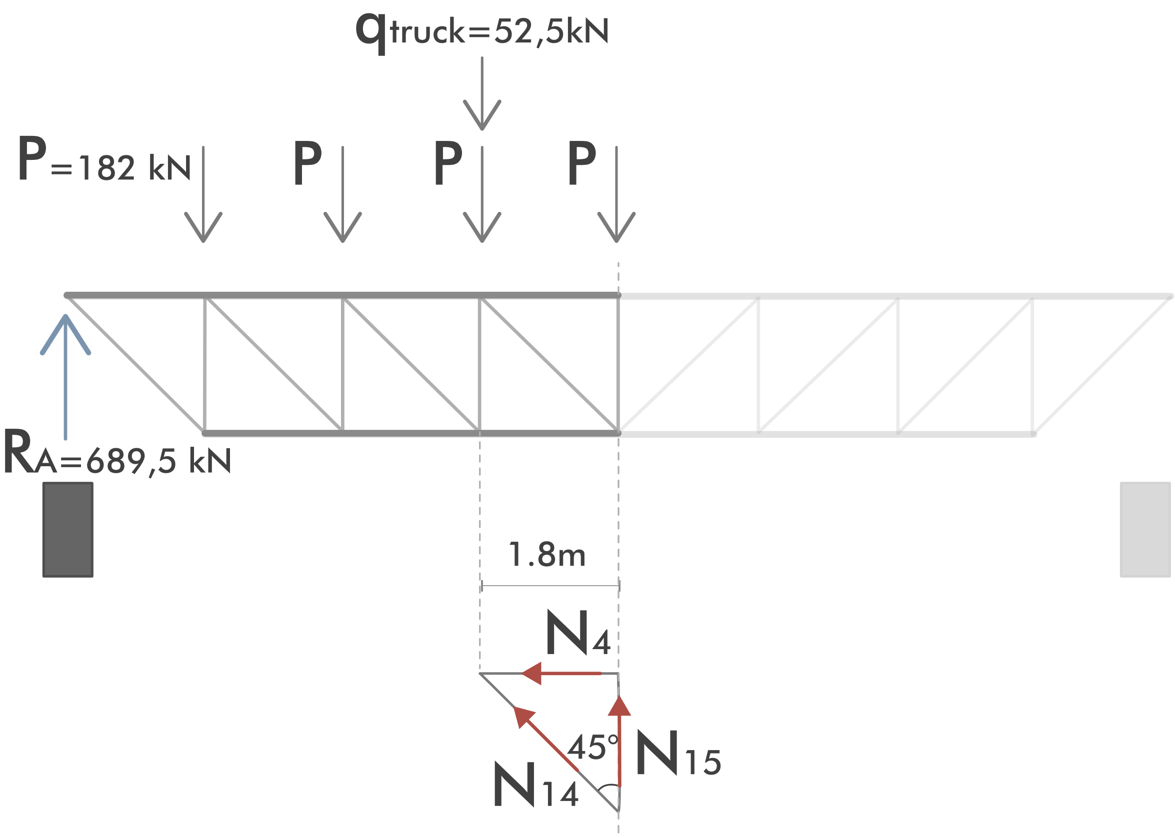
$L_{90x200x12} = 33,6cm^2 > 8,87cm^2$

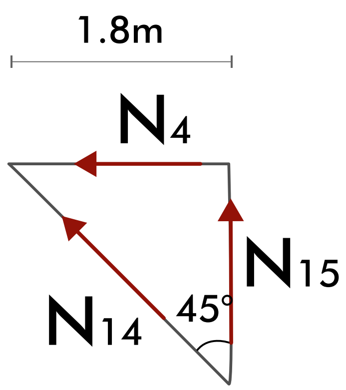




Profilo	b	h	a	r	Peso	Sezione	Momenti di inerzia		Moduli di resistenza		Raggi di inerzia	
							Jx	Jy	Wx	Wy	ix	iy
mm	mm	mm	mm	mm	kg/m	cm²	cm⁴	cm⁴	cm³	cm³	cm	cm
90x200x12	90	200	12	13	26,4	33,6	1391	182	109	25,5	6,44	2,33
90x200x15	90	200	15	13	32,5	41,4	1696	220	135	31,2	6,40	2,30
100x150x12	100	150	12	13	22,6	28,7	650	232	64,2	30,6	4,76	2,84
100x150x14	100	150	14	13	26,1	33,2	744	264	74,1	35,2	4,73	2,82

Design of vertical components





$$N_8 = N_{14} = 487,6\ kN$$

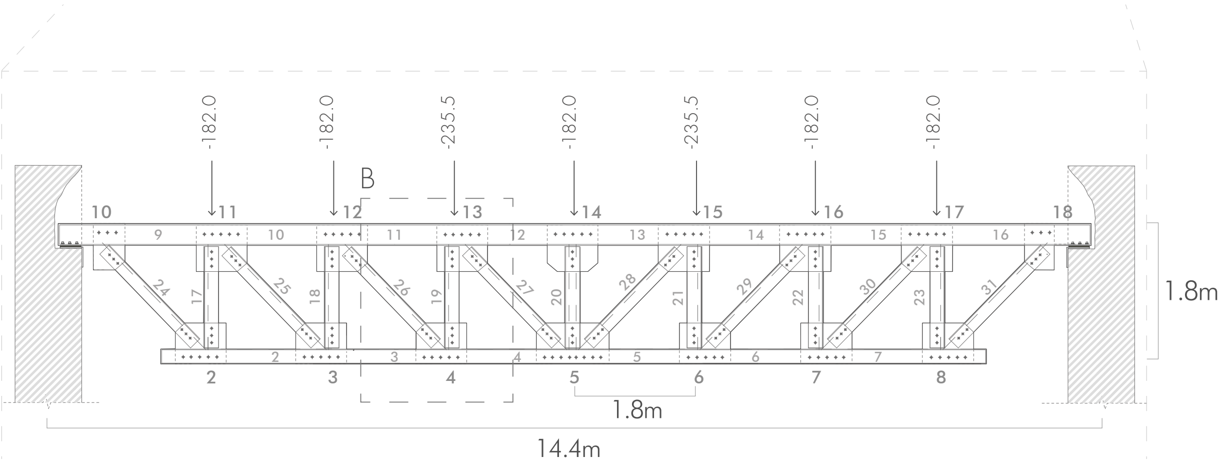
$$N_{15} = N_{14} * cos(45°) = 487,6\ kN\ x\ \frac{\sqrt{2}}{2} = 344,8\ kN = 344800\ N$$

$$2As_{15} = \frac{344800N}{275\frac{N}{mm^2}} = 1253,8\ mm^2 = 12,54\ cm^2$$

$$As_{15} = 12,\frac{54cm^2}{2} = 6,3\ cm^2$$

$$L_{90x200x12} = 33,6cm^2 > 6,3cm^2$$

Final configuration

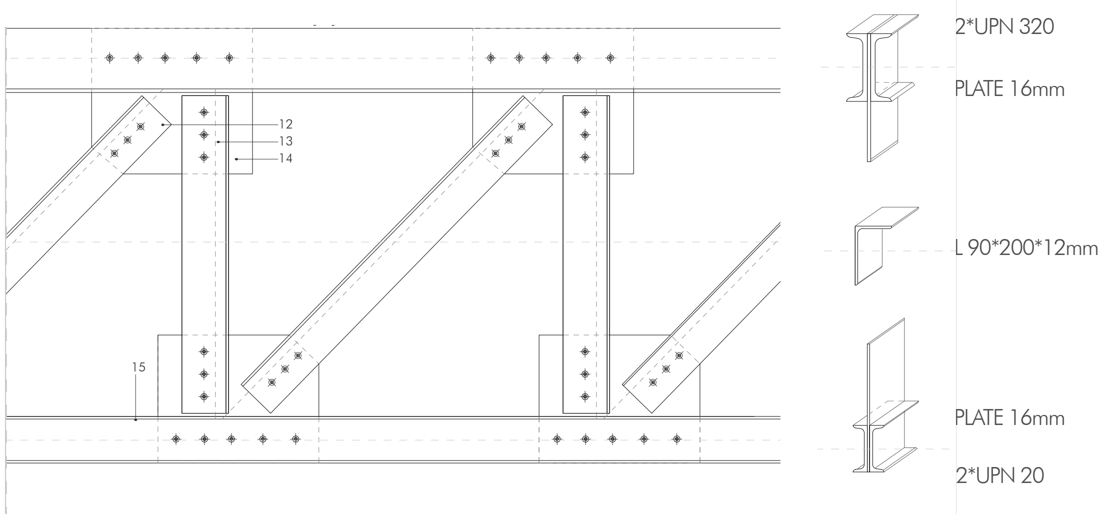


MIDAS software analysis

Finite Element Method (numerical method) is used by using the Midas software to satisfy the boundary conditions with the performance of the structure.
The aspects that is specified with the program are;

- Geometry
- Materials
- Boundary conditions
- Loads(forces)

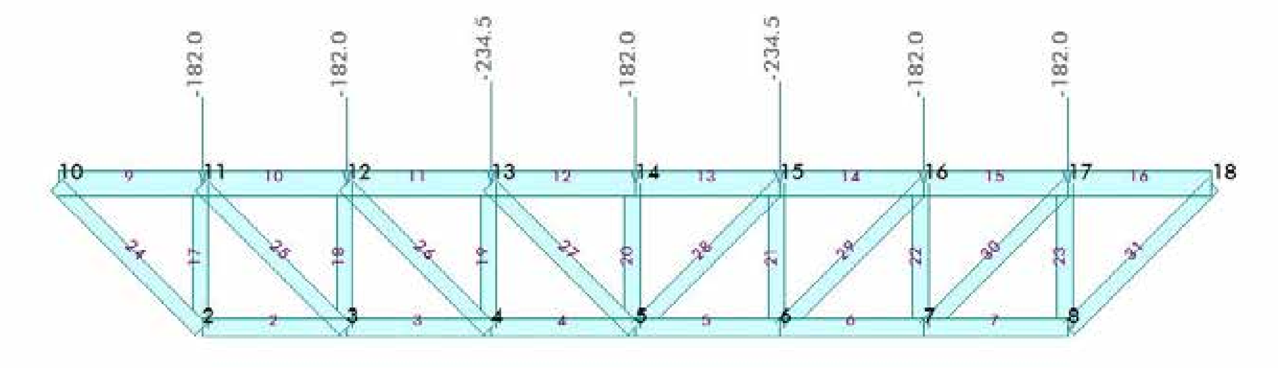
The truss structure is composed of members joint together at their end points and the members are connected together with pinned connections. Since each truss members acts as an axial force member, subject to either axial tension or compression;



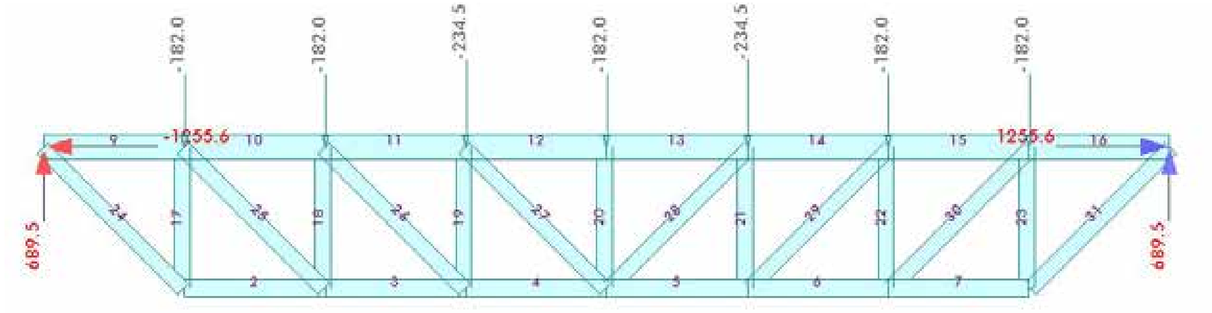
The load are defined on Midas model to and then the behaviour of each element is analysed. The structural system material (**S355**) and each element section is definedas;

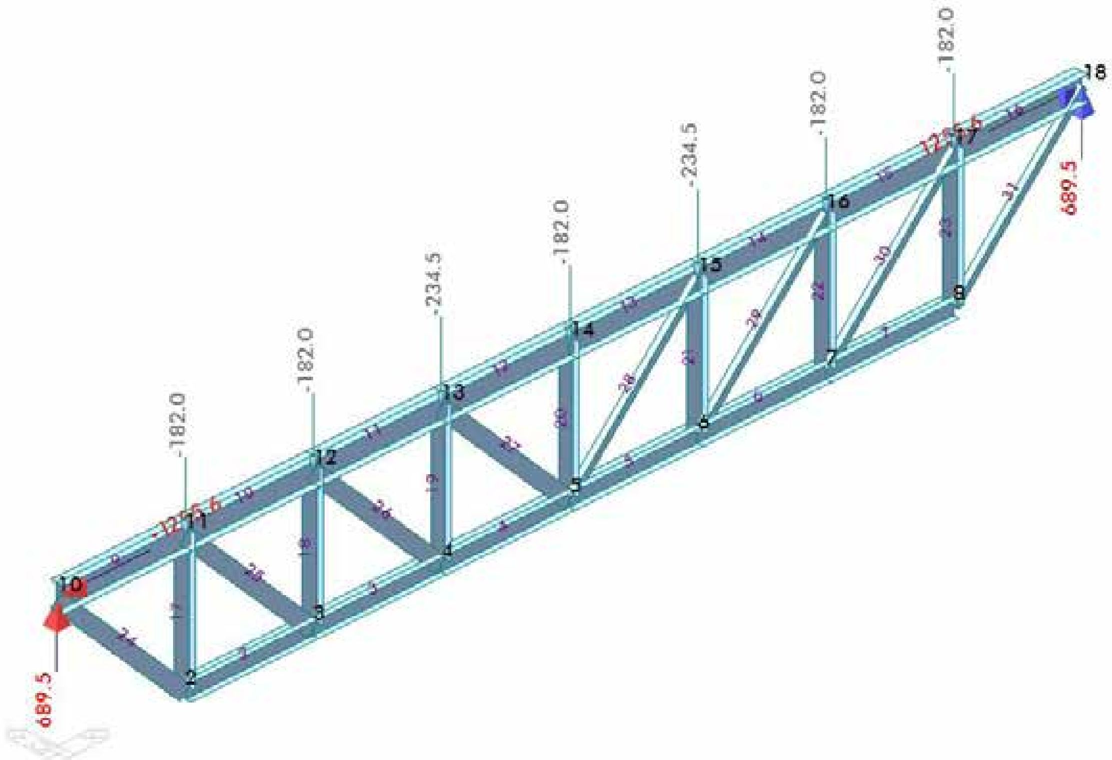
- For top chord **UPN 320**
- For bottom chord **UPN 220**
- For bracings (web) **L 90x200x12**

Applied loads (kN) on structure (MIDAS)



Analysis Results

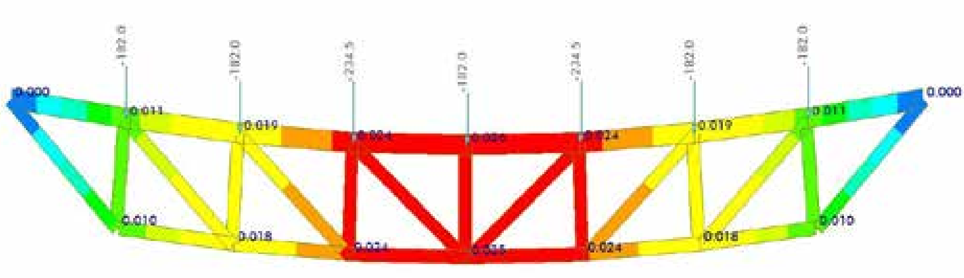


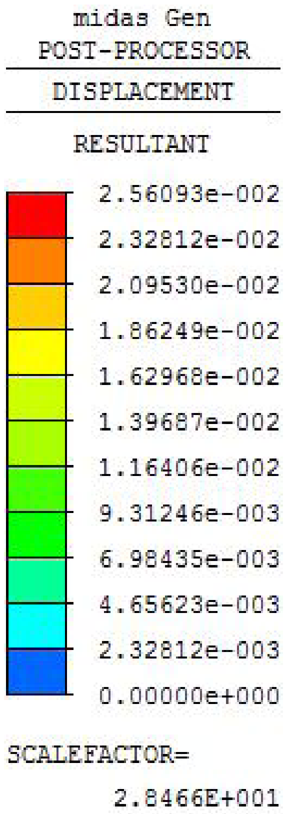


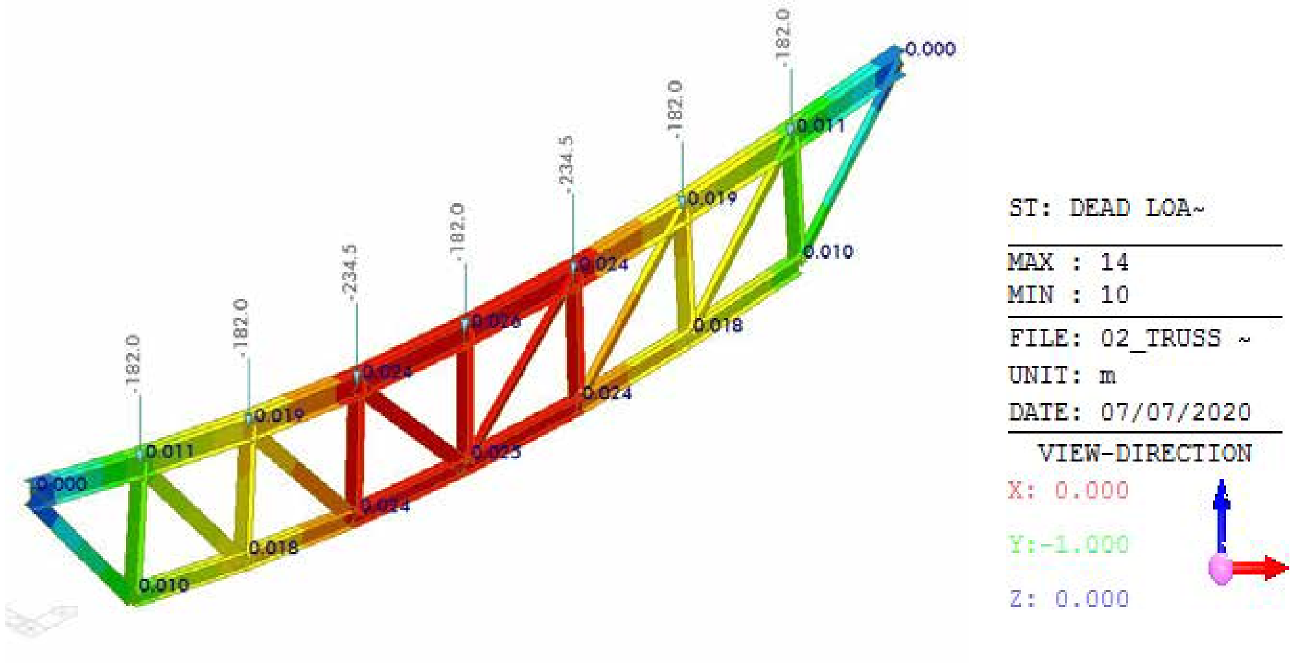
Applied loads on structure and reaction forces (kN)

Displacement Results

Larger displacement is obtained in the middle part of the truss system where the variable load of the track is applied in additionally to permanent and variable load. **The maximum deflection we obtain is equal to 0,025m.**
Considered that the span of the struss is L=14.4m, the limit value for the displacement results to be **L/500=0,03m** , and since **0,025m < 0,03m** such condition is verified.



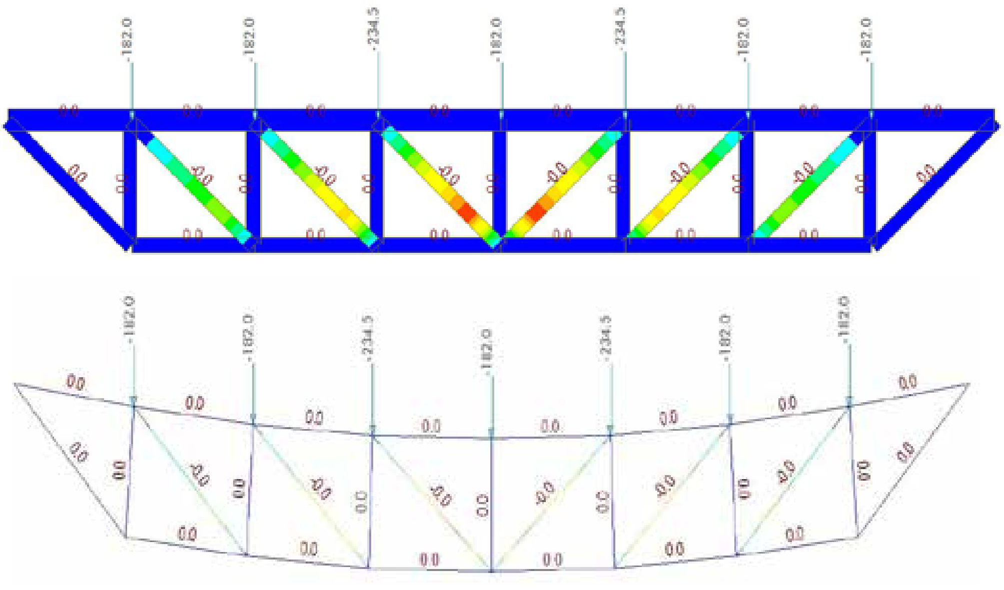


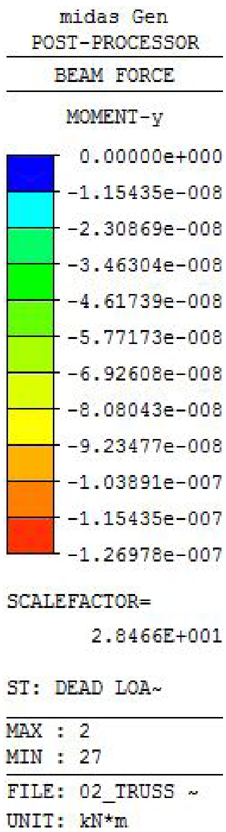


Applied loads on structure (kN) and displacements (m)

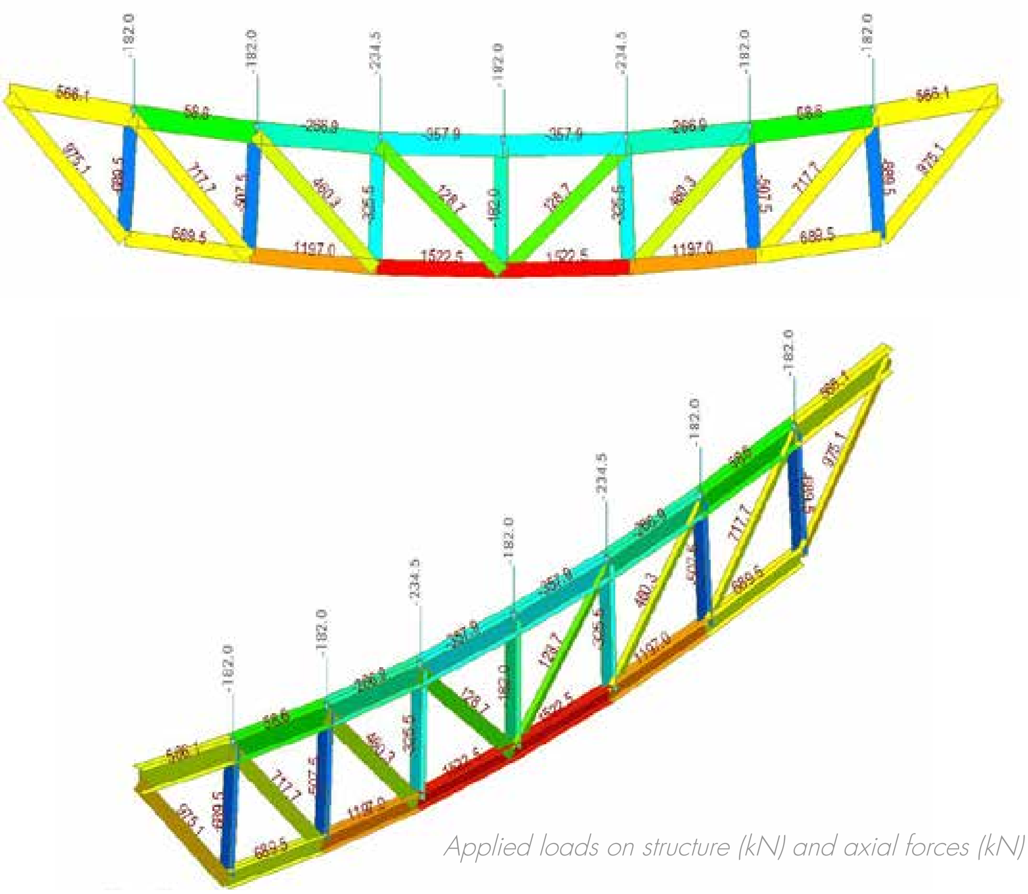
Beam Force Analysis: Moment and Axial Forces

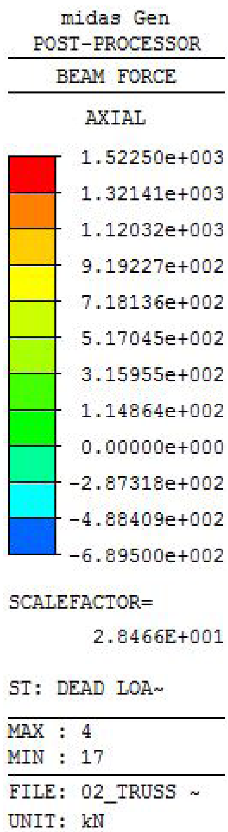
The moment diagram shows that the modelling of boundary conditions was carried out properly, since the bending moment value in each member is null.





Applied loads on structure (kN) and moment values

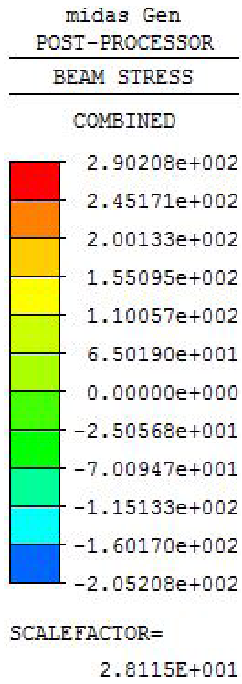


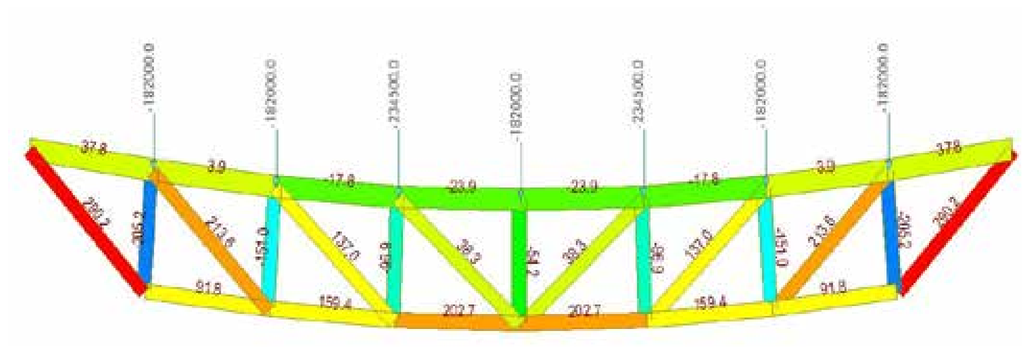


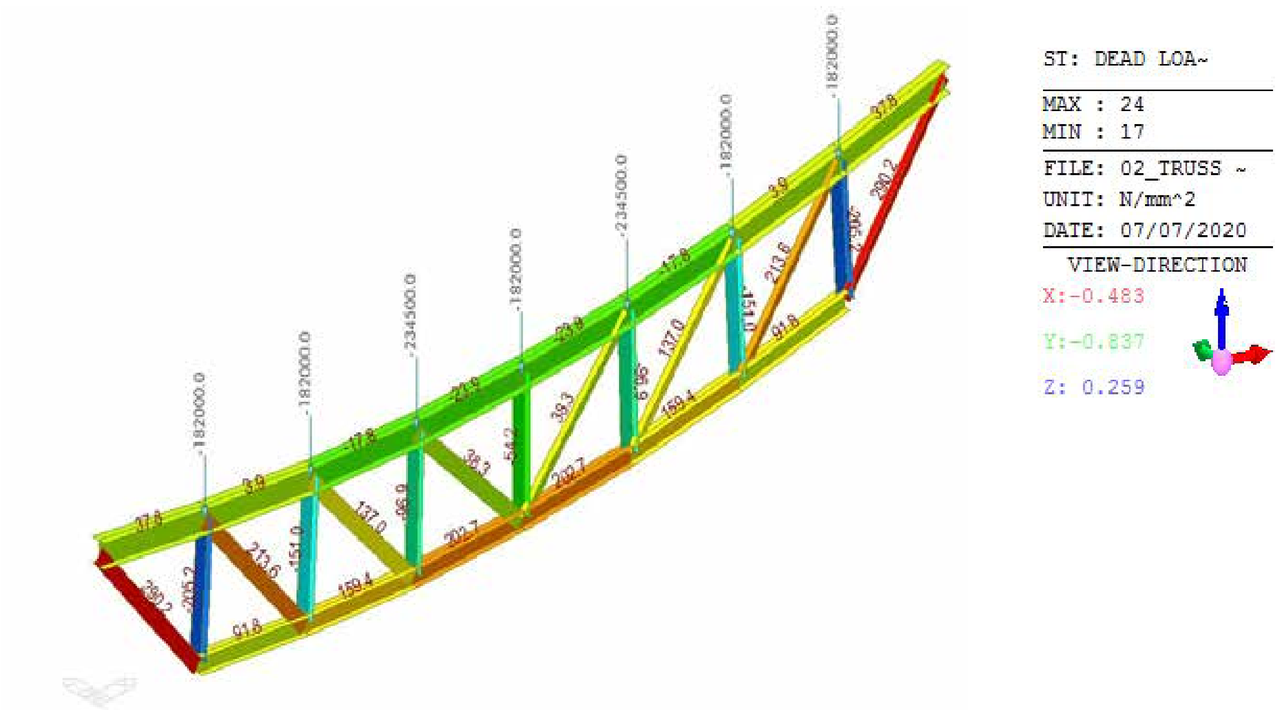
Applied loads on structure (kN) and axial forces (kN)

Beam Stress Analysis

Beam stresses are verified since the maximum value obtained is equal to 290,2 N/mm^2 , and the yield strength of the steel used is equal to 355 MPa= 355 N/mm^2 , and therefore 290,2 N/mm^2 < 355 N/mm^2.







Applied loads on structure (N) and beam stresses (N/mm^2)

BUILDING SERVICES

PROFESSOR FRANCESCO ROMANO

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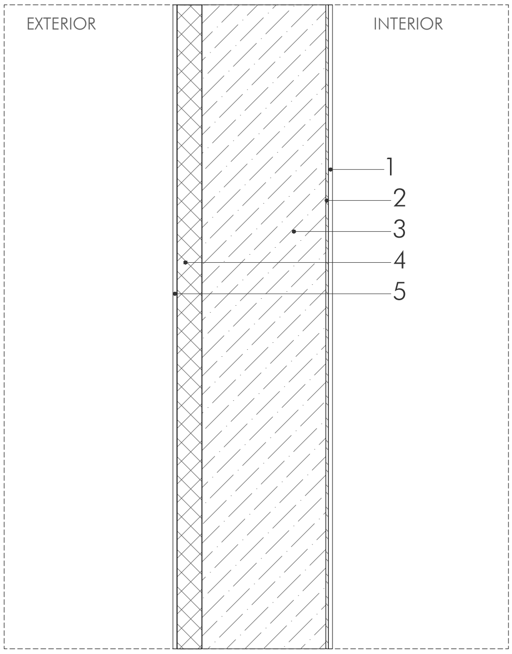
1.

Thermal characteristics of the envelope

THE ENVELOPE

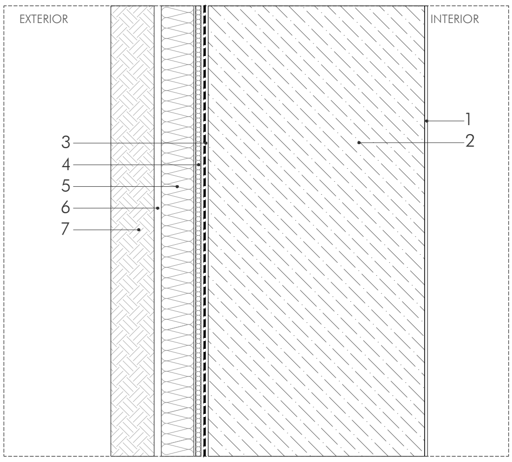
Thermal characteristics of the envelope

Opaque wall U= 0,45 W/m²K



Opaque Wall Envelope

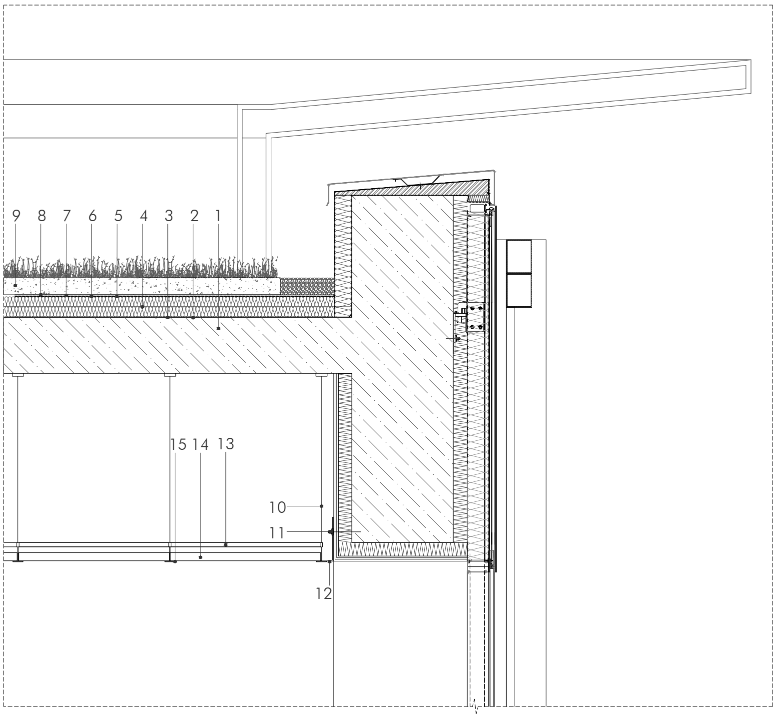
1 Plaster (lime) 15 mm
2 Gypsum plaster board 12.5 mm
3 RC wall 600 mm
4 Mineral Wool insulation 100 mm
5 Exterior plaster (lime) 15 mm



Opaque Wall Envelope

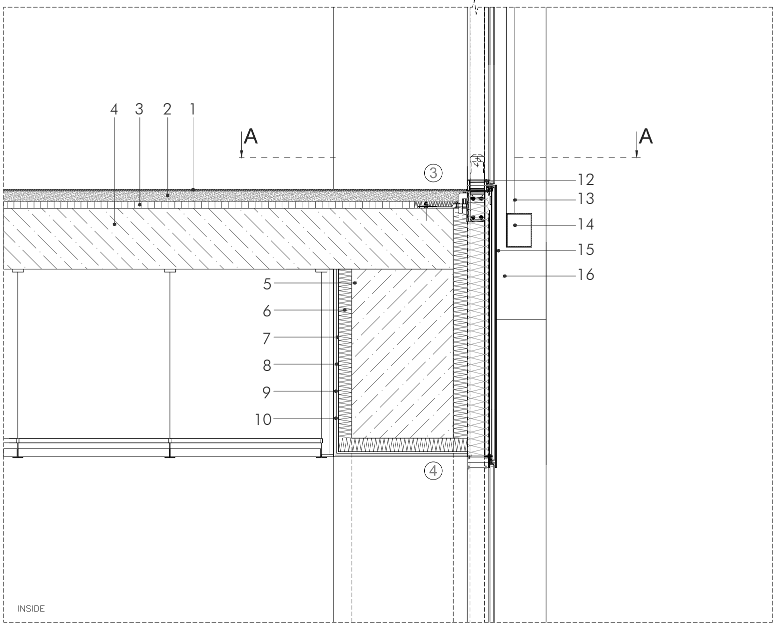
1 Plaster finiture layer 15 mm
2 RC Foundation wall 1500 mm
3 Below grade water proofing membrane 4mm
4 Drainboard 4 mm
5 Owens Corning® Foamular XPS Insulation 200 mm
6 Protecting Panel
7 Grade & Fil

Green roof U= 0,47 W/m²K
Transparent wall U= 0,8 W/m²K



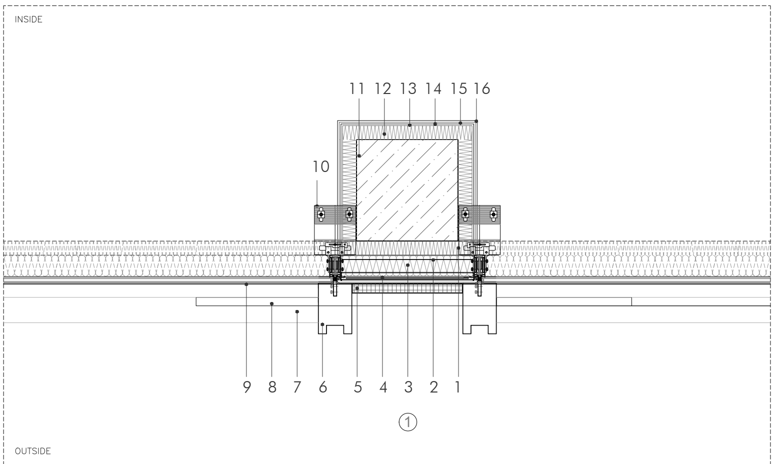
Green Roof Envelope

1 RC slab 330 mm
2 Splast primer 1 mm
3 Preflex - Elastomer bitumen membrane 4 mm
4 Rock mineral wool insulation 120 mm
5 Water proofing membrane 4 mm
6 Root barrier 1 mm
7 Drainage Layer 7 mm
8 Filter Layer 1.1 mm
9 Growing sobstrate 100 mm
10 Vernier suspension
11 Drilling screw
12 L angle
13 Post cap profile
14 Ceiling panel
15 Partition connection profile



Floor Envelope - Partial Facade Section

1 2 component epoxy resin coating
2 Cement screed 80mm
3 Impact sound thermal insulation 40mm
4 Reinforced concrete slab 330 mm
5 Precast RC beam 600*1000 mm
6 XPS Insulation 100 mm
(applied with Forsafoam XPS glue)
7 Base coat 10mm
8 Reinforcing mesh
9 15 Base coat 10 mm
10 Stucco (primer and finish) 10 mm
11 Suspended ceiling 600*600 mm
12 Aluminium shading panels 50 mm
13 Horizontal aluminium profile 200*150 mm
14 Vertical aluminium profile 300*200 mm



Facade Envelope - Partial Facade Plan

1 XPS Insulation 100 mm
2 Horizontal mullion
3 XPS Insulation 120 mm
4 Opaque spandrel panel
5 Aluminium composite panel 60 mm
6 Vertical aluminium profile 300*200 mm
7 Horizontal aluminium profile 200*150 mm
8 Aluminium shading panels 50 mm
9 Aluminium plate 6 mm
10 Gravity bracket
11 RC Coloumn 600*600 mm
12 XPS Insulation 100 mm
(applied with Forsafoam XPS glue)
13 Base coat 10mm
14 Reinforcing mesh
15 Base coat 10 mm
16 Stucco (primer and finish) 10 mm

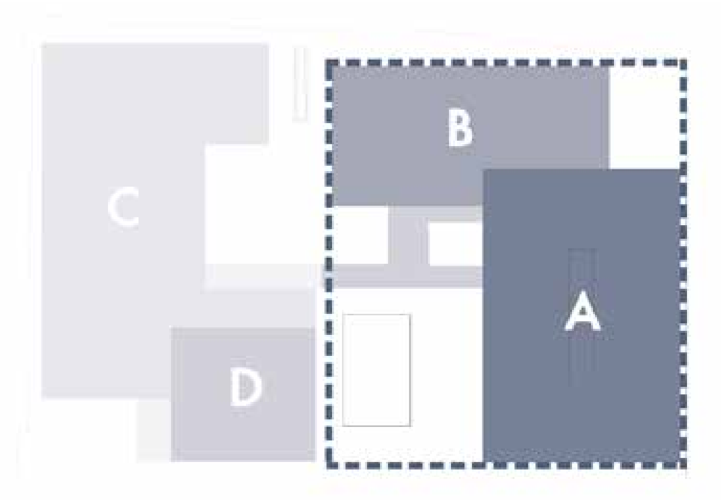
2.

Winter and summer heat loads

HEAT LOADS

Winter heat loads

In order to give a rough estimation of summer heat loads for the buildings of the complex selected to carry out further investigation, which are the **physics and SNI departments**, such volume has been **considered as a unique box**.



LEGEND
A. PHYSICS
B. SNI + ANATOMY
C. CHEMISTRY
D. FACILITY TOWER

The sensible thermal load for winter is calculated according to standard UNI EN 12831 taking into account the most adverse working conditions, while **latent thermal load for winter is neglected in design condition and no standard is available.**

The sensible heat load for winter period is then calculated as follows:

$$Q_{HL,i} = Q_{T,i} + Q_{V,i} + Q_{hu,i}$$

where:

$Q_{T,i}$ = Thermal dispersion by transmission [W]
$Q_{V,i}$ = Thermal dispersion by ventilation [W]
$Q_{hu,i}$ = Extraction power needed for compensating the effects of the intermitting heating [W]

Due to the fact that the calculation is carrie dout in a simplified way on a volumetric box, the **thermal dispersion by transmission** is calculated **considering only the thermal dispersion by transmission of heated spaces towards external spaces ($Q_{T,i,e}$) and the thermal dispersion by transmission of heated spaces towards ground ($Q_{T,i,g}$).**

According to the standard **UNI EN 12831, the thermal dispersion by transmission of heated spaces towards external spaces ($Q_{T,i,e}$) is calculated as:**

$$Q_{T,e} = \sum[e_i A_i U_i (T_{int,i} - T_e)] + \sum[e_i L_i \Psi_i (T_{int,i} - T_e)] + \sum[\chi_m e_i (T_{int,i} - T_e)]$$

e_i = Exposition correction factors which take into account of climatic influences on absorption of humidity, wind velocity, etc. [-]
A_i = dispersing surface [m²]
U_i = Thermal transmittance of building component [W/m²/K]
L_i = Length of thermal bridge[m]
Ψ_i = Lineic thermal transmittance of thermal bridge [W/m/K]
χ_m = Puctual thermal transmittance of thermal bridge [W/K]
$T_{int,i}$ = internal design temperature[°C]
T_e = external design temperature[°C]

However, n this case, due to the high level of simplification, it is **not possible to account for thermal bridges**, and therefore the formula is reduced to:

$$Q_{T,e} = \sum[e_i A_i U_i (T_{int,i} - T_e)]$$

The total value is obtained by summing up the **calculations performed for each orientation of the building**, since each direction corresponds to a certain **exposition correction factor**, and distinguishing **opaque walls, transparent walls and roof components**, since each envelope is associated to a different value of **thermal transmittance U_T and to a different disprsing surface A_i**. In the following table, the different exposion correction factors are indicated:

Exposition factor e_i [-]							
N	NE	E	SE	S	SO	O	NO
1,20	1,20	1,15	1,10	1,00	1,05	1,10	1,15

Here follow the calculations:

NW orientation:
$Q_{T,e}$ = e x A x U x ($T_{int,i}$ - T_e)
$Q_{T,e,opaque,NW}$ = 1,15 x 373,056 m² x 0,45 W/(m²K) x (20°C + 5°C)=4826,41 W
$Q_{T,i,e,glass,NW}$ = 1,15 x 1492,224 m² x 0,8 W/(m²K) x (20°C + 5°C)=34321,152 W

NE orientation:
$Q_{T,e}$ = e x A x U x ($T_{int,i}$ - T_e)
$Q_{T,e,opaque,NE}$ = 1,2 x 491,808 m² x 0,45 W/(m²K) x (20°C + 5°C)=6639,408 W
$Q_{T,e,glass,NE}$ = 1,2 x 1967,232 m² x 0,8 W/(m²K) x (20°C + 5°C)=47213,568 W

SE orientation:
$Q_{T,e}$ = e x A x U x ($T_{int,i}$ - T_e)
$Q_{T,e,opaque,SE}$ = 1,10 x 419,232 m² x 0,45 W/(m²K) x (20°C + 5°C)=5187,996 W
$Q_{T,e,glass,SE}$ = 1,10 x 1676,928 m² x 0,8 W/(m²K) x (20°C + 5°C)=36892,416 W

SW orientation:

$Q_{T,e}$ = e x A x U x ($T_{int,i}$ - T_e)

$Q_{T,e,opaque,SW}$ = 1,05 x 483,12 m^2 x 0,45 W/(m^2K) x (20°C + 5°C)=5706,855 W

$Q_{T,e,glass,SW}$ = 1,05 x 1932,48 m^2 x 0,8 W/(m^2K) x (20°C + 5°C)=40582,080 W

ROOF:

$Q_{T,e}$ = e x A x U x ($T_{int,i}$ - T_e)

$Q_{T,e,ROOF}$ = 1,00 x 4896,4 m^2 x 0,47 W/(m^2K) x (20°C + 5°C)=57532,7 W

TOTAL:

$Q_{T,e,total}$=238902,585 W

According to the standard, **the thermal dispersion by transmission of heated spaces towards ground ($Q_{T,i,g}$) is calculated as:**

$$Q_{T,ig} = f_{\theta,ann} \sum\left[A_i U_{equiv,i} f_{igk}\, \mathrm{f}_{wg,k}\left(T_{int,i} - T_e\right)\right]$$

f_{igk} = correction factor which takes into account the influence of variation of external temperature [-] (values present in UNI EN 12831)

$f_{\theta,ann}$ =correction factor taking into account the annual variation of the external temperature [-]

$f_{WG,k}$ = Correction factor which takes into account presence of water in the underground[−]

$U_{equiv,i}$ =Equivalent thermal transmittance of building component [W/m²/K]

A_i =dispersing surface in contact with ground [m²]

$T_{int,i}$ = space design temperature[°C]

T_e = external design temperature[°C]

Here follow the calculations:

$Q_{T,g}$ = $f_{\theta,ann}$ Σ[($A_{ground\ slab}$ x U_{equiv} x f_{gik} x $f_{wg,k}$ x ($T_{int,i}$ - T_e))+ ($A_{basement\ walls}$ x U_{equiv} x f_{gik} x $f_{wg,k}$ x ($T_{int,i}$ - T_e))]=

$Q_{T,g}$ = 1,45 Σ[(5196 m^2 x 0,11 W/(m^2K) x 0,38 x 1,0 x (20°C +5°C))+ ([4442,1 m^2 x 0,96 W/(m^2K) x 0,38 x 1,0 x (20°C +5°C))]=1,45 Σ[5429,82 W +40511,95 W]=

$Q_{T,g}$ = 66615,6 W

The total thermal dispersion by transmission results then to be equal to:

$Q_{T,total}$ = $Q_{T,e}$ + $Q_{T,g}$= 238902,585 W + 66615,6 W= 305518,185 W

For what concerns the thermal dispersion by ventilation Q_V, the formula is the following:

$$Q_V = \frac{V\,n}{3600}\,\rho\,c_p\,(T_a - T_e)$$

V = volume of the room conditioned [m³]
n = Air change per hour[-] (0,5 -2 by standard)
T_a = design ambient temperature[°C]
T_e = design external temperature[°C]

Here follow the calculations:

Q_V = [(V x n ρ) / 3600)] x ρ x C_ρ (T_a - T_e) =

Q_V = (183742 m³ x 2 /3600) x 1,225 kg/ m³ x 1006 J /Kg K x (25 K)=3144931 W

For what concerns the extraction power needed for compensating the effects of the intermitting heating $Q_{hu,i}$ the formula is the following:

$$Q_{hu,i} = A_i\,\varphi_{hu,i}$$

where:
A_i is the surface of the heated space e $\varphi_{hu,i}$ a correction factor [W/m²]

Considering a correction factor equal to 16 W/m2, the amount of intermitting heating is calculated as:

$Q_{hu,i}$ = 23370,34 m² x 16 W/m² = 373925,44 W

Finally, consideting that the **e total winter heat load is given by the sum of:**

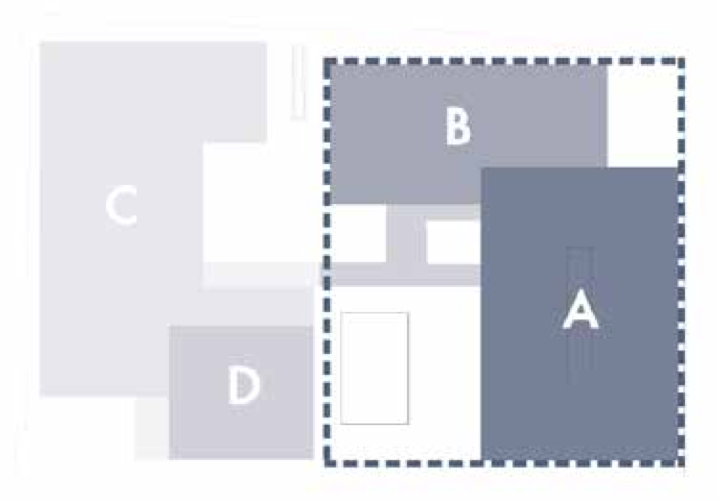
$$Q_{HL,i} = Q_{T,i} + Q_{V,i} + Q_{hu,i}$$

it is obtained that the winter heat load for the selected volume within the complex is equal to:

$$Q_{HL,i} = 3824374{,}625\ W = 3824{,}37\ kW$$

Summer heat loads

In order to give a rough estimation of summer heat loads for the selected buildings of the complex, which are the **physics and SNI departments**, such volume has been **considered as a box**.

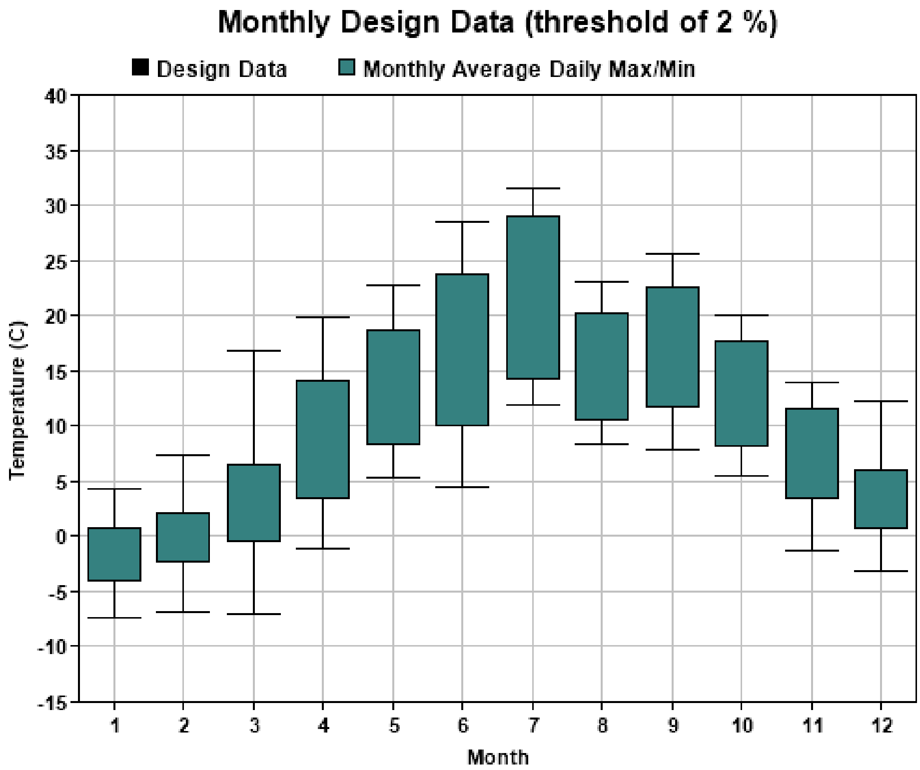


LEGEND
A. PHYSICS
B. SNI + ANATOMY
C. CHEMISTRY
D. FACILITY TOWER

The calculation of the summer design heat load for the simplified volume is carried out according to the simplified **Carrier Method**, by filling out an excell sheet.

GENERAL DATA			
SITE	BASEL		
DESIGN EXTERNAL TEMPERATURE	Te	28,9	°C
DAILY THERMAL EXCURSION	ΔTe	14,5	°C
MAX EXTERNAL ABSOLUTE HUMIDITY	Xe	18	g/kg
LATITUDE		47,6	°
		60	′
AMBIENT TEMPERATURE	Ta	25	°C
AMBIENT ABSOLUTE HUMIDITY	Xa	12	g/kg
MASS IN PLAN	Ma	730	kg/mq
VOLUME OF EXT. AIR FLOW CHANGE	V	2184372	mc/h

Climatic data for the city of basel have been taken from the BIM Green Building Studio platform, in which the BIM model was uploaded. In the weather data section of the platform it is possible to define the **maximum and minimum average temperature for Basel during the moth of July** as **Tav.max= 28.9°C and Tav.min= 14.4°C, and an average daily temperature excursion of ΔTe=15,5°C.**



The maximum external absolute humidity has been determined by considering the fact that on GB Studio, the relative humidity value indicated for the month of July is **RH=75%,** such value, combined with a Dry Bulb Temperature of 28,9°C was used to find the corresponding absolute humidity value using the psychrometric chart. Same procedure was followed to find the ambient absolute humidity of the project, starting from a relative humidity value of RH=60% and a design ambient temperature of Ta=25°C.

The **mass in plan (Ma)** was calculated by multiplying the density of the horizontal components **ρ= 2400 kg/m3** times its thickness **s= 0,33 m.**

Ma= 2400 kg/m3 x 0,33m=792 kg/m2

The **volume of external air flow change V** was taken from the value calculated in the **ventilation section, by considering the different uses and levels of occupancy.**

Name	Area [m2]	Volume [m3]	Crowding rate [p/m2]	Area per person [m2]	Number of People **(D*F)**	Volume of air flow [l/s person]	Ventilation rate per person [m2/h]	Volume of air flow [m3/h]
Laboratories	3466,5	9879,5	0,3	3,3	1040	7	25,2	26208
Open offices	998,4	3165	0,12	8,3	120	11	39,6	4752
Enclosed offices	699,3	2216,8	0,06	16,7	42	11	39,6	1663,2
Seminar rooms	634,6	3022,3	0,6	1,7	381	7	25,2	9601,2
Food & Beverage	372,4	1180,5	0,8	1,3	298	11	39,6	11800,8
Meeting rooms	357,32	1132,7	0,6	1,7	215	10	36	7740
Lounge	8016,8	28812,9	0,5	2	4009	10	36	144324
General warehouse	1630,9	6523,6	0,3	3,3	490	7	25,2	12348
								218437,2

The second portion of the excell datasheet regards the datas about the **envelope**.

ENVELOPE DATA							
	OPAQUE			TRANSPARENT			
ESPOSITION	Up	Mf,p	Sp	Uf	f	F=SC Fv	Sf
	W/(m^{2}K)	kg/m^2	m^2	W/(m^{2}K)	-	-	m^2
NORTH	0,45	174	373,1	0.8	0,8	0,5	1492,224
EAST	0,45	174	491,8	0.8	0,8	0,5	1967,232
WEST	0,45	174	483,1	0.8	0,8	0,5	1932,228
SOUTH	0,45	174	418,2	0.8	0,8	0,5	1676,9
HORIZONTAL SHADOW	0,47	136	4896				
HORIZONTAL SUN	0,47	136	4896				

For what concerns the opaque surfaces of the box, it was necessary to calculate the opaque surface of the facade for each orientation, considering as a 20% of the total surface, versus the 80% of transparent surface. The thermal transmittance value **Up** for the opaque surfaces have been previously calculated as **Up(walls)= 0,45 W/(m^{2}K) and Up(roof)= 0,47 W/(m^{2}K) according to the specific stratigraphies.**

For what concerns the transparent surfaces, calculated for each orientation os the 80% of the total surface, the thermal transmittance value **Uf=0,8 W/(m^{2}K) according to the specific type of glass selected for the curtain wall, which is a product by ACG Glass named Thermobel Advanced 0.8, a solar control double glass with the performance of a triple glazing.** Such product has a solar factor **F=0.5.**
Eventually, the **frontal mass (Mf)** was calculated by multiplying the density of each layer of the wall (or roof) envelope by its thickness, then summing up the values to obtain the frontal mass of the component.

WALL				Mf kg/m2
	Material	S [m]	ρ [kg/m3]	density * thickness
1	Plaster (lime)	0,015	1400	21
2	Gypsum plasterboard	0,125	2406,53	300,81625
3	Reinforced concrete wall	0,6	460	276
4	Expanded Polystyrene (EPS)	0,1	20	2
5	Plaster (lime)	0,15	1800	270
			SUM	869,81625
			AVG	173,96325

GREEN ROOF				Mf kg/m2
	Material	S [m]	ρ [kg/m3]	density*thickness
1	Extensive substrate - growing media	0,1	190	19
2	Drainage layer	0,007	-	0,95
3	Preflex - elastomer bitumen membrane	0,004	0,0036	0,0000144
4	Insulatin (Rock wool)	0,12	45	5,4
5	Preflex - elastomer bitumen membrane	0,004	0,0036	0,0000144
6	RC Slab	0,33	2400	792
			AVG	136,2

The third portion of the excell datasheet concerning the input values for the calculation of the summer heat load regards the **internal loads**.

INTERNAL LOADS					
Constant sensible internal load	$Q_{int,s,const}$	3600	W		
Constant latent internal load	$Q_{int,l,const}$	650	W		
Total internal loads	Hour	Constant	Variable	Constant	Variable
	H	$Q_{int,s,const}$	$Q_{int,s,var}$	$Q_{int,l,const}$	$Q_{int,l,var}$
	h	W	W	W	W
	8	3600	328575	650	600718
	9	3600	328575	650	699765
	10	3600	436540	650	798812
	11	3600	436540	650	798812
	12	3600	7546	650	583894
	13	3600	7546	650	583894
	14	3600	382557	650	699765
	15	3600	382557	650	699765
	16	3600	382557	650	699765
	17	3600	382557	650	699765
	18	3600	157244	650	277650
	19	3600	157244	650	277650
	20	3600	157244	650	277650
	21	3600	153716	650	268830
	22	3600	153716	650	268830
	23	3600	153716	650	268830
	24	3600	153716	650	268830

For what concerns **constant internal loads** ($Q_{int,const}$), they refer to the equipment existing in the building and generating heat. $Q_{int,s,const}$ are the **sensible constant internal loads**, while $Q_{int,l,const}$ are the **latent constant internal loads**: they must be estimated in function of the equipment installed and of the temporal profile of usage (W). Such values are taken from tables provided in standards.

Apparecchiatura	P_{max}	$Q_{int,s,const}$
Apparecchiature per ufficio		
Personal computers	100÷600	90÷550
Minicalcolatori	2000÷6500	2000÷6500
Stampanti laser	850	350
Copiatrici eliografiche	1100÷12500	1100÷12500
Fotocopiatrici	450÷6600	450÷6600
Scanner	1700	1500
Imbustatrici ed etichettatrici	600÷6000	400÷4000
Distributori di acqua refrigerata	700	1750
Distributori di bevande fredde	1200-1900	550-900
Macchine del caffè	1500	1000
Forni a microonde	600	400
Distruttori di documenti	250÷3000	200÷2400

Apparecchiatura	$Q_{int,l,const}$
Apparecchiature per ufficio	
Personal computers	0
Minicalcolatori	0
Stampanti laser	0
Copiatrici eliografiche	0
Fotocopiatrici	0
Scanner	0
Imbustatrici ed etichettatrici	0
Distributori di acqua refrigerata	0
Distributori di bevande fredde	0
Macchine del caffè	650
Forni a microonde	0
Distruttori di documenti	0

For what concerns the constant sensible internal loads **Qint,s,const** the selection of the loads was carried out according to the functions existing within this portion of the building complex.

Constant internal sensible load	
Laboratories	Qint,s,const (W)
mini-calculator	3000
lab oven	200
lab fridge	50
sterilizer	2500
Open offices	
laser print	350
photocopy machine	2000
scanner	500
food machines	1750
coffee machines	1000
pc	3000
Enclosed offices	
pc	3000
Seminar rooms	
pc	3000
Food & Beverage	
food machines	1750
coffee machines	1000
Food & Beverage	
food machines	1750
lounge	
pc	3000
food machines	1750
coffee machines	1000
	30600

For what concerns the constant latent internal loads **Qint,l,const** the only positive value ppresent in the tabl was considered, which is that corresponding to coffee machines.

Regarding **variable internal loads** (Qint,var), they refer to the people occupying the building and generating heat. **Qint,s,var** are the **sensible variable internal loads**, while **Qint,l,const** are the **latent variable internal loads**: they must be estimated in function of personal activity and occupational profile (W). Such values are also taken from tables provided in standards, but in such case thy need to be multiplied by the number of people..

Attività	applicazioni	Qint,s,const
Seduto a riposo	teatro	65
Seduto in attività leggera	ufficio, appartamento	70
Seduto in attività media	ufficio, appartamento	75
Seduto al ristorante	ristorante	80
In piedi, lavoro leggero	negozio	75
In piedi, lavoro medio	officina	80
In piedi, lavoro pesante	officina, cantiere	185
In movimento	banca	75
Danza moderata	sala da ballo	90
In cammino a 1,3 m/s	corridoi	110
Attività atletica	palestra, discoteca	210

Attività	applicazioni	Qint,l,const
Seduto a riposo	teatro	45
Seduto in attività leggera	ufficio, appartamento	65
Seduto in attività media	ufficio, appartamento	80
Seduto al ristorante	ristorante	115
In piedi, lavoro leggero	negozio	80
In piedi, lavoro medio	officina	200
In piedi, lavoro pesante	officina, cantiere	410
In movimento	banca	100
Danza moderata	sala da ballo	230
In cammino a 1,3 m/s	corridoi	265
Attività atletica	palestra, discoteca	450

SENSIBLE VARIABLE INTERNAL LOADS							
Time: 8 am	**Use**	**Activity**	**qs**	**Max n. of people**	**% of people doing that activity over the max n.**	**% of probability of having max n. of people**	**Q**
	Labs	standing in medium activity	80	1040	80%	60%	39936
		sitting in medium activity	75	1040	20%	60%	9360
	Open offices	standing in medium activity	80	120	20%	60%	1152
		sitting in medium activity	75	120	70%	60%	3780
		walking	110	120	10%	60%	792
	Enclosed offices	sitting in medium activity	75	42	100%	60%	1890
	Seminar rooms	sitting in medium activity	75	381	100%	60%	17145
	Food and Beverage	sitting at rest	65	298	40%	5%	387,4
		sitting at restaurant	80	298	60%	30%	4291,2
	Meeting rooms	sitting in medium activity	75	215	100%	60%	9675
	Lounge	sitting at rest	65	4009	50%	60%	78175,5
		walking	110	4009	50%	60%	132297
	General warehouse	standing in medium activity	80	490	30%	60%	7056
		walking	110	490	70%	60%	22638

Total value of $Q_{int,s,const}$ at 8am **328575**

The table above is giving a sample of how the variable internal loads wew calculated, starting from the maximum number of people possibly present in the building according to crowding rates given by standards, multiplying it by the percentage of people doing a specific activity (rather than another) over the total number of people present, and then considering a percentage of probility of having the maximum number of people possible. The same procedure was followed for each hour of the day from 8am to 12pm, for both sensible and latent variable internal loads.

Finally, according to the outputs given by the excell spreadsheet, the **maximum sensible and latent summer heat loads obtained are:**

$$Q_S = 1089881 \text{ W} \text{ and } Q_L = 1892085 \text{ W}$$

or

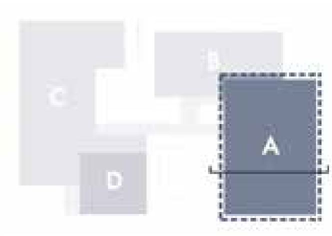
$$Q_S = 1089 \text{ kW} \text{ and } Q_L = 1892 \text{ kW}$$

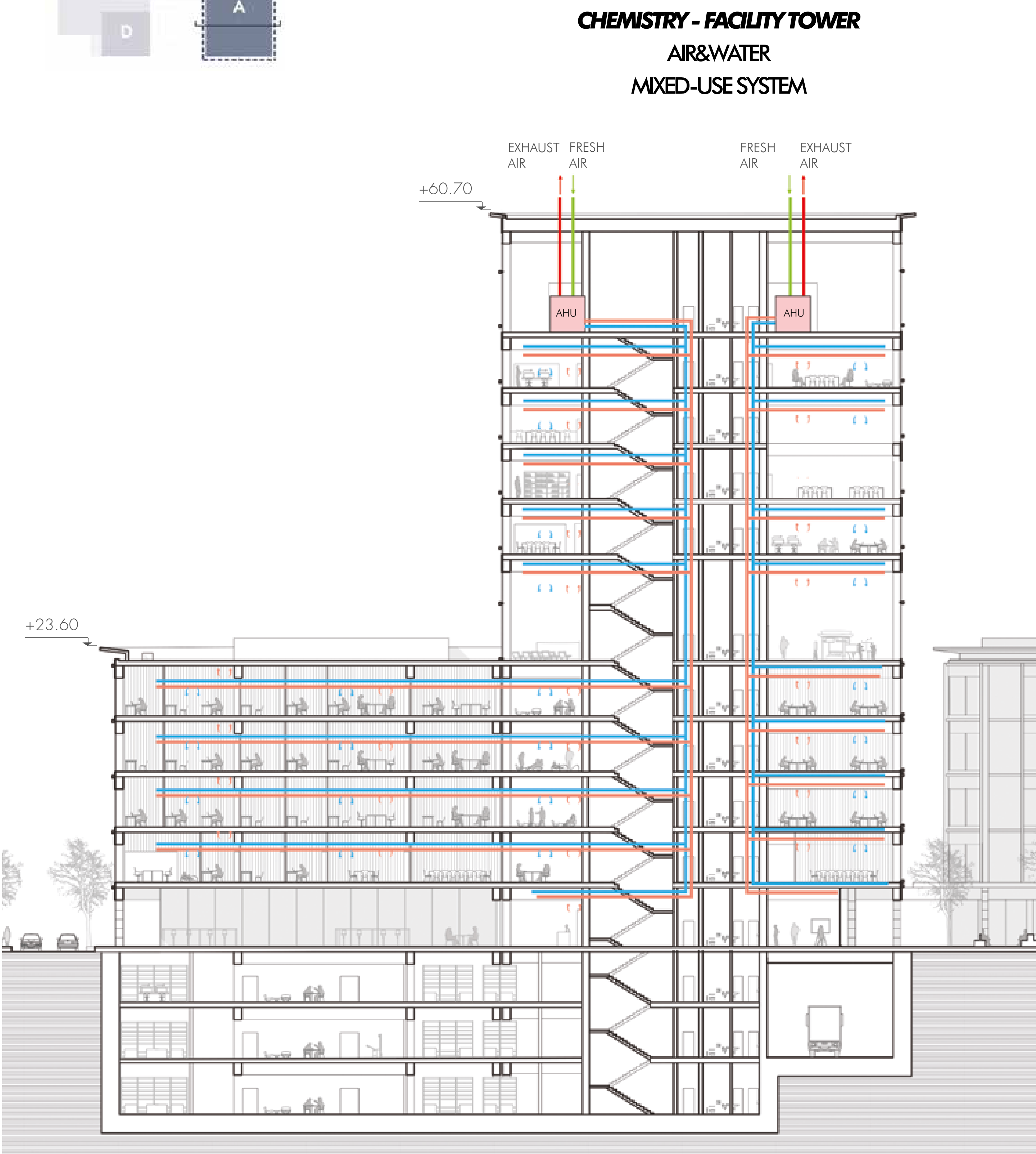
3.

Ventilation layout concept

VENTILATION

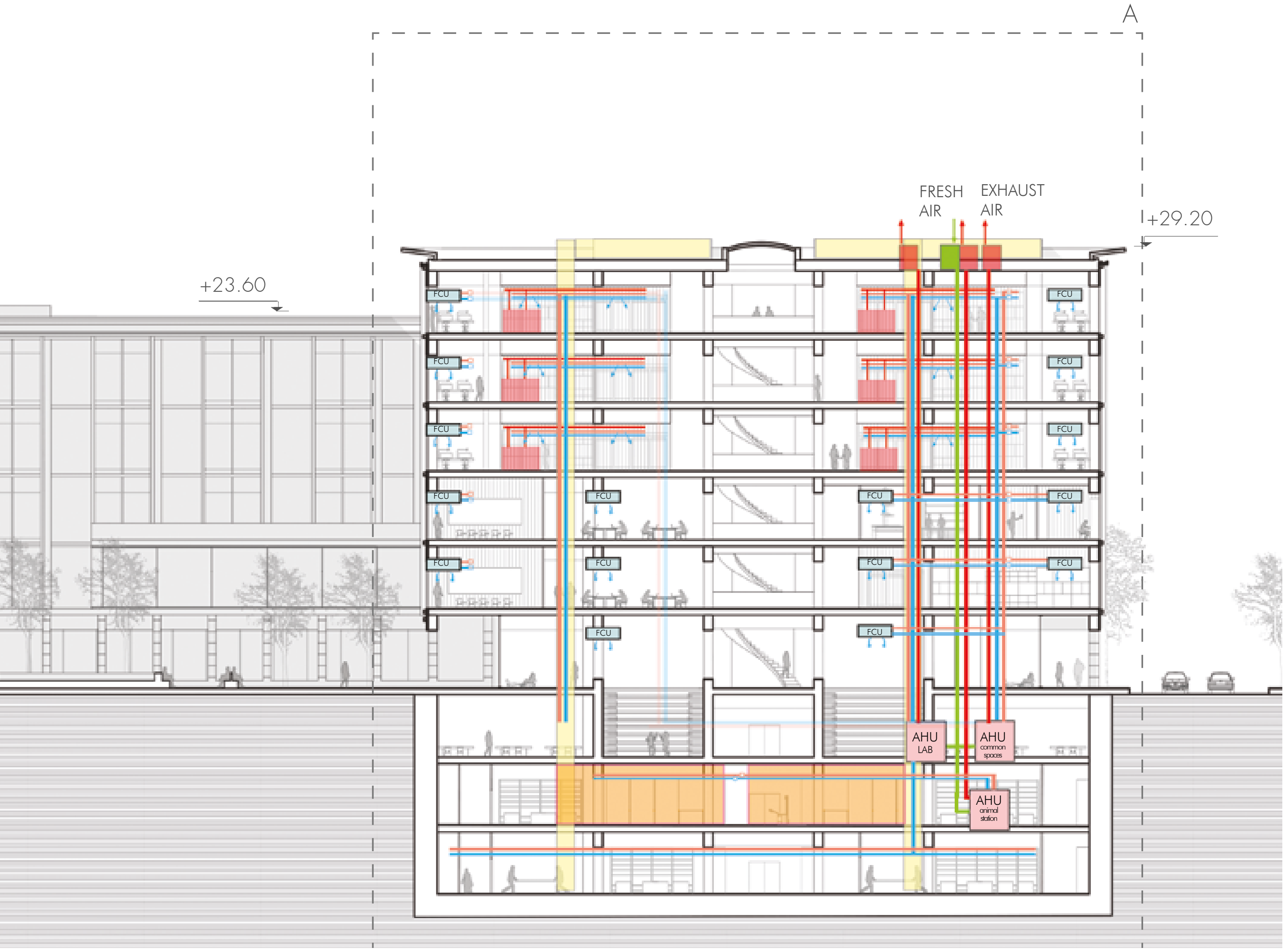
General ventilation layout





PHYSISCS + SNI
AIR&WATER
MIXED-USE SYSTEM

LABS & ANATOMY
ALL- AIR SYSTEM

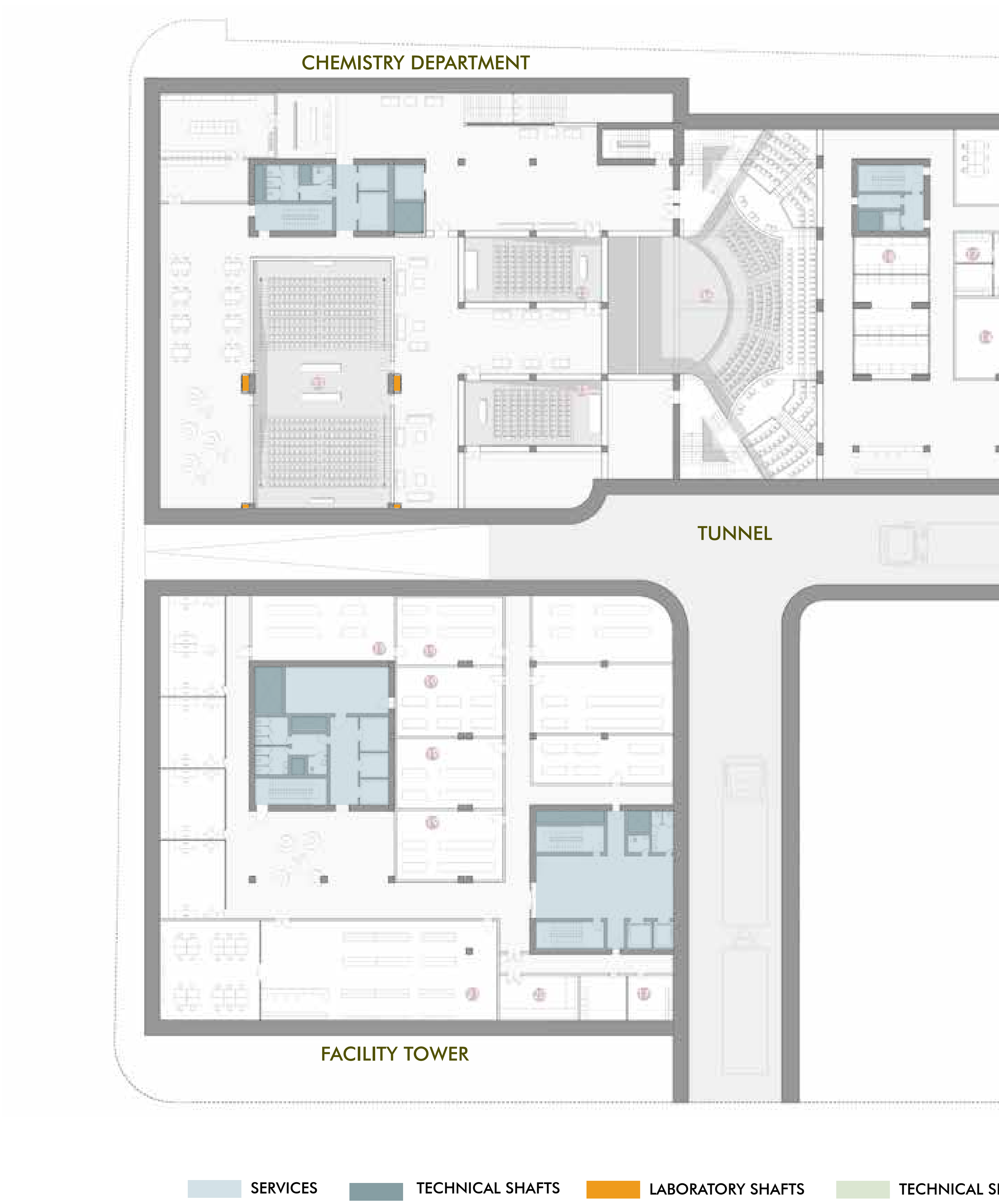


4.

Technical space allocation

TECHNICAL SPACES

Allocation of technical rooms, shafts and spaces



BASEMENT PLAN -4.50
technical allocations

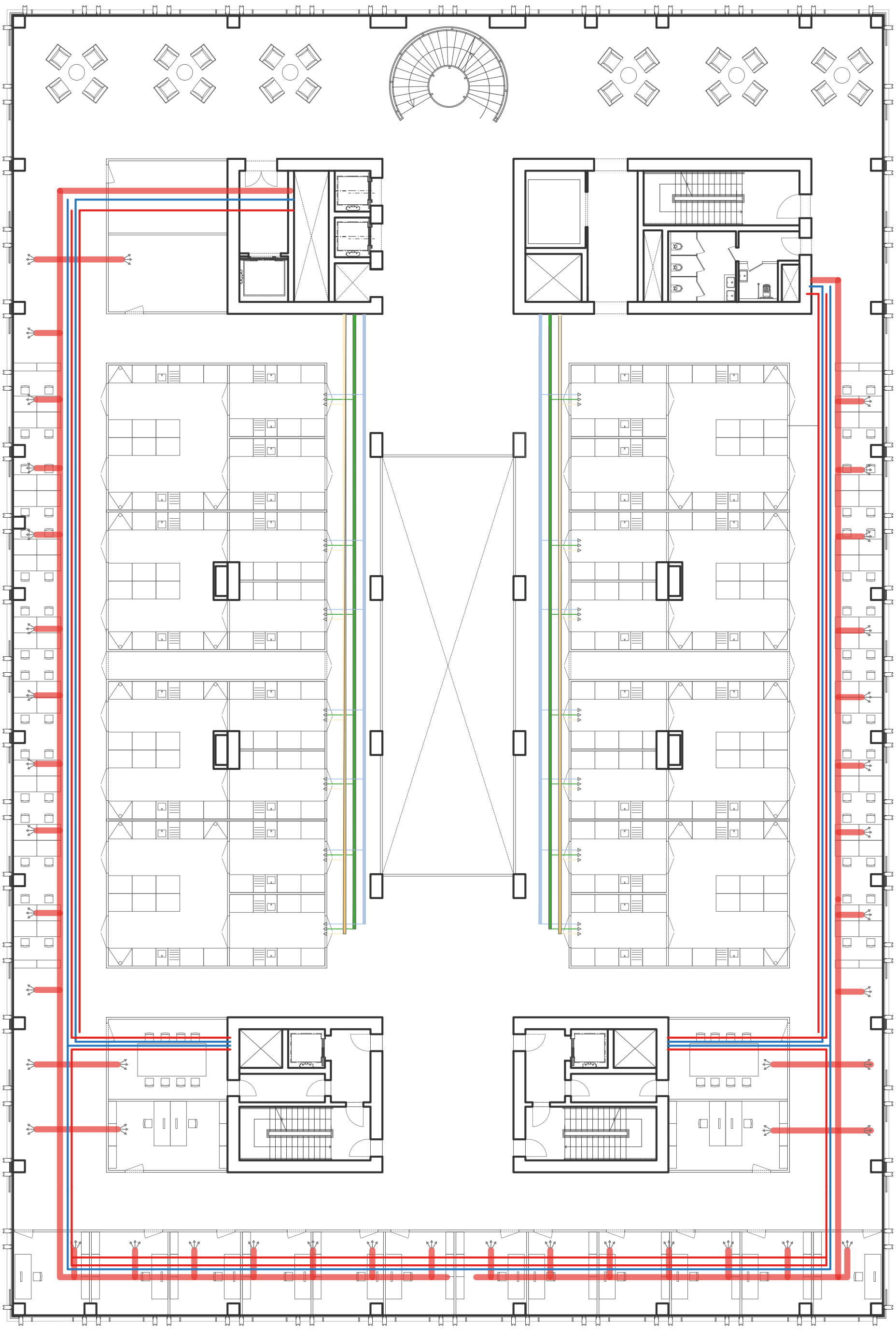
1. Technical Center Ventilation/ Laboratories
2. Outside air intake -ventilation animal rooms (4,5 sqm)
3. Shaft (rising) RDA, HK, exhaust air animal rooms (4.5 sqm)
4. Personal Wardrobe
5. Central disposal room
6. Technical center-refrigeration
7. Technical center-sanitary
8. Technical centerheating/steam
9. Disposal room solvent
10. Disposal for animal rooms
11. Warehouse workshops
12. Washing machines
13. Dissection room
14. Embedding Lab
15. Cadaver storage cooler
16. Freezer- Storage
17. Lockers room
18. Special labs
19. Facility- Storage
20. Cleaning Room
21. Archieve Professorsship
22. Bathroom
23. Autoclave
24. Animal rooms area
25. Security locker room with shower
26. Personal locker room without shower
27. Experiments incl. Irradiation (34 sqm)
28. Unclean Corridor
29. Clean Corridor
30. Room for ultra-freezer
31. Warehouse goods incl. Distribution counter
32. SNI-Physics internship laboratory
33. Lecture Area (stepped) Smal Auditorium 100 seat Medium Auditorim 200 seat
34. Isotope depot bearing
35. Gas bottle space
36. Auditorium
37. Chemistry lab area
38. Laser Laboratory
39. Clean Laboratory
40. Quiet laboratory
41. Scanning Tunneling Microscopy (STM) laboratory
42. X-Ray laboratory
43. CCLS Laboratory
44. NMR Laboratory
45. Power Station
46. Shaft 4 sqm plumbing, exhaust air office

5.

HVAC type and distribution

PHYSICS & SNI DEPARTMENT MIXED SYSTEM

The main distribution system

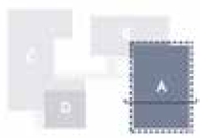


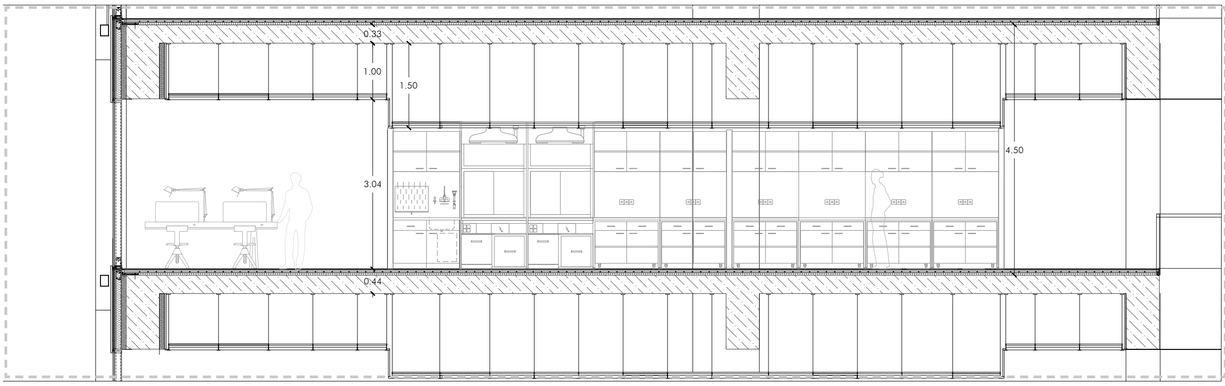
SUPPLY & RETURN DUCTS

4 PIPES
HEATING & COOLING

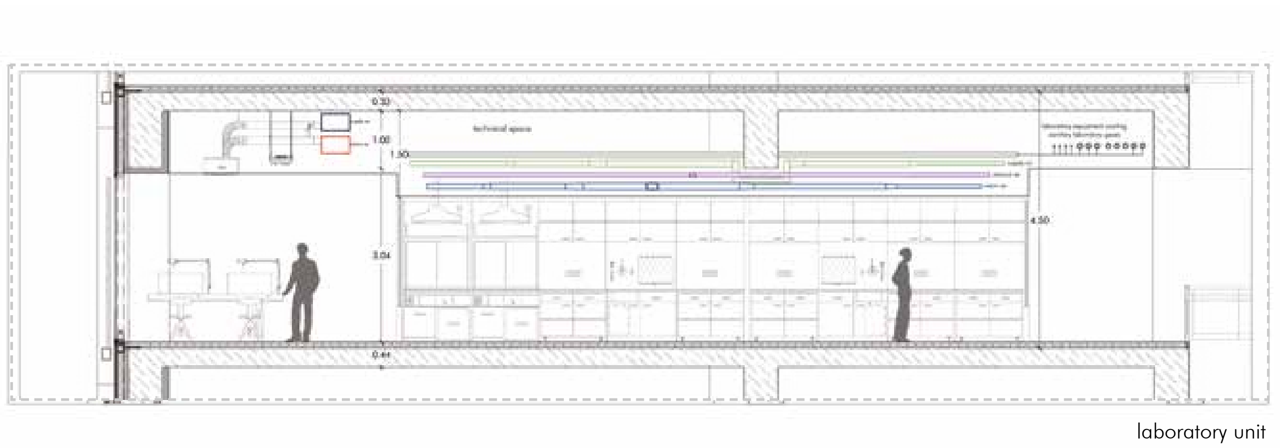
LABORATORY
COOLING
EQUIPMENT

LAB TYPE FLOOR PLAN
ventilation system





laboratory unit
partial section



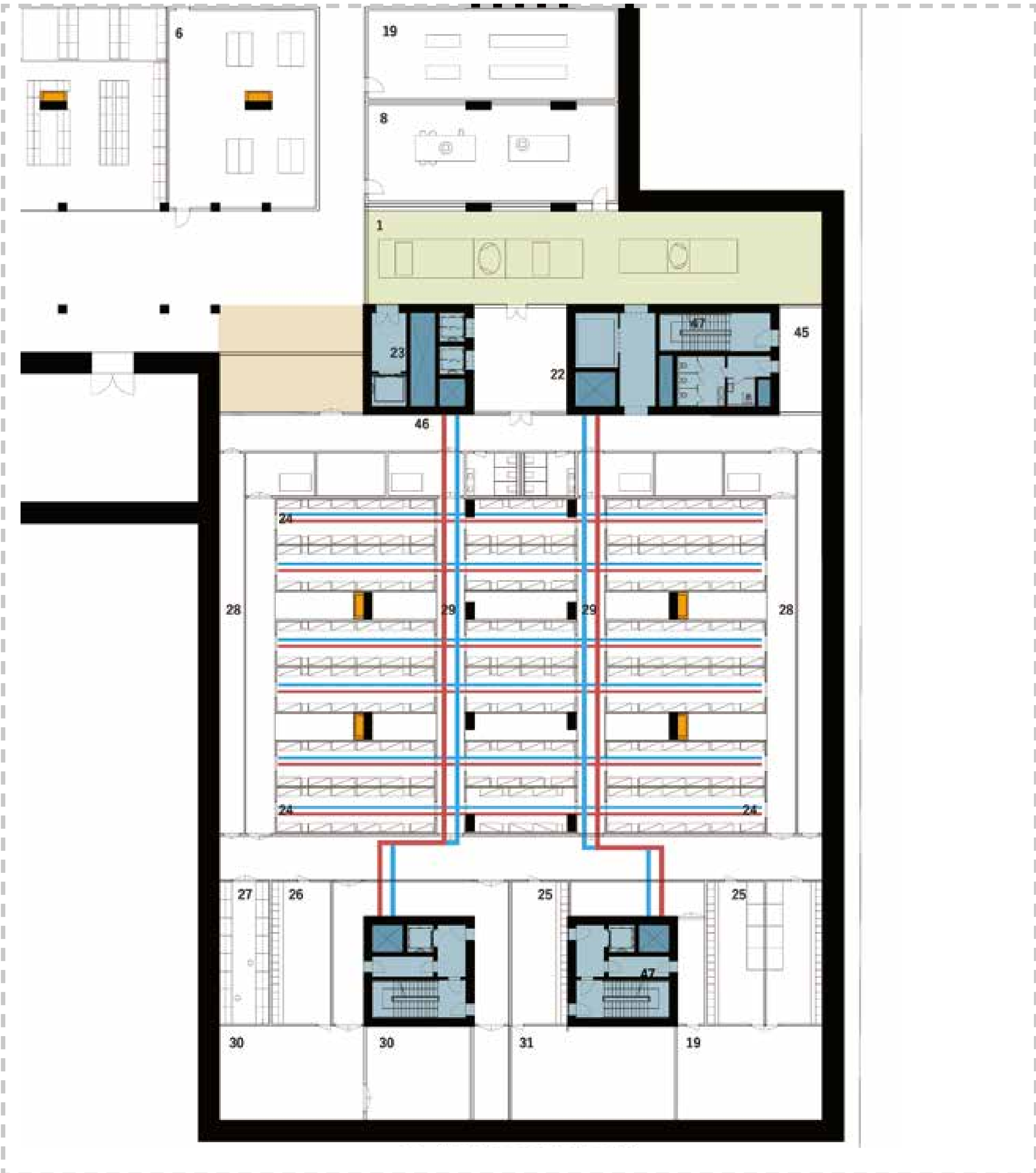
laboratory unit
system section

To provide the right amount of fresh air to the indoor environment, **two different air supplier system will be used for the labs and the office spaces.** For the laboratory spaces, the mono zone system will be used to maintain certain minimum air contamination with a constant air-flow rate. For offices and public spaces, **a multizone system** will be used where we can have variable air flow-rate approach and assuring the right amount of fresh air through the natural ventilation system and mechanical ventilation system.

Advantages of air-water systems Individual zone control is possible in an economic manner using room thermostats, which control either the secondary water flow rate or the secondary air (in fan coil units) or both.It is possible to provide simultaneous cooling and heating using primary air and secondary water. **Space requirement is reduced,** as the amount of primary air supplied is less than that of an all air systems.

ANIMAL STATION ALL AIR SYSTEM

The main distribution system



LABORATORY SHAFTS
TECHNICAL SPACE - VENTILATION
TECHNICAL SPACE - BOILER & CHILLER
SUPPLY AIR
RETURN AIR

BASEMENT PLAN -9.00
technical allocations

For animal stations **all-air systems** will be used to control the temperature and **minimum amount of contamination in the air**.To avoid the risk of contamination , the animal station has seperated all-air system that has its own air handling unit and duct system.Carbonactivated filers will be used to filter the gas molecules to remove trace contaminants.
All-Air Central System supply the latent and sensible cooling capacity with cold air ducted to the conditioned animal stations. By free cooling in summer for the animal stations where we can use outside cold air will be reduce the energy consumption of the system.

HVAC SYSTEM

HVAC calculations – Ventilation duct sizing (EN UNI 10339)

The air flow rate and ventilation distribution system is calculated by using of standards **UNI EN 10339** for sizing the ducts to convey the air with good air flow rate and to minimize the air pressure drop.

VENTILATION SYSTEM/ STANDARTS UNI EN 10339										
Name	Area [m2]	Volume [m3]	Crowding rate [p/m2]	Area per person [m2]	Number of People **(D*F)**	Volume of air flow [l/s person]	Ventilation rate per person [m2/h]	Volume of air flow [m3/h]	Ventilation rate [m3/s]	Cross section of duct [m2]
Laboratories	3466,5	9879,5	0,3	3,3	1040	7	25,2	26208	7,28	1,46
Open offices	998,4	3165	0,12	8,3	120	11	39,6	4752	1,32	0,26
Enclosed offices	699,3	2216,8	0,06	16,7	42	11	39,6	1663,2	0,46	0,09
Seminar rooms	634,6	3022,3	0,6	1,7	381	7	25,2	9601,2	2,67	0,53
Food & Beverage	372,4	1180,5	0,8	1,3	298	11	39,6	11800,8	3,28	0,66
Meeting rooms	357,32	1132,7	0,6	1,7	215	10	36	7740	2,15	0,43
Lounge	8016,8	28812,9	0,5	2	4009	10	36	144324	40,09	8,02
General warehouse	1630,9	6523,6	0,3	3,3	490	7	25,2	12348	3,43	0,69

Starting from the main central ducst system, the network of ventilation system is design according to inner organization principle and the technical allocations space. The number of people and the specifications were taking into consideration and air conditioning system size is obtained through the following calculations.

VENTILATION DUCT SIZING / PHYSICS& SNI BUILDING												
Name	Area [m2]	Volume [m3]	Crowding rate [p/m2]	Area per person [m2]	Number of People **(D*F)**	Volume of air flow [l/s person]	Ventilation rate per person [m2/h]	Volume of air flow [m3/h]	Ventilation rate [m3/s]	Cross section of duct [m2]	Dimension of duct [m]	Cross section ontained of duct [m2]
Laboratories Unit 3 FLOORS	483	1352,4	0,1	10	48	7	25,2	1209,6	0,336	**0,067**	**0,35*0,20**	**0,105**
Laboratories Unit	161	450,8	0,1	10	**16**	7	25,2	403,2	0,112	**0,022**	**0,20*0,11**	**0,022**
Laboratories Unit bigger portion	41,5	116,2	0,2	5	8	7	25,2	201,6	0,06	**0,011**	**0,15*0,08**	**0,012**
Laboratories Unit smaller portion	17,3	48,44	0,2	4	4	7	25,2	100,8	0,03	**0,006**	**0,10*0,06**	**0,006**
Open Offices	947	429	0,14	7,07	134	11	39,6	5306,4	1,47	0,3	**TOTAL**	
									ONE ARM	0,15	0,5*0,3	0,15
Open Offices 3 FLOORS	2841	8523	0,1	7	402	11	39,6	15919,2	4,42	0,9	**TOTAL**	
									ONE SIDE MAIN DUCT(shaft)	0,44	0,8*0,6	0,48

DESIGN OF VENTILATION SYSTEM – LABORATORY UNIT 3 FLOORS 48 PEOPLE

The air ventilation distribution system is calculated by using of standards **UNI 10339**

3 Floors= 16*3= 48 People;

Step 1: computing the maximum number of people according the surface and the standard crowning rate of people ;

Step 2: computing the ventilation rate per person using the standard volume air-flow multiplied with 3,6 which is the transversion conversion from **l/s to m3/h**

7 l/s x 3,6 = 25,2 m3/h

Step 3 : computing the total volume of air flow for all people;

25,2 m3/h x 48 = 1210 m3/h

Step 4: computing the area of the ducts' section by using the relationship;

Volumeair= Section x Velocity; a medium velocity of 5 m/s was considered.

1210 m3/h : 3600= 0,336 m3/s

Section= 0,336 m3/s : 5 m/s = **0,067 m2**

DESIGN OF VENTILATION SYSTEM – LABORATORY UNIT 16 PEOPLE

Step 1: computing the maximum number of people according the surface and the standard crowning rate of people ;

Step 2: computing the ventilation rate per person using the standard volume air-flow multiplied with 3,6 which is the transversion conversion from **l/s to m3/h**

7 l/s x 3,6 = 25,2 m3/h

Step 3 : computing the total volume of air flow for all people;

25,2 m3/h x 16 = 403,2 m3/h

Step 4: computing the area of the ducts' section by using the relationship;

Volumeair= Section x Velocity; a medium velocity of 5 m/s was considered.

403,2 m3/h : 3600= 0,112 m3/s

Section= 0,112 m3/s : 5 m/s = **0,022 m2**

DESIGN OF VENTILATION SYSTEM – LABORATORY UNIT 8 PEOPLE

Step 1: computing the maximum number of people according the surface and the standard crowning rate of people ;

Step 2: computing the ventilation rate per person using the standard volume air-flow multiplied with 3,6 which is the transversion conversion from **l/s to m3/h**

7 l/s x 3,6 = 25,2 m3/h

Step 3 : computing the total volume of air flow for all people;

25,2 m3/h x 8 = 201,6 m3/h

Step 4: computing the area of the ducts' section by using the relationship;

Volumeair= Section x Velocity; a medium velocity of 5 m/s was considered.

201,6 m3/h : 3600= 0,06 m3/s

Section= 0,06 m3/s : 5 m/s = **0,012 m2**

DESIGN OF VENTILATION SYSTEM – LABORATORY UNIT 4 EOPLE

Step 1: computing the maximum number of people according the surface and the standard crowning rate of people ;

Step 2: computing the ventilation rate per person using the standard volume air-flow multiplied with 3,6 which is the transversion conversion from **l/s to m3/h**

7 l/s x 3,6 = 25,2 m3/h

Step 3 : computing the total volume of air flow for all people;

25,2 m3/h x 4 = 108,8 m3/h

Step 4: computing the area of the ducts' section by using the relationship;

Volumeair= Section x Velocity; a medium velocity of 5 m/s was considered.

108,8 m3/h : 3600= 0,03 m3/s

Section= 0,03 m3/s : 5 m/s = **0,006 m2**

DESIGN OF VENTILATION SYSTEM – AN OFFICE ROOM 134 PEOPLE 1 FLOOR

The air ventilation distribution system is calculated by using of standards **UNI 10339**

Step 1: computing the ventilation rate per person using the standard volume air-flow multiplied with 3,6 which is the transversion conversion from l/s to m3/h

11 l/s x 3,6 = 39,6 m3/h

Step 2: computing the total volume of air flow for all people;

39,6 m3/h x 134 = 5306,4 m3/h

Step 34: computing the area of the ducts' section by using the relationship;

Volumeair= Section x Velocity; a medium velocity of 5 m/s was considered.

5306,4 m3/h : 3600= 1,474 m3/s

Section= 0,44 m3/s : 5 m/s = **0,30 m2**

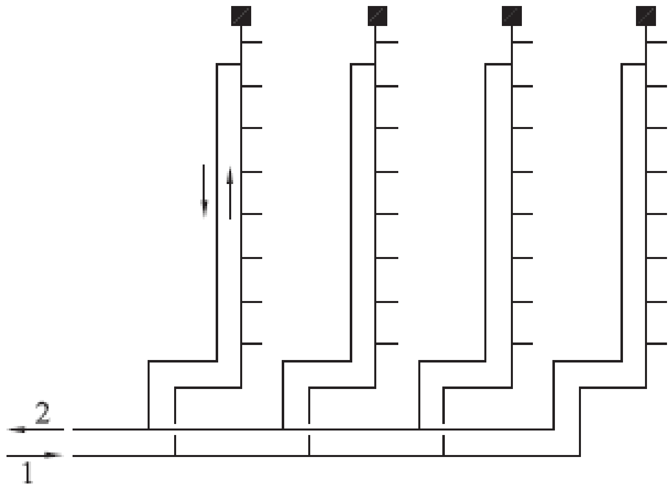
6.

Water supply system

WATER SUPPLY

Water supply system layout

The water system begins at the supply point of the public potable water net, being connected to the city acqueduct of Basel. The water supply system used in the physics building of the Life Science campus is defined as a system with **bottom-up water supply and hot water preparation at bottom level.**



LEGEND
1. SUPPLY
1. RECIRCULATION

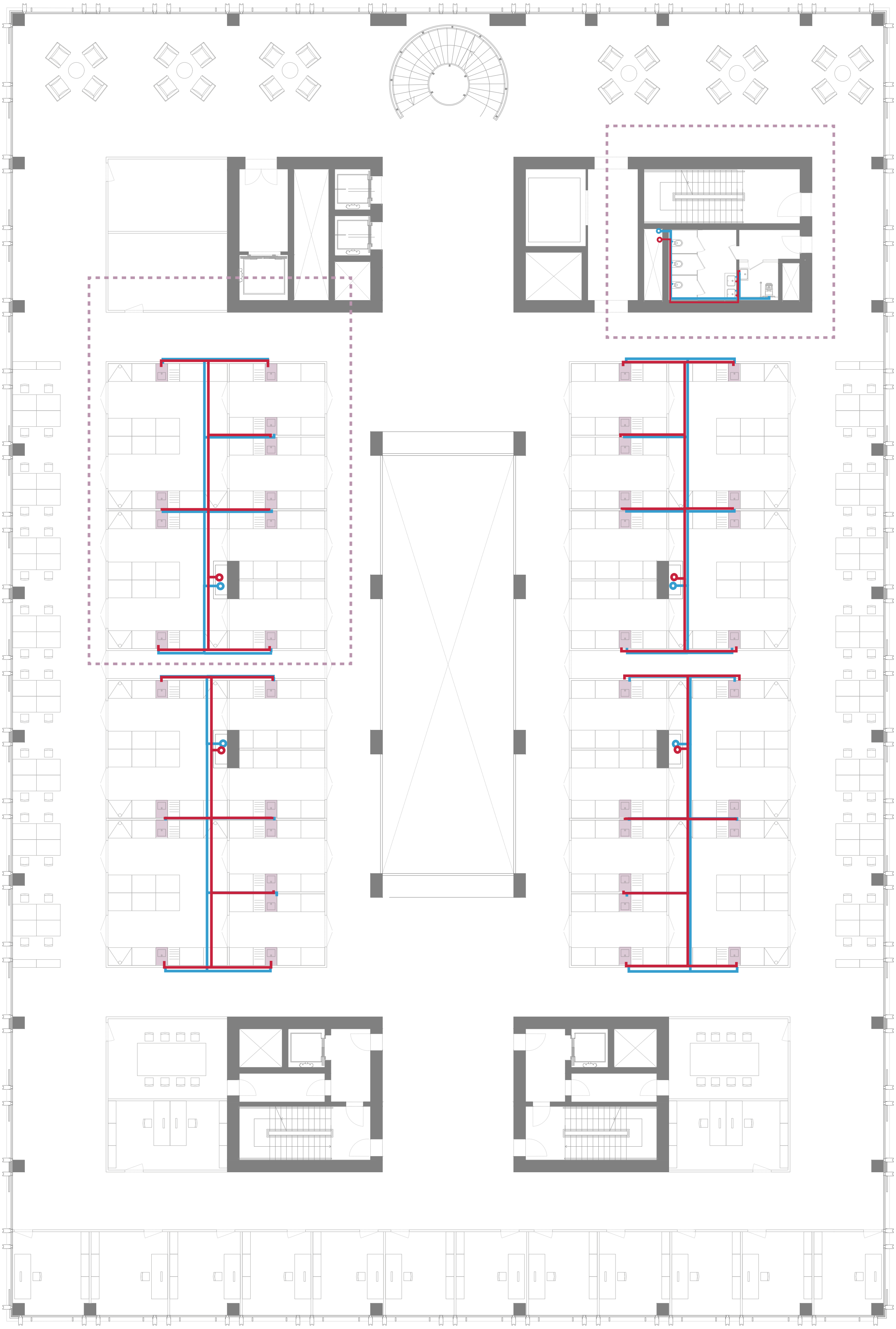
Hot and cold pipe sizing (EN 806–3)

Beginning at the last draw-off point, the loading units for each section of the installation have to be determined, with **1 loading unit** being equaivalent to **a draw-off flow rate QA of 0,1 l/s.**
In order to carry out the calculations for sizing the hot and cold water systems for the selected building (physics department), the simplified method indicated by the norm **EN 806-3** has been adopted, and the following table has been considered for evaluating the draw-off flow-rates **QA** , minimum flow-rates at draw-off points **Qmin** and loading units for draw-off points **LU.**

Draw-off point	Q_A	Q_{min}	Loading units
	l/s	l/s	
Washbasin, handbasin, bidet, WC-cistern	0,1	0,1	1
Domestic kitchen sink, -washing machine [a], dish washing machine, sink, shower head	0,2	0,15	2
Urinal flush valve	0,3	0,15	3
Bath domestic	0,4	0,3	4
Taps /garden/garage)	0,5	0,4	5
Non domestic kitchen sink DN 20, bath non domestic	0,8	0,8	8
Flush valve DN 20	1,5	1,0	15

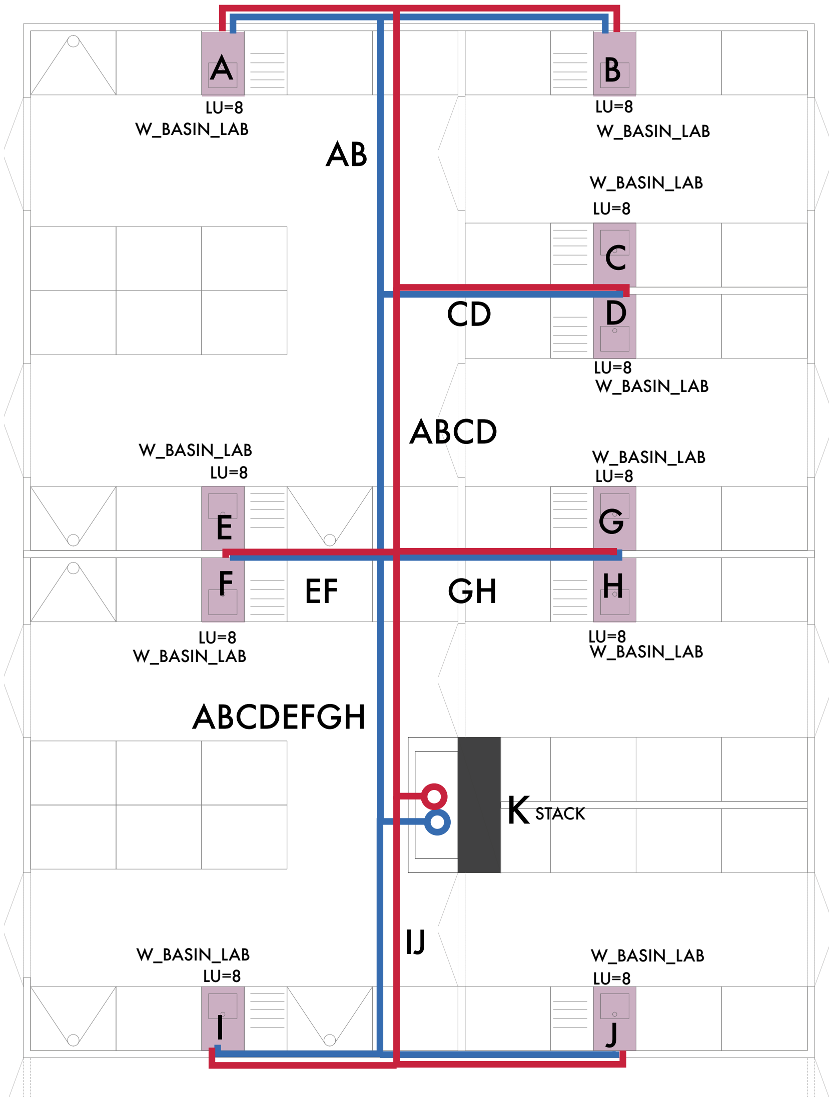
[a] For non domestic appliances check with manufacturer.

The following plan shows the layout of the water supply system for a **type floor plan of laboratories** in the physics building, in which each **installation is indicated** and separated into two groups: **service restrooms and laboratories.**



The fist portion taken into consideration is that of the **laboratories:** the installations located in the labs are **all non-domestic sinks,** which, according to the previous table, correspond to **8 Loading Units.**

Draw-off point	Q_A	Q_{min}	Loading units
	l/s	l/s	
Non domestic kitchen sink DN 20, bath non domestic	0,8	0,8	8

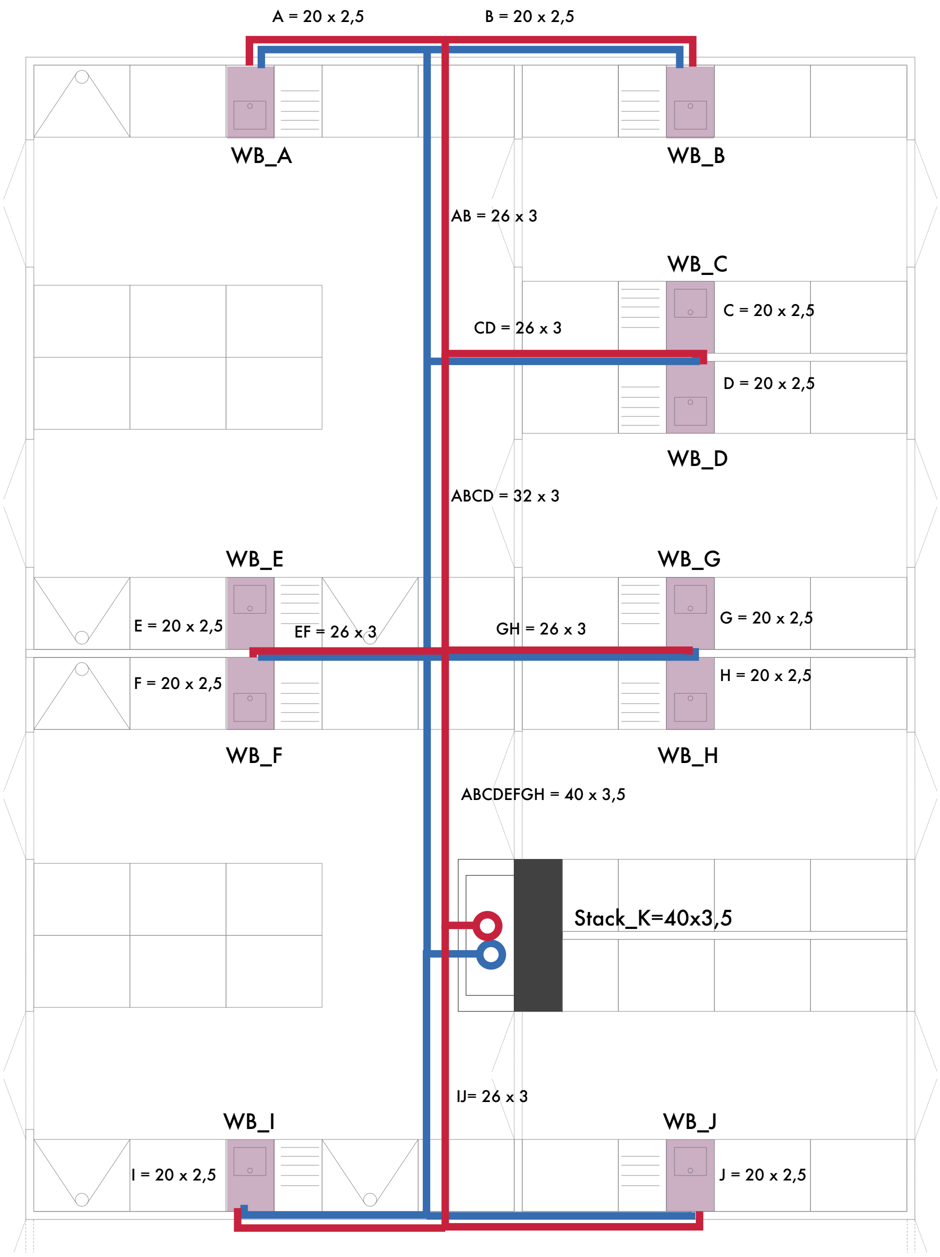


The sizing of each portion of the system depends on the fact that the loading units are summed together, and then dimensioned considering the **maximum loading units in that portion, the highest loading unit value, and the material of the pipes.** In the case under evaluation, the ones used are multilayered pipes made of **PEX/AL/PE-HD**, the dimensioning of which depends on a specific table.

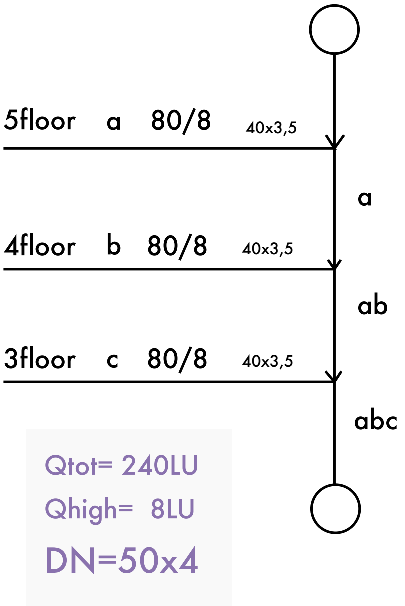
Table 3.8 — PEX/AL/PE-HD resp. PE-MD/AL/PE-HD											
Max. load	**LU**	**3**	**4**	**5**	**6**	**10**	**20**	**55**	**180**	**540**	**1 300**
Highest value	LU			4	5	5	8				
d_a x s	mm	**16** x 2,25/**16** x 2,0			**18** x 2	**20** x 2,5	**26** x 3	**32** x 3	**40** x 3,5	**50** x 4	**63** x 4,5
d_i	mm	11,5/12,0			14	15	20	26	33	42	54
Max length of pipe	m	9	5	4							

The following table shows the calculations carried out in order to dimension each portion of the water supply system, obtained by summing up the loading units along the path and then using the **Table 3.8 from the standards** in order to obtain the **dimensions of pipes' diameter and material thickness.**

	A	B	AB	C	D	CD	ABCD	E	F	EF	G	H	GH	ABCD EFGH	I	J	IJ	KSTACK
QTOT	8	8	16	8	8	16	32	8	8	16	8	8	16	64	8	8	16	80
QHIGH	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
da x s	20 x 2,5	20 x 2,5	26 x 3	20 x 2,5	20 x 2,5	26 x 3	32 x 3	20 x 2,5	20 x 2,5	26 x 3	20 x 2,5	20 x 2,5	26 x 3	40 x 3,5	20 x 2,5	20 x 2,5	26 x 3	40 x 3,5

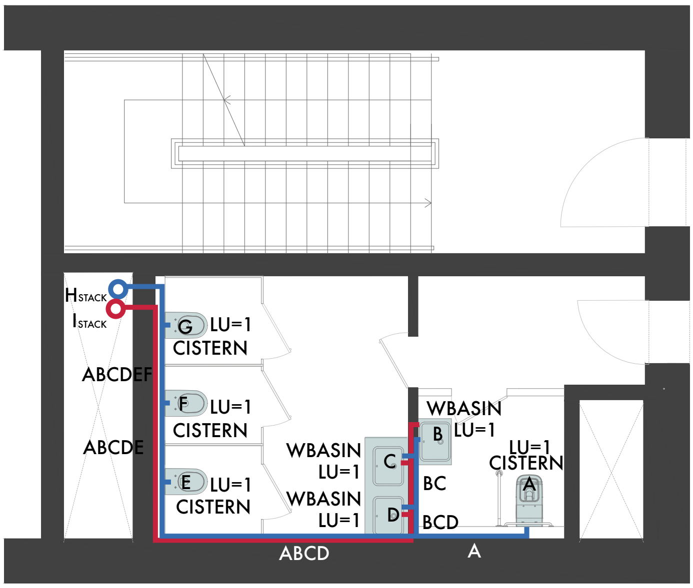


The **stack located in the shaft** at the end of the water system in the type floor is a pipe dimensioned with an internal diameter **di of 33mm,** with material thickness **s of 3,5mm** and an external diameter **da of 40mm.** It is then necessary to size the stack pipe in elevation, considering the fact that **there are only 3 floors of laboratory systems, identical to each other.**



	a	b	ab	c	abc
QTOT	80	80	160	80	240
QHIGH	8	8	8	8	8
da x s	40 x 3,5	40 x 3,5	40 x 3,5	40 x 3,5	50 x 4,0

The **stack located in the shaft** reaches in its larger section an internal diameter **di of 42mm,** with material thickness **s of 4,0 mm** and an external diameter **da of 50mm.**
In the case of laboratory sinks, they are provided in the **same amount of loading units for both hot and cold water, therefore calculations are valid for sizing both piping systems.**



Different is the case of the second area taken into account, which is that of **service restrooms.** In this second case is in fact necessary to **distinguish the calculations for hot and cold water** since not all the installations present in a restroom are provided with both.

Indeed, **WC cisterns are only provided with cold water, while domestic handbasins are provided with both hot and cold water.**

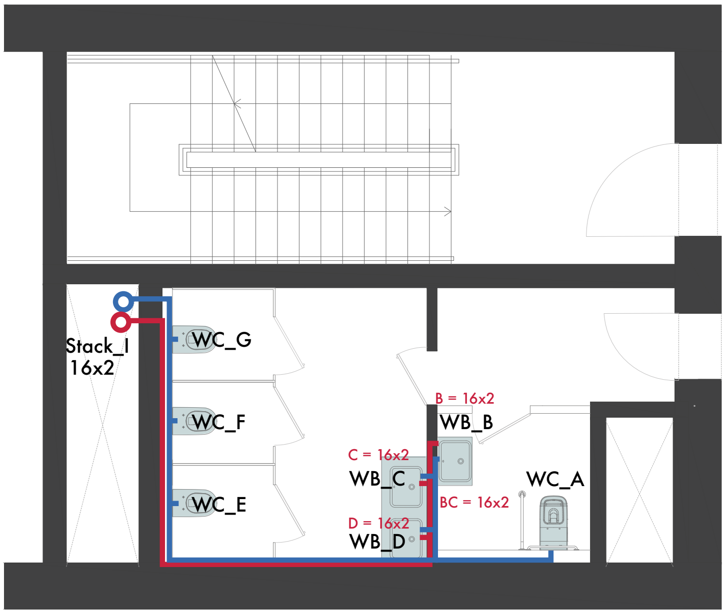
Both **WC cisterns and domestic handbasins correspond to 1 loading unit.**

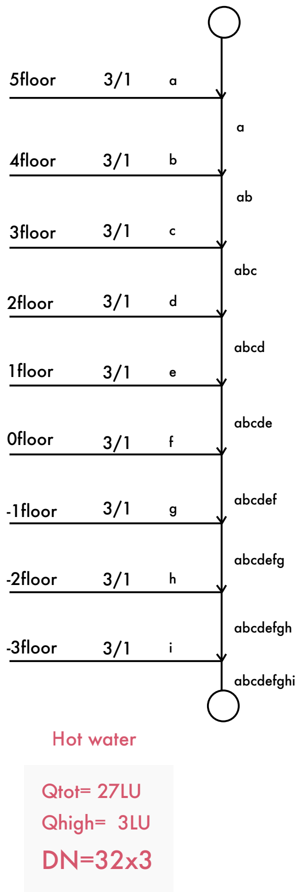
Draw-off point	Q_A	Q_{min}	Loading units
	l/s	l/s	
Washbasin, handbasin, bidet, WC-cistern	0,1	0,1	1

The following table shows the calculations carried out in order to dimension each portion of the water **supply system for hot water in service restrooms**, obtained by summing up the loading units along the path and then using the **Table 3.8 from the standards** in order to obtain the **dimensions of pipes' diameter and material thickness.**

	B	C	BC	D	ISTACK
QTOT	1	1	2	1	3
QHIGH	1	1	1	1	1
da x s	16 x 2,0	16 x 2,0	16 x 2,0	16 x 2,0	16 x 2,0

The **stack located in the shaft** at the end of the water system in the type floor is a pipe dimensioned with an internal diameter **di of 12mm,** with material thickness **s of 2mm** and an external diameter **da of 16mm.**
It is then necessary to size the stack pipe in elevation, considering the fact that **restrooms are located within the cores, without any variations, for 9 floors.**



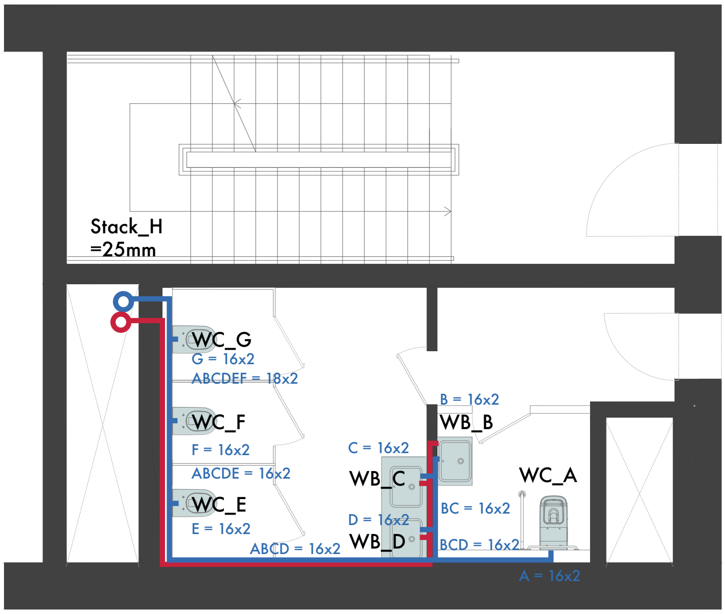


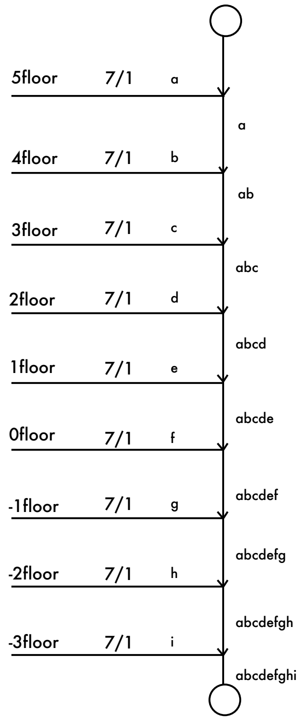
The **stack located in the shaft** reaches in its larger section an internal diameter **di of 26mm,** with material thickness **s of 3,0 mm** and an external diameter **da of 32mm.**

	a	b	ab	c	abc	d	abcd	e	abcde	f	abcdef	g	abcdefg	h	abcdefgh	i	abcdefghi
QTOT	3	3	6	3	9	3	12	3	15	3	18	3	21	3	24	3	27
QHIGH	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
da x s	16 x 2,0	16 x 2,0	18 x 2,0	16 x 2,0	20 x 2,5	16 x 2,0	26 x 3,0	16 x 2,0	26 x 3,0	16 x 2,0	26 x 3,0	16 x 2,0	32 x 3,0	16 x 2,0	32 x 3,0	16 x 2,0	32 x 3,0

The same procedure is carrie dout for the installations existing in the service restrooms which are provided with **cold water.**

	A	B	C	BC	D	BCD	ABCD	E	ABCDE	F	ABCDEF	G	HSTACK
QTOT	1	1	1	8	8	16	32	8	8	16	8	8	80
QHIGH	1	1	1	1	1	1	1	1	1	1	1	1	1
da x s	16 x 2,0	16 x 2,0	16 x 2,0	16 x 2,0	16 x 2,0	16 x 2,0	16 x 2,0	16 x 2,0	16 x 2,0	16 x 2,0	18 x 2,0	16 x 2,0	20 x 2,5





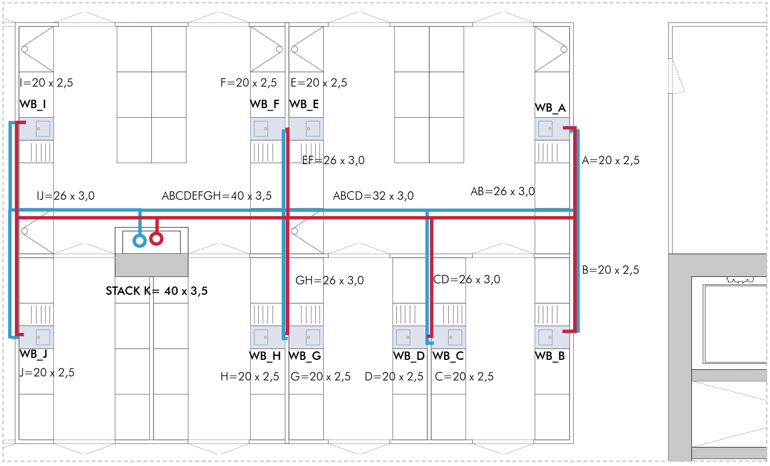
Cold water

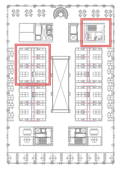
Qtot= 63LU
Qhigh= 7LU
DN=40x3,5

The **stack located in the shaft** at the end of the water system in the type floor is a pipe dimensioned with an internal diameter **di of 15mm,** with material thickness **s of 2,5mm** and an external diameter **da of 20mm.**

Sizing the stack pipe in elevation, considering the fact that **restrooms are located within the cores without any variations, for 9 floors,** the **stack located in the shaft** reaches in its larger section an internal diameter **di of 33mm,** with material thickness **s of 3,5 mm** and an external diameter **da of 40mm.**

	a	b	ab	c	abc	d	abcd	e	abc de	f	abc def	g	abc defg	h	abcd efgh	i	abcdefghi
QTOT	7	7	14	7	21	7	28	7	35	7	42	7	49	7	56	7	63
QHIGH	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
da x s	20 x 2,5	20 x 2,5	26 x 3,0	20 x 2,5	32 x 3,0	20 x 2,5	32 x 3,0	20 x 2,5	32 x 3,0	20 x 2,5	32 x 3,0	20 x 2,5	32 x 3,0	20 x 2,5	40 x 3,5	20 x 2,5	40 x 3,5





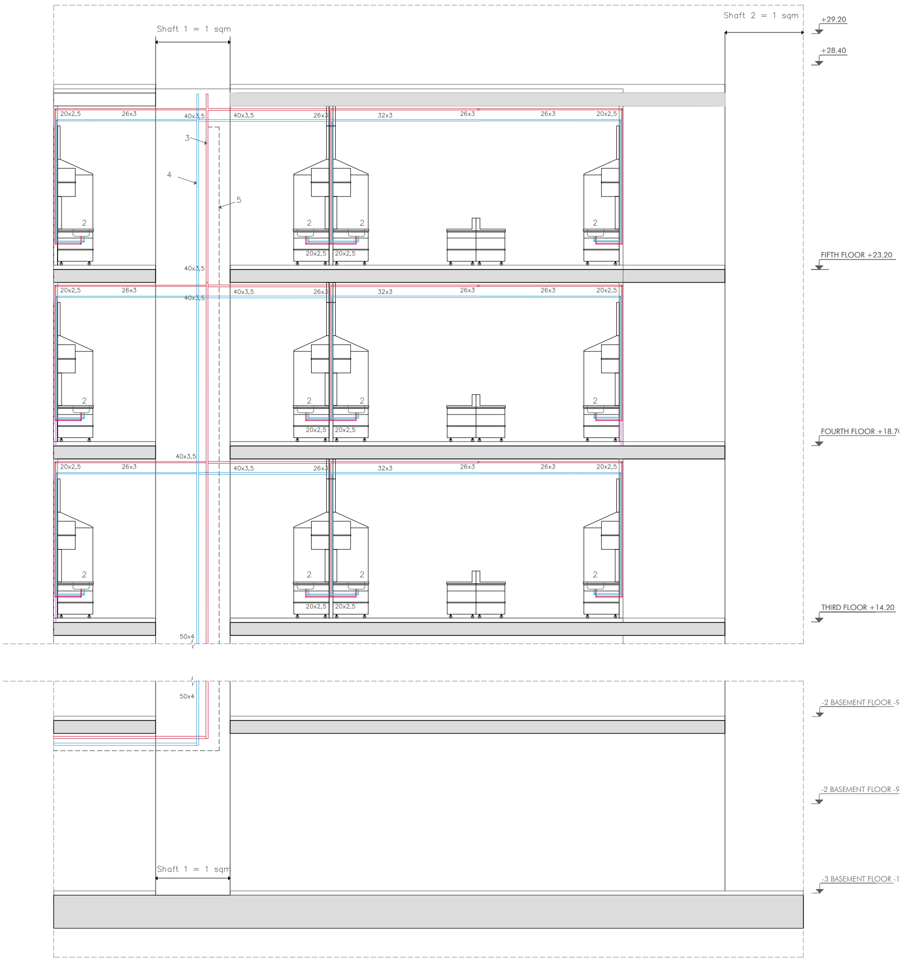
Hot Water Supply

Cold Water Supply

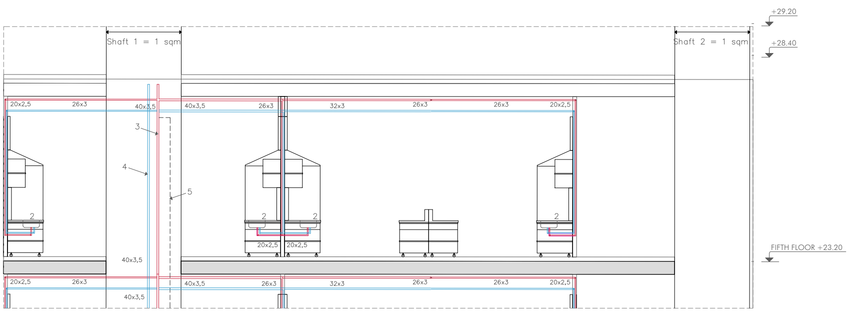
PIPE MATERIAL
Multilayer
PEX/AI/PE-HD

STANDARD
EN-806-3

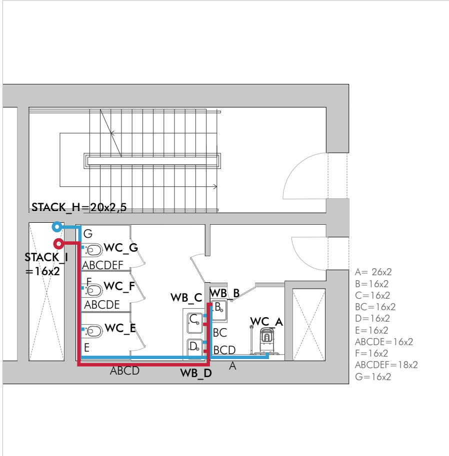
LEGEND
1. WC
2. Wash Basin
3. Hot Water Stack
4. Cold Water Stack
5. Recirculation

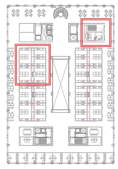


Laboratory Partial Supply System
Hot and cold water suppl



Laboratory Partial Section
Zoom in on 5th floor levelW





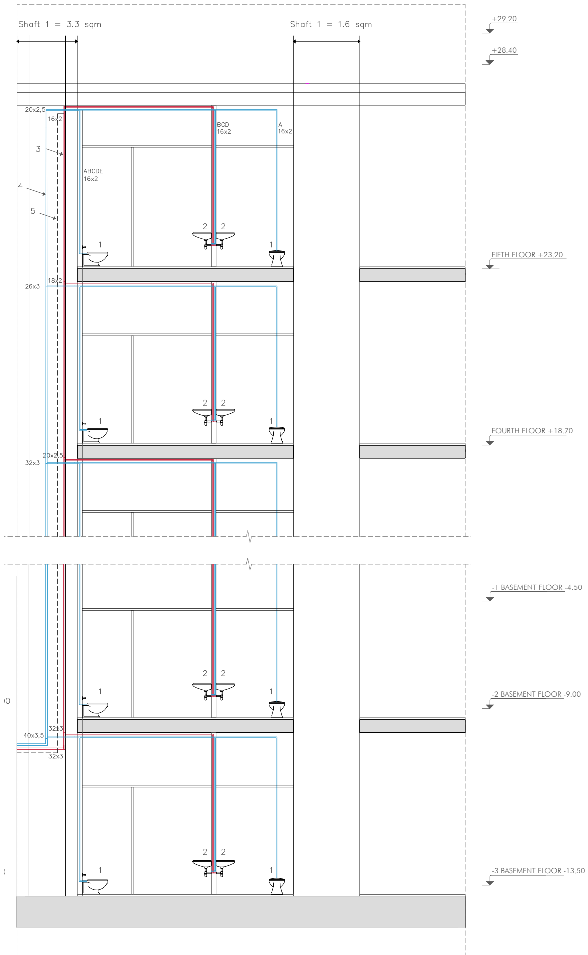
Hot Water Supply

Cold Water Supply

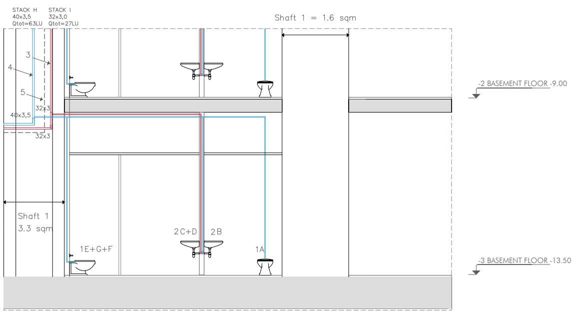
PIPE MATERIAL
Multilayer
PEX/Al/PE-HD

STANDARD
EN-806-3

LEGEND
1. WC
2. Wash Basin
3. Hot Water Stack
4. Cold Water Stack
5. Recirculation



Restroom Partial Drainage System
Hot and cold water supply



Restroom Partial Section
Zoom in n basement -3 level

7.

Water drainage system

WATER DRAINAGE

Configuration of drainage system (EN UNI 12056)

Water sanitary systems comprehend drains in the necessary quantity to satisfy the utility (drainage). The considered type of drainage system is the one defined as **System I**, in which a single discharge stack system with partly filled branch discharge pipes is considered.
For what concerns ventilation, control of pressure in the discharge stack is achieved by air flow in the discharge stack and the stack vent, by means of a primary ventilated system configuration.

Drainage pipe sizing

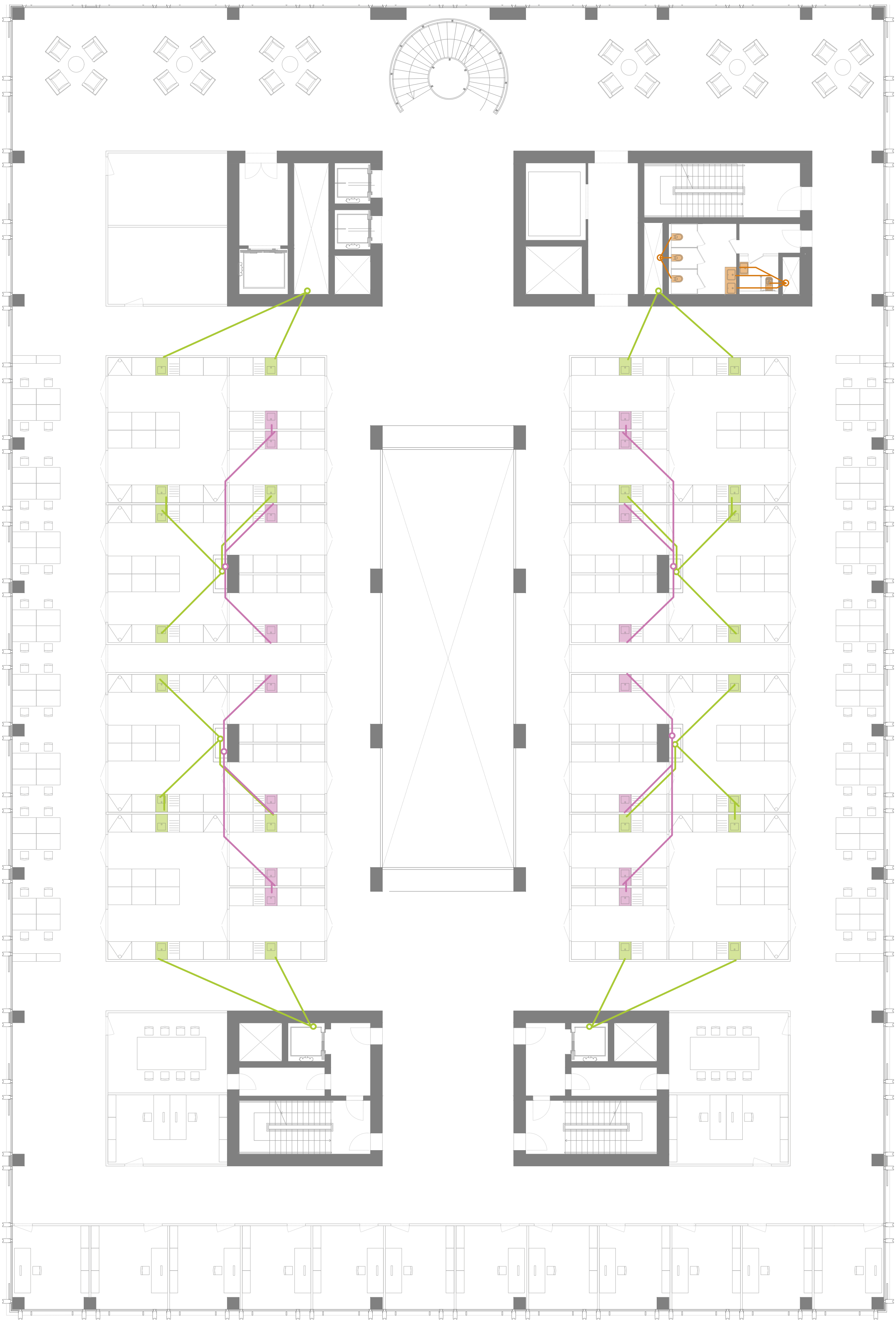
In order to size the pipes for drainage, it is necessary to calculate for each branch discharge the so called **Discharge Units (DU)** and the **frequency factor**, **k.**

Appliance	System I DU l/s	System II DU l/s	System III DU l/s	System IV DU l/s
Wash Basin, Bidet	0,5	0,3	0,3	0,3
Shower without Plug	0,6	0,4	0,4	0,4
Shower with Plug	0,8	0,5	1,3	0,5
Single Urinal with Cistern	0,8	0,5	0,4	0,5
Urinal with Flushing Valve	0,5	0,3	-	0,3
Slab Urinal	0,2*	0,2*	0,2*	0,2*
Bath	0,8	0,6	1,3	0,5
Kitchen Sink	0,8	0,6	1,3	0,5
Dishwasher (Household)	0,8	0,6	0,2	0,5
Washing Machine up to 6 kg	0,8	0,6	0,6	0,5
Washing Machine up to 12 kg	1,5	1,2	1,2	1,0
WC with 4,0 l Cistern	**	1,8	**	**
WC with 6,0 l Cistern	2,0	1,8	1,2 to 1,7***	2,0
WC with 7,5 l Cistern	2,0	1,8	1,4 to 1,8***	2,0
WC with 9,0 l Cistern	2,5	2,0	1,6 to 2,0***	2,5
Floor Gully DN 50	0,8	0,9	-	0,6
Floor Gully DN 70	1,5	0,9	-	1,0
Floor Gully DN 100	2,0	1,2	-	1,3

* per person
** not permitted
*** depending upon type (valid for WC's with siphon flush cistern only)
\- not used or no data

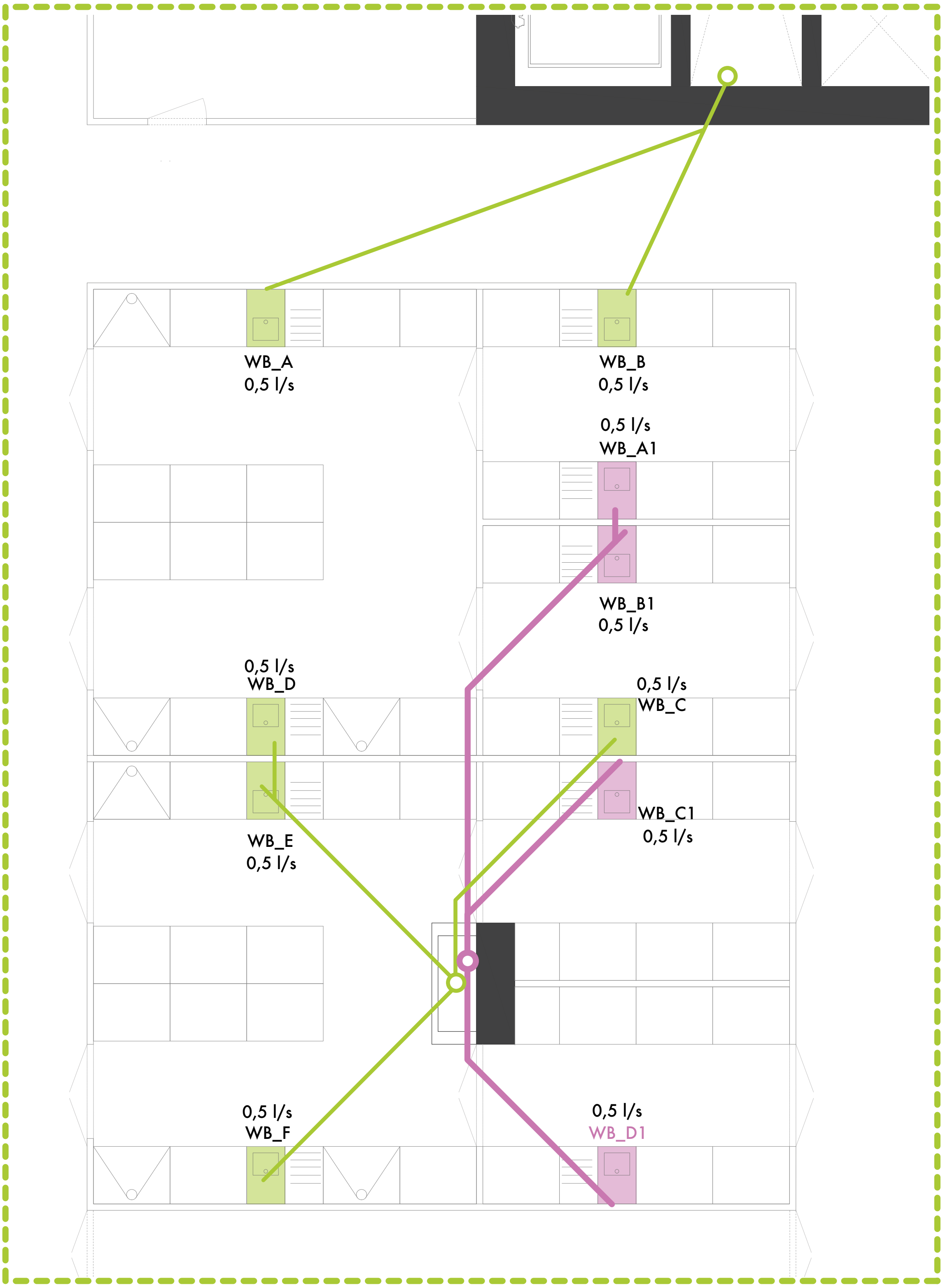
The former table is referring to the **EN UNI 12056 standard** and it is providing the **discharge unit (DU) for each appliance installation.** In this case, there is no distinction between domestic or non domestic **wash basins**, both having **DU= 0,5 l/s,** while **WC cisterns** have **DU= 2,5 l/s.**

The following plan shows the layout of the water drainage system for a **type floor plan of laboratories** in the physics building, in which each **installation is indicated** and separated into two groups: **service restrooms and laboratories.**



The fist portion taken into consideration is that of the **laboratories:** the installations located in the labs are **all washbasins,** which, according to the previous table, correspond to **a discharge unit equal to 0,5 l/s.**

In the case of laboratories' drainage system, however, it is necessary to make a distinction between **domestic water (green sinks) and chemically contaminated water (pink sinks).** In the case under evaluation, calculations will be carried out separately.



After determining the DU for each branch, it is necessary to determine the waste water flow rate **Qww,** which is the expected flowrate of waste water in a part or in the whole drainage system.

$$Q_{ww} = K\sqrt{\sum DU}$$

where:

Q_{ww} = Waste water flowrate (l/s)
K = Frequency factor
ΣDU = Sum of Discharge Units

In order to calculate it, typical **frequency factors (K)** associated with different usage of appliances are indicated in the following table.

Usage of appliances	K
intermittent use e.g. in Dwelling, Guesthouse, Office	0,5
frequent use e.g. in Hospital, School, Restaurant, Hotel	0,7
congested use e.g. in Toilets and/or Showers open to Public	1,0
special use e.g. Laboratory	1,2

The total flow rate **Qtot** is the design flowrate in a part or in the whole drainage system where sanitary appliances, appliances with continuous flow and/or waste water pumps are connected to the system. Continuous flows and pump discharge rates shall be added to the waste water flowrate without any reduction.

$$Q_{tot} = Q_{ww} + Q_c + Q_p$$

where:

Q_{tot} = Total flowrate (l/s)
Q_{ww} = Waste water flowrate (l/s)
Q_c = Continuous flowrate (l/s)
Q_p = Pumped water flowrate (l/s)

Finally, in order to associate waste water flow rates to pipes' nominal diameters, the following tables are used **EN UNI 12056 standard** is used.

Layout of branches

Table 5: Hydraulic capacity (Qmax) and Nominal Diameter (DN) from EN UNI 12056-2.

Q_{max}	System I	System II	System III	System IV
l/s	DN	DN	DN	DN
0,40	*	30	see table 6	30
0,50	40	40		40
0,80	50	*		*
1,00	60	50		50
1,50	70	60		60
2,00	80**	70**		70**
2,25	90***	80****		80****
2,50	100	90		100

* not permitted
** no WC's
*** not more than two WC's and a total change in directions of not more than 90°
**** not more than one WC

DISCHARGE STACKS

Table 7: Hydraulic capacity (Q_{max}) and Nominal Diameter (DN) from EN UNI 12056-2.

Stack and stack vent	System I, II, III, IV Q_{max} (l/s)	
DN	Square entries	Swept entries
60	0,5	0,7
70	1,5	2,0
80*	2,0	2,6
90	2,7	3,5
100**	4,0	5,2
125	5,8	7,6
150	9,5	12,4
200	16,0	21,0

* minimum size where WC's are connected in system II

** minimum size where WC's are connected in system I, III, IV

Such calculations are firstly performed for the **domestic water drainage**, indicated with green colour in the drawings, and in order to associate dimensionings to

	A	B	AB	H stack
QL/S	-	-	1,2	1,2
Qmax stack	0,5	0,5	0,5	0,5
Qmax l/s	0,5	0,5	0,5	0,5
DNpiping (mm)	40	40	70	70

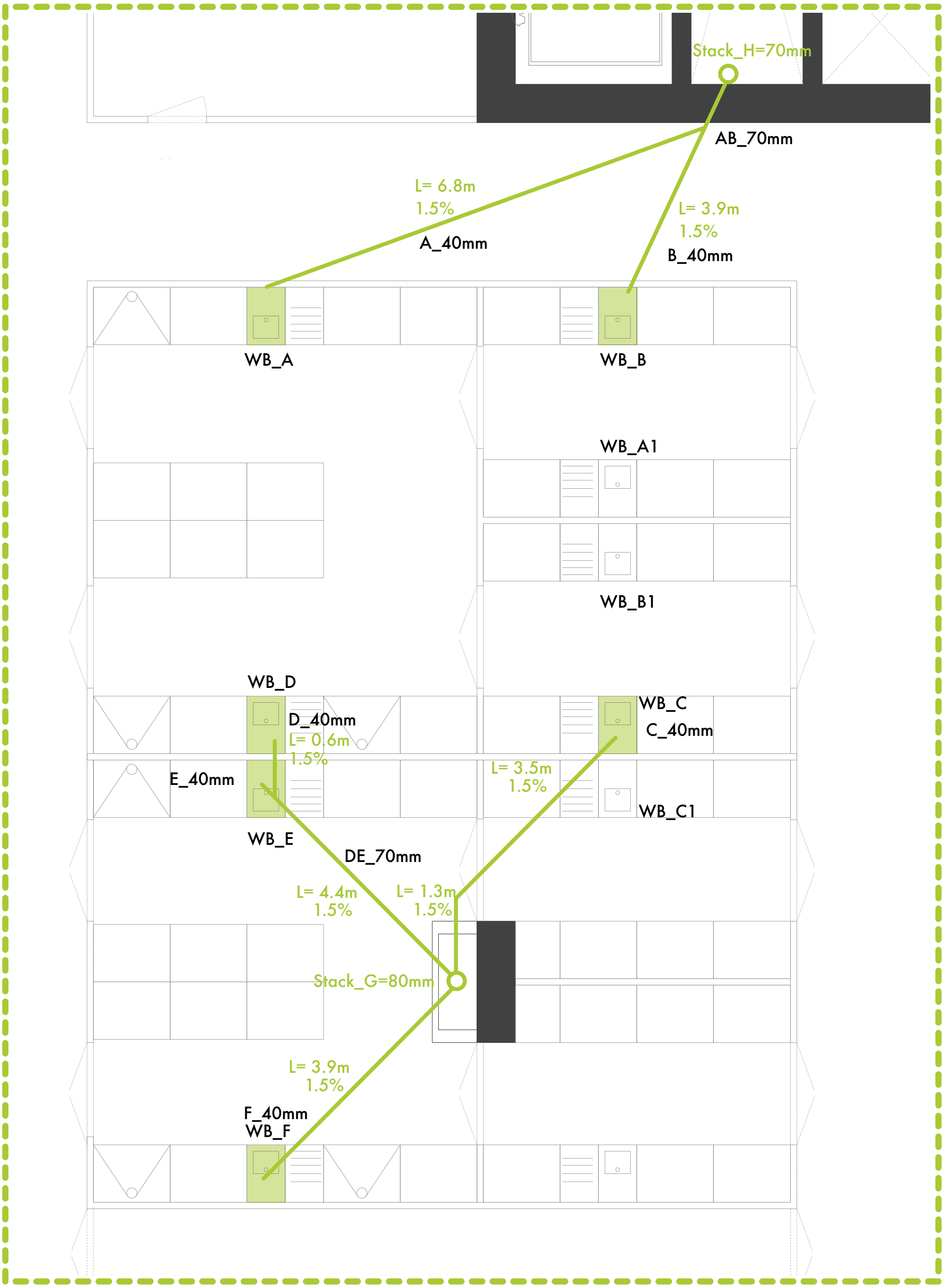
$Q_{AB} = 1.2\sqrt{0,5+0,5} = 1,2$

	C	D	E	DE	F	CDEF	G stack
QL/S	-	-	-	1,2	.-	1,7	1,7
Qmax stack	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Qmax l/s	0,5	0,5	0,5	0,5	0,5	0,5	0,5
DNpiping (mm)	40	40	40	70	40	80	80

$Q_{DE} = 1.2\sqrt{0,5+0,5} = 1,2$

$Q_{CDEF} = 1.2\sqrt{0,5+0,5+0,5+0,5} = 1,7$

Drainage for domestic water in pipes has to be distinguished in two **stacks (G and H), with stack H having a nominal diameter of 70mm,** and **with stack G having a nominal diameter of 80mm.**

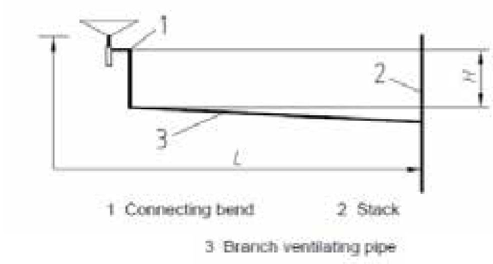


The subdivision into two stacks is related to a serios of **limitations regarding the length and inclination of frainage pipes indicated by the norms as indicated in the following tabel for unventilated discharge branches.**

Limitations	System I	System II	System III	System IV
maximum length (L) of pipe	4,0 m	10,0 m	see table 6	10,0 m
maximum number of 90° bends	3*	1*		3*
maximum drop (H) (45° or more inclination)	1,0 m	**6,0 m DN>70 **3,0 m DN=70		1,0 m
minimum gradient	1%	1,5%		1%

* Connection bend not included

** If DN < 100 mm and a WC is connected to the branch no other appliances can be connected more than 1 m above the connection to a ventilated system.



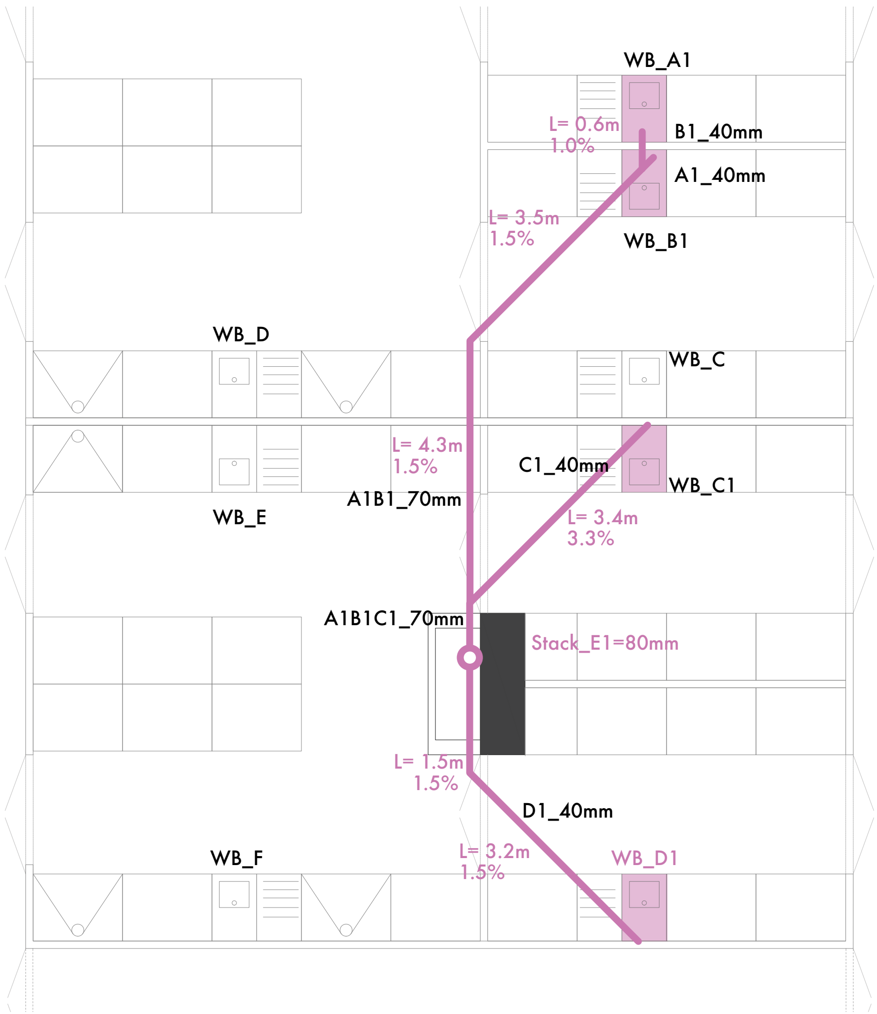
The same procedure is carried out for the calculations of the drainage pipes for **chemical water in laboratories.**

	A1	B1	A1B1	C1	A1B1C1	D1	E1 stack
QL/S	-	-	1,2	-	1,5	-	1,7
Qmax stack	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Qmax l/s	0,5	0,5	0,5	0,5	0,5	0,5	0,5
DNpiping (mm)	40	40	70	40	70	40	80

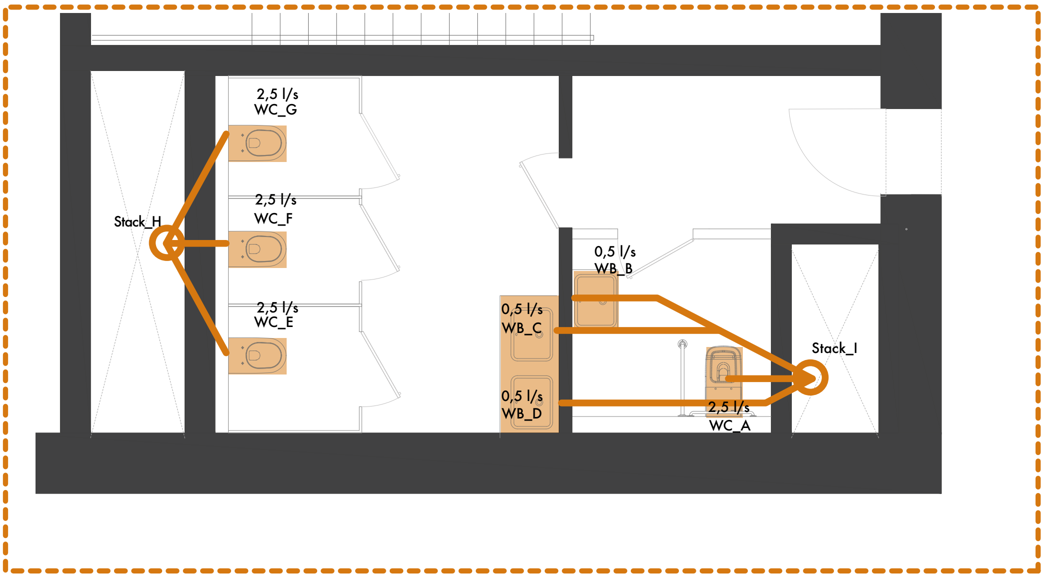
$Q_{A1B1} = 1.2\sqrt{0{,}5+0{,}5} = 1{,}2$

$Q_{A1B1C1} = 1.2\sqrt{0{,}5+0{,}5+0{,}5} = 1.5$

$Q_{A1B1C1D1} = 1.2\sqrt{0{,}5+0{,}5+0{,}5+0{,}5} = 1{,}7$



The same procedure is then carried out for thedrainage of restrooms



	E	F	G	H stack
QL/S	-	-	-	3,3
Qmax stack	2,5	2,5	2,5	2,5
Qmax l/s	2,5	2,5	2,9	2,5
DNpiping (mm)	90	90	90	100

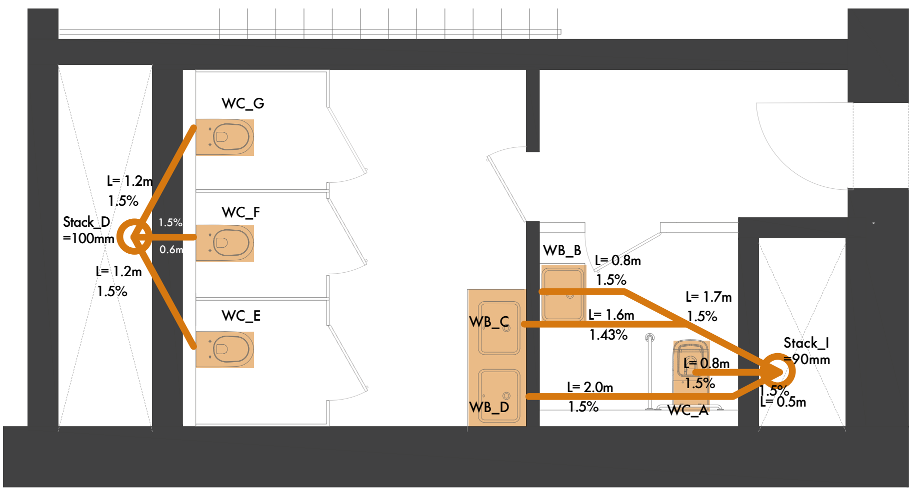
	B	C	BC	D	A	I stack
QL/S	-	-	1,2	-	.-	2,4
Qmax stack	0,5	0,5	0,5	0,5	2,5	2,5
Qmax l/s	0,5	0,5	0,5	0,5	2,5	2,5
DNpiping (mm)	40	40	70	40	90	90

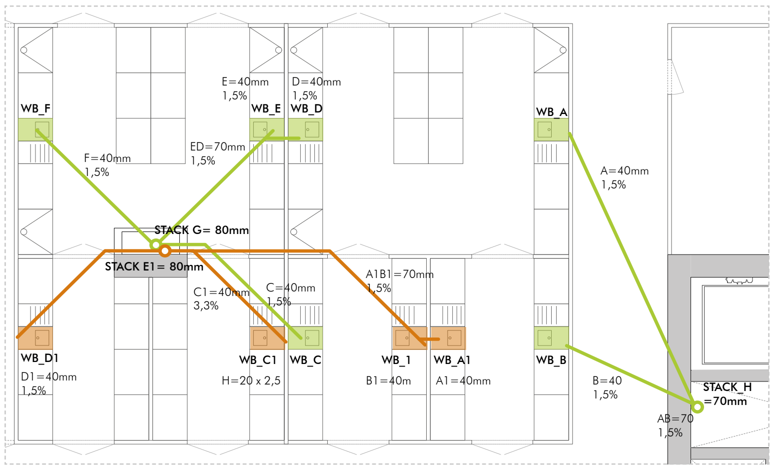
Q MAX (D STACK) $=1.2\sqrt{2{,}5+2{,}5+2{,}5} = 3{,}3$

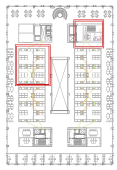
BC $=1.2\sqrt{0{,}5+0{,}5} = 1{,}2$

Q MAX (I STACK) $=1.2\sqrt{0{,}5+0{,}5+0{,}5+2{,}5} = 2{,}4$

Drainage for domestic water in pipes for restrooms has been subdivided in two **stacks (H and I), with stack H having a nominal diameter of 100mm,** and **with stack I having a nominal diameter of 90mm.**







Domestic water laboratories

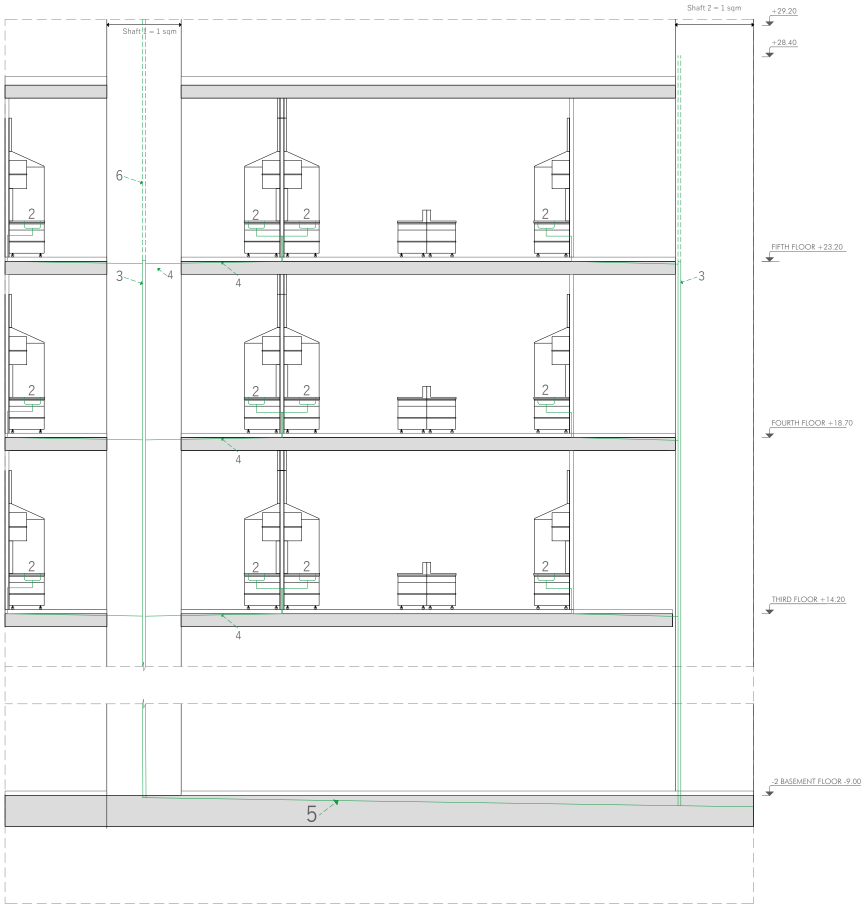
Chemical water laboratories

Domestic water Restrooms

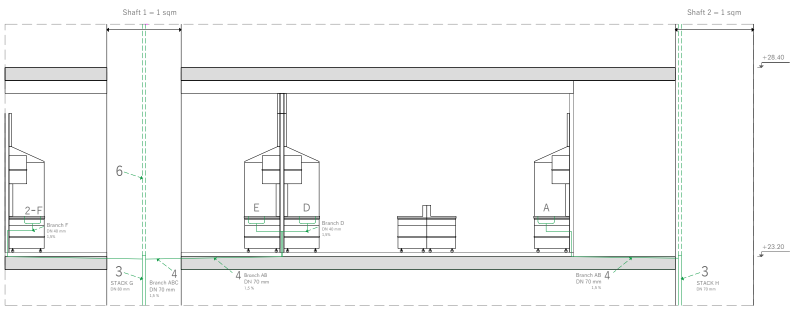
PIPE MATERIAL
Multilayer
PEX/Al/PE-HD

STANDARD
EN-UNI 12056-2

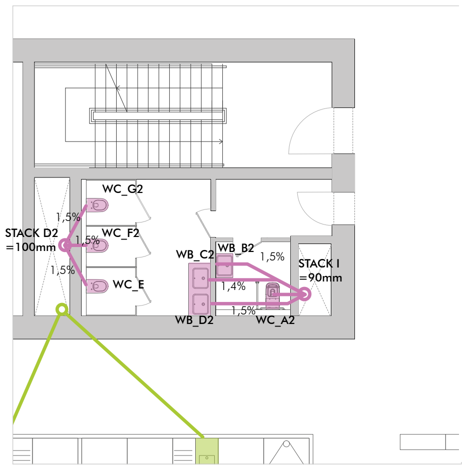
LEGEND
1. WC
2.Wash Basin
3.Stack
4. Branch Discharge
5. Drain (90 mm)
6. Stack Ventilation

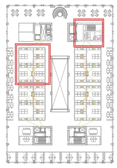


Laboratory Partial Drainage System
Domestic Water



Laboratory Partial Section
Domestic Water Drainage System





Domestic water laboratories

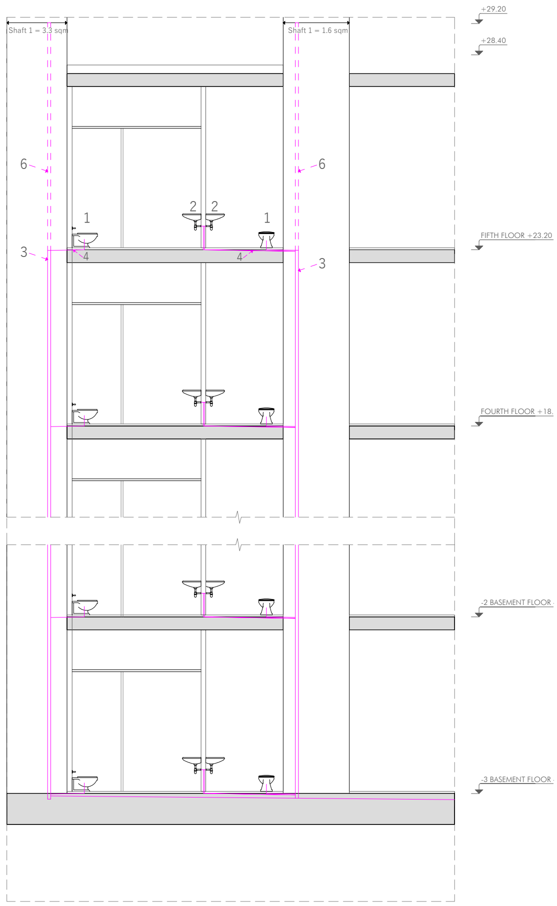
Chemical water laboratories

Domestic water Restrooms

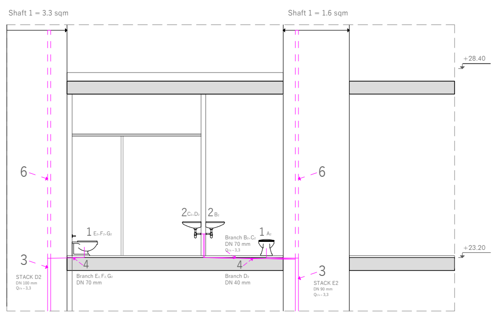
PIPE MATERIAL
Multilayer
PEX/Al/PE-HD

STANDARD
EN-UNI 12056-2

LEGEND
1. WC
2.Wash Basin
3.Stack
4. Branch Discharge
5. Drain (90 mm)
6. Stack Ventilation



Restroom Partial Drainage System
Domestic Water



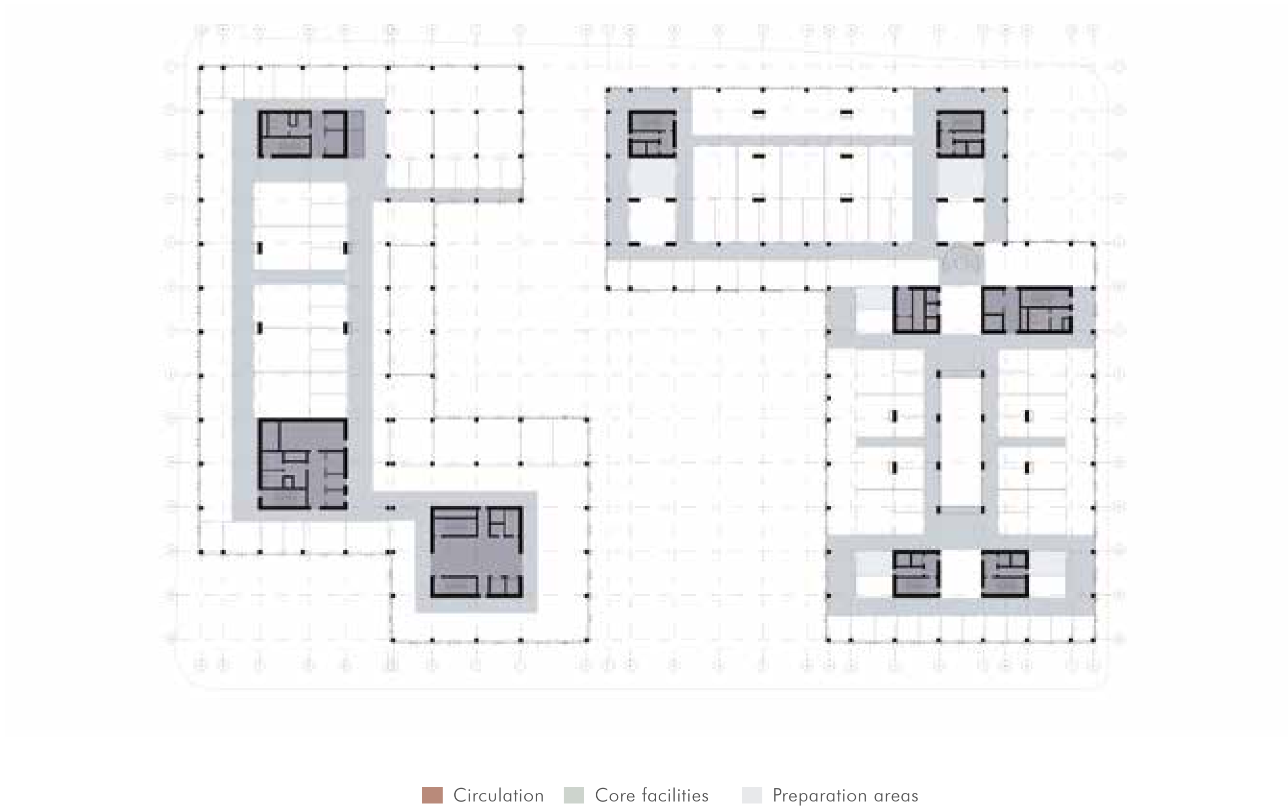
Restroom Partial Section
Domestic Water Drainage System

8.

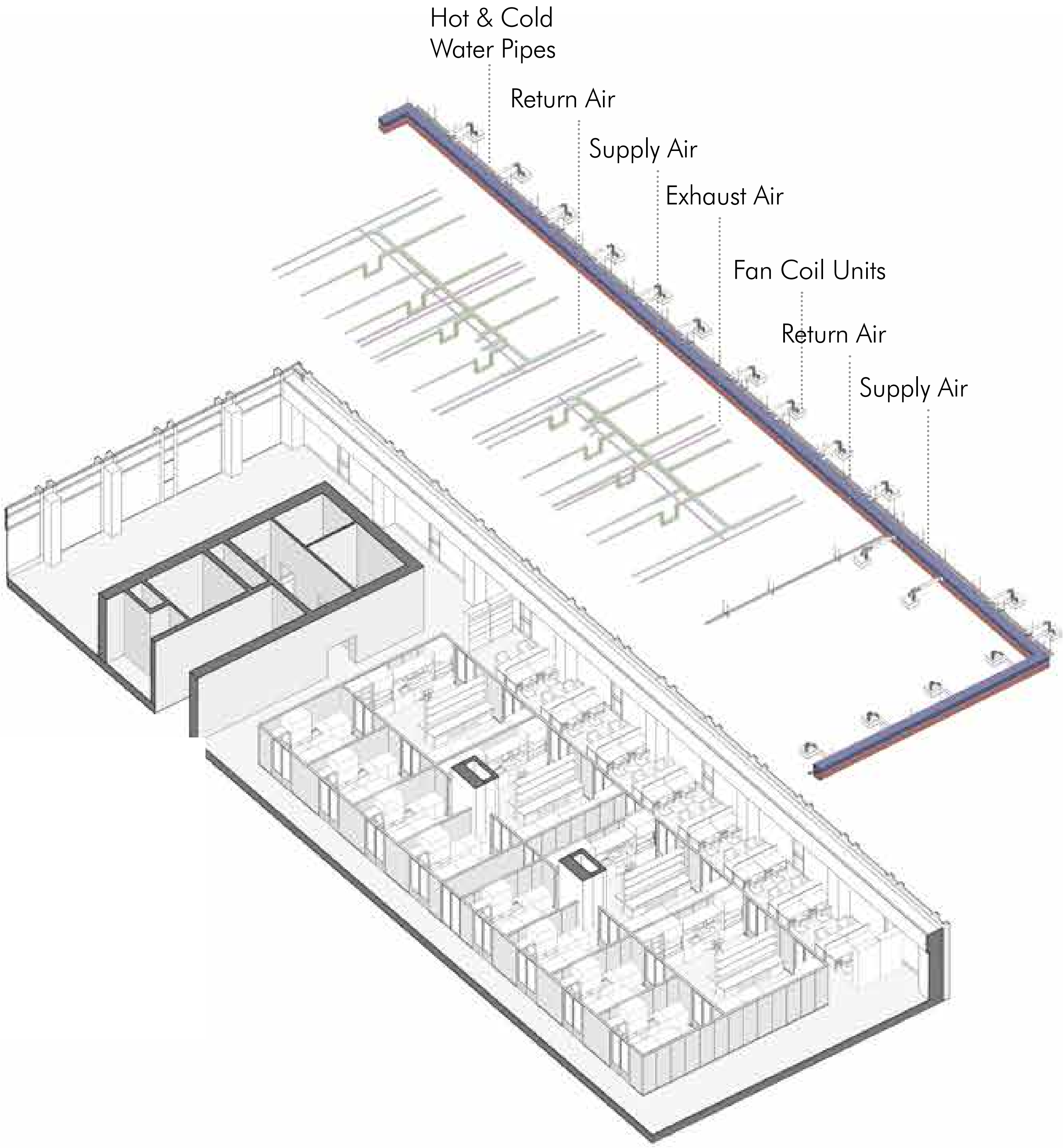
Laboratory design & systems' integration

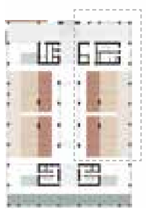
Functional type—floor plan diagram

Services type—floor plan diagram



Aggregation of standard lab units into research units



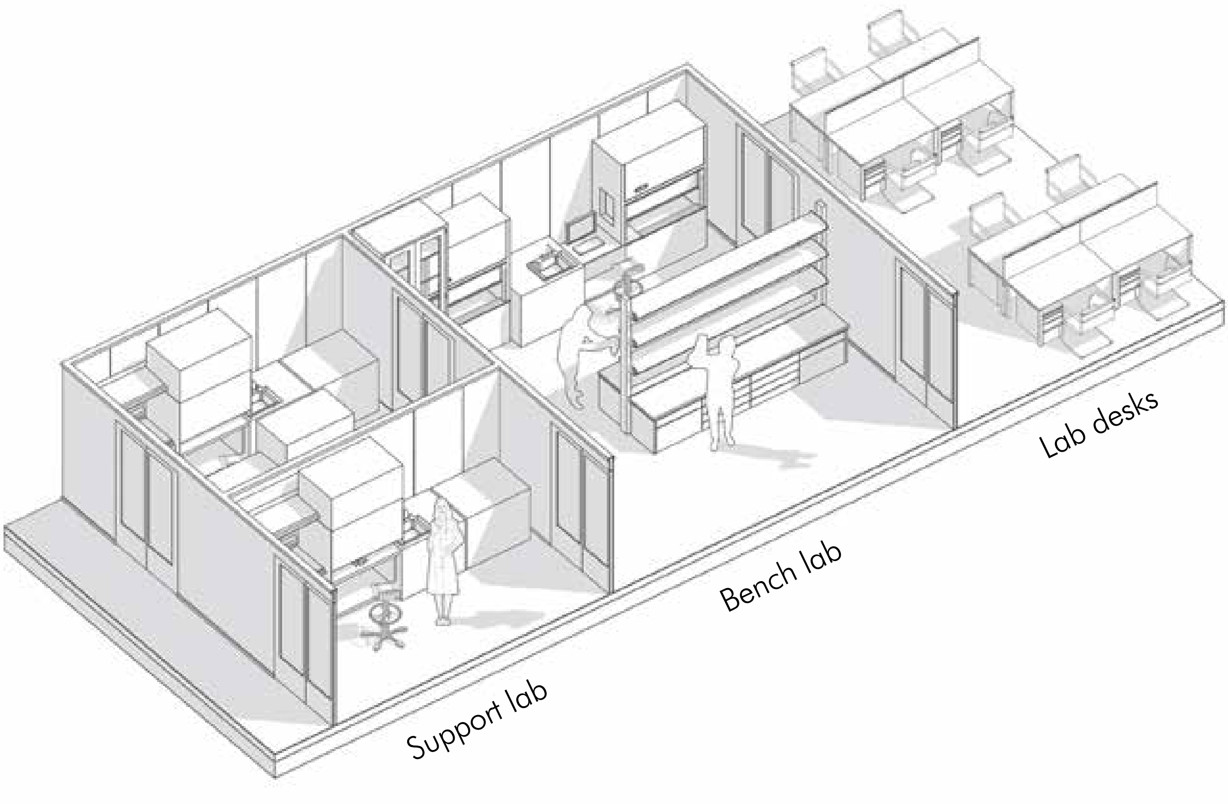


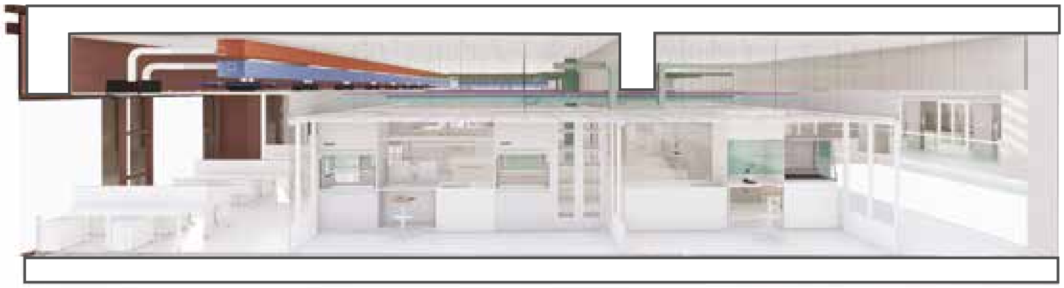
STANDARD LABORATORY UNIT

According to the directives provided by the University of Basel for the design of basic standard laboratory units, each research module is composed of three main functional areas: the ancillary rooms (support labs), the bench laboratory, and the evaluation workstations' area.
The type-floor plan dedicated to each research department is then the result of the combination of more standard units, the dimensions of which are proportioned with the number or workstations to be provided for each research team. The schematic type arrangement provided as a reference by the University of Basel has been defined respecting the distances between benches and office tables that are necessary to meet the requirements of the Office of Economy and Labour.

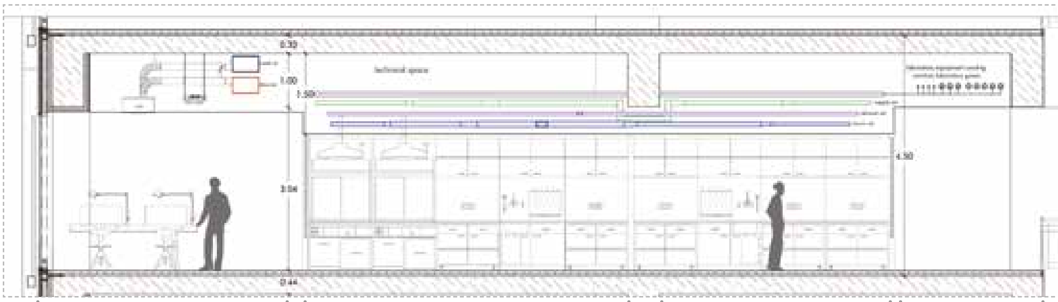
Laboratory and evaluation area, if necessary, can be separated by glazing with doors. The lab area is considered BSL-2 area (area of biosecurity of second level). For exits from this area, gowns and goggles must be deposited and hands washed. The special equipment required in each standard laboratory and evaluation area includes:
- One hood for each standard laboratory
- An explosion proofed solvent cabinet
- Wall cupboards and media access, which should be arranged above the laboratory tables
- Computerized office chairs and tables with high voltage
- Storage for paper files

For what concerns systems, each laboratory is served by an all-air HVAC system including distinct pipes for air supply, air return and exhaust air. The area of the evaluation desks, instead, is treated, as the other offices and shared spaces, by means of a mixed air-water HVAC system including fan-coil units heated and cooled by water pipes and hidden by a false-ceiling.

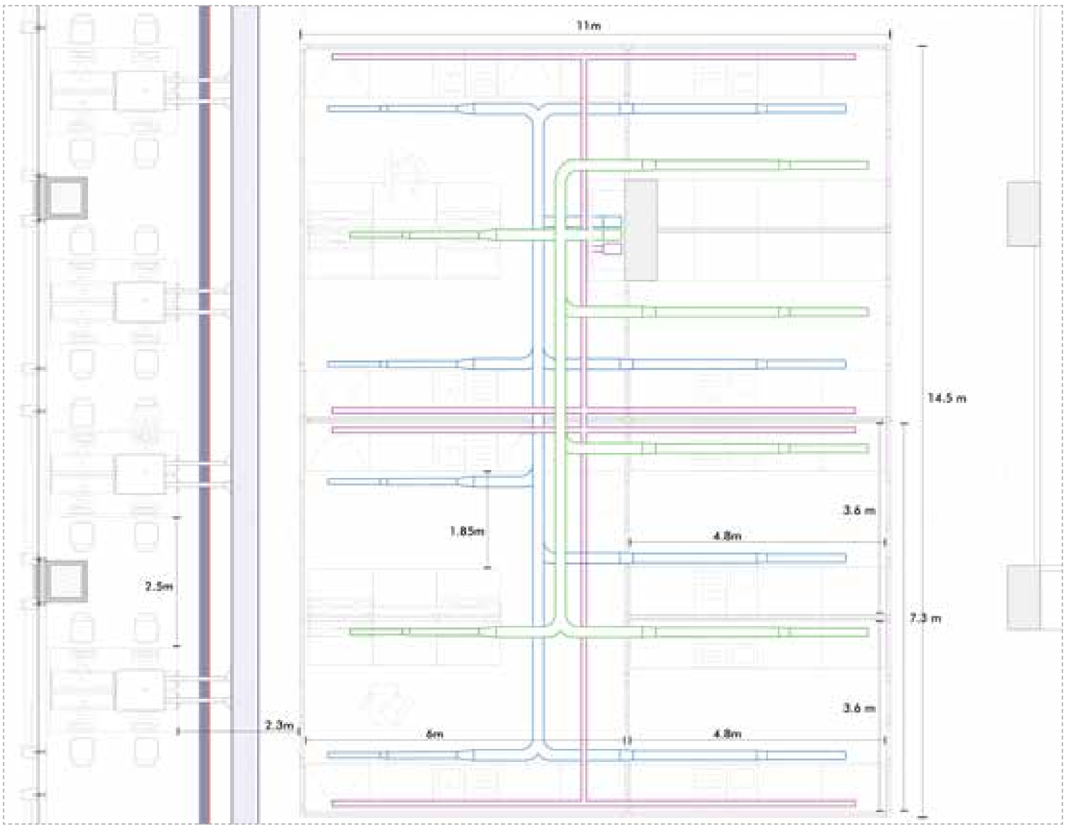




Evaluation desks Bench Lab Support Lab Corridor



Evaluation desks Bench Lab Support Lab Corridor



Evaluation desks Bench Lab Support Lab Corridor

BIM REPORT

PROFESSOR LAVINIA CHIARA TAGLIABUE

TABLE OF CONTENTS

1.

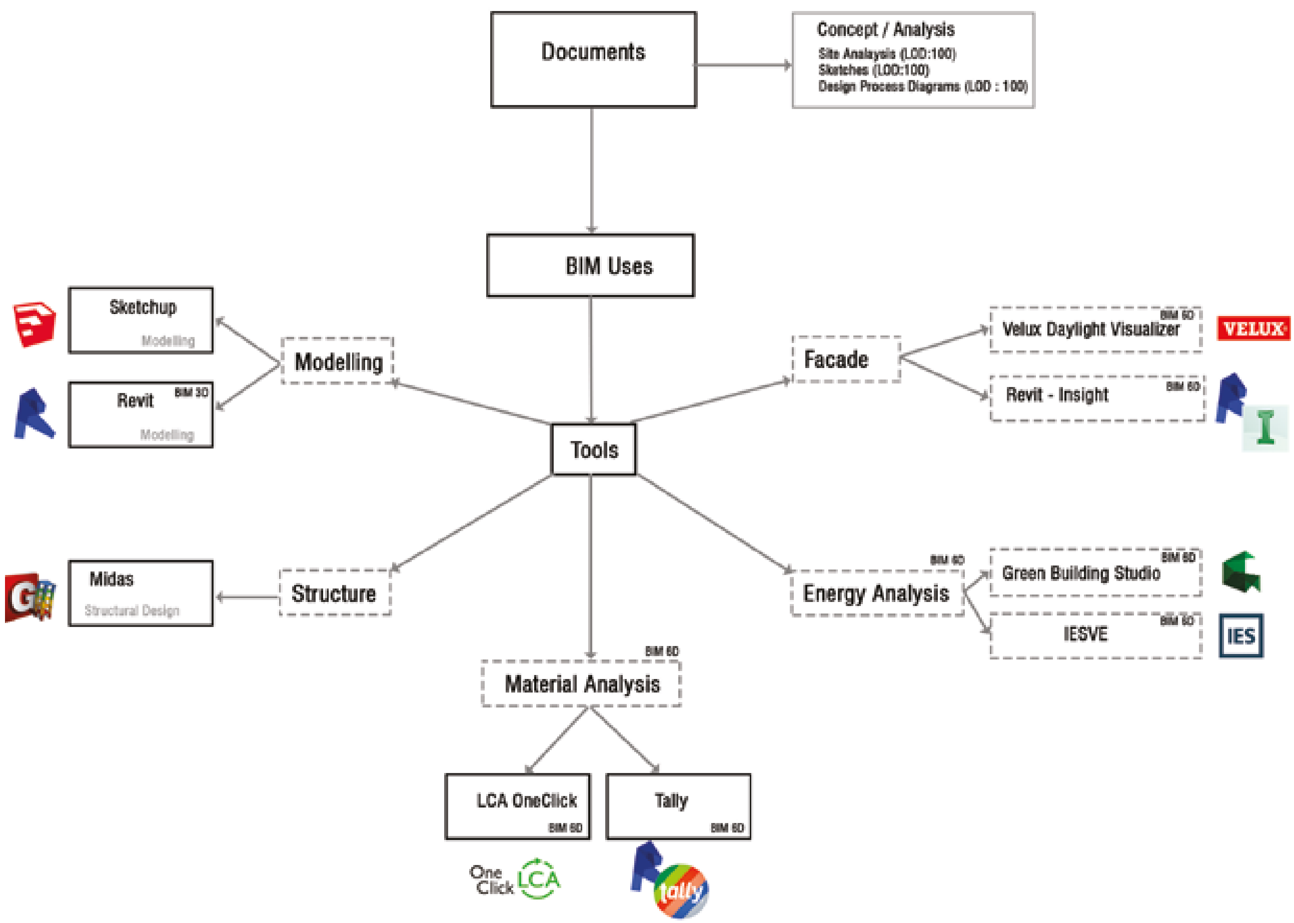
BIM workflow

BIM Workflow

General Description

The proposed design is the project of a building complex belonging to the Life Science Campus of Basel University. In order to have the possibility to better understand and deepen the different aspects of such a complex program, the workflow process took advantage of the possibility to exploit BIM interoperability.

Starting from documents elaborated during the early phases of the project, concerning, for instance, site analysis and conceptual design diagrams, 3D modelling has constantly been part of the design project. Both site modelling and volumetric modelling are indeed useful to make important considerations regarding, for instance, the orientation of the project or the casting of shadows on the surroundings. In order to take advantage of the positive characteristics of each software, 3D modelling was carried out both on Sketchup and on Revit, considering the possibility import components from one software to the other for specific design or grafic-related needs. Revit constituted then the main tool to exchange information between several BIM software, allowing to deepen different topics such as light analysis, energy analysis, material selection according to LCA (Life Cycle Assessment), and structural analysis.



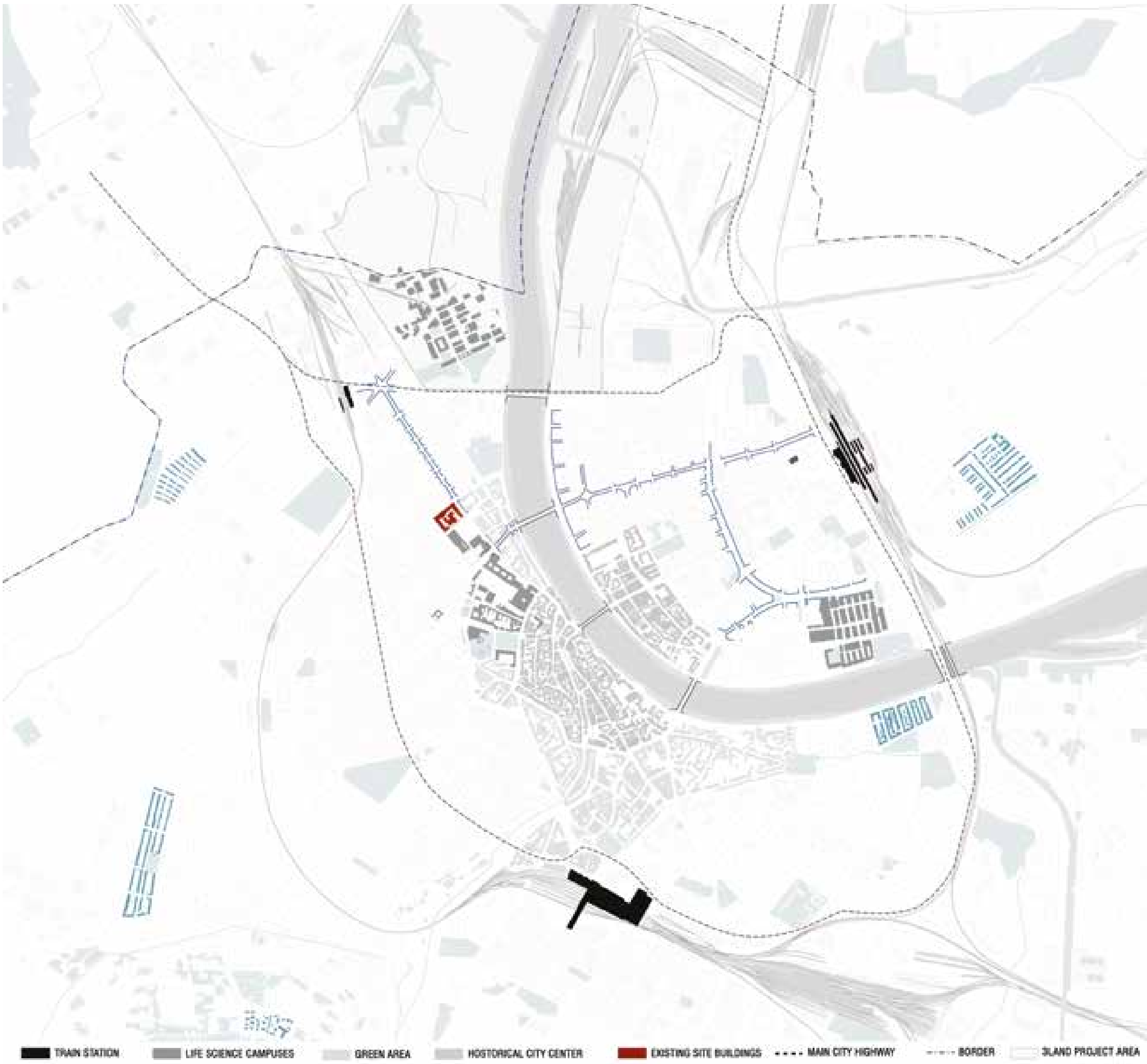
2.

Site Analysis

Site Analysis

Context considerations

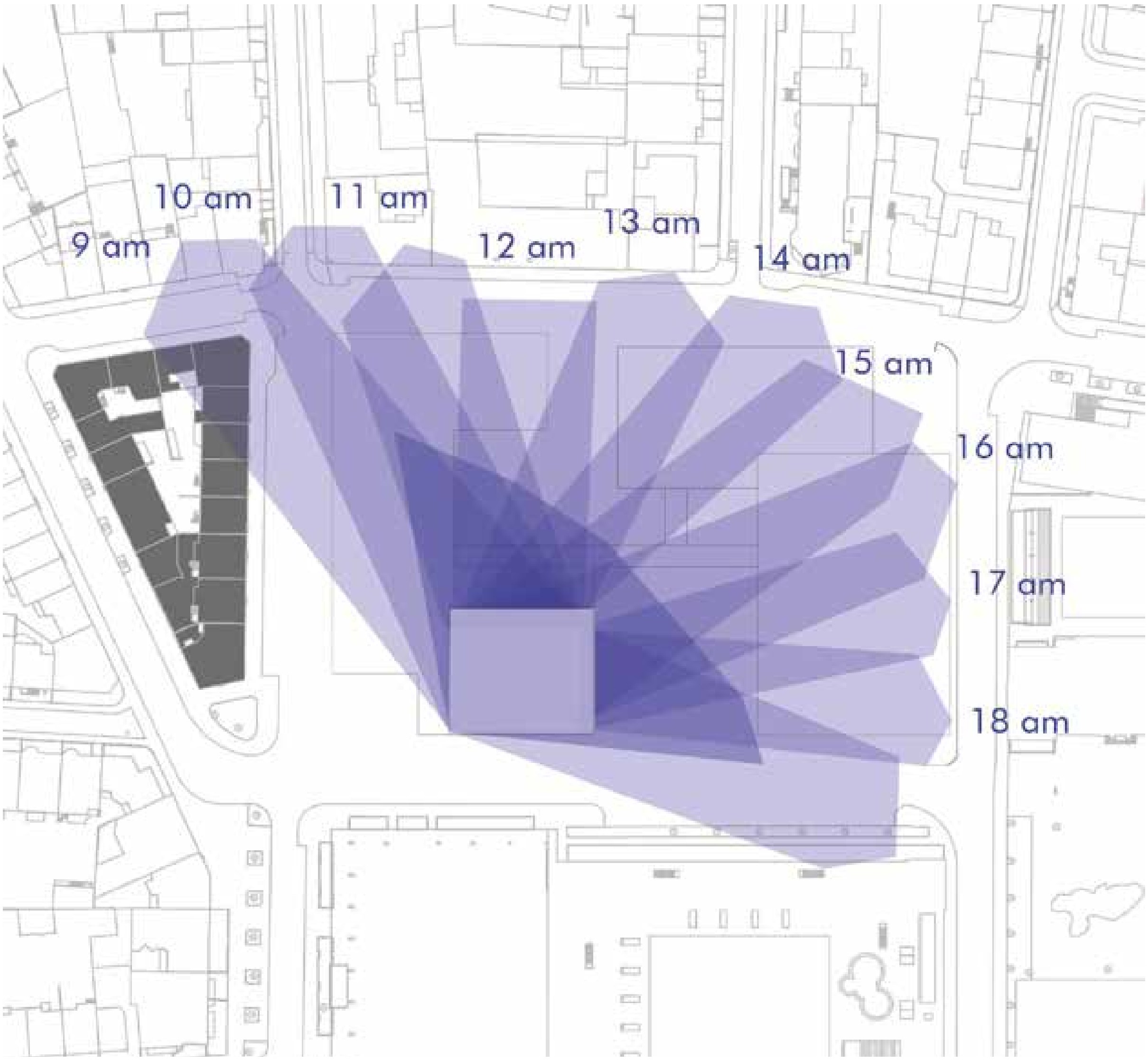
The project under consideratio is locatet in Basel, Switzerland, within the urban Life Science Campus of its University. The University of Basel can be subdivided in different campus areas, and the one concerning our intervention is named Schällemätteli Campus, located at the border of the old city nucleus: the plot is then partially suppounded by consolidated existing fabric, mainly residential, and partially by the recently redeveloped urban blocks belonging to the university campus.



Urban plan of Basel showing the location of the construction site within the city.

Shadow casting

Among site considerations which can be developed thanks to BIM softwares, which are able to combine the geographic information associated with the location of the building, with the geometric characteristics of the volumes designed, it has been possible for instance to verify the satisfaction of requirements such as the so-called "Two-Hours Shadow" rule. The volumetric development of the design was then adjusted by checking the shadow casted by the 3D model according to the specific site location of the project.

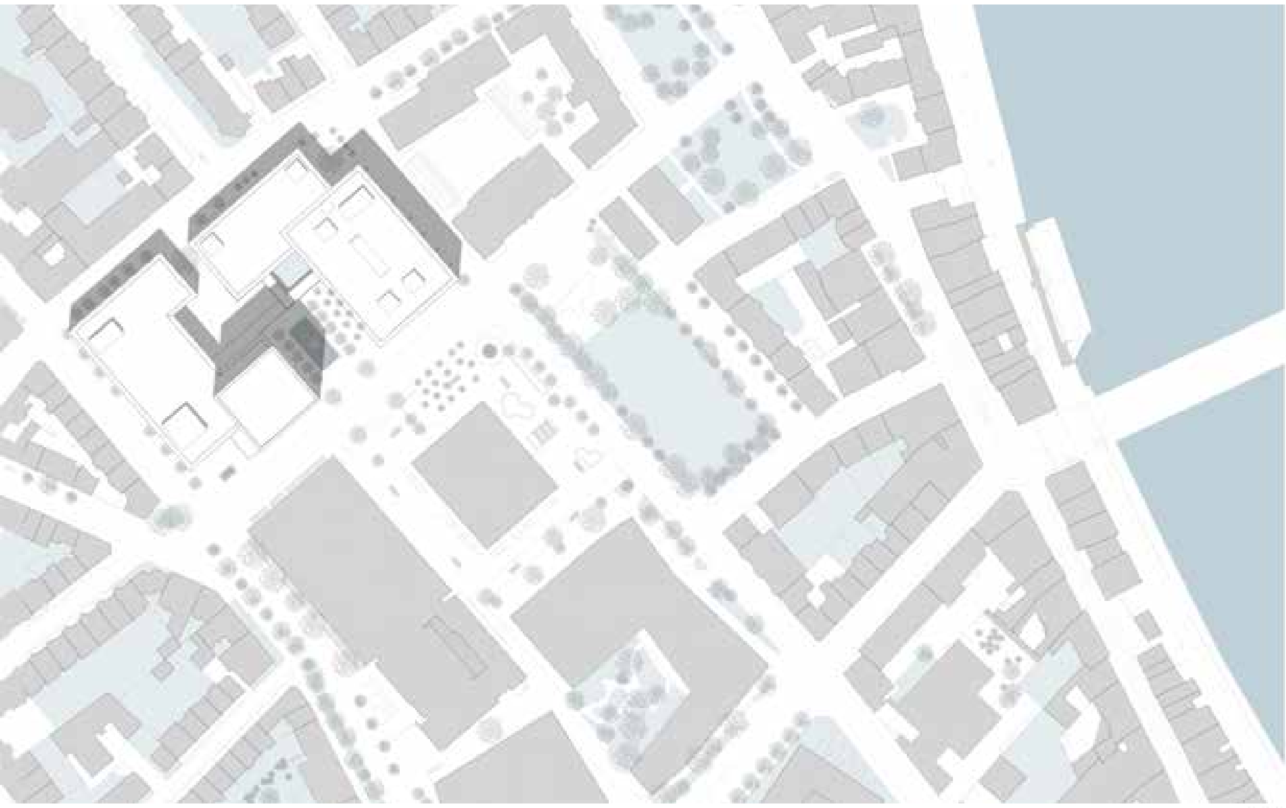


Check of the casted shadows on residential buildings ti safisfy the "Two-hours shadow" rule.

3.

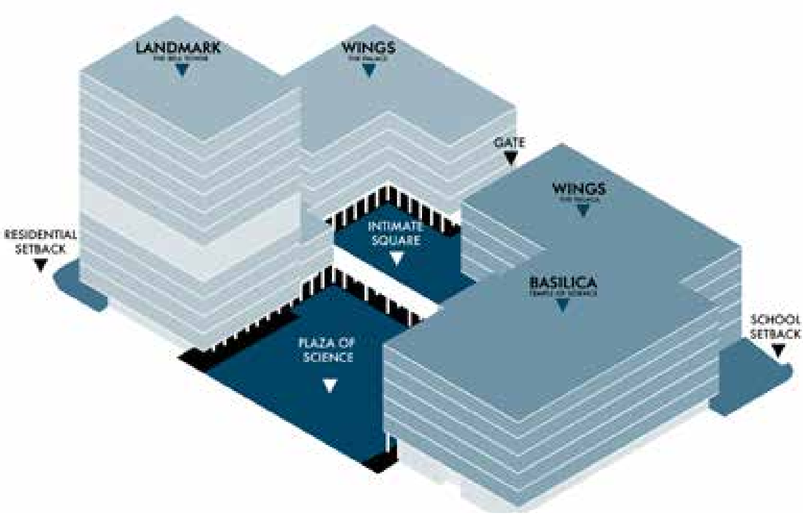
Sun Analysis

Volumetric design considerations



Urban plan of Basel showing the location of the construction site within the city.

The built complex, which finally appears to be composed by two macro-buildings, is the result of the elaboration of 4 spatially integrated volumes, defined by taking into account specific reactions to the existing surrounding and urban framework.



The building here indicated as Volume A is the one hosting the physics department as well as many other educational and public facilities.

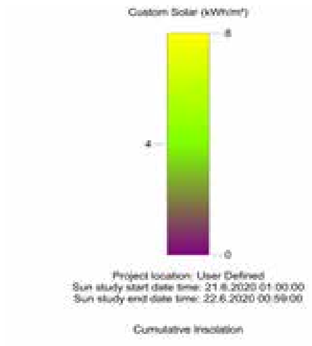
Volume B mainly hosts public facilities at ground floor, the Anatomy museum and the SNI.

Volume C hosts the Chemistry department, partially included also in volume D since the two are linked at some floors.

Volume D mainly hosts public, administrative and educational facilities, especially in the tower.

Combining considerations related to the context, to regulations, to design intentions and to the program defined in the brief, the volumetric development of the design has been carried out trying to introduce BIM applications in order to optimize the result and support decision making.
For instance, **Sun Radiation Analysis,** have been carried out during the design process in **Revit, thanks to the Insight plug-in application,** in order to be aware of the solar exposure of the complex.

JUNE 21st



DECEMBER 21st

4.

Daylight Analysis

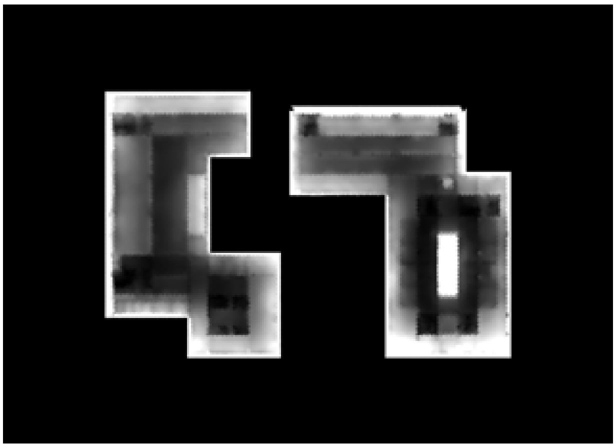
Inner light quality and facade design

During the developing of the project, another aspect which was important to take into account was the quality of light conditions. **Daylight Analysis** have been carried out in several time in order to compare alternatives and experience the spatial outcomes of the design modelled.
By importing the **Revit model in Velux,** it has been possible to rapidly obtain information about values such as **illuminance and daylight factors.**

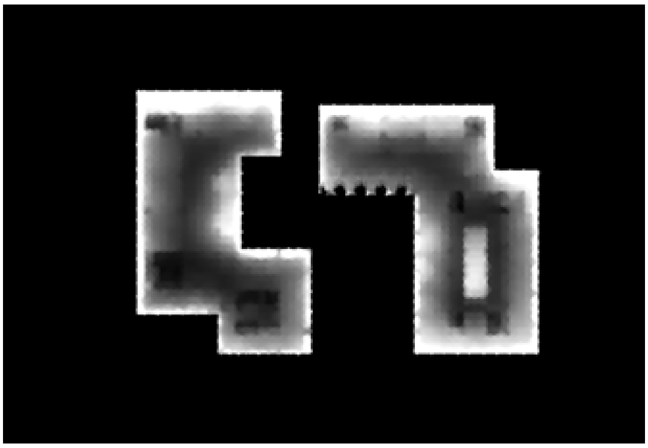
In order to show the way in which the tool was exploited, two different analysis are here compared, showing the progress obtained during the **design and modelling of the facade, before and after introducing shading elements.**

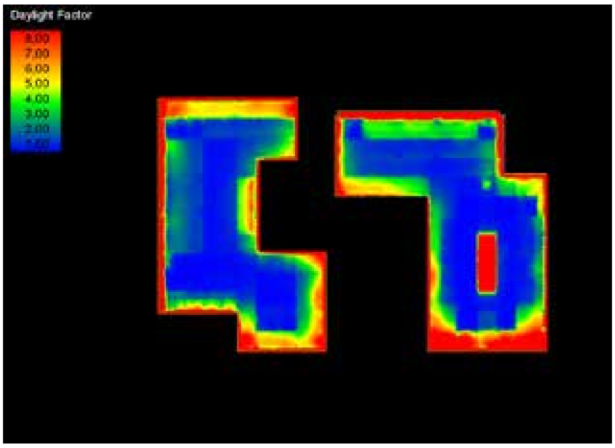
DAYLIGHT ANALYSIS - SUNNY (MARCH 21st) - PLAN VIEW

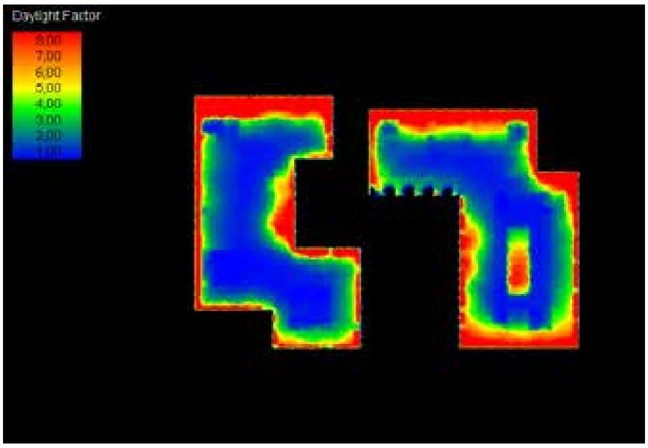
Before

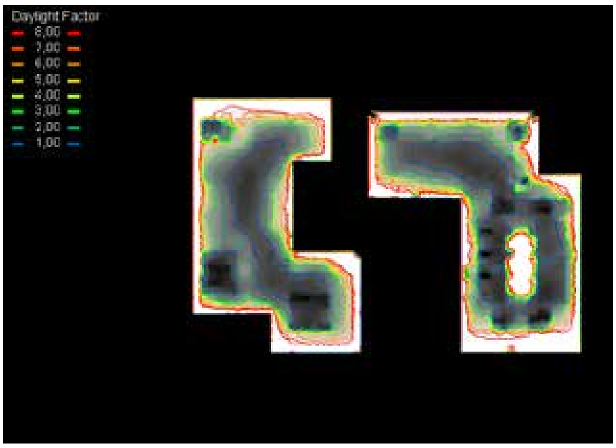


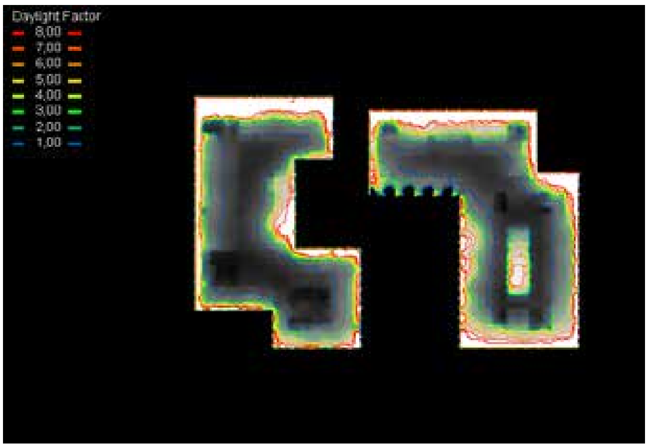
After





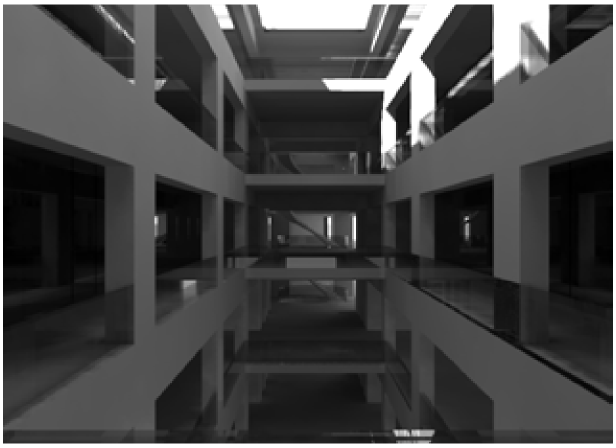


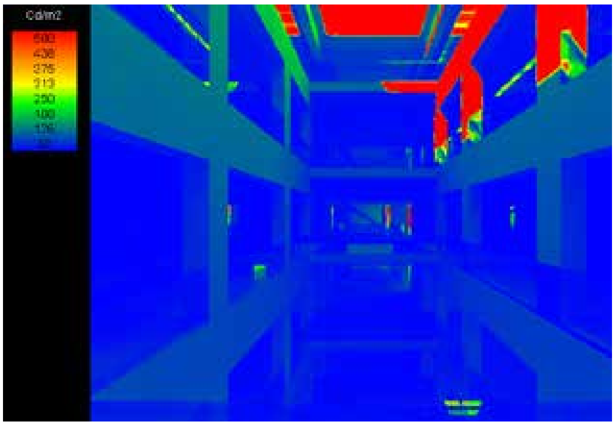


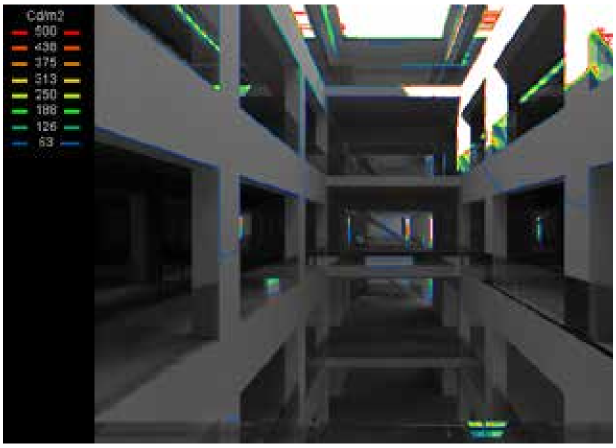


LUMINANCE ANALYSIS - SUNNY (MARCH 21st) - ATRIUM VIEW

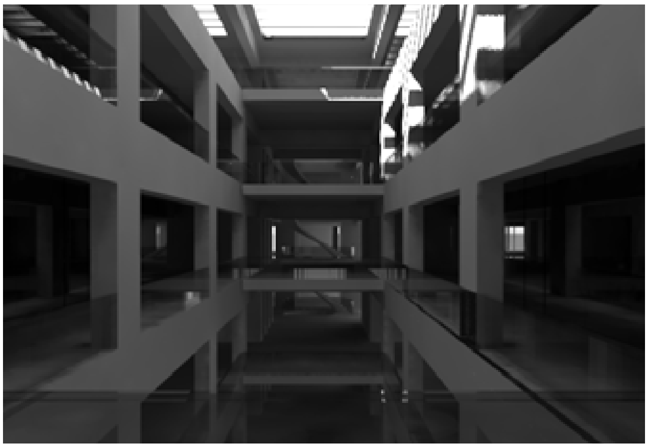
Before

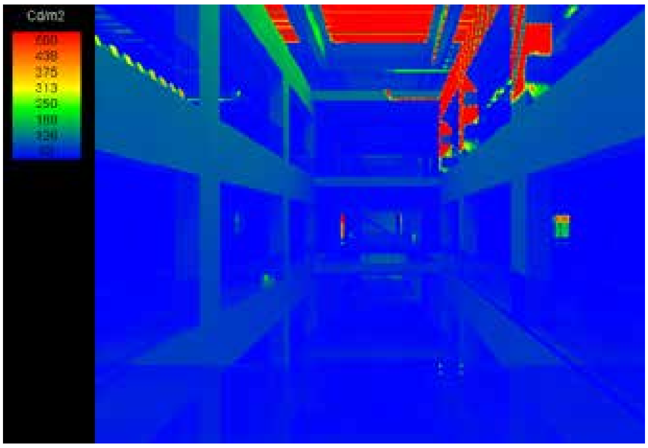


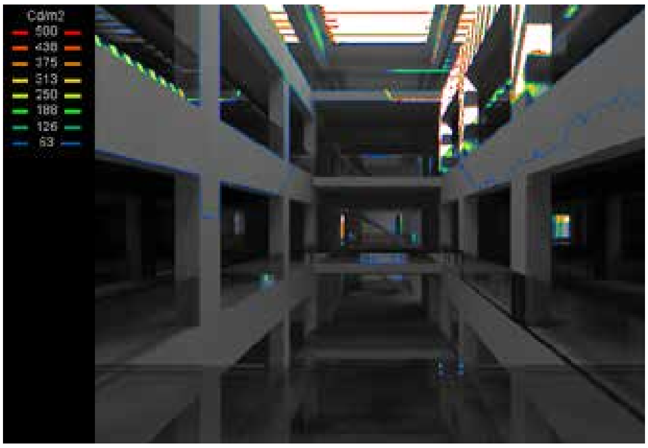




After

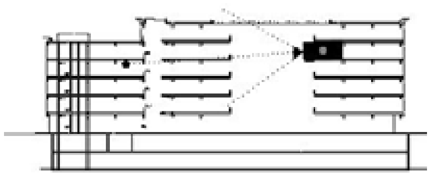






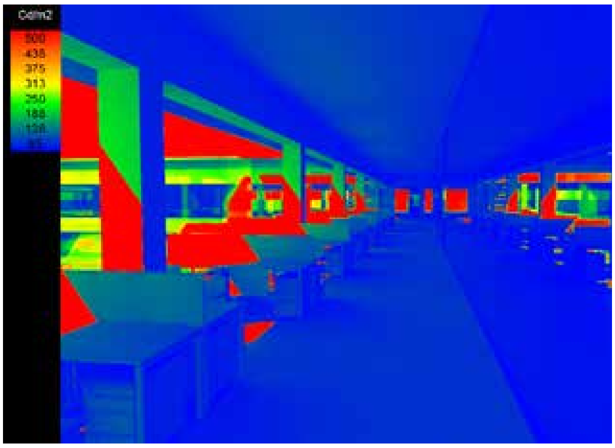
Key Plan

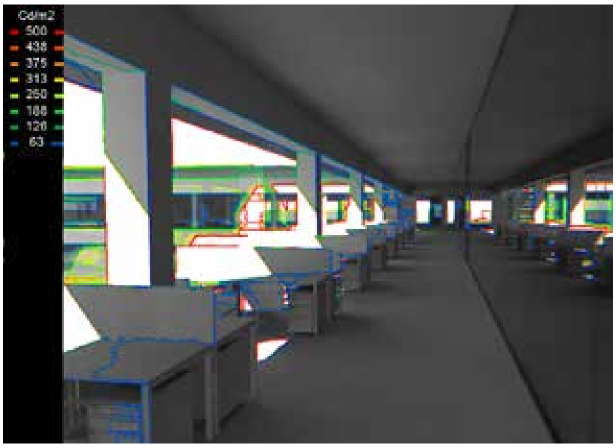
Key Section



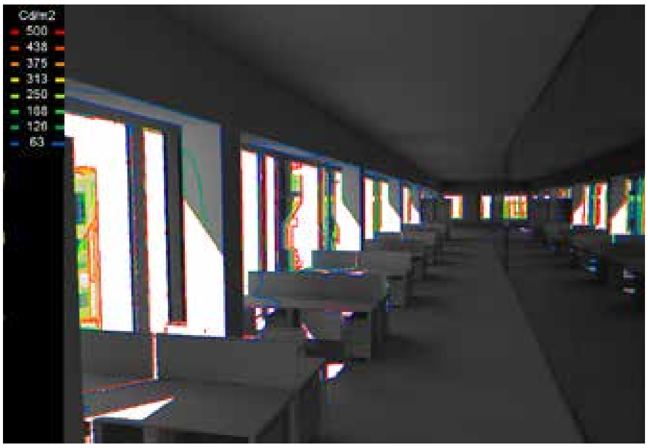
LUMINANCE ANALYSIS - SUNNY (MARCH 21st) - OFFICES VIEW

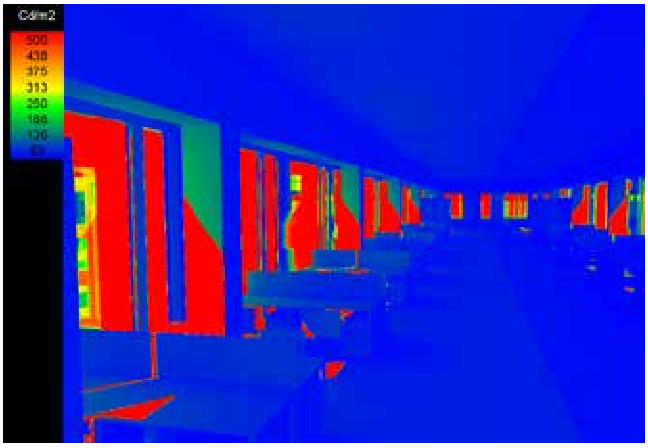
Before





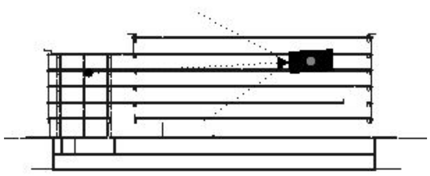
After





Key Plan

Key Section

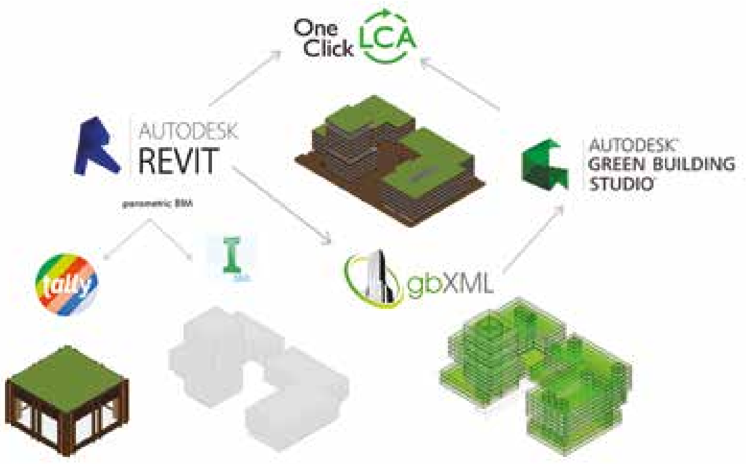


5.

Energy Analysis

Energy Models and Analysis

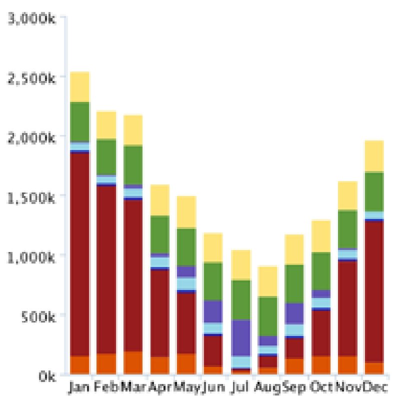
During the development of the project, it has been clear how it is necessary to plan the modelling in a careful way and to plan the modelling differently according to the aim to be reached.
For intance, **Revit energy models** need to be widely simplified with respect to an architectural ones: the level of simplification can go from mass modelling to the use of an energy model made of building components, which however simply includes the main floors and walls of the building, the cores and a very simplified envelope.



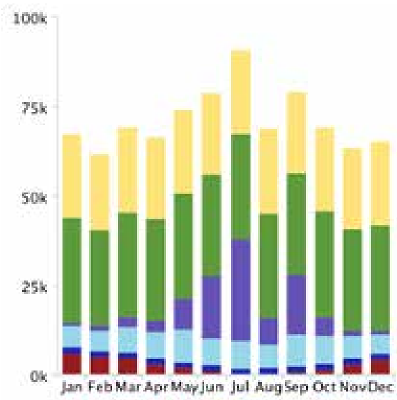
Energy models can then be exported from Revit using, for instance, **IFC or gbLMX files,** to other BIM software or platforms dedicated to energy analysis: in this case, the **Revit Energy Model of the project** was imported into the **Green Building Studio platform,** obtaining the following results.

GB STUDIO - MONTHLY DATA

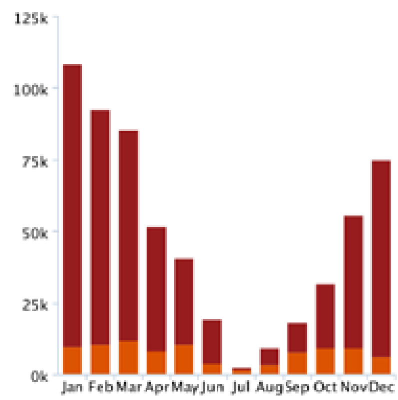
Total Energy, Cost



Electricity, Cost

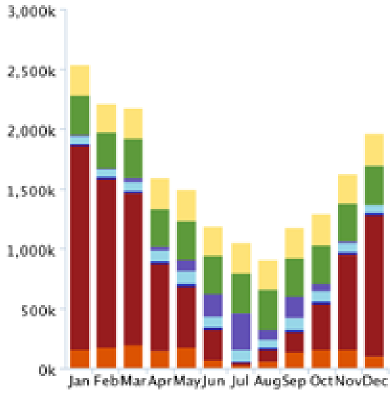


Natural Gas, Cost

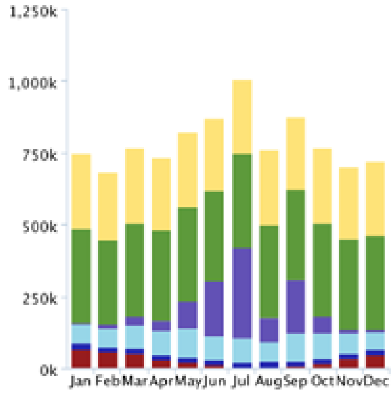


GB STUDIO - MONTHLY DATA

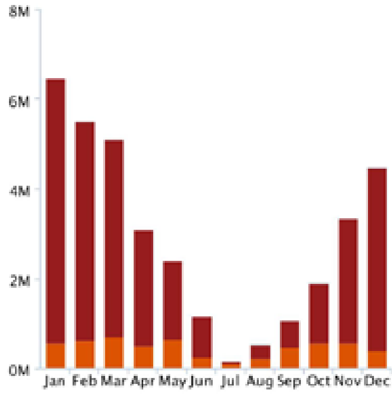
Total Energy, kWh



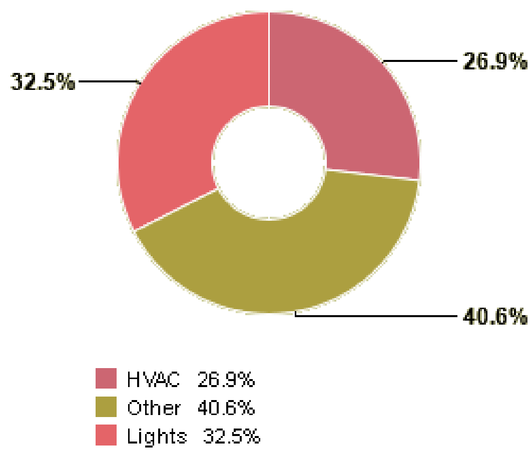
Electricity, kWh



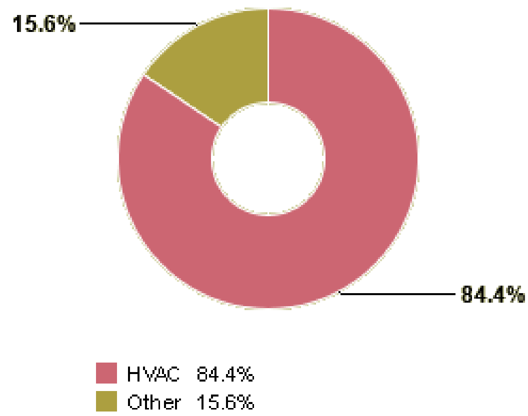
Natural Gas, MJ



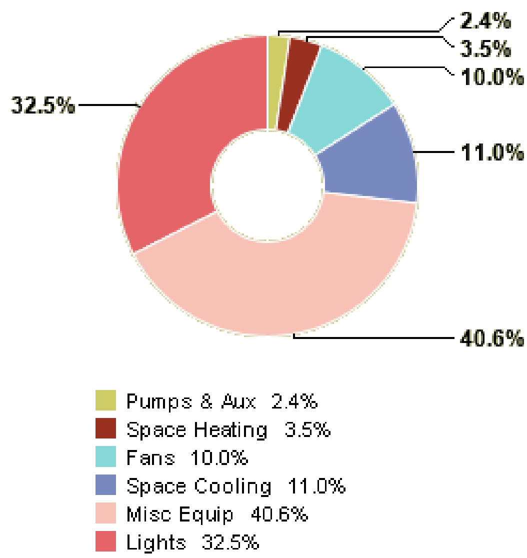
Annual Electric End Use



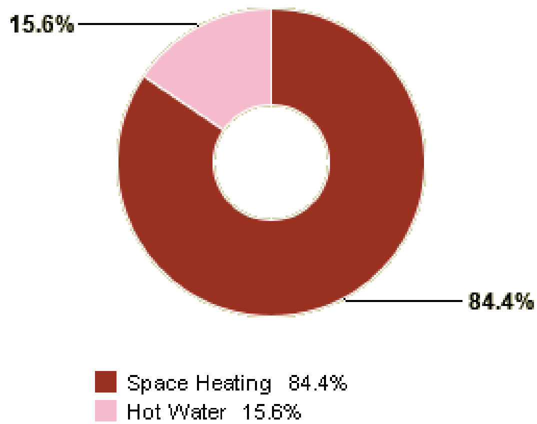
Annual Fuel End Use



Annual Electric End Use



Annual Fuel End Use



GB STUDIO - MONTHLY DATA

Energy, Carbon and Cost Summary	
Annual Energy Cost	CHF1,440,027
Lifecycle Cost	CHF19,613,165
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	1,750.3 Mg
Large SUV Equivalent	175.4 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	994 MJ / m² / year
Electric	9,456,727 kWh
Fuel	35,097,460 MJ
Annual Peak Demand	3,592.8 kW
Lifecycle Energy	
Electric	283,701,810 kW
Fuel	1,052,923,800 MJ
Assumptions (i)	

Building Summary - Quick Stats	
Number of People:	11,662 people
Average Lighting Power Density:	12.90 W / m²
Average Equipment Power Density:	16.11 W / m²
Specific Fan Flow:	5.9 LPerSec / m²
Specific Fan Power:	-67,042.866 W / LPerSec
Specific Cooling:	0 m² / kW
Specific Heating:	0 m² / kW
Total Fan Flow:	407,185 LPerSec
Total Cooling Capacity:	-7,992,584 kW

LEED Water Efficiency (more details)

	L / yr	CHF / yr
Indoor:	54,478,360	CHF87,710
Outdoor:	696,701	CHF481
Total	**55,175,061**	**CHF88,191**

Photovoltaic Potential (more details)	
Annual Energy Savings:	830,868 kWh
Total Installed Panel Cost:	CHF6,124,420
Nominal Rated Power:	766 kW
Total Panel Area:	5,544 m²
Maximum Payback Period:	49 years @ CHF0.09 / kWh

Wind Energy Potential	
Annual Electric Generation:	675 kWh

Natural Ventilation Potential	
Total Hours Mechanical Cooling Required:	6,276 Hours
Possible Natural Ventilation Hours:	1,848 Hours
Possible Annual Electric Energy Savings:	1,283,488 kWh
Possible Annual Electric Cost Savings:	CHF115,514
Net Hours Mechanical Cooling Required:	4,428 Hours

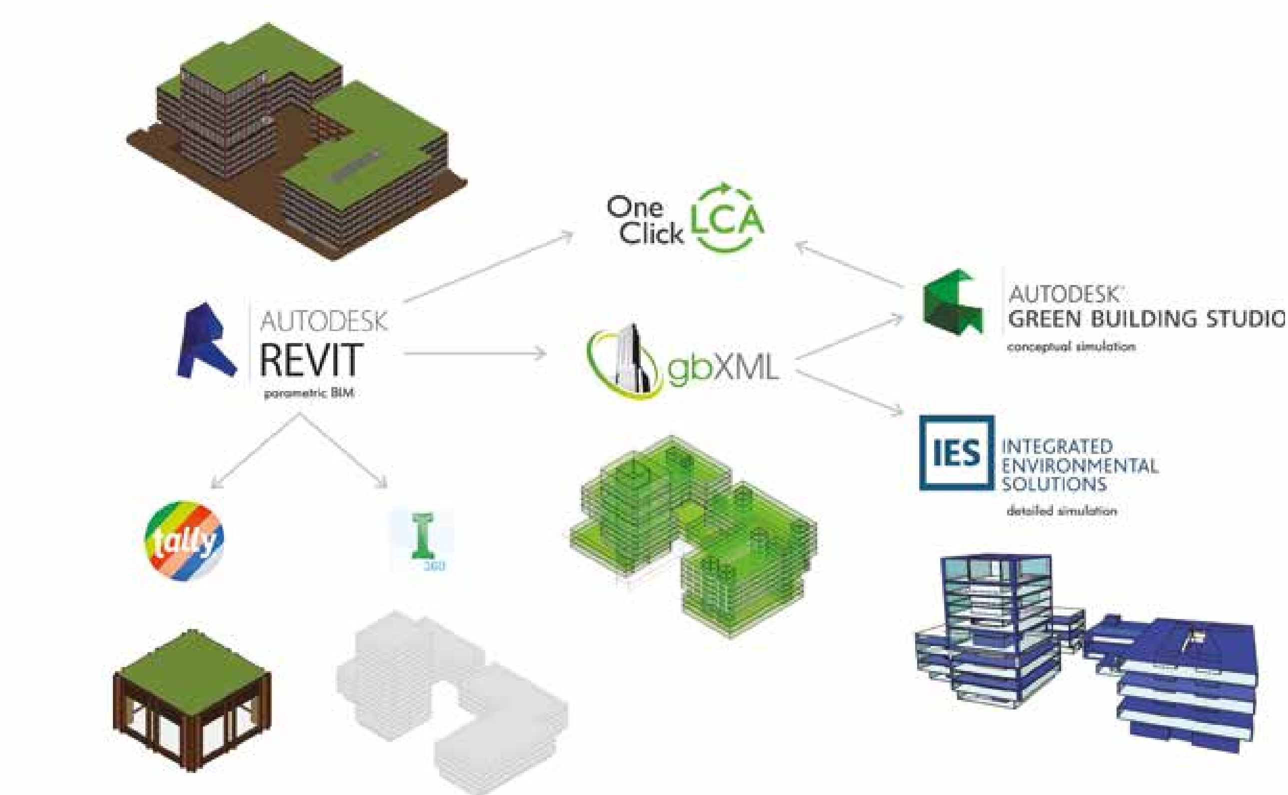
6.

LCA Analysis

Material choices, LCA and EPD considerations

Another field of research for which BIM processes were implemented was that of **materials.** The role of materials was very important in the development of the design proposal, which tries to create atmospheres very stimulating under the sensorial point of view. Such a design-driven choice was then supported by considerations about **sustainability, considering the environmental impact of the construction materials used in the design**.

In order to take into account the **sustainability of the materials selected,** the Architectural **Revit model** was enriched with **information about the stratigraphies adopted,** and it was the used to carry out **Life Cycle Assessments** by means of two plug-ins: **Tally and OneClick LCA.**

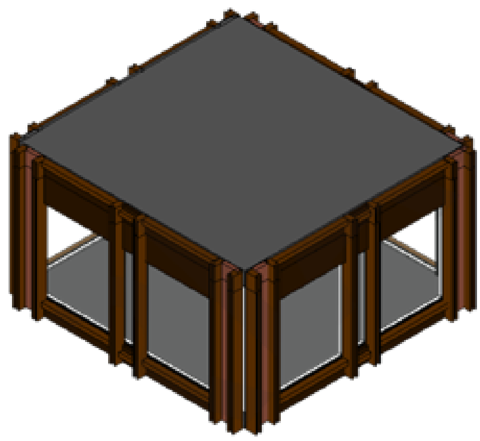


According to the different characteristics that the software have, they were used at different stages and for different aim. **Tally was first used to carry out the analysis on a sample of the buidling, reduced to a simplified box, which could be used as a parametric unit for the whole project**. Tally is indeed a more intuitive software, yet it is also provided with a stricter and more limited material library with respect to OneClick.

Tally Analysis

Also in this case, the process was implemented at different stages of the design, leading the impovement of material choices.

LCA RUN ON 21.04.20 - TALLY

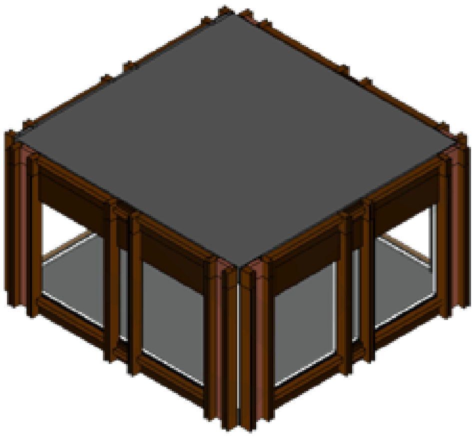


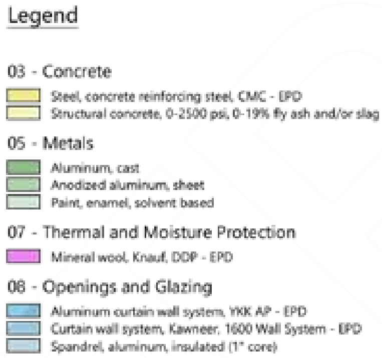
Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO_2eq)	61.286	654,0	4.328	3.327	-7.427
Acidification (kg SO_2eq)	261,0	3,030	16,51	15,40	-69,2
Eutrophication (kg Neq)	10,97	0,2467	0,9069	0,9852	-0,8624
Smog Formation (kg O_3eq)	3.270	100,1	286,2	299,3	-447
Ozone Depletion (kg CFC-11eq)	3,856E-005	2,240E-011	3,036E-005	2,251E-007	-3,367E-005
Primary Energy (MJ)	824.340	9.510	102.724	55.238	-144.829
Non-renewable Energy (MJ)	716.562	9.283	99.094	51.650	-70.174
Renewable Energy (MJ)	107.887	230,0	3.578	3.648	-74.483
Environmental Impacts / Area					
Global Warming (kg CO_2eq/m^2)	0,9013	0,009617	0,06364	0,04893	-0,1092
Acidification (kg SO_2eq/m^2)	0,003838	4,456E-005	2,428E-004	2,264E-004	-0,001017
Eutrophication (kg Neq/m^2)	1,613E-004	3,629E-006	1,334E-005	1,449E-005	-1,268E-005
Smog Formation (kg O_3eq/m^2)	0,04809	0,001473	0,004208	0,004402	-0,006575
Ozone Depletion (kg CFC-11eq/m^2)	5,670E-010	3,294E-016	4,465E-010	3,311E-012	-4,951E-010
Primary Energy (MJ/m^2)	12,12	0,1399	1,511	0,8123	-2,13
Non-renewable Energy (MJ/m^2)	10,54	0,1365	1,457	0,7596	-1,03
Renewable Energy (MJ/m^2)	1,587	0,003382	0,05262	0,05365	-1,10

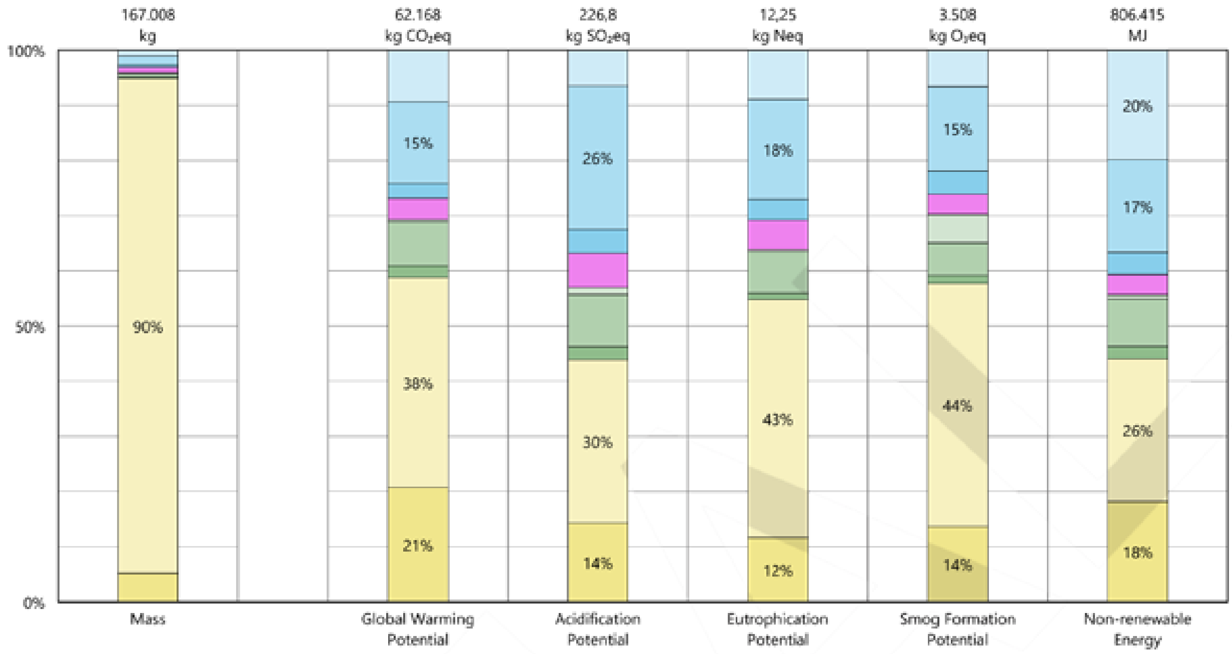
LCA RUN ON 8.05.20 - TALLY

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO_2eq)	79.027	1.156	22.828	4.322	-2.612
Acidification (kg SO_2eq)	288,3	5,356	93,44	21,36	-47,2
Eutrophication (kg Neq)	13,55	0,4361	5,462	2,198	-0,4081
Smog Formation (kg O_3eq)	4.187	177,0	1.513	377,2	-248
Ozone Depletion (kg CFC-11eq)	5,952E-005	3,959E-011	8,168E-005	8,921E-009	-4,588E-005
Primary Energy (MJ)	1.230.127	16.808	573.497	68.305	-85.935
Non-renewable Energy (MJ)	1.103.659	16.406	545.304	63.865	-26.035
Renewable Energy (MJ)	126.990	406,4	28.398	4.511	-59.839
Environmental Impacts / Area					
Global Warming (kg CO_2eq/m^2)	1,162	0,017	0,3357	0,06356	-0,03841
Acidification (kg SO_2eq/m^2)	0,00424	7,876E-005	0,001374	3,142E-004	-6,937E-004
Eutrophication (kg Neq/m^2)	1,993E-004	6,413E-006	8,032E-005	3,233E-005	-6,001E-006
Smog Formation (kg O_3eq/m^2)	0,06158	0,002603	0,02225	0,005546	-0,00364
Ozone Depletion (kg CFC-11eq/m^2)	8,752E-010	5,821E-016	1,201E-009	1,312E-013	-6,747E-010
Primary Energy (MJ/m^2)	18,09	0,2472	8,434	1,004	-1,26
Non-renewable Energy (MJ/m^2)	16,23	0,2413	8,019	0,9392	-0,3829
Renewable Energy (MJ/m^2)	1,868	0,005977	0,4176	0,06634	-0,88

LCA RUN ON 21.04.20 - TALLY







LCA RUN ON 8.05.20 - TALLY

Legend

03 - Concrete
- Lightweight concrete, 2501-3000 psi, 0-19% fly ash and/or slag
- Steel, concrete reinforcing steel, CMC - EPD
- Structural concrete, 0-2500 psi, 0-19% fly ash and/or slag
- Structural concrete, 2501-3000 psi, 0-19% fly ash and/or slag

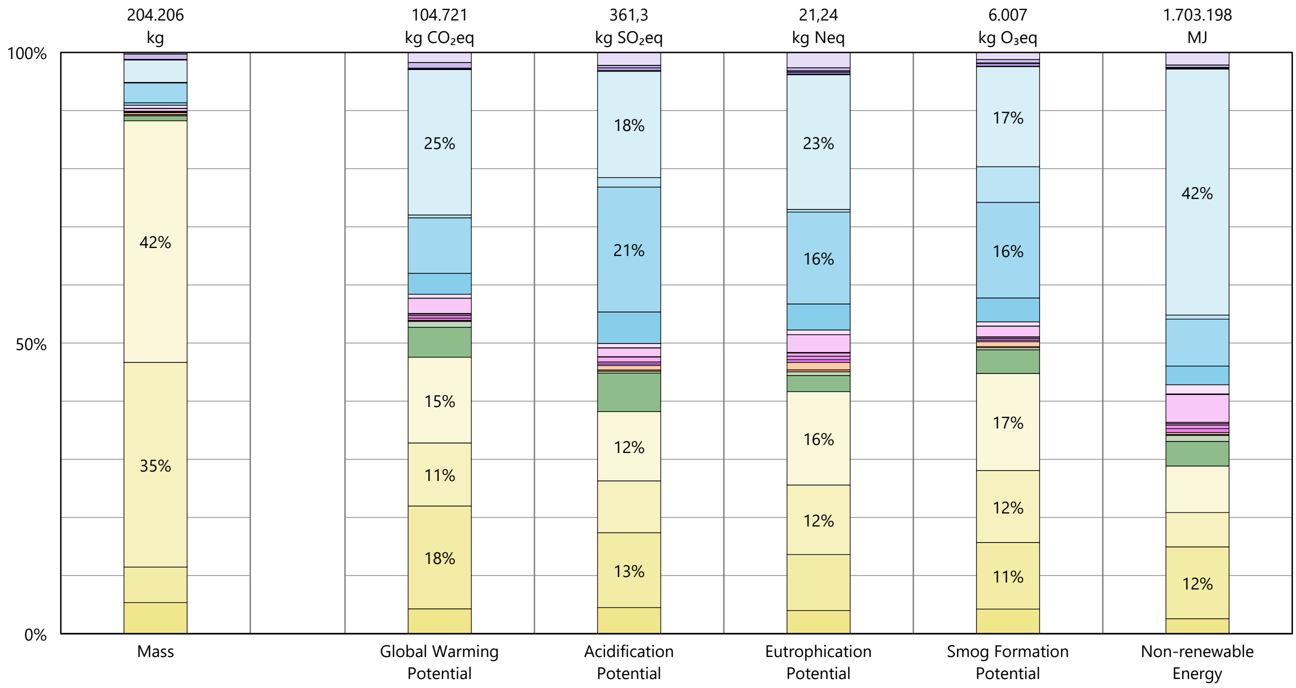
05 - Metals
- Aluminum, sheet
- Powder coating, metal stock

06 - Wood/Plastics/Composites
- Fiberglass mat gypsum sheathing board
- Red oak lumber, 1 inch

07 - Thermal and Moisture Protection
- Adhesive, acrylic
- EPDM, non-reinforced membrane, 60 mils, SPRI - EPD
- Expanded polystyrene (EPS), board
- Mineral wool, Knauf, ECOSE - EPD
- Polyethelene sheet vapor barrier (HDPE)
- Polystyrene board (XPS), Pentane foaming agent
- Roofing adhesive, hot asphalt
- SBS modified bitumen, assembly (base & cap), ARMA - EPD

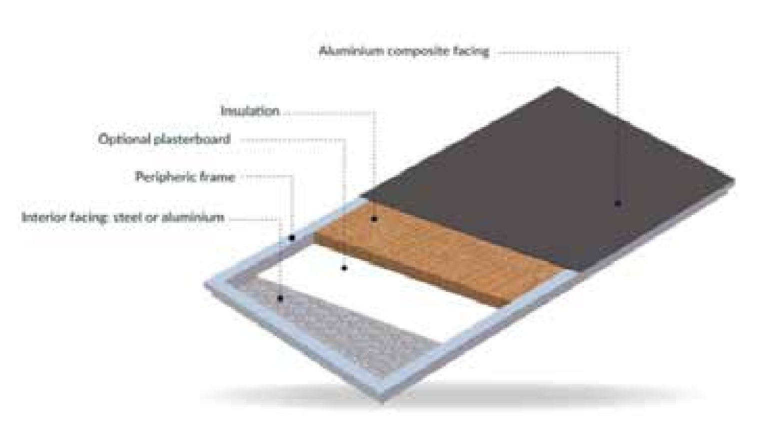
08 - Openings and Glazing
- Aluminum extrusion, anodized, AEC - EPD
- Glazing, double, insulated (air)
- Paint, enamel, solvent based
- Spandrel, aluminum, insulated (1" core)

09 - Finishes
- Floor and wall adhesive, urethane
- Kraft paper
- Polyurethane floor finish, water-based
- Silicate spreadable filler, Brillux - EPD
- Stucco, portland cement
- Underlayment, fibrous
- Vinyl flooring, slip-proof, ERFMI - EPD



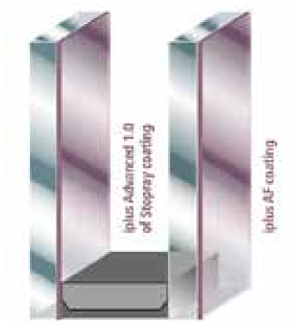
LIFE CYCLE ASSESMENT
ENVIRONMENTAL IMPACT

PHYSICS & SNI
NORTH -EAST FACADE



TECHNICAL INFORMATION
Thermal insulation, compliance with IT249 rules

MATERIAL
Aluminium composite facing
XPS Insulation
Optional Plasterboard
Aluminum frame
Steel or aluminum facing



ACG GLASS THERMOBEL ADVANCED 0.8

TECHNICAL INFORMATION
Ug value of glass : 0.8 W/m^2K
Free Solar Heat : 50%
Light Transmission: 72%
Global warming potential
Total A1-A3 Production:
3.92E+01 kg CO2 eq/FU
Total life cycle
4.37E+01 kg CO2 eq/FU

SCHÜCO FACADE UCC 65 SG

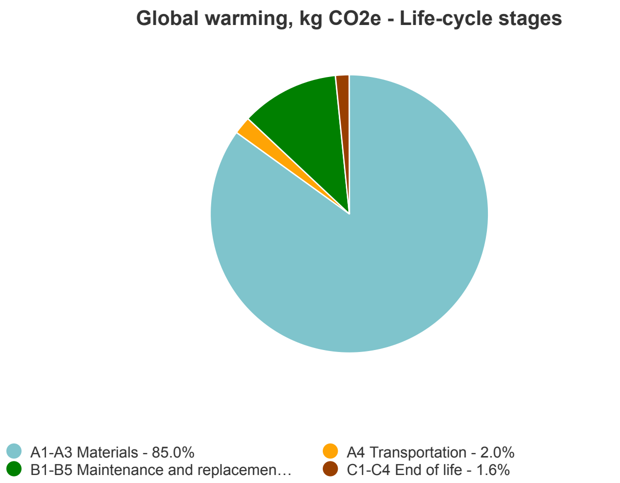
TECHNICAL INFORMATION
U value of frame : 2,2 $W/(m^2K)$
Material : ALuminium
Max height: 3600 mm
Max. width 2700 mm
Max weight: 250 kg
Max. glass thickness : 36 mm
EPD Recycable

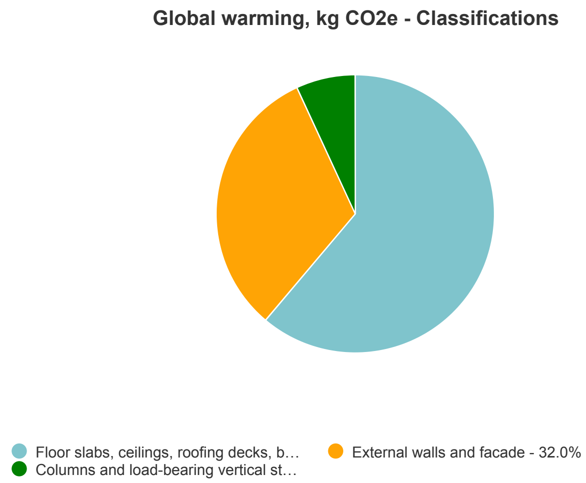
OneClick LCA Analysis

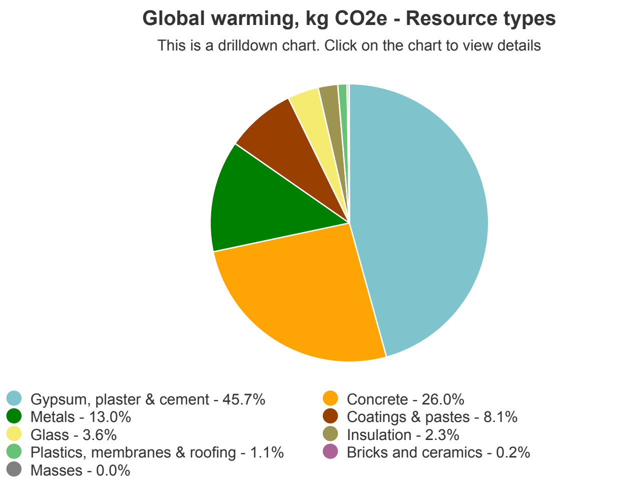
OneClick can be considered as a more advanced version of Tally, and it is provided with a very rich database of information related to material and sustainability. However, due to its greater level of complexity, it is also harder to handle, since it requires a very well developed Revit model, in which many information have to be correctly inserted.

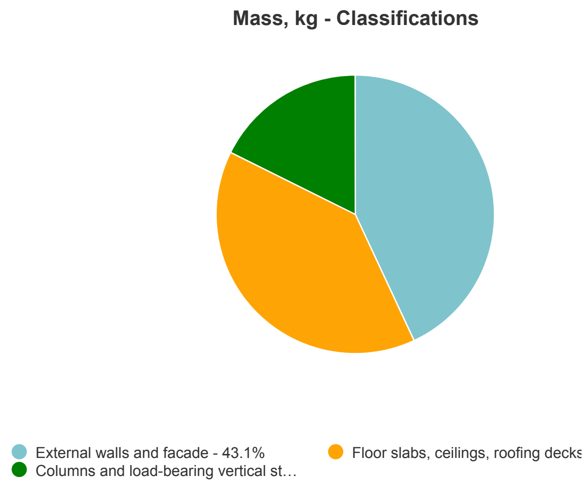
For such reasons, the analysis on OneClick has been run in a later stage, using the entire revit model of the building complex. Also in this case, the process was implemented at different stages of the design, leading the impovement of material choices.

LCA RUN ON 01.06.20 - OneClick

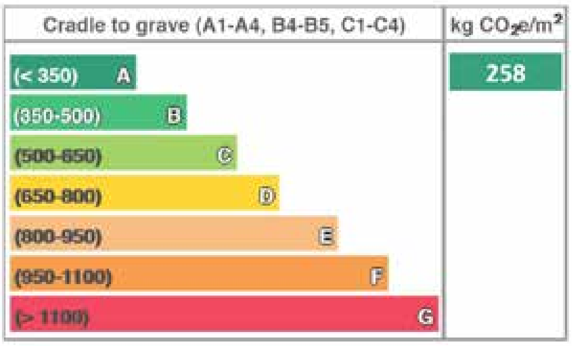




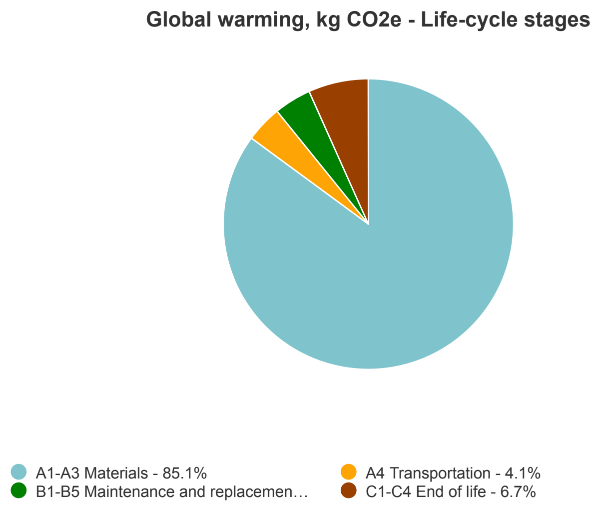


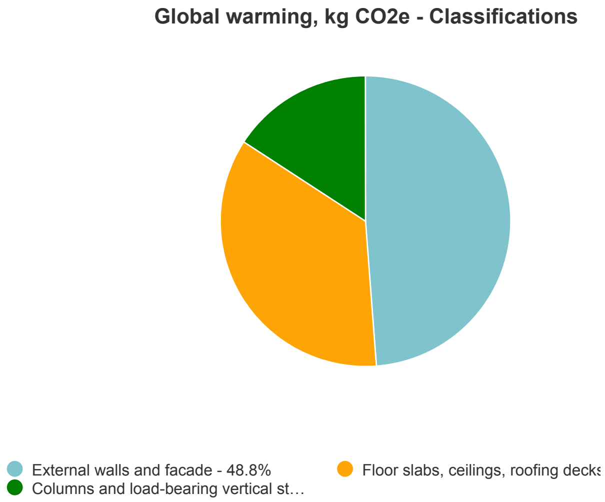


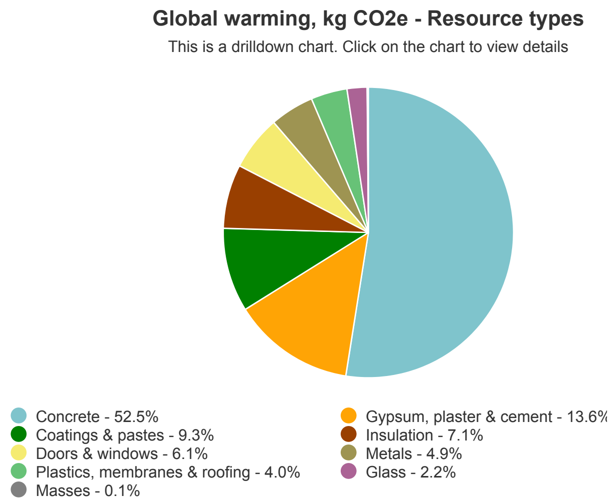
CO_2 40 584 Tons CO_2e 12 kg CO_2e / m2 / year 2 029 198 € Social cost of carbon

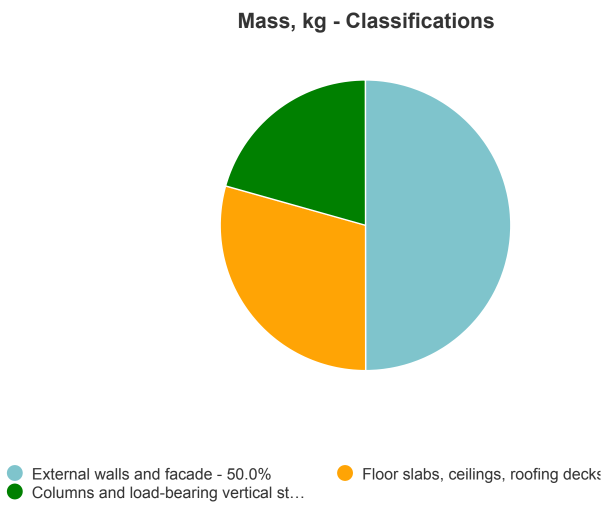


LCA RUN ON 11.06.20 - OneClick









17 576 Tons CO_2e | **5 kg CO_2e / m2 / year** | **878 808 € Social cost of carbon**

LCA RUN ON 01.06.20 - OneClick

Most contributing materials (Global warming)

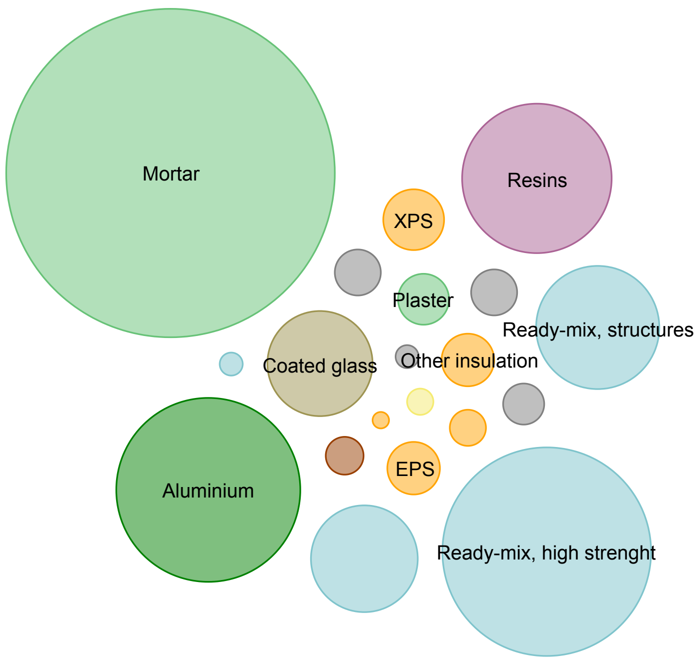
No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)	Sustainable alternatives
1.	Mortar ?	18 108 tons CO_2e	52.5 %	show sustainable alternatives
2.	Concrete (ex rebar) ?	6 320 tons CO_2e	18.3 %	show sustainable alternatives
3.	Aluminium curtain walling ?	2 202 tons CO_2e	6.4 %	show sustainable alternatives
4.	Concrete (ex rebar) ?	1 940 tons CO_2e	5.6 %	show sustainable alternatives
5.	Epoxy resin ?	1 637 tons CO_2e	4.7 %	show sustainable alternatives
6.	Glass, solar control, CVD coated, clear ?	1 451 tons CO_2e	4.2 %	show sustainable alternatives
7.	Ready-mix concrete, lightweight ?	1 399 tons CO_2e	4.1 %	show sustainable alternatives
8.	XPS insulation panels ?	362 tons CO_2e	1.0 %	show sustainable alternatives
9.	Aluminium metal plate ?	286 tons CO_2e	0.8 %	show sustainable alternatives
10.	Insulation composite system ?	234 tons CO_2e	0.7 %	show sustainable alternatives
11.	Interior paint plasters, paste ?	105 tons CO_2e	0.3 %	show sustainable alternatives
12.	Extensive green roof system ?	87 tons CO_2e	0.3 %	show sustainable alternatives
13.	Terrazzo quartz products, with cristobalite and mirror glass inserts ?	86 tons CO_2e	0.2 %	show sustainable alternatives
14.	Insulation, glass wool/mineral wool, (mineral wool), in rolls ?	72 tons CO_2e	0.2 %	show sustainable alternatives
15.	Insulation, EPS hard foam, for ceilings/floors and as perimeter insulation ?	64 tons CO_2e	0.2 %	show sustainable alternatives
16.	Ethylene-copolymer-bitumen granules for sealing of non waterproof membranes ?	42 tons CO_2e	0.1 %	show sustainable alternatives
17.	PVC waterproofing membrane ?	46 tons CO_2e	0.1 %	show sustainable alternatives
18.	Natural stone slab, rigid, outdoor use ?	5 tons CO_2e	0.0 %	show sustainable alternatives
19.	Sandstone cladding ?	12 tons CO_2e	0.0 %	show sustainable alternatives
20.	Concrete masonry units (CMU), for part. walls German average ?	7,6 tons CO_2e	0.0 %	show sustainable alternatives
21.	Gypsum plaster (gypsum - lime plaster) ?	1,3 tons CO_2e	0.0 %	show sustainable alternatives
22.	PUR rigid insulation panels, for wall applications ?	2,4 tons CO_2e	0.0 %	show sustainable alternatives
23.	Geotextile, wooven fabric for reinforcement and separation, water permeable ?	9,7 tons CO_2e	0.0 %	show sustainable alternatives

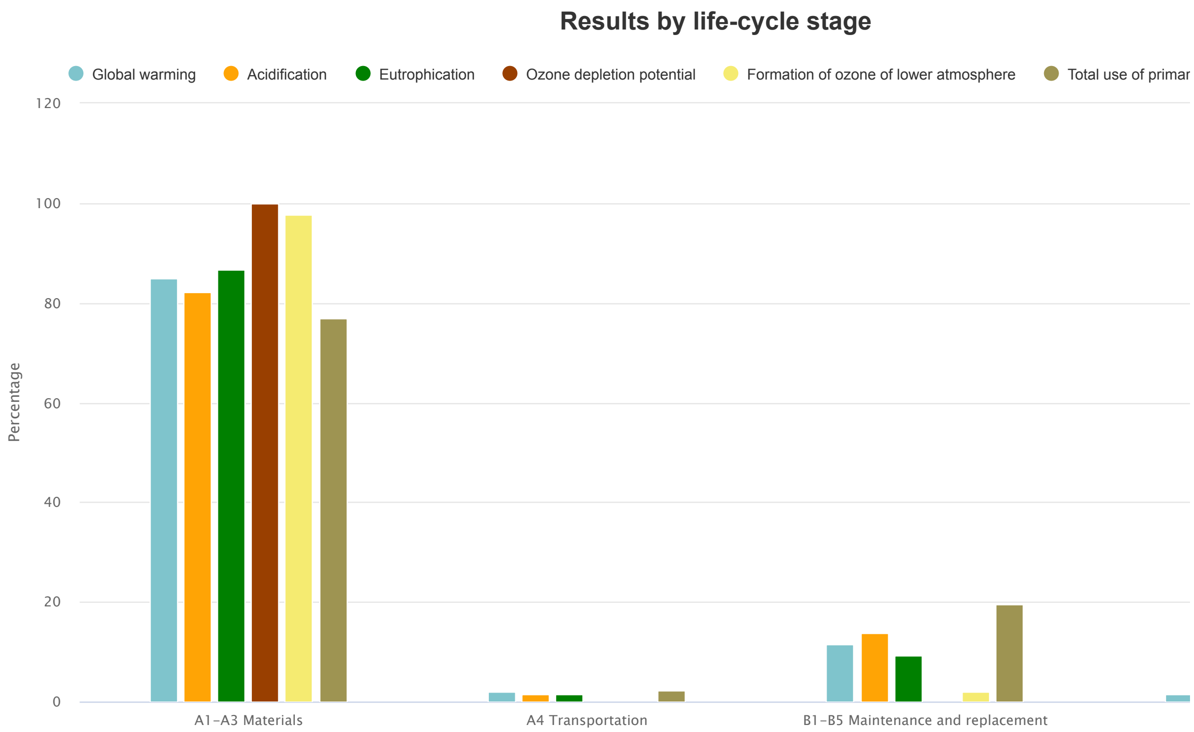
LCA RUN ON 11.06.20 - OneClick

Most contributing materials (Global warming)

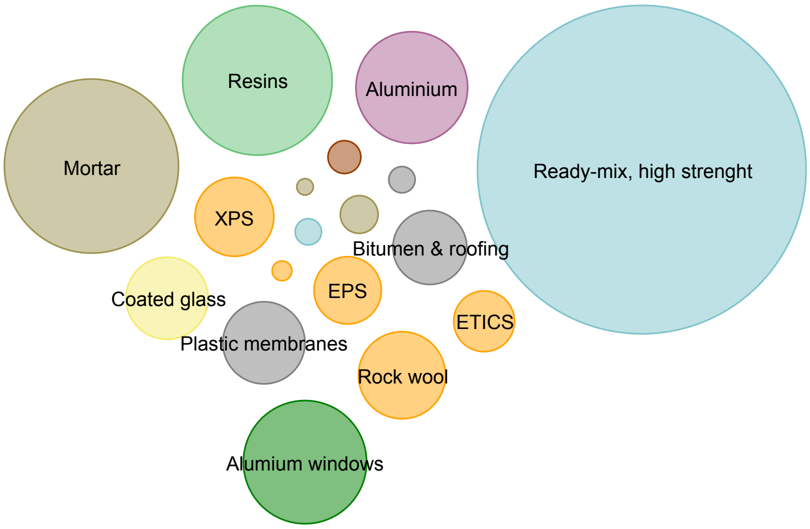
No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)	Sustainable alternatives
1.	Ready-mix concrete, high-strength, generic ?	7 863 tons CO_2e	52.6 %	show sustainable alternatives
2.	Epoxy resin, EU avg. ?	1 630 tons CO_2e	10.9 %	show sustainable alternatives
3.	Aluminium frame, double glazing window, non-operable, per m2 ?	1 066 tons CO_2e	7.1 %	show sustainable alternatives
4.	Mortar, ready-mix, for floors ?	1 041 tons CO_2e	7.0 %	show sustainable alternatives
5.	Leveling screed, cement mortar ?	1 043 tons CO_2e	7.0 %	show sustainable alternatives
6.	Mineral wool (flat roof insulation) ?	459 tons CO_2e	3.1 %	show sustainable alternatives
7.	XPS insulation panels ?	362 tons CO_2e	2.4 %	show sustainable alternatives
8.	Laminated polyamide film water vapour membrane ?	349 tons CO_2e	2.3 %	show sustainable alternatives
9.	Aluminium metal plate ?	286 tons CO_2e	1.9 %	show sustainable alternatives
10.	Glass, solar control, CVD coated, bronze ?	243 tons CO_2e	1.6 %	show sustainable alternatives
11.	Insulation composite system ?	174 tons CO_2e	1.2 %	show sustainable alternatives
12.	Glass, solar control, CVD coated, clear ?	144 tons CO_2e	1.0 %	show sustainable alternatives
13.	Insulation, EPS hard foam, for ceilings/floors and as perimeter insulation ?	64 tons CO_2e	0.4 %	show sustainable alternatives
14.	Extensive green roof system ?	56 tons CO_2e	0.4 %	show sustainable alternatives
15.	Single-layer bitumen-polymer waterproofing membrane for roofing ?	61 tons CO_2e	0.4 %	show sustainable alternatives
16.	Plaster (gypsum-lime) ?	42 tons CO_2e	0.3 %	show sustainable alternatives
17.	Organic mortar adhesive ?	31 tons CO_2e	0.2 %	show sustainable alternatives
18.	Sandstone cladding ?	12 tons CO_2e	0.1 %	show sustainable alternatives
19.	Concrete masonry units (CMU), for part. walls German average ?	7,6 tons CO_2e	0.1 %	show sustainable alternatives
20.	Geotextile from polypropylene ?	10 tons CO_2e	0.1 %	show sustainable alternatives
21.	Natural stone slab, rigid, outdoor use ?	7,2 tons CO_2e	0.0 %	show sustainable alternatives
22.	Plasterboard ?	tons CO_2e	0.0 %	show sustainable alternatives
23.	PUR rigid insulation panels, for wall applications ?	2,5 tons CO_2e	0.0 %	show sustainable alternatives
24.	Gypsum plaster board, regular, generic ?	1,4 tons CO_2e	0.0 %	show sustainable alternatives

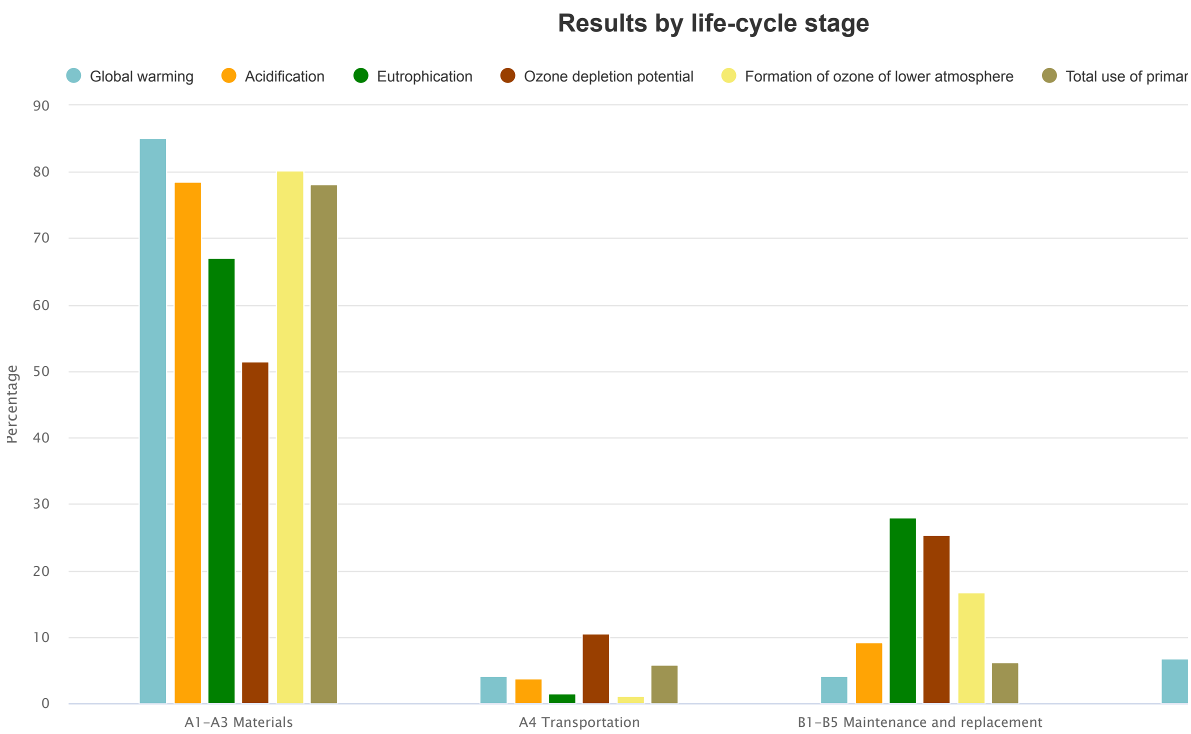
LCA RUN ON 01.06.20 - OneClick





LCA RUN ON 11.06.20 - OneClick





7.

LEED Checklist

LEED Environmental Strategy

In 2005, the administration of the Canton of Basel-Stadt committed to a goal of becoming a carbon-neutral administration over a period of 25 years through a combination of reduction measures, such as energy e ciency in Cantonal buildings.

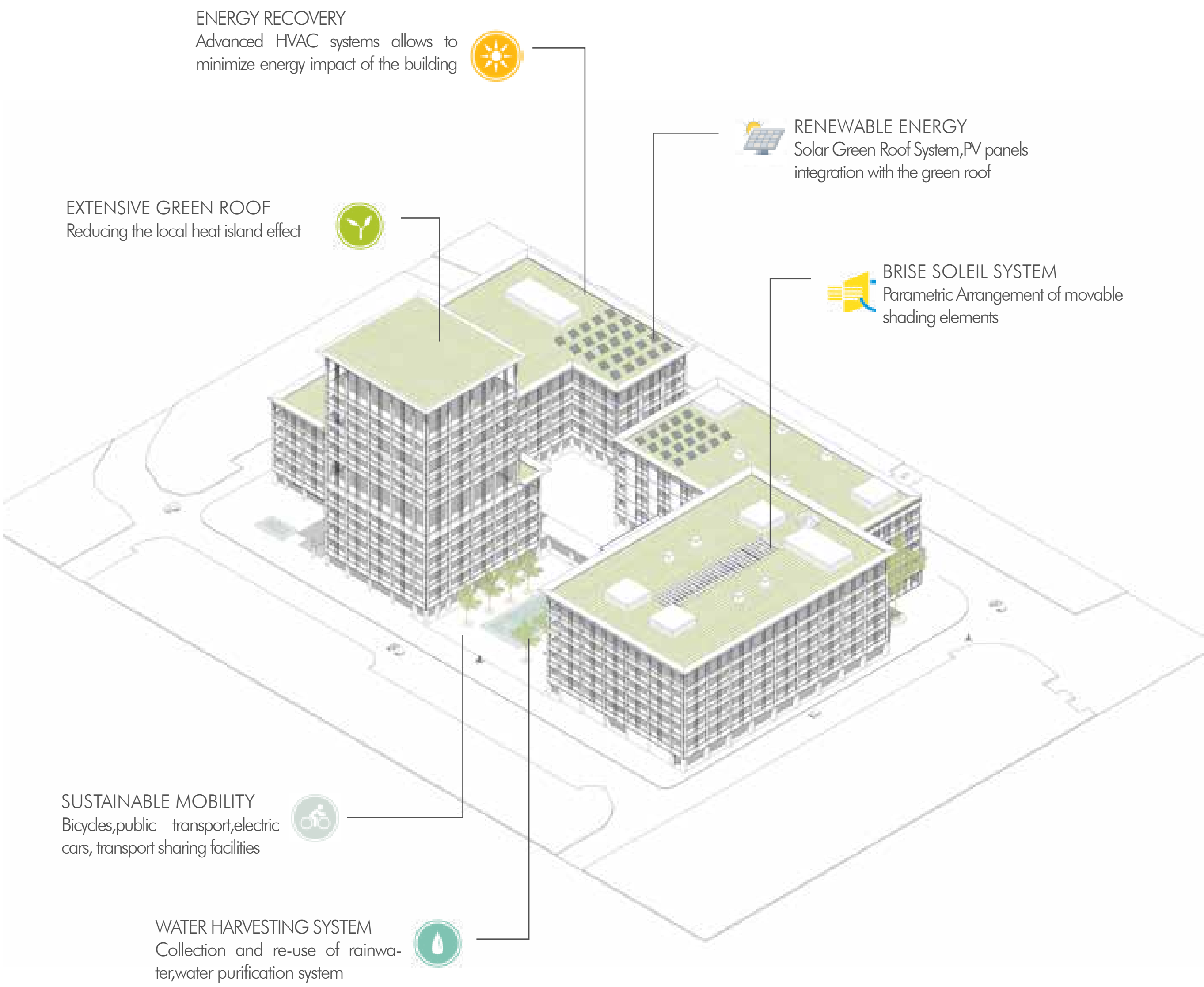
According to such considerations, the design proposal was enriched by the the elaboration of a preliminary design **Environmental Strategy, elaborated following the criteria indicated by the LEED Checklist.**

In order to balance the high level of approximation given by the early stage of design, the filling of the checklist was limited to obtain only the credits which could actually be obtained as a consequence of the design choices indicated in the project, together with energy goals intentioned to be reached.

Considering the main six criteria categories at the base of the LEED rating system, the project obtained **13/16 credits for the category of location and transportation, 6/10 credits for the category of sustainable sites, 8/13 for materials and resources, 23/33 for energy and atmosphere, 7/11 for water efficiency, 9/13 for indoor environmental quality and innovation 3.**

As a results, the project obtained a **silver leed certifivate, for a total score of 55 credits over 110 possible.**


CONCEPT ANALYSIS
AutoCAD
(LOD:100)
Design Process
MODELLING
REVIT
(LOD:300)
Detailed 3D Model
DWG DXT
DWG
MATERIALS
ONECLICK
(LOD:300)
Life Cycle
Assesment
TALLY
(LOD:300)
Life Cycle
Assesment
BIM
WORKFLOW
GBXML
DXF
STRUCTURE
MIDAS
(LOD:300)
Structural analysis
of truss system
GBXML
GBXML
ENERGY
GREEN BUILDING STUDIO
(LOD:300)
Energy Demand
kWH/m²/ yr
DAYLIGHT ANALYSIS
INSIGHT 360
(LOD:300)
VELUX
(LOD:300)


ENERGY RECOVERY
Advanced HVAC systems allows to minimize energy impact of the building
RENEWABLE ENERGY
Solar Green Roof System,PV panels integration with the green roof
EXTENSIVE GREEN ROOF
Reducing the local heat island effect
BRISE SOLEIL SYSTEM
Parametric Arrangement of movable shading elements
SUSTAINABLE MOBILITY
Bicycles,public transport,electric cars, transport sharing facilities
WATER HARVESTING SYSTEM
Collection and re-use of rainwater,water purification system

LEED v4 for BD+C: New Construction and Major Renovation

Project Checklist

Project Name: Basel Life Sciences Campus

Date:14/07/2020

Y	?	N			
1			Credit	Integrative Process	1
13	**0**	**0**		**Location and Transportation**	**16**
			Credit	LEED for Neighborhood Development Location	16
1			Credit	Sensitive Land Protection	1
1			Credit	High Priority Site	2
4			Credit	Surrounding Density and Diverse Uses	5
5			Credit	Access to Quality Transit	5
1			Credit	Bicycle Facilities	1
1			Credit	Reduced Parking Footprint	1
			Credit	Green Vehicles	1
6	**0**	**0**		**Sustainable Sites**	**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Site Assessment	1
1			Credit	Site Development - Protect or Restore Habitat	2
1			Credit	Open Space	1
2			Credit	Rainwater Management	3
2			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1
7	**0**	**0**		**Water Efficiency**	**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
2			Credit	Outdoor Water Use Reduction	2
4			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	2
1			Credit	Water Metering	1
23	**0**	**0**		**Energy and Atmosphere**	**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
18			Credit	Optimize Energy Performance	18
1			Credit	Advanced Energy Metering	1
			Credit	Demand Response	2
3			Credit	Renewable Energy Production	3
			Credit	Enhanced Refrigerant Management	1
1			Credit	Green Power and Carbon Offsets	2

8	**9**	**3**	**0**	**70**
Y	Y	3		
Y	Y			
4				
2				
1	1			
1	1			
	2			
	3			
	1			
	1			

Y	?	N			
8	0	0	**Materials and Resources**		**13**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
4			Credit	Building Life-Cycle Impact Reduction	5
2			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
1			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
1			Credit	Construction and Demolition Waste Management	2
9	0	0	**Indoor Environmental Quality**		**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
1			Credit	Indoor Air Quality Assessment	2
1			Credit	Thermal Comfort	1
2			Credit	Interior Lighting	2
3			Credit	Daylight	3
1			Credit	Quality Views	1
1			Credit	Acoustic Performance	1
3	0	0	**Innovation**		**6**
3			Credit	Innovation	5
			Credit	LEED Accredited Professional	1
0	0	0	**Regional Priority**		**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
70	0	0	**TOTALS**	Possible Points:	**110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

LEED Environmental Strategy – Score explanation

The obtained **13 credits obtained for the category of location and transportation,** can mainly be assessed according to existing site conditions and according to the urban choices carried out at the beginning of the design concept development process.
One credit is obtained for sensitive land protection, since the project footprint is located on a land that was already previously developed; **one credit** is obtained since the project's sice is considered as a **high priority site,** located on an infill location in a historic district. Finally, **three credits are obtained due to surrounding densities and diverse uses condition,** being the site surrounded by existing high density fabric, within a radius of 400m.
For what concerns transportation, **5 credits are obtained thanks to access to quality transit,** thanks to the presence of existing bus stops for several lines within 400m of walking distance from functional entries of the project, other than the presence of a train station for commuters at a distance shorter than 800m.
One more credit is obtained in this first category due to **reduced parking footprint,** as the site does not exceed the minimum local code requirements for parking capacity, while **only half credit is obtained for bycicle facilities,** since the bicycle network present in the area meets all the three requirements indicated by the leed manual, but it was not possible to obtained a full score due to inability to provide all the necessary changing-rooms, showers and covered bike parking needed by bikers, despite open-air biking parking has been included.

For what concerns the **6/10 credits for the category of sustainable sites, 1 credit was obtained thanks to habitat protection and restoration,** related to the fact of using native or adapted vegetation for the project greenery, restoring 30% of all portions of the site identified as previously disturbed, and including vegetated roof surfaces with native or adapted plants, providing habitat, and promoting biodiversity.
Another credit was obtained of rthe criteria of "open space", by providing outdoor space greater than or equal to 30% of the total site area, with a minimum of 25% of that outdoor space being vegetated.
Two "sustainable sites" credits can then be obtained according to **rainwater management,** introducing design elements dealing with the management of on site the run-off water, such as low-impact development (LID) solutions and green infrastructures.
Eventually, the last **two points** can be obtained thanks to **heat island reduction,** which is a goal obtainable tanks to the adoption of vegetated roofs, high-reflectance roof materials and a series of non-roof measures.

Dealing with the LEED category of **materials and resources, 8 out of 13 credits were obtained.** As anticipated in the former chapters of the report, LCA and EPD assessments were taken into account in the selection of construction materials involved in the project. Thanks to such an approach, **3 credits were obtained considering the building life-cycle impact reduction,** controlled by the conduction of a life-cycle assessment of the project's structure and enclosure demonstrating a minimum of 10% reduction, compared with a baseline building.
One more credit was obtained thanks to building product disclosure and optimization, by using at least 20 different permanently installed products sourced (from at least five different manufacturers)that meet one of the disclosure criteria, such as Environmental Product Declarations.
Eventually, **one credit was obtained for the voice "material ingredients",** which involves the use of at least 20 different permanently installed products (from at least five different manufacturers) that demonstrate the chemical inventory of the product to at least 0.1% (1000 ppm).

More complex was dealing with the **categories about energy and atmosphere, water efficiency and indoor environmental quality, since such aspects cannon be directly assessed at this stage of the design. However, they wew introduced in the environmental trategy as a goal to point at.**

For what concerns **energy and atmosphere, 18 possible credits have been assigned aiming to reach an optimized energy performance:** the idea is that of establishing an energy performance target and carry out a Whole-Building Energy Simulation, of analyzing efficiency measures, and focusing on load reduction and HVAC-related strategies.
Considering the installation of energy advanced energy metering, allows to obtain a further credit, while the **production of renewable energy, thanks to installation of photovoltaic systems, allowed to obtain 3 credits.**

About **water efficiency, outdoor water use reduction is taken into account in the design of open spaces,** showing that the landscape does not require a permanent irrigation system beyond a maximum two-year establishment period, which allowed to obtain **2 credits.** Also in this case, **considering the installation of permanent water meters for two or more sub-systems, allowed to obtain a further credit.**

Finally, for what concerns the **9 out of 13 credits related to indoor environmental quality, one credit had been assigned to the field of indoor air quality assessment, thermal comfort, interior lighting, daylight comfort, quality views and acoustic performance. This was done with the intention of carrying out further verifications, yet carrying out design choices keeping such objectives in mind.**

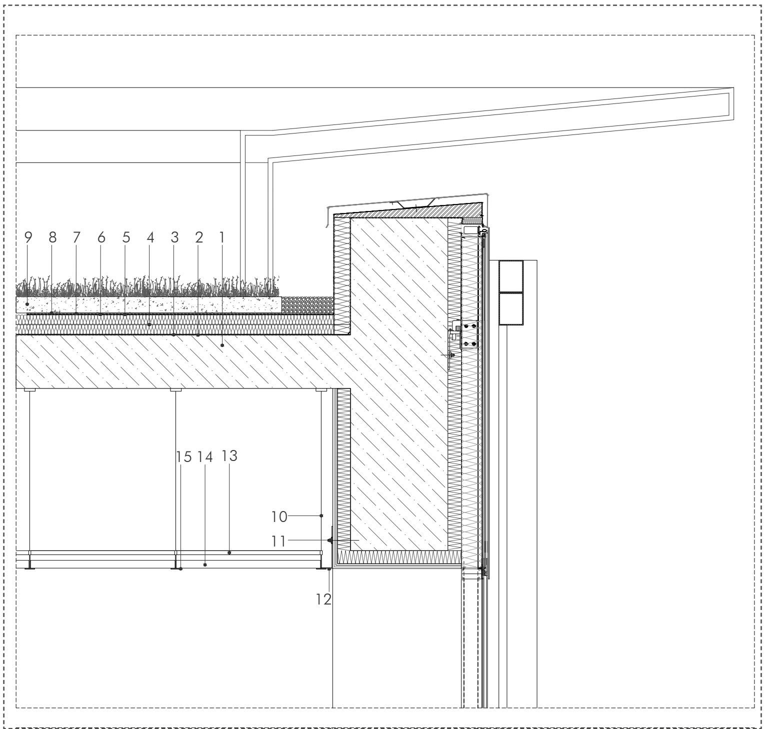
LEED Environmental Strategy – Design solutions

Among the **sustainable design solution introduced in the project, the main ones are:**

- **Vegetated roof**
- **Permeable pavings**
- **Tree pits LID/SUDS solutions**
- **Water pool for water filtering and storage cistern**

SUSTAINABLE SITES
HEAT ISLAND REDUCTION

10 points



The roof of the development hosts an extensive green roof, which forms a microclimate that reduces the local heat island effect, provides habitats, insulates the building, and minimizes the roof's water run-off.

Green Roof Envelope

1. RC slab 330 mm
2. Splast primer 1 mm
3. Preflex - Elastomer bitumenmembrane 4 mm
4. Rock mineral wool insulation 120 mm
5. Water proofing membrane 4 mm
6. Root barrier 1 mm
7. Drainage Layer 7 mm
8. Filter Layer 1.1 mm
9. Growing substrate 100 mm
10. Vernier suspension
11. Drilling screw
12. L angle
13. Post cap profile
14. Ceiling panel 600*600 mm
15. Partition connection profile

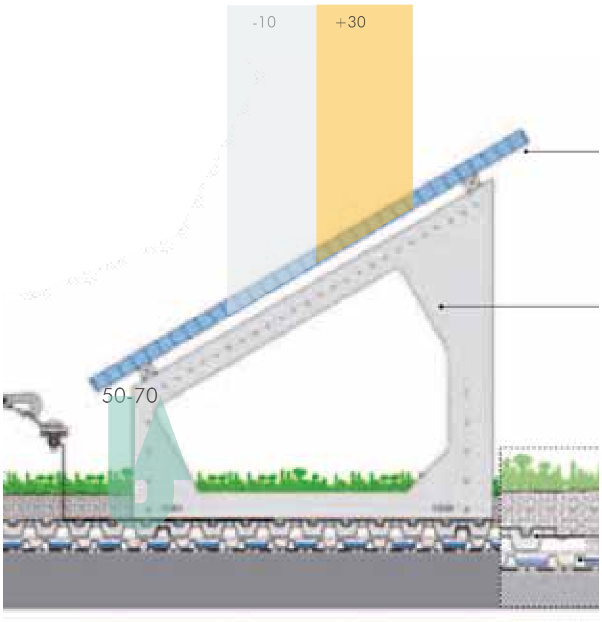
The fact of having only flat roofs eased and made cheaper the solution of a vegetated roof implementation above all the departments composing the complex. Furthermore, the area results wide enough to make possible a substantial contribution in terms of CO_2 absorbtion.

ENERGY AND ATMOSPHERE
RENEWABLE ENERGY PRODUCTION

33 points

Enhanced performance of photovoltaic modules of ZinCo Solar Base, combined with the green roof and significant synergy effects are achieved with combination of two system: Solar Green Roof.

The mounting system ''Saddle'' combines two solar frames onto a dolar base. The inclination of panels directs the rainwater toward the aisle between the panels rows so that increased growth of the vegetation can be expected.



Solar Green Roof
Higher water retention
Higher evaporation and cooling
Minimum surface discharge

SolarVert® System Build-up

WATER EFFICIENCY
RAINWATER MANAGEMENT TECHNIQUES

11 points

Permeable pavements (also known as pervious or porous concrete) is a specific type of pavement with a high porosity that allows rainwater to pass through it into the ground below.

Through this movement, pervious concrete mimics the natural process that occurs on the ground's surface, consequently reducing runoff and returning water to underground aquifers. It also traps suspended solids and pollutants, keeping them from polluting the water stream.

In the desig of the public space, permeable pavings were adopted for the perimeter of the urban block, beign further from the underground floors of the complex. Furthermore, the choice of a specific product took also in consideration the aesthetic final result of the upen space.

ECO-PROMENADE®

ENDURACOLOR™ **PERMEABLE**

OPAL BLEND

Other finishes available: Il Campo®, Series™ & Umbriano®.

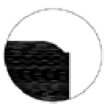
PRODUCT ATTRIBUTES

Visual Appearance	Long, linear look and feel for any contemporary permeable application.
Finish	By special order, you may select from a variety of standard and architectural finishes; Premier *(smooth)*, Il Campo® *(brushed)*, Series™ *(exposed aggregate)* and Umbriano® *(mottled)*.

PRODUCT SPECIFICATIONS

2⅞ x 12 x 4"
75 x 300 x 100mm

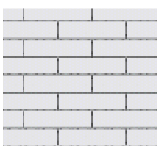
EDGE DETAIL



ROUNDED EDGE

LAYING PATTERNS

ECO-PROMENADE® A



ECO-PROMENADE® B

RECOMMENDED SAND

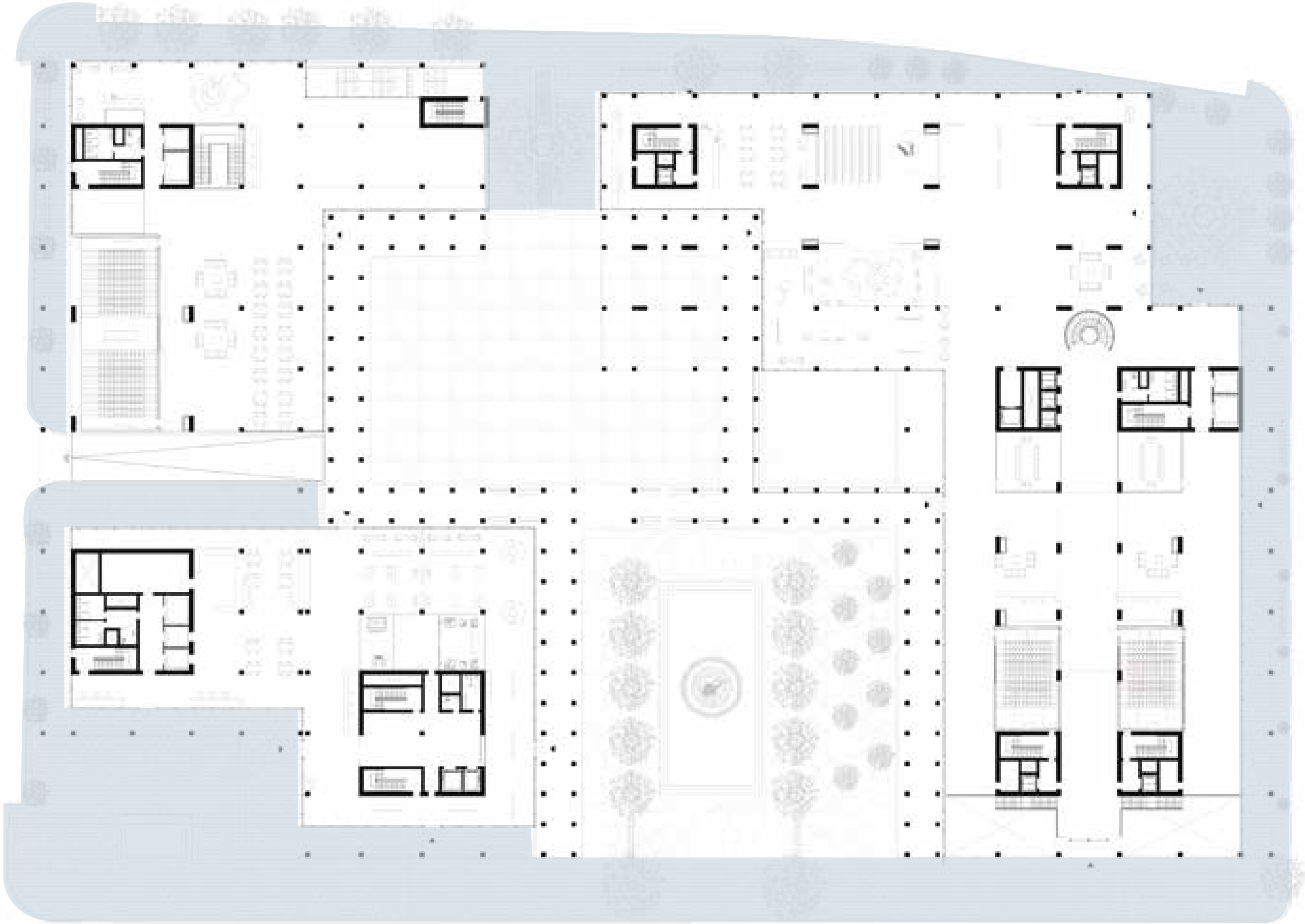
Gator Aqua Rock

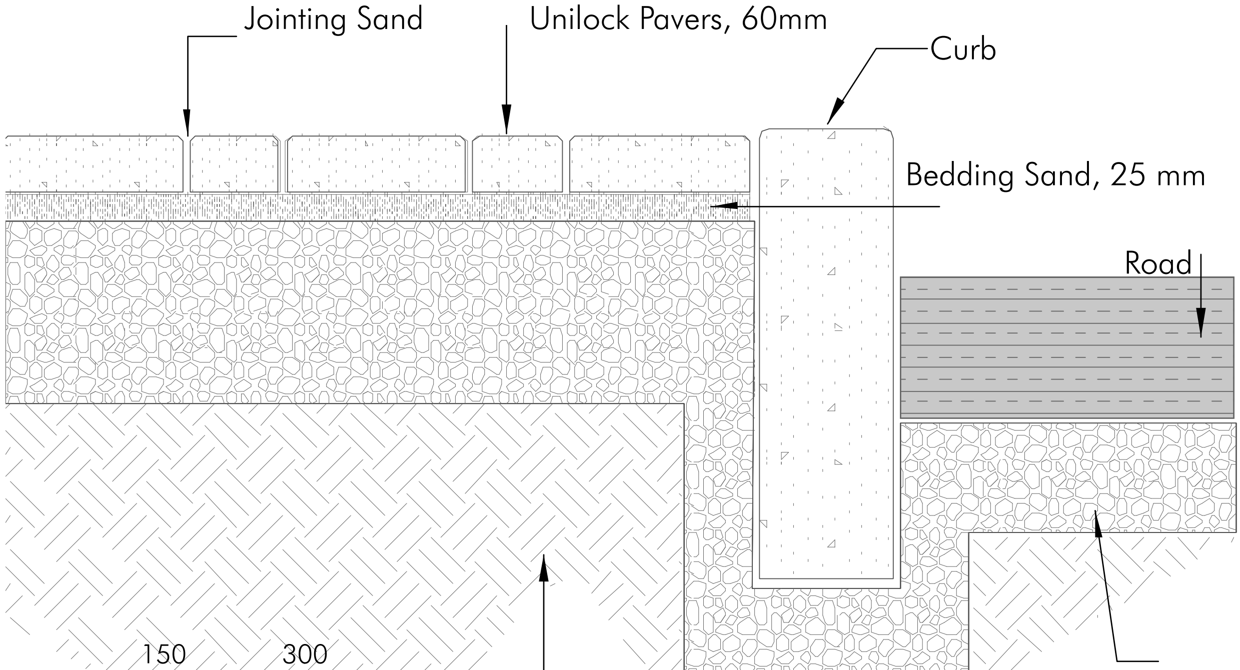
- For Residential & Commercial applications
- For permeable paver joints
- Helps prevent erosion due to climatic conditions
- Use as bedding and jointing material
- Graded to meet ASTM No. 9 water rate
- Long term high infiltration performance
- 2,200 lb Supercack available for large applications

Coverage:

Size	Area
50lb. bag	20-25 sqft
2,200 lb. Super Sack	880-1100 sqft

(Based on 60mm paver.)



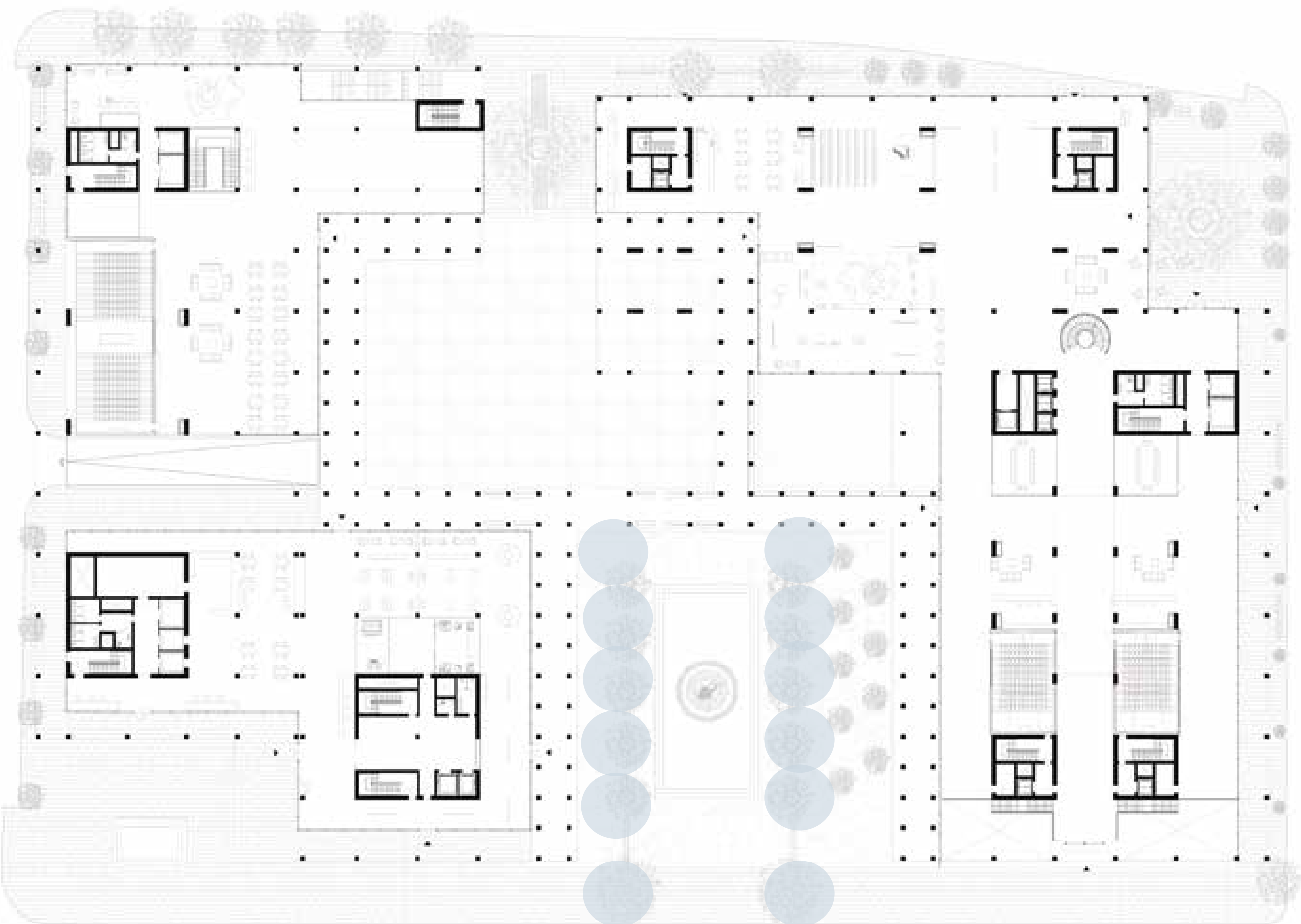


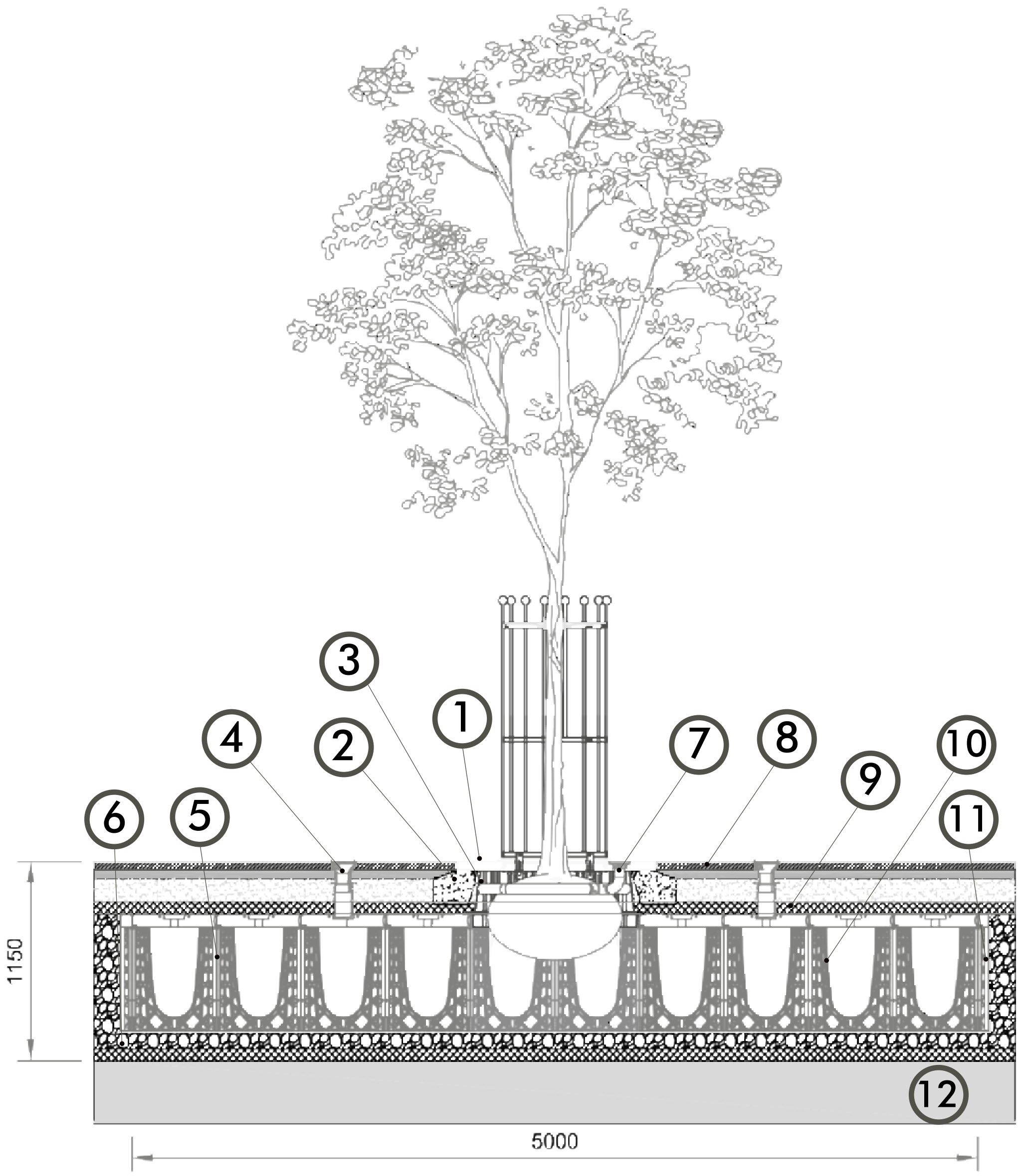
Jointing Sand
Unilock Pavers, 60mm
Curb
Bedding Sand, 25 mm
Road
Subgrade
Aggregate Base, 200 mm
0mm
150
300

TREE PITS - LID/SUDS SOLUTIONS:
Rainwater management techniques

Stormwater tree pits improve water quality of local waterways, reduce peak runoff flows, increase groundwater infiltration (if site appropriate), and improve the health of urban trees.
Potential benefits include:

- Canopy absorption and rainfall interception.
- Dissipate water droplet energy and reduce temperature.
- Evapotranspiration producing cooling effect.
- Root zone attenuation
- . Pollutant filtration
- Water transportation via deep rooting profiles to increase penetrative ground recharge.
- Improved biodiversity
- Aesthetic role

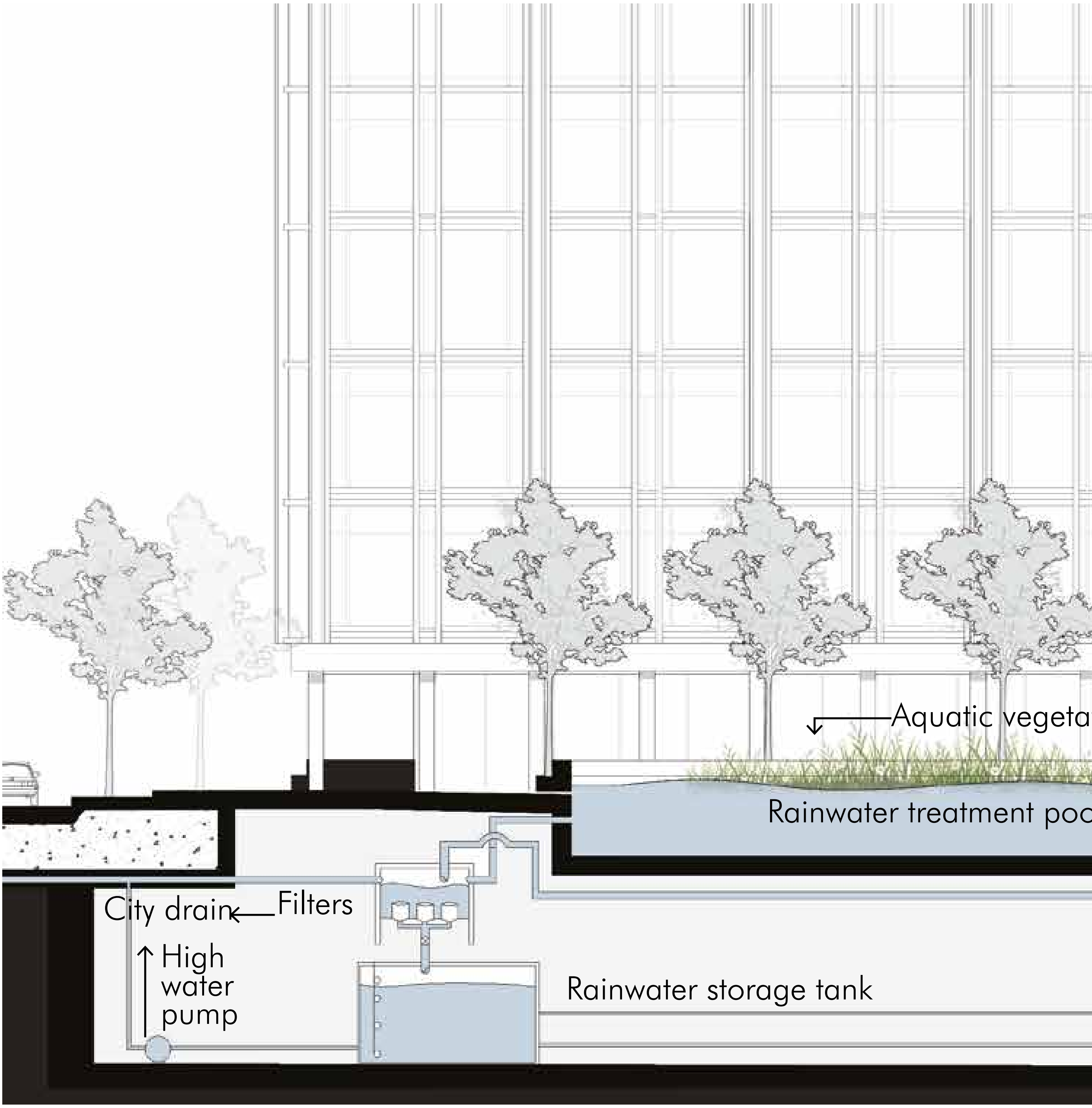




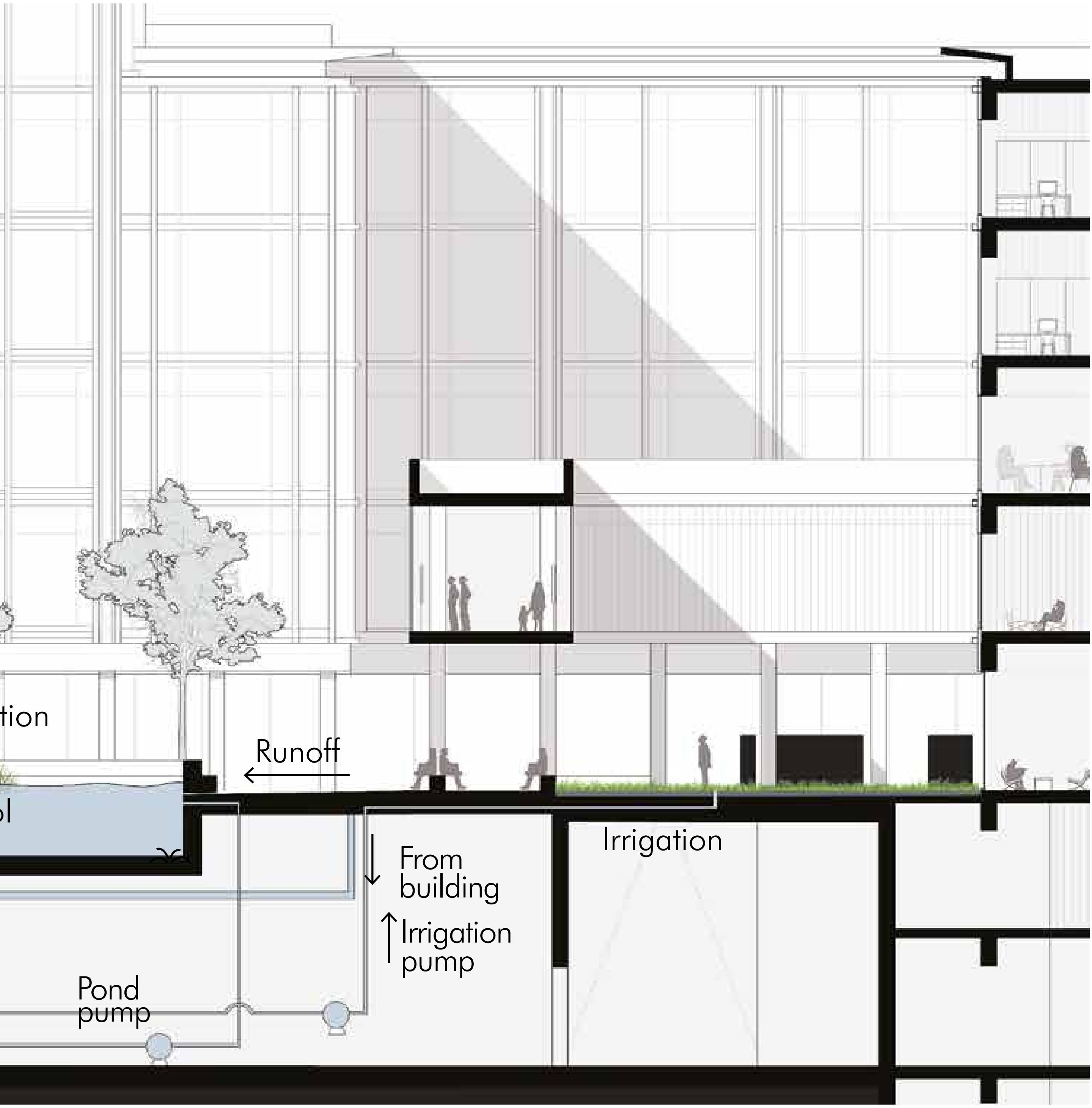
1. 1200mm x 1200mm tree tree grille c/w Root Rain Hydrogrille irrigation inlet
2. Galvanised tree grille support frame set on concrete haunch
3. RD1000-RS RootSpace
4. Arborvent 150 double inlet aeration /irrigation system
5. Strapped anchor system c/w ground anchors
6. Drainage layer - 150mm
7. Root Rain Hydrogrille single inlet aeration/irrigation system with cast inlet
8. Pavement construction
9. Twinwall geonet laid over RootSpace structure
10. RootSpace structure - 1 module deep x 10 modules across x 6 modules wide
11. GRN20 plastic open reinforcing mesh, 20mm aperture laid below and around
12. Sub-base and drainage installed below RootSpac

WATER POOL FOR WATER FILTERING AND STORAGE CISTERN
Rainwater management techniques

This water feature functions as part of the larger stormwater management system that collects all rainwater that falls within the property. The water then drains through a stormwater filter to a cistern located below the courtyard. This water is continuously recirculated. The stored water can also be used to provide irrigation for the courtyard plantings throughout the growing seasons.
A reference project was considered for the adution of such solution: *"The Avenue"* project in *Washington DC* by *Sasaki Associates.*



Water pool with cistern



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