Concept of an Environmentally Effective Solution for a Building

Master of Science Thesis in Civil and Environmental Engineering

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Division of Building Technology, Building Physics
CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

Issues connected with the sustainable construction and the environmental impact of structures are getting into the centre of interest nowadays. The attention to energy consumption of buildings is paid and several methodologies evaluating the sustainability of buildings have started to be used. This thesis deals with the environmental impact of materials used for the construction of a residential building. It shows a design of such a building in four material alternatives in the low-energy standard and their comparison in terms of the environmental impact. The original system of criterions is used as well as a standard methodology SBTool CZ. These two opportunities of how to evaluate the environmental impact of a building are also compared each to other.

Key words: sustainable construction
environmental impact of structures
material alternatives
energy consumption
embodied energy, emissions

Contents

Preface

In this study, the environmental impact of construction materials for residential building has been investigated. The study has been carried out from February 2010 to May 2010 at the Department of Civil and Environmental engineering, Chalmers University of Technology, Sweden. The project has been supported by the Department of Building Structures, Czech Technical University in Prague, Czech Republic.

This project has been carried out under the supervision of Angela Sasic Kalagasidis, assistant professor from the Department of Civil and Environmental engineering, Chalmers University of Technology and prof. Ing. Petr Hájek, CSc from the Department of Building Structures, Czech Technical University in Prague. I would like to express my thanks to both of my supervisors for taking care of me and for valuable information that have helped me. Ing. Karel Mikeš, PhD. is highly appreciated for his help during the work on the thesis. I am also thankful for the help from Ing. Martin Vonka, Ph.D. and Birgit Brunklaus. I would also like to thank to my family and friends for their support during my work.

I declare that I worked out the thesis on my own, using the literature stated in references.

Göteborg May 2010

Petr Schorsch

Nomenclature

Roman upper case letters

A_{tot}	Total floor area of the building
$E_{C,H}$	Energy demand for cooling per year
$E_{P,A}$	Total energy demand for building per year
$E_{P,F}$	Energy demand for ventilation per year
$E_{P,H}$	Energy demand for heating per year
$E_{P,W}$	Energy demand for hot water preparation per year
L_{nw}	Level of impact sound
$Q_{H,nd}$	Specific heat consumption for heating
P_e	Design partial pressure of vapour
R_w	Airborne sound insulation
T_e	Design outdoor temperature
T_i	Design indoor temperature
T_m	Mean temperature during the heating season
T_{st}	Outdoor temperature when the heating starts
U	Heat transmittance coefficient
U_{em}	The average heat transmittance coefficient for the building envelope
U_N	Recommended value of heat transmittance coefficient
V_{tot}	Total volume of the building

Roman lower case letters

e_2	Coefficient of the construction type
b_1	Factor of temperature reduction
c_m	Heat capacity of indoor mass
t_{hs}	Length of the heating season

Greek lower case letters

φ_e	Relative humidity of the outdoor air

1 Introduction

1.1 Why to focus on Sustainable Development in construction

What is sustainable development and why should its rules be followed? Sustainable development itself can be expressed as a rule for mankind on how to behave towards nature, especially when speaking about industry and civil engineering. It can be said that the first and basic definition was stated in The Bruntland Report. This one was made by the World Commission on Environment and Development in 1987. It is stated in there that sustainable development is: „*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". The other expressions, which were stated during the following years, meet the same aim. For example, a note about another definition which was stated in 1996 at the Civil Engineering Research Foundation (CERF) symposium can be maid. This is: „ *Sustainable development is the task of meeting human needs mediated by natural resources, industrial products, energy, food, transportation, dwellings and effective management of waste while preserving and protecting the quality of the environment and natural raw materials basis for the future development.*"

Even though the environment is a very important part, it can not be said that sustainability and environment are exactly the same things. But as it is obvious from the statements written above that, the idea of sustainable development lies mainly in supporting the environment and helping it. The roots of sustainability and sustainable development were set in the tendency and speed of evolution of nowadays world. Sustainability itself involves a huge amount of issues and their influence on each other. Issues like differences between the world of rich and poor people, safety, health basic needs of societies or rights of individuals can be found in it. But the main point of all this is still in the right of the future generation on the certain living opportunity. The environmental aspect is taken as the fundamental for sustainability. One can imagine that our behaviour and our activities can have an impact on current life quality and health. The consequences can hit the other species and future generations as well.

If we want to achieve sustainability, we have to learn how to fit in the limits of the materials that can be provided for us by earth and how to absorb all the waste and pollution which is produced by us and our activities. There is a need for lowering down the amount of emissions and waste that we were used to produce during the last decades. As for the latest progression we can say that the situation has been improving. This is mainly thanks to that of sustainable development which has become a stated policy both of many governments and global companies. The governments have to work together with the building industry, if we want to improve this situation. There are a few main policy aims. These are: reduction of the energy demand of buildings, the increase of energy efficiency of appliances using energy, an encouragement of energy generating and distributing companies to support emission reduction, to change attitudes and behaviour of people to decrease the energy consumption.

Building structures is a branch of industry where it is more difficult to find out the environmental quality of structures in comparison to the other branches of industry. Improvements and environmental standards vary from country to country according to the size and skills of organizations and individuals.

Generally, there is a high pressure on decreasing the energy consumption. This means decreasing the emissions that are emitted when producing the energy needed for heating or cooling. Moreover, it is important to take in account the energy needed for structures themselves. A new methodology of LCA („Life Cycle Approach") used for evaluating them has risen up. This one is used to evaluate the environmental influence of the structure from production of materials needed for it up to the demolition („cradle-to-grave").

We can find out the following as a result of the meaning sustainability and building structures. It is appropriate to design a solution for a building that the requirements on low energy demand are reached in an effective way. Especially with low investment cost and low loading for the environment and this is meant for the whole entire life of the structure. The energy properties of each building can be usually influenced during the creation of the building conception in the preparatory phase of the project. The best points on how to do that are a good coordination of the facade structure with the load bearing structure, the design of the heating system and lighting. Such a conception should be characterized by the equilibrium between the volume and structural design of all areas and structures.

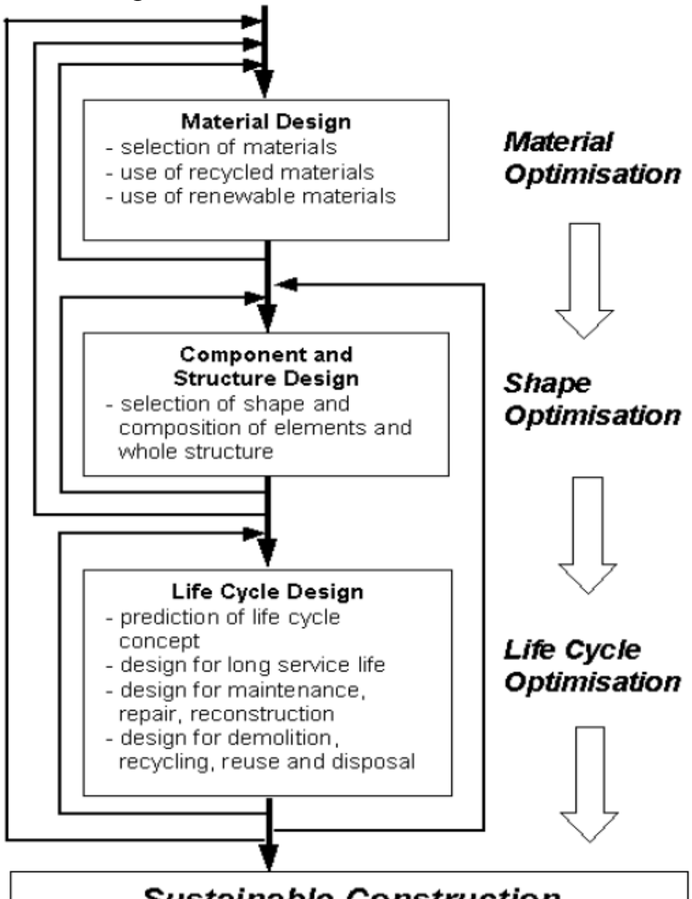


Figure 1.1 Concept of structure optimisation based on the environmental issues (Hájek, P. „Sustainable Construction Through Environment-Based Optimisation")

The environmental based optimisation means to focus on a few basic optimisation steps, which are material optimisation, shape optimisation, life cycle optimisation and optimisation in energy consumption of a building. The goal of all these optimisations should be to keep the materials used for construction in a closed cycle and to minimise inputs like materials from non-renewable sources, energy and outputs like emissions and waste. The idea of this procedure is described in *Figure 1.1*.

Still it has to be kept in mind that buildings have a relatively long service life, when compared with products from any other industry. This results in that every change that is made in the conception of the building design will be shown after many years. This is the reason why the changed wanted to be made has to be considered very carefully. According to this it is necessary to use the Life Cycle Approach. From that it can seen for example that the production and the origin of emissions during the life time of the building. It shows us that approximately 80 % of emissions is produced thanks to the operational phase of the building (heating, cooling, ventilation, lighting and appliances) and the other 20 % is for the materials used for construction (production, transportation, construction, maintenance, renovation and demolition).

1.1.1 Environmental impact of building materials

It can be said that the materials used for building structures can be divided into two major groups. These are stated according to the resource that is used for the certain material. There are these two types, renewable and non-renewable resources. For example timber fits in the group of renewable materials. These resources can be harvested regularly. As for the second group, these resources can be harvested just once. Iron or clay used for masonry fit in this group. The resources for these materials are limited and they can appear scarce as we are getting closer to their depletion. The most affected groups of materials are almost all kinds of ore minerals and also the materials used for energy production such as fossil oil or natural gas. There is a description of reserves of basic building materials in the *Table 1-1*. The scarcity of certain materials may happen in some regions even now. That is why it is reasonable and important to design structures according to materials that can be easily provided in that area. It is usually cost effective.

Raw material		Reserve [years]	Reserve base [years]	Annual growth in consumption 1999–2006 [%]
MINERAL				
1	Aggregate (sand, gravel)	Very Large	Very Large	
2	Arsenic	20	30	6
3	Bauxite	141	180	6
4	Bentonite (Montmorillonite)	Large	Large	
5	Boric salts	35	86	1
6	Brom	Large	Large	
7	Cadmium	26	77	1
8	Chrome	Ca. 25	Ca. 40	8
9	Clay, for fired products	Very Large	Very Large	
10	Cobalt	121	226	15
11	Copper	31	61	3
12	Diatomite (silicious fossil meal)	Large	Large	
13	Earth, for compressing	Very Large	Very large	
14	Feldspar	Large	Large	
15	Gold	17	36	1
16	Gypsum	Large	Large	
17	Iron	95	219	10
18	Kaolin	Large	Large	
19	Lead	20	42	1.5
20	Lime	Very Large	Very Large	
21	Magnesium	Large	Very Large	
22	Manganese	40	472	9
23	Mica	Very Large	Very Large	
24	Mineral salt (sodium chloride)	Very Large	Very Large	
25	Nickel	41	90	5
26	Perlite	Large	Large	
27	Phosphate	124	345	0
28	Potash	Large	Large	
29	Pumice	Large	Large	
30	Quartz	Large	Large	
31	Silica	Large	Large	
32	Silver	14	29	3
33	Soda ash	Large	Large	

Table 1-1 Non-renewable resources for building materials production.
Reserve is defined as that part of the reserve base that could be economically extracted or produced at the time of determination. Reserve base includes those resources that are currently economic (Reserves), marginally economic, and some of those that are currently subeconomic. Both Reserve and Reserve base are estimated without growth in consumption. (Berge, B., (2009): The ecology of building materials. Architectural Press, Oxford, UK)

,, Resources are not anything static, but something as dynamic as civilization itself.˝ Zimmermann 1933

Nowadays civil engineering is the second largest consumer of raw materials in the world. Largest in this consumption is the food production. If we want to follow the concept of sustainability we will have to focus on the reduction of usage of raw materials. Recycling goes hand by hand with this. It is highly recommended to do recycling as a next step after demolition. It is better to keep the materials at the same level of quality. This is much better than to leave them for downcycling. As it is visible in the *Figure 1.2* with increasing the amount of materials that can be reused or recycled we decrease the amount of waste and raw materials that are scarce.

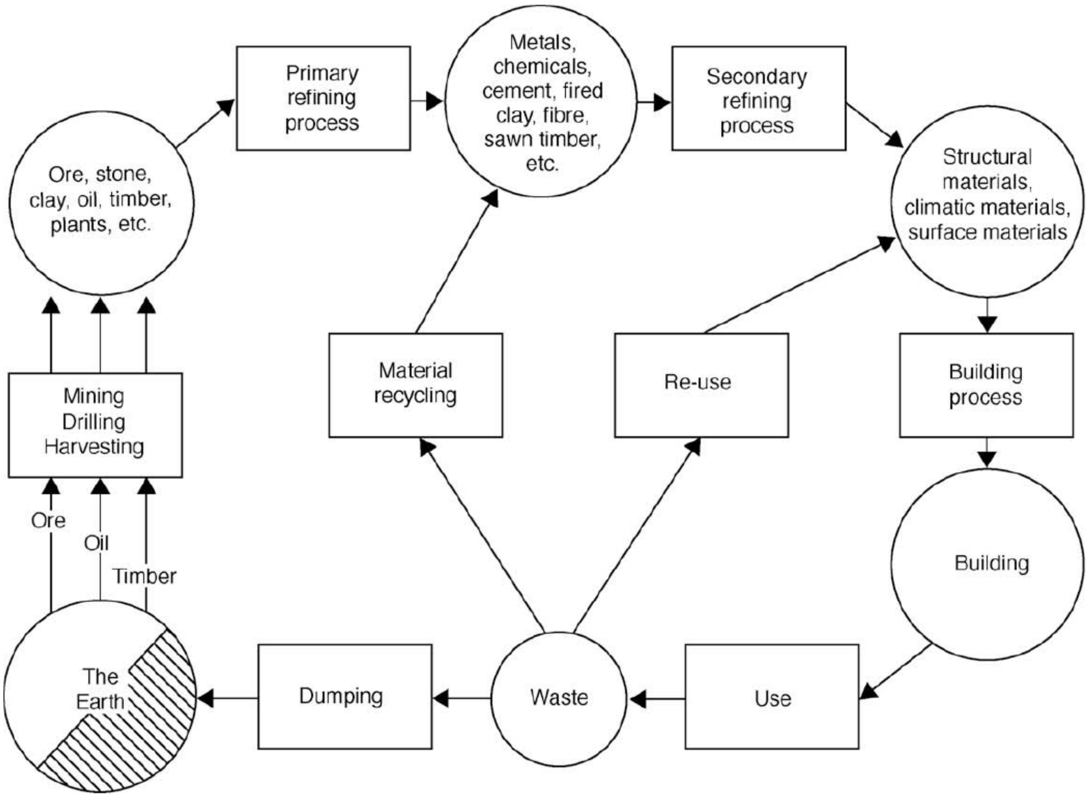


Figure 1.2 The cycle of materials (Berge, B., (2009): The ecology of building materials. Architectural Press, Oxford, UK)

As for the sustainability and building materials it is important to design buildings in the way to lower down the usage of necessary materials and mainly to use the materials from renewable resources or materials that can be recycled or reused. There should be also an effort put to decrease the waste production during the construction and the workmanship, but this is mainly the task for the building companies.

Civil engineering has also a big part in responsibility for emissions of greenhouse gases. The overall emission production has been stated of 30-40% contributing to the total global emission production. In this number we can find emissions that are produced when using a certain building – emissions from energy needed for heating, cooling or lightning. This one represents the major part in the overall amount of emissions. If we look in the past we can see that the major producers of emissions were highly developed countries. As the world has been changing and there are many developing countries becoming richer and rising up a lot of industry in their areas, we can expect that the amount of emissions produced worldwide will rise up as well, if we keep the same amount of produced emissions per capita. The other part of emissions connected to building structures are the emissions produced by the structure itself. By this we mean emissions during the transportation, building up, demolition and production which are set as the embodied emissions of each type of material.

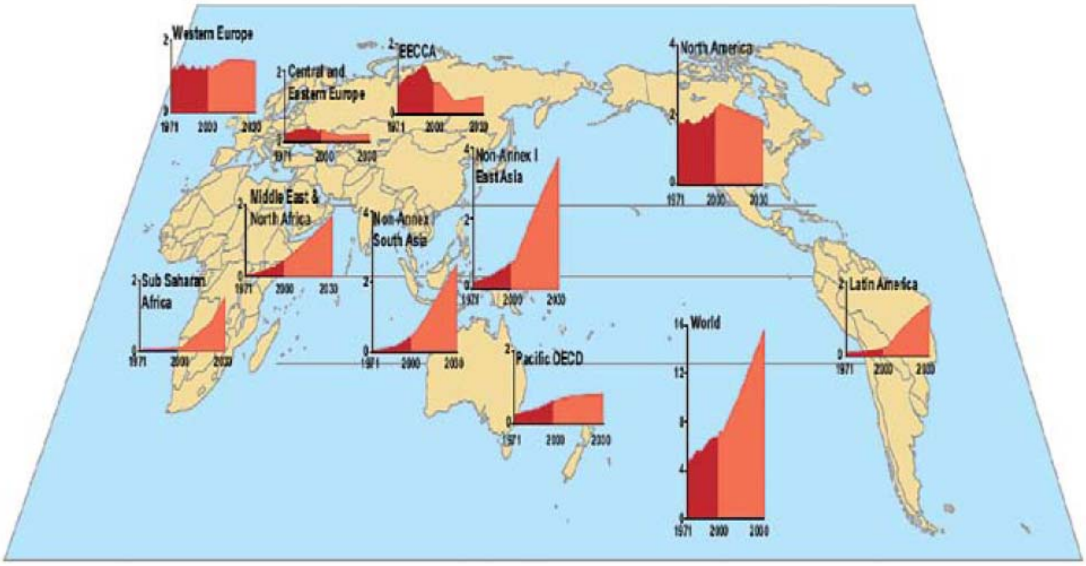


Figure 1.3 CO_2 emissions from buildings (dark red: 1971 – 2000, light red: projection for years 2001 – 2030. („Building and climate change¨, UNEP SBCI 2009)

1.1.2 Why to design buildings with lower energy consumption

Energy is the biggest driving force of the climate change and is the biggest cause of air pollution. The amount of energy consumption all over the world still remains in very high numbers and it is expected to be increased as the new developing countries are increasing their energy demand. The relatively low prices of energy in the past did not set the right atmosphere for improving the efficiency both in energy production and in use. Nowadays we can see that more and more people prefer to build a low-energy house instead of the normal one. It is usually not because they want to be environmental friendly or that they want to behave sustainable, but the main reason for them is that they save money. Another motivation that can lead people to build house with lower energy demand is the government policy. For example, this can be done by encouraging people with some kind of subsidies under condition that they build the house with lower energy consumption. Such a programme was launched in the Czech Republic 2 years ago and it has turned out to be successful.

Buildings consume about 40 % of the global energy usage. This is closely correlated with the production of CO_2 emissions. Greater efficiency in the production and use of energy is then the key to sustainable construction.

In the optimistic predictions we can find that low energy and passive houses will take about 50 % of the market with production of new buildings (according to the ISES study). Speaking generally there is no reason today to build houses in a different standard than in the low-energy one. Low energy consumption for heating has many advantages like lower dependance on the energy supply and saving money for it (especially when the price of energy has still rising up) or better indoor climate. This all is for about 5 – 8 % of increase in costs of the new building.

1.2 The aim of the thesis

The aim of this thesis is to design an environmentally and energy efficient building. There is a given building (the building is called original version more further) to fulfil this task. This one is a residential house located in the suburb of Prague. It is made from reinforced concrete and has five floors. This given object is described more in details in the next chapter. There are made three material alternatives to this chosen building. The different materials that are used then are timber, steel, reinforced concrete and light-weight concrete blocks Ytong. There is done a structural design, thermal performance, acoustic performance, energy and environmental evaluation for all alternatives.

All alternatives are designed as the low-energy buildings. The given building is turned into it as well. This is done in accordance with that what was stated in the previous chapter, that the biggest energy consumption and also production of CO_2 emissions is during the operational phase of the building.

At the end of the thesis the best material is chosen. So there is a comparison of four structural materials and their influence on the environment. The materials are rated according to the original criteria system of this thesis. The results from this system of criteria are compared with the results from evaluation by SBToolCZ methodology, which is the methodology for the comprehensive evaluation. SBTool is one of the possible ways on how to evaluate the sustainability of buildings and thus can determine the potential of how to improve and optimise the design of building.

1.2.1 Methodology used for evaluation according to Sustainable Development

The evaluation and the design of buildings as low-energy ones have a lot of rules stated mainly by the legislation. This became stricter in 2002 when the new standardization became valid. It is stated in there that the low-energy houses should have now the specific heat consumption for heating lower than 50 kWh/m^{2}y and passive ones lower than 15 kWh/m^{2}y. The other requirements on these structures were set as well. Next one is that the value η_{50} for airtightness should be maximally 0,6 h^{-1} at pressure difference 50 Pa. This should be proved by the Blower Door test which is done after the construction of the building is finished. The total amount of primary energy consumed during the operational mode should not overcome 120 kWh/m^{2}y.

In the *Table 1-2* you can see the requirements on heat transfer coefficient that are valid today. These are used for the normal category of new buildings. Recommended values for low-energy houses are about 2/3 of recommended values stated in this table and values for passive houses should be even lower. This is the basic overview on the basic requirements used in the Czech Republic. More detailed ones are used directly in the evaluations.

Description of the construction	Type of construction	Required values U_N [W/(m^2.K]	Recommended values U_N [W/(m^2.K]	Coefficient of the construction type e_2 [-]	Factor of temperature reduction b1 [-]
Flat roof or pitched roof with maximal angle of 45 °, including The floor above the outdoor space The ceiling under the unheated garret where is a roof without thermal insulation Floor or wall with heating	**light**	0,24	0,16	0,80	1,25
	heavy	0,30	0,20	0,80	1,00
External wall Pitched roof with the angle over 45°	**light**	0,30	0,20	1,00	1,25
	heavy	0,38	0,25	1,00	1,00
Floor or wall adjacent to the soil (with the exception of Note 2) Ceiling or wall between the heated and unheated area		0,60	0,40	0,80	0,49
Ceiling or wall between the heated and partially heated area		0,75	0,50	0,80	0,40
Wall between neighbouring buildings Ceiling between rooms with the max. difference in temperatures 10°C, incl.		1,05	0,70	0,80	0,29
Wall between rooms with the max. difference in temperatures 10°C, incl.		1,30	0,90	1,00	0,29
Ceiling between rooms with the max. difference in temperatures 5°C, incl.		2,20	1,45	0,80	0,14
Wall between rooms with the max. difference in temperatures 5°C, incl.		2,70	1,80	1,00	0,14
Window or the other type of construcion hole filling from the heatened room (including the frame, that has max. 2.0 W/(m^2.K))	**new**	1,80	1,20	5,50	0,15
	reconstr.	2,00	1,35	6,00	0,15
Doors, gates and the other types of construction hole filling from the partially heatened or unheatened room (including the frame)		3,50	2,30	6,00	0,66

Table 1-2 Required and recommended values of heat transfer coefficient U_N for buildings with the prevailing internal temperature θ_{im} = 20 °C

1.2.1.1 Description of used programmes

Teplo 2009 („Heat 2009″)

The programme Teplo 2009 allows the steady-state calculation of the basic thermal performance of the building structures according to the Czech standardizations ČSN EN ISO 6946, ČSN EN ISO 13788 and ČSN 73 0540 The programme calculates the thermal resistance, thermal transmittance, inner surface temperature, temperature factor, thermal inhibition, decrease in the contact temperature of the floor structure and an annual review of condensed and evaporated moisture. It is possible to solve structures consisting of up to 15 layers in any of boundary conditions. Calculation of the annual balance of water vapour is in the program, implemented in accordance with European methodology prescribed in ČSN EN ISO 13788 and with the national methodology specified in ČSN 73 0540-4 as well

Area 2009 („Area 2009″)

The programme Area 2009 allows the calculation of the steady-state two-dimensional thermal fields, partial pressures of vapour and the estimation of annual balance of vapour in the construction of two-dimensional details. The programme also calculates the heat flow through thermal bridges. It includes an auxiliary calculation of modules to determine the thermal transmittance of window designs and light cladding according to the standardisations ČSN EN ISO 10077 and ČSN EN 13947, for determination of linear factors of heat according to ČSN EN ISO 10211 and to determinate the temperature factor of the 3D thermal bridges and bonds under ČSN EN ISO 10211-2. The Calculation of steady-state two-dimensional field is done using the finite element method.

Energie 2010 („Energy 2010″)

The programme Energie 2010 allows the calculation of average heat transfer coefficient of the building envelope according to ČSN 730 540, the energy performance of the building according to ČSN EN ISO 13790, the energy performance of low-energy residential buildings in the TNI 73 0330 TNI 73 0329 and a specific energy needs according to. The programme can determine the energy consumption of the building according to ČSN EN ISO 13790 in two ways: one the more detailed calculation for individual months or through the simplified calculation of the heating season (seasonal calculation).

Neprůzvučnost 2005 („Soundproof 2005″)

The programme Neprůzvučnost 2005 allows the theoretical calculation of air and impact soundproof of structures according to ČSN EN ISO 717. The programme calculates the weighted soundproof and calculation of the weighted normalized levels of impact noise for simple (single-layer, sandwich and multi-layer) for double structures, the construction of composites (combined) and the ceiling with floating floor coating. It is possible to solve structures consisting of up to 5 layers.

Fin 3D

The programme FIN 3D performs structural analysis of 3D frame and beam structures, computation of deformations, internal forces, eigen modes and frequencies. Features like the second order analysis and linear stability are also available. The programme includes other programmes for dimensioning of structures and verification of fire situation.

List of standardisations used in programmes:

ČSN EN ISO 6946, (2008) : *Stavební prvky a stavební konstrukce - Tepelný odpor a součinitel prostupu tepla - Výpočtová metoda, (Building components and building elements - Thermal resistance and thermal transmittance - Calculation method)*. Czech Standards Institute

ČSN EN ISO 13788, (2002) : *Tepelně vlhkostní chování stavebních dílců a stavebních prvků - Vnitřní povrchová teplota pro vyloučení kritické povrchové vlhkosti a kondenzace uvnitř konstrukce - Výpočtové metody, (Hygrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods)*. Czech Standards Institute

ČSN 73 0540, (2005) : *Tepelná ochrana budov, (Thermal protection of buildings)*. Czech Standards Institute

ČSN EN ISO 10077, (2004) : *Tepelné chování oken, dveří a okenic, (Thermal performance of windows, doors and shutter)*. Czech Standards Institute

ČSN EN 13947, (2007) : *Tepelné chování lehkých obvodových plášťů - Výpočet součinitele prostupu tepla, (Thermal performance of curtain walling - Calculation of thermal transmittance).* Czech Standards Institute

ČSN EN ISO 10211, (2009) : *Tepelné mosty ve stavebních konstrukcích - Tepelné toky a povrchové teploty - Podrobné výpočty, (Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations)*. Czech Standards Institute

ČSN EN ISO 13790, (2009) : *Energetická náročnost budov - Výpočet spotřeby energie na vytápění a chlazení, (Energy performance of buildings - Calculation of energy use for space heating and cooling)*. Czech Standards Institute

TNI 73 0330, (2009) : *Zjednodušené výpočtové hodnocení a klasifikace obytných budov s velmi nízkou potřebou tepla na vytápění - Bytové domy, (Simplified computational evaluation and classification of residential buildings with very low for heating - Residential buildings)*. Czech Standards Institute

TNI 73 0329, (1998) : *Zjednodušené výpočtové hodnocení a klasifikace obytných budov s velmi nízkou potřebou tepla na vytápění - Rodinné domy, (Simplified calculation of evaluation and classification of residential buildings with very low for heating – Detached houses)*. Czech Standards Institute

ČSN EN ISO 717, (1998) : *Akustika – Hodnocení zvukové izolace stavebních konstrukcí a v budovách, (Acoustics – Rating of sound insulation in buildings and of building elements)*. Czech Standards Institute

1.3 Limitations

The thesis is based on already prepared project documentation. This point itself is one of the biggest limitations if speaking about the structural design, because there are set fixed dispositions. The project documentation of an apartment building ´´Viladům Kobylisy" is used for this work. Supporting documents were given by the architectural studio A + R System Ltd. To have the project solution of all variants the design is focused on statics, building physics – heat engineering, acoustic, evaluation of material influence on environment and overall evaluation of energy consumption and sustainability. The illumination is assumed to be already done within the project design of the chosen building. For all evaluations like snow, wind loading or moisture and temperature the conditions for Prague, the Czech Republic are taken.

Other limitation that was taken in concern is the allowed height of the building for timber structure. As for Sweden there is no limitation, but for the Czech Republic there is a limit of 9 meters. I was told that this limit will be risen up to 12 meter in the near future. But still the height of the timber variant is bit more (13 meters). Because of this the design is meant as a model situation, not as a proposal of a building that can be built nowadays.

2 Description of the original building

2.1 Purpose and architectural description

This is a residential house with five floors. Under the building there is a basement used for garages, cellars and technical background of the building. The first floor is designed for a non-residential use. Above it there are three residential floors, the latest one is designed as a recessive one. The building is situated in the suburb of Prague in the Czech Republic.

The main entrance to the house and garages is on the eastern edge of the lot. Behind the entrance gate a pavement runs along the entrance ramp to garages and rises into the garden, where the access to the house is. This entrance is designed also for disabled people. The entrance is done as roofed vestibule. After that there is the entrance hall with the stairway that connects the residential house with the basement floor.

Living part of the building occupies two full floors and a recessive one. On the 2nd and 3rd floor there are always five flats of size category 1x 2+kk and 4x 3+kk (x+kk, this means the number of rooms in the flat + kitchen corner) proposed. Apartments are accessible from the corridor which is separated from the stairway area. Facilities for each flat include a storage cellar and one common room of the house (cleaning room in 2nd floor / bikes and strollers in 3rd floor). The layout of the 2nd and 3rd floor is described in the *Figure 2.1*. On the recessed floor there are four flats of categories 3x 3+kk and 1x 4+kk with high surface area standards. There is a direct access to the terrace from all the rooms. Apartments are individually accessible from a separate corridor. The layout of the 4th floor is visible in the *Figure 2.2*.

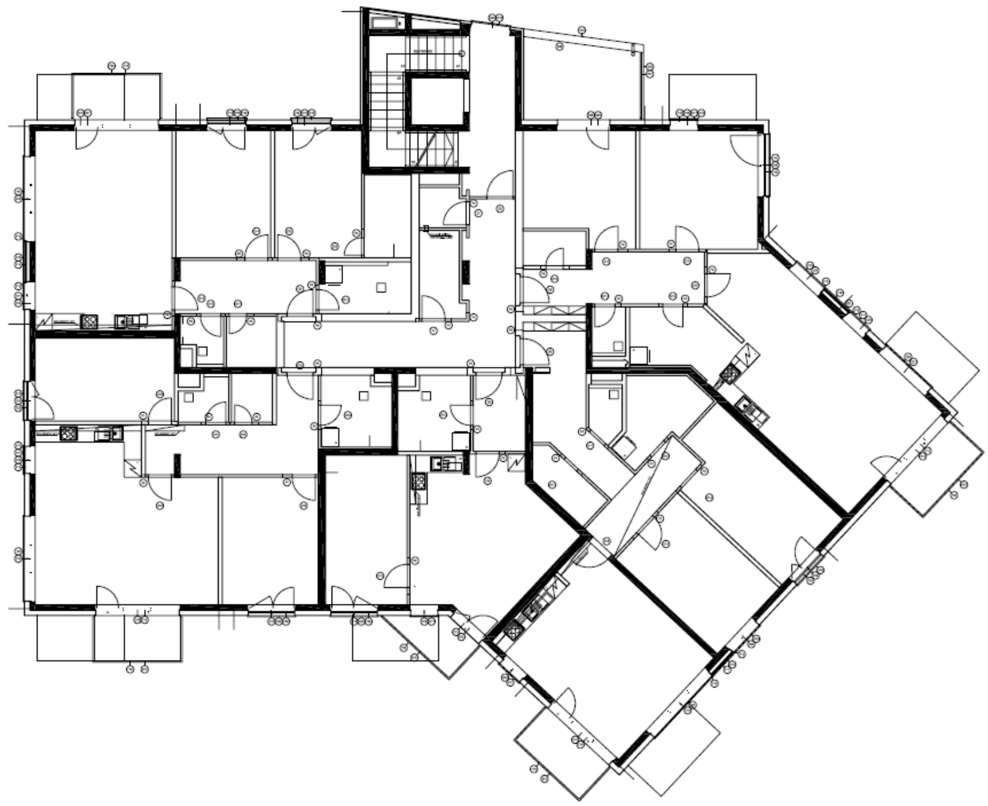


Figure 2.1 Layout of the 2nd and 3rd floor

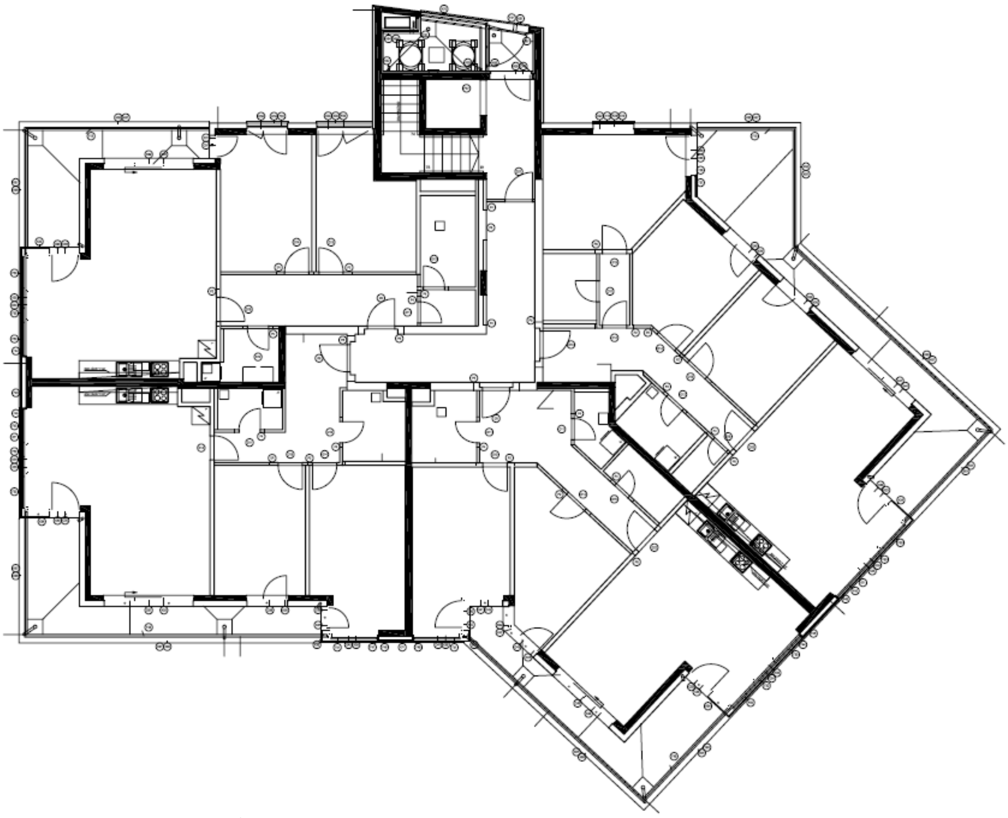


Figure 2.2 Layout of the 4th floor

The non living area on the 1st floor is done as a open space which offers the ability for the future owner to create the disposition. The layout of the 1st floor can be seen in the *Figure 2.3*.

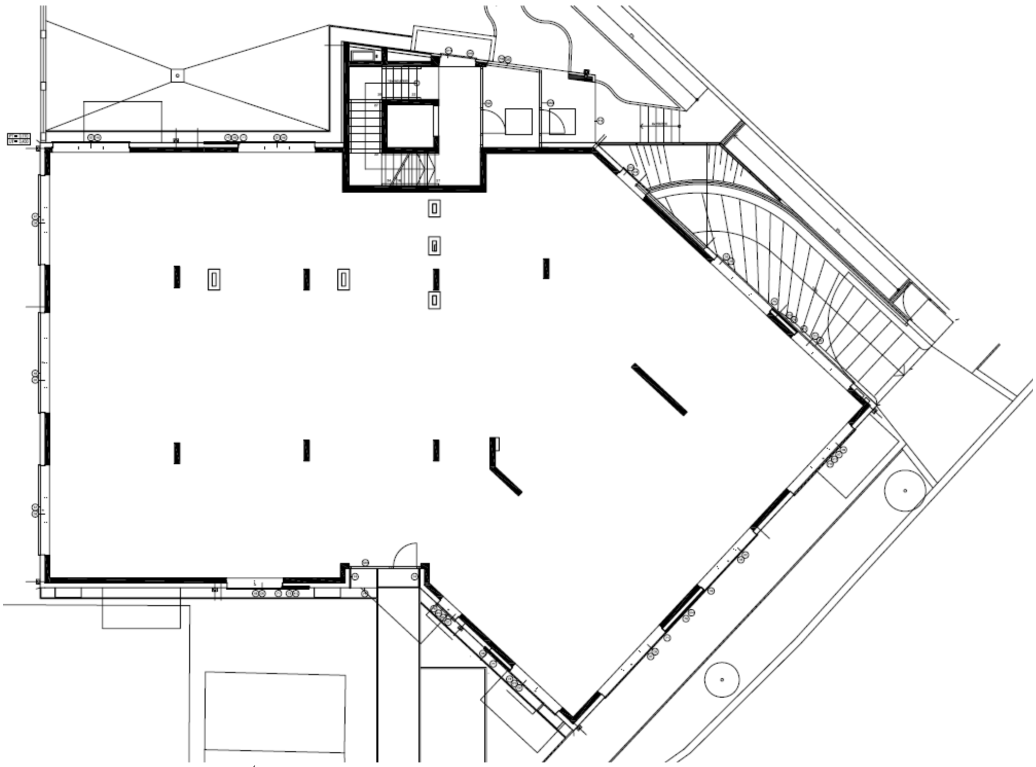


Figure 2.3 Layout of the 1st floor

The basement is primarily for garaging. In total, the proposed garage contains 18 parking places and one which is dimensionally adapted for people with reduced mobility. This one is located right at the entrance to the stairs area with an elevator. The basement is also proposed for common facilities. There is a room with a heat exchanger station, room with ventilation technology for parking area and a place for water meter assembly. Residual area of the basement is used for storage cellars of dwellings in a total capacity of 6 separate cellars. All the layouts can be found in the appendix.

Figure 2.4 Northern view of the building

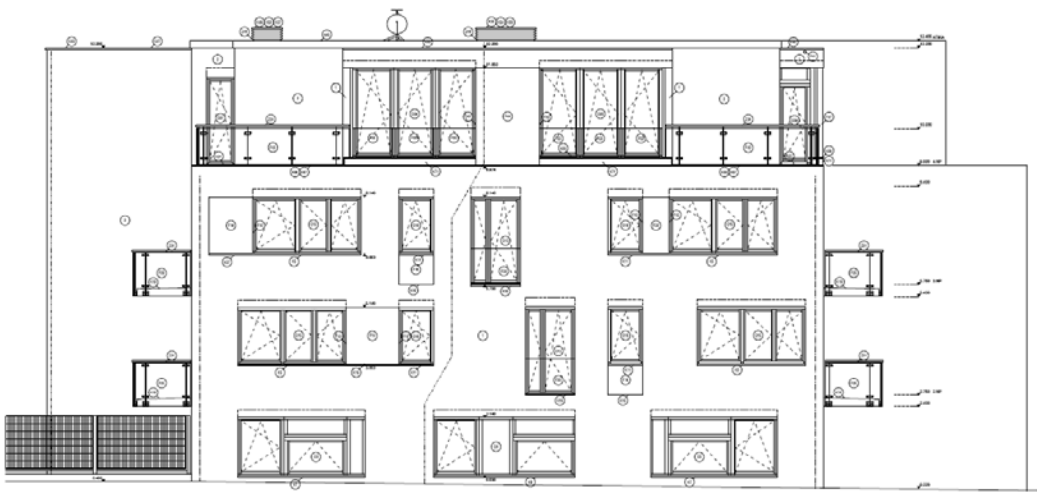


Figure 2.5 Western view of the building

2.2 Structure description

2.2.1 Vertical structures

The actual building is designed as a solid reinforced concrete monolithic skeleton with concrete walls forming the facade, internal reinforced concrete flat columns (short walls) and internal reinforcing concrete walls. Basic spans of various supporting structures are designed in the range from 5.0 m to 6.6 m. Reinforced concrete walls on each floor inside the dispositions have not just a function as reinforcements, but also serve as a supporting structure for ceiling slabs, allowing the minimization of their thickness. Moreover, they also have an acoustic function. The lowest floor (garages) has around its perimeter load-bearing reinforcing monolithic reinforced concrete wall connected to the base-related structures. Inside, the layout of garage floor flat columns are designed for better handling of vehicles. The reinforced concrete stair core passes through all of the floors of the house to the object surface. This also serves as a reinforcement to the entire height of the object. Elevator shaft is separated from the other structures, because of the acoustical reasons. Arrangement of vertical structures of the garage floor and the rest of the building is maintained in the same modular outline and vertical loading goes directly to the foundations of the house.

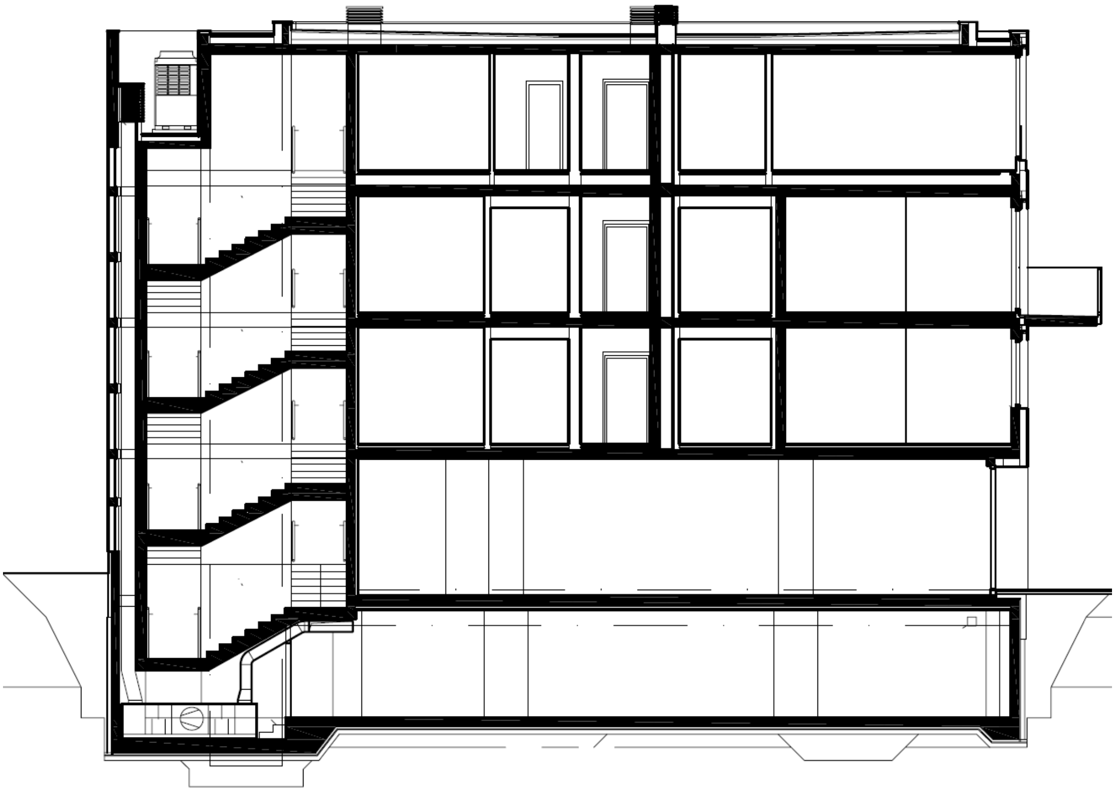


Figure 2.6 Section of the building

2.2.2 Horizontal structures

All of the horizontal structures are designed as reinforced concrete, monolithic, cross reinforced slabs supported linearly by circumferential and inner reinforcing walls and locally supported by flat columns. Slab thicknesses are optimized according to spans and loads, and are designed emphasizing to the use of conventional concrete reinforcement. Ceiling slabs over the basement and 3rd floor have a thickness of 250 mm, there are slabs with thickness of 200 mm in the other floors. Ceiling slab above the 3rd floor will be loaded by the recessive 4th floor. Balcony slabs are thermally separated from the structure using, ISO beams. Thickness of the balcony slabs are 160 mm at the connection to the main structure. The roof is designed as a flat one and the layers are placed directly on the ceiling slab.

Composition	Heat transfer coefficient U	
Main wall	0.24	W/m^2K
Wall in the basement	0.33	W/m^2K
Insert spaces between windows	0.28	W/m^2K
Roof	0.20	W/m^2K
Terrace	0.20	W/m^2K
Ceiling above the basement	0.30	W/m^2K
Stairway wall	0.42	W/m^2K
Stairway wall to interior	0.65	W/m^2K

Table 2-1 An overview of the heat transfer coefficient of the reference building
These values were evaluated according to the compositions of the given building)

3 Material alternatives – skeleton construction systems

3.1 Steel based structure

3.1.1 Design of the structure

First alternative is designed as a steel skeleton system. There is a particular attention paid to preserve the dispositions of the original building when designing this alternative. The only place where it was necessary to change the original disposition is the 1st floor with open space offices. This was because there were new columns added in this floor. Parts that were needed to change and the other opportunity how to arrange the disposition in there is given in the appendix of this thesis. The variability of this area is still kept. Some of the windows in the other floors had slightly to change the place as well, but the glazing area remained at the same level.

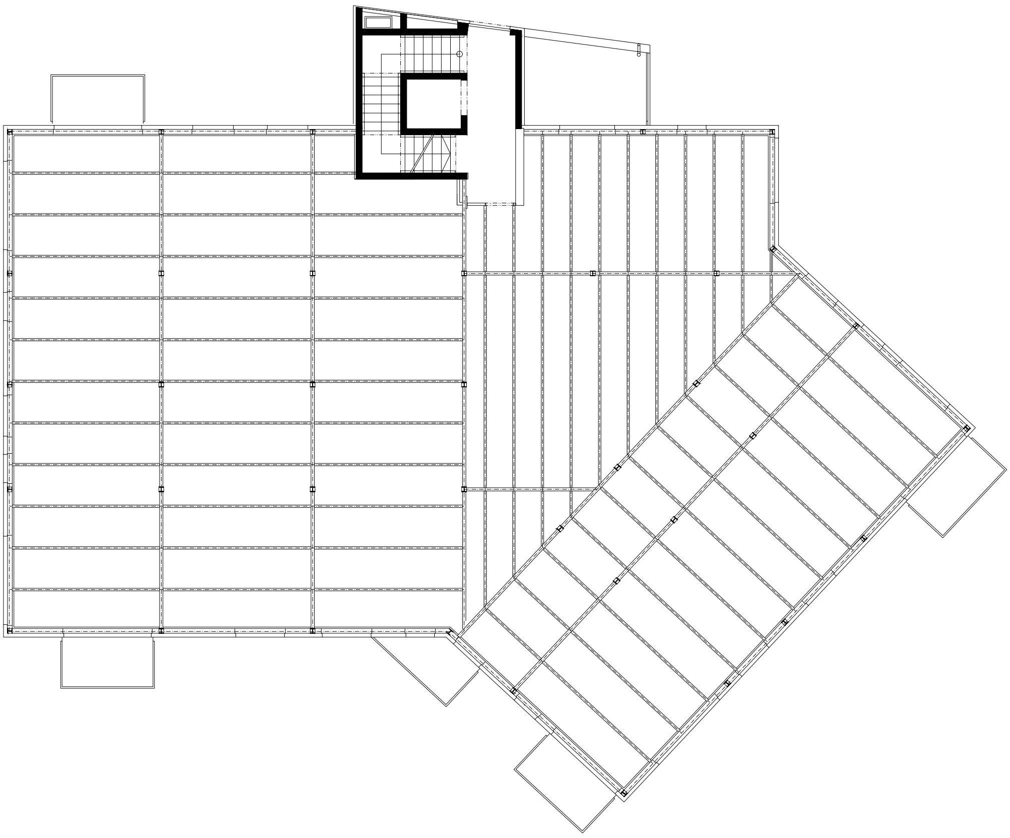


Figure 3.1 Layout of the structure of the 1st, 2nd and 3rd floor

The material used for the basement of the building, the floor with garages and the stairway is the same as in the original building (reinforced concrete). The change of the material is done in the residential part (1st, 2nd, 3rd, 4th floor). The structure is designed as a heavy skeleton, just the 4th floor is done as a light one. The main load bearing parts of the structure are columns set in the maximum span of 5 m. The HEB profiles are used for the columns. Columns in the 4th floor are also in HEB, but placed in the maximal distance of 1,25 m.

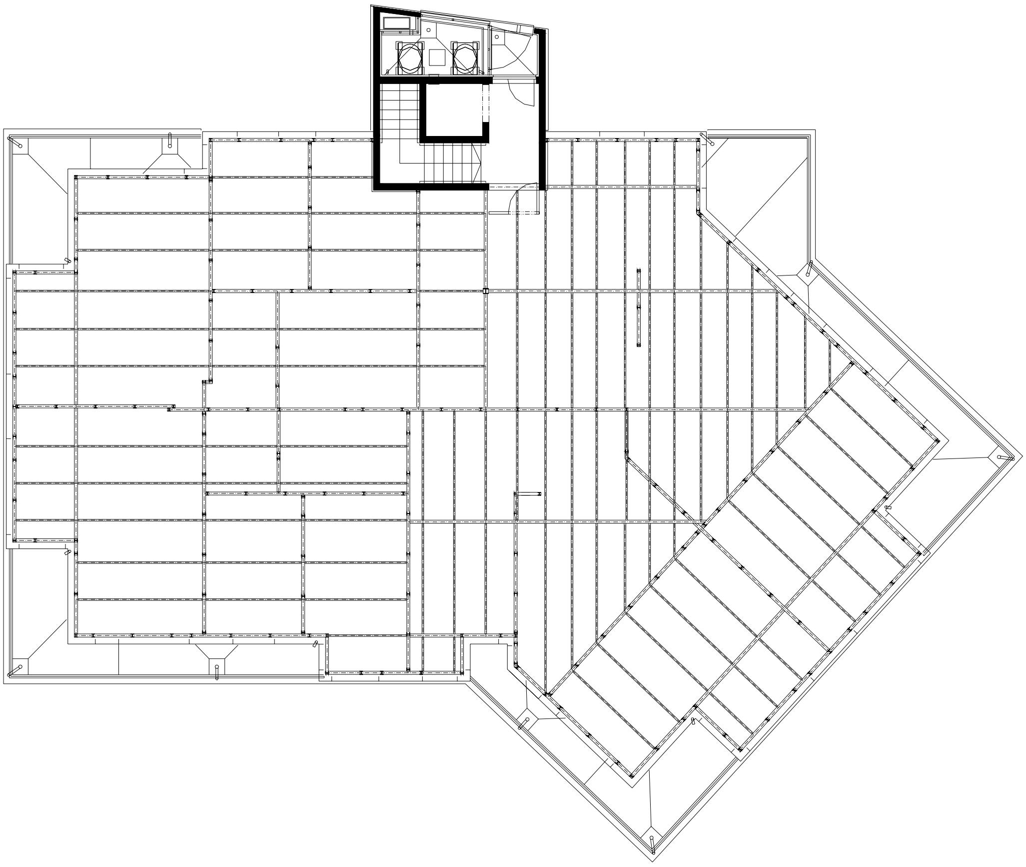


Figure 3.2 Layout of the structure of the 4th floor

The horizontal load bearing structure is designed from girders and joists. There is a difference between profiles used in the ceiling above the 3rd floor and the rest. This is because of the recessed floor above it. Joists and beams in the ceiling above the 3rd floor have to carry the load from roof and 4th floor walls as well. When designing the horizontal structure it was considered the interaction between the steel profiles and the concrete slab above which is used for the flooring. The only part of the horizontal structure that was not properly designed are the profiles that would be used for the construction of balcony.

The loadings that were used for the evaluation are: self-weight load, imposed load, snow load and wind load. The area of stairway is kept in the same place and is used as the reinforcement mainly for the wind load. There is a presumption that the rigid concrete slab used in the floor and roof compositions will interact with steel load bearing elements and therefore it will distribute the horizontal forces caused by the wind loading. It is also presumed that the internal and circumference walls will act as reinforcements thank to their composition which consists of at least two OSB boards in every case. The overall static evaluation can be found at the end of this thesis in the appendix.

According to the structure system the compositions of walls and floors had to be changed as well. All these compositions are described later in this chapter.

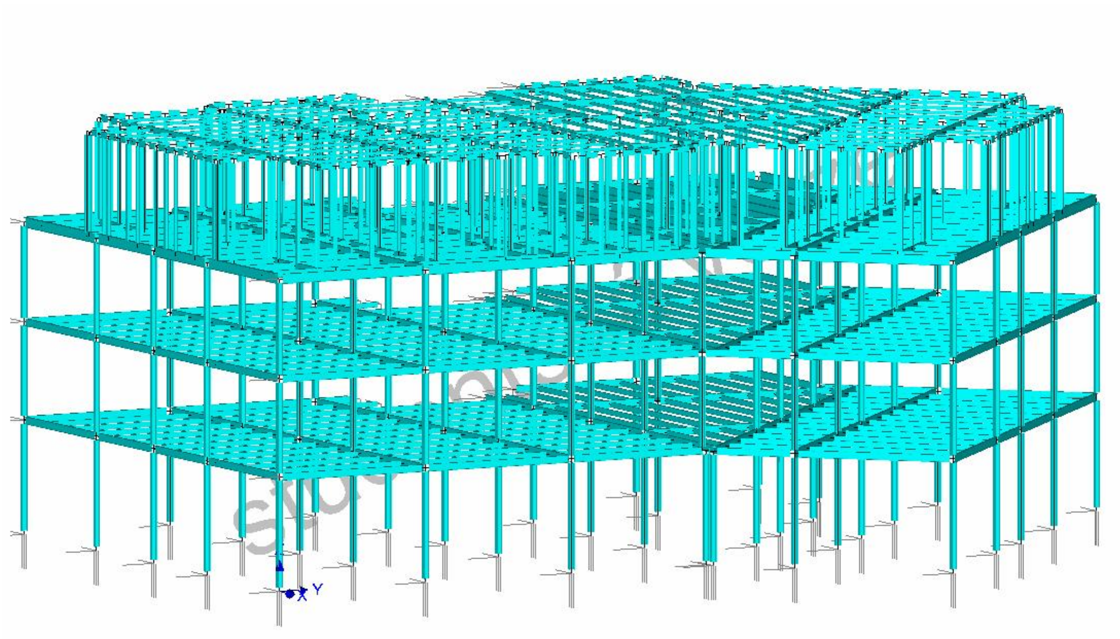


Figure 3.3 Image of the designed steel structure (result from the programme FIN 3D)

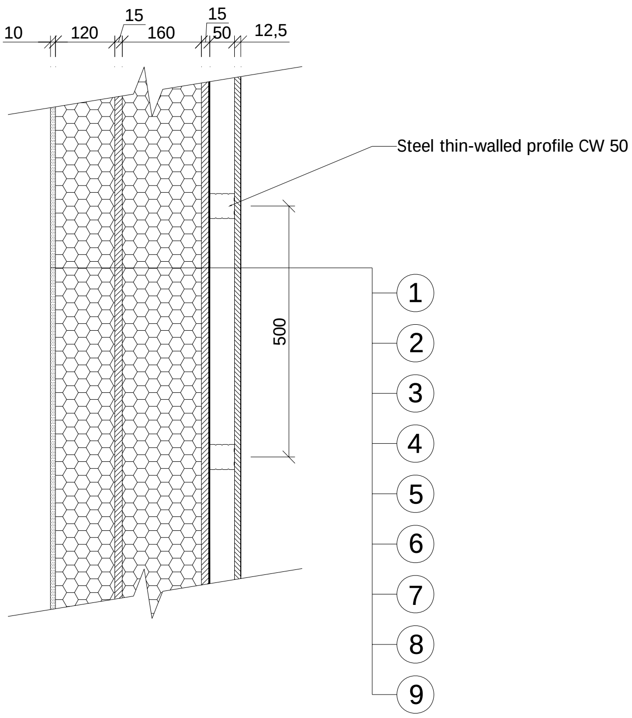
List of elements designed for the steel structure		
Element		**Profile**
joist	**roof**	**IPE 100**
	2^{nd}, 3^{rd} floor	**IPE 160**
	4^{th} floor	**IPE 220**
girder	**2^{nd}, 3^{rd} floor**	**IPE 220**
	4^{th} floor	**IPE 300**
column	**1^{st}, 2^{nd}, 3^{rd} floor**	**HEB 160**
	4^{th} floor	**HEB 100**

Table 3-1 An overview of the designed steel elements

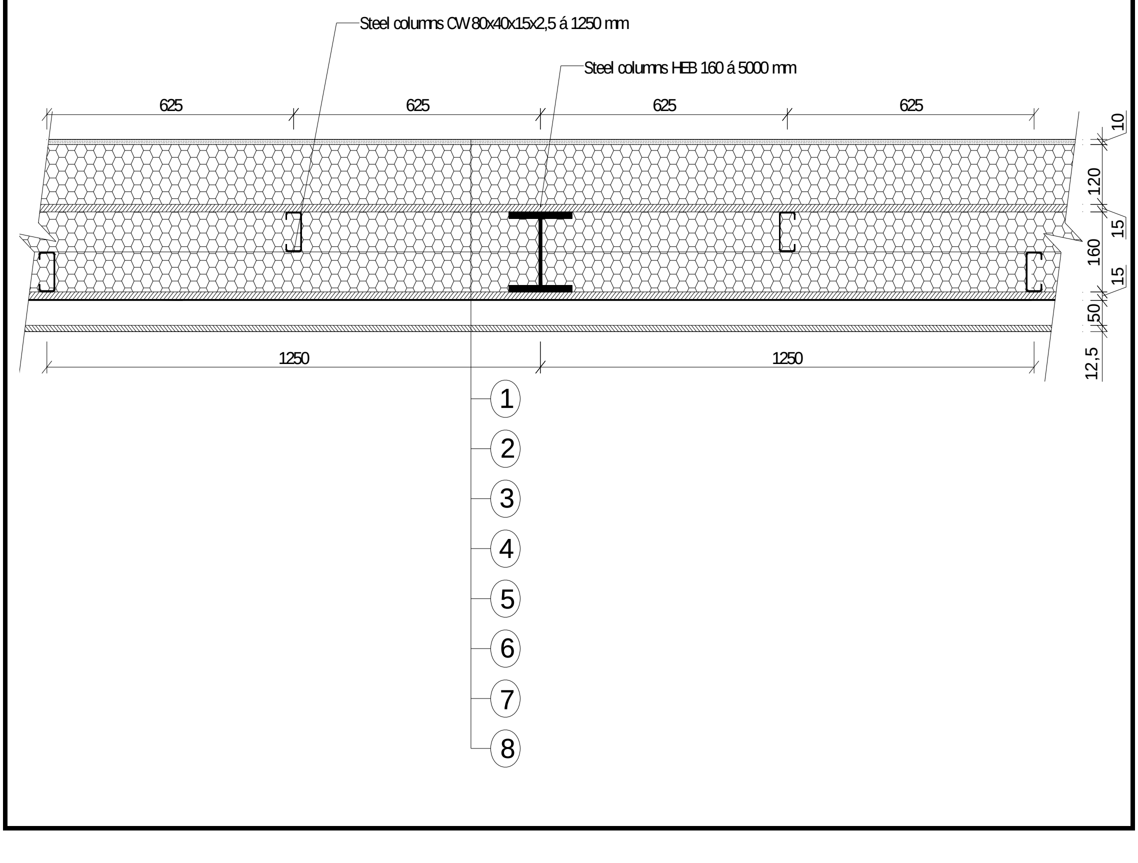
3.1.2 Description of used compositions

Here is an overview of all compositions designed for the steel structure variant. The aim was to get the value of heat transmission coefficient that the specific heat consumption of the building is about 20 kWh/m^2y. The compositions of all variants were done with an idea to get nearly the same values of heat transmission coefficient for all alternatives. To avoid the moisture condensation in the structure itself and to ensure the airtightness, the vapour barrier was used in all of the compositions. All the used OSB boards are produced without an addition of formaldehyde. Compositions are described in *Table 3-2* below. Mineral wool is used as a thermal insulation. Only in the composition of roof and terrace extruded polystyrene is used. This is because of the need to use a thermal insulation with the resistance to the moisture. Always there is a risk of perforation of the first layer of waterproofing. The other reason for extruded polystyrene is the resistance to pressure. This allows to put the walking coat on terrace and keeps the same possibility for roof.

Main wall



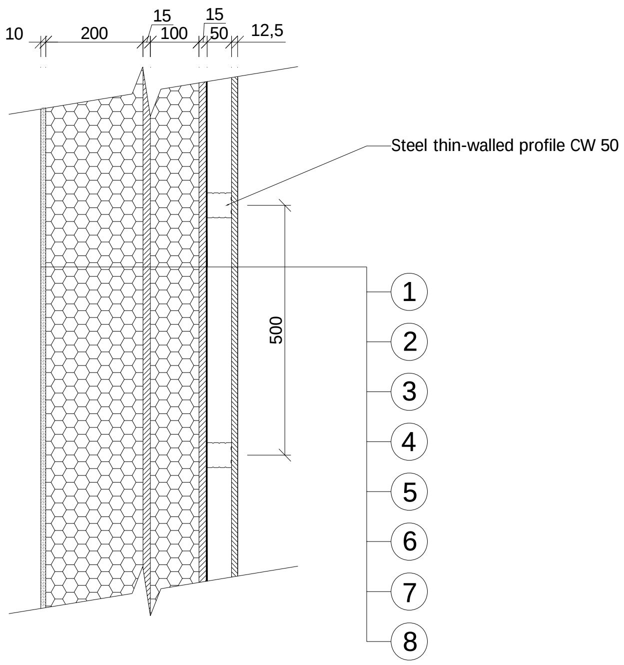
10
120
15
160
15
50
12,5
Steel thin-walled profile CW 50
500
1
2
3
4
5
6
7
8
9

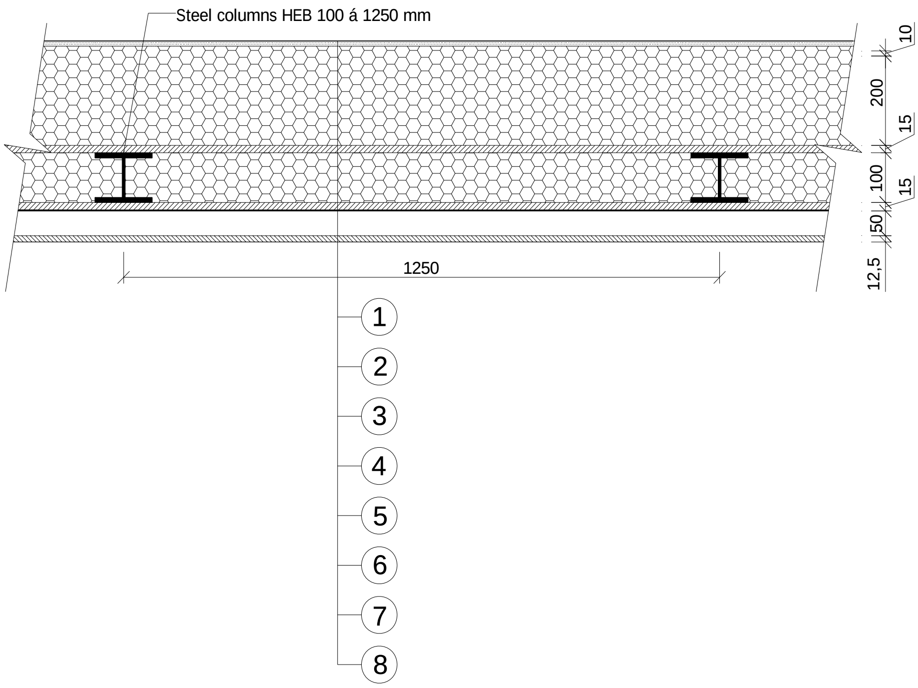


Steel columns CW 80x40x15x2,5 á 1250 mm
Steel columns HEB 160 á 5000 mm
625
625
625
625
10
120
15
160
15
50
12,5
1250
1250
1
2
3
4
5
6
7
8

Number	Layer	Thickness [mm]	Specification
1	External plaster	10	Tubag Mineralischer Dämmputz
2	Thermal insulation	80	Rockwool Fasrock
3	OSB board	15	Superfinish ECO
4	Thermal insulation + CW 80 profiles	100	Rockwool Fasrock
5	Thermal insulation + CW 80 profiles	100	Rockwool Fasrock
6	OSB board	15	Superfinish ECO
7	Vapour barrier	0,25	Jutafol N 140 Special
8	Air gap with CW 50 profiles	50	
9	Plasterboard	12,5	

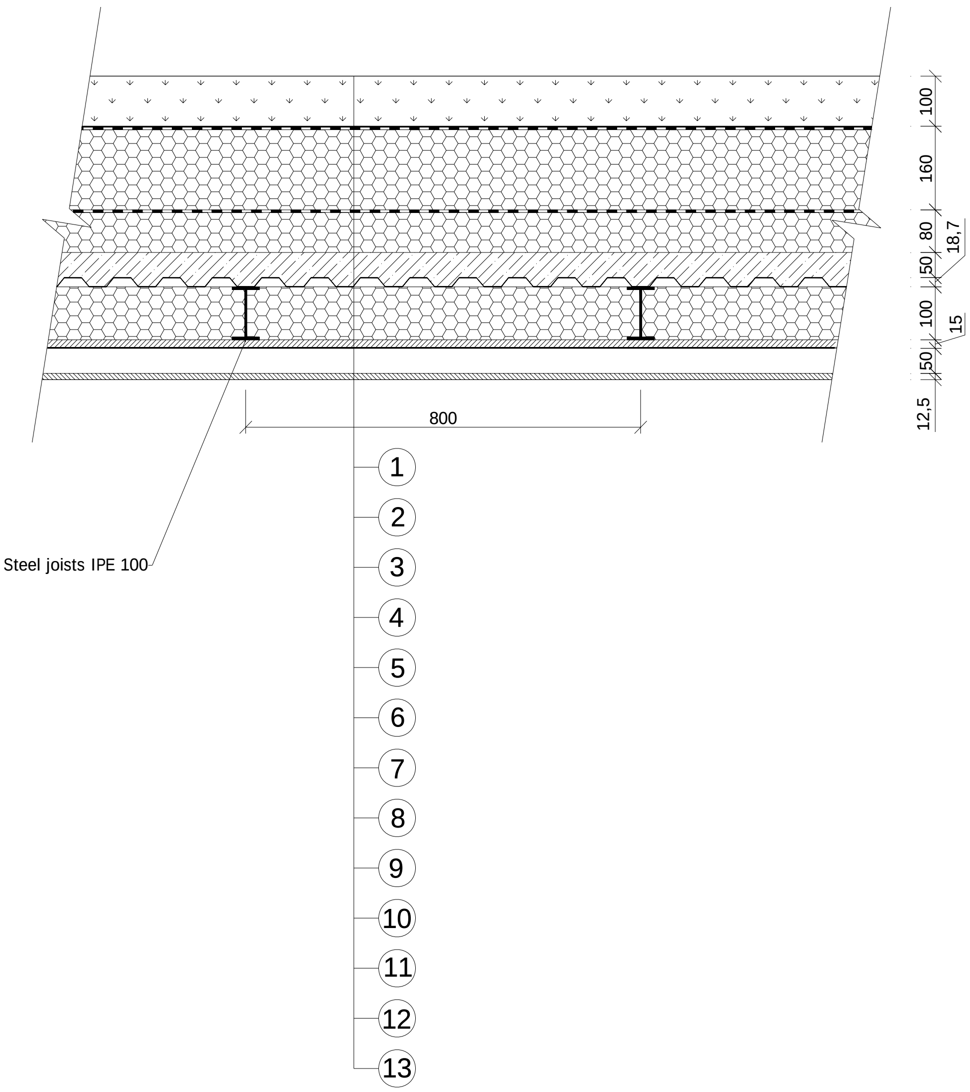
Main wall of the 4th floor





Number	Layer	Thickness [mm]	Specification
1	External plaster	10	Tubag Mineralischer Dämmputz
3	Thermal insulation	200	Rockwool Fasrock
5	OSB board	15	Superfinish ECO
4	Thermal insulation + steel columns HEB 100	100	Rockwool Fasrock
5	OSB board	15	Superfinish ECO
6	Vapour barrier	0,25	Jutafol N 140 Special
7	Air gap with CW 50 profiles	50	
8	Plasterboard	12,5	

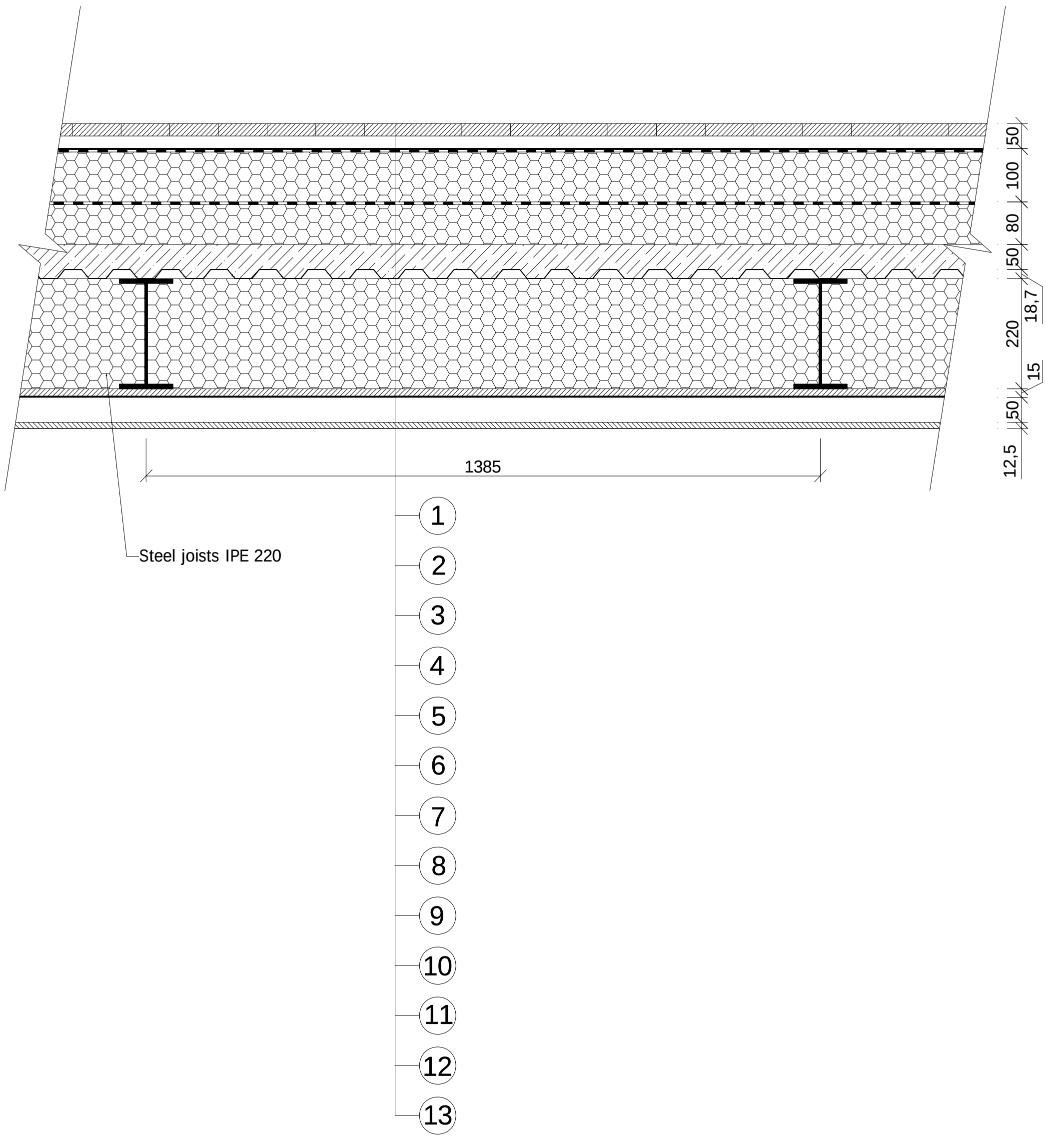
Roof



100
160
80
18,7
50
100
15
50
12,5
800
Steel joists IPE 100
1
2
3
4
5
6
7
8
9
10
11
12
13

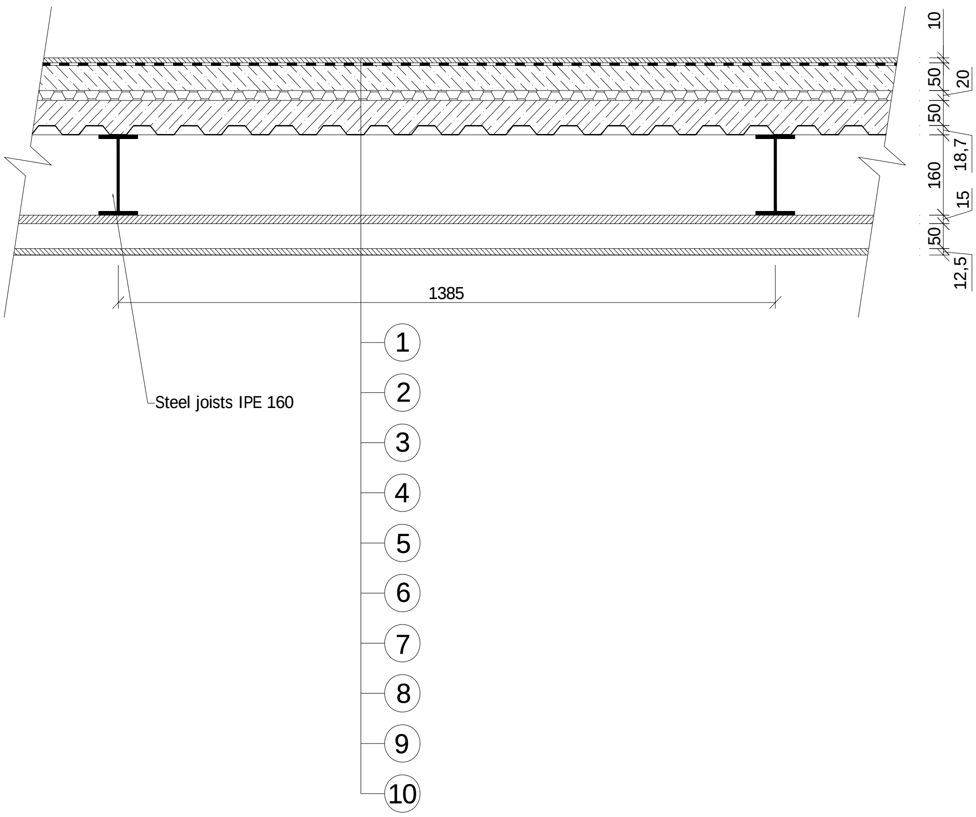
Number	Layer	Thickness [mm]	Specification
1	Greening	100	
2	Geotextile	0,25	Filtek
3	Waterproofing	2,4	Sarnafil G 441-24EL
4	Thermal insulation	160	Dow Roofmate SL
5	Waterproofing	1,2	Sikaplan D
6	Thermal insulation	80	Dow Roofmate SL
7	Concrete slab	50	Reinforced concrete
8	Trapezoidal sheets	18,7	Lindab LLP 20
9	Thermal insulation + steel joists IPE 100	100	Rockwool Rockroll
10	OSB board	15	Superfinish ECO
11	Vapour barrier	0,25	Jutafol N 140 Special
12	Air gap with timber joists 60 x 40	50	
13	Plasterboard	12,5	

Terrace


50
100
80
50
18,7
220
15
50
12,5
1385
Steel joists IPE 220
1
2
3
4
5
6
7
8
9
10
11
12
13

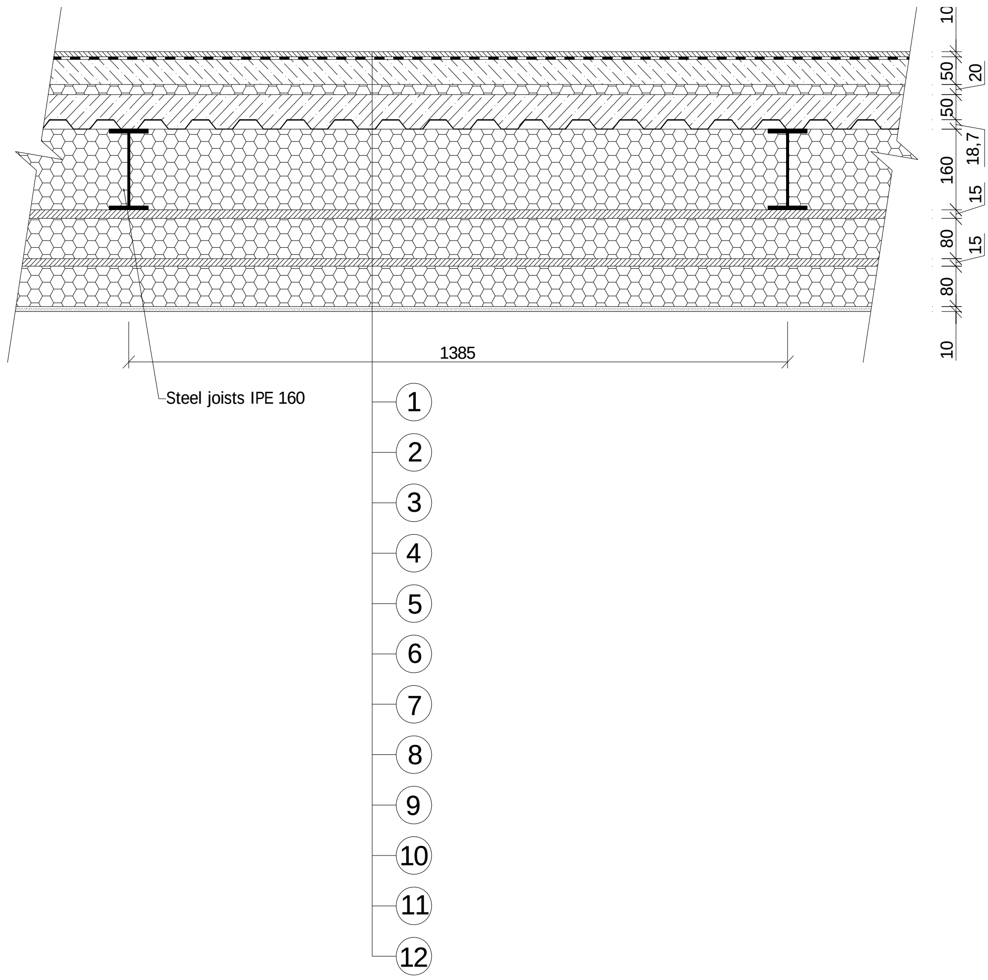
Number	Layer	Thickness [mm]	Specification
1	Final layer - walking coat	50	Parador outdoor classic 7020
2	Geotextile	0,25	Filtek
3	Waterproofing	2,4	Sarnafil G 441-24EL
4	Thermal insulation	100	Dow Roofmate SL
5	Waterproofing	1,2	Sikaplan D
4	Thermal insulation	80	Dow Roofmate SL
7	Concrete slab	50	Reinforced concrete
8	Trapezoidal sheets	18,7	Lindab LLP 20
9	Thermal insulation + steel joists IPE 220	220	Rockwool Rockroll
13	OSB board	15	Superfinish ECO
14	Vapour barrier	0,25	Jutafol N 140 Special
15	Air gap with timber joists 60 x 40	50	
16	Plasterboard	12,5	

Ceiling



Number	Layer	Thickness [mm]	Specification
1	Final layer - ceramic tiles	10	Rako Tanse
2	Waterproofing	2,4	Sarnafil G 441-24EL
3	Anhydrite	50	Anhyment AE 20
4	Impact sound insulation	20	Dow Ethafoam
5	Concrete slab	50	Reinforced concrete
6	Trapezoidal sheets	18	Lindab LLP 20
7	Air gap + steel joists IPE 160		
8	OSB board	15	Superfinish ECO
9	Air gap with CW 50 profiles	50	
10	Plasterboard	12,5	

Floor on air


10
50
20
50
18,7
160
15
80
15
80
10
1385
Steel joists IPE 160
1
2
3
4
5
6
7
8
9
10
11
12

Number	Layer	Thickness [mm]	Specification
1	Final layer - ceramic tiles	10	Rako Tanse
2	Waterproofing	2,4	Sarnafil G 441-24EL
3	Anhydrite	50	Anhyment AE 20
4	Impact sound insulation	20	Dow Ethafoam
5	Concrete slab	50	Reinforced concrete
6	Trapezoidal sheets	18,7	Lindab LLP 20
7	Thermal insulation + steel joists IPE 160	160	Rockwool Rocknroll
8	OSB board	15	Superfinish ECO
9	Thermal insulation + CW 80 profiles	80	Rockwool Fasrock
10	OSB board	15	Superfinish ECO
11	Thermal insulation	80	Rockwool Fasrock
12	External plaster	10	Tubag Mineralischer Dämmputz

Table 3-2 An overview of the designed steel compositions

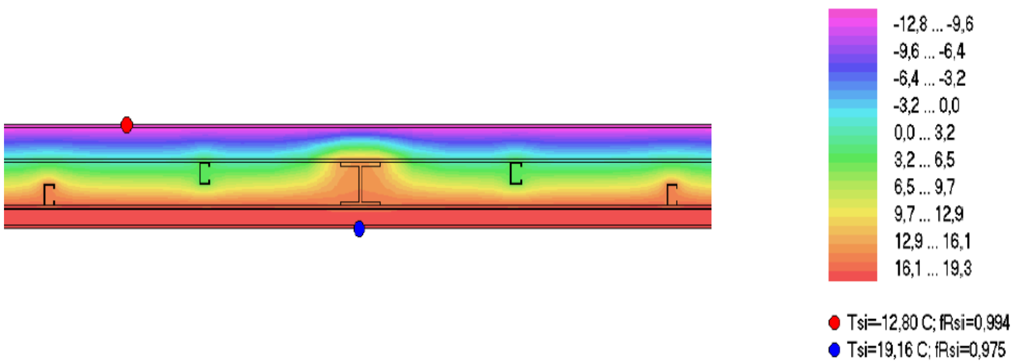
3.1.3 Thermal performance of designed compositions

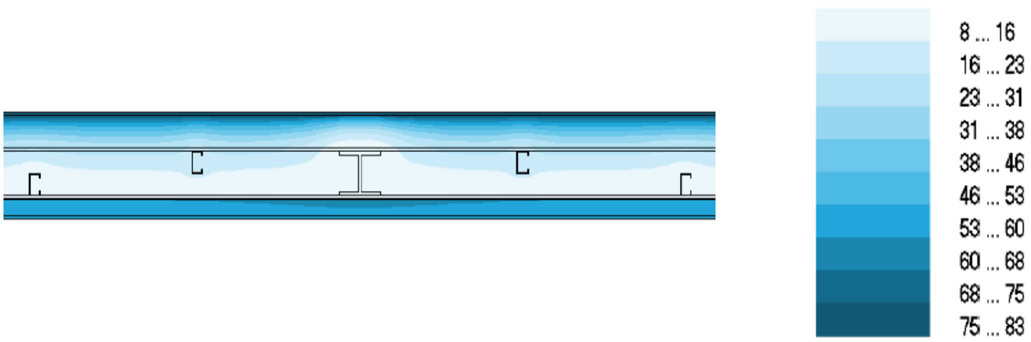
The programme Area 2009 was used for the evaluation of thermal fields and moisture situation. Here are described results for the location of Prague. Design conditions are shown in the *Table 3-3* below. These solutions were made for the steady-state condition. All the solutions are stated in the *Table 3-4.* The recommended values stated in there show the value recommended by the czech standardization ČSN 73 0540 for the certain type of structure. Evaluated values are the exact values for each of the compositions. The steel elements that are in each composition were taken in account when evaluating the heat transmittance coefficient. The value of thermal conductivity of each layer was increased by the value thermal conductivity of steel according to the amount and size of used steel elements.

Design conditions for the location of Prague		
Design outdoor temperature during the winter period T_e	-13	°C
Design relative humidity of the outdoor air during the winter period φ_e	84	%
Design partial pressure of vapour P_e	167	Pa
Mean temperature during the heating season T_m	4,3	°C
Length of the heating season t_{hs}	225	days
The outdoor temperature when the heating is started T_{st}	13	°C

Table 3-3 Design conditions for the location of Prague

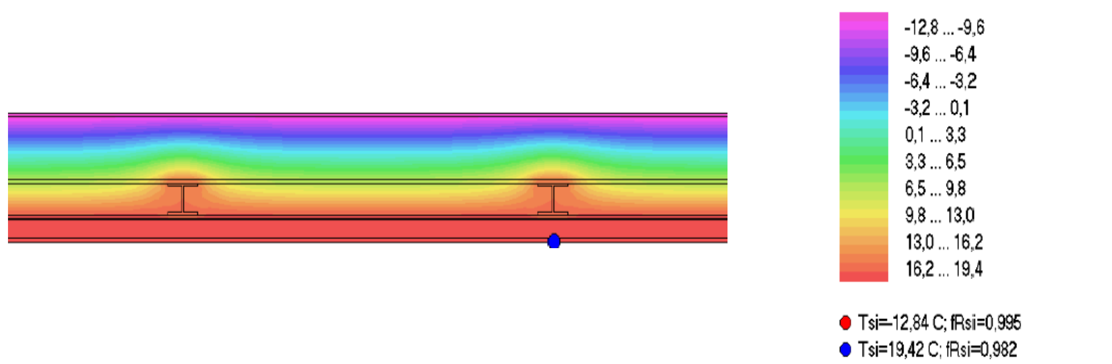
Main wall

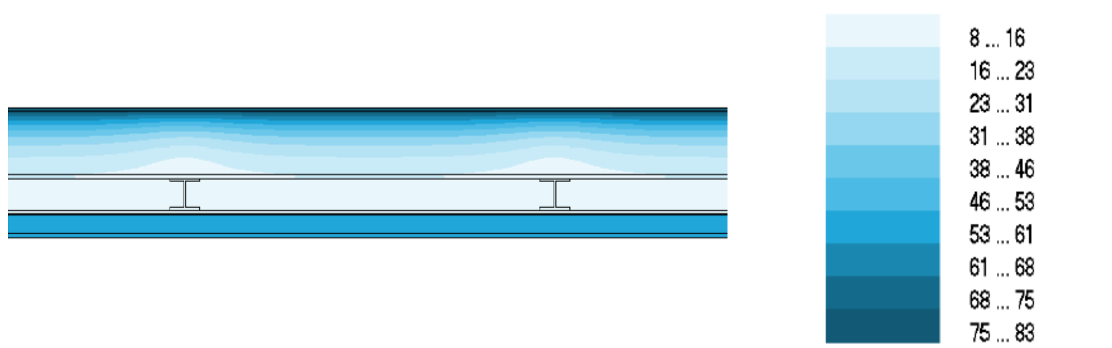




Coefficient of heat transmittance U [W/m^{2}K]	Evaluated	0.15
	Recommended	0,20

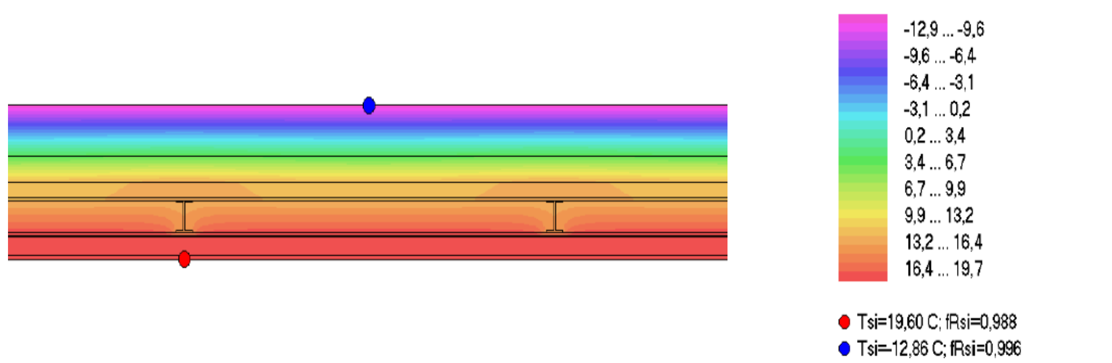
Main wall of the 4th floor

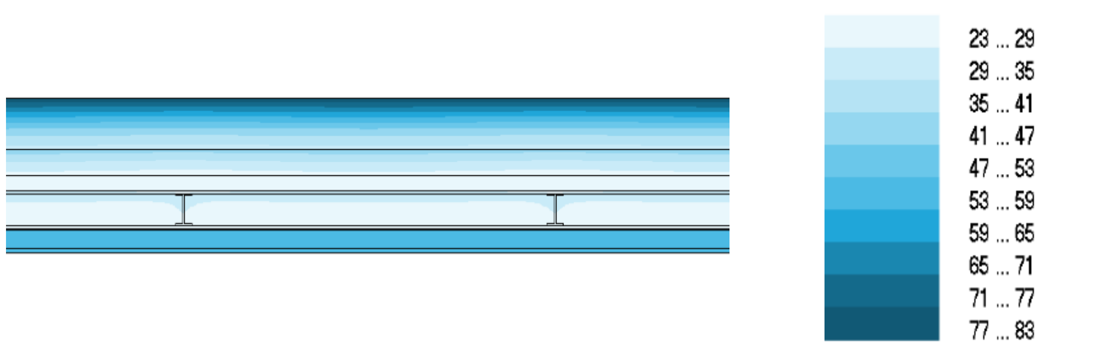




Coefficient of heat transmittance U [W/m²K]		
	Evaluated	0.15
	Recommended	0,20

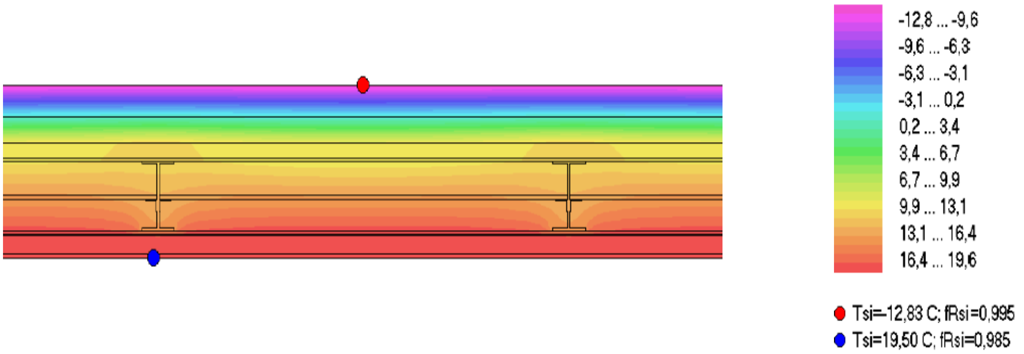
Roof

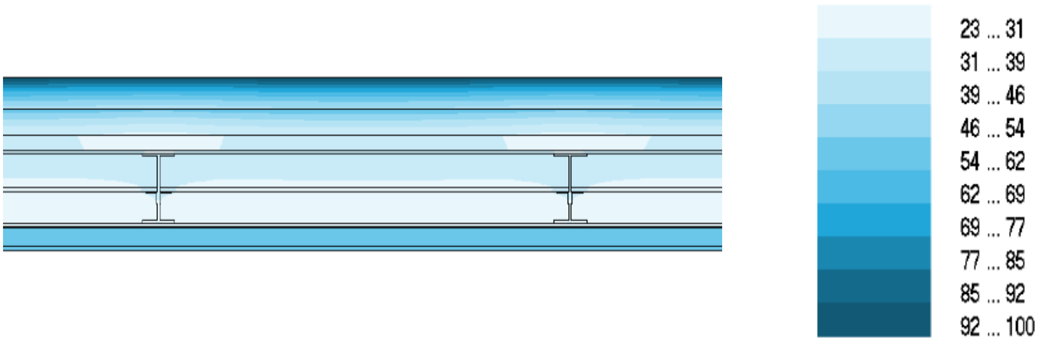




Coefficient of heat transmittance U [W/m²K]		
	Evaluated	0.11
	Recommended	0,16

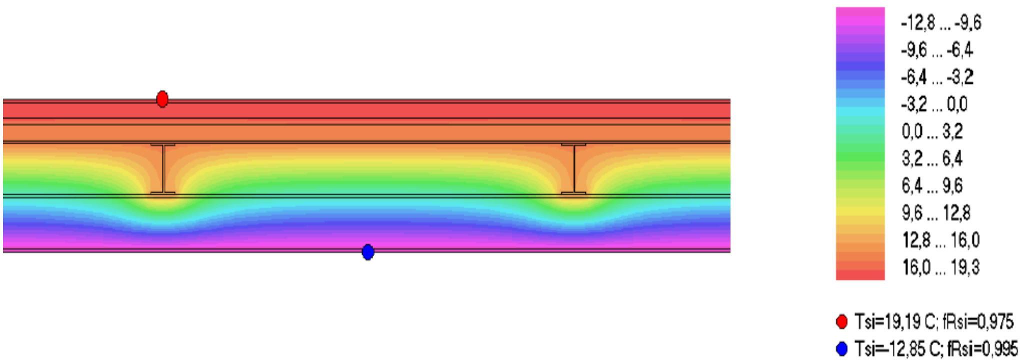
Terrace

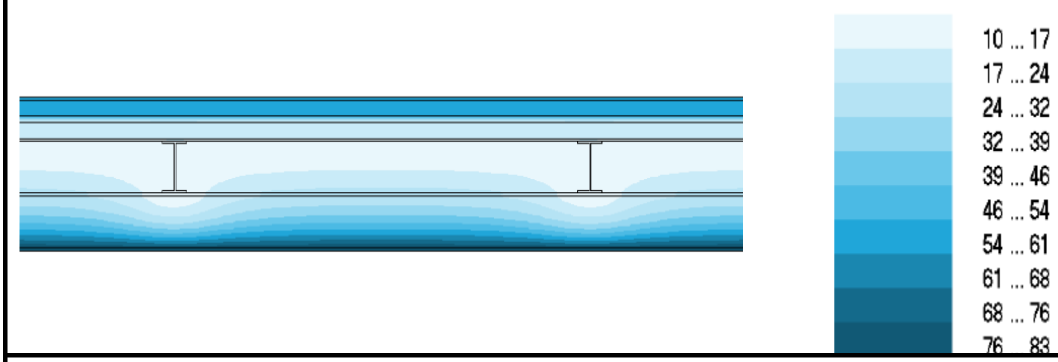




Coefficient of heat transmittance U [W/m²K]	Evaluated	0.12
	Recommended	0,16

Floor on air





Coefficient of heat transmittance U [W/m²K]	Evaluated	0.12
	Recommended	0,16

Table 3-4 Thermal performance of designed compositions for the steel structure variant

3.1.4 Acoustics performance

The sound proof of structures dividing two flats or flats from the corridor was evaluated. The reason why exactly these are evaluated is that there are the highest requests on them. The partition between two flats or between a flat and a corridor has to fulfil the request of 52 dB on airborne sound insulation. The request for ceiling is that the maximal level of impact sound must be lower than 58 dB. These requests are stated according to the Czech standardisation ČSN EN ISO 717. The programme Neprůzvučnost was used for the evaluation. Results are show in Tables 3-5 and 3-6 below.

Composition layers	Thickness [mm]	Values of Airborne sound insulation R_W [dB]
Plasterboard	25	**Requested**
Mineral wool	50	
Gypsum-fibre board	15	**52**
Mineral wool + CW 100 profiles	100	
Gypsum-fibre board	15	**Evaluated**
Mineral wool	50	**53**
Plasterboard	25	

Table 3-5 Values for airborne sound insulation of the steel variant

Composition layers	Thickness [mm]	Values of impact sound level L_{nW} [dB]
Anhydrite	50	**Requested**
Impact sound insulation	20	
Concrete slab	50	**58**
Trapezoidal sheets	18	
OSB board	15	**Evaluated**
Air gap with CW 50 profiles	50	**27**
Plasterboard	12,5	

Table 3-6 Values for impact sound level of the steel variant

3.2 Timber based construction

3.2.1 Design of the structure

This alternative was done in a quite similar style as the previous steel one. The attention to preserve dispositions was paid here as well. The only place where it was necessary to change a bit the original disposition is also the 1st floor with open space offices. Extra columns were needed to be put in there. But the other opportunity how to arrange the disposition in there is given in the appendix of this thesis. The variability of this area is still kept. As in the steel variant some of the windows had slightly to change the place as well, but the glazing area remained at the same level.

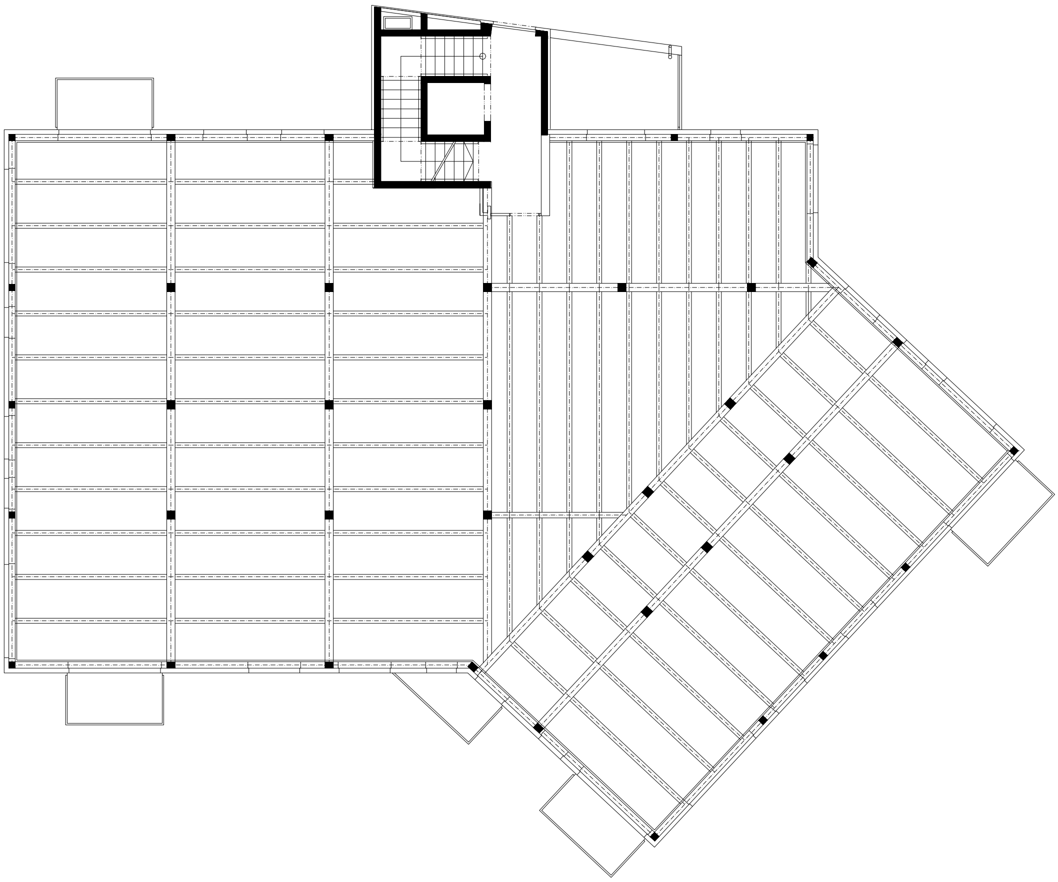


Figure 3.4 Layout of the structure of the 1st, 2nd and 3rd floor

The material used for the basement of the building, the floor with garages and the stairway is the same as in the original building (reinforced concrete). The change of the material is done in the residential part (1st, 2nd, 3rd, 4th floor). The structure is designed as a heavy skeleton just the 4th floor is done as the 2by4 system. The main load bearing parts of the structure are columns set in the maximum span of 5 m. According to the force that was counted in each element the certain material was chosen. Joists were designed from the grown timber, girders and columns will be made from the glue-laminated timber.

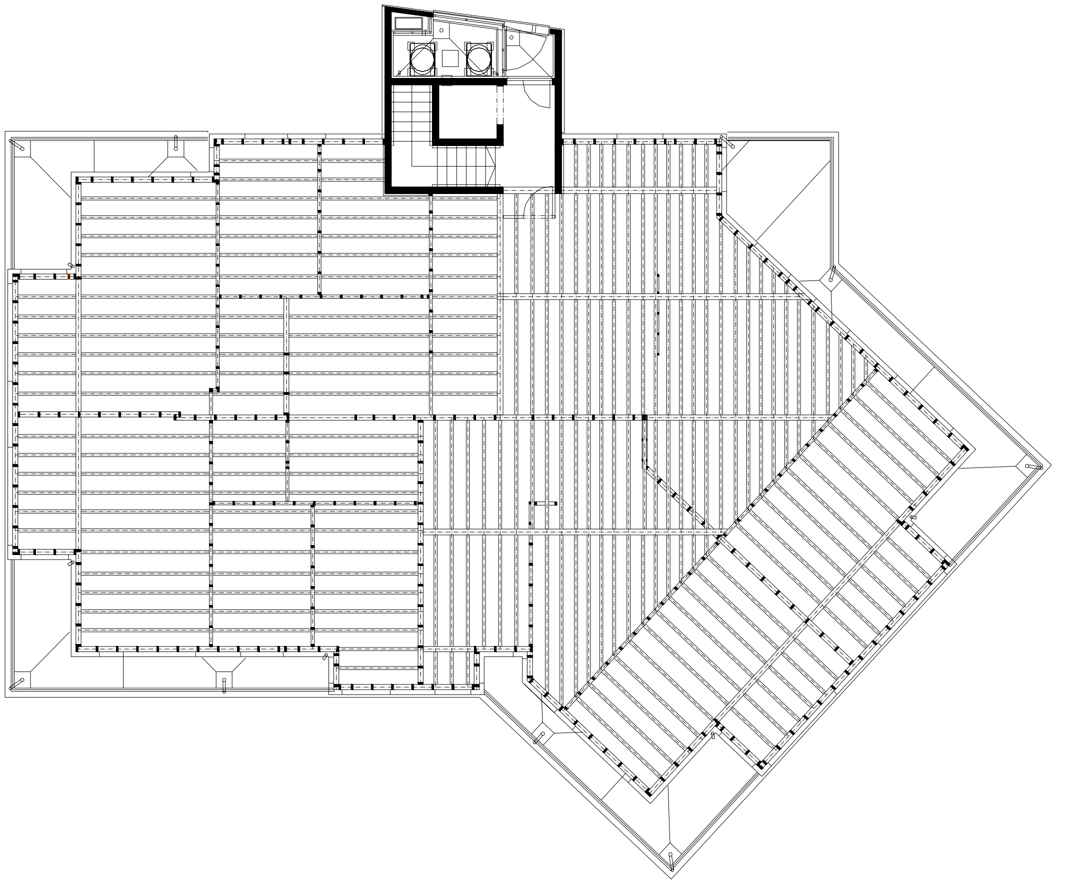


Figure 3.5 Layout of the structure of the 4th floor

The horizontal structure is designed from girders and joists. There is a difference between profiles used in the ceiling of the 3rd floor and the rest. This is because of the recessed floor above it. Joists and girders in the ceiling above the 3rd floor have to carry the load from roof and 4th floor walls as well. All of the elements were designed as simple beams. The only part of the horizontal structure that was not properly designed are the profiles that would be used for the construction of balcony.

The loadings that were used for the evaluation are these: self-weight load, imposed load, snow load and wind load. The area of stairway is kept in the reinforced concrete in the same place and is used as the reinforcement mainly for the wind load. There is a presumption that the ceiling will act as a rigid slab. There are at least three OSB boards used in every composition. All of the walls are also assumed to act as the wind reinforcement. This is thanks to their composition that consists of OSB boards as well. The overall static evaluation can be found at the end of this thesis in the appendix.

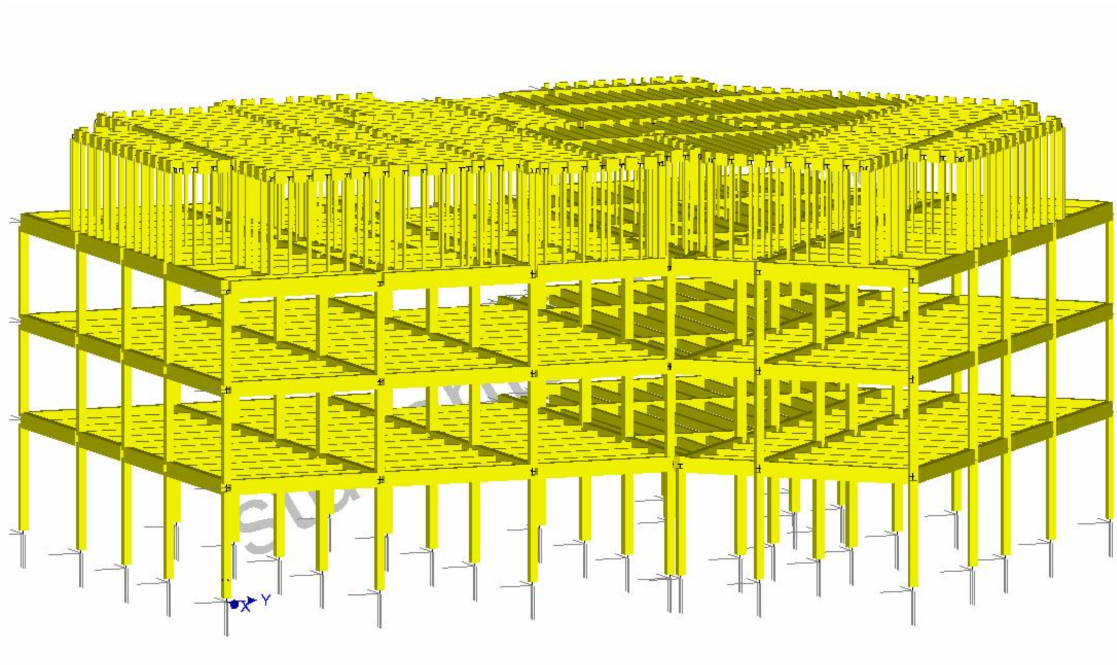


Figure 3.6 Image of the designed timber structure (result from the programme FIN 3D)

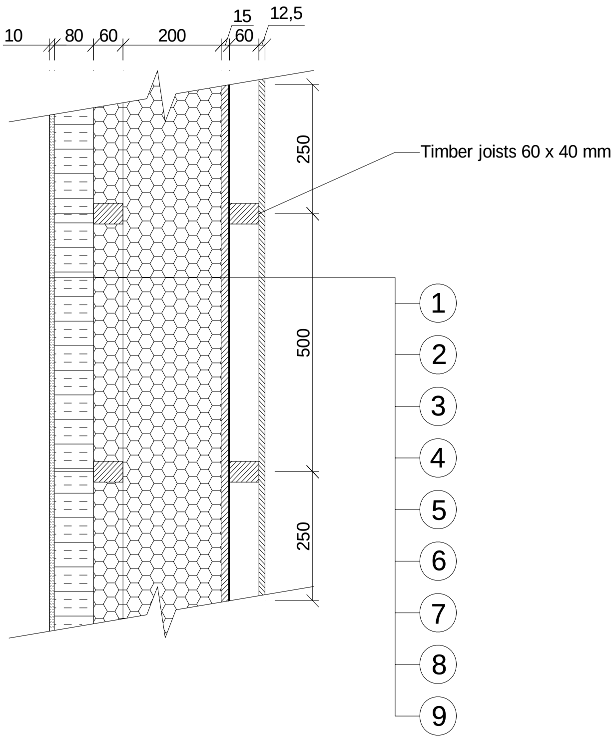
List of elements designed for the timberl structure		
Element		**Profile**
joist	**roof**	**200x100**
	2^{nd}, 3^{rd} floor	**280x160**
	4^{th} floor	**360x180**
	4^{th} floor terrace	**460x220**
	4^{th} floor large	**500x260**
girder	**2^{nd}, 3^{rd} floor**	**380x200**
	4^{th} floor	**520x260**
	roof	**280x160**
column	**2^{nd}, 3^{rd} floor**	**260x260**
	1^{sr}, 2^{nd}, 3^{rd} floor wall	**200x260**
	4^{th} floor	**160x80**

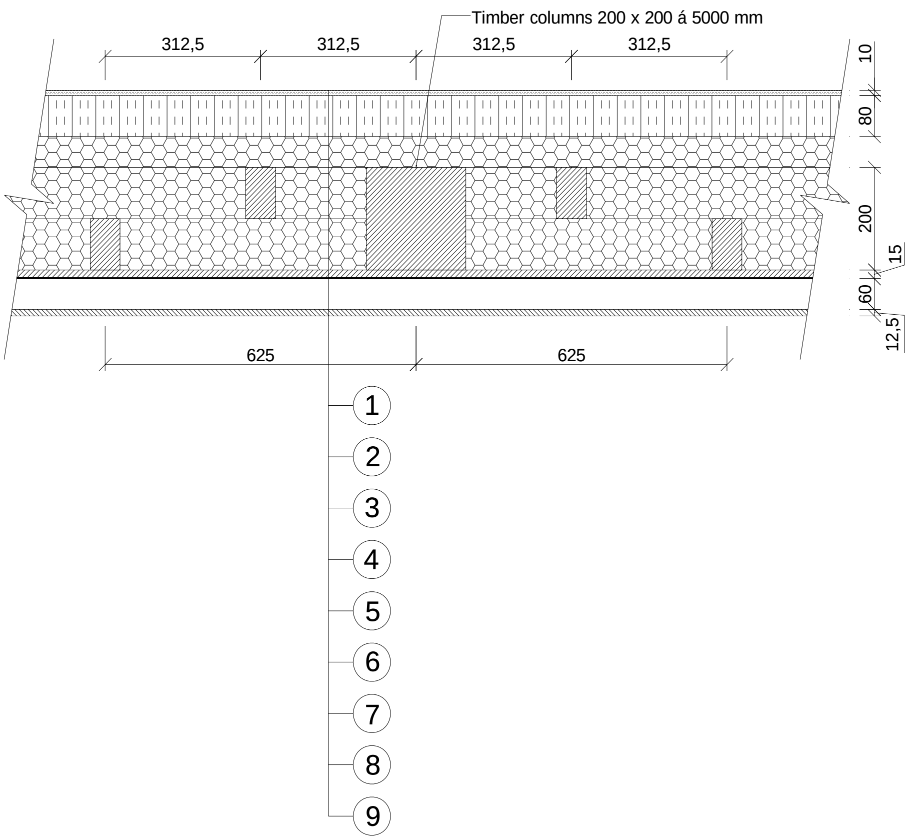
Table 3-7 An overview of the designed timber elements

3.2.2 Description of used compositions

Here is an overview of all compositions designed for the timber structure alternative. The aim was to get the value of heat transmission coefficient that the specific heat consumption of the building is about 20 kWh/m^{2}y. The compositions of all variants were done with an idea to get nearly the same values of heat transmission coefficient for all alternatives. To avoid the moisture condensation in the structure itself and to ensure the airtightness, the vapour barrier was used in all of the compositions. All the used OSB boards are produced without an addition of formaldehyde. Compositions are described in *Table 3-8* below. Mineral wool is used as a thermal insulation. Only in the composition of roof and terrace extruded polystyrene is used. This is because of the need to use a thermal insulation with the resistance to the moisture. Always there is a risk of perforation of the first layer of waterproofing. The other reason for extruded polystyrene is the resistance to pressure. This allows to put the walking coat on terrace and keeps the same possibility for roof.

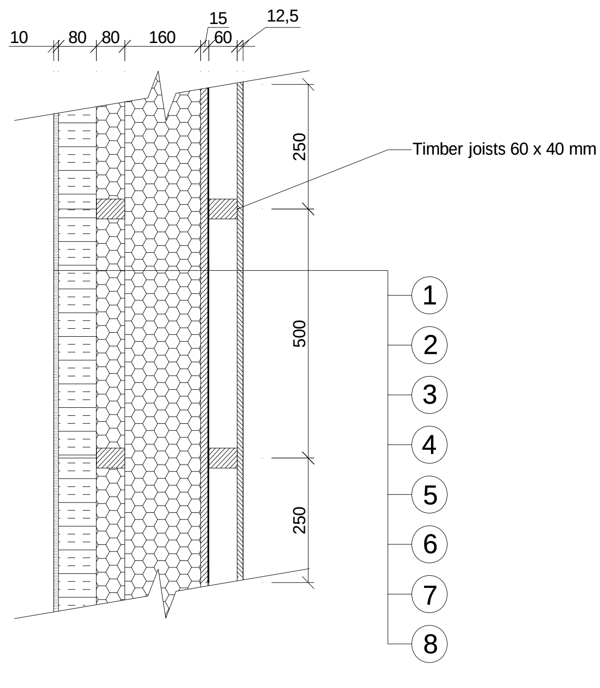
Main wall

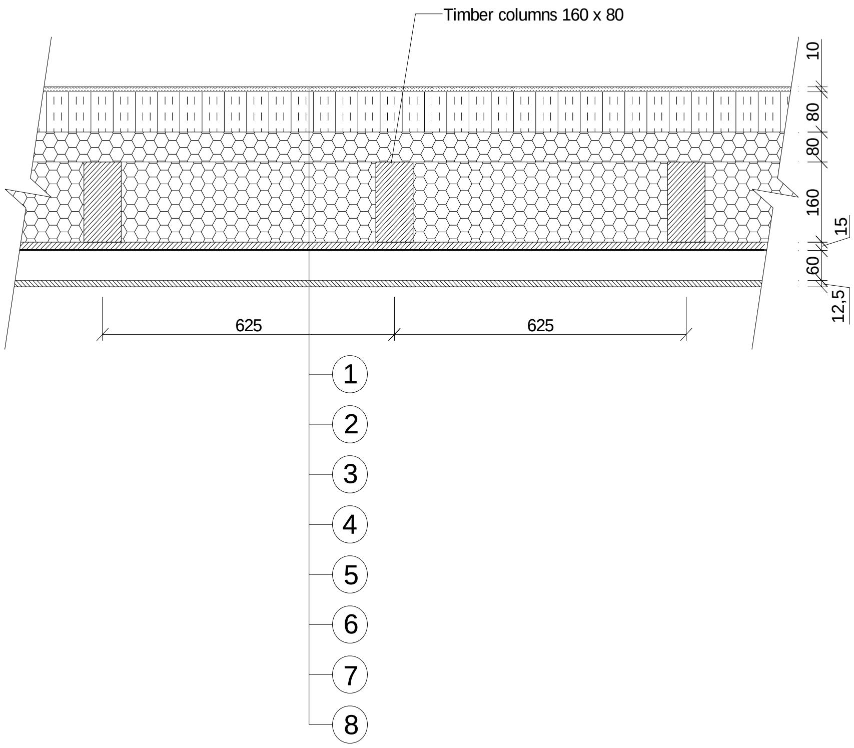

10
80
60
200
15
60
12,5
250
500
250
Timber joists 60 x 40 mm
1
2
3
4
5
6
7
8
9


Timber columns 200 x 200 á 5000 mm
312,5
312,5
312,5
312,5
10
80
200
15
60
12,5
625
625
1
2
3
4
5
6
7
8
9

Number	Layer	Thickness [mm]	Specification
1	External plaster	10	Tubag Mineralischer Dämmputz
2	Wooden fibre board	80	Hofatex Therm DK
3	Thermal insulation	60	Rockwool Fasrock
4	Thermal insulation + timber columns 100 x 60	100	Rockwool Fasrock
5	Thermal insulation + timber columns 100 x 60	100	Rockwool Fasrock
6	OSB board	15	Superfinish ECO
7	Vapour barrier	0,25	Jutafol N 140 Special
8	Air gap with timber joists 60 x 40	60	
9	Plasterboard	12,5	

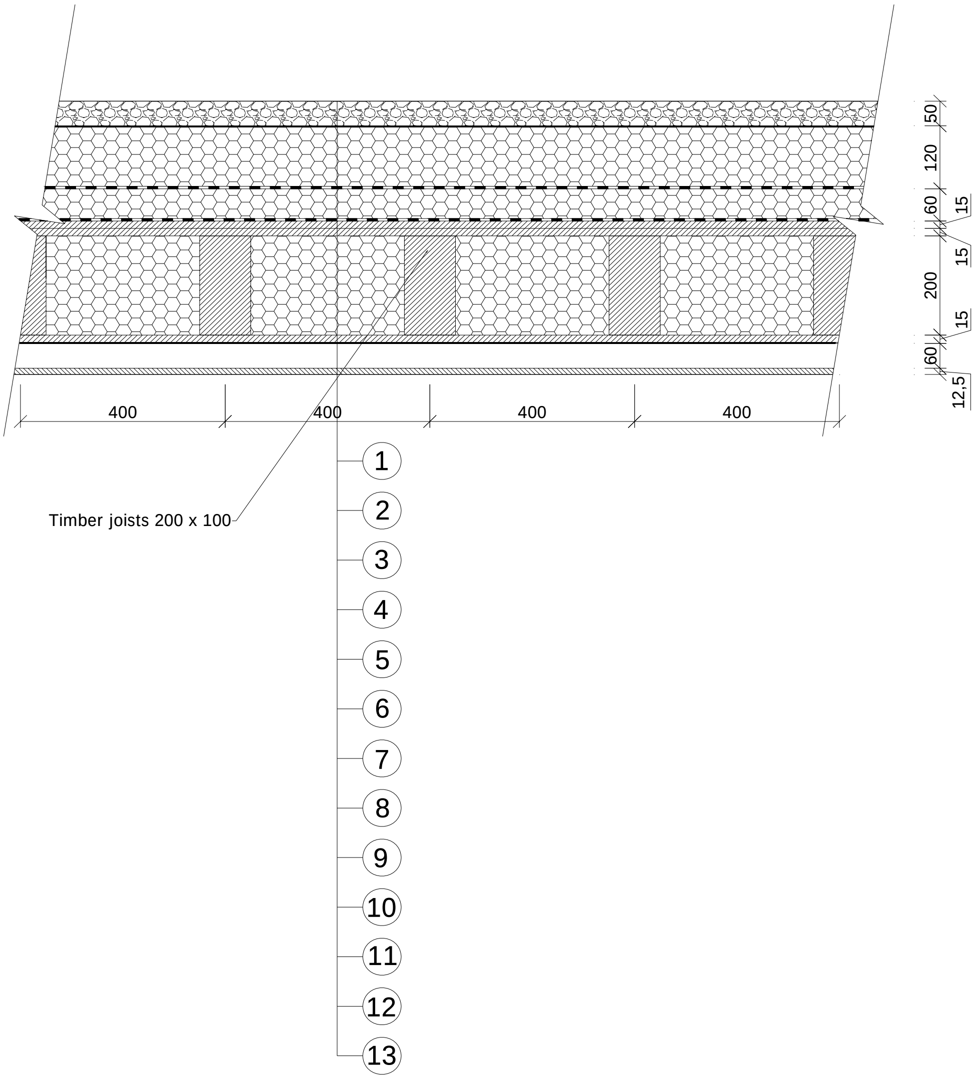
Main wall of the 4th floor





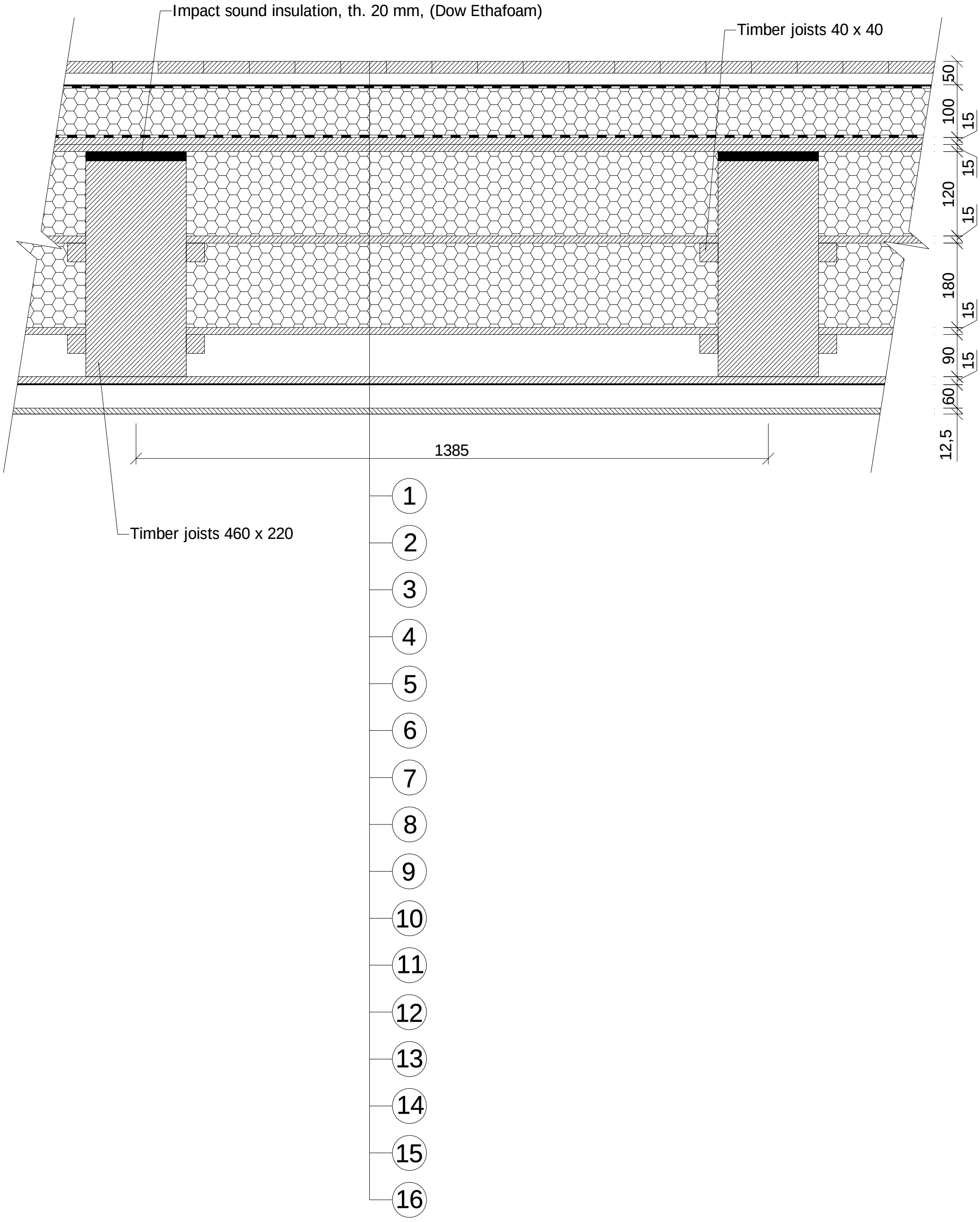
Number	Layer	Thickness [mm]	Specification
1	External plaster	10	Tubag Mineralischer Dämmputz
2	Wooden fibre board	80	Hofatex Therm DK
3	Thermal insulation	80	Rockwool Fasrock
4	Thermal insulation + timber columns 160 x 80	100	Rockwool Fasrock
5	OSB board	15	Superfinish ECO
6	Vapour barrier	0,25	Jutafol N 140 Special
7	Air gap with timber joists 60 x 40	60	
8	Plasterboard	12,5	

Roof


50
120
60
15
15
200
15
60
12,5
400
400
400
400
Timber joists 200 x 100
1
2
3
4
5
6
7
8
9
10
11
12
13

Number	Layer	Thickness [mm]	Specification
1	Gravel	50	
2	Geotextile	0,25	Filtek
3	Waterproofing	2,4	Sarnafil G 441-24EL
4	Thermal insulation	120	Dow Roofmate SL
5	Waterproofing	1,2	Sikaplan D
6	Thermal insulation	60	Dow Roofmate SL
7	OSB board	15	Superfinish ECO
8	OSB board	15	Superfinish ECO
9	Thermal insulation + timber joists 200 x 80	200	Rockwool Rockroll
10	OSB board	15	Superfinish ECO
11	Vapour barrier	0,25	Jutafol N 140 Special
12	Air gap with timber joists 60 x 40	60	
13	Plasterboard	12,5	

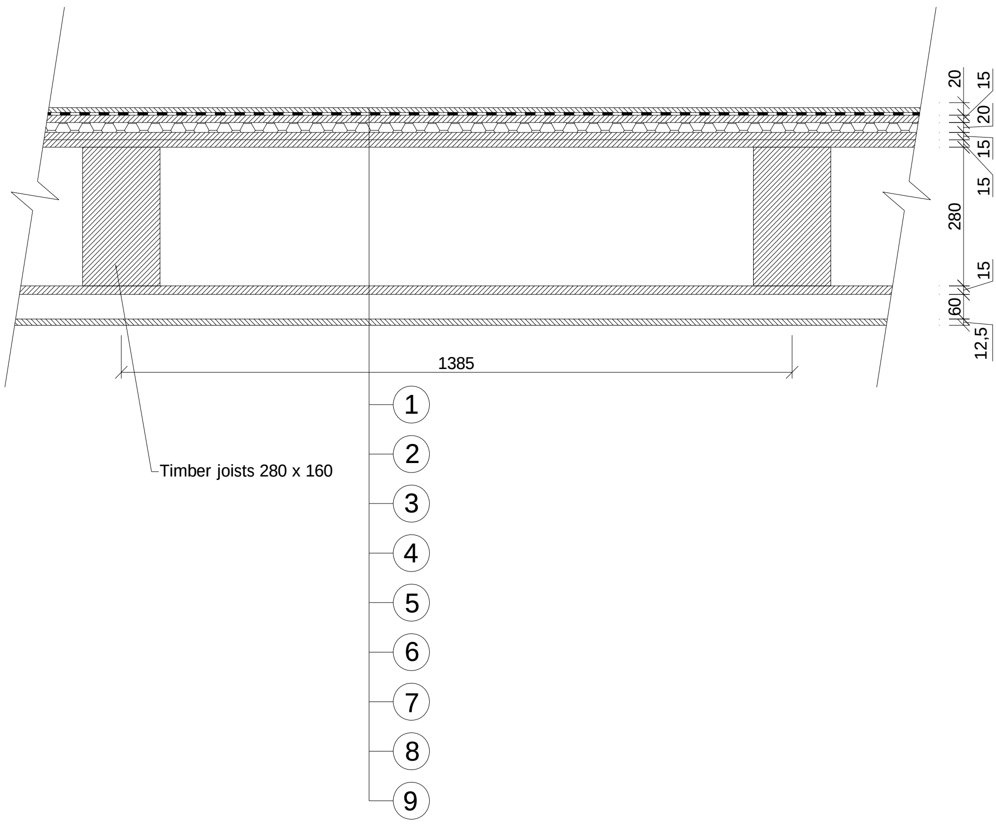
Terrace



Impact sound insulation, th. 20 mm, (Dow Ethafoam)
Timber joists 40 x 40
Timber joists 460 x 220
1385
50
100
15
15
120
15
180
15
90
15
60
12,5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

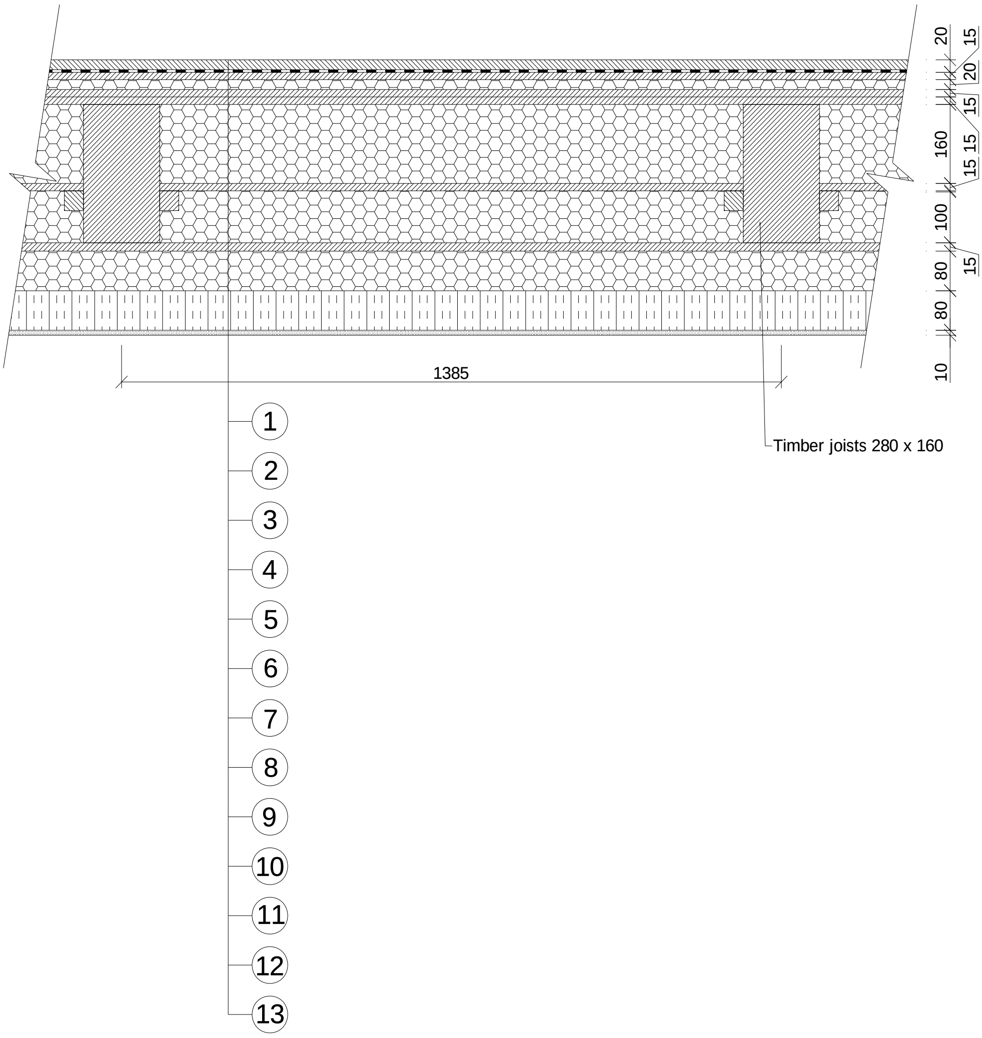
Number	Layer	Thickness [mm]	Specification
1	Final layer - walking coat	50	Parador outdoor classic 7020
2	Geotextile	0,25	Filtek
3	Waterproofing	2,4	Sarnafil G 441-24EL
4	Thermal insulation	100	Dow Roofmate SL
5	Waterproofing	1,2	Sikaplan D
6	OSB board	15	Superfinish ECO
7	OSB board	15	Superfinish ECO
8	Thermal insulation + timber joists 460 x 220	180	Rockwool Rockroll
9	OSB board	15	Superfinish ECO
10	Thermal insulation + timber joists 460 x 220	180	Rockwool Rockroll
11	OSB board	15	Superfinish ECO
12	Air gap	90	
13	OSB board	15	Superfinish ECO
14	Vapour barrier	0,25	Jutafol N 140 Special
15	Air gap with timber joists 60 x 40	60	
16	Plasterboard	12,5	

Ceiling



Number	Layer	Thickness [mm]	Specification
1	Final layer - ceramic tiles	10	Rako Tanse
2	Waterproofing	2,4	Sarnafil G 441-24EL
3	OSB board	15	Superfinish ECO
4	Impact sound insulation	20	Dow Ethafoam
5	OSB board	15	Superfinish ECO
6	OSB board	15	Superfinish ECO
7	OSB board	15	Superfinish ECO
8	Air gap with timber joists 60 x 40	60	
9	Plasterboard	12,5	

Floor on air


20
15
20
15
160
15 15
15
100
80
15
80
10
1385
Timber joists 280 x 160
1
2
3
4
5
6
7
8
9
10
11
12
13

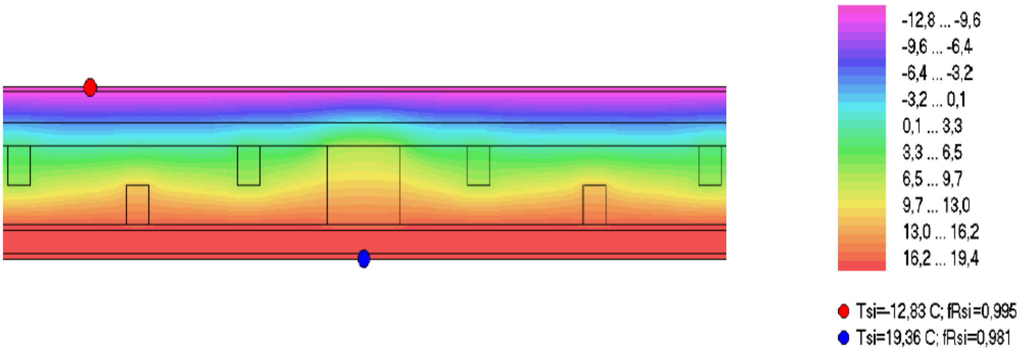
Number	Layer	Thickness [mm]	Specification
1	Final layer - ceramic tiles	10	Rako Tanse
2	Waterproofing	2,4	Sarnafil G 441-24EL
3	OSB board	15	Superfinish ECO
4	Impact sound insulation	20	Dow Ethafoam
5	OSB board	15	Superfinish ECO
6	OSB board	15	Superfinish ECO
7	Thermal insulation + timber joists 280 x 160	160	Rockwool Rocknroll
8	OSB board	15	Superfinish ECO
9	Thermal insulation + timber joists 280 x 160	100	Rockwool Rocknroll
10	OSB board	15	Superfinish ECO
11	Thermal insulation + timber joists 80 x 40	80	Rockwool Fasrock
12	Wooden fibre board	80	Hofatex Therm DK
13	External plaster	10	Tubag Mineralischer Dämmputz

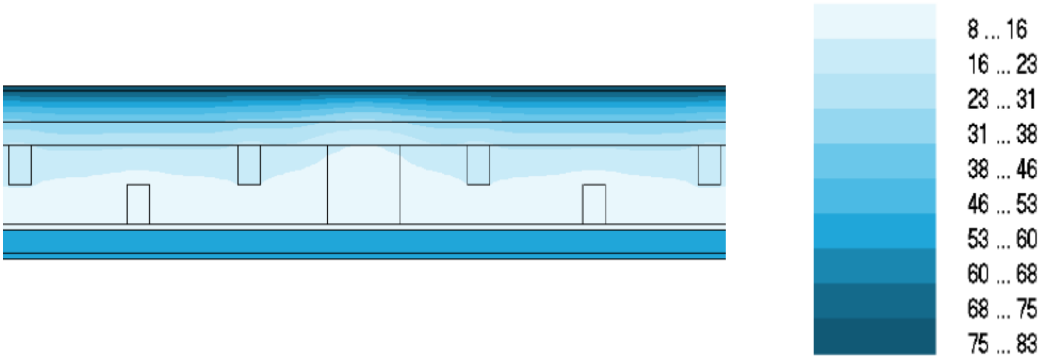
Table 3-8 An overview of the designed timber compositions

3.2.3 Thermal performance of designed compositions

The programme Area 2009 was used for the evaluation of thermal fields and moisture situation. Here are described results for the location of Prague. Design conditions are shown in the *Table 3-3* in the previous chapter. These solutions were made for the steady-state conditions. All the solutions are stated in the *Table 3-9*. The recommended values stated in there show the value recommended by the Czech standardization ČSN 73 0540 for the certain type of structure. Evaluated values are the exact values for each of the compositions. The timber elements that are in each composition were taken in account when evaluating the heat transmittance coefficient. The value of thermal conductivity of each layer was increased by the value thermal conductivity of steel according to the amount and size of used steel elements.

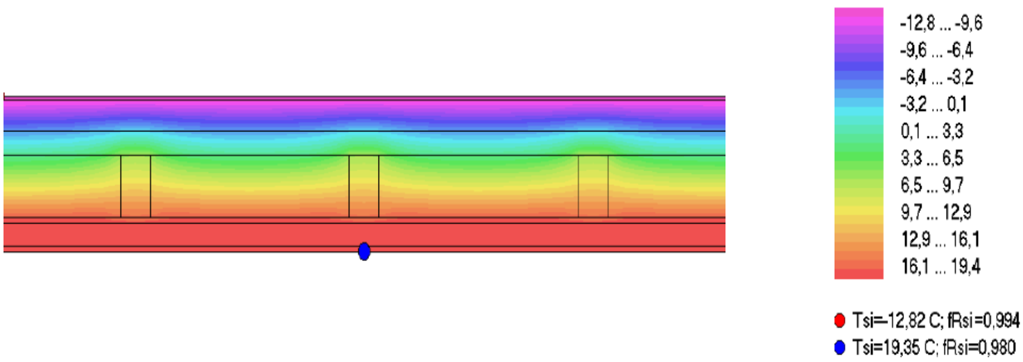
Main wall

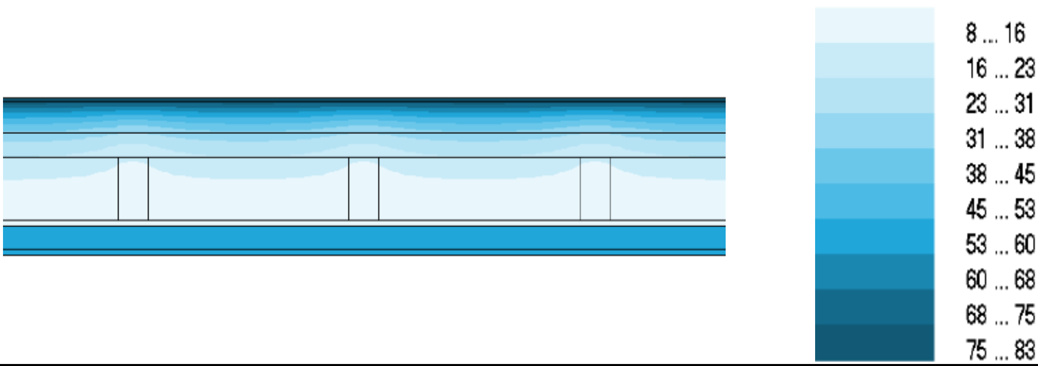




Coefficient of heat transmittance U [W/m^{2}K]	Evaluated	0.15
	Recommended	0,20

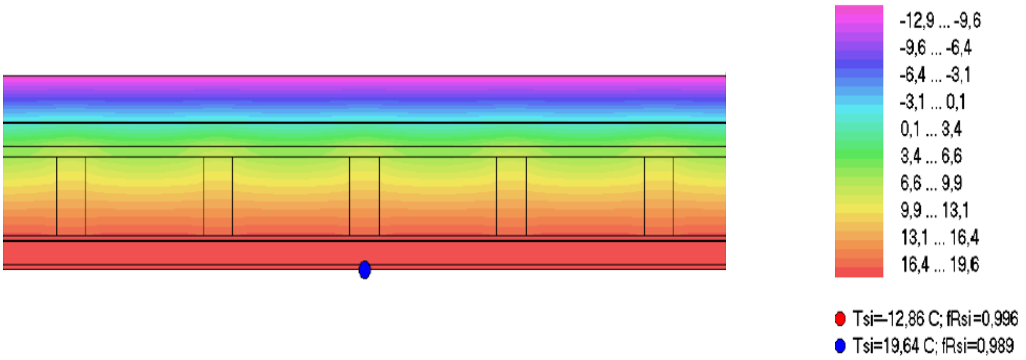
Main wall of the 4th floor

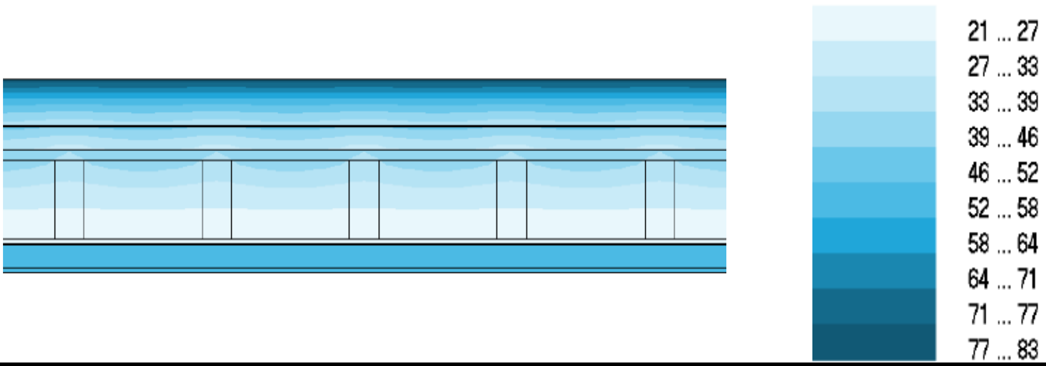




Coefficient of heat transmittance U [W/m^{2}K]	Evaluated	0.15
	Recommended	0,20

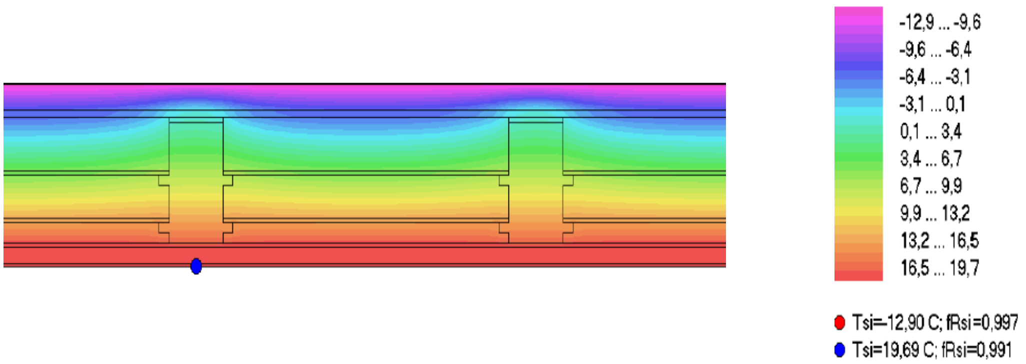
Roof

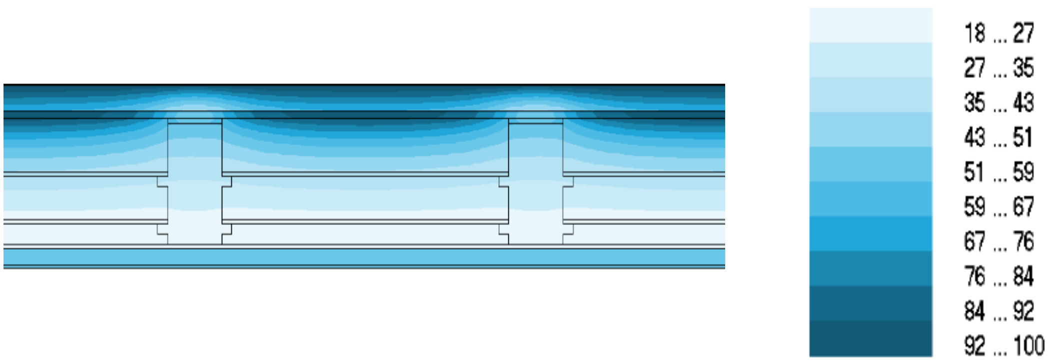




Coefficient of heat transmittance U [W/m²K]		
	Evaluated	0.11
	Recommended	0,16

Terrace





Coefficient of heat transmittance U [W/m²K]		
	Evaluated	0.10
	Recommended	0,16

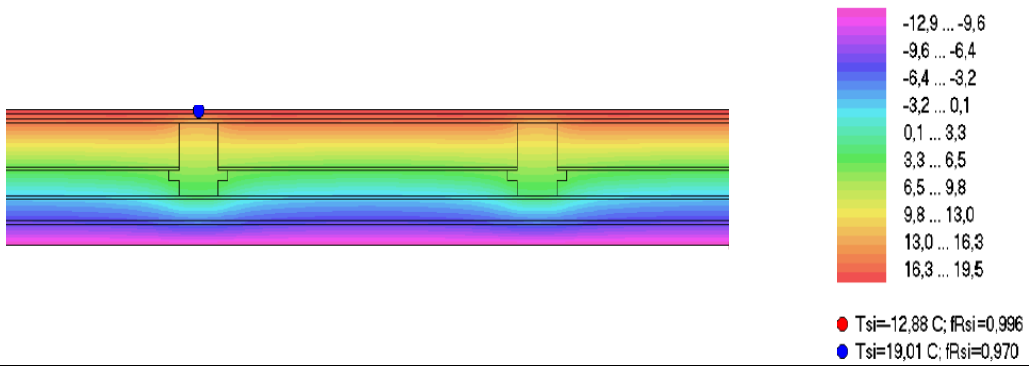
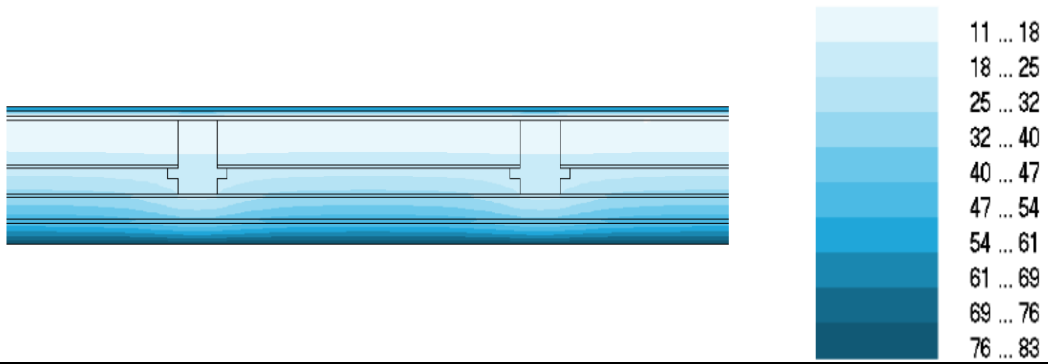
Floor on air		
		
		
Coefficient of heat transmittance U [W/m^{2}K]	Evaluated	0.10
	Recommended	0,16

Table 3-9 Thermal performance of designed compositions for the timber structure variant

3.2.4 Acoustics performance

The sound proof of structures dividing two flats or flats from the corridor was evaluated. The reason why exactly these are evaluated is that there are the highest requests on them.

Composition layers	Thickness [mm]	Values of Airborne sound insulation R_w [dB]
Plasterboard	25	**Requested**
Mineral wool	60	**52**
Gypsum-fibre board	22	
Mineral wool + CW 100 profiles	100	**Evaluated**
Gypsum-fibre board	22	
Mineral wool	60	**52**
Plasterboard	25	

Table 3-10 Values for airborne sound insulation of the timber variant

4.2 Light-weight concrete blocks based structure

4.2.1 Design of the structure

The layout of the original building was also followed when designing this alternative. The basement, the floor with garages and the stairway were kept in reinforced concrete as in the previous variants. For the living part of the building, the load bearing walls and also the inner walls were changed to light-weight concrete blocks. The static evaluation of the load bearing capacity of such a wall can be found in the appendix. The horizontal structures remained in the reinforced concrete, so they are the same like in the previous alternative.

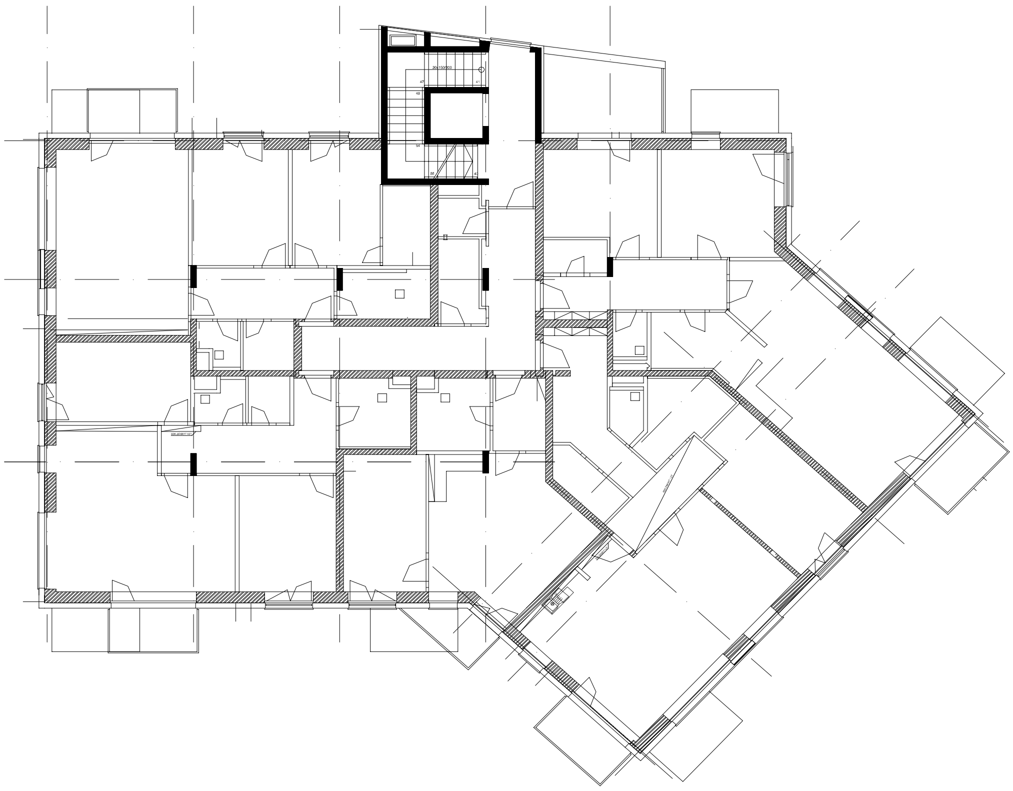


Figure 4.2 Layout of the 2nd and 3rd floor

4.2.2 Description of used compositions

This is an overview of all compositions used for the light-weight concrete structure variant. The aim was kept to get the specific heat consumption of the building about 20 kWh/m^{2}y. There is only the composition of the main wall in this alternative. The other compositions are the same in the reinforced concrete alternative. The composition of the main wall is described in the *Table 4-5* below.

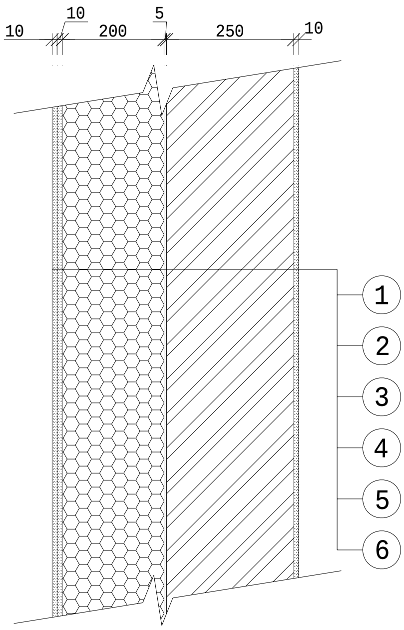
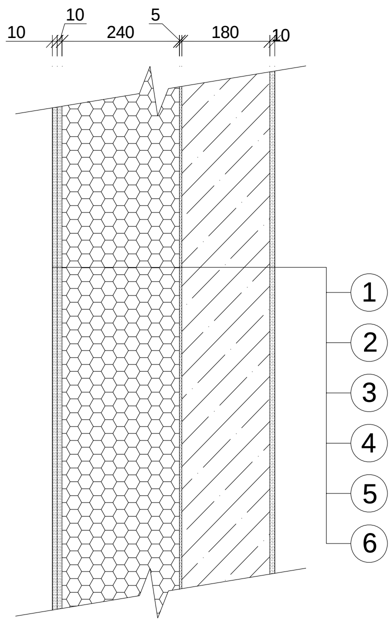
Main wall and main wall of the 4th floor			
			
Number	**Layer**	**Thickness [mm]**	**Specification**
1	External plaster	10	Tubag Mineralischer Dämmputz
2	Reinforcing layer	10	System ETICS
3	Thermal insulation	200	Rockwool Fasrock
4	Glue layer	5	
5	Light-weight concrete blocks	250	YTONG P-4-500
6	Internal plaster	10	Gypsum based

Table 4-5 An overview of the designed light-weight concrete compositions

4.1.2 Description of used compositions

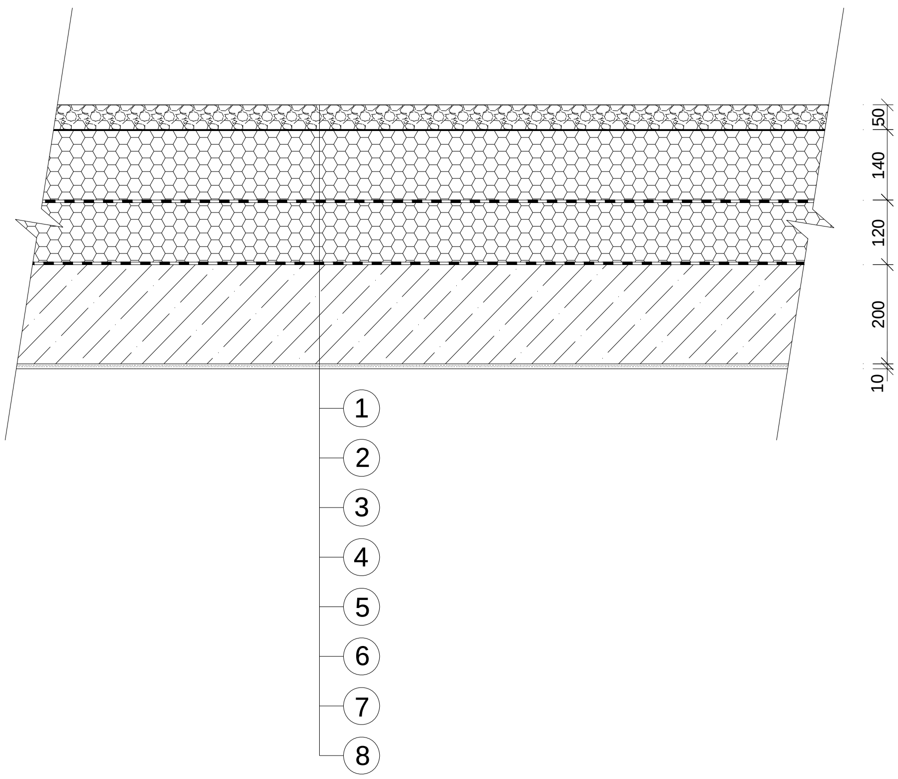
Here is an overview of all compositions designed for the reinforced concrete structure variant. The aim was to get the specific heat consumption of the building about 20 kWh/m^{2}y. The compositions of all variants were done with an idea to get nearly the same values of heat transmission coefficient. Compositions are described in *Table 4-1.*

Main wall and main wall of the 4th floor



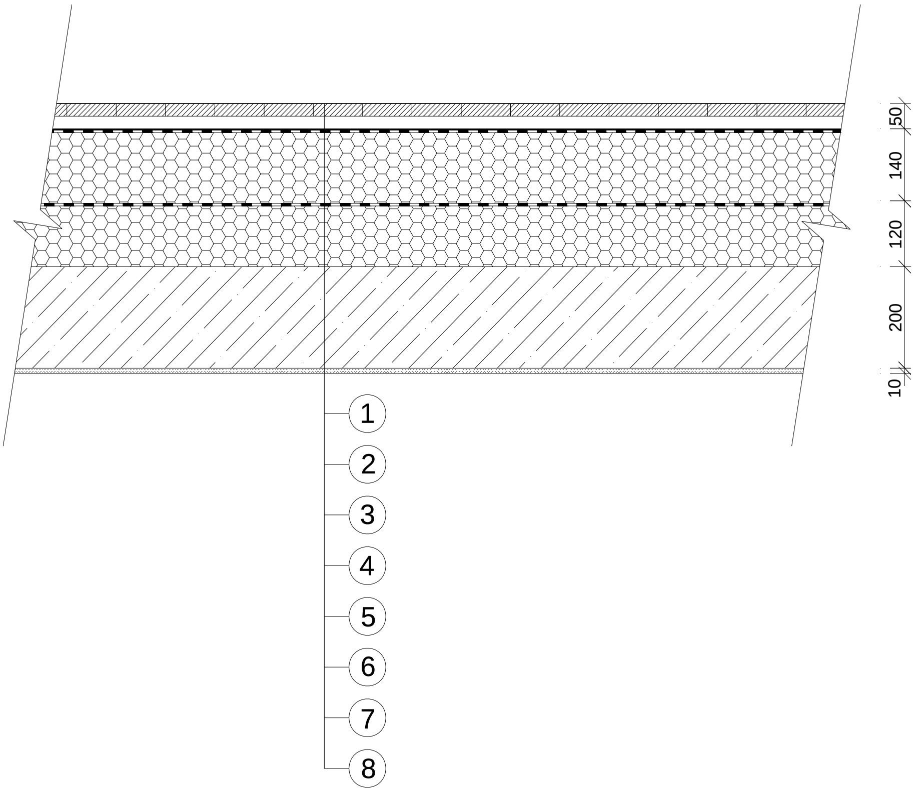
Number	Layer	Thickness [mm]	Specification
1	External plaster	10	Tubag Mineralischer Dämmputz
2	Reinforcing layer	10	System ETICS
3	Thermal insulation	240	Rigips Greywall
4	Glue layer	5	
5	Reinforced concrete	180	
6	Internal plaster	10	Gypsum based

Roof			



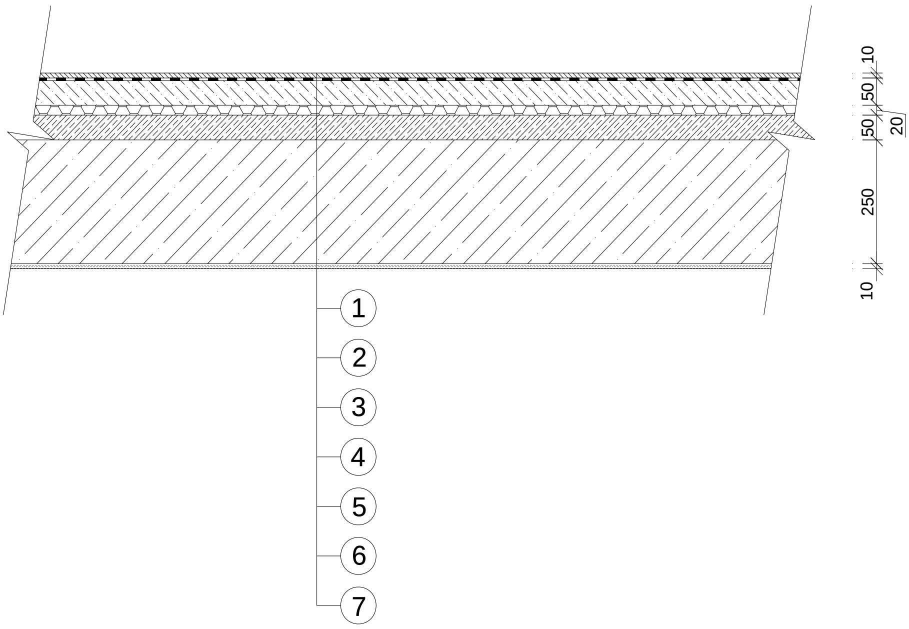
Number	Layer	Thickness [mm]	Specification
1	Gravel	50	
2	Geotextile	0,25	Filtek
3	Thermal insulation	140	Dow Roofmate SL
4	Waterproofing	2,4	Sarnafil G 441-24EL
5	Thermal insulation	80	Dow Roofmate SL
6	Waterproofing	1,2	Sikaplan D
7	Concrete slab	200	Reinforced concrete
8	Internal plaster	10	Gypsum based

Terrace



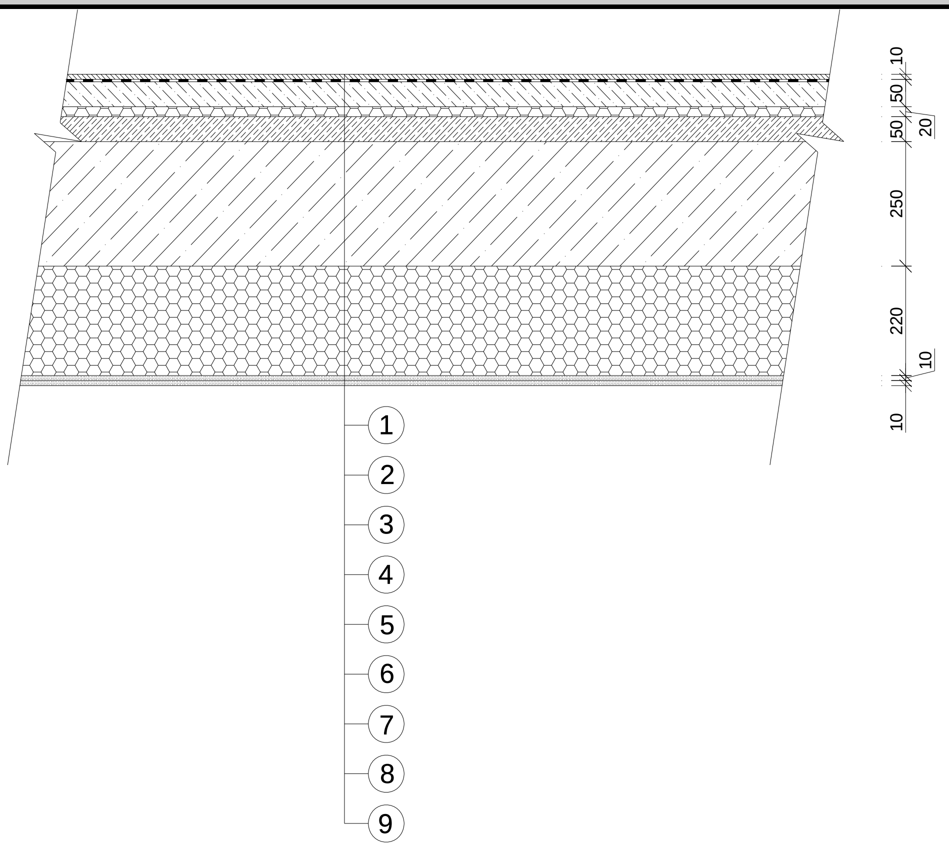
Number	Layer	Thickness [mm]	Specification
1	Final layer - walking coat	50	Parador outdoo;;r classic 7020
2	Geotextile	0,25	Filtek
3	Waterproofing	2,4	Sarnafil G 441-24EL
4	Thermal insulation	140	Dow Roofmate SL
5	Waterproofing	1,2	Sikaplan D
6	Thermal insulation	120	Dow Roofmate SL
7	Concrete slab	200	Reinforced concrete
8	Internal plaster	10	Gypsum based

Ceiling



Number	Layer	Thickness [mm]	Specification
1	Final layer - ceramic tiles	10	Rako Tanse
2	Waterproofing	2,4	Sarnafil G 441-24EL
3	Anhydrite	50	Anhyment AE 20
4	Poriment	50	
5	Impact sound insulation	20	Dow Ethafoam
6	Concrete slab	250	Reinforced concrete
7	Internal plaster	10	Gypsum based

Floor on air

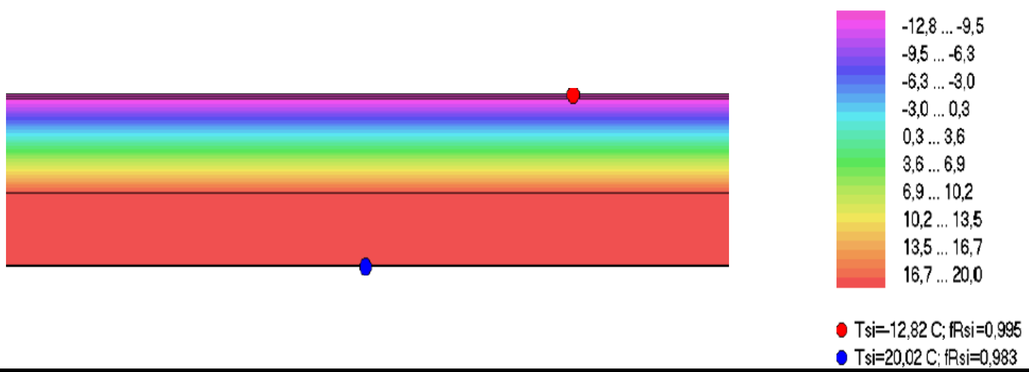
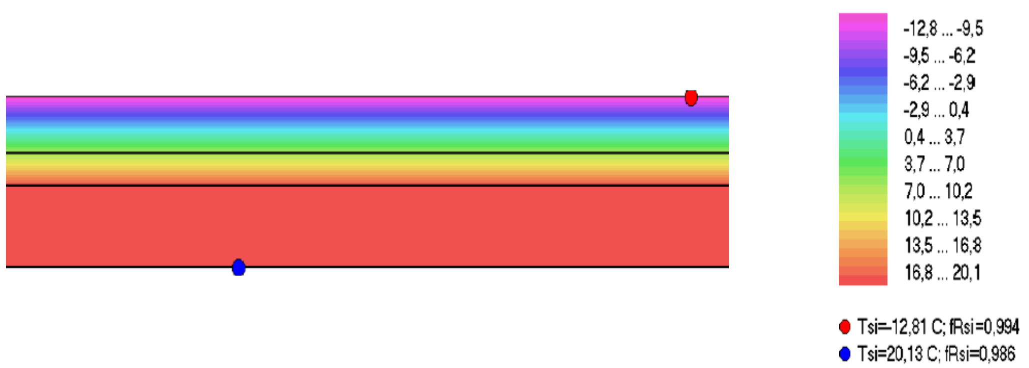


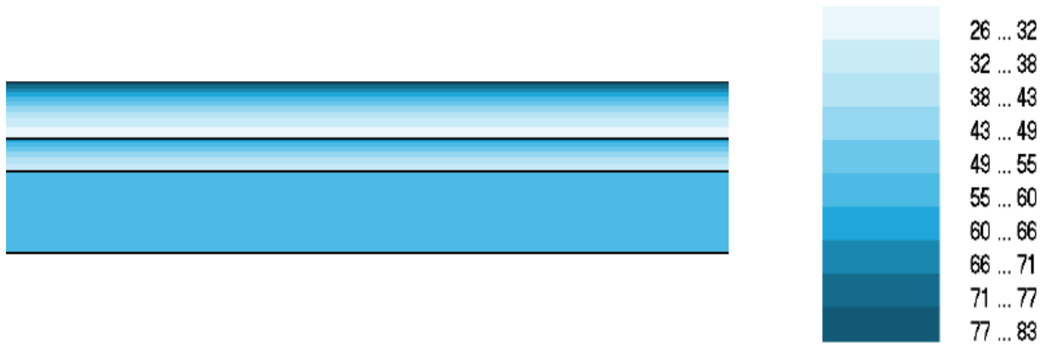
Number	Layer	Thickness [mm]	Specification
1	Final layer - ceramic tiles	10	Rako Tanse
2	Waterproofing	2,4	Sarnafil G 441-24EL
3	Anhydrite	50	Anhyment AE 20
4	Poriment	50	
5	Impact sound insulation	20	Dow Ethafoam
6	Concrete slab	250	Reinforced concrete
7	Thermal insulation	220	Rigips Greywall
8	Reinforcing layer	10	System ETICS
9	External plaster	10	Tubag Mineralischer Dämmputz

Table 4-1 An overview of the designed concrete compositions

4.1.3 Thermal performance of designed compositions

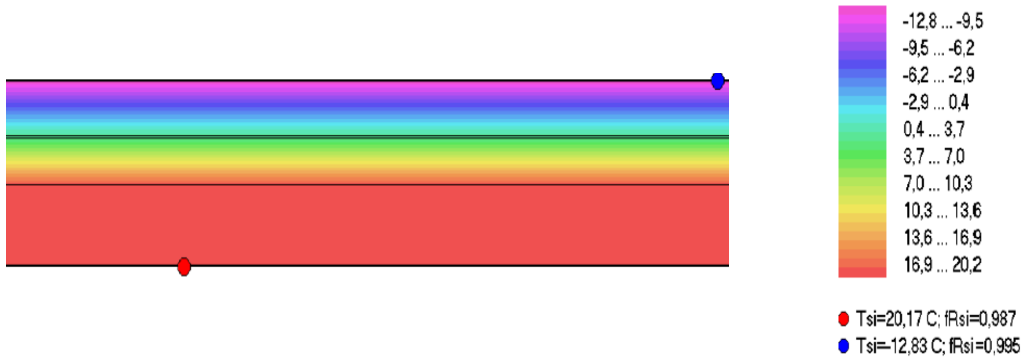
The programme Area 2009 was used for the evaluation of thermal fields and moisture situation. Here are described results for the location of Prague. Design conditions are shown in the *Table 3-3*.. These solutions were made for the steady-state condition. All the solutions are stated in the *Table 4-2*. The recommended values stated in there mean the value recommended by the Czech standardization ČSN 73 0540 for the certain type of the structure. Evaluated values are the exact values for each of the compositions.

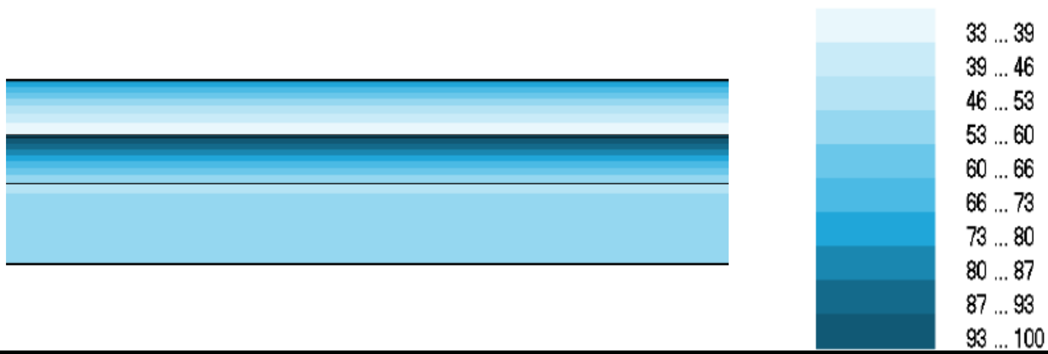
Main wall and main wall of the 4th floor		
		
		
Coefficient of heat transmittance U [W/m²K]	Evaluated Recommended	0.15 0,24
Roof		
		



Coefficient of heat transmittance U [W/m²K]	Evaluated	0.12
	Recommended	0,20

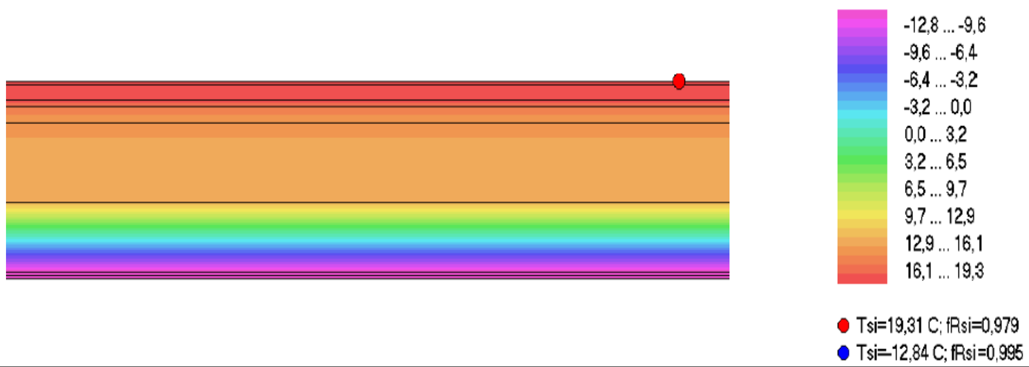
Terrace

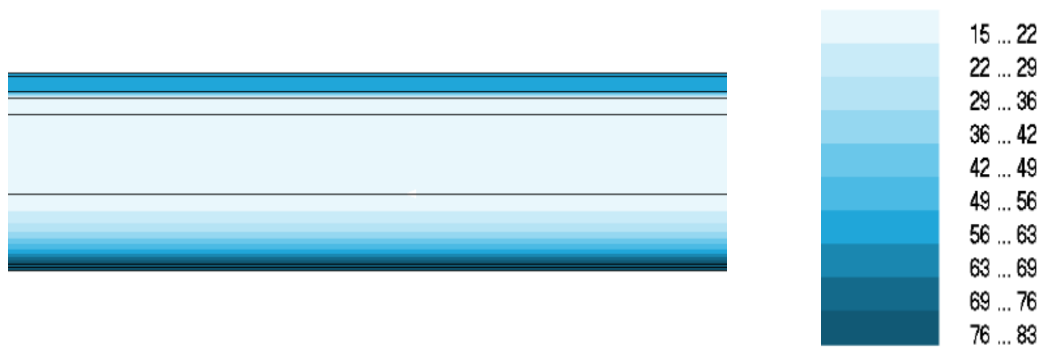




Coefficient of heat transmittance U [W/m²K]	Evaluated	0.12
	Recommended	0,20

Floor on air





Coefficient of heat transmittance U [W/m^{2}K]	Evaluated	0.12
	Recommended	0,20

Table 4-2 Thermal performance of designed compositions for the concrete structure variant

4.1.4 Acoustics performance

The sound proof of structures dividing two flats or flats from the corridor was evaluated. The reason why exactly these are evaluated is that there are the highest requests on them. The partition between two flats or between a flat and a corridor has to fulfil the request of 52 dB on airborne sound insulation. The request for ceiling is that the maximal level of impact sound must be lower than 58 dB. These requests are stated according to the Czech standardisation ČSN EN ISO 717. The programme Neprůzvučnost was used for the evaluation. Results are show in Tables 4-3 and 4-4 below.

Composition layers	Thickness [mm]	Values of Airborne sound insulation R_w [dB]
Reinforced concrete	200	**Requested**
		52
		Evaluated
		55

Table 4-3 Values for airborne sound insulation of the concrete variant

Composition layers	Thickness [mm]	Values of impact sound level L_{nw} [dB]
Anhydrite	50	**Requested**
Poriment	50	**58**
Impact sound insulation	20	**Evaluated**
Concrete slab	250	**27**

Table 4-4 Values for impact sound level of the concrete variant

4.2 Light-weight concrete blocks based structure

4.2.1 Design of the structure

The layout of the original building was also followed when designing this alternative. The basement, the floor with garages and the stairway were kept in reinforced concrete as in the previous variants. For the living part of the building, the load bearing walls and also the inner walls were changed to light-weight concrete blocks. The static evaluation of the load bearing capacity of such a wall can be found in the appendix. The horizontal structures remained in the reinforced concrete, so they are the same like in the previous alternative.

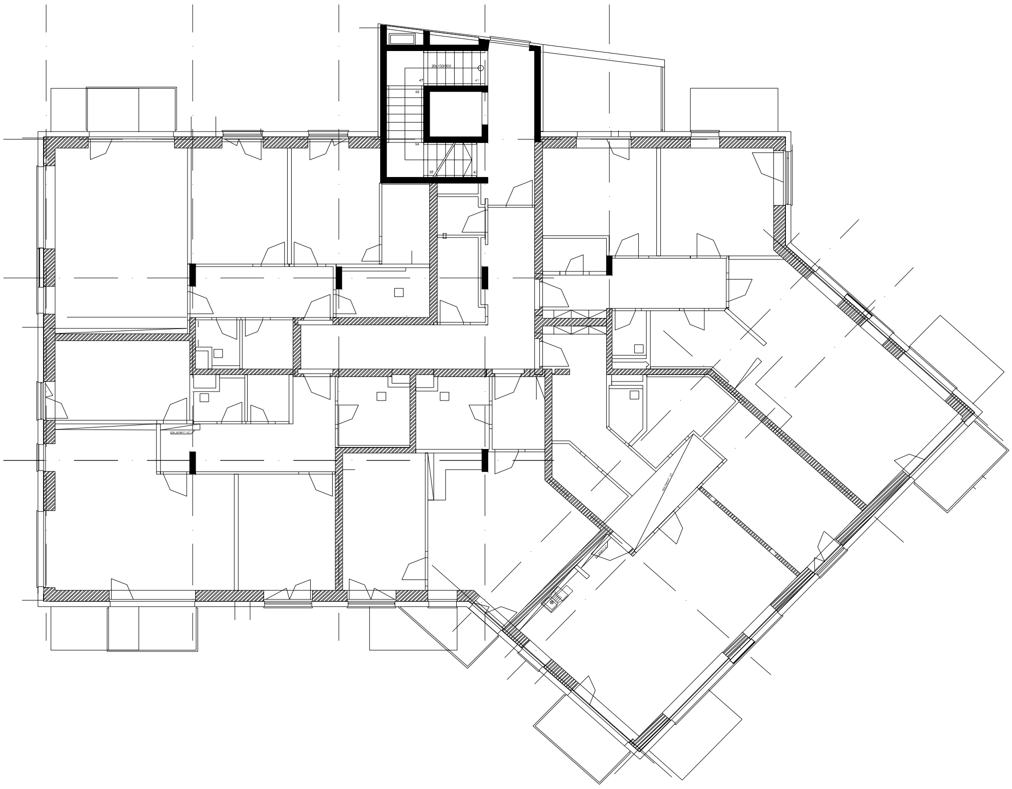
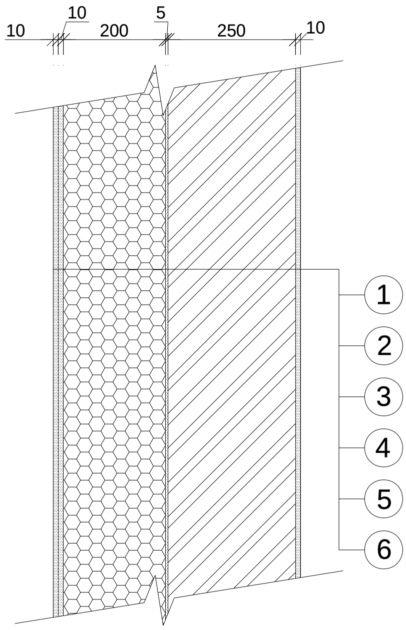


Figure 4.2 Layout of the 2nd and 3rd floor

4.2.2 Description of used compositions

This is an overview of all compositions used for the light-weight concrete structure variant. The aim was kept to get the specific heat consumption of the building about 20 kWh/m^{2}y. There is only the composition of the main wall in this alternative. The other compositions are the same in the reinforced concrete alternative. The composition of the main wall is described in the *Table 4-5* below.

Main wall and main wall of the 4th floor



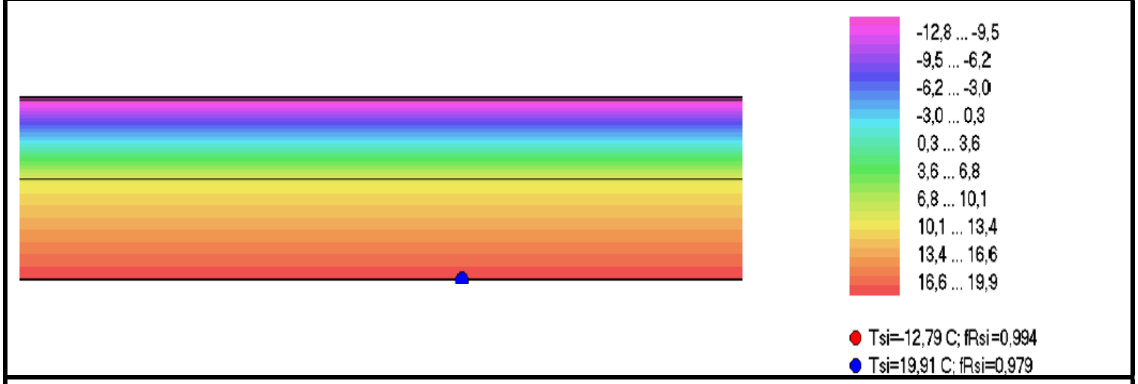
Number	Layer	Thickness [mm]	Specification
1	External plaster	10	Tubag Mineralischer Dämmputz
2	Reinforcing layer	10	System ETICS
3	Thermal insulation	200	Rockwool Fasrock
4	Glue layer	5	
5	Light-weight concrete blocks	250	YTONG P-4-500
6	Internal plaster	10	Gypsum based

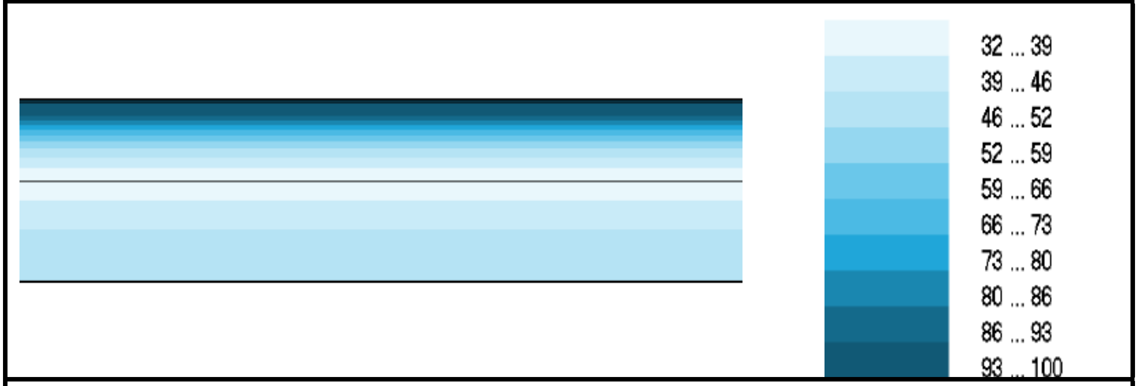
Table 4-5 An overview of the designed light-weight concrete compositions

4.2.3 Thermal performance of designed compositions

The programme Area 2009 was used for the evaluation of thermal fields and moisture situation. Here are described results for the location of Prague. Design conditions are shown in the *Table 3-3*.. These solutions were made for the steady-state conditions. All the solutions are stated in the *Table 4-4*. The recommended values stated in there mean the value recommended by the czech standardization ČSN 73 0540 for the certain type of the structure. Evaluated values are the exact values for each of the compositions.

Main wall + 4th floor wall





Coefficient of heat transmittance U [W/m²K]	Evaluated	0.15
	Recommended	0,25

Table 4-6 Thermal performance of designed compositions for the light-weight concrete structure variant

4.2.4 Acoustics performance

The sound proof of structures dividing two flats or flats from the corridor was evaluated. The reason why exactly these are evaluated is that there are the highest requests on them. The partition between two flats or between a flat and a corridor has to fulfil the request of 52 dB on airborne sound insulation. The request for ceiling is that the maximal level of impact sound must be lower than 58 dB. These requests are stated according to the Czech standardisation ČSN EN ISO 717. The programme Neprůzvučnost was used for the evaluation. Results are show in Tables 4-7 and 4-8 below.

Composition layers	Thickness [mm]	Values of Airborne sound insulation R_w [dB]
Plasterboard	15	**Requested**
Mineral wool	50	**52**
Light-weight concrete	200	
Mineral wool	50	**Evaluated**
Plasterboard	15	**52**

Table 4-7 Values for airborne sound insulation of the light-weight concrete variant

Composition layers	Thickness [mm]	Values of impact sound level L_{nw} [dB]
Anhydrite	50	**Requested**
Poriment	50	**58**
Impact sound insulation	20	**Evaluated**
Concrete slab	250	**27**

Table 4-8 Values for impact sound level of the light-weight concrete variant

5 Evaluation of the energy consumption

There is a description of energy consumption evaluated for each alternative and for the original building in this chapter. To do this, the building was divided into two zones: the living part with flats (zone 1) and the stairway (zone 2). Temperature used for calculation of the energy demand for heating was for the living part of the building 20,0 °C and for the stairway 13,0 °C. Garages in the basement were stated as an unheated space (5,0 °C) which is separated from the main part of the building by the floor in the lowest storey. Temperature used for the calculation of the energy demand for cooling was 26 °C.

For all options natural gas is assumed to be as a energy source for heating. Furthermore, the wooden windows with double glazing and coefficient of heat transmittance of 1,2 W/m^2K. The evaluation was made in the programme Energie 2010 for the conditions of Prague – the Czech Republic. Energy consumptions and values used for the evaluation are described for each variant separately.

5.1 Evaluation of the original building

There is a presumption of natural ventilation in the evaluation of the energy consumption of the original building. Multiplicity of air exchange 0,5 1/h is considered for the natural ventilation. This is a minimal value according to the valid standards. This value was chosen, although the intensity can be higher in the reality. Basic values used in the evaluation itself are described in the *Table 5-1* below. Further, there are shown values of heat losses and energy consumptions.

Total volume of the original building Q_{tot}		6 800	m^3
Total floor area of the original building A_{tot}		2 064	m^2
The average heat transmittance coefficient for the building envelope U_{em}		0.44	W/m^2K
Heat capacity of indoor mass C_m	zone 1	518	$kJ/(Km^2)$
	zone 2	565	$kJ/(Km^2)$
Indoor temperature T_i	zone 1	20	°C
	zone 2	13	°C

Table 5-1 Basic values used in the evaluation of energy consumption of the original building. Evaluation of heat capacity of indoor mass can be found in the appendix. Layer of 100 mm of all structures that are in the contact with indoor air was taken in account. The final value was reached by dividing the heat capacity by the total floor area.

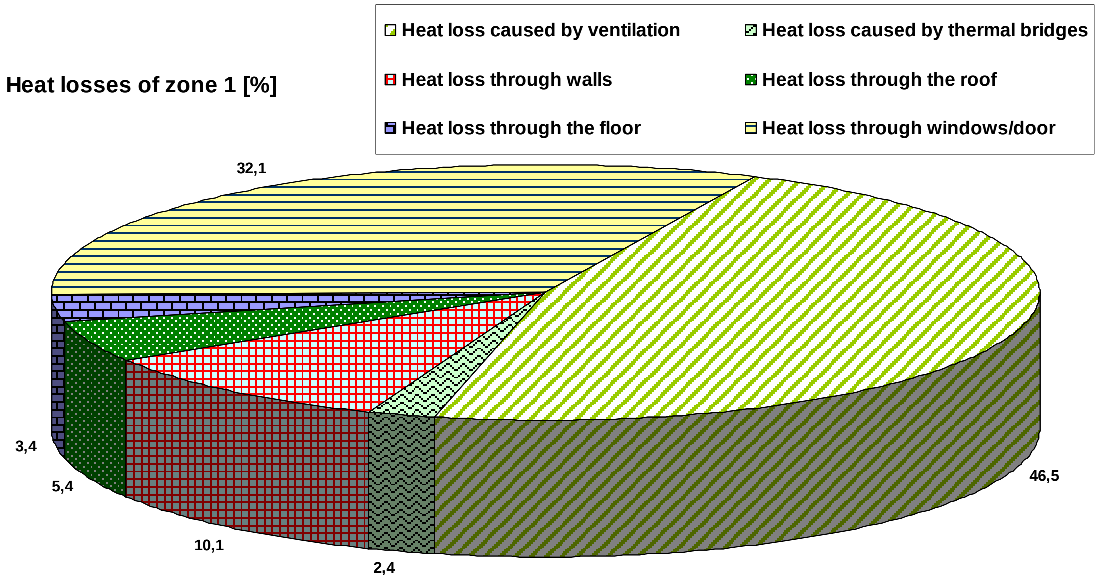


Figure 5.1 Heat losses of the zone 1

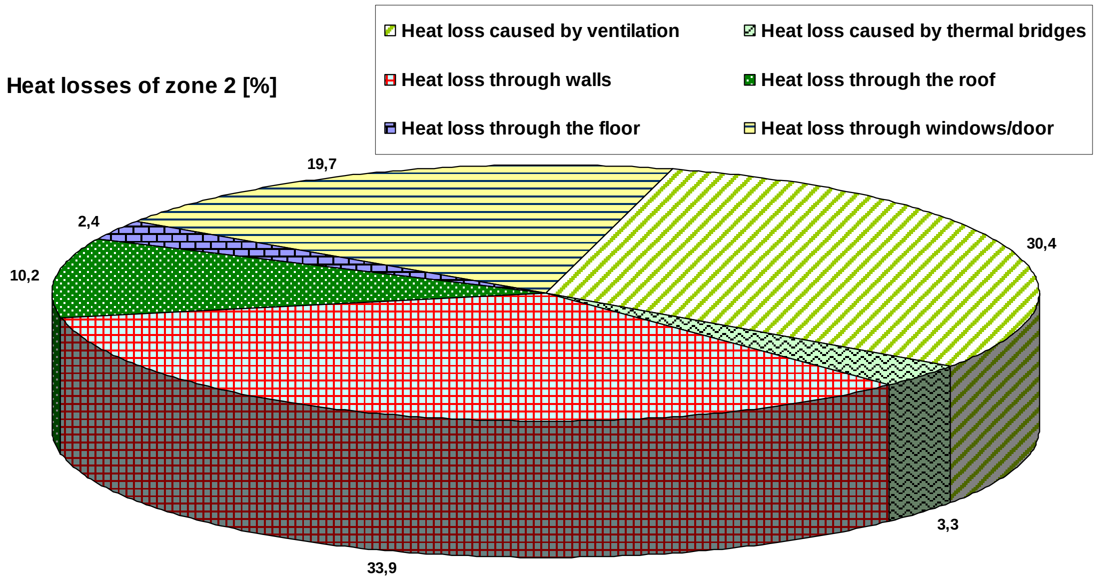


Figure 5.2 Heat losses of the zone 2

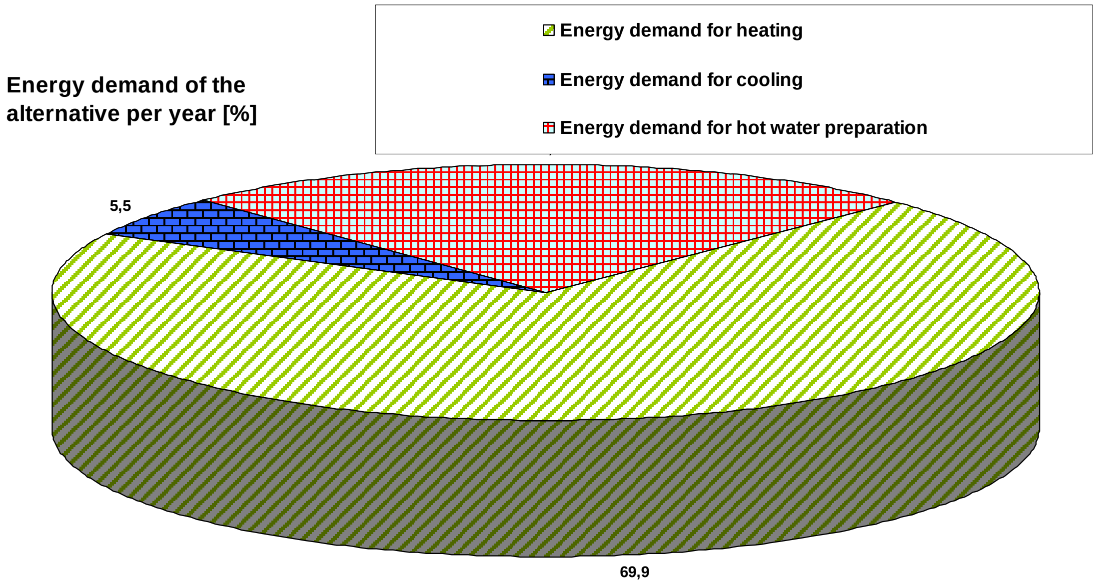


Figure 5.3 Total energy demand of the original building

Specific heat consumption for heating $Q_{h,nd}$	319	GJ	43	kWh/(m^2.y)
Energy demand for heating per year $E_{P,H}$	380	GJ	51	kWh/m^2
Energy demand for cooling per year $E_{C,H}$	33	GJ	4	kWh/m^2
Energy demand for hot water preparation $E_{P,W}$	132	GJ	18	kWh/m^2
Total energy needed $E_{P,A}$	545	GJ	73	kWh/m^2

Table 5-2 Energy consumption of the original building

5.2 Evaluation of the steel variant

There is a presumption of mechanical ventilation in evaluation of the energy consumption of the steel variant. Considered efficiency of the heat recovery is 70%. Basic values used in the evaluation itself are described in the *Table 5-3* below. Further, there are shown values of heat losses and energy consumptions. The energy consumption of fans for mechanical ventilation was calculated separately and is stated in the appendix.

Total volume of the assessed building Q_{tot}		6 800	m^3
Total floor area of the assessed building A_{tot}		2064	m^2
The average heat transmittance coefficient for the building envelope U_{em}		0.40	W/m^2K
Heat capacity of indoor mass C_m	zone 1	156	$kJ/(Km^2)$
	zone 2	565	$kJ/(Km^2)$
Indoor temperature T_i	zone 1	20	°C
	zone 2	13	°C

Table 5-3 Basic values used in the evaluation of energy consumption of the steel alternative
Evaluation of heat capacity of indoor mass can be found in the appendix. Layer of 100 mm of all structures that are in the contact with indoor air was taken in account. The final value was reached by dividing the heat capacity by the total floor area.

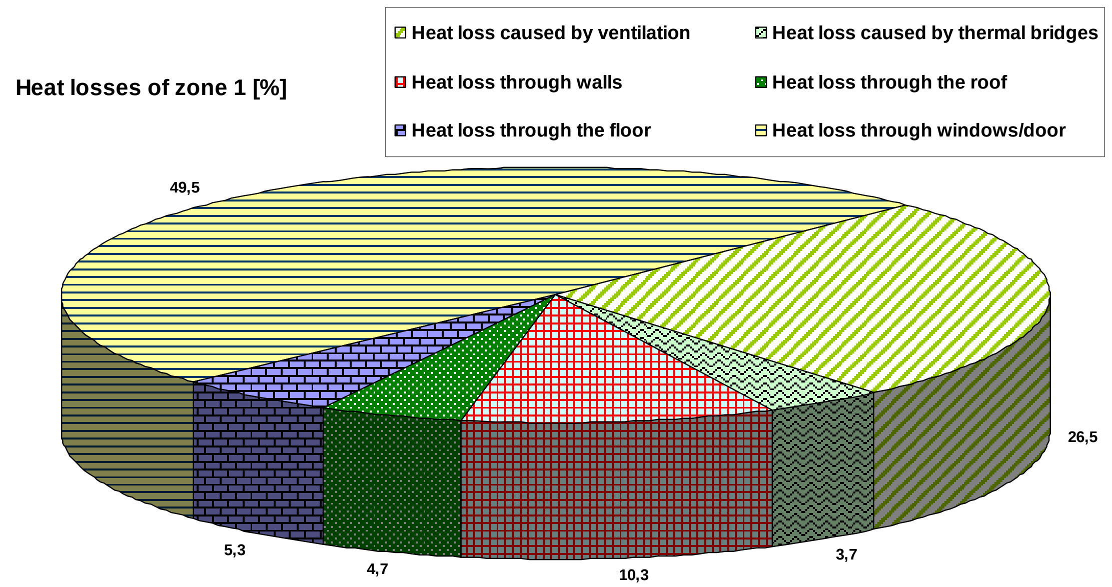


Figure 5.4 Heat losses of the zone 1

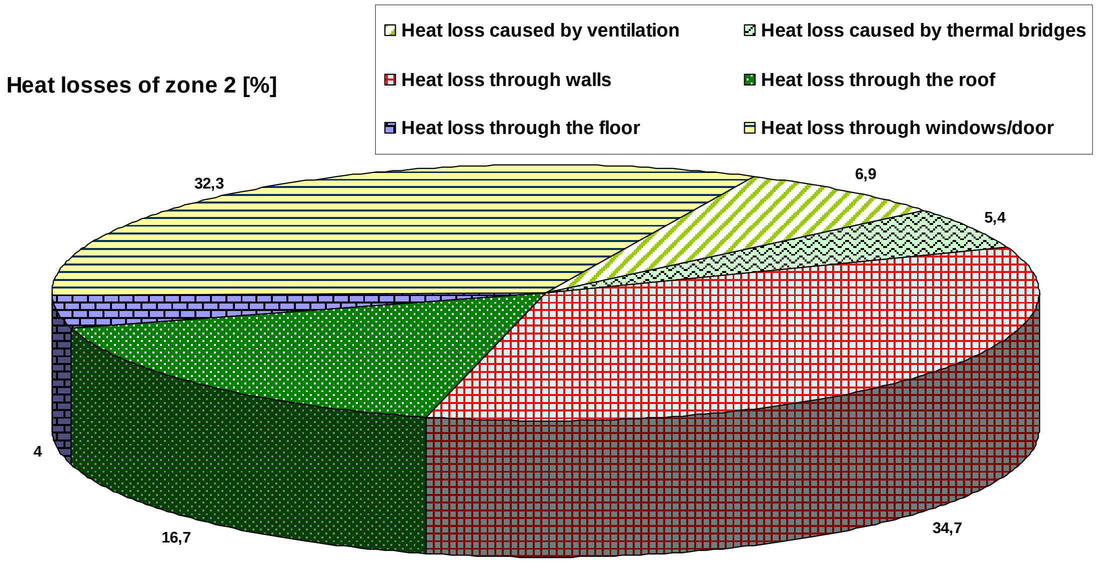


Figure 5.5 Heat losses of the zone 2

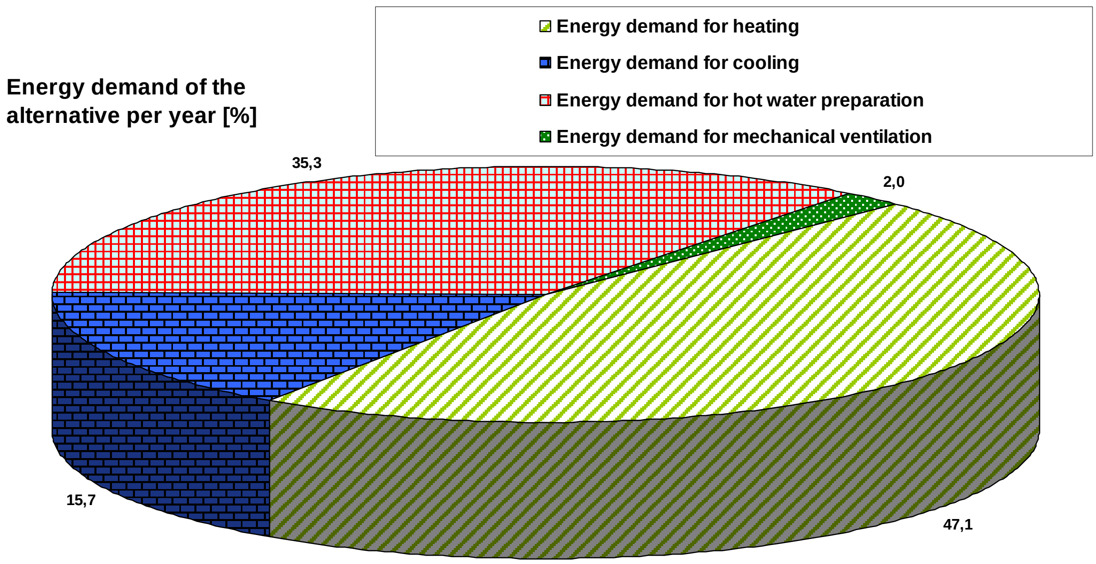


Figure 5.6 Total energy demand of the steel variant

Specific heat consumption for heating $Q_{h,nd}$	150	GJ	20	kWh/(m^2.y)
Energy demand for heating per year $E_{P,H}$	179	GJ	24	kWh/m^2
Energy demand for cooling per year $E_{C,H}$	61	GJ	8	kWh/m^2
Energy demand for mechanical ventilation $E_{P,F}$	24	GJ	3	kWh/m^2
Energy demand for hot water preparation $E_{P,W}$	132	GJ	18	kWh/m^2
Total energy needed $E_{P,A}$	396	GJ	53	kWh/m^2

Table 5-4 Energy consumption of the steel variant

5.3 Evaluation of the timber variant

There is a presumption of mechanical ventilation in the evaluation of the energy consumption for the timber variant. Efficiency of heat recovery is 70%. Basic values used in the evaluation itself are described in the *Table 5-5* below. Further, there are shown values of heat losses and energy consumptions. The energy consumption of fans for mechanical ventilation was calculated separately and is stated in the appendix.

Total volume of the assessed building Q_{tot}		6 800	m^3
Total floor area of the assessed building A_{tot}		2064	m^2
The average heat transmittance coefficient for the building envelope U_{em}		0.40	W/m^2K
Heat capacity of indoor mass C_m	zone 1	120	$kJ/(Km^2)$
	zone 2	565	$kJ/(Km^2)$
Indoor temperature T_i	zone 1	20	°C
	zone 2	13	°C

Table 5-5 Basic values used in the evaluation of energy consumption of the timber alternative
Evaluation of heat capacity of indoor mass can be found in the appendix. Layer of 100 mm of all structures that are in the contact with indoor air was taken in account. The final value was reached by dividing the heat capacity by the total floor area

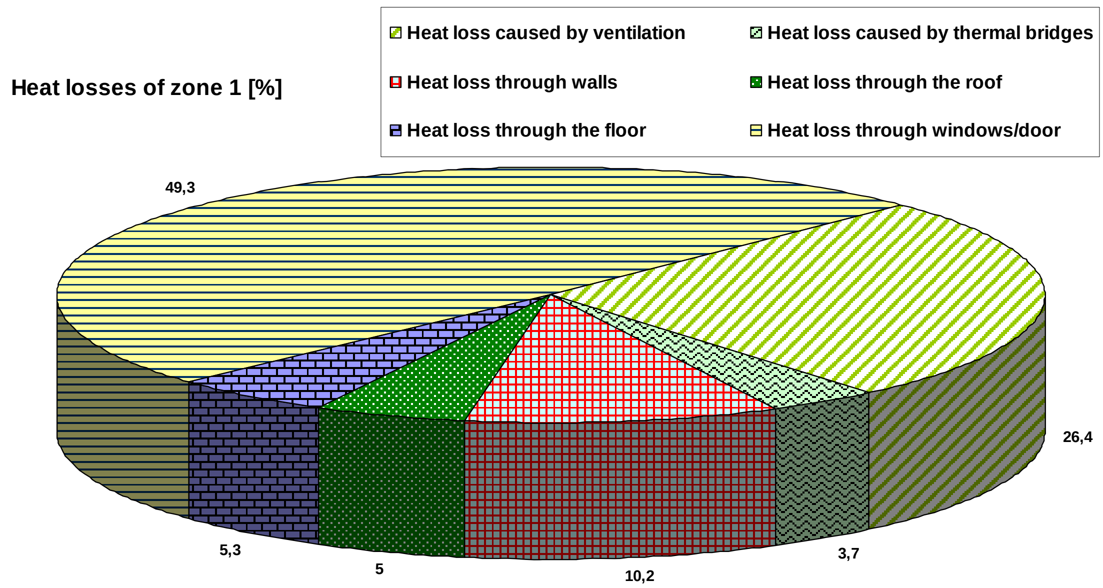


Figure 5.7 Heat losses of the zone 1

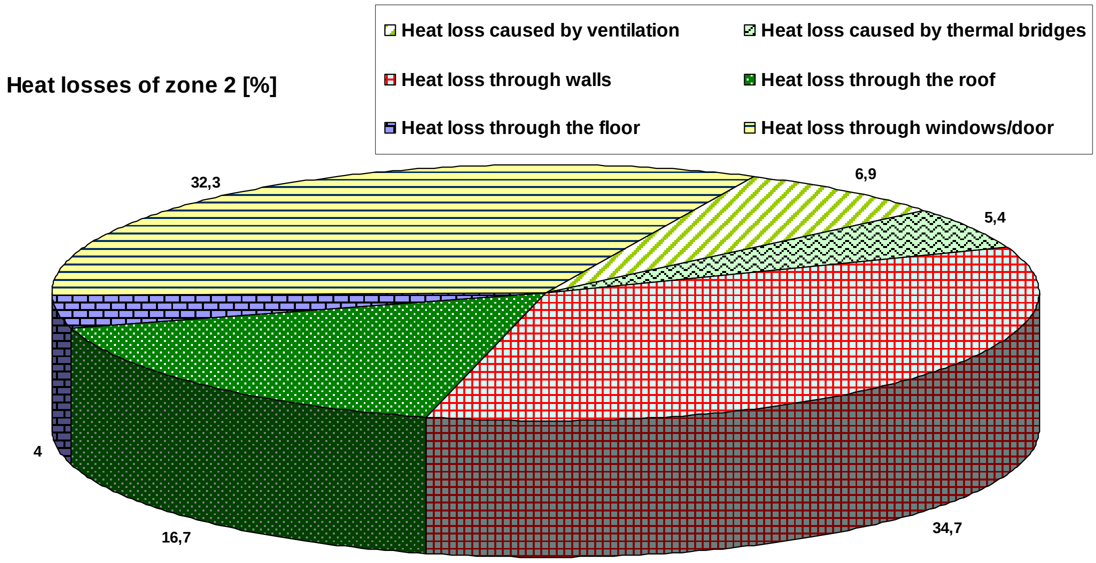


Figure 5.8 Heat losses of the zone 2

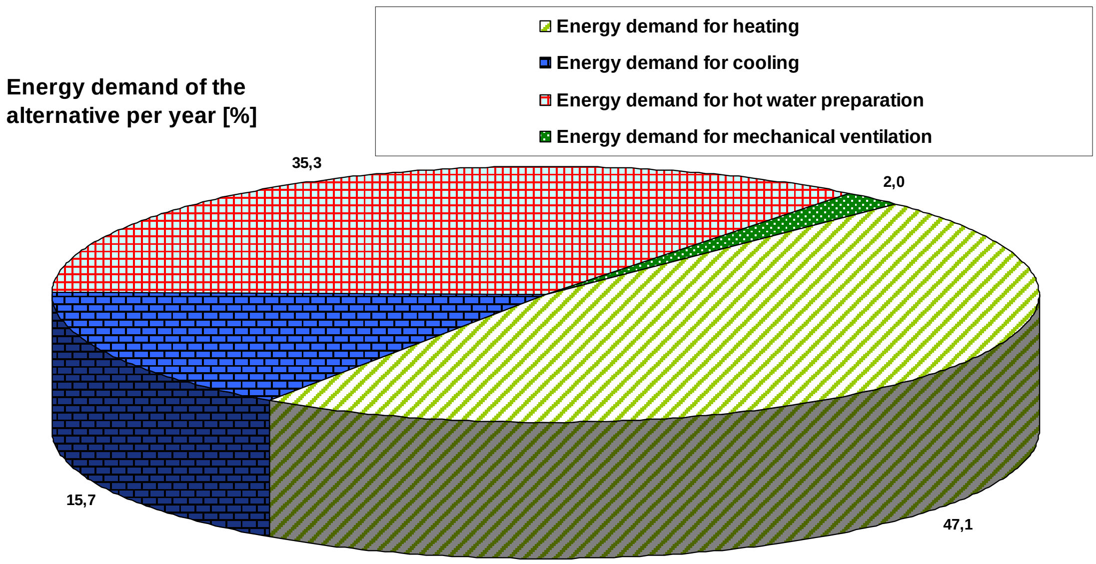


Figure 5.9 Total energy demand of the timber variant

Specific heat consumption for heating $Q_{h,nd}$	155	GJ	21	kWh/(m^2.y)
Energy demand for heating per year $E_{P,H}$	185	GJ	25	kWh/m^2
Energy demand for cooling per year $E_{C,H}$	63	GJ	8	kWh/m^2
Energy demand for mechanical ventilation $E_{P,F}$	24	GJ	3	kWh/m^2
Energy demand for hot water preparation $E_{P,W}$	132	GJ	18	kWh/m^2
Total energy needed $E_{P,A}$	404	GJ	54	kWh/m^2

Table 5-6 Energy consumption of the timber variant

5.4 Evaluation of the concrete variant

There is a presumption of mechanical ventilation in the evaluation of the energy consumption for the concrete variant. Efficiency of heat recovery is 70%. Basic values used in the evaluation itself are described in the *Table 5-7* below. Further, there are shown values of heat losses and energy consumptions. The energy consumption of fans for mechanical ventilation was calculated separately and is stated in the appendix.

Total volume of the assessed building Q_{tot}		6 800	m^3
Total floor area of the assessed building A_{tot}		2064	m^2
The average heat transmittance coefficient for the building envelope U_{em}		0.40	W/m^2K
Heat capacity of indoor mass C_m	zone 1	518	$kJ/(Km^2)$
	zone 2	565	$kJ/(Km^2)$
Indoor temperature T_i	zone 1	20	°C
	zone 2	13	°C

Table 5-7 Basic values used in the evaluation of the energy consumption of the concrete alternative Evaluation of heat capacity of indoor mass can be found in the appendix. Layer of 100 mm of all structures that are in the contact with indoor air was taken in account. The final value was reached by dividing the heat capacity by the total floor area

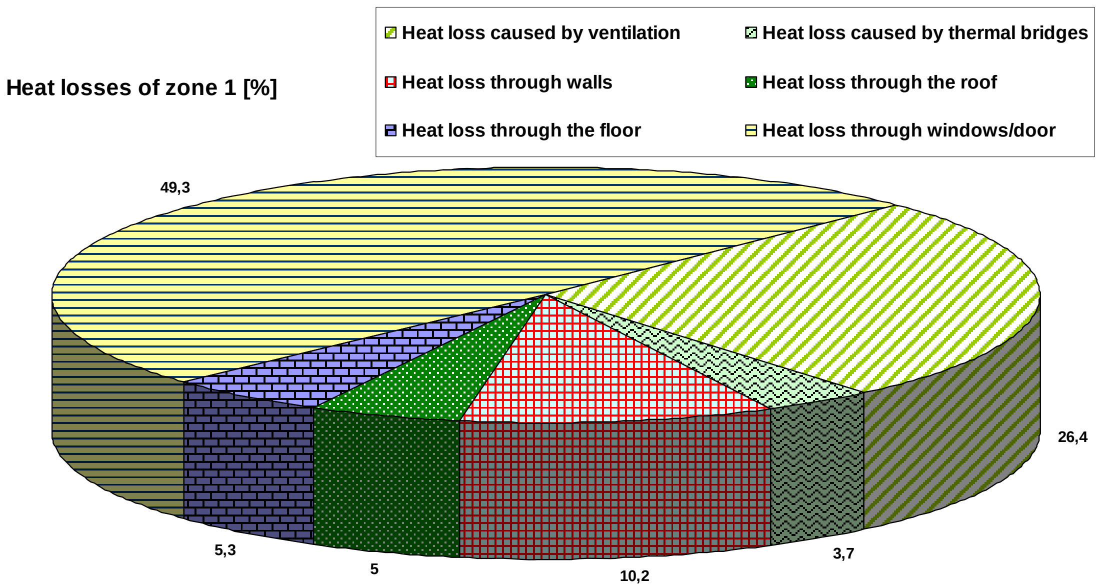


Figure 5.10 Heat losses of the zone 1

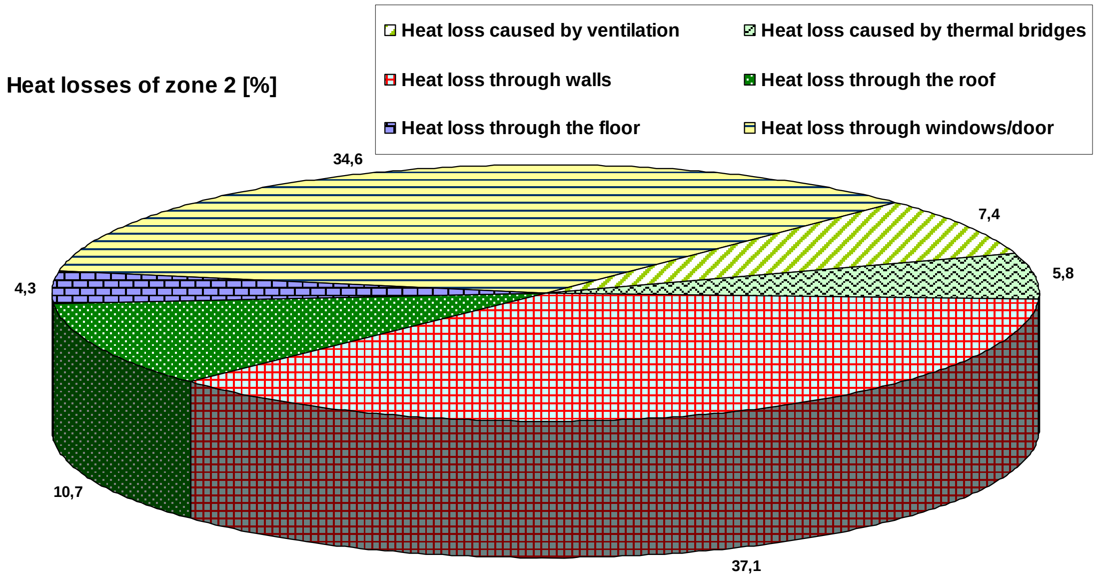


Figure 5.11 Heat losses of the zone 2

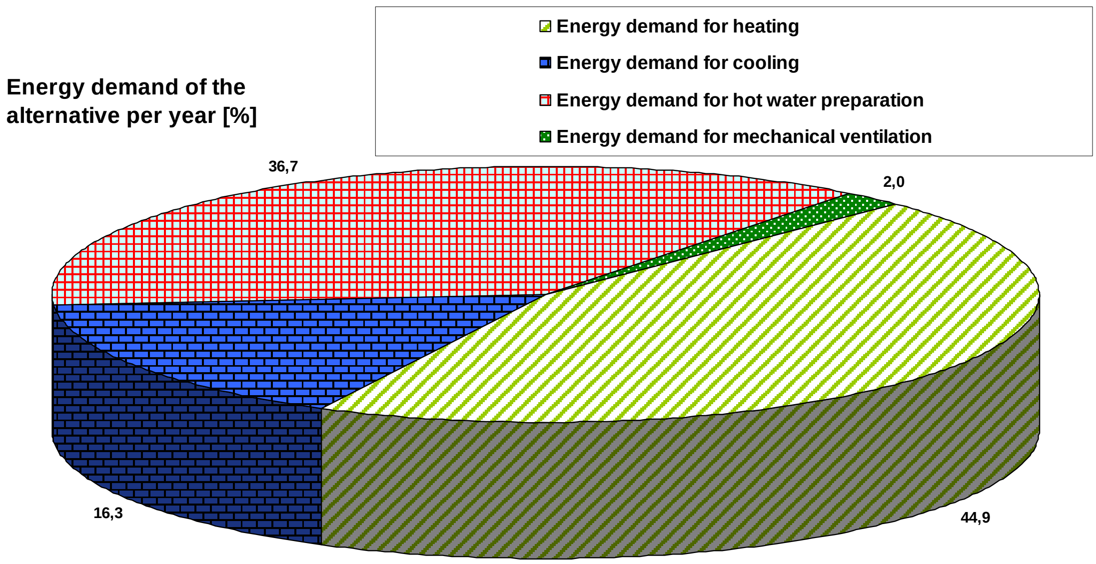


Figure 5.12 Total energy demand of the concreter variant

Specific heat consumption for heating $Q_{h,nd}$	143	GJ	19	$kWh/(m^2.y)$
Energy demand for heating per year $E_{P,H}$	170	GJ	23	kWh/m^2
Energy demand for cooling per year $E_{C,H}$	57	GJ	8	kWh/m^2
Energy demand for mechanical ventilation $E_{P,F}$	24	GJ	3	kWh/m^2
Energy demand for hot water preparation $E_{P,W}$	132	GJ	18	kWh/m^2
Total energy needed $E_{P,A}$	383	GJ	52	kWh/m^2

Table 5-8 Energy consumption of the concrete variant

5.5 Evaluation of the light-weight concrete variant

There is a presumption of mechanical ventilation in evaluation of energy consumption for the reference building. Efficiency of heat recovery is 70%. Basic values used in the evaluation itself are described in the *Table 5-9* below. Further, there are shown values of heat losses and energy consumptions. The energy consumption of fans for mechanical ventilation was calculated separately and is stated in the appendix.

Total volume of the assessed building Q_{tot}		6 800	m^3
Total floor area of the assessed building A_{tot}		2064	m^2
The average heat transmittance coefficient for the building envelope U_{em}		0.40	W/m^2K
Heat capacity of indoor mass C_m	zone 1	327	$kJ/(Km^2)$
	zone 2	565	$kJ/(Km^2)$
Indoor temperature T_i	zone 1	20	°C
	zone 2	13	°C

Table 5-9 Basic values used in the evaluation of the energy consumption of the LW concrete alternative Evaluation of heat capacity of indoor mass can be found in the appendix. Layer of 100 mm of all structures that are in the contact with indoor air was taken in account. The final value was reached by dividing the heat capacity by the total floor area

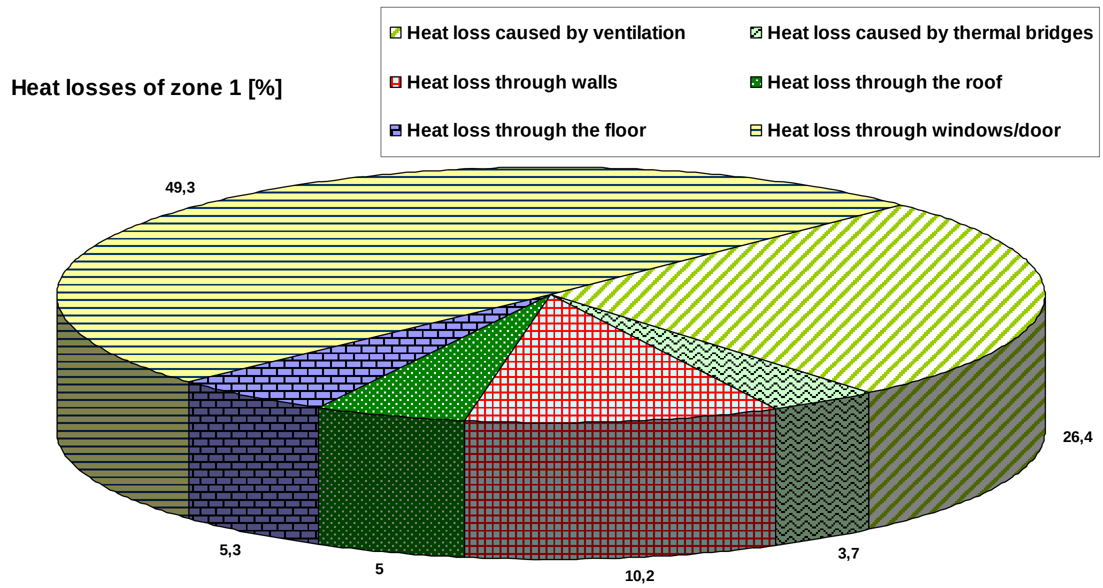


Figure 5.13 Heat losses of the zone 1

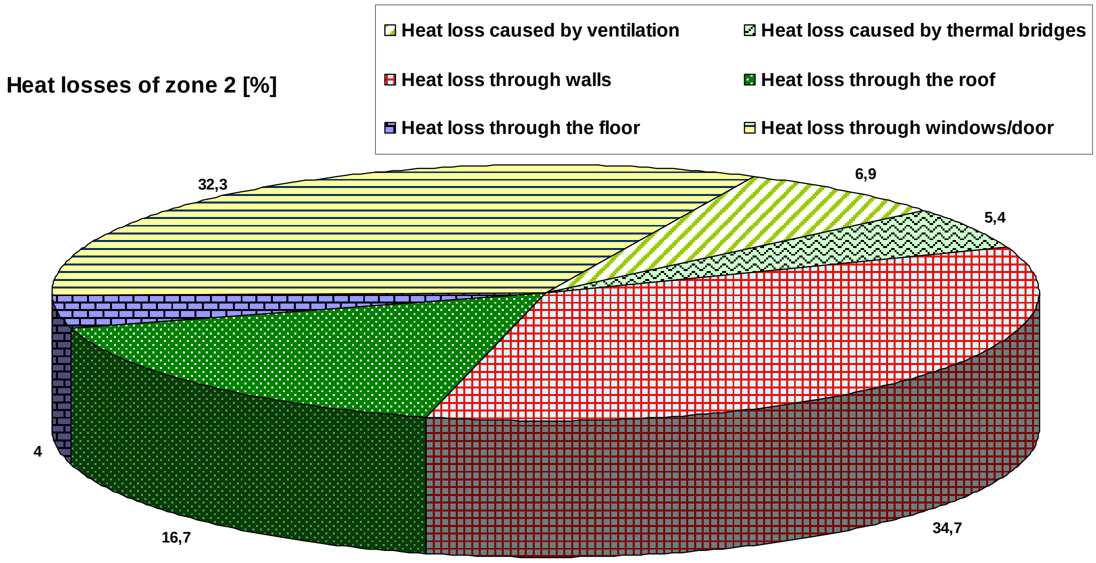


Figure 5.14 Heat losses of zone 2

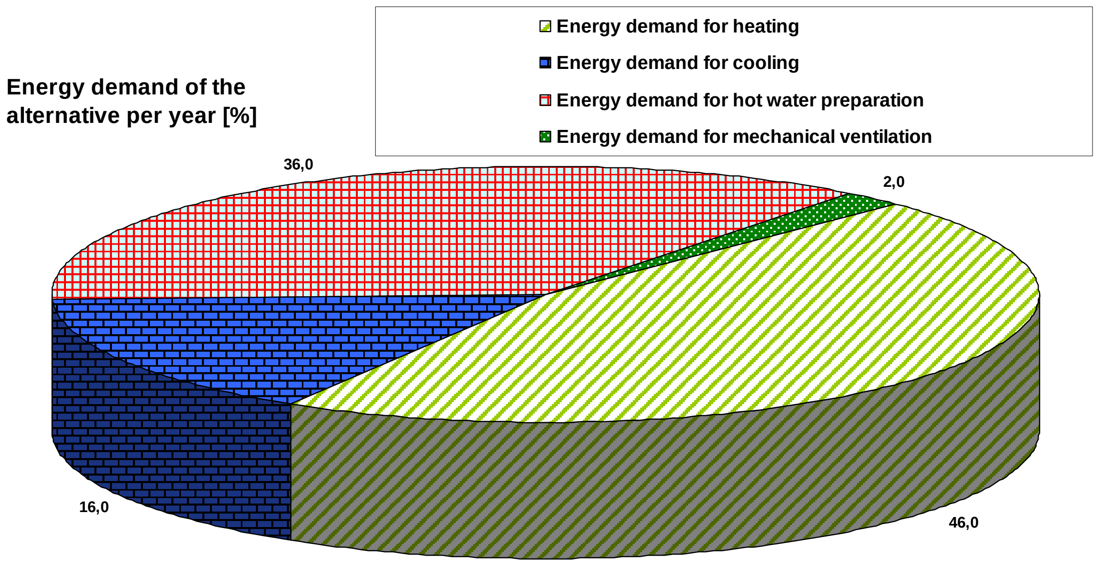


Figure 5.15 Total energy demand of the L-W concrete variant

Specific heat consumption for heating $Q_{h,nd}$	145	GJ	19	kWh/(m^2.y)
Energy demand for heating per year $E_{P,H}$	172	GJ	23	kWh/m^2
Energy demand for cooling per year $E_{C,H}$	58	GJ	8	kWh/m^2
Energy demand for mechanical ventilation $E_{P,F}$	24	GJ	3	kWh/m^2
Energy demand for hot water preparation $E_{P,W}$	132	GJ	18	kWh/m^2
Total energy needed $E_{P,A}$	386	GJ	52	kWh/m^2

Table 5-10 Energy consumption of the light-weight concrete variant

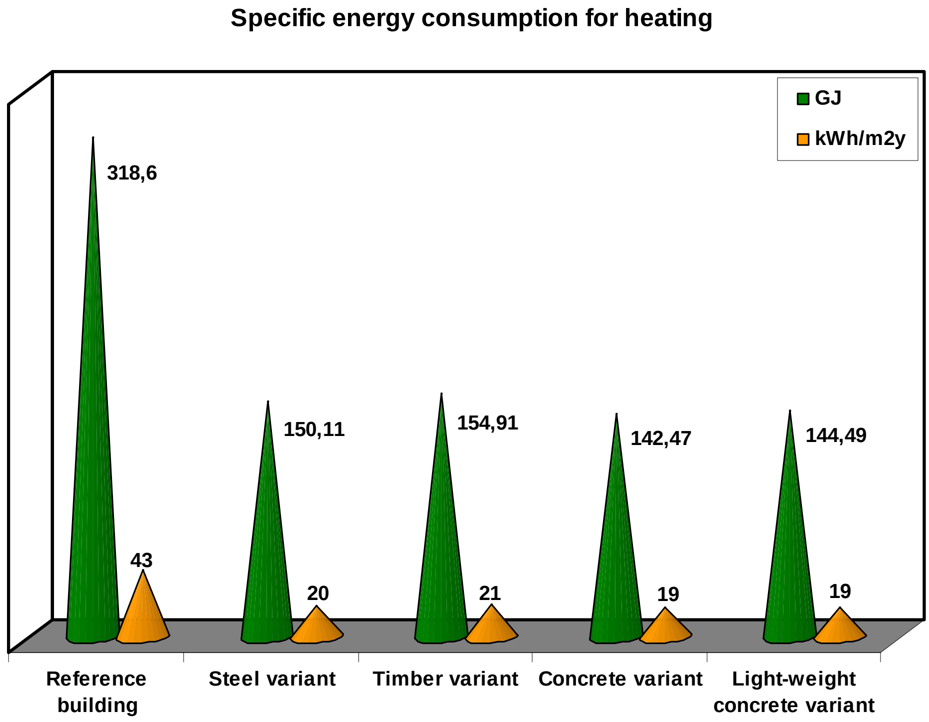


Figure 5.16 Specific heat consumption for heating for all variants

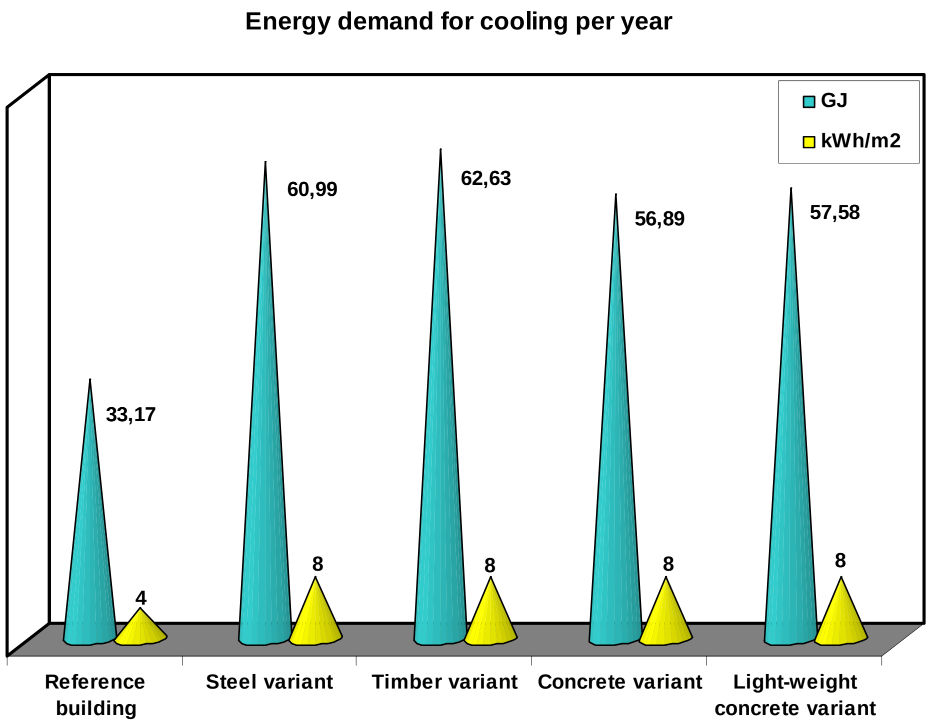


Figure 5.17 Energy demand for cooling per year for all variants

From the energy consumptions it is obvious that, when improving the heat transmission coefficient of the building envelope the energy needed for heating is decreasing, but the energy needed for cooling is increasing. We have to deal with this mainly when designing the ventilation systems. The way to solve this problem can be in decreasing the solar gains. To be successful in this we have to lower them down just during the summer period, but to allow them during the winter time when they are helping us with heating up the building.

There are several ways how to do this. One of them is to use interior or exterior blinds. From these two types we can say that the exterior ones are more efficient, because they are stopping the solar radiation outdoors and then there is no risk of overheating in areas close to windows. These blinds can be divided in anther two groups: with automatic control or that we can let to be controlled by the people currently living in the building. Me personally I do not think than any of these possibilities are good ones. If you let people to control the shading system on their own there is a risk that they just forget to do it. (especially if they leave to work in the morning when it is not so hot). The other type with automatic control is usually quite complicated system and due to that this system is often exposed to rain it can break down. I would recommend using rather some of the passive systems. For example we can use marquees which have their lamellas in the angle that they prevent the building from the solar gains during the summer when the sun is higher at the horizon and during the winter time when the sun is much lower it allows them. Other possibility of passive solution is to plant trees around the building. During the summer time when they have their leaves on they prevent and obviously during the winter they let the solar radiation to get in the building.

6 Assessment of the individually designed options in terms of the environmental impact

Here is described an evaluation of the environmental impact of materials used for the construction. The calculation is based on the overall amounts of materials used in the building. The sheets with those exact amounts of materials can be found in the appendix of this thesis. The amounts were stated for two cases. First one is the whole building including basement, floor with garages and the stairway (these parts are made from reinforced concrete in every variant). In the second case only the living part is considered. So the differences between each construction system according to used materials are more visible.

The values needed for every kind of material (values of embodied energy, CO_2 emissions and SO_2 emissions) were taken from the list that is given in the „Details for Passive Houses - A Catalogue of Ecologically Rated Constructions" (Waltjen, 2008). Values taken from this publication are world-wide accepted and so are considered as the proved ones. All the values given to each material are stated in the appendix in the part with amounts of materials. In the *Figure 6.1* there are shown differences in the weight of the construction system of each variant. What is impressive is the difference between the weight of the concrete and the timber variant.

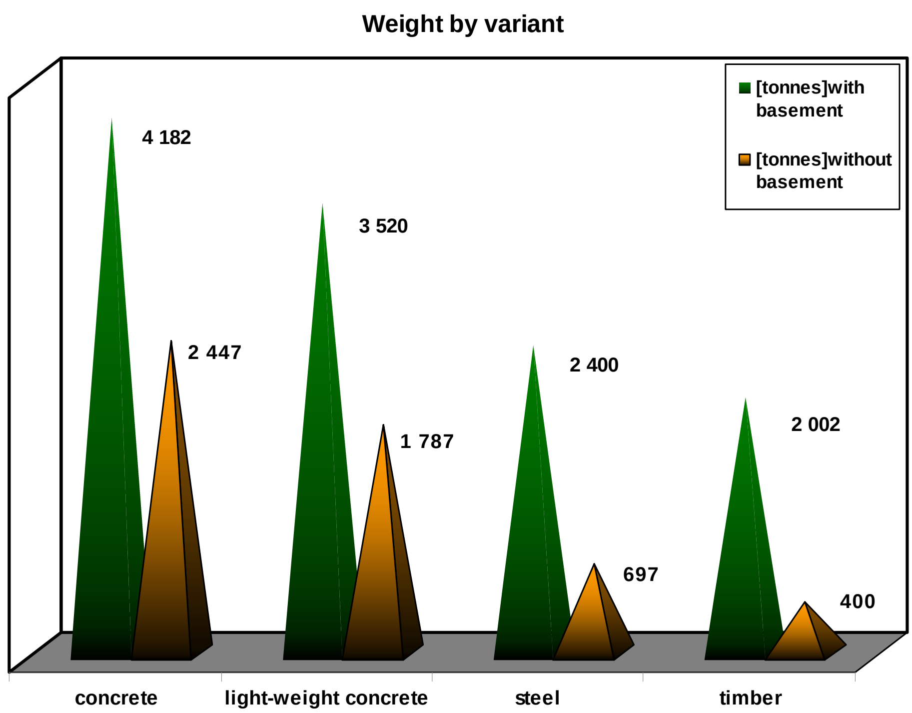


Figure 6.1 Weight by variant.
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

6.1 Embodied energy, CO_2 and SO_2 emissions assessment

As it was said before the values of the embodied energy, CO_2 and SO_2 emissions for all materials are stated in the appendix. The values for the basic materials used in the structure are shown in the *Table 6-1*.

Material	Embodied energy MJ/kg	Embodied CO_2 emissions kg/kg	Embodied SO_2 emissions g/kg
concrete	0,69	0,103	0,24
light-weight concrete	4,2	0,5	1,4
steel	125	8,91	42,8
timber	2,72	-1,49	1,61
glue - lam. timber	8,04	-1,26	3,41

Table 6-1 An overview of embodied values for the main materials used in the structure

Here more further are the results for the comparison of each variant. In these numbers the environmental impact of steel is clearly shown. Steel is one of the most influential building materials. The energy needed for producing it and the emissions connected to its production are very high. The embodied values of steel are much higher than of the other materials. Even though the weight of the structure is on the half of the weight when compared with the concrete variant, the energy needed for producing it is at the almost same level. This is shown in *Figure 6.2*. In *Figures 6.3* and *6.4* are the values for the embodied emission of each variant and in these numbers the steel variant is getting even worse. As for these first numbers the steel seems to be the worst material that we can use for the construction, but as it is shown in the next part the big advantage of steel is the possibility of recycling it.

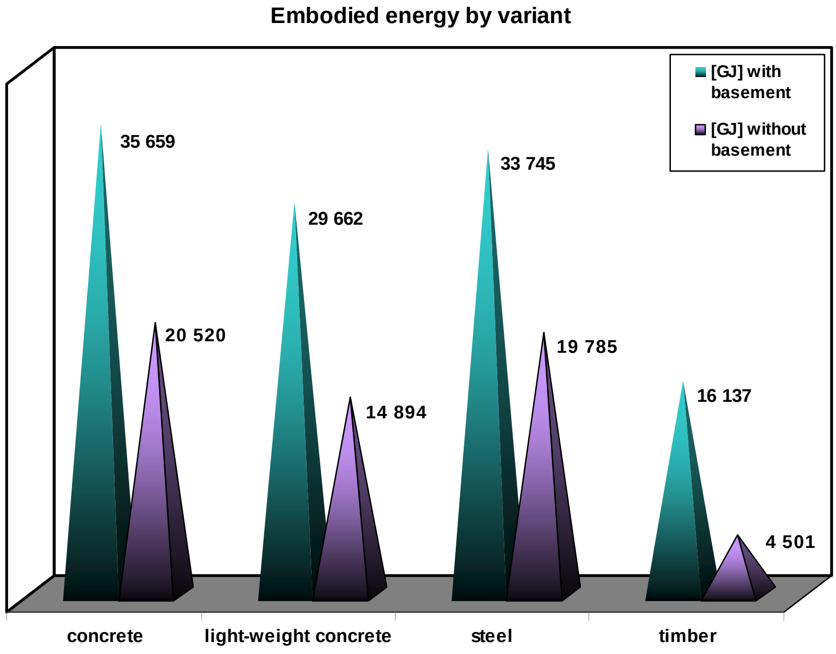


Figure 6.2 Amount of embodied energy for each variant.
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

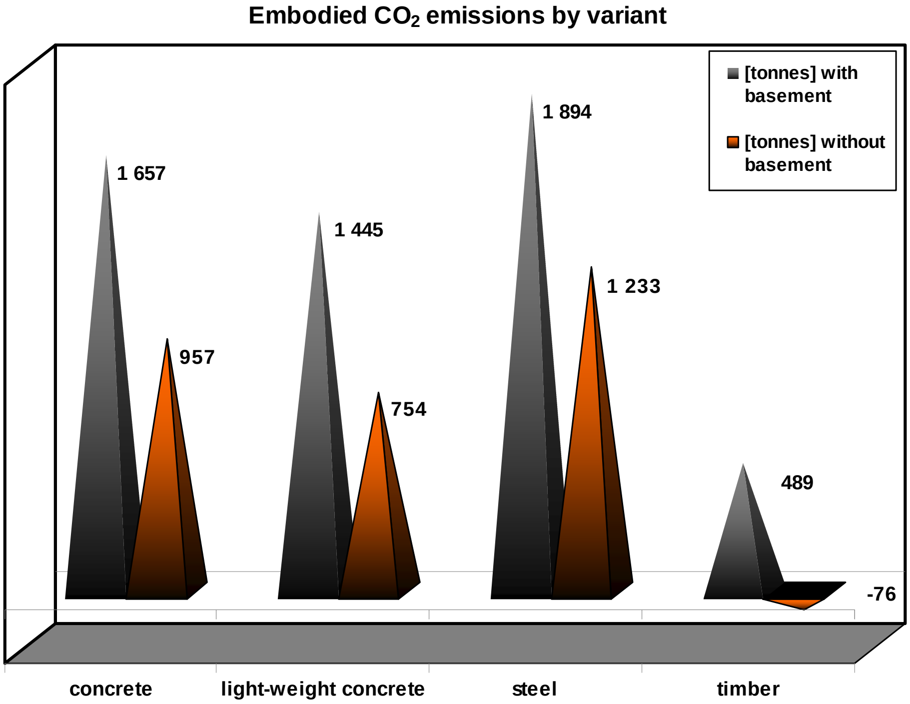


Figure 6.3 Amount of embodied CO_2 emissions for each variant.
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

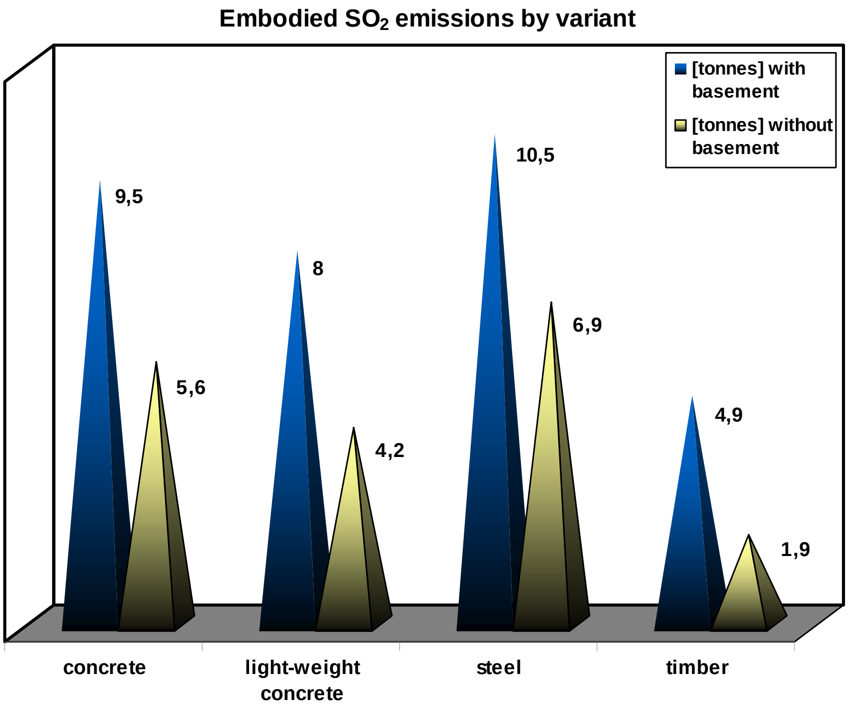


Figure 6.4 Amount of embodied SO_2 emissions for each variant.
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

6.2 Usage of raw materials vs. recycled materials

It can be said that the consumption of raw materials is a significant problem for the whole civil engineering. It is getting more necessary and reasonable to use recycled or renewable materials as much as it is possible. In the next *Figures 6.4* and *6.5* the percentage of materials used for construction of each variant is shown. It is quite clear that the concrete based structures are really bad at this point. For both concrete and light-weight concrete we get almost 100 % of usage of raw materials. In comparison to this the steel has much lower value and timber is even better. The difference is much more significant when looking at *Figure 6.5* where the material comparison is without foundations, stairway and floor with garages.

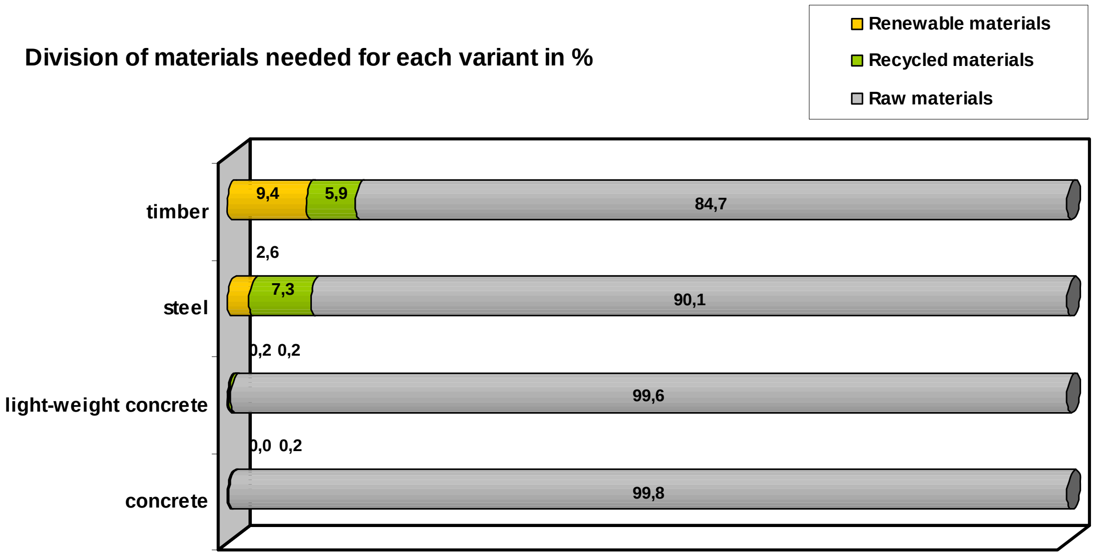


Figure 6.5 Usage of materials in the structure (including foundations, floor with garages and the stairway)

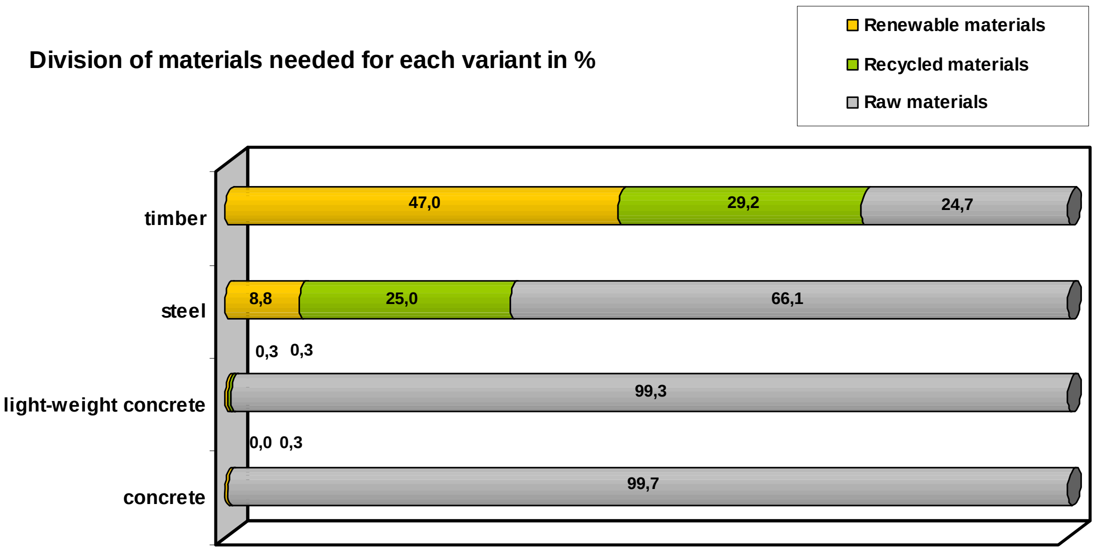


Figure 6.6 Usage of materials in the structure (only the living part of the building)

Next point used for assessment of different variants was production of waste during construction and demolition. This one is assessed by the percentage division of materials used in the structure according to what can be done with them after the demolition. Materials were divided into three parts. Those that can be fully recycled (this is a material that has the same qualities and properties after recycling), partly recycled (this is recycling with down cycling effect, which means that the recycled material has worse qualities and properties than that one which came to recycling) and waste. It should be kept in mind that the graph is shown in percentages, so it does not describe the real amount of waste produced. Here it is stated as a ratio with the total amount of materials.

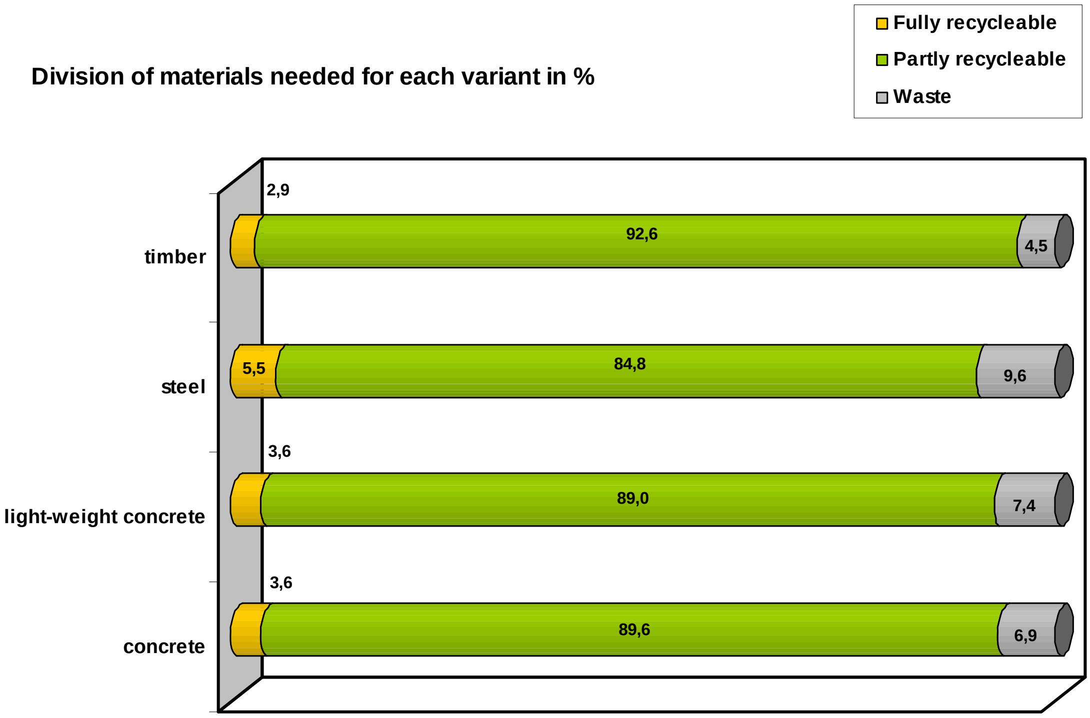


Figure 6.7 Usage of materials in the structure (including foundations, floor with garages and the stairway)

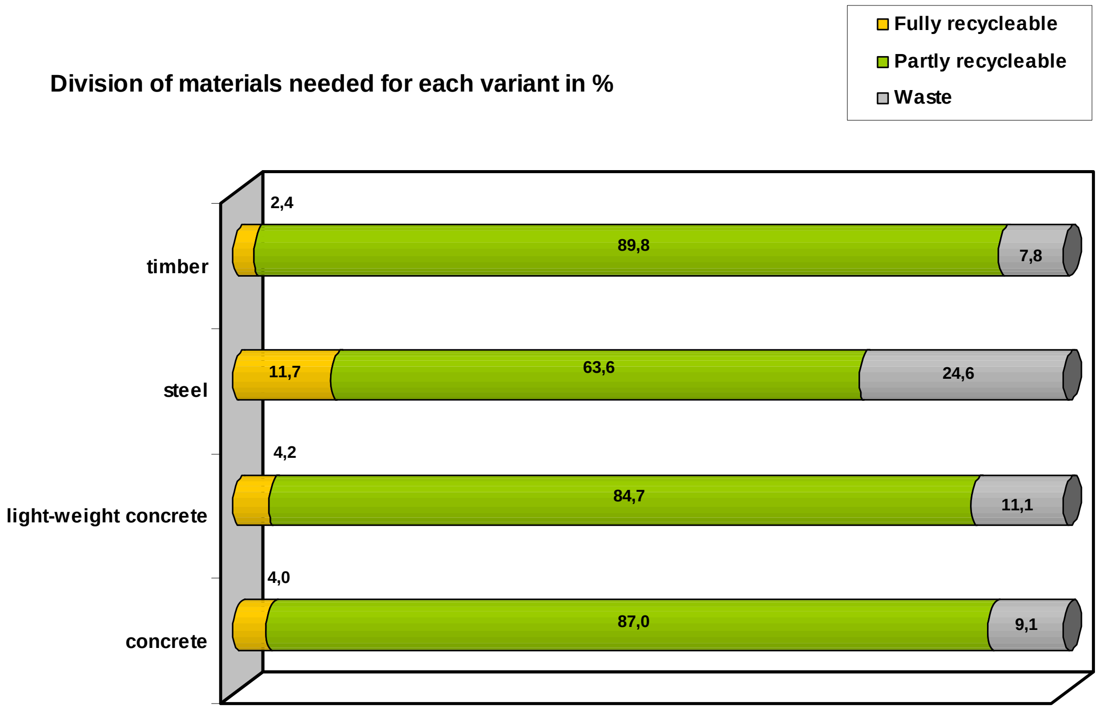


Figure 6.8 Usage of materials in the structure (only the living part of the building)

6.3 Ranking of evaluated variants

Several criterions were used to compare the designed structures one to each other. There were given weights to each of these to show their importance. The criterions and their weights can be found in the *Table 6-2*. These basic criterions and their weight were provided by Ing. Martin Vonka, Ph.D. The real values evaluated for each variant according to the field of importance were described previously. The description of the system of ranking is provided in this part.

Criterion	**Weight of each criterion**
Embodied energy	40 %
Embodied CO_2 emissions	10 %
Embodied SO_2 emissions	10 %
Usage of raw materials	20 %
Raw materials / all used materials	6 %
Waste / all used materials	6 %
Volume of used materials / volume of the building	8 %

Table 6-2 An overview of criterions used for the comparison of the designed variants

The list of these criterions was chosen, because exactly these ones include all the bad environmental influences of building materials used during the construction.

There were given points to each variant for each criterion. These points are based on the values that each variant has. Points were distributed in this way: for each criterion the best variant was given 10 points and the worst one was given 1 point. Points for variants between this were evaluated according to the linear dependency. For the final ranking all of these points were multiplied by the weight and than summarized. This was done for each variant separately. In *Figures 6.9 – 6.14* below the results for every criterion are shown.

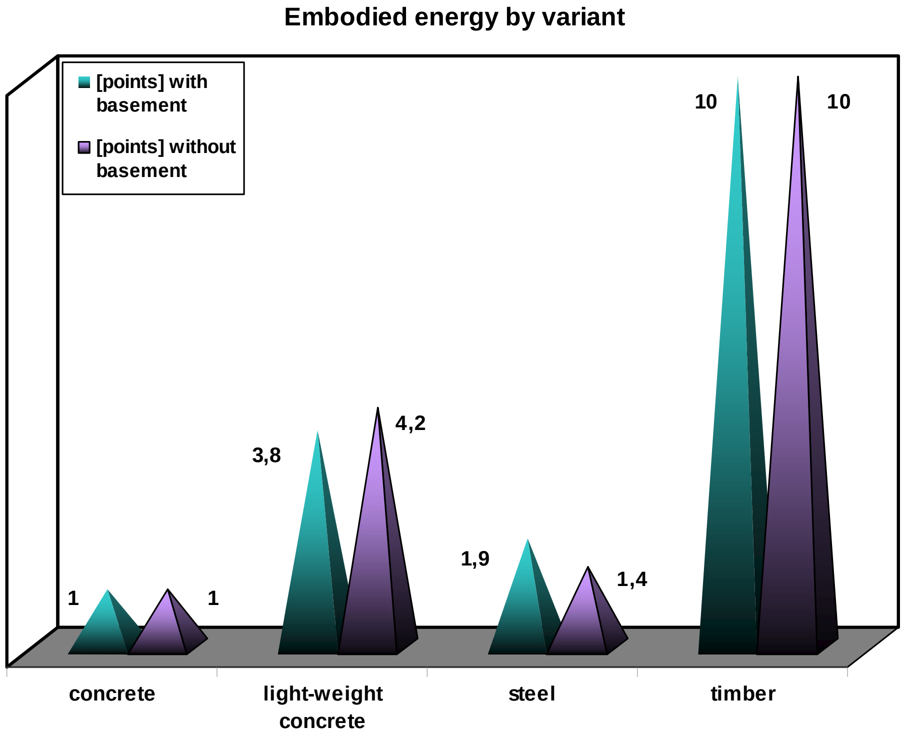


Figure 6.9 Given points for embodied energy for all variants
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

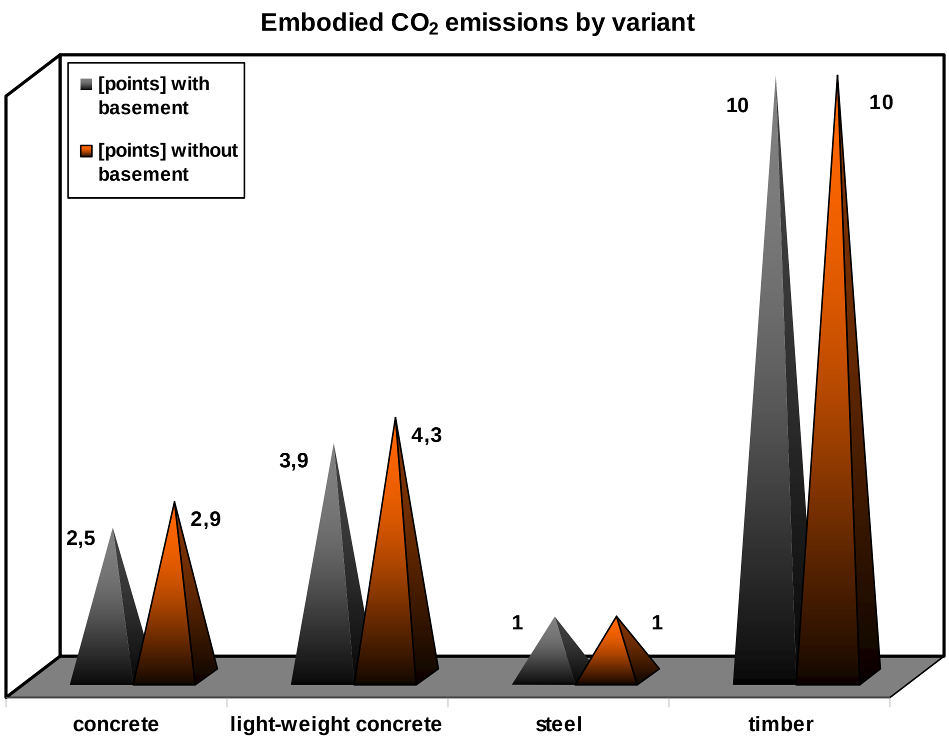


Figure 6.10 Given points for embodied CO_2 emissions for all variants
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

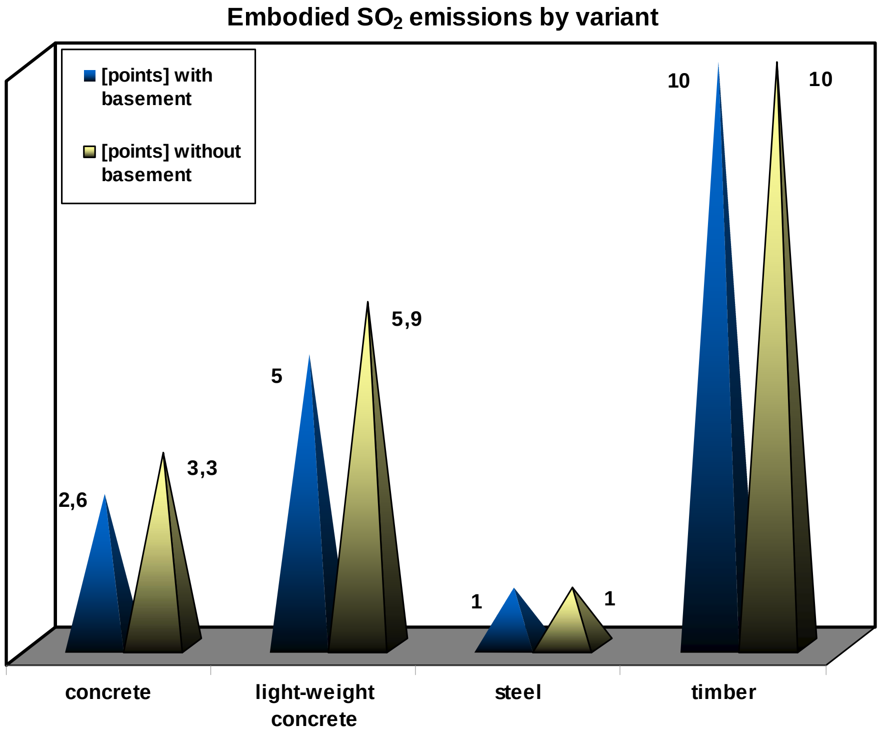


Figure 6.11 Given points for embodied SO_2 emissions for all variants
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

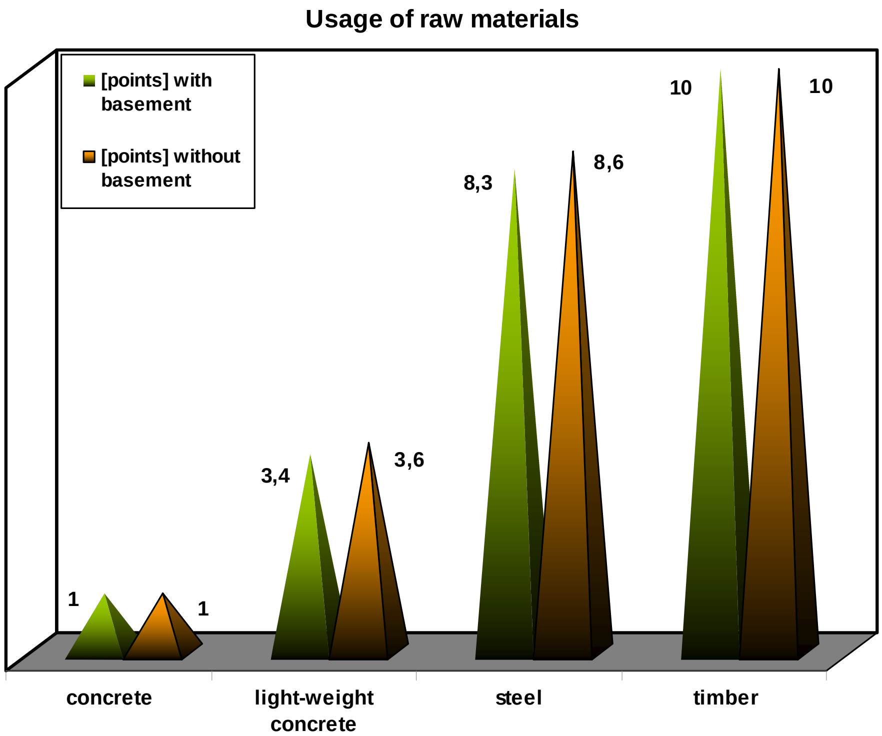


Figure 6.12 Given points for the usage of materials during construction for all variants
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

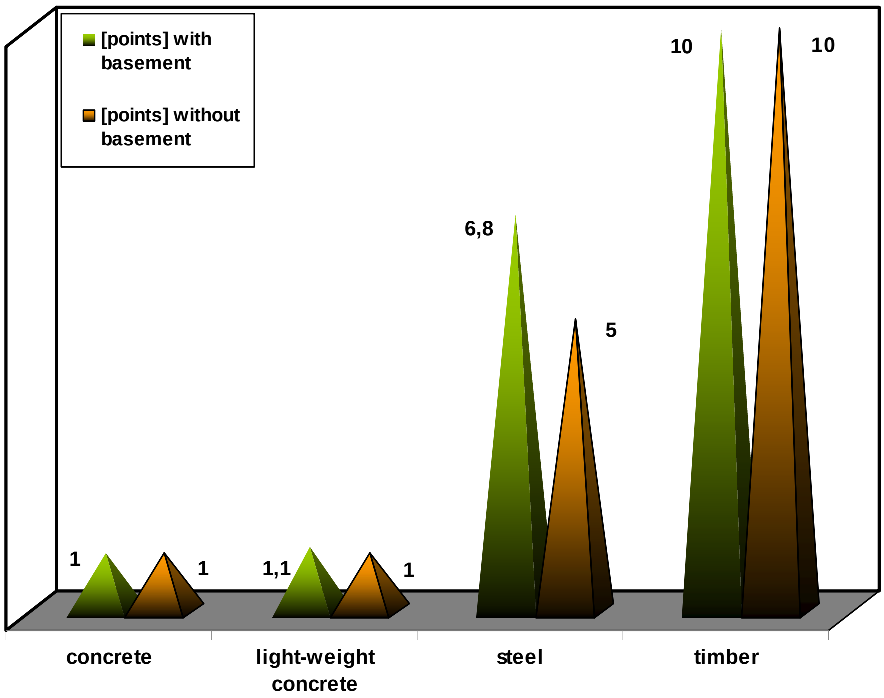


Figure 6.13 Given points for usage of raw materials during construction in contrast with all used materials for all variants
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

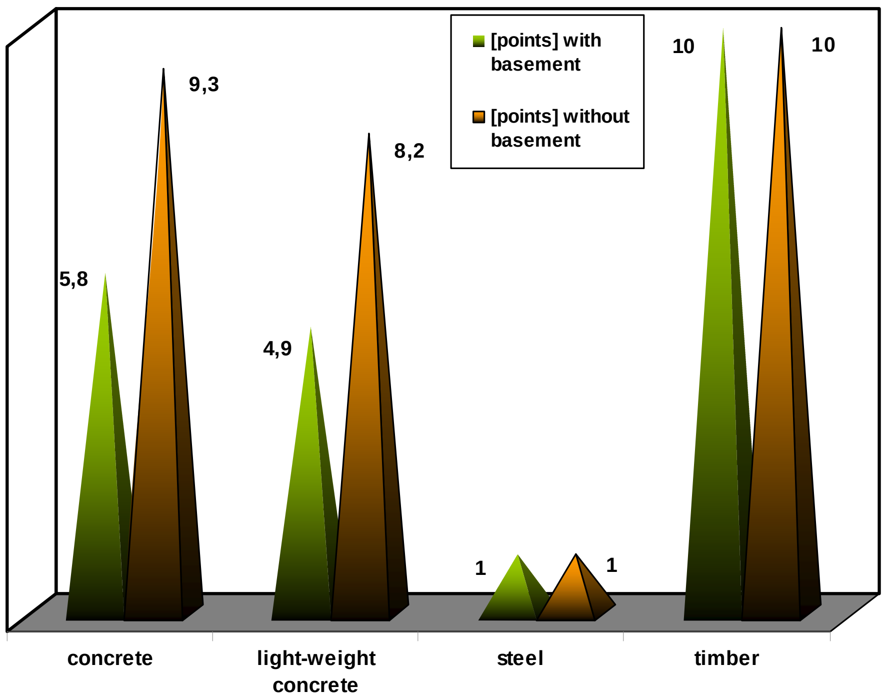


Figure 6.14 Given points for embodied energy for all variants
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

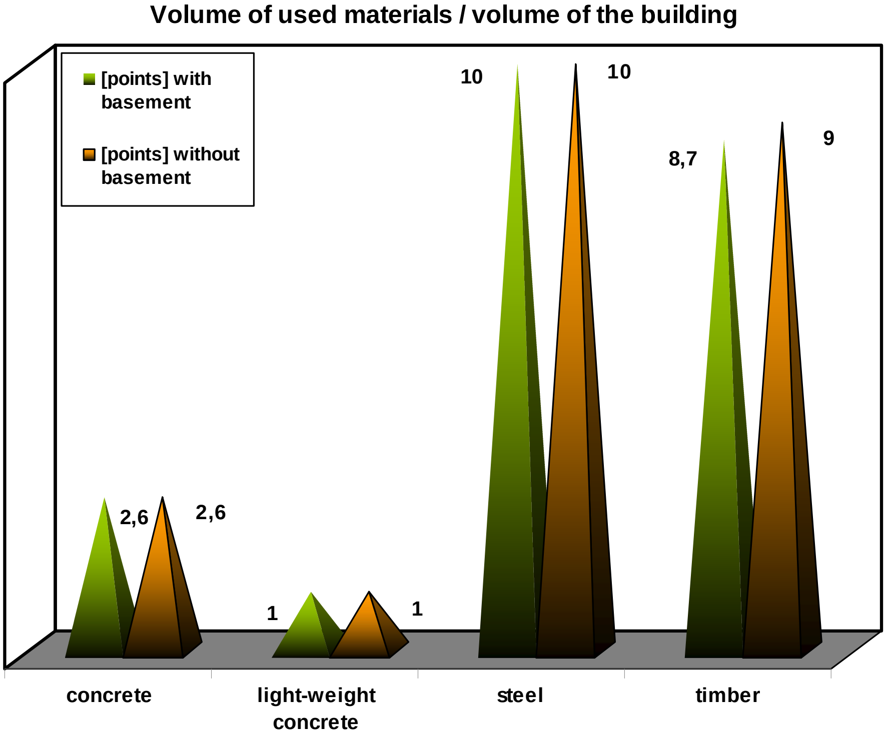


Figure 6.15 Given points for embodied energy for all variants
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

A review of points given to each variant is given in the *Figure 6.15*. These are still without weights. The comparison of all variants under all criterions can be seen in here. Obviously the timber variant is the best in almost all criterions. So we can predict that also after multiplying it by weights, timber will be found as the best solution in case of environmental issues.

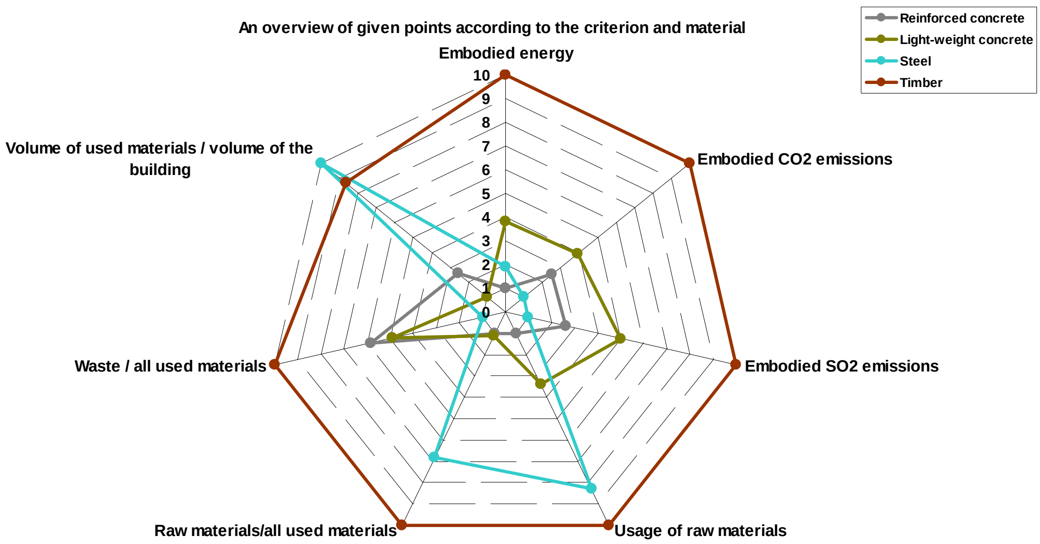


Figure 6.16 Summary of given points to each variant (relative comparison)

The final ranking is shown in the next *Figure 6.16*. Weights are included in this summary so we have the real comparison for all variants. From this it can be said that the timber variant is the best solution that can be provided. This variant got significantly much higher points than the other variants. What is quite interesting is the change at the second and third position. This can be explained by the amount of points that were given in the part where the percentage of waste was evaluated. The big difference is caused by the weight of light-weight concrete structure that gives to the variant lower percentage of waste. But it can be said that these two possibilities have almost the same environmental impact. The structure made completely from reinforced concrete is stated as the worst variant for the environment. The other possibility how to evaluate the environmental influence of the structure is provided in the next chapter.

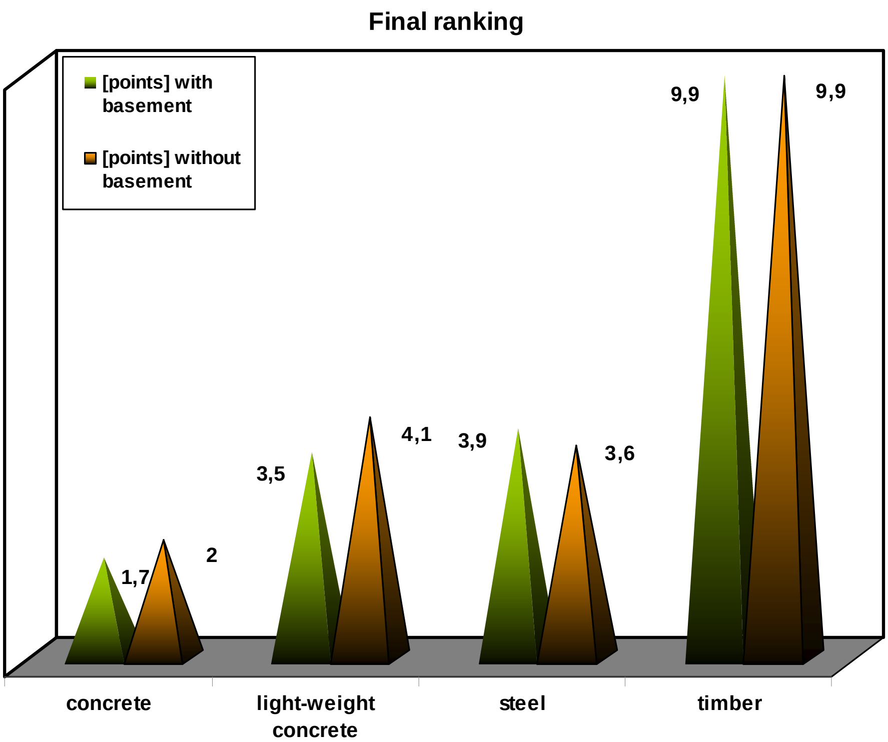


Figure 6.17 Summary of result points for all variants
There are two numbers for each material – for the whole building („with basement") and only for the parts where the structure was changed („without basement")

7 Assessment of the individually designed options in terms of the environmental impact, done by the SBTool CZ methodology

7.1 Description of the SBTool CZ methodology

The SBTool CZ methodology for comprehensive assessment of the quality of buildings is based on the general scheme of the international SBTool. This is developed by the organization International Initiative for a Sustainable Built Environment (iiSBE), which offers huge database of criterions for sustainable constructions for-specific conditions of participating states.

The structure of the criterions used for evaluation by the SBTool CZ methodology is divided in accordance with the principles of sustainable construction into the three basic groups: environmental, socio-cultural and economics. Each of these groups are divided into subgroups, and then to the final evaluation criterions. The range of the criterions that are used for the evaluation of each building varies according to the type of the building (residential building, office block, hospital, commercial building) and by the phase of the life cycle (phase of project planning, commissioning, operation phase of the building). The structure of criterions and weights between them are designed in accordance with the principles of sustainable construction.

Each criterion has its own algorithm for the evaluation. Then there are points given according to the result from this algorithm. The points are given from the scale 0 - 10. The scale corresponds to the limits (benchmarks) that are provided to every criterion. The value of ten points corresponds to the best available technology. Five points correspond to the current best experience and zero expresses the usual condition in the region or meets the requirements given by the government.

It should be noted that the benchmarks are set so that the scoring of 10 points really means the best and the most advanced solutions in practice and it is practically unrealistic at the moment to achieve these values. Most of the rated buildings have reached levels between 1 and 5, which is something between a permissible and a good solution.

Values of benchmarks are one of the basic values of this methodology. Their work out is mainly based on the statistical data (for example: limits for operational energy, embodied energy, operational emissions or embodied emissions) or is based on the scientific research (such as use of the rainwater, the availability of services, etc.). Values of benchmarks can be stated in numbers or by word as well.

The SBTool methodology is one of the possible ways on how to evaluate the sustainability of buildings and thus can determine the potential of how to improve and optimise the design of building.

Criterions for the environmental area		60 %
Group of criterions	**Criterion**	**Weight of criterion**
Climate change	Operational CO_2 emissions	21,8 %
	Embodied CO_2 emissions	3,8 %
Air quality	Operational SO_2 emissions	5,6 %
	Operational NO_x emissions	5,6 %
Biodiversity	Use of greenery on the land	8,4 %
	Use of greenery on the facade and roof	4,0 %
	Ecological value of the place	6,0 %
Use of resources	Consumption of primary energy for operation of the building	12,2 %
	Embodied energy	4,0 %
	Use of structural material during construction	9,2 %
	Construction waste during construction and demolition	4,0 %
	Use of rainwater	6,0 %
	Reuse of land	4,4 %
Environmental risks	Ration of rainwater kept on the land	5,0 %

Table 7-1 Criterions used for evaluation of the environmental impact of the residential building

Criterion for the socio – cultural area		30 %
Group of criterions	**Criterion**	**Weight of criterion**
Quality of indoor environment	Eyesight comfort	8,9 %
	Acoustic comfort	12,6 %
	Thermal comfort	13,4 %
	Air quality in the building	9,4 %
Availability	Access to public places for relaxation	10,9 %
	Availability of services	9,7 %
	Availability of public transport	9,1 %
	Promotion of cycling	6,3 %
	Access for disabled people	3,4 %
Safety	Safety in the building and its	6,6 %
	Security of the building	6,6 %
Functionality	Adaptability	3,1 %

Table 7-2 Criterions for the socio – cultural area used for evaluation of the residential building

Criterion for the area of economics		10 %
Group of criterions	**Criterion**	**Weight of criterion**
LCC	Analysis of operating costs	33 %
Support of the local economy	Use locally produced products	22 %
Externalities	Innovative approach	15 %
	Provision of operational and detailed documentation	10 %
Risks	Minimisation of regional climatologic risks	8,7 %
	Embodied energy	11,3 %

Table 7-3 Criterions for the area of economics used for evaluation of the residential building

7.2 Results from the SBTool CZ methodology

Criterion	Benchmarks					Given points				
	Concrete	L-w concrete.	Steel	Timber	Original	Concrete	L-w concrete.	Steel	Timber	Original
Operational CO_2 emissions	7,2	7,1	7,1	7,0	6,7	1,57	1,56	1,54	1,53	1,46
Embodied CO_2 emissions	0,0	0,0	0,0	2,7	0,0	0,00	0,00	0,00	0,10	0,00
Operational SO_2 emissions	7,1	7,0	6,9	6,9	7,2	0,39	0,39	0,39	0,39	0,4
Operational NO_x emissions	6,8	6,8	6,7	6,7	6,5	0,38	0,38	0,38	0,37	0,36
Use of greenery on the land	2,0	2,0	2,0	2,0	2,0	0,17	0,17	0,17	0,17	0,17
Use of greenery on the facade and roof	0,0	0,0	0,0	0,0	0,0	0,00	0,00	0,00	0,00	0,00
Ecological value of the place	10,0	10,0	10,0	10,0	10,0	0,60	0,60	0,60	0,60	0,60
Consumption of primary energy for operation of the building	7,7	7,7	7,6	7,6	1,3	0,94	0,94	0,93	0,93	0,89
Embodied energy	0,0	0,0	0,0	0,0	0,0	0,00	0,00	0,00	0,00	0,00
Use of structural material during construction	0,0	0,1	1,8	2,8	0,0	0,00	0,01	0,16	0,25	0,00
Construction waste during construction and demolition	0,0	0,0	0,0	0,0	0,0	0,00	0,00	0,00	0,00	0,00
Use of rainwater	0,0	0,0	0,0	0,0	0,0	0,00	0,00	0,00	0,00	0,00
Reuse of land	0,0	0,0	0,0	0,0	0,0	0,00	0,00	0,00	0,00	0,00
Ration of rainwater kept on the land	0,0	0,0	0,0	0,0	0,0	0,00	0,00	0,00	0,00	0,00
Total points for the environmental area						**4,06**	**4,04**	**4,17**	**4,34**	**3,89**
Eyesight comfort	8,0	8,0	8,0	8,0	8,0	0,71	0,71	0,71	0,71	0,71
Acoustic comfort	4,0	4,0	4,0	4,0	4,0	0,50	0,50	0,50	0,50	0,50
Thermal comfort	4,0	4,0	4,0	4,0	2,0	0,54	0,54	0,54	0,54	0,27
Air quality in the building	6,0	6,0	6,0	6,0	6,0	0,56	0,56	0,56	0,56	0,56
Access to public places for relaxation	10,0	10,0	10,0	10,0	10,0	1,09	1,09	1,09	1,09	1,09
Availability of services	10,0	10,0	10,0	10,0	10,0	0,97	0,97	0,97	0,97	0,97
Availability of public transport	10,0	10,0	10,0	10,0	10,0	0,91	0,91	0,91	0,91	0,91
Promotion of cycling	7,0	7,0	7,0	7,0	7,0	0,44	0,44	0,44	0,44	0,44

Access for disabled people	5,5	5,5	5,5	5,5	5,5	0,19	0,19	0,19	0,19	0,19
Safety in the building and its surroundings	0,0	0,0	0,0	0,0	0,0	0,00	0,00	0,00	0,00	0,00
Security of the building	0,0	0,0	0,0	0,0	0,0	0,00	0,00	0,00	0,00	0,00
Adaptability	1,0	1,0	10,0	10,0	1,0	0,03	0,03	0,03	0,03	0,03
Total points for the socio – cultural area						**5,95**	**5,95**	**6,22**	**6,22**	**5,67**
Analysis of operating costs	3,0	3,0	3,0	3,0	3,0	0,99	0,99	0,99	0,99	0,99
Use locally produced products	1,0	1,0	1,0	1,0	1,0	0,22	0,22	0,22	0,22	0,22
Innovative approach	10,0	10,0	10,0	10,0	10,0	1,50	1,50	1,50	1,50	1,50
Provision of operational and detailed documentation	5,0	5,0	5,0	5,0	5,0	0,50	0,50	0,50	0,50	0,50
Minimisation of regional climatologic risks	10,0	10,0	10,0	10,0	10,0	0,87	0,87	0,87	0,87	0,87
Autonomy of operation	0,0	0,0	0,0	0,0	0,0	0,00	0,00	0,00	0,00	0,00
Total points for the area of economy						**4,08**	**4,08**	**4,08**	**4,08**	**4,08**
Total points for each variant						**4,63**	**4,61**	**4,78**	**4,88**	**4,45**

Table 7-4 An overview of points evaluated by the SBTool methodology

Results that came from the evaluation of structures in the SBTool methodology gave nearly the same ranking as the one previously stated. The only difference is in the change of positions of reinforced concrete structure and the structure made from light-weight concrete. The difference between the positions of each variant is also much lower. This is caused by the amount of criterions, which is used in each evaluation. The first methodology was focused only on the environmental impact of the structure itself and the criterions were chosen according to it. As for the second one, the criterions for the overall evaluation of the building are implemented. This causes the reduction of the influence of the structure itself.

The other issue is that the limits set for the assessment of the environmental impact are really strict. This means that almost all variants got zero points for the environmental criterions connected with the structure. This can be found for the criterions like embodied energy and emissions, waste production and usage of materials. Only the timber variant got some points in all of these parts. The reason for such a strict limitation of the criterions is in that the methodology should be used over a long term period. If the limitation was not that strict, all the structures would be revealed as the best ones in a few years. The comparison of all variants is shown in *Figure 7.1* below.

Also the better position of concrete is caused by the stricter limitation. As a result of this it appears that the concrete variant is better thanks to the lower operational emissions and energy. But as stated previously the difference between the structural materials can not be shown in the set of SBTool CZ criterions.

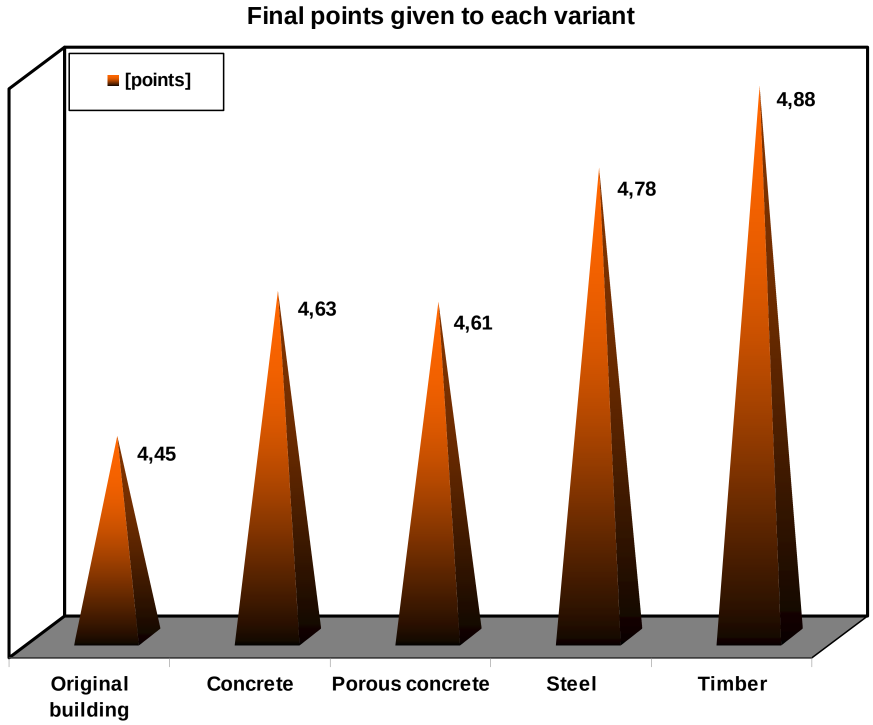


Figure 7.1 Total ranking evaluated by the SBTool CZ

The result for the original building is also shown. Here the difference caused by the operational phase of the building is visible. It can be found when comparing the result of the original building and the concrete variant. The difference is not substantial because of the reasons stated previously and also because of the different source of energy used for the original building and for the concrete variant. In terms of the original building the main source of energy is natural gas. For the concrete variant the main source is the same, but the consumption of energy needed for ventilation is rising up and the source for it is electricity. In fact the energy needed for the concrete variant is lower, but partly the energy is changed from the natural gas to electricity. This means higher operational emissions and higher consumption of primary energy for this changed part of energy.

From these results it can be seen that the use of the SBTool methodology for the comparison of several material variants does not prove to be efficient. This methodology is definitely better for the ranking of different buildings thanks to the wide range of criterions and their weights, but when considering which material is better for the structure it is better to use a system developed from your own criterions. This helps to distinguish the variants one from each other in much better resolution.

8 Conclusions

There were four material alternatives of a residential building designed in this thesis. All of them were done to fulfil the requests in the field of structural design, thermal performance, acoustics performance and energy consumption. The idea was to compare real structures from different materials under the same conditions according to their environmental impact. Therefore the compositions in all of the variants have nearly the same values of heat transmission coefficient (facade U = 0.15 and roof U = 0.12) and in the end nearly the same energy consumptions.

The original system of criterions was used for the comparison of material options and the other opportunity when using the multi-criterion assessment methodology SBTool CZ. From the first system it was stated that timber option is definitely the best possibility. Timber variant has two times lower values of embodied energy and emissions than the second best option. Huge differences between points given to the timber option and the rest were described in chapter 5. According to the second possibility of evaluation timber is also stated as the best solution, but it can be found that the differences between each option are not that clear. It is hard to distinguish the alternatives.

So, it can be said, that when trying to compare several possibilities it is more essential to use an original system of criterions that fulfils the requests set on it. This allows for clearer results. It has to be stated here, that a lot of attention should be paid to the chosen criterion and their weights. It is up to everyone which criterion to choose. Which of them are the most essential ones to fulfil the task.

9 List of Tables

10 List of Figures

11 References

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ČSN EN 1991-1-3, (2004) : *Eurokód 1 : Zatížení konstrukcí – Část 1-3 : Obecná zatížení – Zatížení sněhem, (Eurocode 1 : Actions on structures – Part 1-3 : General actions – Snow loads)*. Czech Standards Institute

ČSN EN 1991-1-4, (2005) : *Eurokód 1 : Zatížení konstrukcí – Část 1-4 : Obecná zatížení – Zatížení větrem, (Eurocode 1 : Actions on structures – Part 1-4 : General actions – Wind loads)*. Czech Standards Institute

ČSN EN 1993-1-1, (2006) : *Eurokód 3 : Navrhování ocelových konstrukcí – Část 1-1: Obecná pravidla pro pozemní stavby, (Eurocode 3: Design of steel structures – Part 1-1: General rules for buildings)*. Czech Standards Institute

ČSN EN 1996-1-1, (2007) : *Eurokód 6: Navrhování zděných konstrukcí – Část 1-+ : Obecná pravidla pro vyztužené a nevyztužené zděné konstrukce, (Eurocode 6 : Design of masonry structures – Part 1-1 : General rules for reinforced and unreinforced masonry structures)*. Czech Standards Institute

ČSN EN 1995-1-1, (2006) : *Eurokód 5 : Navrhování dřevěných konstrukcí – Část 1-1: Obecná pravidla – Společná pravidla a pravidla pro pozemní stavby, (Eurocode 5: Design of timber structures – Part 1-1: General - Common rules and rules for buildings)*. Czech Standards Institute

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ČSN EN ISO 717, (1998) : *Akustika – Hodnocení zvukové izolace stavebních konstrukcí a v budovách, (Acoustics – Rating of sound insulation in buildings and of building elements)*. Czech Standards Institute

12 Visited web pages

www.substance.cz	sustainable building
www.xella.cz	light-weight concrete blocks producer
www.ferona.cz	steel profiles producer
www.lindab.cz	trapezoidal sheets producer
www.rockwool.cz	thermal insulation from mineral wool producer
www.hofatex.eu	wooden fiber boards producer
www.unep.org	United Nations Environment Programme
www.dow.com	producer of thermal insulation from extruded polystyrene and impact sound insulation
www.ibo.at	Austrian Institute for Healthy and Ecological buildings
www.kronospan.cz	OSB boards producer
www.knauf.cz	gypsum boards producer

13 Appendix

A Static evaluation of the timber structure variant

B Static evaluation of the steel structure variant

C Static evaluation of the Light-weight concrete variant

D Energy consumption of fans used for mechanical ventilation

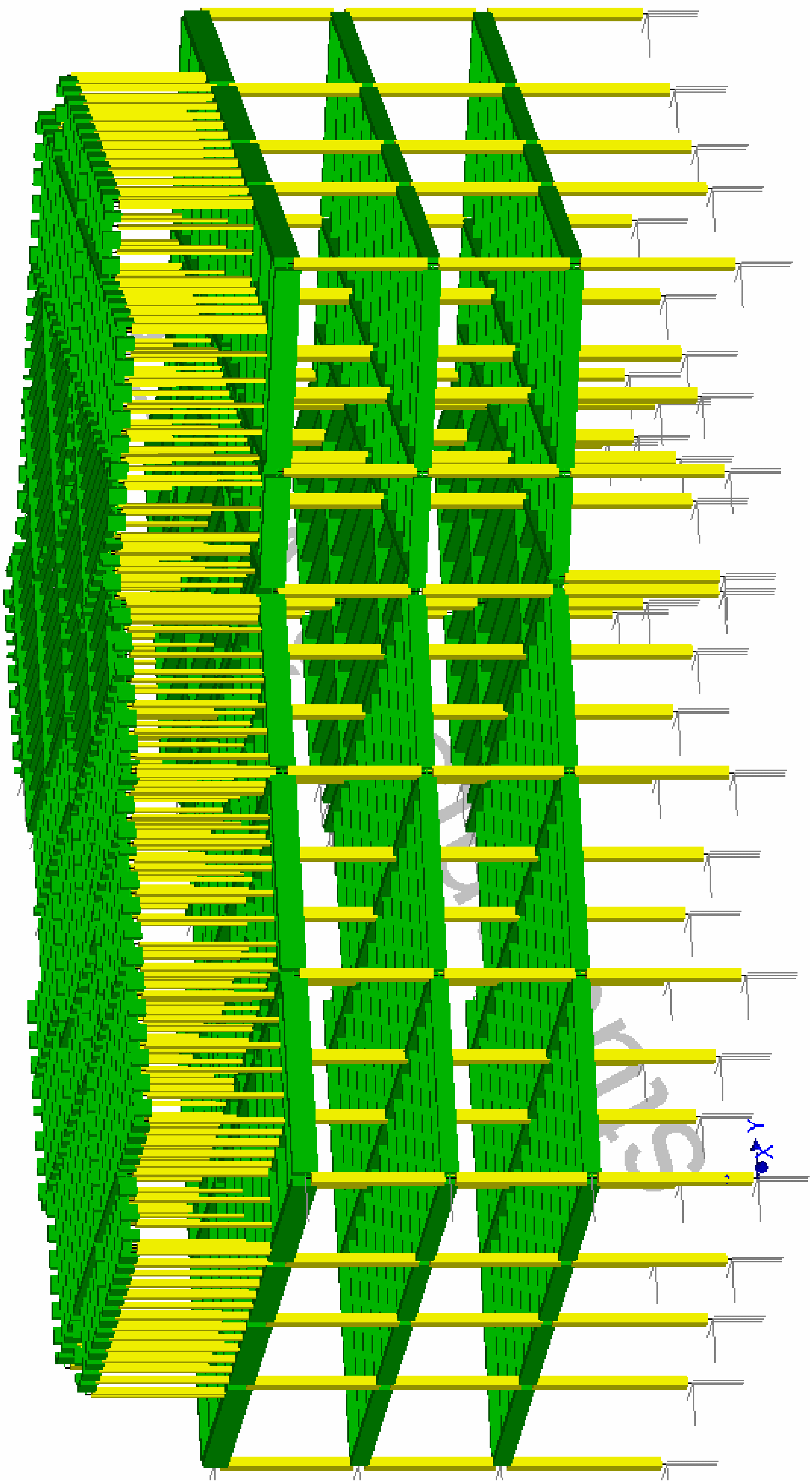
E Evaluation of heat capacity of indoor mass for all alternatives

F Amounts of materials

G Basic drawings of the original building

A

Static evaluation of the timber structure variant


Y
X

Wind load

Basic speed of the wind

v_b - basic speed of the wind [m/s]

$v_b = C_{dir} * C_{season} * v_{b,0}$

C_{dir}= coefficient - wind direction C_{season}= coefficient - season

C_{dir}= *1,0* C_{season}= *1,0*

$v_{b,0}$ - initial basic speed of the wind [m/s]

$v_{b,0}$ - estimated from the map of the wind speed, *ČSN EN 1991-1-4, location: Prague*

$v_{b,0}$= *25* m/s

v_b= 1*1*25

v_b= 25 m/s

basic dynamic pressure of the wind

q_b - basic dynamic pressure of the wind [N/m^2]

$q_b = 1/2 * \rho * v_b^2(z)$

ρ= density of the air

ρ= 1,25 kg/m^3

q_b= 1/2*1,25*25^2

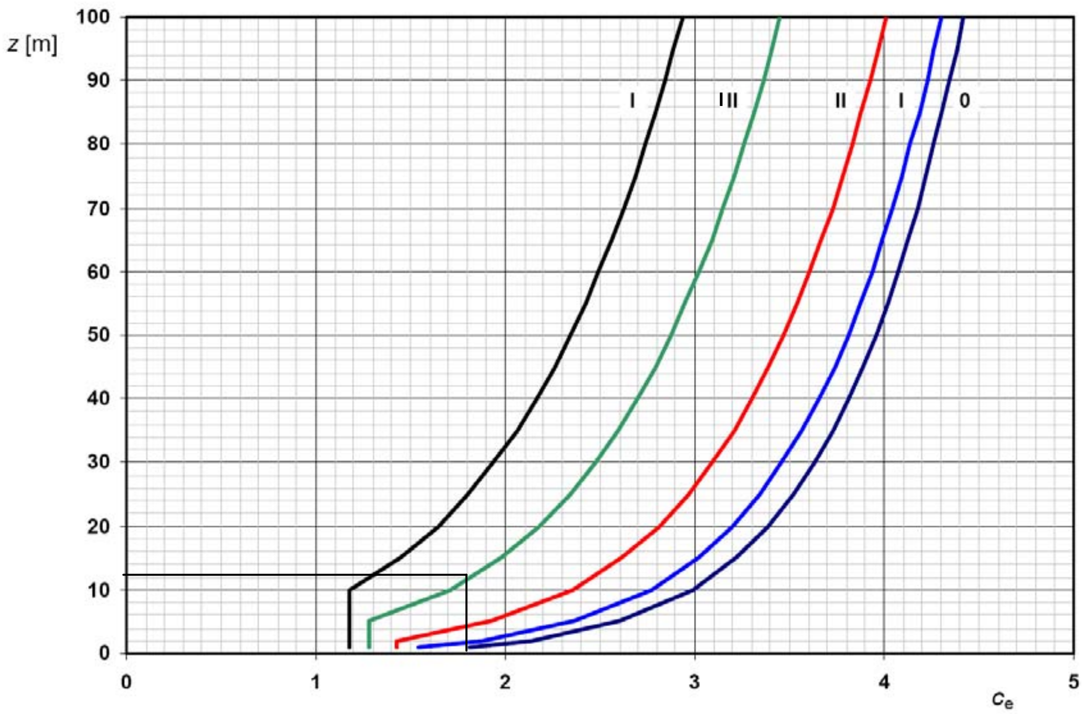
q_b= 390,625 N/m^2

maximal dynamic pressure of the wind

$q_p = c_e(z) * q_b$

c_e= 1,8

c_e (estimated as a function of height beyond terrain and the terrain cathegory, picture 4.2, ČSN EN 1991-1-4)



terrain cathegory - **III** (areas equally covered by vegetation or buildings)

q_p= 703,125 N/m^2

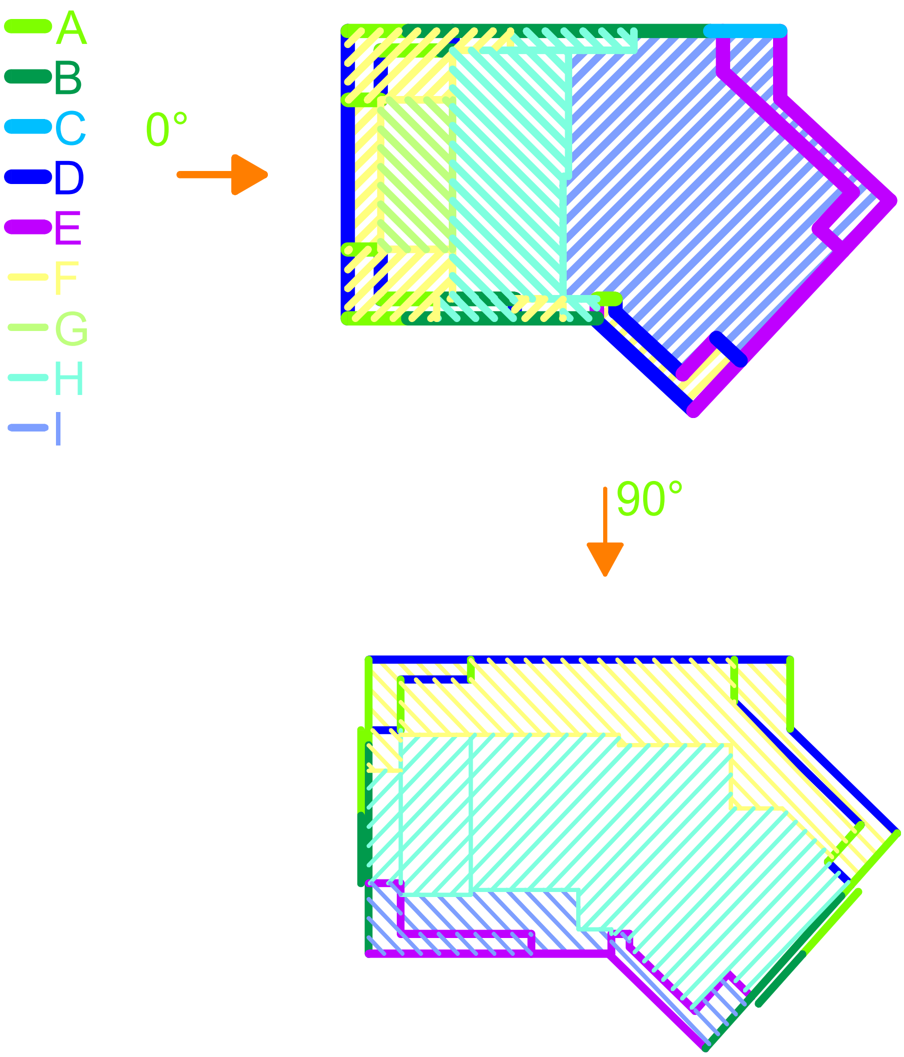
wind pressure on the surface of the construction

$w_e=q_p(z)*C_{pe}$ (-) suction

q_p= 703,125 N/m^2 (   ) pressure

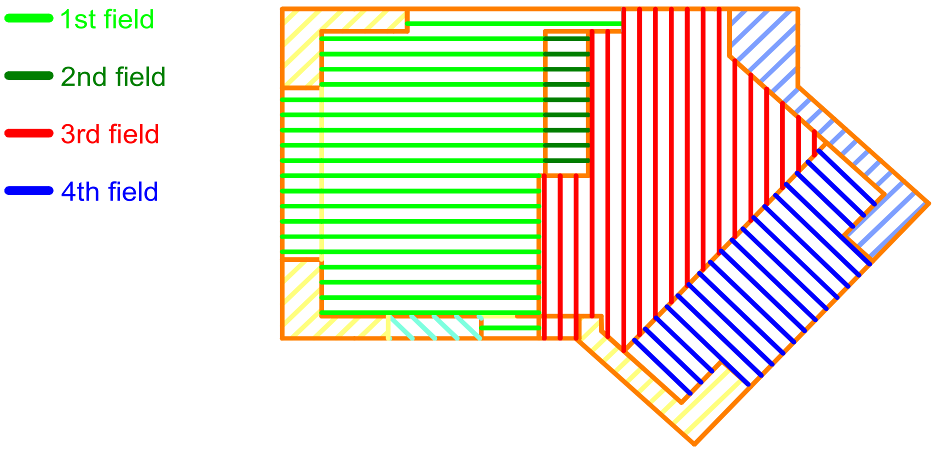
C_{pe}

area	wind orientation θ=0°	wind orientation θ=90°
A	-1,2	-1,2
B	-1,1	-1,1
C	-0,5	-0,5
D	0,75	0,75
E	-0,4	-0,4
F	-1,6	-1,6
G	-1,1	-1,1
H	-0,7	-0,7
I	-0,2	-0,2



w_e [N/m²]

area	wind orientation θ=0°	wind orientation θ=90°
A	-843,8	-843,8
B	-773,4	-773,4
C	-351,6	-351,6
D	527,3	527,3
E	-281,3	-281,3
F	-1 125,0	-1 125,0
G	-773,4	-773,4
H	-492,2	-492,2
I	-140,6	-140,6

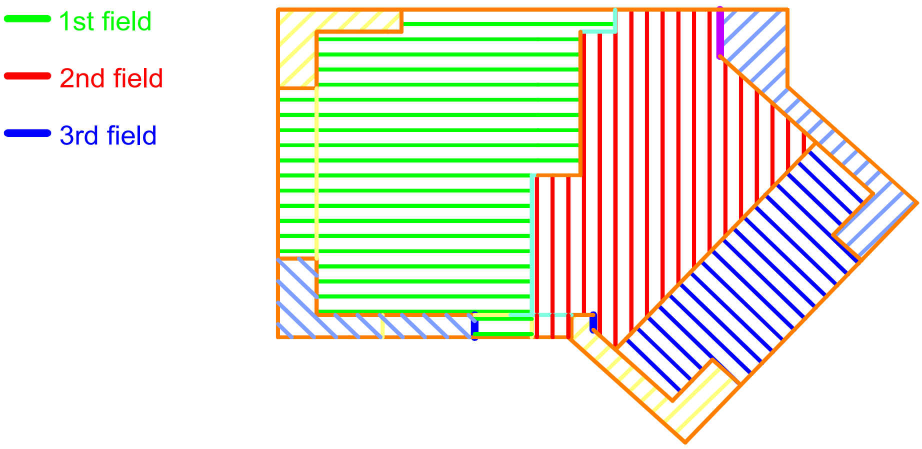


conversion of the wind load from square load to linear one for roof joists (θ=0°)

purlin	distance	w_e	q/2 [kN/m´]	**q [kN/m´]**
1st field 1-29 F	0,575	-1125,000	-0,323	**-0,647**
1st field 9 - 21 G	0,630	-773,438	-0,244	**-0,487**
1st field 1-29 H	0,630	-492,188	-0,155	**-0,310**
2nd 4-15 I	0,610	-140,625	-0,043	**-0,086**
3rd field 1-33 I	0,450	-140,625	-0,032	**-0,063**
4th field 1-25 I	0,630	-140,625	-0,044	**-0,089**

conversion of the wind load from square load to linear one for terrace joists (θ=0°)

purlin	distance	w_e	q/2 [kN/m´]	**q [kN/m´]**
F area	1,385	-1125,000	-0,779	**-1,558**
H area	1,385	-492,188	-0,341	**-0,682**
I area	1,385	-140,625	-0,097	**-0,195**
I area turned	0,945	-140,625	-0,066	**-0,133**



conversion of the wind load from square load to linear one for roof joists (θ=90°)

purlin	distance	w_e	q/2 [kN/m´]	**q [kN/m´]**
1st field 1-11 F	0,610	-1125,000	-0,343	**-0,686**
1st field 12-23 H	0,630	-492,188	-0,155	**-0,310**
1st field 24-29 I	0,575	-140,625	-0,040	**-0,081**
2nd field 6-33 F	0,450	-1125,000	-0,253	**-0,506**
2nd field 1-33 H	0,450	-492,188	-0,111	**-0,221**
2nd field 1-5 I	0,500	-140,625	-0,035	**-0,070**
3rd field 1-5 F	0,575	-1125,000	-0,323	**-0,647**
3rd field 6-25 H	0,630	-492,188	-0,155	**-0,310**

conversion of the wind load from square load to linear one for terrace joists (θ=90°)

purlin	distance	w_e	q/2 [kN/m´]	**q [kN/m´]**
F area	1,150	-1125,000	-0,647	**-1,294**
I area	1,150	-140,625	-0,081	**-0,162**
F area turned	0,630	-1125,000	-0,354	**-0,709**

conversion of the wind load from square load to linear one for wall girders (θ=0°)

beam	distance 1	distance 2	w_e	**q [kN/m´]**
1st - 2nd floor D	1,750	1,500	527,344	**1,714**
2nd - 3rd floor D	1,500	1,525	527,344	**1,595**
3rd - 4th floor D	1,525	1,600	527,344	**1,648**
4th floor D	1,600	0,000	527,344	**0,844**
1st - 2nd floor A	1,750	1,500	-843,750	**-2,742**
2nd - 3rd floor A	1,500	1,525	-843,750	**-2,552**
3rd floor A	0,000	1,525	-843,750	**-1,287**
4th floor A	1,600	0,000	-843,750	**-1,350**
1st - 2nd floor B	1,750	1,500	-773,438	**-2,514**
2nd - 3rd floor B	1,500	1,525	-773,438	**-2,340**
3rd - 4th floor B	1,525	1,600	-773,438	**-2,417**
3rd floor B	0,000	1,525	-773,438	**-1,179**
4th floor B	1,600	0,000	-773,438	**-1,238**
1st - 2nd floor E	1,750	1,500	-281,250	**-0,914**
2nd - 3rd floor E	1,500	1,525	-281,250	**-0,851**
3rd - 4th floor E	1,525	1,600	-281,250	**-0,879**
3rd floor E	0,000	1,525	-281,250	**-0,429**
4th floor E	1,600	0,000	-281,250	**-0,450**

conversion of the wind load from square load to linear one for wall columns (θ=0°)

column	distance	w_e	q/2 [kN/m´]	**q [kN/m´]**
A area	0,625	-843,750	-0,264	**-0,527**
B area	0,625	-773,438	-0,242	**-0,483**
D area	0,625	527,344	0,165	**0,330**
E area	0,625	-281,250	-0,088	**-0,176**

conversion of the wind load from square load to linear one for wall girders (θ=90°)

beam	distance 1	distance 2	w_e	**q [kN/m´]**
1st - 2nd floor D	1,750	1,500	527,344	**1,714**
2nd - 3rd floor D	1,500	1,525	527,344	**1,595**
3rd - 4th floor D	1,525	1,600	527,344	**1,648**
4th floor D	1,600	0,000	527,344	**0,844**
1st - 2nd floor A	1,750	1,500	-843,750	**-2,742**
2nd - 3rd floor A	1,500	1,525	-843,750	**-2,552**
3rd floor A	0,000	1,525	-843,750	**-1,287**
4th floor A	1,600	0,000	-843,750	**-1,350**
1st - 2nd floor B	1,750	1,500	-773,438	**-2,514**
2nd - 3rd floor B	1,500	1,525	-773,438	**-2,340**
3rd - 4th floor B	1,525	1,600	-773,438	**-2,417**
3rd floor B	0,000	1,525	-773,438	**-1,179**
4th floor B	1,600	0,000	-773,438	**-1,238**
1st - 2nd floor E	1,750	1,500	-281,250	**-0,914**
2nd - 3rd floor E	1,500	1,525	-281,250	**-0,851**
3rd - 4th floor E	1,525	1,600	-281,250	**-0,879**
3rd floor E	0,000	1,525	-281,250	**-0,429**
4th floor E	1,600	0,000	-281,250	**-0,450**

conversion of the wind load from square load to linear one for wall columns (θ=90°)

column	distance	w_e	q/2 [kN/m´]	**q [kN/m´]**
A area	0,625	-843,750	-0,264	**-0,527**
B area	0,625	-773,438	-0,242	**-0,483**
D area	0,625	527,344	0,165	**0,330**
E area	0,625	-281,250	-0,088	**-0,176**

Snow load

specification of snow load, done according to the ČSN EN 1991-1-3
for permanent or temporary design situations

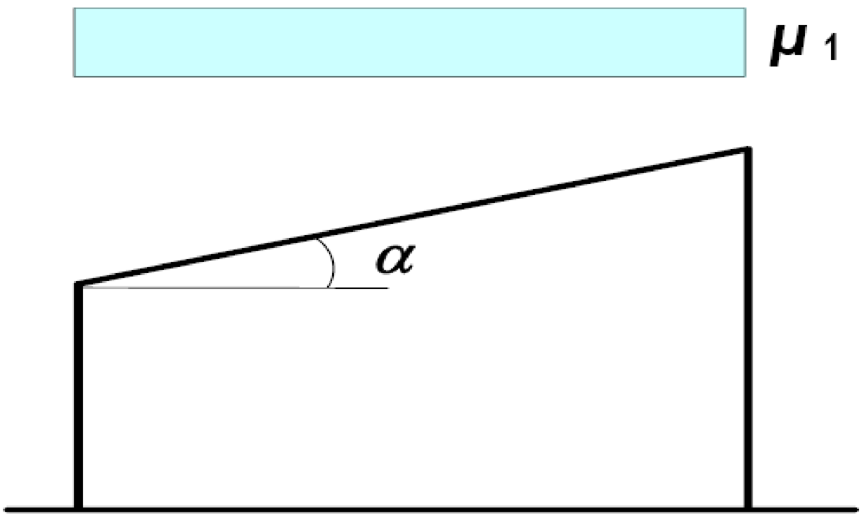
$s=\mu_i*C_e*C_t*s_k$

s_k=0,7 kN/m^2 estimated according to the map of snow areas of the Czech Republic
location Prague, I. snow area

C_e=1,0 coefficient of exposition
estimated for the normal shape of the landscape

C_t=1,0 thermal coefficient

μ coefficient of the shape of snow load



μ_1=0,8 0°≤α≤30° α=0°

s=0,8*1,0*1,0*0,7= **0,56** KN/m^2 s_d=s*1,5=0,56*1,5= **0,84** KN/m^2

conversion of the snow pressure to joists

purlin	width for loading	q [kN/m´]
boundary 1	0,315	0,265
middle 1	0,630	0,529
boundary 2	0,250	0,210
middle 2	0,500	0,420
boundary 3	0,200	0,168
middle 3	0,400	0,336
terrace boundary 1	0,693	0,582
terrace middle 1	1,385	1,163
terrace boundary 2	0,473	0,397
terrace middle 2	0,945	0,794

Self-weight load + imposed load for each composition

Construction of the floor

(There is concidered floor in the bathroom - ceramic tiles and waterproofing)
(There will be used wooden floor in the other rooms - the composition is lighter)

Self weight of the composition					
Layers of the composition	**Thickness [mm]**	**Density [kg/m³]**	**g_k [kN/m²]**	**γ_F**	**q_d [kN/m²]**
Final layer - ceramic tiles Rako Tanse	10,00	2000,00	0,200	1,35	0,270
Waterproofing Sarnafil G 441-24EL	2,40	3200,00	0,077	1,35	0,104
Impact sound insulation Dow Ethafoam	20,00	35,00	0,007	1,35	0,009
OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Thermal insulation Rockwool Rocknroll	100,00	100,00	0,100	1,35	0,135
OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Plasterboard	12,50	750,00	0,094	1,35	0,127
Summary			**0,725**		**0,979**

Self weight of timber joists included in the composition								
Profile	**Height of profile [mm]**	**Width of profile [mm]**	**Lenght of element [mm]**	**Number of elements**	**Density [kg/m³]**	**g_k [kN/m]**	**γ_F**	**g_d [kN/m]**
40 x 60	40	60	1000	3	470	0,034	1,35	0,046
Summary						**0,034**		**0,046**

Imposed load for the composition			
	q_k [kN/m²]	**γ_F**	**g_d [kN/m²]**
	1,500	1,500	2,250
Summary	**1,500**		**2,250**

Joist	**Width for loading [m]**	**g_d [kN/m´]**	**q_d [kN/m´]**
boundary 1	0,693	0,709	1,558
middle 1	1,385	1,419	3,116
boundary 2	0,473	0,484	1,063
middle 2	0,945	0,968	2,126

Construction of the roof

Self weight of the composition					
Layers of the composition	Thickness [mm]	Density [kg/m³]	g_k [kN/m²]	γ_F	q_d [kN/m²]
Gravel	50,00	1650,00	0,825	1,35	1,114
Waterproofing Sarnafil G 441-24EL	2,40	3200,00	0,077	1,35	0,104
Thermal insulation Dow Roofmate SL	120,00	35,00	0,042	1,35	0,057
Waterproofing Sikaplan D	1,20	1300,00	0,016	1,35	0,021
Thermal insulation Dow Roofmate SL	60,00	35,00	0,021	1,35	0,028
OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Thermal insulation Rockwool Fasrock	200,00	183,00	0,366	1,35	0,494
OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Vapour barrier Jutafol N 140 Special	0,25	560,00	0,001	1,35	0,002
Plasterboard	12,50	750,00	0,094	1,35	0,127
Summary			**1,689**		**2,280**

Self weight of timber joists included in composition								
Profile	Height of profile [mm]	Width of profile [mm]	Lenght of element [mm]	Number of elements	Density [kg/m³]	g_k [kN/m]	γ_F	g_d [kN/m]
40 x 60	40	60	1000	3	470	0,034	1,35	0,046
Summary						**0,034**		**0,046**

Imposed load for the composition			
	q_k [kN/m²]	γ_F	g_d [kN/m²]
	1,500	1,500	2,250
Summary	**1,500**		**2,250**

Joist	Width for loading [m]	g_d [kN/m´]	q_d [kN/m´]
boundary 1	0,315	0,733	0,709
middle 1	0,630	1,465	1,418
boundary 2	0,250	0,581	0,563
middle 2	0,500	1,163	1,125
boundary 3	0,195	0,454	0,439
middle 3	0,390	0,907	0,878

Construction of the terrace

Self weight of the composition						
Layers of the composition		Thickness [mm]	Density [kg/m³]	g_k [kN/m²]	γ_F	q_d [kN/m²]
	Final layer - walking coat Parador outdoor classic 7020	50,00	1650,00	0,825	1,35	1,114
	waterproofing Sarnafil G 441-24EL	2,40	3200,00	0,077	1,35	0,104
	Thermal insulation Dow Roofmate SL	100,00	35,00	0,035	1,35	0,047
	Waterproofing Sikaplan D	1,20	1300,00	0,016	1,35	0,021
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Impact sound insulation Dow Ethafoam	20,00	35,00	0,007	1,35	0,009
	Thermal insulation Rockwool Rocknroll	180,00	100,00	0,180	1,35	0,243
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Thermal insulation Rockwool Rocknroll	180,00	100,00	0,180	1,35	0,243
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Vapour barrier Jutafol N 140 Special	0,25	560,00	0,001	1,35	0,002
	Plasterboard	12,50	750,00	0,094	1,35	0,127
	Summary			**1,827**		**2,467**

Self weight of timber joists included in the composition								
Profile	Height of profile [mm]	Width of profile [mm]	Lenght of element [mm]	Number of elements	Density [kg/m³]	g_k [kN/m]	γ_F	g_d [kN/m]
40 x 60	40	60	1000	3	470	0,034	1,35	0,046
	Summary					**0,034**		**0,046**

Imposed load for the composition				
		q_k [kN/m²]	γ_F	g_d [kN/m²]
		2,500	1,500	3,750
Summary		**2,500**		**3,750**

Joist	Width for loading [m]	g_d [kN/m´]	q_d [kN/m´]
boundary 1	0,693	1,740	2,597
middle 1	1,385	3,479	5,194
boundary 2	0,473	1,187	1,772
middle 2	0,945	2,374	3,544

Construction of the floor on the air

Self weight of the composition						
Layers of the composition		Thickness [mm]	Density [kg/m³]	g_k [kN/m²]	γ_F	q_d [kN/m²]
Final layer - wooden floor	Efloor	20,00	470,00	0,094	1,35	0,127
OSB board	Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Impact sound insulation	Dow Ethafoam	20,00	35,00	0,007	1,35	0,009
OSB board	Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Thermal insulation	Rockwool Rocknroll	160,00	100,00	0,160	1,35	0,216
OSB board	Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Thermal insulation	Rockwool Rocknroll	100,00	100,00	0,100	1,35	0,135
OSB board	Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Thermal insulation	Rockwool Fasrock	80,00	183,00	0,146	1,35	0,198
Wooden fibre board	Hofatex Therm DK	80,00	150,00	0,120	1,35	0,162
External plaster	Tubag Mineralischer Dämmputz	10,00	625,00	0,063	1,35	0,084
Summary				**1,020**		**1,377**

Imposed load for the composition	q_k [kN/m²]	γ_F	g_d [kN/m²]
	1,500	1,500	2,250
Summary	**1,500**		**2,250**

Joist	Width for loading [m]	g_d [kN/m´]	q_d [kN/m´]
boundary	0,473	1,165	1,772
middle	0,945	2,331	3,544

Construction of the main wall

Self weight of the composition							
Layers of the composition		Thickness [mm]	Density [kg/m³]	g_k [kN/m²]	γ_F	q_d [kN/m²]
	External plaster Tubag Mineralischer Dämmputz	10,00	625,00	0,063	1,35	0,084
	Wooden fibre board Hofatex Therm DK	80,00	150,00	0,120	1,35	0,162
	Thermal insulation Rockwool Fasrock	80,00	128,00	0,102	1,35	0,138
	Thermal insulation Rockwool Fasrock	100,00	128,00	0,128	1,35	0,173
	Thermal insulation Rockwool Fasrock	100,00	128,00	0,128	1,35	0,173
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Vapour barrier Jutafol N 140 Special	0,25	560,00	0,001	1,35	0,002
	Platerboard	12,50	750,00	0,094	1,35	0,127
	Summary			**0,719**		**0,970**

Self weight of timber joists and columns included in the main wall composition								
Profile	Height of profile [mm]	Width of profile [mm]	Lenght of element [mm]	Number of elements	Density [kg/m³]	g_k [kN/m]	γ_F	g_d [kN/m]
40 x 80	40	80	1000	12	470	0,180	1,35	0,244
100 x 60	100	60	3100	3	470	0,262	1,35	0,354
	Summary					**0,443**		**0,598**

Boundary girder	Width for loading [m]	Layers g_d [kN/m´]	Layers+Profiles q_d [kN/m´]
1st-2nd floor	3,000	2,910	3,508
2nd-3rd floor	3,050	2,959	3,556

Construction of the 4th floor main wall

Self weight of the composition						
Layers of the composition		Thickness [mm]	Density [kg/m³]	g_k [kN/m²]	γ_F	q_d [kN/m²]
	External plaster Tubag Mineralischer Dämmputz	10,00	625,00	0,063	1,35	0,084
	Wooden fibre board Hofatex Therm DK	80,00	150,00	0,120	1,35	0,162
	Thermal insulation Rockwool Fasrock	80,00	128,00	0,102	1,35	0,138
	Thermal insulation Rockwool Fasrock	160,00	128,00	0,205	1,35	0,276
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Vapour barrier Jutafol N 140 Special	0,25	560,00	0,001	1,35	0,002
	Plasterboard	12,50	750,00	0,094	1,35	0,127
	Summary			**0,667**		**0,901**

Self weight of timber joists and columns included in the main wall composition								
Profile	Height of profile [mm]	Width of profile [mm]	Lenght of element [mm]	Number of elements	Density [kg/m³]	g_k [kN/m]	γ_F	g_d [kN/m]
40 x 80	40	80	1000	12	0	0,000	1,35	0,000
	Summary					**0,000**		**0,000**

Boundary girder	Width for loading [m]	Layers g_d [kN/m´]	Layers+Profiles q_d [kN/m´]
3rd-4th floor	3,000	6,841	6,841

Load combinations

$$\sum_{j\geq1}\gamma_{Gj}G_{kj}+\gamma_{Q1}Q_{k1}+\sum_{i\geq1}\gamma_{Qi}\psi_{0i}Q_{ki}$$

1. self weight load + imposed load

$1{,}35*G_k+1{,}5*Q_N$

2. self weight load + imposed load + snow load

$1{,}35*G_k+1{,}5*Q_N+0{,}6*1{,}5*Q_S$

3. self weight load + wind load θ=0°

$1{,}0*G_k+1{,}5*Q_V$

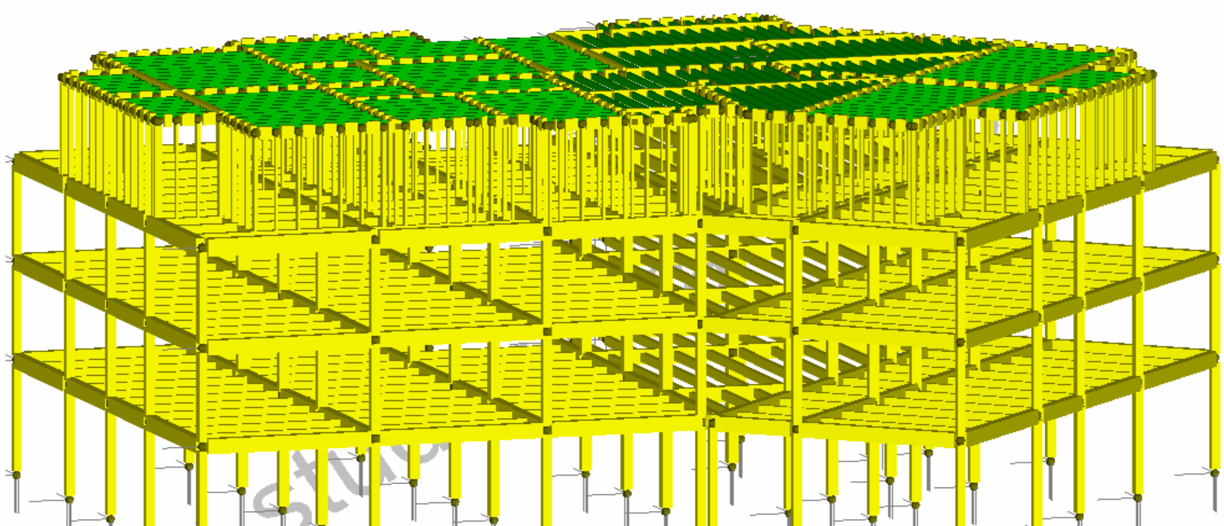
4. self weight load + wind load θ=90°

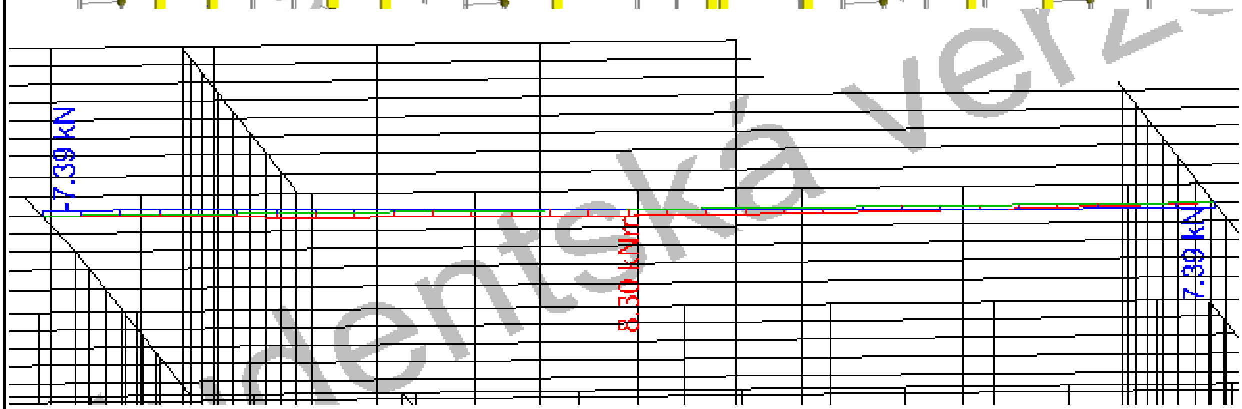
$1{,}0*G_k+1{,}5*Q_V$

Design of the roof joist

Material used for the design

grown wood C24





The design strength in bending

$f_{m,y,d}= k_{mod}*(f_{m,g,k}/\gamma_M)$ | $k_{mod}=$ 0,8 humidity class 1

$f_{m,y,k}=$ 24 [MPa] strength class C24

$\gamma_M=$ 1,3 sub factor of wood properties >1

$f_{m,y,d}=$ **14,769** **MPa**

Counted bending moment

$M_{yd}=$ **8,300** **kNm** (counted with the software FIN 3D)

Counted reactions

$R_{sd}=V_{sd}=$ **7,400** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	**200x100**	
h=	200,000	mm
b=	100,000	mm
m=	9,400	kg/m
A=	20000,000	mm^2
I_y=	66666,667	$*10^3\ mm^4$
i_y=	57,735	mm
W_y=	666,667	$*10^3\ mm^3$
I_z=	16666,667	$*10^3\ mm^4$
i_z=	28,868	mm
W_z=	333,333	$*10^3\ mm^3$

Normal stress in bending

$\sigma_{m,y,d}= M_{yd}/W_y$

$\sigma_{m,y,d}=$ 8,3*10^3/(666,667*10^3)

$\sigma_{m,y,d}=$ **12,450** **MPa**

Assessment of bending

$(\sigma_{m,y,d}/f_{m,y,d}) \leq 1$

(12,45/14,769) ≤ 1

0,843 **≤** **1**

—>Roof joist complies

Assessment to flexural shear

The design strength in shear

$f_{v,y,d}= k_{mod}*(f_{v,y,k}/\gamma_M)$ | $k_{mod}=$ 0,8 humidity class 1

$f_{v,y,k}=$ 2,5 [MPa] strength class C24

$\gamma_M=$ 1,3 sub factor of wood properties >1

$f_{v,y,d}=$ **1,538** **MPa**

Shear stress

$\tau_{v,d}$= $3V_d/2A$

$\tau_{v,d}$= 3*10^-3*7,4/(2*20000)

$\tau_{v,d}$= **0,555** ≤ **1**

—>Roof joist complies

Assessment of the joists on the deflection

l= 4400 mm

E= 11 000 MPa

I= 66,667 $*10^{3}mm^4$

Deflection from a unit uniform load

u_{ref}= $(5/384)*(q_{ref}*l^4)/(EI)$

u_{ref}= (5/384)*(1*4400^4)/(11000*66,667*10^3)

u_{ref}= **6,655** **mm**

Deflection from the imposed load

q_k= 1,95 kN/m

$u_{2,inst}$= q_k*u_{ref} ≤ l/300 mm

$u_{2,inst}$= 1,95*6,655 ≤ l/300 mm

$u_{2,inst}$= **12,977** **mm** ≤ **14,667** **mm**

—>Roof joist complies

Deflection from the selfweight load

g_k= 1,44 kN/m

$u_{2,inst}$= g_k*u_{ref} ≤ l/300 mm

$u_{2,inst}$= 1,44*6,655 ≤ l/300 mm

$u_{2,inst}$= **9,583** **mm** ≤ **14,667** **mm**

—>Roof joist complies

$k_{1,def}$= 0,6

$k_{2,def}$= 0

Total deflection from imposed and self-weight load

$u_{net,fin}$= $u_{1,inst}*(1+k_{1,def})+u_{2,inst}*(1+k_{2,def})$ ≤ l/150 mm

$u_{net,fin}$= 9,583*(1+0,6)+12,977*(1+0) ≤ l/150 mm

$u_{net,fin}$= **28,310** **mm** ≤ **29,333** **mm**

—>Roof joist complies

Ratio of deflection from bending moment and shearing forces

-done for simply supported beams with rectangular cross-section

(u_v/u_m)= $0,96*(E/G)*(h/l)^2$ G= 690 MPa

u_v= **0,032** u_m

Total deflection

u= $u_{net,fin}+0,032*_{unet,fin}$ ≤ l/150 mm

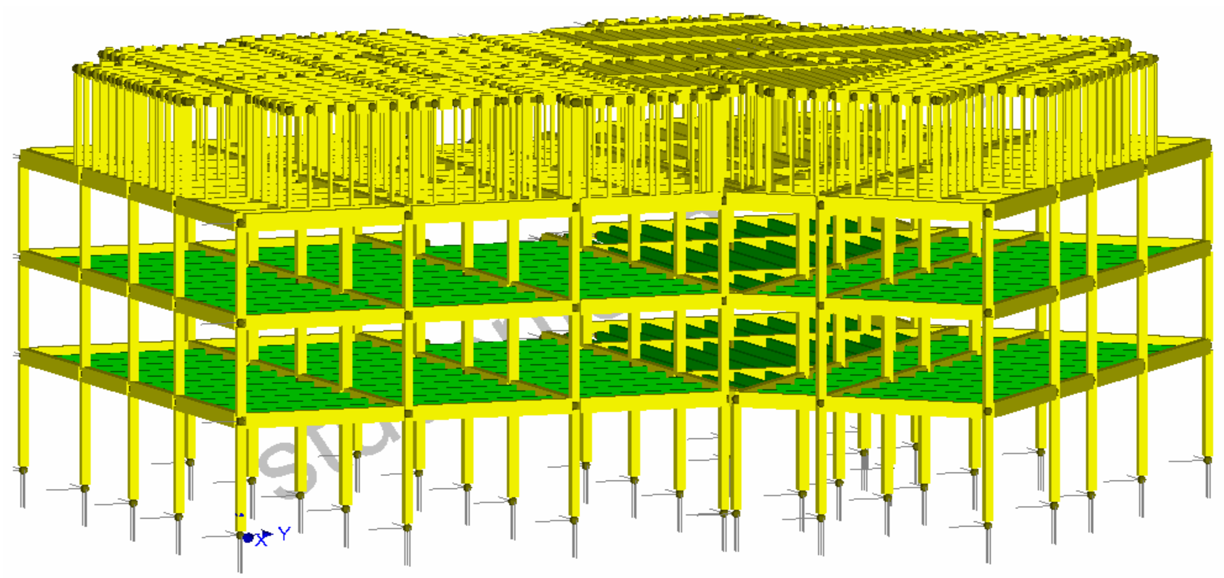
u= **29,206** **mm** ≤ **29,333** **mm**

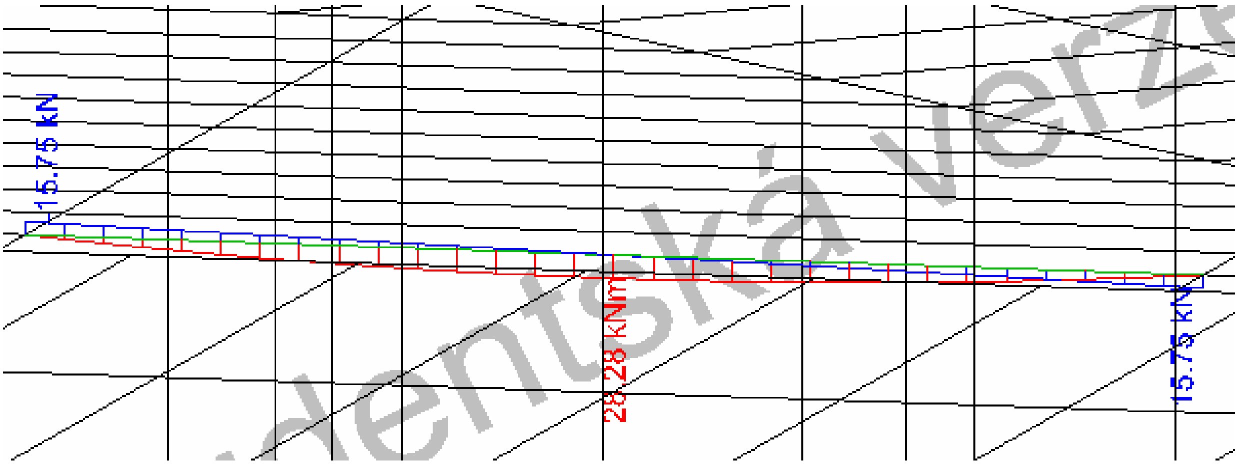
—>Roof joist complies

Design of the joist 2nd - 3rd floor

Material used for the design

grown wood C24





The design strength in bending

$f_{m,y,d}= k_{mod}*(f_{m,g,k}/\gamma_M)$	$k_{mod}=$	0,8	humidity class 1
	$f_{m,y,k}=$	24	[MPa] strength class C24
	$\gamma_M=$	1,3	sub factor of wood properties >1

$f_{m,y,d}=$ **14,769** **MPa**

Counted bending moment

$M_{yd}=$ **28,300** **kNm** (counted with the software FIN 3D)

Counted reactions

$R_{sd}=V_{sd}=$ **15,800** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	280x160	
$h=$	280,000	mm
$b=$	160,000	mm
$m=$	21,056	kg/m
$A=$	44800,000	mm^2
$I_y=$	292693,333	$*10^3\ mm^4$
$i_y=$	80,829	mm
$W_y=$	2090,667	$*10^3\ mm^3$
$I_z=$	95573,333	$*10^3\ mm^4$
$i_z=$	46,188	mm
$W_z=$	1194,667	$*10^3\ mm^3$

Normal stress in bending

$\sigma_{m,y,d}= M_{yd}/W_y$

$\sigma_{m,y,d}=$ 28,3*10^3/(2090,667*10^3)

$\sigma_{m,y,d}=$ **13,536** **MPa**

Assessment of the bending

$(\sigma_{m,y,d}/f_{m,y,d}) \leq 1$

(13,536/14,769) ≤ 1

0,917 **≤** **1**

—>Joist complies

Assessment to flexural shear

The design strength in shear

$f_{v,y,d}= k_{mod}*(f_{v,y,k}/\gamma_M)$

$k_{mod}=$	0,8	humidity class 1
$f_{v,y,k}=$	2,5	[MPa] strength class C24
$\gamma_M=$	1,3	sub factor of wood properties >1

$f_{v,y,d}=$ **1,538** **MPa**

Shear stress

$\tau_{v,d}= 3V_d/2A$

$\tau_{v,d}=$ 3*10^-3*15,8/(2*44800)

$\tau_{v,d}=$ **0,529**

$(\tau_{v,d}/f_{v,y,d}) \leq 1$

(0,529/1,538) ≤ 1

0,344 **≤** **1**

—>Joist complies

Assessment of the joists on the deflection

l=	7000	mm
E=	11 000	MPa
I=	292,693	$*10^3 mm^4$

Deflection from a unit uniform load

u_{ref}= (5/384)*(q_{ref}*l^4)/(EI)

u_{ref}= (5/384)*(1*7000^4)/(11000*292,693*10^3)

u_{ref}= **9,710** **mm**

Deflection from the imposed load

q_k= 2,13 kN/m

$u_{2,inst}$= q_k*u_{ref}		≤	l/300	mm
$u_{2,inst}$= 2,13*9,71		≤	l/300	mm
$u_{2,inst}$= **20,683**	**mm**	**≤**	**23,333**	**mm**

—>Joist complies

Deflection from the selfweight loading

g_k= 0,97 kN/m

$u_{2,inst}$= g_k*u_{ref}		≤	l/300	mm
$u_{2,inst}$= 0,97*9,71		≤	l/300	mm
$u_{2,inst}$= **9,419**	**mm**	**≤**	**23,333**	**mm**

—>Joist complies

$k_{1,def}$= 0,6

Total deflection from imposed and self-weight load

$k_{2,def}$= 0

$u_{net,fin}$= $u_{1,inst}$*(1+$k_{1,def}$)+$u_{2,inst}$*(1+$k_{2,def}$)			≤ l/150	mm
$u_{net,fin}$= 9,419*(1+0,6)+20,683*(1+0)			≤ l/150	mm
$u_{net,fin}$= **35,753**	**mm**	**≤**	**46,667**	**mm**

—>Joist complies

Ratio of deflection from bending moment and shearing forces

-done for simply supported beams with rectangular cross-section

(u_v/u_m)= 0,96*(E/G)*$(h/l)^2$ G= 690 MPa

u_v= **0,024** u_m

Total deflection

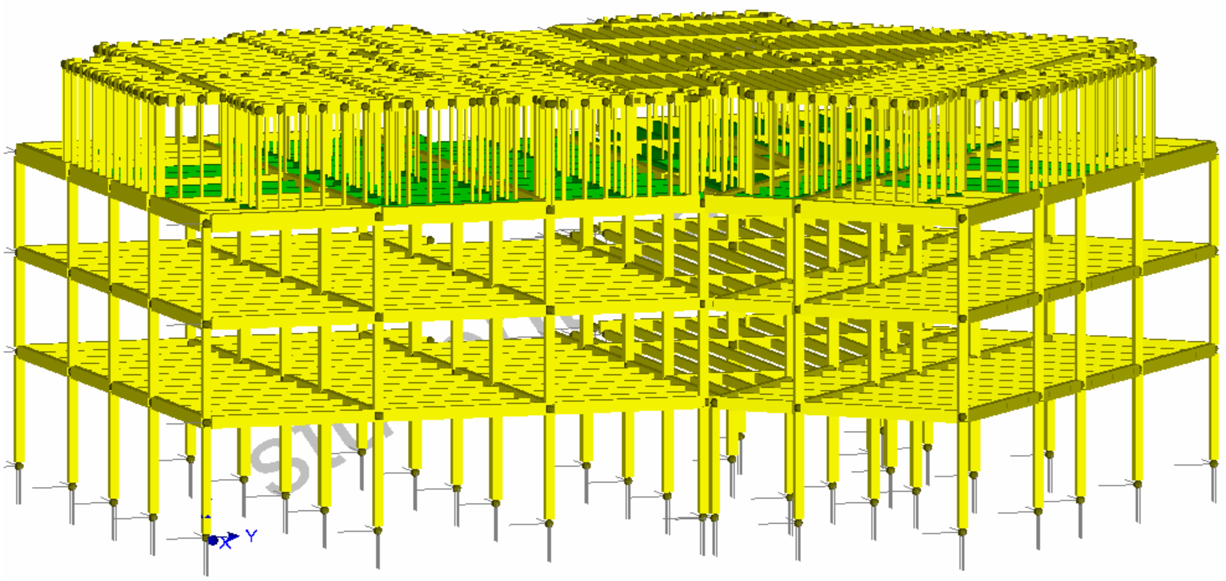
u= $u_{net,fin}$+0,024*$u_{net,fin}$		≤	l/150	mm
u= **36,628**	**mm**	≤	**46,667**	**mm**

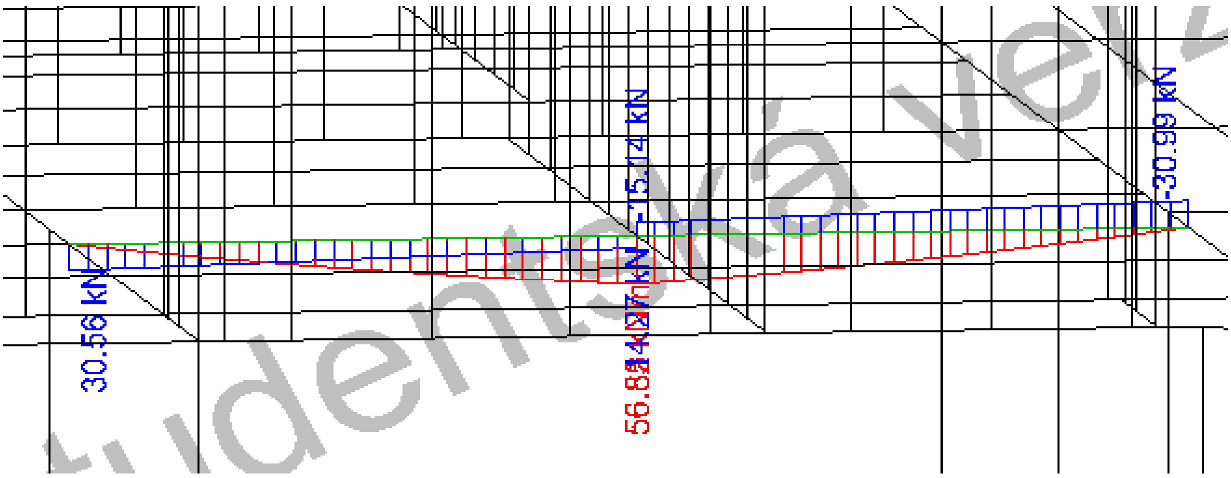
—>Joist complies

Design of the joist 4th floor

Material used for the design

glue-laminated timber GL 24h





The design strength in bending

$f_{m,y,d}= k_{mod}*(f_{m,g,k}/\gamma_M)$

k_{mod}=	0,8	humidity class 1
$f_{m,y,k}$=	24	[MPa] strength class GL 24h
γ_M=	1,3	sub factor of wood properties >1

$f_{m,y,d}$= **14,769** **MPa**

Counted bending moment

M_{yd}= **57,000** **kNm** (counted with the software FIN 3D)

Counted reactions

$R_{sd}=V_{sd}$= **63,000** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	**360x180**	
$h=$	360,000	mm
$b=$	180,000	mm
$m=$	30,456	kg/m
$A=$	64800,000	mm^2
$I_y=$	699840,000	$*10^3\ mm^4$
$i_y=$	103,923	mm
$W_y=$	3888,000	$*10^3\ mm^3$
$I_z=$	174960,000	$*10^3\ mm^4$
$i_z=$	51,962	mm
$W_z=$	1944,000	$*10^3\ mm^3$

Normal stress in bending

$\sigma_{m,y,d}=$ M_{yd}/W_y

$\sigma_{m,y,d}=$ 57*10^3/(3888*10^3)

$\sigma_{m,y,d}=$ **13,860** **MPa**

Assessment of bending

$(\sigma_{m,y,d}/f_{m,y,d})$	≤	1
(13,86/14,769)	≤	1
0,938	**≤**	**1**

—>Joist complies

Assessment to flexural shear

The design strength in shear

$f_{v,y,d}=$ $k_{mod}*(f_{v,y,k}/\gamma_M)$

$k_{mod}=$	0,8	humidity class 1
$f_{v,y,k}=$	2,7	[MPa] strength class GL 24h
$\gamma_M=$	1,3	sub factor of wood properties >1

$f_{v,y,d}=$ **1,662** **MPa**

Shear stress

$\tau_{v,d}=$ $3V_d/2A$

$\tau_{v,d}=$ 3*10^-3*63/(2*64800)

$\tau_{v,d}=$ **1,458**

$(\tau_{v,d}/f_{v,y,d})$	≤	1
(1,458/1,662)	≤	1
0,878	**≤**	**1**

—>Joist complies

Assessment of the joists on the deflection

$l=$	5000	mm
$E=$	10 000	MPa
$I=$	699,840	$*10^{\wedge 3}mm^4$

Deflection from a unit uniform load

$u_{ref}=$ $(5/384)*(q_{ref}*l^4)/(EI)$

$u_{ref}=$ (5/384)*(1*5000^4)/(10000*699,84*10^3)

$u_{ref}=$ **1,163** **mm**

Deflection from the imposed load

q_k= 3,2 kN/m

$u_{2,inst}$= q_k*u_{ref} ≤ l/300 mm

$u_{2,inst}$= 3,2*1,163 ≤ l/300 mm

$u_{2,inst}$= **3,721** **mm** ≤ **16,667** **mm**

—>Joist complies

Deflection from the selfweight load

g_k= 1,5 kN/m

$u_{2,inst}$= g_k*u_{ref} ≤ l/300 mm

$u_{2,inst}$= 1,5*1,163 ≤ l/300 mm

$u_{2,inst}$= **1,744** **mm** ≤ **16,667** **mm**

—>Joist complies

$k_{1,def}$= 0,6

Total deflection from imposed and self-weight load

$k_{2,def}$= 0

$u_{net,fin}$= $u_{1,inst}$*(1+$k_{1,def}$)+$u_{2,inst}$*(1+$k_{2,def}$) ≤ l/150 mm

$u_{net,fin}$= 1,744*(1+0,6)+3,721*(1+0) ≤ l/150 mm

$u_{net,fin}$= **6,512** **mm** ≤ **33,333** **mm**

—>Joist complies

Ratio of deflection from bending moment and shearing forces

-done for simply supported beams with rectangular cross-section

(u_v/u_m)= 0,96*(E/G)*$(h/l)^2$ G= 630 MPa

u_v= **0,079** u_m

Total deflection

u= $u_{net,fin}$+0,079*$_{unet,fin}$ ≤ l/150 mm

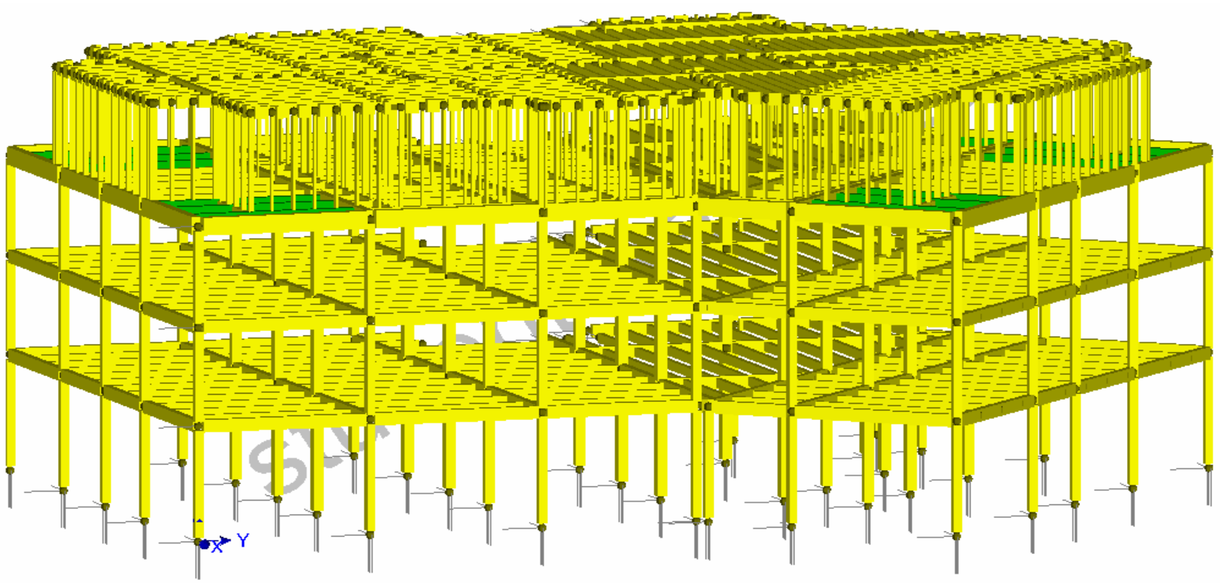
u= **7,026** **mm** ≤ **33,333** **mm**

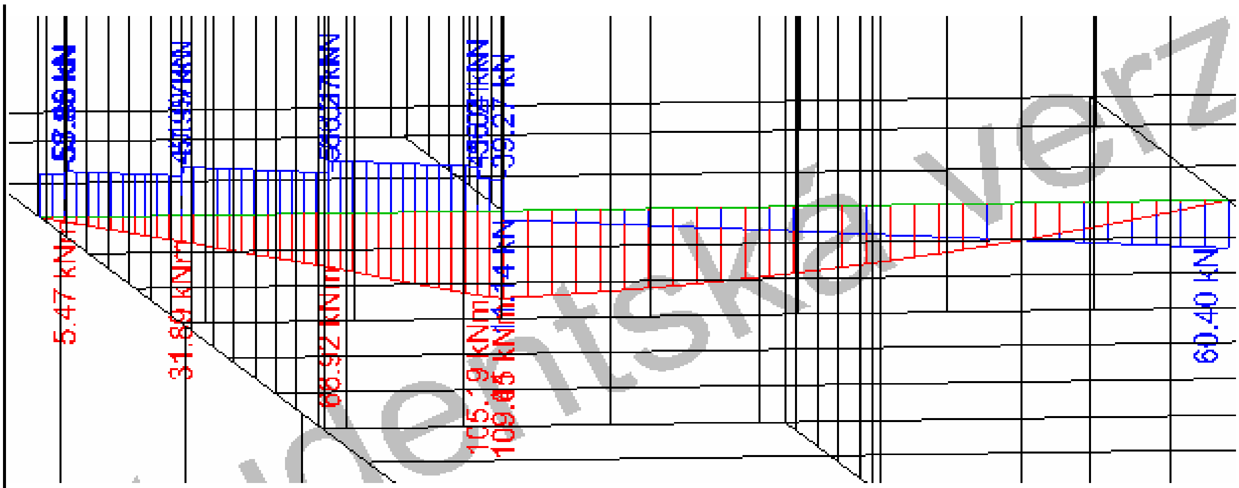
—>Joist complies

Design of the joist 4th floor - terrace

Material used for the design

glue-laminated timber GL 24h





The design strength in bending

$f_{m,y,d}$= k_{mod}*($f_{m,g,k}$/γ_M)

k_{mod}=	0,8	humidity class 1
$f_{m,y,k}$=	24	[MPa] strength class GL 24h
γ_M=	1,3	sub factor of wood properties >1

$f_{m,y,d}$= **14,769** **MPa**

Counted bending moment

M_{yd}= **110,000** **kNm** (counted with the software FIN 3D)

Counted reactions

R_{sd}=V_{sd}= **79,000** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	**460x220**	
h=	460,000	mm
b=	220,000	mm
m=	47,564	kg/m
A=	101200,000	mm^2
I_y=	1784493,333	$*10^3$ mm^4
i_y=	132,791	mm
W_y=	7758,667	$*10^3$ mm^3
I_z=	408173,333	$*10^3$ mm^4
i_z=	63,509	mm
W_z=	3710,667	$*10^3$ mm^3

Normal stress in bending

$\sigma_{m,y,d}$= M_{yd}/W_y

$\sigma_{m,y,d}$= 110*10^3/(7758,667*10^3)

$\sigma_{m,y,d}$= **13,778** **MPa**

Assessment of bending

($\sigma_{m,y,d}$/$f_{m,y,d}$) ≤ 1

(13,778/14,769) ≤ 1

0,933 **≤** **1**

—>Joist complies

Assessment to flexural shear

The design strength in shear

$f_{v,y,d}= k_{mod}*(f_{v,y,k}/\gamma_M)$ $k_{mod}=$ 0,8 humidity class 1

$f_{v,y,k}=$ 2,7 [MPa] strength class GL 24h

$\gamma_M=$ 1,3 sub factor of wood properties >1

$f_{v,y,d}=$ **1,662** **MPa**

Shear stress

$\tau_{v,d}= 3V_d/2A$

$\tau_{v,d}=$ 3*10^-3*79/(2*101200)

$\tau_{v,d}=$ **1,171**

$(\tau_{v,d}/f_{v,y,d}) \leq 1$

$(1,171/1,662) \leq 1$

0,705 **≤** **1**

—>Joist complies

Assessment of the joists on the deflection

l= 5000 mm

E= 10 000 MPa

I= 1784,493 $*10^3$ mm^3

Deflection from a unit uniform load

$u_{ref}= (5/384)*(q_{ref}*l^4)/(EI)$

$u_{ref}=$ (5/384)*(1*5000^4)/(10000*1784,493*10^3)

$u_{ref}=$ **0,456** **mm**

Deflection from the imposed load

$q_k=$ 5,2 kN/m

$u_{2,inst}= q_k*u_{ref} \leq$ l/300 mm

$u_{2,inst}=$ 5,2*0,456 ≤ l/300 mm

$u_{2,inst}=$ **2,371** **mm** **≤** **16,667** **mm**

—>Joist complies

Deflection from the selfweight load

$g_k=$ 3,3 kN/m

$u_{2,inst}= g_k*u_{ref} \leq$ l/300 mm

$u_{2,inst}=$ 3,3*0,456 ≤ l/300 mm

$u_{2,inst}=$ **1,505** **mm** **≤** **16,667** **mm**

—>Joist complies

$k_{1,def}=$ 0,6

$k_{2,def}=$ 0

Total deflection from imposed and self-weight load

$u_{net,fin}= u_{1,inst}*(1+k_{1,def})+u_{2,inst}*(1+k_{2,def})$ ≤ l/150 mm

$u_{net,fin}=$ 1,505*(1+0,6)+2,371*(1+0) ≤ l/150 mm

$u_{net,fin}=$ **4,779** **mm** **≤** **33,333** **mm**

—>Joist complies

Ratio of deflection from bending moment and shearing forces

-done for simply supported beams with rectangular cross-section

$(u_v/u_m)= 0,96*(E/G)*(h/l)^2$ G= 630 MPa

$u_v=$ **0,129** u_m

Total deflection

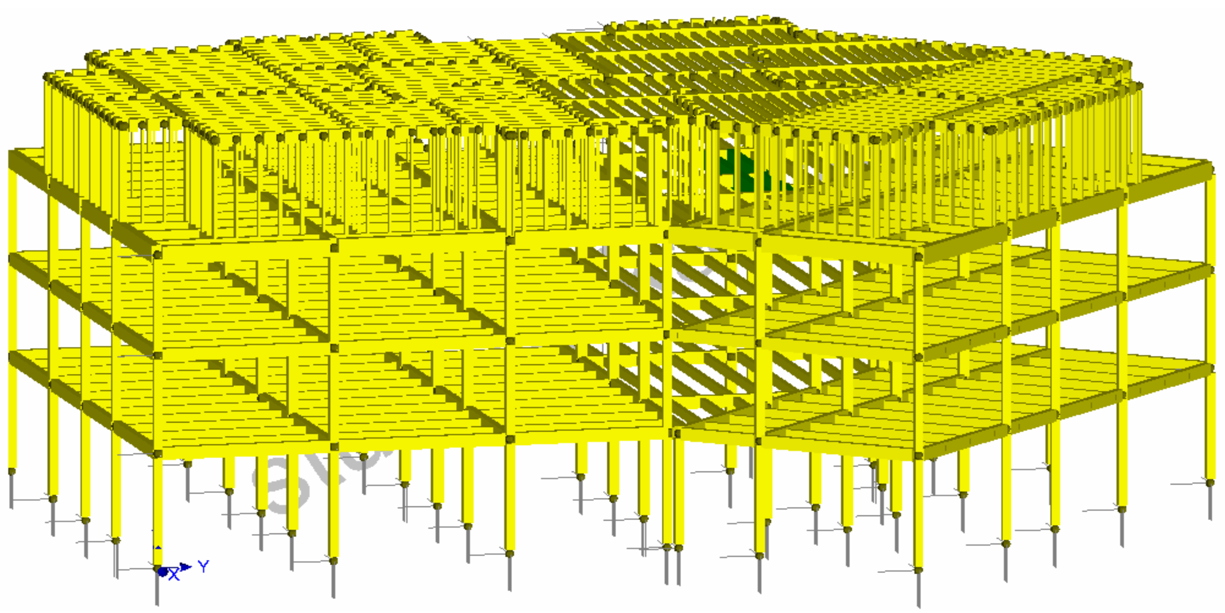
$u=$	$u_{net,fin}+0{,}129{*}u_{net,fin}$		$\leq$	l/150	mm
$u=$	**5,396**	**mm**	$\leq$	**33,333**	**mm**

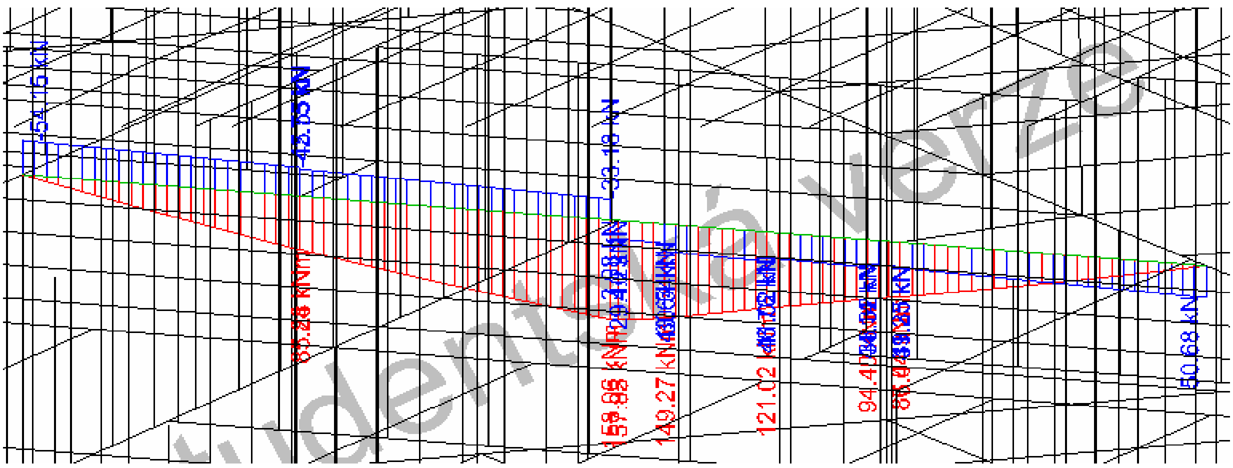
—>Joist complies

Design of the joist 4[th] floor

Material used for the design

glue-laminated timber GL 24h





The design strength in bending

$f_{m,y,d}= k_{mod}{*}(f_{m,g,k}/\gamma_M)$

$k_{mod}=$	0,8	humidity class 1
$f_{m,y,k}=$	24	[MPa] strength class GL 24h
$\gamma_M=$	1,3	sub factor of wood properties >1

$f_{m,y,d}=$ **14,769** **MPa**

Counted bending moment

$M_{yd}=$ **159,000** **kNm** (counted with the software FIN 3D)

Counted reactions

$R_{sd}=V_{sd}=$ **55,000** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	**500x260**	
h=	500,000	mm
b=	260,000	mm
m=	61,100	kg/m
A=	130000,000	mm^2
I_y=	2708333,333	$*10^3$ mm^4
i_y=	144,338	mm
W_y=	10833,333	$*10^3$ mm^3
I_z=	732333,333	$*10^3$ mm^4
i_z=	75,056	mm
W_z=	5633,333	$*10^3$ mm^3

Normal stress in bending

$\sigma_{m,y,d}$= M_{yd}/W_y

$\sigma_{m,y,d}$= 159*10^3/(10833,333*10^3)

$\sigma_{m,y,d}$= **13,877** **MPa**

Assessment of bending

$(\sigma_{m,y,d}/f_{m,y,d})$ ≤ 1

(13,877/14,769) ≤ 1

0,940 **≤** **1**

—>Joist complies

Assessment to flexural shear

The design strength in shear

$f_{v,y,d}$= $k_{mod}*(f_{v,y,k}/\gamma_M)$

k_{mod}=	0,8	humidity class 1
$f_{v,y,k}$=	2,7	[MPa] strength class GL 24h
γ_M=	1,3	sub factor of wood properties >1

$f_{v,y,d}$= **1,662** **MPa**

Shear stress

$\tau_{v,d}$= $3V_d/2A$

$\tau_{v,d}$= 3*10^-3*55/(2*130000)

$\tau_{v,d}$= **0,635**

$(\tau_{v,d}/f_{v,y,d})$ ≤ 1

(0,635/1,662) ≤ 1

0,382 **≤** **1**

—>Joist complies

Assessment of the joists on the deflection

l=	7000	mm
E=	11 000	MPa
I=	2708,333	$*10^3$ mm^3

Deflection from a unit uniform load

u_{ref}= $(5/384)*(q_{ref}*l^4)/(EI)$

u_{ref}= (5/384)*(1*7000^4)/(11000*2708,333*10^3)

u_{ref}= **1,049** **mm**

Deflection from the imposed load

q_k= 5,2 kN/m

$u_{2,inst}$= q_k*u_{ref} ≤ l/300 mm

$u_{2,inst}$= 5,2*1,049 ≤ l/300 mm

$u_{2,inst}$= **5,457 mm** ≤ **23,333 mm**

—>Joist complies

Deflection from the selfweight load

g_k= 3,3 kN/m

$u_{2,inst}$= g_k*u_{ref} ≤ l/300 mm

$u_{2,inst}$= 3,3*1,049 ≤ l/300 mm

$u_{2,inst}$= **3,463 mm** ≤ **23,333 mm**

—>Joist complies

$k_{1,def}$= 0,6

Total deflection from imposed and self-weight load

$k_{2,def}$= 0

$u_{net,fin}$= $u_{1,inst}$*(1+$k_{1,def}$)+$u_{2,inst}$*(1+$k_{2,def}$) ≤ l/150 mm

$u_{net,fin}$= 3,463*(1+0,6)+5,457*(1+0) ≤ l/150 mm

$u_{net,fin}$= **10,998 mm** ≤ **46,667 mm**

—>Joist complies

Ratio of deflection from bending moment and shearing forces

-done for simply supported beams with rectangular cross-section

(u_v/u_m)= 0,96*(E/G)*$(h/l)^2$ G= 630 MPa

u_v= **0,086** u_m

Total deflection

u= $u_{net,fin}$+0,086*$_{unet,fin}$ ≤ l/150 mm

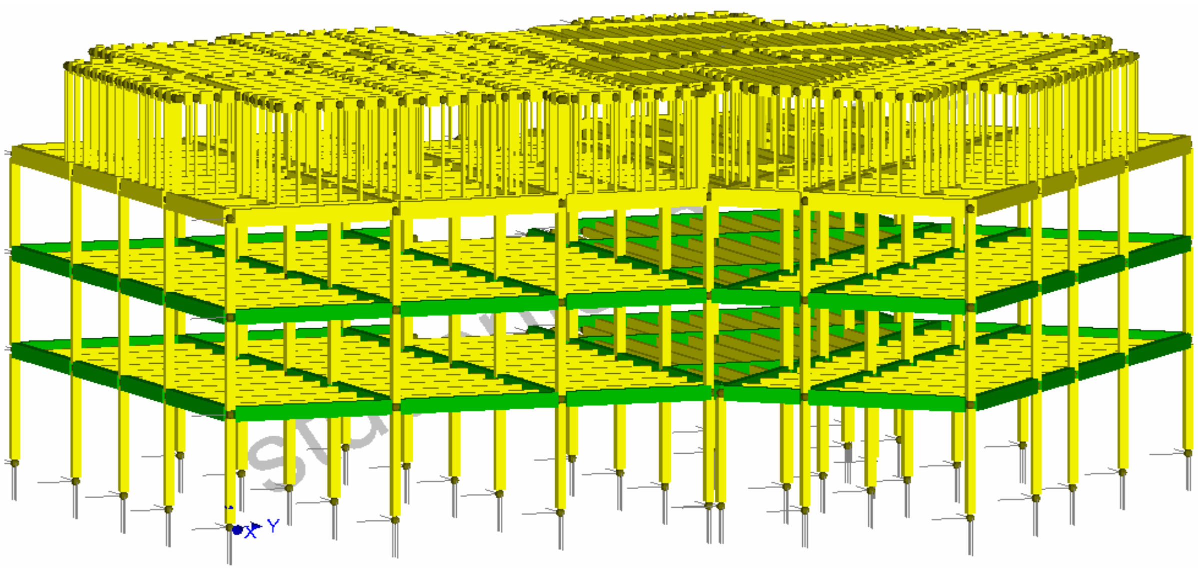
u= **11,938 mm** ≤ **46,667 mm**

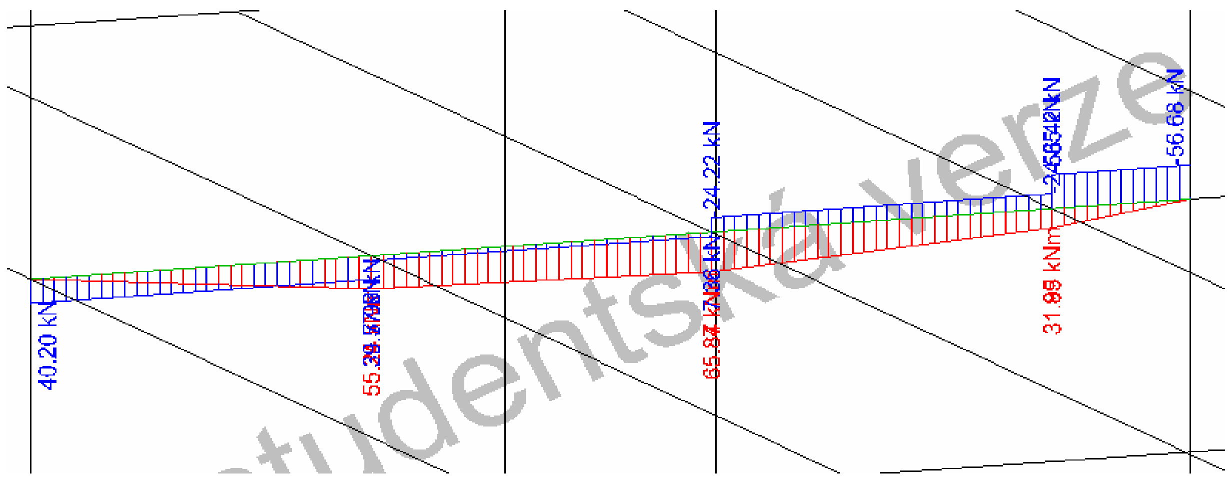
—>Joist complies

Design of the girder 2nd - 3rd floor

Material used for the design

glue-laminated timber GL 24h





The design strength in bending

$f_{m,y,d} = k_{mod} \cdot (f_{m,g,k}/\gamma_M)$

k_{mod}=	0,8	humidity class 1
$f_{m,y,k}$=	24	[MPa] strength class GL 24h
γ_M=	1,3	sub factor of wood properties >1

$f_{m,y,d}$= **14,769** **MPa**

Counted bending moment

M_{yd}= **66,000** **kNm** (counted with the software FIN 3D)

Counted reactions

$R_{sd}=V_{sd}$= **63,000** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	**380x200**	
h=	380,000	mm
b=	200,000	mm
m=	35,720	kg/m
A=	76000,000	mm^2
I_y=	914533,333	$\cdot 10^3\ mm^4$
i_y=	109,697	mm
W_y=	4813,333	$\cdot 10^3\ mm^3$
I_z=	253333,333	$\cdot 10^3\ mm^4$
i_z=	57,735	mm
W_z=	2533,333	$\cdot 10^3\ mm^3$

Normal stress in bending

$\sigma_{m,y,d} = M_{yd}/W_y$

$\sigma_{m,y,d}$= 66*10^3/(4813,333*10^3)

$\sigma_{m,y,d}$= **13,712** **MPa**

Assessment of bending

$(\sigma_{m,y,d}/f_{m,y,d}) \leq 1$

(13,712/14,769) ≤ 1

0,928 **≤** **1**

—>Girder complies

Assessment to flexural shear

The design strength in shear

$f_{v,y,d}= k_{mod}*(f_{v,y,k}/\gamma_M)$ | $k_{mod}=$ 0,8 humidity class 1

$f_{v,y,k}=$ 2,7 [MPa] strength class GL 24h

$\gamma_M=$ 1,3 sub factor of wood properties >1

$f_{v,y,d}=$ **1,662** **MPa**

Shear stress

$\tau_{v,d}= 3V_d/2A$

$\tau_{v,d}=$ 3*10^-3*63/(2*76000)

$\tau_{v,d}=$ **1,243**

$(\tau_{v,d}/f_{v,y,d}) \leq 1$

(1,243/1,662) ≤ 1

0,748 ≤ **1**

—>Girder complies

Assessment of the girders on the deflection

Deflection from a unit uniform load

l= 5000 mm

E= 11 000 MPa

I= 914,533 $*10^{3}mm^{4}$

$u_{ref}= (5/384)*(q_{ref}*l^4)/(EI)$

$u_{ref}=$ (5/384)*(1*5000^4)/(11000*914,533*10^3)

$u_{ref}=$ **0,809** **mm**

Deflection from the imposed load

$q_k=$ 11,200 kN/m

$u_{2,inst}= q_k*u_{ref}$ ≤ l/300 mm

$u_{2,inst}=$ 11,2*0,809 ≤ l/300 mm

$u_{2,inst}=$ **9,060** **mm** ≤ **16,667** **mm**

—>Girder complies

Deflection from the selfweight load

$g_k=$ 5,200 kN/m

$u_{2,inst}= g_k*u_{ref}$ ≤ l/300 mm

$u_{2,inst}=$ 5,2*0,809 ≤ l/300 mm

$u_{2,inst}=$ **4,207** **mm** ≤ **16,667** **mm**

—>Girder complies

Total deflection from imposed and self-weight load

$k_{1,def}=$ 0,6

$k_{2,def}=$ 0

$u_{net,fin}= u_{1,inst}*(1+k_{1,def})+u_{2,inst}*(1+k_{2,def})$ ≤ l/150 mm

$u_{net,fin}=$ 4,207*(1+0,6)+9,06*(1+0) ≤ l/150 mm

$u_{net,fin}=$ **15,791** **mm** ≤ **33,333** **mm**

—>Girder complies

Ratio of deflection from bending moment and shearing forces

-done for simply supported beams with rectangular cross-section

$(u_v/u_m)= 0,96*(E/G)*(h/l)^2$ G= 630 MPa

$u_v=$ **0,097** u_m

Total deflection

u= $u_{net,fin}+0,097*u_{net,fin}$ ≤ l/150 mm

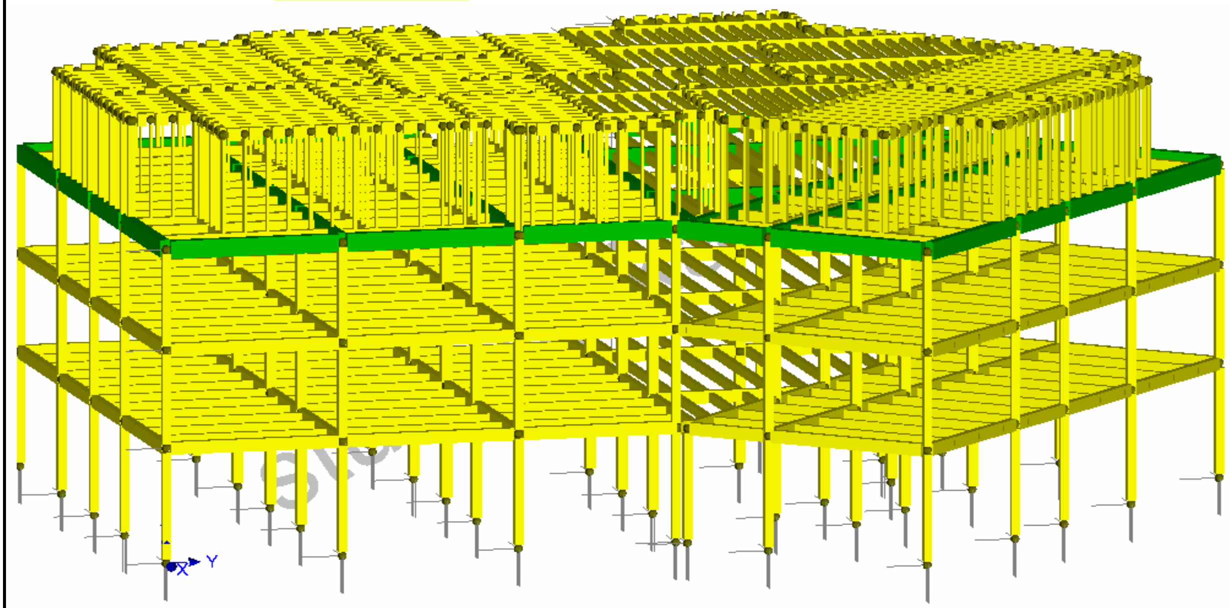
u= **17,320** **mm** ≤ **33,333** **mm**

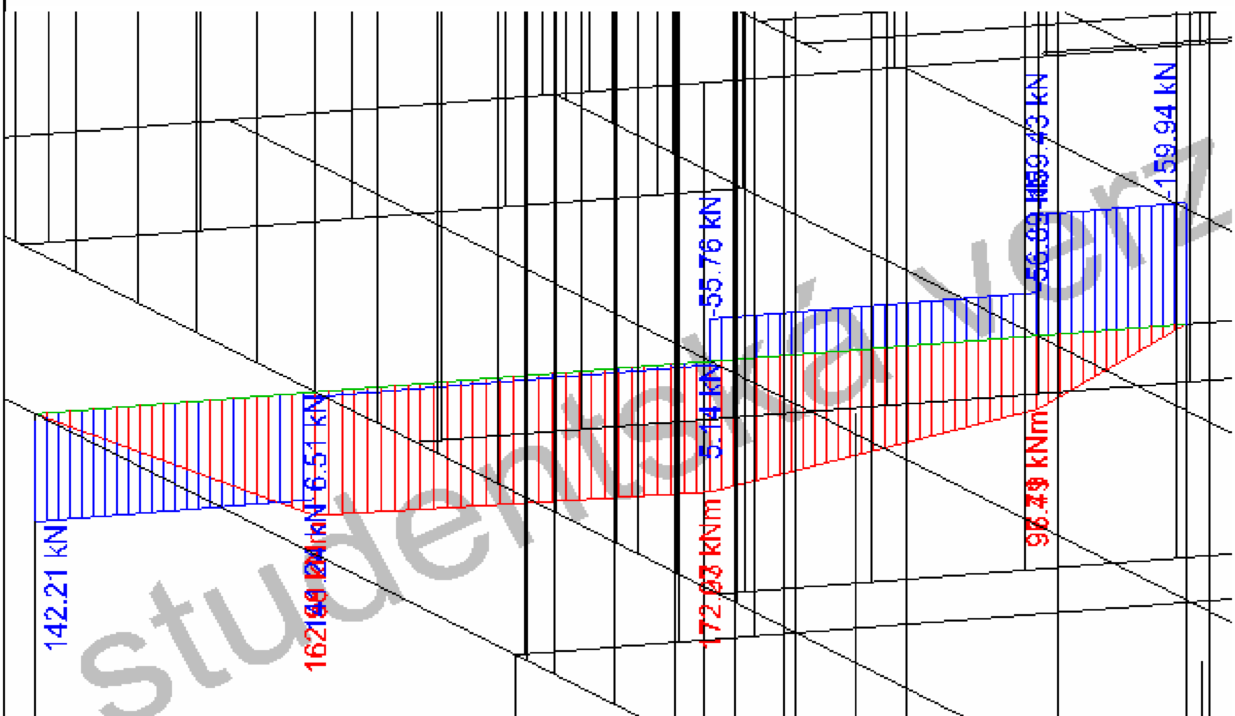
—>Girder complies

Design of the girder 4th floor

Material used for the design

glue-laminated timber GL 24h





The design strength in bending

$f_{m,y,d}$= k_{mod}*($f_{m,g,k}$/γ_M)

k_{mod}=	0,8	humidity class 1
$f_{m,y,k}$=	24	[MPa] strength class GL 24h
γ_M=	1,3	sub factor of wood properties >1

$f_{m,y,d}$= **14,769** **MPa**

Counted bending moment

M_{yd}= **173,000** **kNm** (counted with the software FIN 3D)

Counted reactions

R_{sd}=V_{sd}= **168,000** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	**520x260**	
h=	520,000	mm
b=	260,000	mm
m=	63,544	kg/m
A=	135200,000	mm^2
I_y=	3046506,667	$*10^3$ mm^4
i_y=	150,111	mm
W_y=	11717,333	$*10^3$ mm^3
I_z=	761626,667	$*10^3$ mm^4
i_z=	75,056	mm
W_z=	5858,667	$*10^3$ mm^3

Normal stress in bending

$\sigma_{m,y,d}$= M_{yd}/W_y

$\sigma_{m,y,d}$= 173*10^3/(11717,333*10^3)

$\sigma_{m,y,d}$= **13,964** **MPa**

Assessment of bending

($\sigma_{m,y,d}$/$f_{m,y,d}$) ≤ 1

(13,964/14,769) ≤ 1

0,946 **≤** **1**

—>Girder complies

Assessment to flexural shear

The design strength in shear

$f_{v,y,d}$= k_{mod}*($f_{v,y,k}$/γ_M)

k_{mod}=	0,8	humidity class 1
$f_{v,y,k}$=	2,7	[MPa] strength class GL 24h
γ_M=	1,3	sub factor of wood properties >1

$f_{v,y,d}$= **1,662** **MPa**

Shear stress

$\tau_{v,d}$= 3V_d/2A

$\tau_{v,d}$= 3*10^-3*168/(2*135200)

$\tau_{v,d}$= **1,514**

$(\tau_{v,d}/f_{v,y,d}) \le 1$

$(1{,}514/1{,}662) \le 1$

0,911 ≤ **1**

—>Girder complies

Assessment of the girders on the deflection

Deflection from a unit uniform load

$l=$ 5000 mm

$E=$ 11 000 MPa

$I=$ 3046,507 $*10^{\wedge 3}mm^4$

$u_{ref}= (5/384)*(q_{ref}*l^4)/(EI)$

$u_{ref}= (5/384)*(1*5000^4)/(11000*3046{,}507*10^3)$

$u_{ref}=$ **0,243** **mm**

Deflection from the imposed load

$q_k=$ 11,200 kN/m

$u_{2,inst}= q_k * u_{ref} \le l/300$ mm

$u_{2,inst}= 11{,}2*0{,}243 \le l/300$ mm

$u_{2,inst}=$ **2,720** **mm** ≤ **16,667** **mm**

—>Girder complies

Deflection from the selfweight load

$g_k=$ 5,200 kN/m

$u_{2,inst}= g_k * u_{ref} \le l/300$ mm

$u_{2,inst}= 5{,}2*0{,}243 \le l/300$ mm

$u_{2,inst}=$ **1,263** **mm** ≤ **16,667** **mm**

—>Girder complies

Total deflection from imposed and self-weight load

$k_{1,def}=$ 0,6

$k_{2,def}=$ 0

$u_{net,fin}= u_{1,inst}*(1+k_{1,def})+u_{2,inst}*(1+k_{2,def}) \le l/150$ mm

$u_{net,fin}= 1{,}263*(1+0{,}6)+2{,}72*(1+0) \le l/150$ mm

$u_{net,fin}=$ **4,740** **mm** ≤ **33,333** **mm**

—>Girder complies

Ration of deflection from bending moment and shearing forces

-done for simply supported beams with rectangular cross-section

$(u_v/u_m)= 0{,}96*(E/G)*(h/l)^2$ G= 630 MPa

$u_v=$ **0,181** u_m

Total deflection

$u= u_{net,fin}+0{,}0179*_{unet,fin} \le l/150$ mm

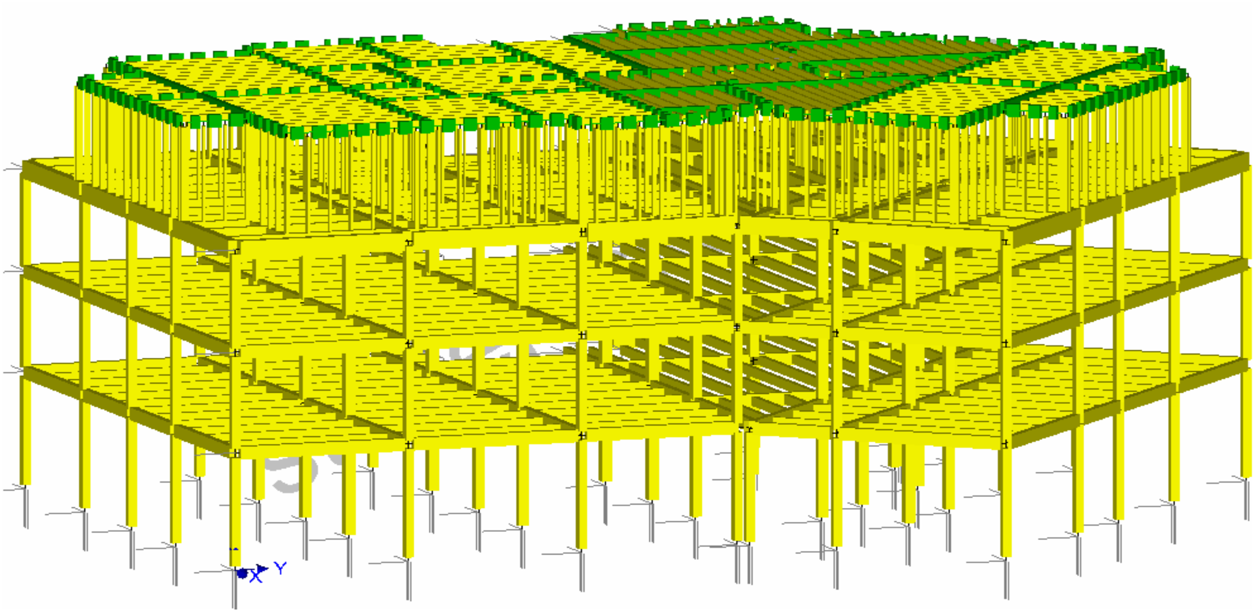
$u=$ **5,600** **mm** ≤ **33,333** **mm**

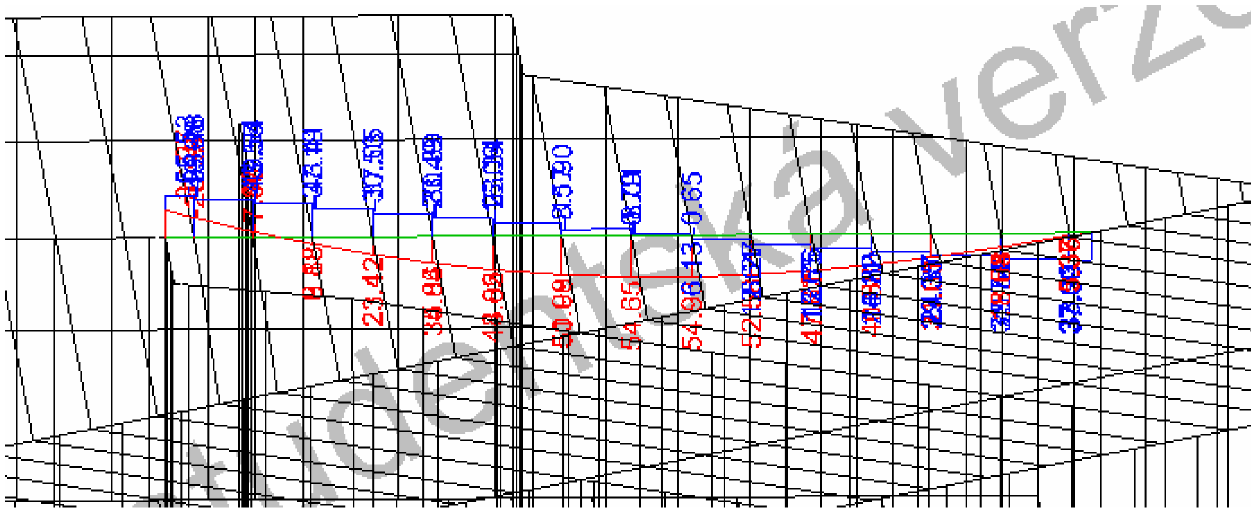
—>Girder complies

Design of the girder - roof

Material used for the design

glue-laminated timber GL 24h





The design strength in bending

$f_{m,y,d}= k_{mod}*(f_{m,g,k}/\gamma_M)$

$k_{mod}=$	0,8	humidity class 1
$f_{m,y,k}=$	24	[MPa] strength class GL 24h
$\gamma_M=$	1,3	sub factor of wood properties >1

$f_{m,y,d}=$ **14,769** **MPa**

Counted bending moment

$M_{yd}=$ **55,000** **kNm** (counted with the software FIN 3D)

Counted reactions

$R_{sd}=V_{sd}=$ **63,000** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	**380x160**	
h=	380,000	mm
b=	160,000	mm
m=	28,576	kg/m
A=	60800,000	mm^2
I_y=	731626,667	$*10^3\ mm^4$
i_y=	109,697	mm
W_y=	3850,667	$*10^3\ mm^3$
I_z=	129706,667	$*10^3\ mm^4$
i_z=	46,188	mm
W_z=	1621,333	$*10^3\ mm^3$

Normal stress in bending

$\sigma_{m,y,d}= M_{yd}/W_y$

$\sigma_{m,y,d}=$ 55*10^3/(3850,667*10^3)

$\sigma_{m,y,d}=$ **14,283** **MPa**

Assessment of bending

$(\sigma_{m,y,d}/f_{m,y,d}) \leq 1$

(14,283/14,769) ≤ 1

0,967 **≤** **1**

—>Girder complies

Assessment to flexural shear

The design strength in shear

$f_{v,y,d}= k_{mod}*(f_{v,y,k}/\gamma_M)$

k_{mod}=	0,8	humidity class 1
$f_{v,y,k}$=	2,7	[MPa] strength class SA
γ_M=	1,3	sub factor of wood properties >1

$f_{v,y,d}=$ **1,662** **MPa**

Shear stress

$\tau_{v,d}= 3V_d/2A$

$\tau_{v,d}=$ 3*10^-3*63/(2*60800)

$\tau_{v,d}=$ **1,554**

$(\tau_{v,d}/f_{v,y,d}) \leq 1$

(1,554/1,662) ≤ 1

0,935 **≤** **1**

—>Girder complies

Assessment of the girders on the deflection

l=	5000	mm
E=	11 000	MPa
I=	731,627	$*10^{\wedge 3}mm^4$

Deflection from a unit uniform load

$u_{ref}= (5/384)*(q_{ref}*l^4)/(EI)$

$u_{ref}=$ (5/384)*(1*5000^4)/(11000*731,627*10^3)

$u_{ref}=$ **1,011** **mm**

Deflection from the imposed load

q_k= 11,200 kN/m

$u_{2,inst}$= q_k*u_{ref} ≤ l/300 mm

$u_{2,inst}$= 11,2*1,011 ≤ l/300 mm

$u_{2,inst}$= **11,325** **mm** **≤** **16,667** **mm**

—>Girder complies

Deflection from the selfweight load

g_k= 5,200 kN/m

$u_{2,inst}$= g_k*u_{ref} ≤ l/300 mm

$u_{2,inst}$= 5,2*1,011 ≤ l/300 mm

$u_{2,inst}$= **5,258** **mm** **≤** **16,667** **mm**

—>Girder complies

$k_{1,def}$= 0,6

Total deflection from imposed and self-weight load

$k_{2,def}$= 0

$u_{net,fin}$= $u_{1,inst}$*(1+$k_{1,def}$)+$u_{2,inst}$*(1+$k_{2,def}$) ≤ l/150 mm

$u_{net,fin}$= 5,258*(1+0,6)+11,325*(1+0) ≤ l/150 mm

$u_{net,fin}$= **19,739** **mm** **≤** **33,333** **mm**

—>Girder complies

Ration of deflection from bending moment and shearing forces

-done for simply supported beams with rectangular cross-section

(u_v/u_m)= 0,96*(E/G)*$(h/l)^2$ G= 630 MPa

u_v= **0,097** u_m

Total deflection

u= $u_{net,fin}$+0,0179*$_{unet,fin}$ ≤ l/150 mm

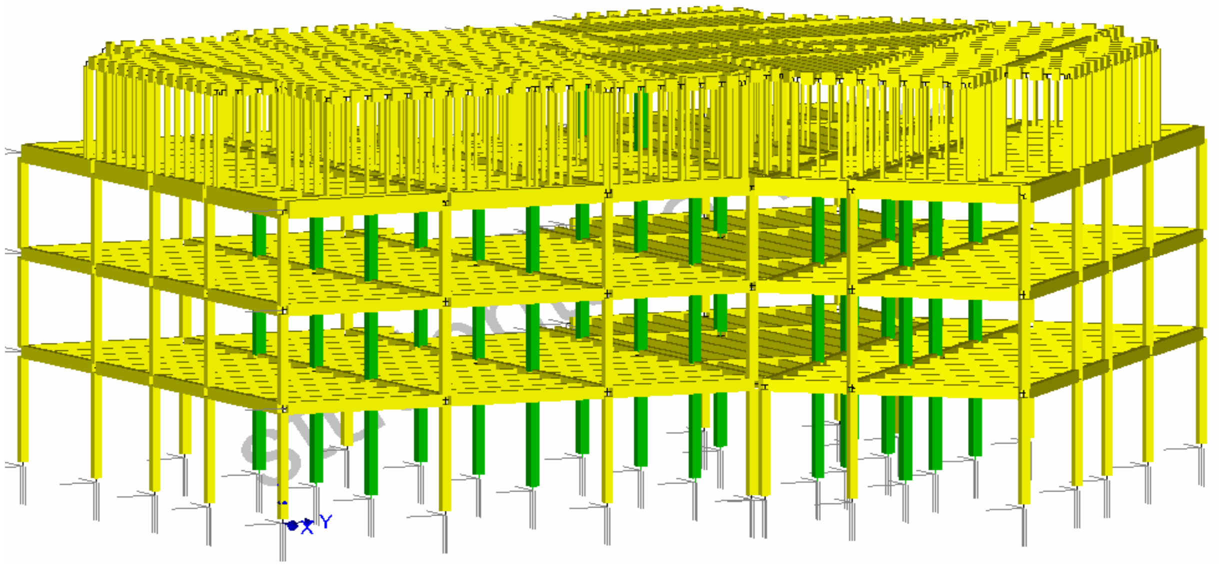
u= **21,650** **mm** ≤ **33,333** **mm**

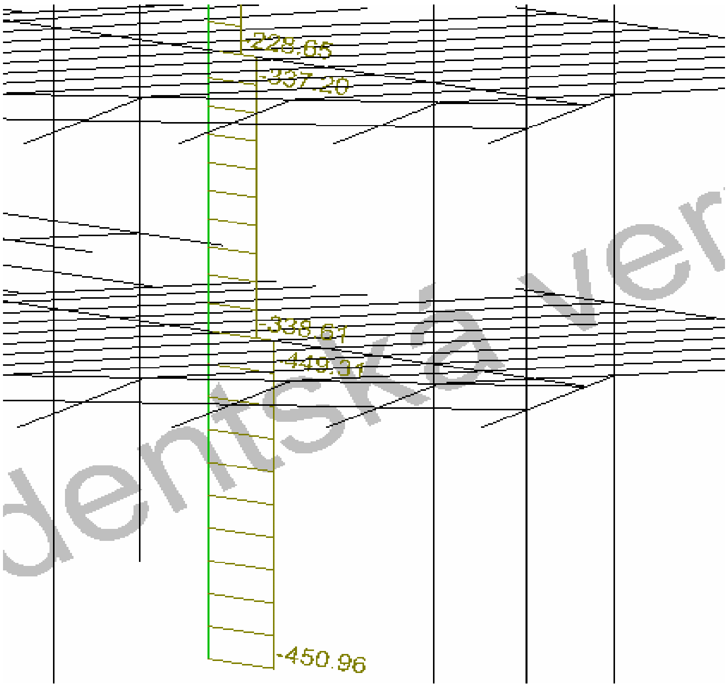
—>Girder complies

Design of the column

Material used for the design

glue-laminated timber GL 24h





The design strength in pressure

$f_{m,y,d}= k_{mod}*(f_{m,g,k}/\gamma_M)$		$k_{mod}=$	0,8	humidity class 1
		$f_{m,y,k}=$	24	[MPa] strength class GL 24h
		$\gamma_M=$	1,3	sub factor of wood properties >1
$f_{m,y,d}=$	**14,769**	**MPa**		

Counted force in pressure

$F_{sd}=$	**451,000**	**kN**	(counted with the software FIN 3D)

Profile design

chosen profile:	**260x260**	
h=	260,000	mm
b=	260,000	mm
m=	31,772	kg/m
A=	67600,000	mm^2
$I_y=$	380813,333	$*10^3\ mm^4$
$i_y=$	75,056	mm
$W_y=$	2929,333	$*10^3\ mm^3$
$I_z=$	380813,333	$*10^3\ mm^4$
$i_z=$	75,056	mm
$W_z=$	2929,333	$*10^3\ mm^3$

Normal stress in compression

$\sigma_{c,0,d}=N_d/A$

$N_d=$	**451,000**	**kN**	(counted with the software FIN 3D)
A=	**67600,000**	**mm^2**	
$\sigma_{c,0,d}=$	**6,672**	**MPa**	

Ratio of slenderness

$\lambda = l_{ef}/i$

l_{ef}= 3200 mm, buckling lenght of element

$i=\sqrt{(I/A)}$ radius of inertia

$I=(1/12)*b*h^3$

I_z= 380813,333 mm^4

A= 67600,00 mm^2

i= **75,056** **mm**

λ= **42,635**

$\sigma_{c,crit}=\pi^2(E_{0,05}/\lambda^2)$ $E_{0,05}$= 8800 MPa, modulus of elasticity

$\sigma_{c,crit}$= **47,780** **MPa**

$\lambda_{rel}=\sqrt{(f_{c,0,k}/\sigma_{c,crit})}$

λ_{rel}= **0,709**

Coefficient for buckling

$k=0{,}5[1+\beta_c(\lambda_{rel}-0{,}3)+\lambda_{rel}^2]$ β_c= 0,1 glue-laminated timber

k= **0,772**

$k_c=1/(k+\sqrt{(k^2-\lambda_{rel}^2)})$

k_c= **0,929**

Assessement of buckling

$(\sigma_{c,0,d}/k_c * f_{c,0,d})$ ≤ 1

(5,932/(0,6368*13,034)) ≤ 1

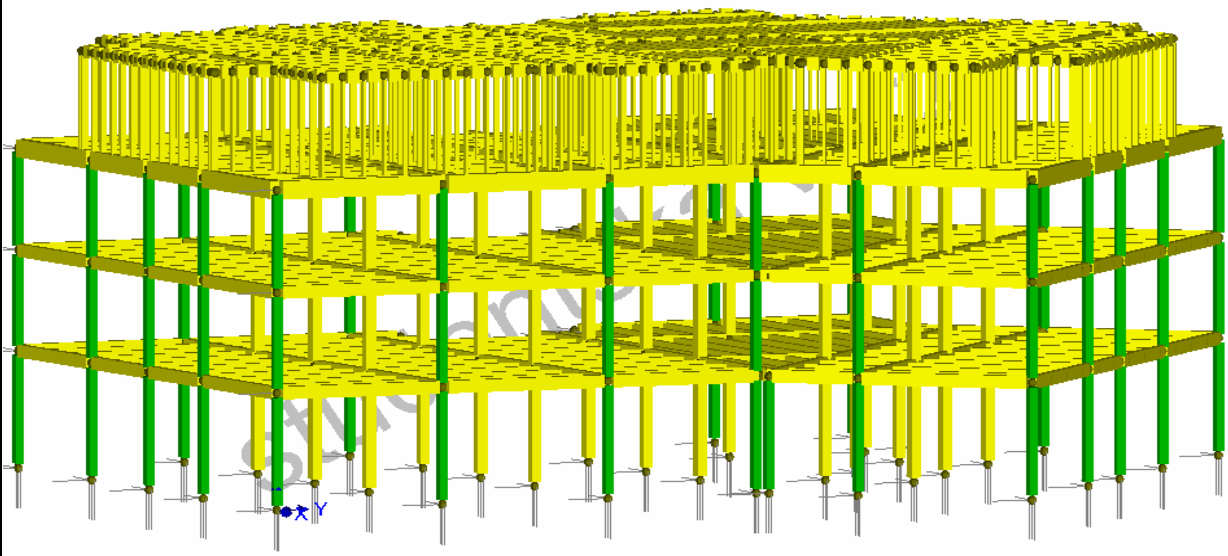
0,486 **≤** **1**

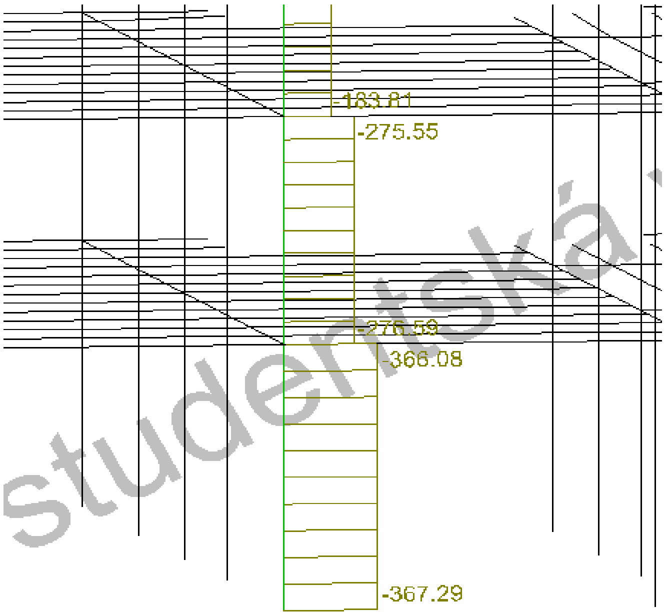
—>Column complies

Design of the wall column

Material used for the design

glue-laminated timber GL 24h





The design strength in pressure

$f_{m,y,d}= k_{mod}*(f_{m,g,k}/\gamma_M)$		$k_{mod}=$	0,8	humidity class 1
		$f_{m,y,k}=$	24	[MPa] strength class GL 24h
		$\gamma_M=$	1,3	sub factor of wood properties >1
$f_{m,y,d}=$	**14,769**	**MPa**		

Counted force in pressure

$F_{sd}=$ **368,000** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	**200x260**	
h=	200,000	mm
b=	260,000	mm
m=	24,440	kg/m
A=	52000,000	mm^2
$I_y=$	173333,333	$*10^3$ mm^4
$i_y=$	57,735	mm
$W_y=$	1733,333	$*10^3$ mm^3
$I_z=$	292933,333	$*10^3$ mm^4
$i_z=$	75,056	mm
$W_z=$	2253,333	$*10^3$ mm^3

Normal stress in compression

$\sigma_{c,0,d}=N_d/A$

$N_d=$	**368,000**	**kN**	(counted with the software FIN 3D)
A=	**52000,000**	**mm^2**	
$\sigma_{c,0,d}=$	**7,077**	**MPa**	

Ratio of slenderness

$\lambda = l_{ef}/i$

$l_{ef} =$ 3200 mm, buckling lenght of element

$i = \sqrt{(I/A)}$ radius of inertia

$I = (1/12)*b*h^3$

$I_z =$ 292933,333 mm^4

$A =$ 52000,00 mm^2

$i =$ **75,056** **mm**

$\lambda =$ **42,635**

$\sigma_{c,crit} = \pi^2(E_{0,05}/\lambda^2)$

$E_{0,05} =$ 8800 MPa, modulus of elasticity

$\sigma_{c,crit} =$ **47,780** **MPa**

$\lambda_{rel} = \sqrt{(f_{c,0,k}/\sigma_{c,crit})}$

$\lambda_{rel} =$ **0,709**

Coefficient for buckling

$k = 0,5[1+\beta_c(\lambda_{rel}-0,3)+\lambda_{rel}^2]$

$\beta_c =$ 0,1 glue-laminated timber

$k =$ **0,772**

$k_c = 1/(k+\sqrt{(k^2-\lambda_{rel}^2)})$

$k_c =$ **0,929**

Assessement of buckling

$(\sigma_{c,0,d}/k_c * f_{c,0,d}) \leq 1$

$(5,932/(0,6368*13,034)) \leq 1$

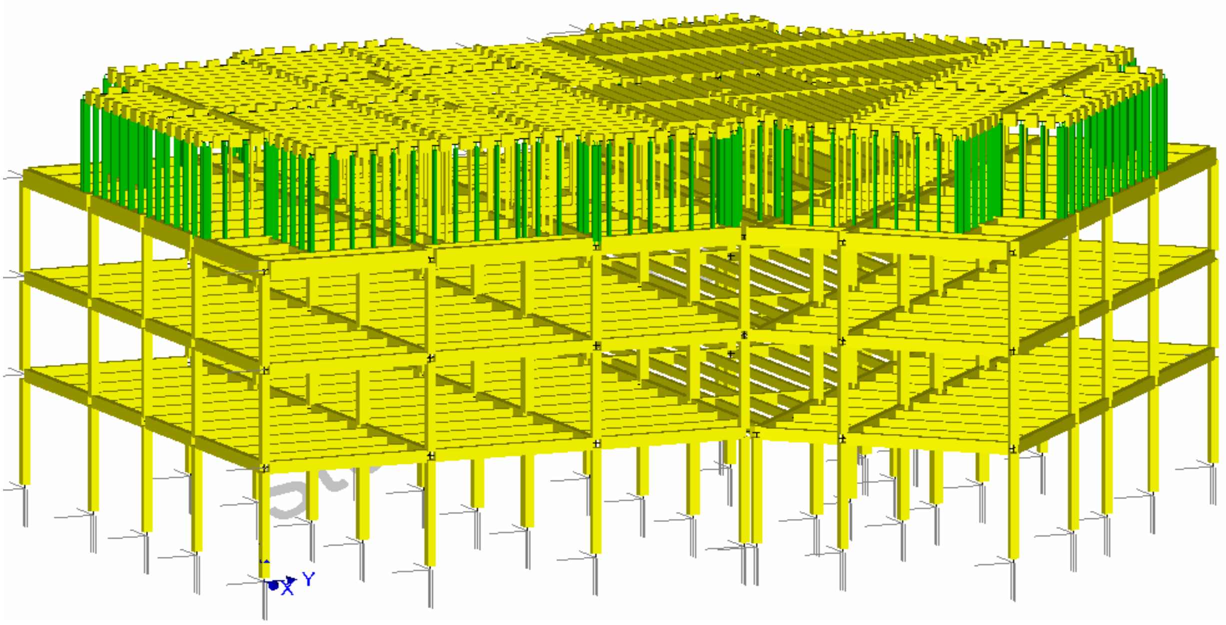
0,516 **≤** **1**

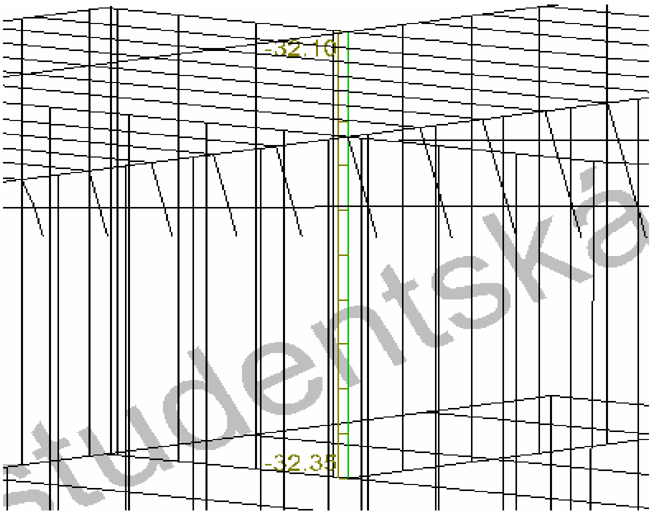
—>Wall column complies

Design of the 4th floor column

Material used for the design

grown wood C 24





The design strength in pressure

$f_{m,y,d}= k_{mod}*(f_{m,g,k}/\gamma_M)$

k_{mod}=	0,8	humidity class 1
$f_{m,y,k}$=	24	[MPa] strength class C22
γ_M=	1,3	sub factor of wood properties >1

$f_{m,y,d}$= **14,769** **MPa**

Counted force in pressure

F_{sd}= **33,000** **kN** (counted with the software FIN 3D)

Profile design

chosen profile:	**200x260**	
h=	160,000	mm
b=	80,000	mm
m=	6,016	kg/m
A=	12800,000	mm^2
I_y=	27306,667	$*10^3$ mm^4
i_y=	46,188	mm
W_y=	341,333	$*10^3$ mm^3
I_z=	6826,667	$*10^3$ mm^4
i_z=	23,094	mm
W_z=	170,667	$*10^3$ mm^3

Normal stress in compression

$\sigma_{c,0,d}=N_d/A$

N_d= **33,000** **kN** (counted with the software FIN 3D)

A= **12800,000** **mm^2**

$\sigma_{c,0,d}$= **2,578** **MPa**

Ratio of slenderness

$\lambda= l_{ef}/i$

l_{ef}= 3200 mm, buckling lenght of element

$i=\sqrt{(I/A)}$ radius of inertia

$I= (1/12)*b*h^3$

I_z= 6826,667 mm^4

A= 12800,00 mm^2

i= **23,094** **mm**

λ= **138,564**

$\sigma_{c,crit}=\pi^2(E_{0,05}/\lambda^2)$ $E_{0,05}=$ 8800 MPa, modulus of elasticity

$\sigma_{c,crit}=$ **4,524** **MPa**

$\lambda_{rel}=\sqrt{(f_{c,0,k}/\sigma_{c,crit})}$

$\lambda_{rel}=$ **2,303**

Coefficient for buckling

$k=0,5[1+\beta_c(\lambda_{rel}-0,3)+\lambda_{rel}^2]$ $\beta_c=$ 0,1 grown wood

$k=$ **3,253**

$k_c=1/(k+\sqrt{(k^2-\lambda_{rel}^2)})$

$k_c=$ **0,180**

Assessement of buckling

$(\sigma_{c,0,d}/k_c * f_{c,0,d})$ ≤ 1

(5,932/(0,6368*13,034)) ≤ 1

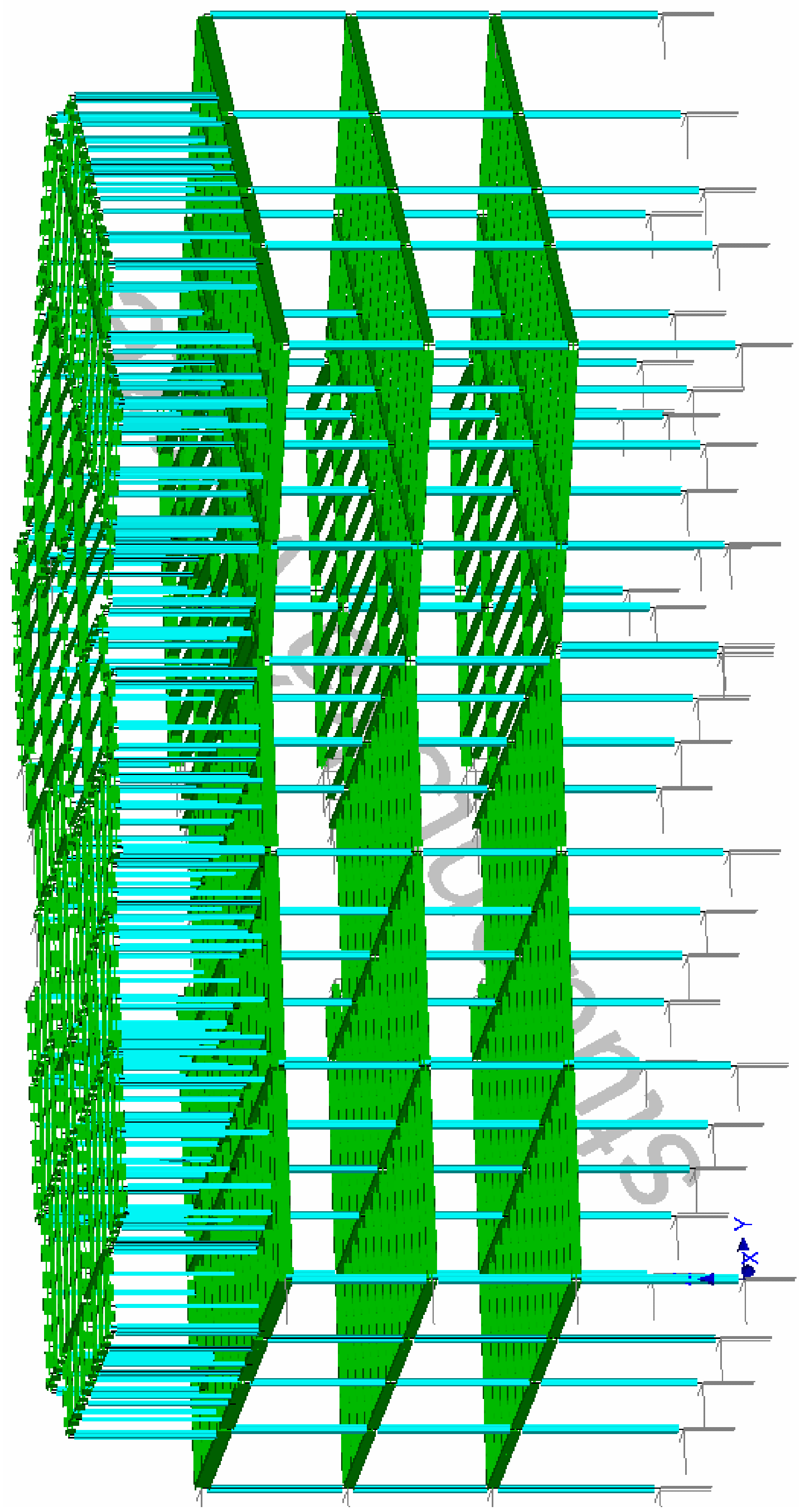
0,969 **≤** **1**

—>Wall column complies

List of elements designed for the timberl structure		
Element		**Profile**
purlin	**roof**	**200x100**
	2nd, 3rd floor	**280x160**
	4th floor	**360x180**
	4th floor terrace	**460x220**
	4th floor large	**500x260**
beam	**2nd, 3rd floor**	**380x200**
	4th floor	**520x260**
	roof	**380x160**
column	**2nd, 3rd floor**	**260x260**
	2nd, 3rd floor wall	**200x260**
	4th floor	**160x80**

B

Static evaluation of the steel structure variant



Wind load

Basic speed of the wind

v_b - basic speed of the wind [m/s]

$v_b = C_{dir} * C_{season} * v_{b,0}$

C_{dir}= coefficient - wind direction

C_{dir}= *1,0*

C_{season}= coefficient - season

C_{season}= *1,0*

$v_{b,0}$ - initial basic speed of the wind [m/s]

$v_{b,0}$ - estimated from the map of wind speed, *ČSN EN 1991-1-4, location: Prague*

$v_{b,0}$= *25* m/s

v_b= 1*1*25

v_b= 25 m/s

basic dynamic pressure of the wind

q_b - basic dynamic pressure of the wind [N/m^2]

$q_b = 1/2 * \rho * v_b^2(z)$

ρ= density of the air

ρ= 1,25 kg/m^3

q_b= 1/2*1,25*25^2

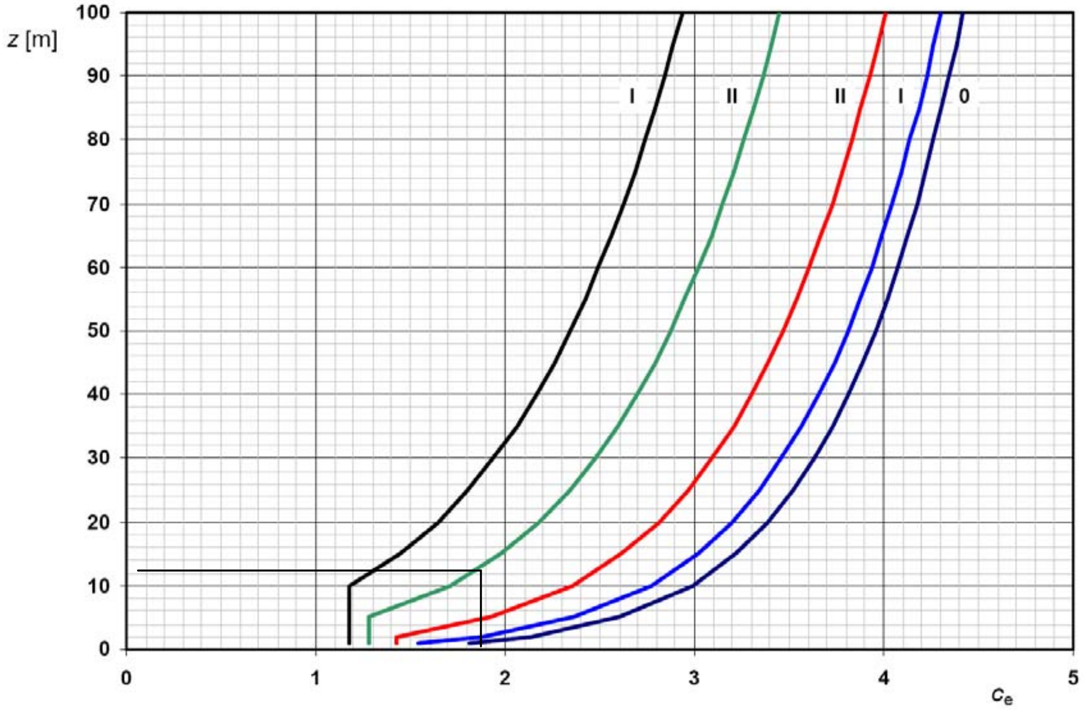
q_b= 390,625 N/m^2

maximal dynamic pressure of the wind

$q_p = c_e(z) * q_b$

c_e= 1,8

c_e (estimated as a function of height beyond terrain and the terrain cathegory, picture 4.2, *ČSN EN 1991-1-4*)



terrain cathegory - **III** (areas equally covered by vegetation or buildings)

q_p= 703,125 N/m^2

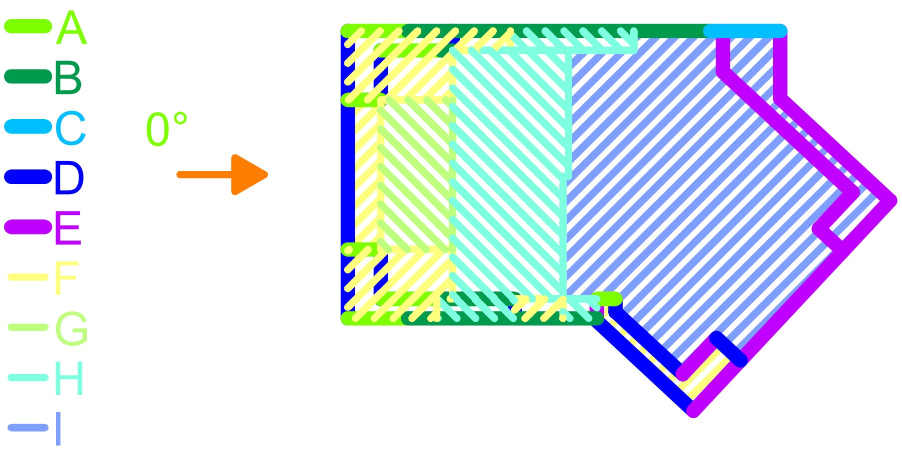
wind pressure on the surface of the cc

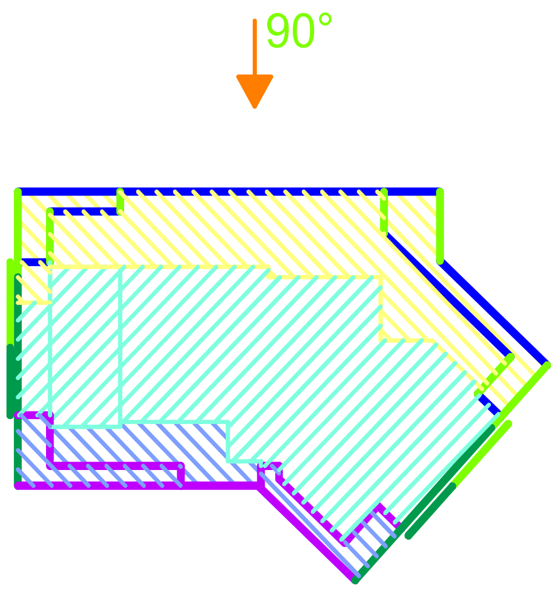
$w_e=q_p(z)*C_{pe}$ (-) suction

q_p= 703,125 N/m^2 ( ) pressure

C_{pe}

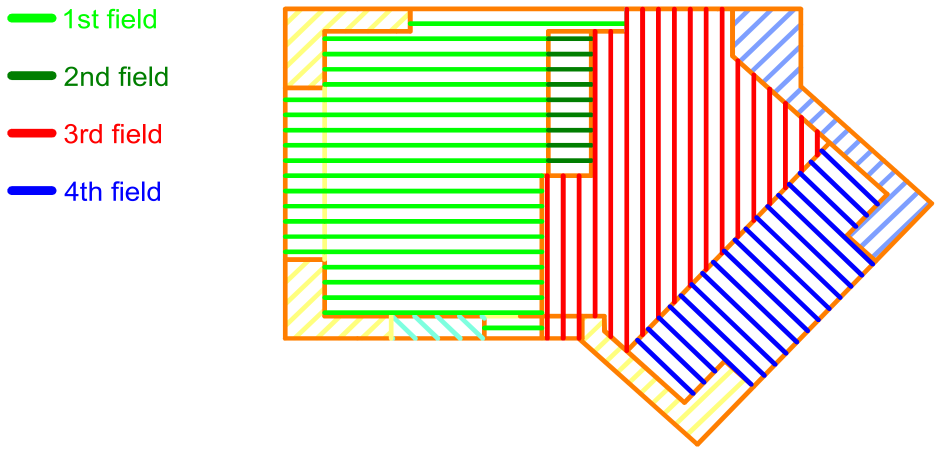
area	wind orientation θ=0°	wind orientation θ=90°
A	-1,2	-1,2
B	-1,1	-1,1
C	-0,5	-0,5
D	0,75	0,75
E	-0,4	-0,4
F	-1,6	-1,6
G	-1,1	-1,1
H	-0,7	-0,7
I	-0,2	-0,2





w_e [N/m²]

area	wind orientation θ=0°	wind orientation θ=90°
A	-843,8	-843,8
B	-773,4	-773,4
C	-351,6	-351,6
D	527,3	527,3
E	-281,3	-281,3
F	-1125,0	-1125,0
G	-773,4	-773,4
H	-492,2	-492,2
I	-140,6	-140,6

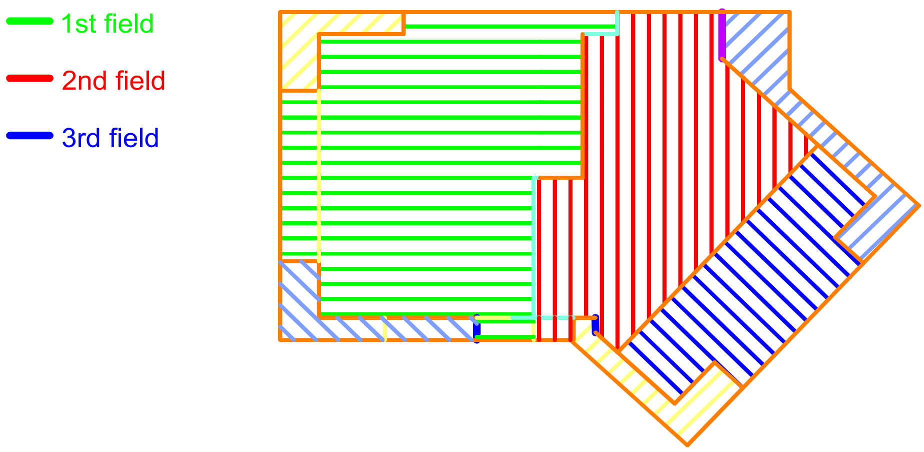


conversion of the wind load from square load to linear one for roof joists (θ=0°)

purlin	distance	w_e	q/2 [kN/m´]	q [kN/m´]
1st field 1-15 F	1,150	-1125,000	-0,647	**-1,294**
1st field 5-11 G	1,260	-773,438	-0,487	**-0,975**
1st field 1-15 H	1,260	-492,188	-0,310	**-0,620**
2nd 3-8 I	1,220	-140,625	-0,086	**-0,172**
3rd field 1-17 I	0,900	-140,625	-0,063	**-0,127**
4th field 1-13 I	1,260	-140,625	-0,089	**-0,177**

conversion of the wind load from square load to linear one for terrace joists (θ=0°)

purlin	distance	w_e	q/2 [kN/m´]	q [kN/m´]
F area	1,385	-1125,000	-0,779	**-1,558**
H area	1,385	-492,188	-0,341	**-0,682**
I area	1,385	-140,625	-0,097	**-0,195**
I area turned	0,945	-140,625	-0,066	**-0,133**



conversion of the wind load from square load to linear one for roof joists (θ=90°)

purlin	distance	w_e	q/2 [kN/m´]	q [kN/m´]
1st field 1-6 F	1,220	-1125,000	-0,686	**-1,373**
1st field 7-12 H	1,260	-492,188	-0,310	**-0,620**
1st field 13-15 I	1,150	-140,625	-0,081	**-0,162**
2nd field 4-17 F	0,900	-1125,000	-0,506	**-1,013**
2nd field 1-17 H	0,900	-492,188	-0,221	**-0,443**
2nd field 1-3 I	1,000	-140,625	-0,070	**-0,141**
3rd field 1-3 F	1,150	-1125,000	-0,647	**-1,294**
3rd field 4-13 H	1,260	-492,188	-0,310	**-0,620**

conversion of the wind load from square load to linear one for terrace joists (θ=90°)

purlin	distance	w_e	q/2 [kN/m´]	q [kN/m´]
F area	1,385	-1125,000	-0,779	**-1,558**
H area	1,385	-492,188	-0,341	**-0,682**
I area	1,385	-140,625	-0,097	**-0,195**
F area turned	0,945	-1125,000	-0,532	**-1,063**

conversion of the wind load from square load to linear one for wall girders (θ=0°)

beam	distance 1	distance 2	w_e	q [kN/m´]
1st - 2nd floor D	1,750	1,500	527,344	**1,714**
2nd - 3rd floor D	1,500	1,525	527,344	**1,595**
3rd - 4th floor D	1,525	1,600	527,344	**1,648**
4th floor D	1,600	0,000	527,344	**0,844**
1st - 2nd floor A	1,750	1,500	-843,750	**-2,742**
2nd - 3rd floor A	1,500	1,525	-843,750	**-2,552**
3rd floor A	0,000	1,525	-843,750	**-1,287**
4th floor A	1,600	0,000	-843,750	**-1,350**
1st - 2nd floor B	1,750	1,500	-773,438	**-2,514**
2nd - 3rd floor B	1,500	1,525	-773,438	**-2,340**
3rd - 4th floor B	1,525	1,600	-773,438	**-2,417**
3rd floor B	0,000	1,525	-773,438	**-1,179**
4th floor B	1,600	0,000	-773,438	**-1,238**
1st - 2nd floor E	1,750	1,500	-281,250	**-0,914**
2nd - 3rd floor E	1,500	1,525	-281,250	**-0,851**
3rd - 4th floor E	1,525	1,600	-281,250	**-0,879**
3rd floor E	0,000	1,525	-281,250	**-0,429**
4th floor E	1,600	0,000	-281,250	**-0,450**

conversion of the wind load from square load to linear one for wall columns (θ=0°)

column	distance	w_e	q/2 [kN/m´]	q [kN/m´]
A area	1,250	-843,750	-0,527	**-1,055**
B area	1,250	-773,438	-0,483	**-0,967**
D area	1,250	527,344	0,330	**0,659**
E area	1,250	-281,250	-0,176	**-0,352**

conversion of the wind load from square load to linear one for wall girders (θ=90°)

beam	distance 1	distance 2	w_e	q [kN/m´]
1st - 2nd floor D	1,750	1,500	527,344	**1,714**
2nd - 3rd floor D	1,500	1,525	527,344	**1,595**
3rd - 4th floor D	1,525	1,600	527,344	**1,648**
4th floor D	1,600	0,000	527,344	**0,844**
1st - 2nd floor A	1,750	1,500	-843,750	**-2,742**
2nd - 3rd floor A	1,500	1,525	-843,750	**-2,552**
3rd floor A	0,000	1,525	-843,750	**-1,287**
4th floor A	1,600	0,000	-843,750	**-1,350**
1st - 2nd floor B	1,750	1,500	-773,438	**-2,514**
2nd - 3rd floor B	1,500	1,525	-773,438	**-2,340**
3rd - 4th floor B	1,525	1,600	-773,438	**-2,417**
3rd floor B	0,000	1,525	-773,438	**-1,179**
4th floor B	1,600	0,000	-773,438	**-1,238**
1st - 2nd floor E	1,750	1,500	-281,250	**-0,914**
2nd - 3rd floor E	1,500	1,525	-281,250	**-0,851**
3rd - 4th floor E	1,525	1,600	-281,250	**-0,879**
3rd floor E	0,000	1,525	-281,250	**-0,429**
4th floor E	1,600	0,000	-281,250	**-0,450**

conversion of the wind load from square load to linear one for wall columns (θ=90°)

column	distance	w_e	q/2 [kN/m´]	q [kN/m´]
A area	1,250	-843,750	-0,527	**-1,055**
B area	1,250	-773,438	-0,483	**-0,967**
D area	1,250	527,344	0,330	**0,659**
E area	1,250	-281,250	-0,176	**-0,352**

Snow load

specification of snow load, done according to the ČSN EN 1991-1-3
for permanent or temporary design situations

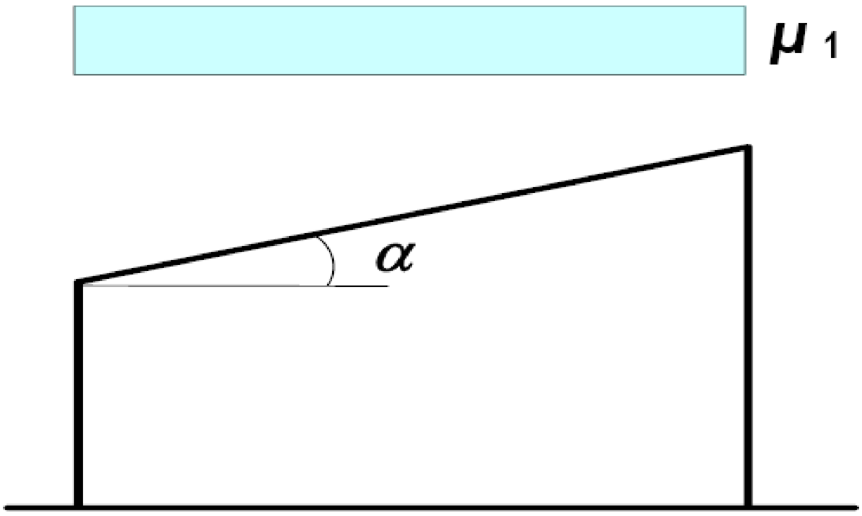
$s=\mu_i*C_e*C_t*s_k$

s_k=0,7 KN/m^2 estimated according to the map of snow areas of the Czech Republic location Prague, I. snow area

C_e=1,0 coefficient of exposition
estimated fot the normal shape of the landscape

C_t=1,0 thermal coefficient

μ coeffitient of the shape of snow loading



μ_1=0,8 0°≤α≤30° α=0°

s=0,8*1,0*1,0*0,7=0,56 **KN/m^2** s_d=s*1,5=0,56*1,5= **0,84** KN/m^2

conversion of the snow pressure to joists

joist	width for loading	value of loading q [kN/m´]
boundary 1	0,630	0,529
middle 1	1,260	1,058
boundary 2	0,500	0,420
middle 2	1,000	0,840
boundary 3	0,400	0,336
middle 3	0,800	0,672
terrace boundary 1	0,693	0,582
terrace middle 1	1,385	1,163
terrace boundary 2	0,473	0,397
terrace middle 2	0,945	0,794

Self-weight load + imposed load for each composition

Construction of the floor

(There is concidered floor in the bathroom - ceramic tiles and waterproofing)
(There will be used wooden floor in the other rooms - the composition is lighter)

Self weight of the composition					
Layers of the composition	Thickness [mm]	Density [kg/m³]	g_k [kN/m²]	γ_F	q_d [kN/m²]
Final layer - ceramic tiles Rako Tanse	10,00	2000,00	0,200	1,35	0,270
Waterproofing Sarnafil G 441-24EL	2,40	3200,00	0,077	1,35	0,104
Anhydrite Anhyment AE 20	50,00	2100,00	1,050	1,35	1,418
Impact sound insulation Dow Ethafoam	20,00	35,00	0,007	1,35	0,009
Concrete slab	50,00	2400,00	1,200	1,35	1,620
Trapezoidal sheets Lindab LLP 20					0,070
OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Plasterboard	12,50	750,00	0,094	1,35	0,127
Summary			**2,710**		**3,729**

Self weight of steel joists included in the composition								
Profile	Height of profile [mm]	Width of profile [mm]	Lenght of element [mm]	Number of elements	Weight [kg/m]	g_k [kN/m]	γ_F	g_d [kN/m]
CW 60	60	40	1000	3	3,38	0,101	1,35	0,137
Summary						**0,101**		**0,137**

Imposed load for the composition			
	q_k [kN/m²]	γ_F	g_d [kN/m²]
	1,500	1,500	2,250
Summary	**1,500**		**2,250**

Joist	Width for load [m]	g_d [kN/m´]	q_d [kN/m´]
boundary 1	0,693	2,677	1,558
middle 1	1,385	5,354	3,116
boundary 2	0,473	1,826	1,063
middle 2	0,945	3,653	2,126

Construction of the roof

Self weight of the composition					
Layers of the composition	Thickness [mm]	Density [kg/m^3]	g_k [kN/m²]	γ_F	q_d [kN/m²]
Greening			1,000	1,35	1,350
Waterproofing Sarnafil G 441-24EL	2,40	3200,00	0,077	1,35	0,104
Thermal insulation Dow Roofmate SL	160,00	35,00	0,056	1,35	0,076
Waterproofing Sikaplan D	1,20	1300,00	0,016	1,35	0,021
Thermal insulation Dow Roofmate SL	80,00	35,00	0,028	1,35	0,038
Concrete slab	50,00	2400,00	1,200	1,35	1,620
Trapezoidal sheets Lindab LLP 20					0,070
Thermal insulation Rockwool Rocknroll	100,00	100,00	0,100	1,35	0,135
OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Vapour barrier Jutafol N 140 Special	0,25	560,00	0,001	1,35	0,002
Plasterboard	12,50	750,00	0,094	1,35	0,127
Summary			**2,654**		**3,653**

Self weight of steel joists included in the composition								
Profile	Height of profile [mm]	Width of profile [mm]	Lenght of element [mm]	Number of elements	Weight [kg/m]	g_k [kN/m]	γ_F	g_d [kN/m]
CW 60	60	40	1000	3	3,38	0,101	1,35	0,137
Summary						**0,101**		**0,137**

Imposed load for the composition			
	q_k [kN/m^2]	γ_F	g_d [kN/m²]
	1,500	1,500	2,250
Summary	**1,500**		**2,250**

Joist	Width for load [m]	g_d [kN/m´]	q_d [kN/m´]
boundary 1	0,630	2,388	1,418
middle 1	1,260	4,775	2,835
boundary 2	0,500	1,895	1,125
middle 2	1,000	3,790	2,250
boundary 3	0,400	1,516	0,900
middle 3	0,800	3,032	1,800

Construction of the terrace

Self weight of the composition					
Layers of the composition	**Thickness [mm]**	**Density [kg/m³]**	**g_k [kN/m²]**	**γ_F**	**q_d [kN/m²]**
Final layer - walking coat Parador outdoor classic 7020	50,00	1650,00	0,825	1,35	1,114
Waterproofing Sarnafil G 441-24EL	2,40	3200,00	0,077	1,35	0,104
Thermal insulation Dow Roofmate SL	100,00	35,00	0,035	1,35	0,047
Waterproofing Sikaplan D	1,20	1300,00	0,016	1,35	0,021
Thermal insulation Dow Roofmate SL	80,00	35,00	0,028	1,35	0,038
Concrete slab	50,00	2400,00	1,200	1,35	1,620
Trapezoidal sheets Lindab LLP 20					0,070
Thermal insulation Rockwool Rocknroll	220,00	100,00	0,220	1,35	0,297
OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
Vapour barrier Jutafol N 140 Special	0,25	560,00	0,001	1,35	0,002
Plasterboard	12,50	750,00	0,094	1,35	0,127
Summary			**2,578**		**3,550**

Self weight of steel joists included in the composition								
Profile	**Height of profile [mm]**	**Width of profile [mm]**	**Lenght of element [mm]**	**Number of elements**	**Weight [kg/m]**	**g_k [kN/m]**	**γ_F**	**g_d [kN/m]**
CW 60	60	40	1000	3	3,38	0,101	1,35	0,137
Summary						**0,101**		**0,137**

Imposed load for the composition			
	q_k [kN/m²]	**γ_F**	**g_d [kN/m²]**
	2,500	1,500	3,750
Summary	**2,500**		**3,750**

Joist	**Width for load [m]**	**g_d [kN/m´]**	**q_d [kN/m´]**
boundary 1	0,693	2,553	2,597
middle 1	1,385	5,107	5,194
boundary 2	0,473	1,742	1,772
middle 2	0,945	3,484	3,544

Construction of the floor on the air

Self weight of the composition						
Layers of the composition		Thickness [mm]	Density [kg/m³]	g_k [kN/m²]	γ_F	q_d [kN/m²]
	Final layer - wooden floor Efloor	20,00	470,00	0,094	1,35	0,127
	Anhydrite Anhyment AE 20	50,00	2100,00	1,050	1,35	1,418
	Impact sound insulation Dow Ethafoam	20,00	35,00	0,007	1,35	0,009
	Concrete slab	50,00	2400,00	1,200	1,35	1,620
	Trapezoidal sheets Lindab LLP 20					0,070
	Thermal insulation Rockwool Rocknroll	160,00	100,00	0,160	1,35	0,216
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Thermal insulation Rockwool Fasrock	80,00	100,00	0,080	1,35	0,108
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Thermal insulation Rockwool Fasrock	80,00	183,00	0,146	1,35	0,198
	External plaster Tubag Mineralischer Dämmputz	10,00	625,00	0,063	1,35	0,084
	Summary			**2,965**		**4,073**

Self weight of timber joists included in the composition								
Profile	Height of profile [mm]	Width of profile [mm]	Lenght of element [mm]	Number of elements	Density [kg/m³]	g_k [kN/m]	γ_F	g_d [kN/m]
CW 80	80	40	1000	3	3,38	0,101	1,35	0,137
	Summary					**0,101**		**0,137**

Imposed load for the roof composition			
	q_k [kN/m²]	γ_F	g_d [kN/m²]
	1,500	1,500	2,250
Summary	**1,500**		**2,250**

Joist	Width for load [m]	g_d [kN/m´]	q_d [kN/m´]
boundary	0,473	1,989	1,063
middle	0,945	3,978	2,126

Construction of the main wall

Self weight of the composition						
Layers of the composition		Thickness [mm]	Density [kg/m³]	g_k [kN/m²]	γ_F	q_d [kN/m²]
	External plaster Tubag Mineralischer Dämmputz	10,00	625,00	0,063	1,35	0,084
	Thermal insulation Rockwool Fasrock	160,00	128,00	0,205	1,35	0,276
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Thermal insulation Rockwool Fasrock	80,00	128,00	0,102	1,35	0,138
	Thermal insulation Rockwool Fasrock	80,00	128,00	0,102	1,35	0,138
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Vapour barrier Jutafol N 140 Special	0,25	560,00	0,001	1,35	0,002
	Plasterboard	12,50	750,00	0,094	1,35	0,127
	Summary			**0,732**		**0,989**

Self weight of timber joists and columns included in the main wall composition								
Profile	Height of profile [mm]	Width of profile [mm]	Lenght of element [mm]	Number of elements	Weight [kg/m]	g_k [kN/m]	γ_F	g_d [kN/m]
CW 60	60	40	3100	7	3,38	0,733	1,35	0,990
	Summary					**0,733**		**0,990**

Boundary girder	Width for load [m]	Layers g_d [kN/m´]	Layers+Profiles q_d [kN/m´]
1st-2nd floor	3,000	2,966	3,956
2nd-3rd floor	3,050	3,015	4,005

Construction of the 4th floor wall

Self weight of the composition						
Layers of the composition		**Thickness [mm]**	**Density [kg/m³]**	**g_k [kN/m²]**	**γ_F**	**q_d [kN/m²]**
	External plaster Tubag Mineralischer Dämmputz	10,00	625,00	0,063	1,35	0,084
	Thermal insulation Rockwool Fasrock	120,00	128,00	0,154	1,35	0,207
	Thermal insulation Rockwool Fasrock	100,00	128,00	0,128	1,35	0,173
	OSB board Superfinish ECO	15,00	550,00	0,083	1,35	0,111
	Vapour barrier Jutafol N 140 Special	0,25	560,00	0,001	1,35	0,002
	Plasterboard	12,50	750,00	0,094	1,35	0,127
	Summary			**0,522**		**0,704**

Boundary girder	Width for load [m]	Layers g_d [kN/m´]	Layers+Profiles q_d [kN/m´]
3rd-4th floor	3,000	2,113	2,113

Note: Self weight of load bearing steel profiles is set in the program FIN3D itself. This programe was used for overall evaluation of the structure

Load combinations

$\sum_{j\geq1}\gamma_{Gj}G_{kj}+\gamma_{Q1}Q_{k1}+\sum_{i\geq1}\gamma_{Qi}\psi_{0i}Q_{ki}$

1. self weight load + imposed load

$1,35*G_k+1,5*Q_N$

2. self weight load + imposed load + snow load

$1,35*G_k+1,5*Q_N+0,6*1,5*Q_S$

3. self weight load + wind load θ=0°

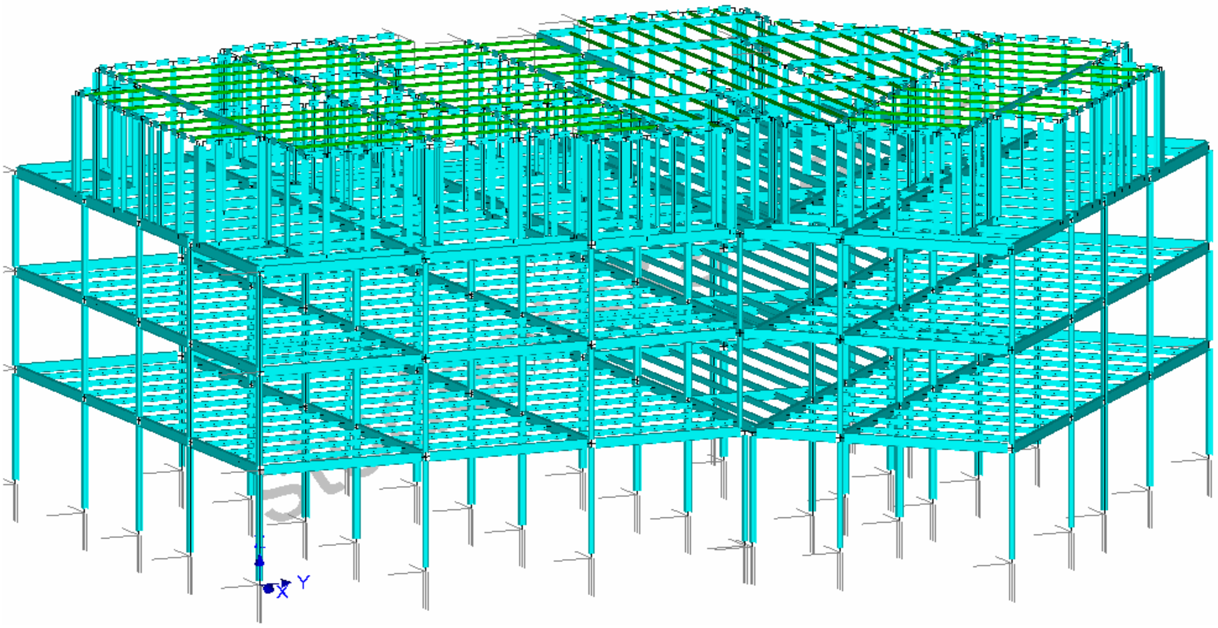
$1,0*G_k+1,5*Q_V$

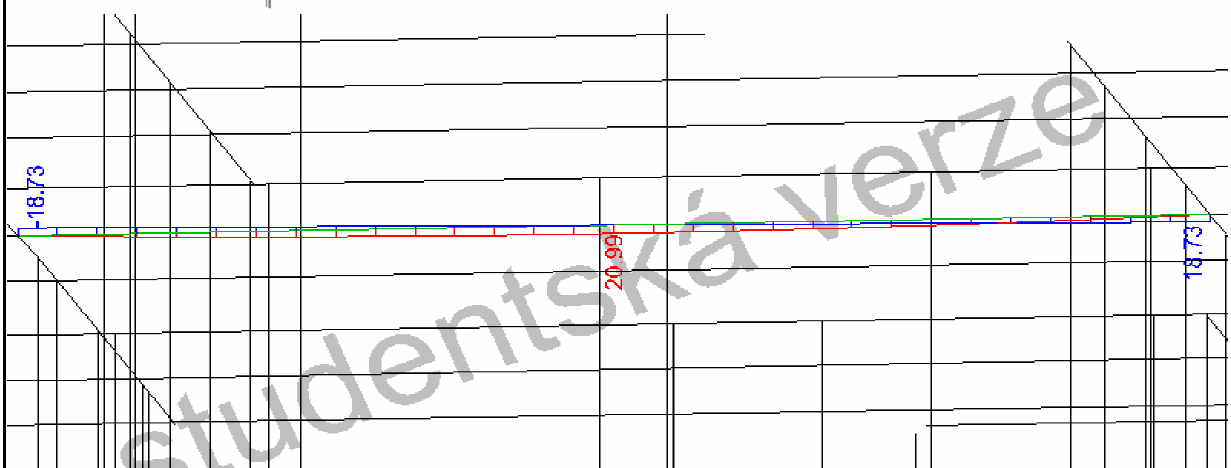
4. self weight load + wind load θ=90°

$1,0*G_k+1,5*Q_V$

Design of the roof joist

(there is used steel S 355 for the design)





Counted shear force (counted with software FIN 3D)

Q_{Sd}= 19,000 kN

Counted bending moment (counted with software FIN 3D)

M_{Sd}= 21,000 kNm

Horizontal module needed

W_{min}= M_{Sd}/f_{yd} f_{yd}= 308,7 Mpa (steel S355)

W_{min}= 21*10^3/308,7

W_{min}= **68,0272** mm^3

Profile design

concrete C25/30 is used

chosen profile	**IPE 100**		**concrete slab + trapezoidal sheets**			
m=	8,1	kg/m	d=	60	mm	
A=	1032	mm^2	t_p=	20	mm	
W_y=	34200	mm^3	f_{ck}=	25	Mpa	
$W_{pl,y}$=	39410	mm^3	f_{cd}=	$0,85*f_{ck}/\gamma_c$=	0,85*25/1,5	
I_y=	1710000	mm^4	f_{cd}=	14,167	Mpa	
A_{vz}=	508	mm^2				
b=	55	mm				
t_f=	5,7	mm				
h=	100	mm				

Recognition of the designed profile

Plastic flexural loading capacity steel-concrete section

co-width cof oncrete slab

b_{eff}= $2b_{e1}$

b_{eff}= L/4

b_{eff}= 1125 mm

presumption of neutral axis location in the concrete slab (concrete in the rib is neglected)

balance of internal forces

N_a= N_c

$A_a f_{yd}$= x b_{eff} f_{cd}

1032*308,7= x*1125*14,167

x= (1032*308,7)/(1125*14,167)

x= **19,989** mm < 60 mm

—>It is apparent that the neutral axis lies in the concrete slab

Torque loading capacity

arm of internal forces

r= h/2+t_p+d-x/2

r= 50+20+60-9,995

r= **120,005** mm

$M_{pl,Rd}$= N_{a1}*r = N_c*r

$M_{pl,Rd}$= 1032*308,7*120,005

$M_{pl,Rd}$= **38,231** kNm > M_{Sd}= **21,000** kNm

—>Roof joist complies

Shear carrying capacity

$V_{pl,Rd}= A_{VZ}*f_{yd}/\sqrt{3}$

$V_{pl,Rd}=$ 508*308,7/√3

$V_{pl,Rd}=$	**90,540**	kN	>	$V_{Sd}=$	**19**	kN

—>Roof joist complies

Deflection

$E_c=$ 15250 MPa $E_s=$ 210000 MPa

ration of modulus elasticity for steel and concrete

$\eta= E_s/E_c$

η= 210000/15250

η= **13,770**

ideal cross-section area

$A_i= A_s+d*b_{eff}/\eta$

$A_i=$ 1032+60*1125/13,77

$A_i=$ **5933,786** mm^2

gravity center of ideal cross-section

$e= (A_s*e_s + d*b_{eff}/\eta * (h+t_p+d-d/2))/A_i$

e= (1032*50+60*1125/13,77*(100+20+60-30)/5933,786

e= **132,608** mm

inertia moment of ideal cross-section

$I_i= I_{ys}+A_s*(e-h/2)^2+1/\eta*(b_{eff}*d^3/12+b_{eff}*d*(e-h-t_p-d/2)^2)$

$I_i=$ 1,71*10^6+1032*(132,608-50)^2+1/13,77*(1125*60^3/12+1125*60*(133-100-20-30)^2)

$I_i=$ **11705688,29** mm^4

Limit the applicability of state - deflection

(all load) $g_k=$ 4,796 kN/m $g_k+q_k=$ 7,6

$q_k=$ 2,835 kN/m

$\delta= (5/384) * (g_k*L^4)/(EI_i)$

δ= (5/384)*(4,796*4500^4)/(210000*11705688,291)

δ=	**16,575**	mm	<	$\delta_{lim}=$	L/250=	**18**	mm

(imposed load)

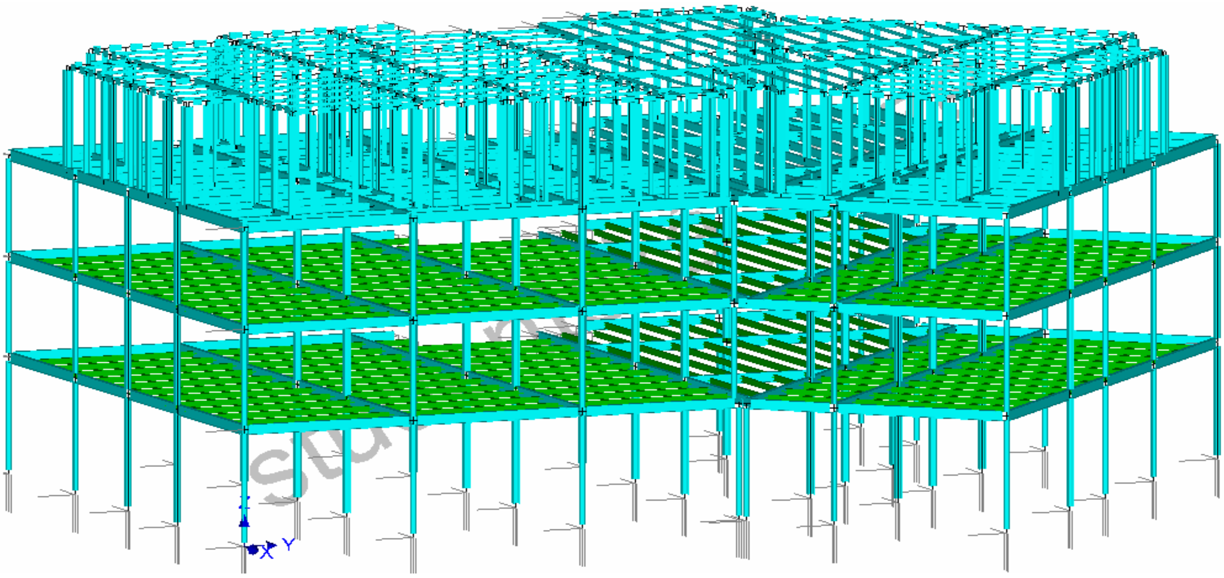
$\delta_2= q_k/g_k * \delta$

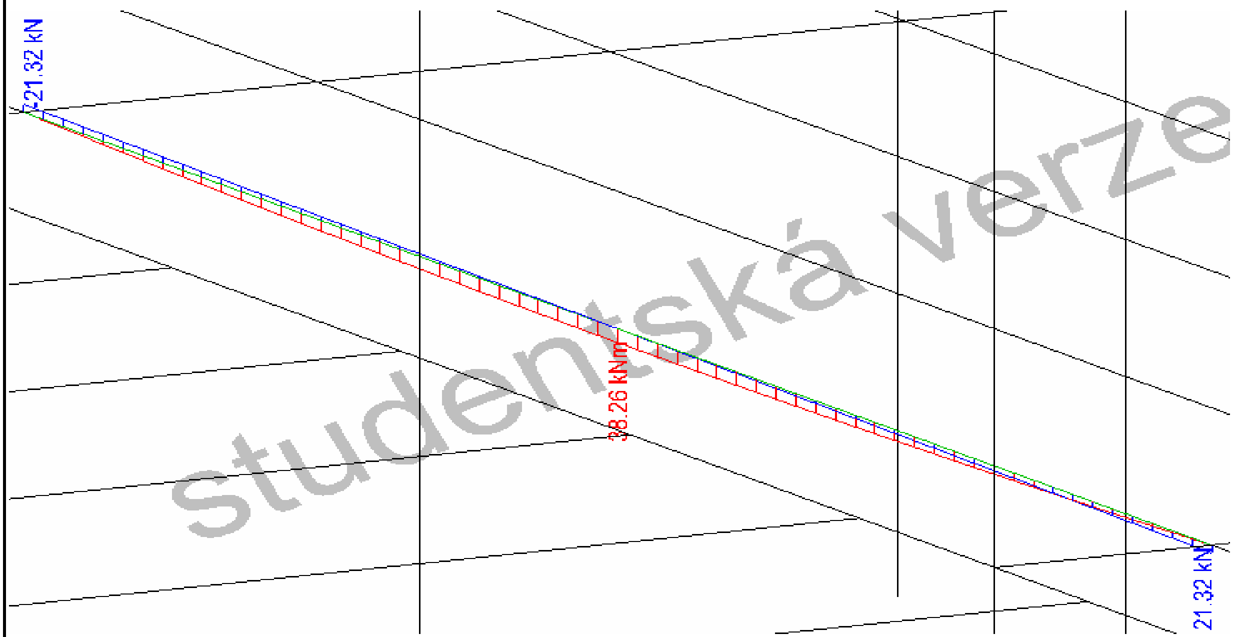
$\delta_2=$ 0/7,631*16,575

$\delta_2=$	**6,158**	mm	<	$\delta_{lim}=$	L/300=	**15,833**	mm

Design of the joist

(there is used steel S 355 for the design)





Counted shear force *(counted with software FIN 3D)*

Q_{Sd}= 22,000 kN

Counted bending moment *(counted with software FIN 3D)*

M_{Sd}= 38,500 kNm

Horizontal module needed

W_{min}= M_{Sd}/f_{yd} f_{yd}= 308,7 Mpa *(steel S355)*

W_{min}= 38,5*10^3/308,7

W_{min}= **124,717** mm^3

Profile design

concrete C25/30 is used

chosen profile	**IPE 160**	
$m=$	15,8	kg/m
$A=$	2009	mm^2
$W_y=$	109000	mm^3
$W_{pl,y}=$	123900	mm^3
$I_y=$	8693000	mm^4
$A_{vz}=$	965	mm^2
$b=$	82	mm
$t_f=$	7,4	mm
$h=$	160	mm

concrete slab + trapezoidal sheets

$d=$	60	mm
$t_p=$	20	mm
$f_{ck}=$	25	Mpa
$f_{cd}=$	$0,85*f_{ck}/\gamma_c=$	0,85*25/1,5
$f_{cd}=$	14,1667	Mpa

Recognition of the designed profile

Plastic flexural loading capacity steel-concrete section

co-width cof oncrete slab

$b_{eff}=$ $2b_{e1}$

$b_{eff}=$ L/4

$b_{eff}=$ 945 mm

presumption of neutral axis location in the concrete slab (concrete in the rib is neglected)

balance of internal forces

$N_a= N_c$

$A_a f_{yd}= x\, b_{eff}\, f_{cd}$

2009*308,7= x*945*14,167

x= (2009*308,7)/(945*14,167)

x= **46,325** mm < 60 mm

—>It is apparent that the neutral axis lies in the concrete slab

Torque loading capacity

arm of internal forces

$r= h/2+t_p+d-x/2$

r= 80+20+60-23,163

r= **136,837** mm

$M_{pl,Rd}= N_{a1}*r = N_c*r$

$M_{pl,Rd}=$ 2009*308,7*136,837

$M_{pl,Rd}=$ **84,864** kNm > $M_{Sd}=$ **38,500** kNm

—>Roof joist complies

Shear carrying capacity

$V_{pl,Rd}= A_{VZ}*f_{yd}/\sqrt{3}$

$V_{pl,Rd}=$ 965*308,7/√3

$V_{pl,Rd}=$ **171,990** kN > $V_{Sd}=$ **22** kN

—>Roof joist complies

Deflection

E_c= 15 250 MPa E_s= 210 000 MPa

ration of modulus elasticity for steel and concrete

$\eta = E_s/E_c$

η= 210000/15250

η= **13,770**

ideal cross-section area

$A_i = A_s + d*b_{eff}/\eta$

A_i= 2009+60*945/13,77

A_i= **6126,500** mm^2

gravity center of ideal cross-section

$e = (A_s*e_s + d*b_{eff}/\eta * (h+t_p+d-d/2))/A_i$

e= (2009*80+60*945/13,77*(160+20+60-30)/6126,5

e= **167,370** mm

inertia moment of ideal cross-section

$I_i = I_{ys}+A_s*(e-h/2)^2+1/\eta*(b_{eff}*d^3/12+b_{eff}*d*(e-h-t_p-d/2)^2)$

I_i= 8,693*10^6+2009*(167,37-80)^2+1/13,77*(945*60^3/12+945*60*(167-160-20-30)^2)

I_i= **32746787,79** mm^4

Limit the applicability of state - deflection

(all load)

g_k= 3,653 kN/m g_k+q_k= 5,8

q_k= 2,126 kN/m

$\delta = (5/384) * (g_k*L^4)/(EI_i)$

δ= (5/384)*(3,653*7000^4)/(210000*32746787,787)

δ= **17,237** mm < δ_{lim}= L/250= **18** mm

(imposed load)

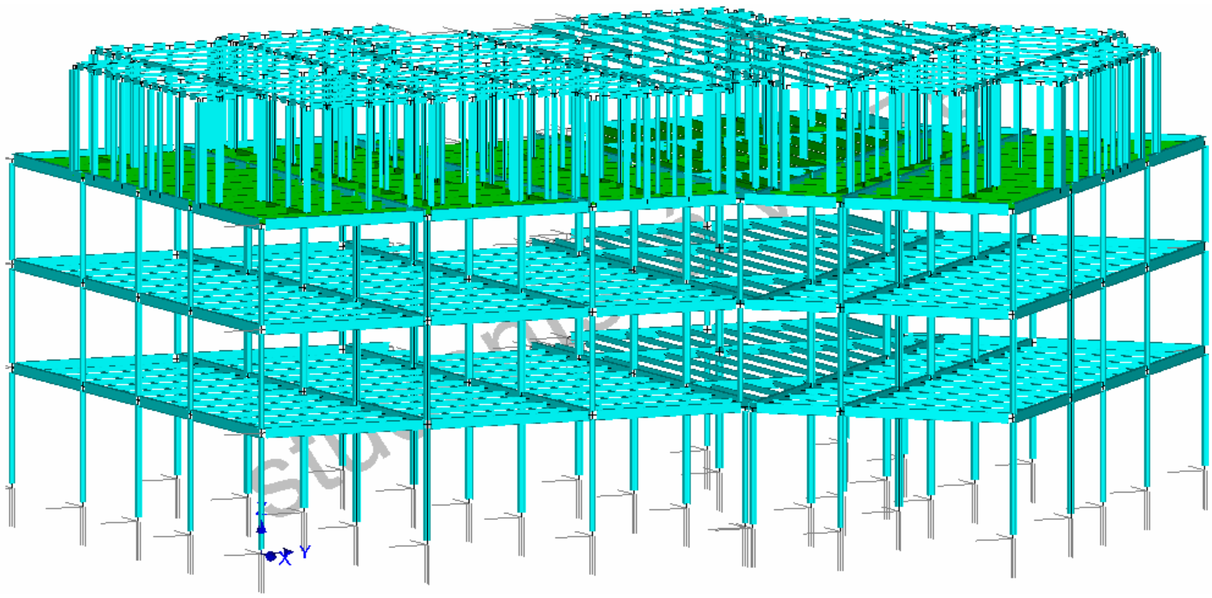
$\delta_2 = q_k/g_k * \delta$

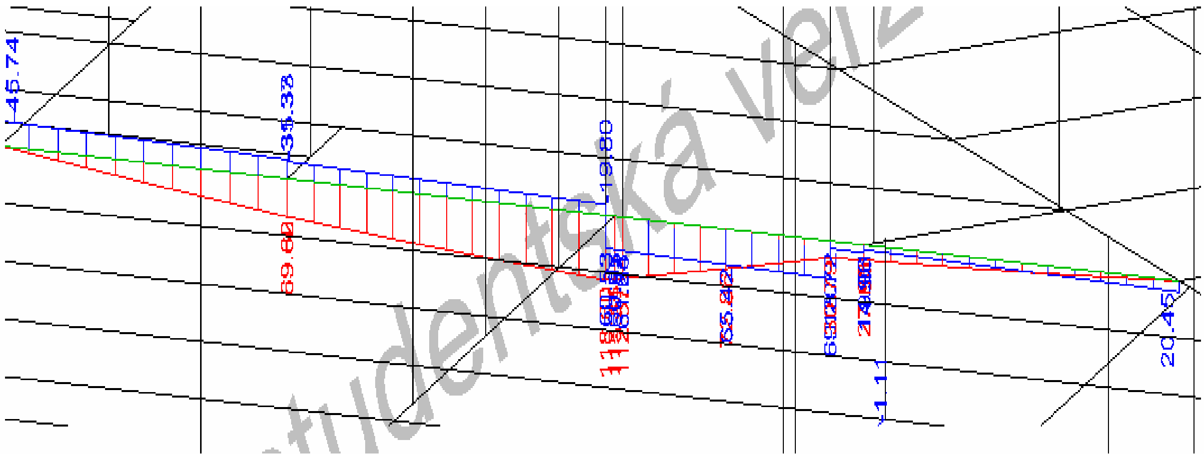
δ_2= 2,126/5,779*17,237

δ_2= **6,341** mm < δ_{lim}= L/300= **15,833** mm

Design of the joist for the 4th floor

(there is used steel S 355 for the design)





Counted shear force				*(counted with software FIN 3D)*
	Q_{Sd}=	171,000	kN	

Counted bending moment				*(counted with software FIN 3D)*
	M_{Sd}=	119,000	kNm	

Horizontal module needed

W_{min}= M_{Sd}/f_{yd} f_{yd}= 308,7 Mpa *(steel S355)*

W_{min}= 119*10^3/308,7

W_{min}= **385,488** mm^3

Profile design

concrete C25/30 is used

chosen profile	**IPE 220**	
$m=$	26,2	kg/m
$A=$	3337	mm^2
$W_y=$	252000	mm^3
$W_{pl,y}=$	285400	mm^3
$I_y=$	27720000	mm^4
$A_{vz}=$	1588	mm^2
$b=$	110	mm
$t_f=$	8,5	mm
$h=$	200	mm

concrete slab + trapezoidal sheets

$d=$	60	mm
$t_p=$	20	mm
$f_{ck}=$	25	Mpa
$f_{cd}=$	$0{,}85 \cdot f_{ck}/\gamma_c = 0{,}85 \cdot 25/1{,}5$	
$f_{cd}=$	14,167	Mpa

Recognition of the designed profile

Plastic flexural loading capacity steel-concrete section

co-width cof oncrete slab

$b_{eff}=$ $2b_{e1}$

$b_{eff}=$ $L/4$

$b_{eff}=$ 1250 mm

presumption of neutral axis location in the concrete slab (concrete in the rib is neglected)

balance of internal forces

$N_a = N_c$

$A_a f_{yd} = x\, b_{eff}\, f_{cd}$

$3337 \cdot 308{,}7 = x \cdot 1250 \cdot 14{,}167$

$x = (3337 \cdot 308{,}7)/(1250 \cdot 14{,}167)$

$x =$ **58,172** mm < 60 mm

—>It is apparent that the neutral axis lies in the concrete slab

Torque loading capacity

arm of internal forces

$r = h/2 + t_p + d - x/2$

$r = 100+20+60-29{,}086$

$r =$ **150,914** mm

$M_{pl,Rd} = N_{a1} \cdot r = N_c \cdot r$

$M_{pl,Rd} = 3337 \cdot 308{,}7 \cdot 150{,}914$

$M_{pl,Rd} =$ **155,461** kNm > $M_{Sd} =$ **119,000** kNm

—>Roof joist complies

Shear carrying capacity

$V_{pl,Rd} = A_{VZ} \cdot f_{yd}/\sqrt{3}$

$V_{pl,Rd} = 1588 \cdot 308{,}7/\sqrt{3}$

$V_{pl,Rd} =$ **283,026** kN > $V_{Sd} =$ **171** kN

—>Roof joist complies

Deflection

$E_c =$ 15 250 MPa $E_s =$ 210 000 MPa

ration of modulus elasticity for steel and concrete

$\eta = E_s/E_c$

$\eta = 210000/15250$

$\eta =$ **13,770**

ideal cross-section area

$A_i = A_s + d*b_{eff}/\eta$

$A_i = 3337+60*1250/13,77$

$A_i =$ **8783,429** mm^2

gravity center of ideal cross-section

$e = (A_s*e_s + d*b_{eff}/\eta * (h+t_p+d-d/2))/A_i$

$e = (3337*100+60*1250/13,77*(200+20+60-30)/8783,429$

$e =$ **193,012** mm

inertia moment of ideal cross-section

$I_i = I_{ys}+A_s*(e-h/2)\text{^}2+1/\eta*(b_{eff}*d\text{^}3/12+b_{eff}*d*(e-h-t_p-d/2)\text{^}2)$

$I_i = 27,72*10\text{^}6+3337*(193,012-100)\text{^}2+1/13,77*(1250*60\text{^}3/12+1250*60*(193-200-20-30)\text{^}2)$

$I_i =$ **75911086,73** mm^4

Limit the applicability of state - deflection

(all load) $g_k =$ 3,653 kN/m $g_k+q_k =$ 5,8

$q_k =$ 2,126 kN/m

$\delta = (5/384) * (g_k*L^4)/(EI_i)$

$\delta = (5/384)*(3,653*7000\text{^}4)/(210000*75911086,735)$

$\delta =$ **7,436** mm	<	$\delta_{lim} = L/250 =$ **18** mm

(imposedload)

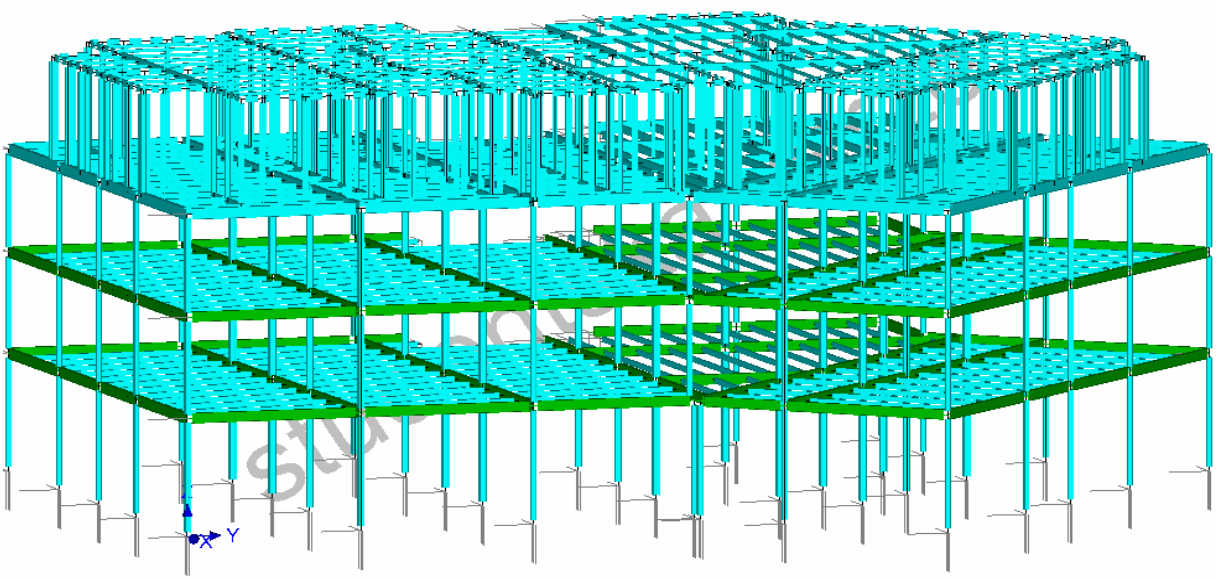
$\delta_2 = q_k/g_k * \delta$

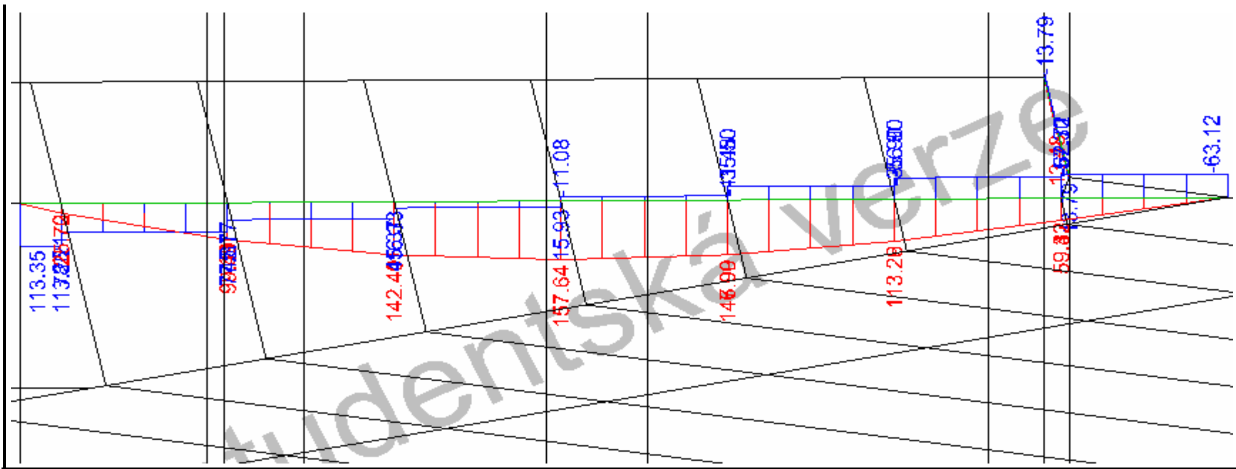
$\delta_2 = 2,126/5,779*7,436$

$\delta_2 =$ **2,736** mm	<	$\delta_{lim} = L/300 =$ **15,833** mm

Design of the beam

(there is used steel S 355 for the design)





Counted shear force *(counted with software FIN 3D)*

$R_{Sd}=V_{Sd}=$ 256,000 kN

Counted bending moment *(counted with software FIN 3D)*

$M_{Sd}=$ 159,0000 kNm

Horizontal module needed

$W_{min}= M_{Sd}/f_{yd}$ $f_{yd}=$ 308,7 Mpa *(steel S355)*

$W_{min}=$ 159*10^3/308,7

$W_{min}=$ **515,0632** mm^3

Profile design

concrete C25/30 is used

chosen profile	IPE 220	
$m=$	26,2	kg/m
$A=$	3337	mm^2
$W_y=$	252000	mm^3
$W_{pl,y}=$	285400	mm^3
$I_y=$	27720000	mm^4
$A_{vz}=$	1588	mm^2
$b=$	110	mm
$t_f=$	9,2	mm
$h=$	220	mm

concrete slab + trapezoidal sheets

$d=$	60	mm
$t_p=$	20	mm
$f_{ck}=$	25	Mpa
$f_{cd}=$	$0,85 \cdot f_{ck}/\gamma_c=$	0,85*25/1,5
$f_{cd}=$	14,1667	Mpa

Recognition of the designed profile

Plastic flexural loading capacity steel-concrete section

co-width cof oncrete slab

$b_{eff}= 2b_{e1}$

$b_{eff}= L/4$

$b_{eff}=$ 1250 mm

presumption of neutral axis location in the concrete slab (concrete in the rib is neglected)

balance of internal forces

$N_a= N_c$

$A_a f_{yd}= x\, b_{eff}\, f_{cd}$

3337*308,7= x*1250*14,167

x= (3337*308,7)/(1250*14,167)

x= **58,172** mm > 60 mm

—>It is apparent that the neutral axis lies in the concrete slab

Torque loading capacity

arm of internal forces

$r = h/2+t_p+d-x/2$

$r = 110+20+60-29{,}086$

$r =$ **160,914** mm

$M_{pl,Rd} = N_{a1}*r = N_{c*}r$

$M_{pl,Rd} = 3337*308{,}7*160{,}914$

$M_{pl,Rd} =$ **165,763**	kNm	>	$M_{Sd} =$	**159,000**	kNm

—>Girder complies

Shear carrying capacity

$V_{pl,Rd} = A_{VZ}*f_{yd/}\sqrt{3}$

$V_{pl,Rd} = 1588*/\sqrt{3}$

$V_{pl,Rd} =$ **283,026**	kN	>	$V_{Sd} =$	**256,000**	kN

—>Girder complies

Shear carrying capacity

$V_{pl,Rd} = A_{VZ}*f_{yd/}\sqrt{3}$

$V_{pl,Rd} = 1588*308{,}7/\sqrt{3}$

$V_{pl,Rd} =$ **283,026**	kN	>	$V_{Sd} =$	**256**	kN

—>Girder complies

Deflection

$E_c =$ 15250 MPa $E_s =$ 210000 MPa

ration of modulus elasticity for steel and concrete

$\eta = E_s/E_c$

$\eta = 210000/15250$

$\eta =$ **13,770**

ideal cross-section area

$A_i = A_s+d*b_{eff}/\eta$

$A_i = 3337+60*1250/13{,}77$

$A_i =$ **8783,429** mm^2

gravity center of ideal cross-section

$e = (A_s*e_s + d*b_{eff}/\eta * (h+t_p+d-d/2))/A_i$

$e = (3337*110+60*1250/13{,}77*(220+20+60-30)/8783{,}429$

$e =$ **209,213** mm

inertia moment of ideal cross-section

$I_i = I_{ys}+A_s*(e-h/2)^2+1/\eta*(b_{eff}*d^3/12+b_{eff}*d*(e-h-t_p-d/2)^2)$

$I_i = 27{,}72*10^6+3337*(209{,}213-110)^2+1/13{,}77*(1250*60^3/12+1250*60*(209-220-20-30)^2)$

$I_i =$ **82325628,53** mm^4

Limit the applicability of state - deflection

(all load) $g_k =$ 9,260 kN/m $g_k+q_k =$ ####

$q_k =$ 3,695 kN/m

$\delta = (5/384) * (g_k*L^4)/(EI_y)$

$\delta = (5/384)*(9{,}26*6800^4)/(210000*27720000)$

$\delta =$ **14,912**	mm	<	$\delta_{lim} =$ L/250=	**19,000**	mm

(imposedl load)

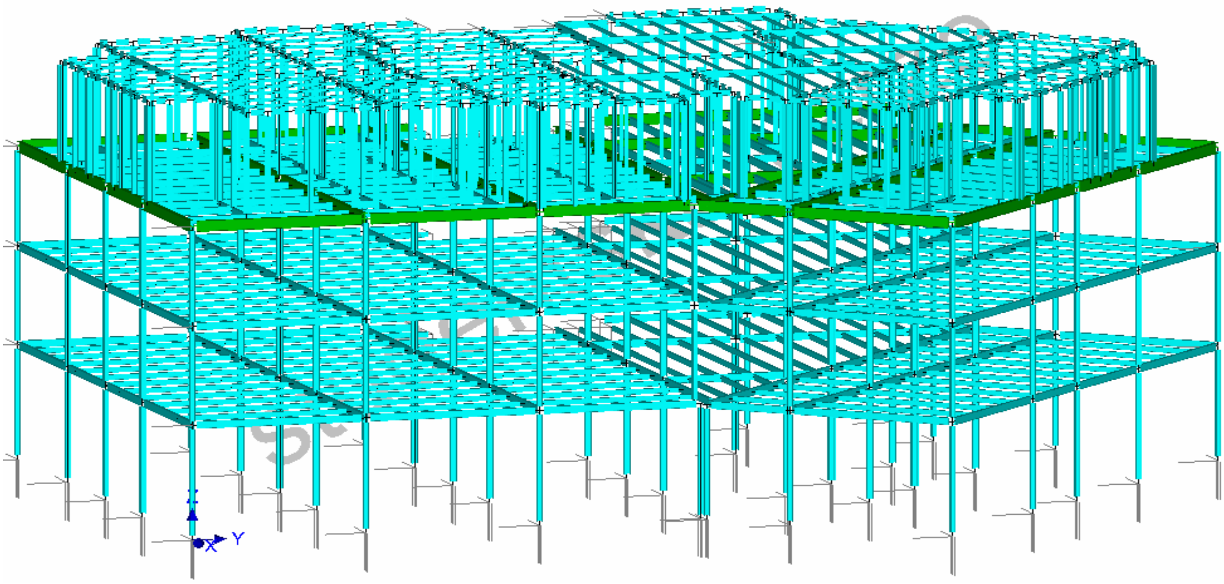
$\delta_2 = q_k/g_k * \delta$

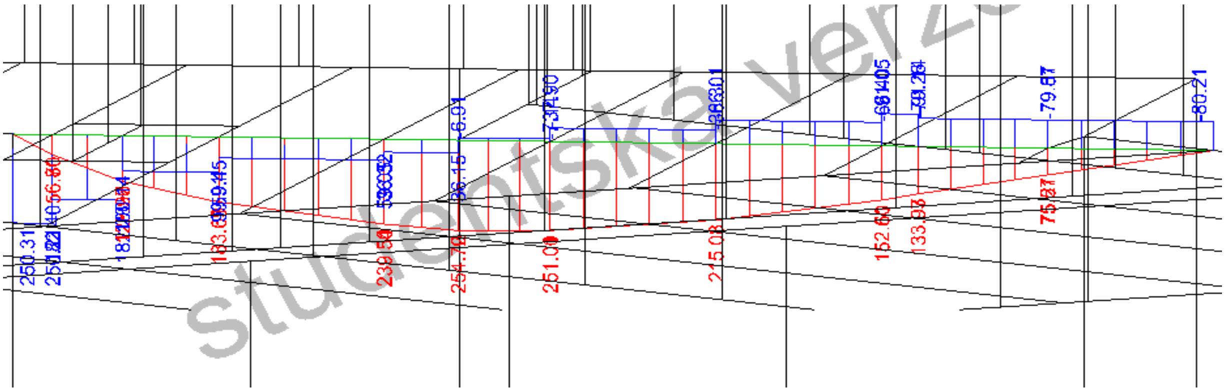
$\delta_2 =$ 0/12,955*14,912

$\delta_2 =$	**4,253**	mm	<	$\delta_{lim} =$ L/300=	**15,833**	mm

Design of the girder of the 4th floor

(there is used steel S 355 for the design)





Counted shear force *(counted with software FIN 3D)*

$R_{Sd} = V_{Sd} =$ 251,000 kN

Counted bending moment *(counted with software FIN 3D)*

$M_{Sd} =$ 255,0000 kNm

Horizontal module needed

$W_{min} = M_{Sd}/f_{yd}$ $f_{yd} =$ 308,7 Mpa *(steel S355)*

$W_{min} =$ 255*10^3/308,7

$W_{min} =$ **826,0447** mm^3

Profile design

concrete C25/30 is used

chosen profile	**IPE 300**	
$m=$	42,2	kg/m
$A=$	5381	mm^2
$W_y=$	557000	mm^3
$W_{pl,y}=$	628400	mm^3
$I_y=$	83560000	mm^4
$A_{vz}=$	2568	mm^2
$b=$	150	mm
$t_f=$	10,7	mm
$h=$	300	mm

concrete slab + trapezoidal sheets

$d=$	60	mm
$t_p=$	20	mm
$f_{ck}=$	25	Mpa
$f_{cd}=$	$0{,}85 \cdot f_{ck}/\gamma_c=$	0,85*25/1,5
$f_{cd}=$	14,1667	Mpa

Recognition of the designed profile

Plastic flexural loading capacity steel-concrete section

co-width cof oncrete slab

$b_{eff}= 2b_{e1}$

$b_{eff}= L/4$

$b_{eff}=$ 1250 mm

presumption of neutral axis location in the concrete slab (concrete in the rib is neglected)

balance of internal forces

$N_a= N_c$

$A_a f_{yd}= x\, b_{eff}\, f_{cd}$

5381*308,7= x*1250*14,167

x= (5381*308,7)/(1250*14,167)

x= **93,804** mm > 60 mm

—>It is apparent that the neutral axis lies outside the concrete slab

presumption of a neutral axis location in a steel profile

balance of internal forces

$N_a= N_c + 2N_{a1}$

$N_a=$	$A_s f_{yd}=$	5381*308,7=	**1661,1147**	kN
$N_c=$	$d * b_{eff} * f_{cd}=$	60*1250*14,167=	**1062,5**	kN
$N_{a1}=$	$(N_a-N_c)/2=$	(1661,1147-1062,5)/2=	**299,307**	kN

presumption of a neutral axis position in the upper flange of steel profile

$x= N_{a1}/(f_{yd}*b)$

x= 299,307*1000/(308,7*150)

x= **6,464** mm < 10,7 mm

—>The neutral axis is located in the upper flange of steel profile

Torque loading capacity

$M_{pl,Rd}= N_c*r_c + N_{a1}*r_{a1}$

$M_{pl,Rd}=$ 1062,5*(150+80-30)+299,30735*(150-3,232)

$M_{pl,Rd}=$ **256,429** kNm > $M_{Sd}=$ **255,000** kNm

—>Girder complies

Shear carrying capacity

$V_{pl,Rd}= A_{VZ}*f_{yd}/\sqrt{3}$

$V_{pl,Rd}= 2568*308{,}7/\sqrt{3}$

$V_{pl,Rd}=$ **457,690** kN > $V_{Sd}=$ **251** kN

—>Girder complies

Deflection

E_c= 15 250 MPa E_s= 210 000 MPa

ration of modulus elasticity for steel and concrete

$\eta = E_s/E_c$

η= 210000/15250

η= **13,770**

ideal cross-section area

$A_i = A_s + d*b_{eff}/\eta$

A_i= 5381+60*1250/13,77

A_i= **10827,429** mm^2

gravity center of ideal cross-section

$e = (A_s*e_s + d*b_{eff}/\eta * (h+t_p+d-d/2))/A_i$

e= (5381*150+60*1250/13,77*(300+20+60-30)/10827,429

e= **250,604** mm

inertia moment of ideal cross-section

$I_i = I_{ys} + A_s*(e-h/2)^2 + 1/\eta*(b_{eff}*d^3/12 + b_{eff}*d*(e-h-t_p-d/2)^2)$

I_i= 83,56*10^6+5381*(250,604-150)^2+1/13,77*(1250*60^3/12+1250*60*(251-300-20-30)^2)

I_i= **193464260,5** mm^4

Limit the applicability of state - deflection

(all load) g_k= 9,420 kN/m g_k+q_k= 13,1

q_k= 3,695 kN/m

$\delta = (5/384) * (g_k*L^4)/(EI_y)$

δ= (5/384)*(9,42*6800^4)/(210000*83560000)

δ=	**6,455**	mm	<	δ_{lim}= L/250=	**19,000**	mm

(incidental load)

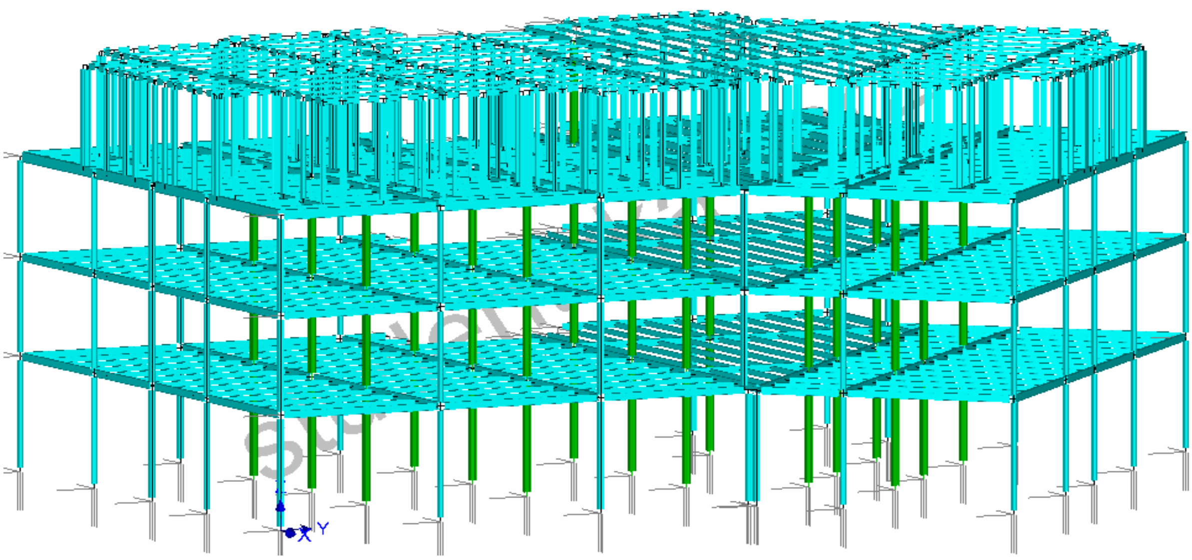
$\delta_2 = q_k/g_k * \delta$

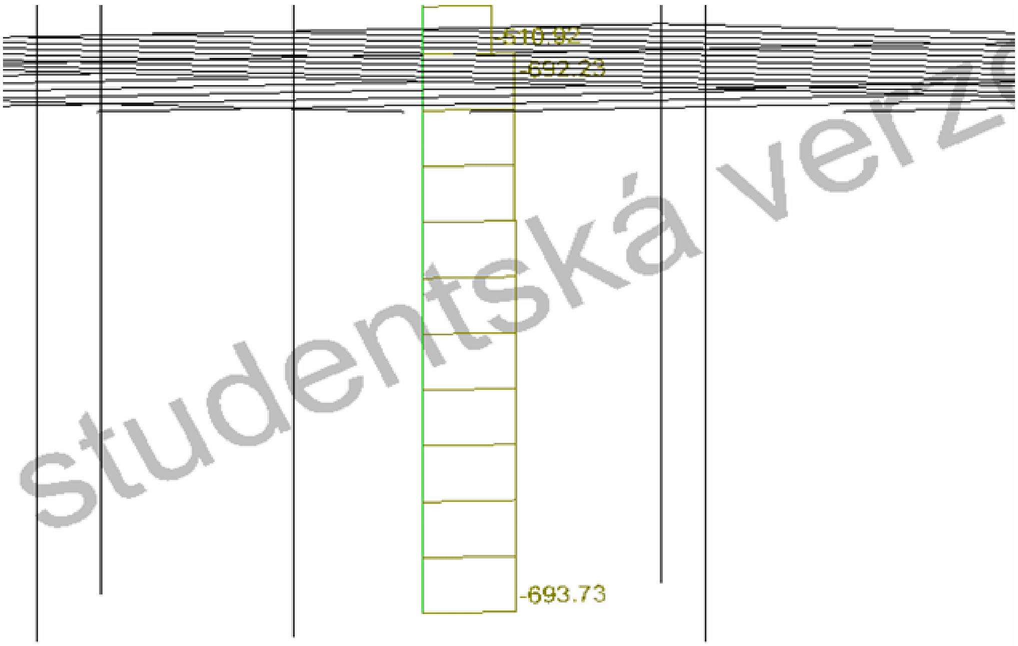
δ_2= 0/13,115*6,455

δ_2=	**1,819**	mm	<	δ_{lim}= L/300=	**15,833**	mm

Design of the column

(there is used steel S 355 for the design)





Loading force

F_{Sd}= 694 kN

Profile design

	HEB 160			
m=	42,6	kg/m	λ_1= 93,9√(235/355)=	76,4
A=	5425	mm^2	β_A= 1	
i_y=	67,8	mm	f_{yd}= 308,7 Mpa	
i_z=	40,5	mm	*(steel S355)*	

Recognition of the designed profile

(buckling length)

$L_{cr,y} = L_{cr,z}$ = 3,5 m

λ_y =	$L_{cr,z}/i_y$=	3500/67,8=	51,62242
λ_z =	$L_{cr,y}/i_z$=	3500/40,5=	86,41975

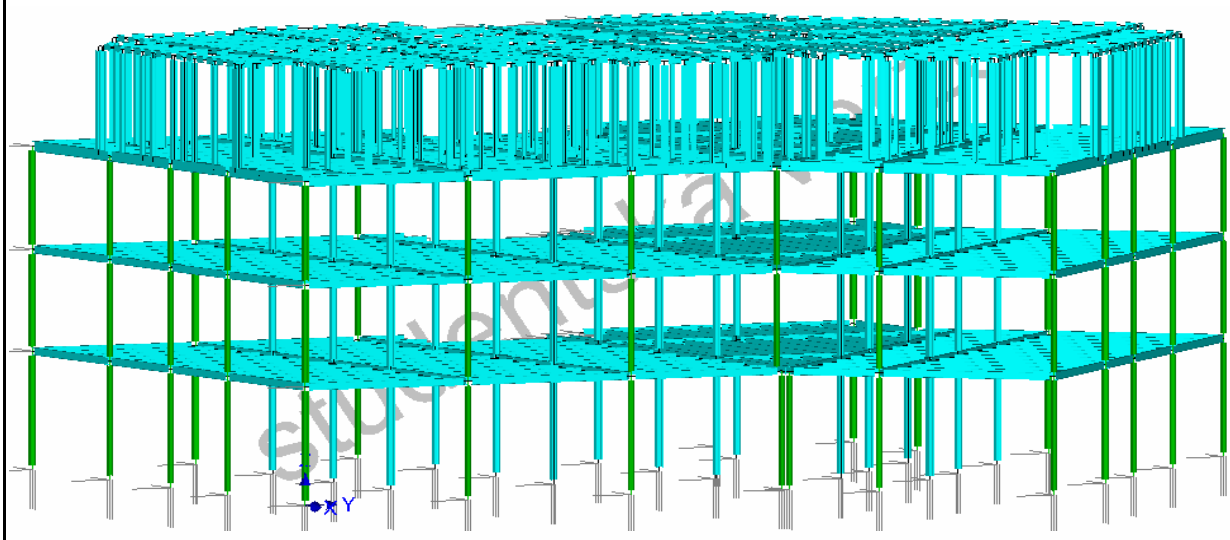
				buckling curve	coefficient of buckling
$\bar{\lambda}_y$ =	$\lambda_y/\lambda_1 \cdot \sqrt{\beta_A}$=	51,622/76,399*√1	0,6757	b	0,795
$\bar{\lambda}_z$ =	$\lambda_y/\lambda_1 \cdot \sqrt{\beta_A}$=	86,42/76,399*√1	1,1312	c	0,469

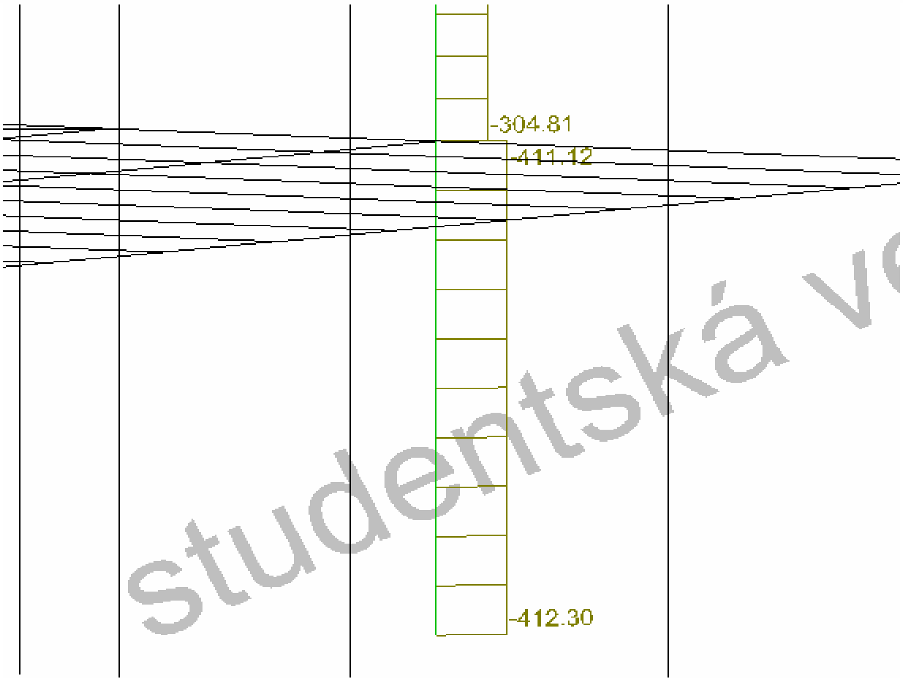
buckling pressure loading capacity

$N_{b,Rd}$= **785,4331275** kN > F_{Sd}= **694,000** kN

Design of the column

(there is used steel S 355 for the design)





Loading force

F_{Sd}= 412 kN

Profile design

		HEB 160	
m=	42,6	kg/m	
A=	5425	mm^2	
i_y=	67,8	mm	
i_z=	40,5	mm	

λ_1= 93,9√(235/355)= 76,4

β_A= 1

f_{yd}= 308,7 Mpa

(steel S355)

Recognition of the designed profile

(buckling length)

$L_{cr,y} = L_{cr,z} =$ 3,5 m

λ_y = $L_{cr,z}/i_y$= 3500/67,8= 51,62242

λ_z = $L_{cr,y}/i_z$= 3500/40,5= 86,41975

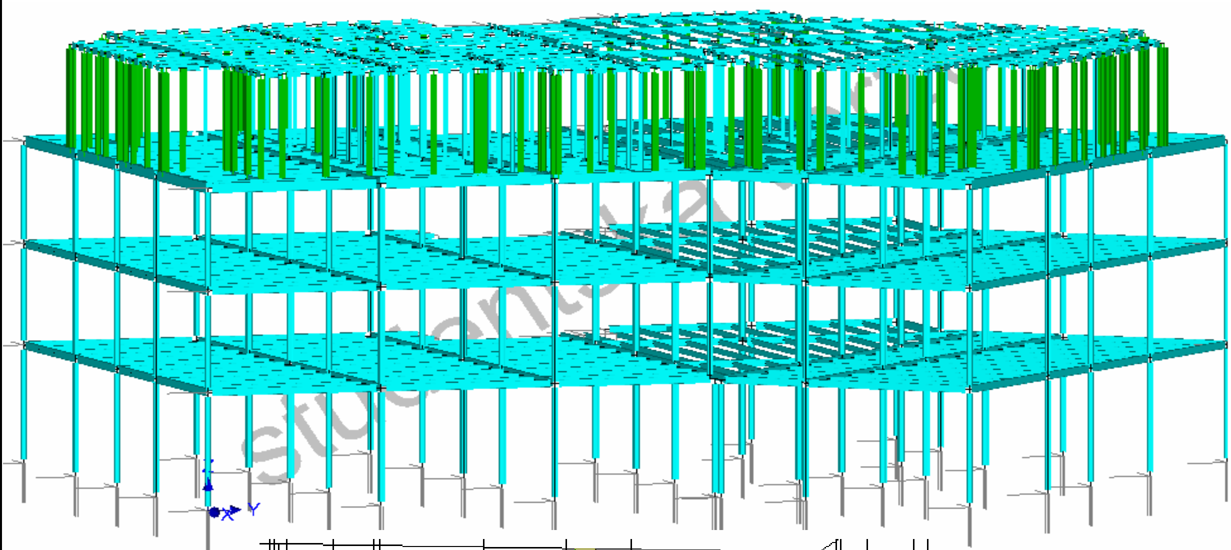
			buckling curve	coefficient of buckling
λ_y =	$\lambda_y/\lambda_1*\sqrt{\beta_A}$= 51,622/76,399*√1	0,6757	b	0,795
λ_z =	$\lambda_y/\lambda_1*\sqrt{\beta_A}$= 86,42/76,399*√1	1,1312	c	0,469

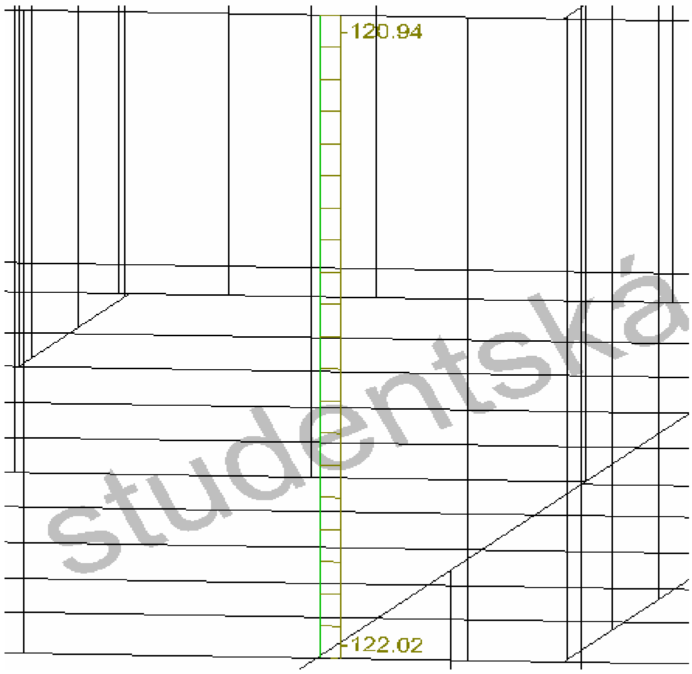
buckling pressure loading capacity

$N_{b,Rd}$=	**785,4331275**	kN	>	F_{Sd}=	**412,000**	kN

Design of the 4th floor column

(there is used steel S 355 for the design)





Loading force

F_{Sd}= 122 kN

Profile design

	HEB 100	
m=	20,4	kg/m
A=	2604	mm^2
i_y=	41,5	mm
i_z=	25,3	mm

λ_1= 93,9√(235/355)= 76,4

β_A= 1

f_{yd}= 308,7 Mpa

(steel S355)

Recognition of the designed profile

(buckling length)

$L_{cr,y} = L_{cr,z}$ = 3,5 m

λ_y = $L_{cr,z}/i_y$= 3500/41,5= 84,337

λ_z = $L_{cr,y}/i_z$= 3500/25,3= 138,340

				buckling curve	coefficient of buckling
λ_y =	$\lambda_y/\lambda_1 * \sqrt{\beta_A}$=	84,337/76,399*√1	1,1039	b	0,535
λ_z =	$\lambda_y/\lambda_1 * \sqrt{\beta_A}$=	138,34/76,399*√1	1,8108	c	0,232

buckling pressure loading capacity

$N_{b,Rd}$=	**186,494**	kN	>	F_{Sd}=	**122,000**	kN

List of elements designed for the steel structure

Element		Profile
purlin	**roof**	**IPE 100**
	2nd, 3rd floor	**IPE 160**
	4th floor	**IPE 220**
beam	**2nd, 3rd floor**	**IPE 220**
	4th floor	**IPE 300**
column	**2nd, 3rd floor**	**HEB 160**
	4th floor	**HEB 100**

C

Static evaluation of the light-weight concrete structure variant

Self-weight load + imposed load for each composition

Construction of the floor

(There is concidered floor in the bathroom - ceramic tiles and waterproofing)
(There will be used wooden floor in the other rooms - the composition is lighter)

Self weight of the composition					
Layers of the composition	Thickness [mm]	Density [kg/m³]	g_k [kN/m²]	γ_F	q_d [kN/m²]
Final layer - ceramic tiles Rako Tanse	10,00	2000,00	0,200	1,35	0,270
Waterproofing Sarnafil G 441-24EL	2,40	3200,00	0,077	1,35	0,104
Anhydrite Anhyment AE 20	400,00	2100,00	8,400	1,35	11,340
Impact sound insulation Dow Ethafoam	20,00	35,00	0,007	1,35	0,009
Poriment	240,00	420,00	1,008	1,35	1,361
Concrete slab	250,00	2400,00	6,000	1,35	8,100
Internal plaster	12,50	750,00	0,094	1,35	0,127
Summary			**15,786**		**21,310**

Imposed load for the composition			
	q_k [kN/m²]	γ_F	g_d [kN/m²]
	1,500	1,500	2,250
Summary	**1,500**		**2,250**

Joist	Width for loading [m]	g_d [kN/m´]	q_d [kN/m´]
middle 2	2,500	53,276	5,625

Construction of the roof

Self weight of the composition					
Layers of the composition	Thicknes s [mm]	Density [kg/m^3]	g_k [kN/m²]	γ_F	q_d [kN/m²]
Greening			1,000	1,35	1,350
Waterproofing Sarnafil G 441-24EL	2,40	3200,00	0,077	1,35	0,104
Thermal insulation Dow Roofmate SL	140,00	35,00	0,049	1,35	0,066
Waterproofing Sikaplan D	1,20	1300,00	0,016	1,35	0,021
Thermal insulation Dow Roofmate SL	120,00	35,00	0,042	1,35	0,057
Concrete slab	200,00	2300,00	4,600	1,35	6,210
Internal plaster	12,50	750,00	0,094	1,35	0,127
Summary			**5,877**		**7,934**

Imposed and snow load for the roof composition			
	q_k [kN/m^2]	γ_F	g_d [kN/m²]
imposed load	1,500	1,500	2,250
snow load	0,560	1,500	0,840
Summary	**2,060**		**3,090**

Chosen wall	Width for loading [m]	g_d [kN/m´]	q_d [kN/m´]
middle 3	3,500	27,770	10,815

Evaluation of the carrying capacity of the wall

material used for the wall design	YTONG P-4-500	
load bearing capacity	4	MPa
density	650	kg/m^3
wall thickness	250	mm

Self weigt of the wall						
Floor	height [m]	Thicknes s [m]	self weight [kg/m^3]	q_k [kN/m^2]	γ_F	g_d [kN/m²]
4th floor	3,200	0,250	520,000	5,200	1,350	7,020
3rd floor	3,050	0,250	495,625	4,956	1,350	6,691
2nd floor	3,000	0,250	487,500	4,875	1,350	6,581
1st floor	3,330	0,250	541,125	5,411	1,350	7,305
Total				**20,443**		**27,597**

Statement of loading normal force N_{Ed}	**g_d [kN/m²]**
load from roof	
self weight of compositions	27,770
imposed load	10,815
load of each floor	
self weight of compositions	53,276
imposed load	5,625

Total load on the wall in 1st floor - normal force in the heel

N_{Ed}= **242,886** **kN/m´**

$N_{Ed} < N_{Rd}$

$N_{Rd} = \Phi * t * f_d$

Assessment of the design strenght in the pressure

f_b= **4** **MPa**

$f_k = K * f_b^{0,85}$ K= 0,8

f_k= 0,8*4^(0,85)

f_k= **2,599** **MPa**

$f_d = f_k/\gamma_M$ γ_M= 2,2

f_d= 2,599/2,2

<u>f_d=</u> **<u>1,181</u>** **<u>MPa</u>**

Decreasing coefficient expressing the effect of slenderness and load eccentricity

$\Phi = 1-2*(e_i/t)$ h= 3200 mm

ρ_n= 0,75

$e_i = e_{init}$ $h_{ef} = \rho_n * h$

$e_i = h_{ef}/450$ h_{ef}= 0,75*3200

e_i= 2400/450 h_{ef}= 2400

e_i= **5,333** **mm**

$\Phi = 1-2*(e_i/t)$

Φ= 1-2*(5,333/250)

Φ= **0,957**

Assessment for the pressure

$N_{Rd} = \Phi * t * f_d$

N_{Rd}= 0,957*250*1,181

<u>N_{Rd}=</u> **<u>282,762</u>** **<u>kN/m´</u>**

N_{Rd}	>	N_{Ed}
<u>282,762</u>	**<u>></u>**	**<u>242,886</u>**

—>Wall complies

D

Energy consumption of fans used for mechanical ventilation

Energy consumption of fans used for mechanical ventilation

Used power supplied to a fan

$P_{mains}= (q_{fan}*\Delta p_{fan})/(\eta_{tot}*1000)$

Air flow through each fan

$q_{fan}=$ 1500 m^3/h

$q_{fan}=$ 0,42 m^3/s

(this value was stated according to the amount of people supposed to be in the building and the requirements on fresh air per person)

Efficiency of the fan

$\eta_{tot}=$ 0,7

Total pressure loss for a fan Δp [Pa]			
Income fan		Outcome fan	
filter	150	filter	150
heat recover	200	heat recover	200
filter	150	duct	80
duct	80		
pressure difference	80		
Summary	**660**		**430**

Used power supplied to each fan

Income fan

$P_{mains}= (0,42*660)/(0,7*1000)$

$P_{mains}=$ 0,40 kW

Outcome fan

$P_{mains}= (0,42*430)/(0,7*1000)$

$P_{mains}=$ 0,26 kW

Used power supplied to each fan per m^2 and year

Income fan

$P_I= P_{mains}*24*365/1940$

$P_I=$ 1,79 kwh/m^2y

Outcome fan

$P_O= P_{mains}*24*365/1940$

$P_O=$ 1,16 kwh/m^2y

Total power suply to fans

$P_{tot}= P_I+P_O$

$P_{tot}=$ 2,95 kwh/m^2y

SFP - Specific fan power

$SFP= P_{tot}/q_{max}$

SFP= 1,56 $kW/(m^3/s)$

E

Evaluation of heat capacity of indoor mass for all alternatives

Evaluation of internal heat mass capacity

Internal heat mass capacity c

$$c = \Sigma \rho * c * d * A$$

ρ - density of material [kg/m³]
c- specific heat mass capacity of the layer [J/kgK]
d- thickness of the layer [m]
A- area of the element [m²]

The evaluation is done for all of the structures in contact with the internal air. The maximal thicknss of the elemet taken in account is 100 mm.

Concrete structure alternative		Compositons	A [m²]	ρ [kg/m³]	d[m]	c[J/kgK]	C_{int}[kJ/K]
		Ceiling above the basement					
	1.	final layer - ceramic tiles	496,5	2000	0,010	840	8341,20
	2.	anhydrite	496,5	2100	0,050	840	43791,30
	3.	impact sound insulation Ethafoam	496,5	35	0,020	1000	347,55
	4.	concrete slab	496,5	2400	0,020	1020	24308,64
		Circumference wall - main wall					
	1.	internal plaster (gypsum based)	701,42	1300	0,010	1000	9118,46
	2.	reinforced concrete	701,42	2400	0,090	1020	154536,85
		Roof					
	1.	internal plaster (gypsum based)	430,75	1300	0,010	1000	5599,75
	2.	concrete slab	430,75	2400	0,090	1020	94902,84
		Windows/door					
	1.	glass	342,3	2600	0,008	840	5980,67
	2.	frame	60,41	600	0,020	2520	1826,80
		Partition between flats					
	1.	internal plaster (gypsum based)	427,6	1300	0,010	1000	5558,80
	2.	reinforced concrete	427,6	2400	0,040	1020	41870,59
	2.	reinforced concrete	427,6	2400	0,040	1020	41870,59
	1.	internal plaster (gypsum based)	427,6	1300	0,010	1000	5558,80
		Ceiling					
	1.	final layer - ceramic tiles	1442,85	2000	0,010	840	24239,88
	2.	anhydrite	1442,85	2100	0,040	840	101807,50
	3.	concerete slab	1442,85	2400	0,040	1000	138513,60
	4.	internal plaster (gypsum based)	1442,85	1300	0,010	1000	18757,05
		Partitions					
	1.	internal plaster (gypsum based)	1250,7	1300	0,010	1000	16259,10
	2.	reinforced concrete	1250,7	2400	0,040	1020	122468,54
	2.	reinforced concrete	1250,7	2400	0,040	1020	122468,54
	1.	internal plaster (gypsum based)	1250,7	1300	0,010	1000	16259,10
		Internal heat mass capacity			**517,72**		**kJ/(Km²)**

Stairway

	Compositons	A [m²]	ρ [kg/m³]	d[m]	c[J/kgK]	C_{int}[kJ/K]
	Stairway					
1.	final layer - ceramic tiles	92	2000	0,010	2520	4636,80
2.	concrete slab	92	2400	0,090	1020	20269,44
	Stairway - Wall to exterior					
1.	inenal plaster (gypsum based)	155,47	2000	0,010	2520	7835,69
2.	concrete	155,47	2400	0,090	1020	34253,15
	Stairway - Wall to interior					
1.	inenal plaster (gypsum based)	103,4	2000	0,010	2520	5211,36
2.	concrete	103,4	2400	0,090	1020	22781,09
	Internal heat mass capacity			**564,49**		**kJ/(Km²)**

Light-weight concrete alternative

	Compositons	A [m²]	ρ [kg/m³]	d[m]	c[J/kgK]	C_{int}[kJ/K]
	Ceiling above garages					
1.	final layer - ceramic tiles	496,5	2000	0,010	840	8341,20
2.	anhydrite	496,5	2100	0,050	840	43791,30
3.	impact sound insulation Ethafoam	496,5	35	0,020	1000	347,55
4.	concrete slab	496,5	2400	0,020	1020	24308,64
	Circumference wal - main wall					
1.	internal plaster (gypsum based)	701,42	1300	0,010	1000	9118,46
2.	YTONG - P-4-500	701,42	500	0,090	1000	31563,90
	Roof					
1.	internal plaster (gypsum based)	430,75	1300	0,010	1000	5599,75
2.	concrete slab	430,75	2400	0,090	1020	94902,84
	Windows/door					
1.	glass	342,3	2600	0,008	840	5980,67
2.	frame	60,41	600	0,020	2520	1826,80
	Partitions between flats					
1.	plasterboard	427,6	750	0,013	1000	4008,75
2.	insulation - Orsil N	427,6	100	0,037	1150	1831,73
5.	insulation - Orsil N	427,6	100	0,037	1150	1831,73
6.	gypsumboard	427,6	750	0,013	1000	4008,75
	Ceiling					
1.	final layer - ceramic tiles	1442,85	2000	0,010	840	24239,88
2.	anhydrite	1442,85	2100	0,040	840	101807,50
3.	concerete slab	1442,85	2400	0,040	1000	138513,60
4.	internal plaster (gypsum based)	1442,85	1300	0,010	1000	18757,05
	Partitions					
1.	internal plaster (gypsum based)	1250,7	1000	0,010	1000	12507,00
2.	YTONG-P-4-500	1250,7	500	0,040	1000	25014,00
3.	YTONG-P-4-500	1250,7	500	0,040	1000	25014,00
4.	internal plaster (gypsum based)	1250,7	1000	0,010	1000	12507,00
	Concrete columns					
1.	inenal plaster (gypsum based)	145,53	2000	0,010	2520	7334,71
2.	concrete	145,53	2400	0,090	1020	32063,17
	Internal heat mass capacity			**327,43**		**kJ/(Km²)**

Steel structure alterntive

	Compositons	A [m^2]	ρ [kg/m^3]	d[m]	c[J/kgK]	C_{int}[kJ/K]
	Ceiling above the garages					
1.	final layer - ceramic tiles	496,5	2000	0,010	840	8341,20
2.	anhydrite	496,5	2100	0,050	840	43791,30
3.	impact sound insulation Ethafoam	496,5	35	0,020	1000	347,55
4.	concrete slab	496,5	2400	0,020	1020	24308,64
	Circumference wall - main wall					
1.	plasterboard	701,42	750	0,013	1060	6970,36
2.	air gap	701,42	1,2	0,050	1010	42,51
2.	OSB board	701,42	650	0,015	1700	11626,04
3.	mineral wool	701,42	138,4	0,023	1053,8	2301,73
	Roof					
1.	plasterboard	430,75	750	0,013	1060	4280,58
2.	air gap	430,75	1,2	0,050	1010	26,10
2.	OSB board	430,75	650	0,015	1700	7139,68
3.	mineral wool	430,75	138,4	0,023	1053,8	1413,52
	Windows/door					
1.	glass	342,3	2600	0,008	840	5980,67
2.	frame	60,41	600	0,020	2520	1826,80
	Partition between floors					
1.	plasterboard	427,6	750	0,013	1060	4249,28
2.	insulation Orsil N	427,6	100	0,037	1150	1831,73
3.	insulation Orsil N	427,6	100	0,037	1150	1831,73
4.	plasterboard	427,6	750	0,013	1060	4249,28
	Ceiling					
1.	final layer - ceramic tiles	1442,85	2000	0,010	840	24239,88
2.	anhydrite	1442,85	2100	0,040	840	101807,50
3.	air gap	1442,85	1,2	0,038	1010	65,58
1.	plasterboard	1442,85	750	0,013	1060	14338,32
	Partitions					
1.	plasterboard	1250,7	750	0,013	1060	12428,83
2.	mineral wool	1250,7	67,2	0,038	950	2994,18
2.	mineral wool	1250,7	67,2	0,038	950	2994,18
1.	plasterboard	1250,7	750	0,013	1060	12428,83
	Internal heat mass capacity			**155,60**		**kJ/(Km^2)**

Timber structure alternative

	Compositons	A [m²]	ρ [kg/m³]	d[m]	c[J/kgK]	C_{int}[kJ/K]
	Ceiling above the garages					
1.	final layer - ceramic tiles	496,5	2000	0,010	840	8341,20
2.	anhydrite	496,5	2100	0,050	840	43791,30
3.	impact sound insulation Ethafoam	496,5	35	0,020	1000	347,55
4.	concrete slab	496,5	2400	0,020	1020	24308,64
	Circumference wall - main wall					
1.	plasterboard	701,42	750	0,013	1060	6970,36
2.	air gap	701,42	1,2	0,050	1010	42,51
2.	OSB board	701,42	650	0,015	1700	11626,04
3.	mineral wool	701,42	138,4	0,023	1053,8	2301,73
	Roof					
1.	plasterboard	430,75	750	0,013	1060	4280,58
2.	air gap	430,75	1,2	0,050	1010	26,10
2.	OSB board	430,75	650	0,015	1700	7139,68
3.	mineral wool	430,75	138,4	0,023	1053,8	1413,52
	Windows/door					
1.	glass	342,3	2600	0,008	840	5980,67
2.	frame	60,41	600	0,020	2520	1826,80
	Partition between flats					
1.	gypsumboard	427,6	750	0,013	1060	4249,28
2.	insulation Orsil N	427,6	100	0,037	1150	1831,73
3.	insulation Orsil N	427,6	100	0,037	1150	1831,73
4.	plasterboard	427,6	750	0,013	1060	4249,28
	Ceiling					
1.	final layer - ceramic tiles	1442,85	2000	0,010	840	24239,88
2.	OSB board	1442,85	650	0,015	1700	23915,24
3.	impact sound insulation - Ethafoam	1442,85	30	0,020	840	727,20
2.	OSB board	1442,85	650	0,005	1700	7971,75
3.	air gap	1442,85	1,2	0,038	1010	65,58
1.	gypsumboard	1442,85	750	0,013	1060	14338,32
	Partitions					
1.	gypsumboard	1250,7	750	0,013	1060	12428,83
2.	mineral wool	1250,7	67,2	0,038	950	2994,18
2.	mineral wool	1250,7	67,2	0,038	950	2994,18
1.	gypsumboard	1250,7	750	0,013	1060	12428,83
	Internal heat mass capacity			**119,93**		**kJ/(Km²)**

F

Amounts of materials

Reinforced concrete variant

Type of structure / Used material	Weight [kg]	Embodied energy [MJ/kg]	Embodied energy total [MJ]	Embodied CO_2 emissions [kg/kg]	Embodied CO_2 emissions total [kg]	Embodied SO_2 emissions [kg/kg]	Embodied SO_2 emissions total [kg]	Renewable materials		Recycled materials		Raw materials		Fully recycleable		Partly recycleable		Waste	
Foundations																			
concrete	524 058,150	0,690	361 600,124	0,103	53 977,989	0,00024	125,774	0	0	0	0	100	524058,15	3,148	16497,35056	96,852	507560,7994	0	0
reinforcing steel	279 502,080	22,700	6 344 697,216	0,935	261 334,445	0,00567	1 584,777	0	0	0	0	100	279502,08	3,148	8798,725478	96,852	270703,3545	0	0
waterproofing	4 913,568	77,000	378 344,736	2,020	9 925,407	0,02100	103,185	0	0	0	0	100	4913,568	0	0	0	0	100	4913,568
Garages																			
concrete	396 369,346	0,690	273 494,849	0,103	40 826,043	0,00024	95,129	0	0	0	0	100	396369,346	3,148	12477,70701	96,852	383891,639	0	0
reinforcing steel	234 733,524	22,700	5 328 451,006	0,935	219 475,845	0,00567	1 330,939	0	0	0	0	100	234733,5245	3,148	7389,411351	96,852	227344,1131	0	0
extruded polystyren	301,080	102,000	30 710,160	3,440	1 035,715	0,02110	6,353	0	0	0	0	100	301,08	0	0	0	0	100	301,08
poriment	9 729,090	3,400	33 078,906	0,300	2 918,727	0,00230	22,377	0	0	0	0	100	9729,09	0	0	100	9729,09	0	0
impact sound insulation	324,303	102,000	33 078,906	3,440	1 115,602	0,02110	6,843	0	0	0	0	100	324,303	0	0	0	0	100	324,303
anhydrite	48 645,450	1,600	77 832,720	0,090	4 378,091	0,00080	38,916	0	0	0	0	100	48645,45	0	0	0	0	100	48645,45
vapour barrier	1 779,034	93,400	166 161,738	2,550	4 536,536	0,02530	45,010	0	0	0	0	100	1779,0336	0	0	0	0	100	1779,0336
ceramic tiles	9 265,800	13,900	128 794,620	0,717	6 643,579	0,00298	27,612	0	0	0	0	100	9265,8	0	0	50	4632,9	50	4632,9
mineral wool	1 260,149	23,300	29 361,467	1,640	2 066,644	0,01050	13,232	0	0	20	252,02976	80	1008,11904	0	0	100	1260,1488	0	0
Load bearing structure																			
concrete	1 368 980,327	0,690	944 596,426	0,103	141 004,974	0,00024	328,555	0	0	0	0	100	1368980,327	3,148	43095,50071	96,852	1325884,827	0	0
reinforcing steel	811 462,749	22,700	18 420 204,395	0,935	758 717,670	0,00567	4 600,994	0	0	0	0	100	811462,7487	3,148	25544,84733	96,852	785917,9014	0	0
Ceilings								0											
poriment	28 717,080	3,400	97 638,072	0,300	8 615,124	0,00230	66,049	0	0	0	0	100	28717,08	0	0	100	28717,08	0	0
impact sound insulation	957,236	102,000	97 638,072	3,440	3 292,892	0,02110	20,198	0	0	0	0	100	957,236	0	0	0	0	100	957,236
anhydrite	143 585,400	1,600	229 736,640	0,090	12 922,686	0,00080	114,868	0	0	0	0	100	143585,4	0	0	0	0	100	143585,4
vapour barrier	5 251,123	93,400	490 454,907	2,550	13 390,364	0,02530	132,853	0	0	0	0	100	5251,1232	0	0	0	0	100	5251,1232
ceramic tiles	27 349,600	13,900	380 159,440	0,717	19 609,663	0,00298	81,502	0	0	0	0	100	27349,6	0	0	0	0	100	27349,6
Facade																			
external plaster	4 628,290	1,400	6 479,606	0,140	647,961	0,00130	6,017	0	0	0	0	100	4628,29	0	0	0	0	100	4628,29
thermal insulation	3 342,578	98,500	329 243,887	3,350	11 197,635	0,02160	72,200	0	0	0	0	100	3342,577536	0	0	0	0	100	3342,577536
internal plaster	3 832,554	1,400	5 365,575	0,140	536,558	0,00130	4,982	0	0	0	0	100	3832,55375	0	0	0	0	100	3832,55375
Roof structure																			
gravel	35 345,700	0,080	2 827,656	0,004	141,383	0,00005	1,767	0	0	0	0	100	35345,7	100	35345,7	0	0	0	0
extruded polystyren	4 259,073	102,000	434 425,446	3,440	14 651,211	0,02110	89,866	0	0	0	0	100	4259,073	0	0	0	0	100	4259,073
waterproofing	3 257,489	77,000	250 826,638	2,020	6 580,127	0,02100	68,407	0	0	0	0	100	3257,4888	0	0	0	0	100	3257,4888
wooden walking coat	7 530,000	2,720	20 481,600	-1,490	-11 219,700	0,00161	12,123	90	6777	0	0	10	753	0	0	100	7530	0	0
Separation walls																			
Liapor blocks	192 050,640	2,480	476 285,587	0,260	49 933,166	0,00144	275,785	0	0	0	0	100	192050,64	0	0	100	192050,64	0	0
internal plaster	30 890,356	1,400	43 246,499	0,140	4 324,650	0,00130	40,157	0	0	0	0	100	30890,35625	0	0	0	0	100	30890,35625
Windows																			
Wooden with double glazing	388,130	626,700	243 241,071	35,9	13 933,867	0,46560	180,713	25,77	100,021101	68,88	267,343944	5,36	20,803768	53,57	207,921241	43,37	168,331981	3,06	11,876778
Total	**4 182 321,769**	**35 658 457,964**		**1 656 514,853**		**9 497,184**		**6 877,021**		**519,374**		**4 175 313,543**		**149 357,164**		**3 745 390,825**		**287 961,910**	
Floor area [m²]	**2 363,770**	**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**	
Total per m²	**1 769,344**	**15 085,418**		**700,794**		**4,018**		**2,909**		**0,220**		**1 766,379**		**63,186**		**1 584,499**		**121,823**	
[%]								**0,164**		**0,012**		**99,832**		**3,571**		**89,553**		**6,885**	

Reinforced concrete variant without basement

Type of structure / Used material	Weight [kg]	Embodied energy [MJ/kg]	Embodied energy total [MJ]	Embodied CO_2 emissions [kg/kg]	Embodied CO_2 emissions total [kg]	Embodied SO_2 emissions [kg/kg]	Embodied SO_2 emissions total [kg]	Renewable materials		Recycled materials		Raw materials		Fully recycleable		Partly recycleable		Waste	
Load bearing structure																			
concrete	1 230 635,309	0,690	849 138,363	0,103	126 755,437	0,00024	295,352	0	0	0	0	100	1230635,309	3,148	38740,39953	96,852	1191894,909	0	0
reinforcing steel	731 348,984	22,700	16 601 621,928	0,935	683 811,300	0,00567	4 146,749	0	0	0	0	100	731348,9836	3,148	23022,866	96,852	708326,1176	0	0
Ceilings								0											
poriment	27 845,160	3,400	94 673,544	0,300	8 353,548	0,00230	64,044	0	0	0	0	100	27845,16	0	0	100	27845,16	0	0
impact sound insulation	928,172	102,000	94 673,544	3,440	3 192,912	0,02110	19,584	0	0	0	0	100	928,172	0	0	0	0	100	928,172
anhydrite	139 225,800	1,600	222 761,280	0,090	12 530,322	0,00080	111,381	0	0	0	0	100	139225,8	0	0	0	0	100	139225,8
vapour barrier	5 091,686	93,400	475 563,510	2,550	12 983,800	0,02530	128,820	0	0	0	0	100	5091,6864	0	0	0	0	100	5091,6864
ceramic tiles	26 519,200	13,900	368 616,880	0,717	19 014,266	0,00298	79,027	0	0	0	0	100	26519,2	0	0	0	0	100	26519,2
Facade																			
external plaster	4 628,290	1,400	6 479,606	0,140	647,961	0,00130	6,017	0	0	0	0	100	4628,29	0	0	0	0	100	4628,29
thermal insulation	3 342,578	98,500	329 243,887	3,350	11 197,635	0,02160	72,200	0	0	0	0	100	3342,577536	0	0	0	0	100	3342,577536
internal plaster	3 832,554	1,400	5 365,575	0,140	536,558	0,00130	4,982	0	0	0	0	100	3832,55375	0	0	0	0	100	3832,55375
Roof structure																			
gravel	35 345,700	0,080	2 827,656	0,004	141,383	0,00005	1,767	0	0	0	0	100	35345,7	100	35345,7	0	0	0	0
extruded polystyren	4 259,073	102,000	434 425,446	3,440	14 651,211	0,02110	89,866	0	0	0	0	100	4259,073	0	0	0	0	100	4259,073
waterproofing	3 257,489	77,000	250 826,638	2,020	6 580,127	0,02100	68,407	0	0	0	0	100	3257,4888	0	0	0	0	100	3257,4888
wooden walking coat	7 530,000	2,720	20 481,600	-1,490	-11 219,700	0,00161	12,123	90	6777	0	0	10	753	0	0	100	7530	0	0
Separation walls																			
Liapor blocks	192 050,640	2,480	476 285,587	0,260	49 933,166	0,00144	275,785	0	0	0	0	100	192050,64	0	0	100	192050,64	0	0
internal plaster	30 890,356	1,400	43 246,499	0,140	4 324,650	0,00130	40,157	0	0	0	0	100	30890,35625	0	0	0	0	100	30890,35625
Windows																			
Wooden with double glazing	388,130	626,700	243 241,071	35,9	13 933,867	0,46560	180,713	25,77	100,021101	68,88	267,343944	5,36	20,803768	53,57	207,921241	43,37	168,331981	3,06	11,876778
Total	**2 446 730,990**	**20 519 472,614**		**957 368,442**		**5 596,976**		**6 877,021**		**267,344**		**2 439 974,794**		**97 316,887**		**2 127 815,159**		**221 987,075**	
Total floor area	**2 363,770**	**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**	
Total per m2	**1 035,097**	**8 680,825**		**405,018**		**2,368**		**2,909**		**0,113**		**1 032,239**		**41,170**		**900,179**		**93,912**	
								0,281		**0,011**		**99,724**		**3,977**		**86,966**		**9,073**	

Light-weight concrete variant

Type of structure / Used material	Weight [kg]	Embodied energy [MJ/kg]	Embodied energy total [MJ]	Embodied CO_2 emissions [kg/kg]	Embodied CO_2 emissions total [kg]	Embodied SO_2 emissions [kg/kg]	Embodied SO_2 emissions total [kg]	Renewable materials		Recycled materials		Raw materials		Fully recyclable		Partly recyclable		Waste	
Foundations																			
concrete	524 058,150	0,690	361 600,124	0,103	53 977,989	0,00024	125,774	0	0	0	0	100	524058,15	3,148	16497,35056	96,852	507560,7994	0	0
reinforcing steel	279 502,080	22,700	6 344 697,216	0,935	261 334,445	0,00567	1 584,777	0	0	0	0	100	279502,08	3,148	8798,725478	96,852	270703,3545	0	0
waterproofing	4 913,568	77,000	378 344,736	2,020	9 925,407	0,02100	103,185	0	0	0	0	100	4913,568	0	0	0	0	100	4913,568
Garages																			
concrete	396 369,346	0,690	273 494,849	0,103	40 826,043	0,00024	95,129	0	0	0	0	100	396369,346	3,148	12477,70701	96,852	383891,639	0	0
reinforcing steel	234 733,524	22,700	5 328 451,006	0,935	219 475,845	0,00567	1 330,939	0	0	0	0	100	234733,5245	3,148	7389,411351	96,852	227344,1131	0	0
extruded polystyren	301,080	102,000	30 710,160	3,440	1 035,715	0,02110	6,353	0	0	0	0	100	301,08	0	0	0	0	100	301,08
poriment	9 729,090	3,400	33 078,906	0,300	2 918,727	0,00230	22,377	0	0	0	0	100	9729,09	0	0	100	9729,09	0	0
impact sound insulation	324,303	102,000	33 078,906	3,440	1 115,602	0,02110	6,843	0	0	0	0	100	324,303	0	0	0	0	100	324,303
anhydrite	48 645,450	1,600	77 832,720	0,090	4 378,091	0,00080	38,916	0	0	0	0	100	48645,45	0	0	0	0	100	48645,45
vapour barrier	1 779,034	93,400	166 161,738	2,550	4 536,536	0,02530	45,010	0	0	0	0	100	1779,0336	0	0	0	0	100	1779,0336
ceramic tiles	9 265,800	13,900	128 794,620	0,717	6 643,579	0,00298	27,612	0	0	0	0	100	9265,8	0	0	50	4632,9	50	4632,9
mineral wool	3 706,320	23,300	86 357,256	1,640	6 078,365	0,01050	38,916	0	0	20	741,264	80	2965,056	0	0	100	3706,32	0	0
Load bearing structure																			
concrete	923 581,003	0,690	637 270,892	0,103	95 128,843	0,00024	221,659	0	0	0	0	100	923581,0034	3,148	29074,32999	96,852	894506,6734	0	0
reinforcing steel	543 538,722	22,700	12 338 328,986	0,935	508 208,705	0,00567	3 081,865	0	0	0	0	100	543538,7219	3,148	17110,59896	96,852	526428,1229	0	0
Ytong blocks	143 629,301	4,200	603 243,065	0,500	71 814,651	0,00140	201,081	0	0	0	0	100	143629,3013	0	0	100	143629,3013	0	0
Ceilings								0											
poriment	28 717,080	3,400	97 638,072	0,300	8 615,124	0,00230	66,049	0	0	0	0	100	28717,08	0	0	100	28717,08	0	0
impact sound insulation - Ethafoam	957,236	102,000	97 638,072	3,440	3 292,892	0,02110	20,198	0	0	0	0	100	957,236	0	0	0	0	100	957,236
anhydrite	143 585,400	1,600	229 736,640	0,090	12 922,686	0,00080	114,868	0	0	0	0	100	143585,4	0	0	0	0	100	143585,4
vapour barrier	668,605	93,400	62 447,748	2,550	1 704,944	0,02530	16,916	0	0	0	0	100	668,60544	0	0	0	0	100	668,60544
ceramic tiles	27 349,600	13,900	380 159,440	0,717	19 609,663	0,00298	81,502	0	0	0	0	100	27349,6	0	0	50	13674,8	50	13674,8
Facade																			
external plaster	4 628,290	1,400	6 479,606	0,140	647,961	0,00130	6,017	0	0	0	0	100	4628,29	0	0	0	0	100	4628,29
thermal insulation - mineral wool	18 805,163	23,300	438 160,293	1,640	30 840,467	0,01050	197,454	0	0	20	3761,03256	80	15044,13024	0	0	100	18805,1628	0	0
internal plaster	3 832,554	1,400	5 365,575	0,140	536,558	0,00130	4,982	0	0	0	0	100	3832,55375	0	0	0	0	100	3832,55375
Roof structure																			
gravel	35 345,700	0,080	2 827,656	0,004	141,383	0,00005	1,767	0	0	0	0	100	35345,7	100	35345,7	0	0	0	0
extruded polystyren	4 259,073	102,000	434 425,446	3,440	14 651,211	0,02110	89,866	0	0	0	0	100	4259,073	0	0	0	0	100	4259,073
waterproofing	3 257,489	77,000	250 826,638	2,020	6 580,127	0,02100	68,407	0	0	0	0	100	3257,4888	0	0	0	0	100	3257,4888
wooden walking coat	7 530,000	2,720	20 481,600	-1,490	-11 219,700	0,00161	12,123	90	6777	0	0	10	753	0	0	100	7530	0	0
Separation walls																			
Ytong blocks	74 872,625	4,200	314 465,025	0,500	37 436,313	0,00140	104,822	0	0	0	0	100	74872,625	0	0	100	74872,625	0	0
sound insulation - mineral wool	7 618,374	23,300	177 508,124	1,640	12 494,134	0,01050	79,993	0	0	20	1523,67488	80	6094,69952	0	0	100	7618,3744	0	0
gypsumboard	10 253,177	4,440	45 524,104	0,209	2 142,914	0,00070	7,177	0	0	0	0	100	10253,17656	0	0	100	10253,17656	0	0
internal plaster	23 819,200	1,400	33 346,880	0,140	3 334,688	0,00130	30,965	0	0	0	0	100	23819,2	0	0	0	0	100	23819,2
Windows																			
Wooden with double glazing	388,130	626,700	243 241,071	35,9	13 933,867	0,46560	180,713	25,77	100,021101	68,88	267,343944	5,36	20,803768	53,57	207,921241	43,37	168,331981	3,06	11,876778
Total	**3 519 576,337**	**29 661 717,170**		**1 445 063,773**		**8 014,256**		**6 877,021**		**6 293,315**		**3 506 794,170**		**126 901,745**		**3 133 771,864**		**259 290,858**	
Total floor area [m^2]	**2 363,770**	**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**	
Total per m^2	**1 488,967**	**12 548,479**		**611,339**		**3,390**		**2,909**		**2,662**		**1 483,560**		**53,686**		**1 325,752**		**109,694**	
[%]								**0,195**		**0,179**		**99,637**		**3,606**		**89,038**		**7,367**	

Light-weight concrete without basement

Type of structure / Used material	Weight [kg]	Embodied energy [MJ/kg]	Embodied energy total [MJ]	Embodied CO_2 emissions [kg/kg]	Embodied CO_2 emissions total [kg]	Embodied SO_2 emissions [kg/kg]	Embodied SO_2 emissions total [kg]	Renewable materials		Recycled materials		Raw materials		Fully recycleable		Partly recycleable		Waste	
Load bearing structure																			
concrete	785 765,298	0,690	542 178,055	0,103	80 933,826	0,00024	188,584	0	0	0	0	100	785765,2975	3,148	24735,89157	96,852	761029,406	0	0
reinforcing steel	463 424,957	22,700	10 519 746,519	0,935	433 302,335	0,00567	2 627,620	0	0	0	0	100	463424,9568	3,148	14588,61764	96,852	448836,3392	0	0
Ytong blocks	143 629,301	4,200	603 243,065	0,500	71 814,651	0,00140	201,081	0	0	0	0	100	143629,3013	0	0	100	143629,3013	0	0
Ceilings								0											
poriment	27 845,160	3,400	94 673,544	0,300	8 353,548	0,00230	64,044	0	0	0	0	100	27845,16	0	0	100	27845,16	0	0
impact sound insulation - Ethafoam	928,172	102,000	94 673,544	3,440	3 192,912	0,02110	19,584	0	0	0	0	100	928,172	0	0	0	0	100	928,172
anhydrite	139 225,800	1,600	222 761,280	0,090	12 530,322	0,00080	111,381	0	0	0	0	100	139225,8	0	0	0	0	100	139225,8
vapour barrier	5 091,686	93,400	475 563,510	2,550	12 983,800	0,02530	128,820	0	0	0	0	100	5091,6864	0	0	0	0	100	5091,6864
ceramic tiles	26 519,200	13,900	368 616,880	0,717	19 014,266	0,00298	79,027	0	0	0	0	100	26519,2	0	0	50	13259,6	50	13259,6
Facade																			
external plaster	4 628,290	1,400	6 479,606	0,140	647,961	0,00130	6,017	0	0	0	0	100	4628,29	0	0	0	0	100	4628,29
thermal insulation - mineral wool	18 805,163	23,300	438 160,293	1,640	30 840,467	0,01050	197,454	0	0	20	3761,03256	80	15044,13024	0	0	100	18805,1628	0	0
internal plaster	3 832,554	1,400	5 365,575	0,140	536,558	0,00130	4,982	0	0	0	0	100	3832,55375	0	0	0	0	100	3832,55375
Roof structure																			
gravel	35 345,700	0,080	2 827,656	0,004	141,383	0,00005	1,767	0	0	0	0	100	35345,7	100	35345,7	0	0	0	0
extruded polystyren	4 259,073	102,000	434 425,446	3,440	14 651,211	0,02110	89,866	0	0	0	0	100	4259,073	0	0	0	0	100	4259,073
waterproofing	3 257,489	77,000	250 826,638	2,020	6 580,127	0,02100	68,407	0	0	0	0	100	3257,4888	0	0	0	0	100	3257,4888
wooden walking coat	7 530,000	2,720	20 481,600	-1,490	-11 219,700	0,00161	12,123	90	6777	0	0	10	753	0	0	100	7530	0	0
Separation walls																			
Ytong blocks	74 872,625	4,200	314 465,025	0,500	37 436,313	0,00140	104,822	0	0	0	0	100	74872,625	0	0	100	74872,625	0	0
sound insulation - mineral wool	7 618,374	23,300	177 508,124	1,640	12 494,134	0,01050	79,993	0	0	20	1523,67488	80	6094,69952	0	0	100	7618,3744	0	0
gypsumboard	10 253,177	4,440	45 524,104	0,209	2 142,914	0,00070	7,177	0	0	0	0	100	10253,17656	0	0	100	10253,17656	0	0
internal plaster	23 819,200	1,400	33 346,880	0,140	3 334,688	0,00130	30,965	0	0	0	0	100	23819,2	0	0	0	0	100	23819,2
Windows																			
Wooden with double glazing	388,130	626,700	243 241,071	35,9	13 933,867	0,46560	180,713	25,77	100,021101	68,88	267,343944	5,36	20,803768	53,57	207,921241	43,37	168,331981	3,06	11,876778
Total	1 786 651,218	14 894 108,415		753 645,581		4 204,428		6 877,021		5 552,051		1 774 610,315		74 878,130		1 513 847,477		198 313,741	
Total floor area [m²]	2 363,770	2 363,770		2 363,770		2 363,770		2 363,770		2 363,770		2 363,770		2 363,770		2 363,770		2 363,770	
Total per m²	755,848	6 300,997		318,832		1,779		2,909		2,349		750,754		31,677		640,438		83,897	
[%]								0,385		0,311		99,326		4,191		84,731		11,100	

Steel structure variant

Type of structure / Used material	Weight [kg]	Embodied energy [MJ/kg]	Embodied energy total [MJ]	Embodied CO_2 emissions [kg/kg]	Embodied CO_2 emissions total [kg]	Embodied SO_2 emissions [kg/kg]	Embodied SO_2 emissions total [kg]	Renewable materials		Recycled materials		Raw materials		Fully recycleable		Partly recycleable		Waste	
Foundations																			
concrete	524 058,150	0,690	361 600,124	0,103	53 977,989	0,00024	125,774	0	0	0	0	100	524058,15	3,148	16497,35056	96,852	507560,7994	0	0
reinforcing steel	279 502,080	22,700	6 344 697,216	0,935	261 334,445	0,00567	1 584,777	0	0	0	0	100	279502,08	3,148	8798,725478	96,852	270703,3545	0	0
waterproofing	4 913,568	77,000	378 344,736	2,020	9 925,407	0,02100	103,185	0	0	0	0	100	4913,568	0	0	0	0	100	4913,568
Garages																			
concrete	396 369,346	0,690	273 494,849	0,103	40 826,043	0,00024	95,129	0	0	0	0	100	396369,346	3,148	12477,70701	96,852	383891,639	0	0
reinforcing steel	234 733,524	22,700	5 328 451,006	0,935	219 475,845	0,00567	1 330,939	0	0	0	0	100	234733,5245	3,148	7389,411351	96,852	227344,1131	0	0
extruded polystyren	301,080	102,000	30 710,160	3,440	1 035,715	0,02110	6,353	0	0	0	0	100	301,08	0	0	0	0	100	301,08
poriment	9 729,090	3,400	33 078,906	0,300	2 918,727	0,00230	22,377	0	0	0	0	100	9729,09	0	0	100	9729,09	0	0
impact sound insulation	324,303	102,000	33 078,906	3,440	1 115,602	0,02110	6,843	0	0	0	0	100	324,303	0	0	0	0	100	324,303
anhydrite	48 645,450	1,600	77 832,720	0,090	4 378,091	0,00080	38,916	0	0	0	0	100	48645,45	0	0	0	0	100	48645,45
vapour barrier	177,903	93,400	16 616,174	2,550	453,654	0,02530	4,501	0	0	0	0	100	177,90336	0	0	0	0	100	177,90336
ceramic tiles	9 265,800	13,900	128 794,620	0,717	6 643,579	0,00298	27,612	0	0	0	0	100	9265,8	0	0	50	4632,9	50	4632,9
mineral wool	3 706,320	23,300	86 357,256	1,640	6 078,365	0,01050	38,916	0	0	20	741,264	80	2965,056	0	0	100	3706,32	0	0
Load bearing structure																			
concrete	315 643,492	0,690	217 794,009	0,103	32 511,280	0,00024	75,754	0	0	0	0	100	315643,492	3,148	9936,457129	96,852	305707,0349	0	0
reinforcing steel	80 113,765	22,700	1 818 582,467	0,935	74 906,370	0,00567	454,245	0	0	0	0	100	80113,76506	3,148	2521,981324	96,852	77591,78373	0	0
Steel profiles	75 121,940	125,000	9 390 242,500	8,910	669 336,485	0,04280	3 215,219	0	0	80	60097,552	20	15024,388	100	75121,94	0	0	0	0
Ceilings																			
ceramic tiles	27 349,600	13,900	380 159,440	0,717	19 609,663	0,00298	81,502	0	0	0	0	100	27349,6	0	0	50	13674,8	50	13674,8
poriment	871,920	3,400	2 964,528	0,300	261,576	0,00230	2,005	0	0	0	0	100	871,92	0	0	100	871,92	0	0
waterproofing	509,169	93,400	47 556,351	2,550	1 298,380	0,02530	12,882	0	0	0	0	100	509,16864	0	0	0	0	100	509,16864
anhydrite	143 585,400	1,600	229 736,640	0,090	12 922,686	0,00080	114,868	0	0	0	0	100	143585,4	0	0	0	0	100	143585,4
Ethafoam	957,236	102,000	97 638,072	3,440	3 292,892	0,02110	20,198	0	0	0	0	100	957,236	0	0	0	0	100	957,236
trapezoidal sheets	9 281,720	125,000	1 160 215,000	8,910	82 700,125	0,04280	397,258	0	0	80	7425,376	20	1856,344	0	0	100	9281,72	0	0
OSB boards	12 602,909	9,320	117 459,110	-1,168	-14 720,197	0,00603	75,996	80	10082,327	0	0	20	2520,58175	0	0	100	12602,90875	0	0
thin walled CW 50 profiles	5 240,194	125,000	655 024,240	8,910	46 690,128	0,04280	224,280	0	0	80	4192,155136	20	1048,038784	0	0	100	5240,19392	0	0
gypsumboard	12 016,513	4,440	53 353,316	0,209	2 511,451	0,00070	8,412	0	0	100	12016,5125	0	0	0	0	100	12016,5125	0	0
Facade																			
external plaster	4 914,589	1,400	6 880,425	0,140	688,043	0,00130	6,389	0	0	0	0	100	4914,589375	0	0	0	0	100	4914,589375
thermal insulation - mineral wool	21 992,008	23,300	512 413,777	1,640	36 066,892	0,01050	230,916	0	0	20	4398,40152	80	17593,60608	0	0	100	21992,0076	0	0
OSB boards	15 537,097	9,320	144 805,743	-1,168	-18 147,329	0,00603	93,689	80	12429,67752	0	0	20	3107,41938	0	0	100	15537,0969	0	0
vapour barrier	1 010,217	93,400	94 354,223	2,550	2 576,052	0,02530	25,558	0	0	0	0	100	1010,216525	0	0	0	0	100	1010,216525
thin walled CW 80 profiles	10 879,482	125,000	1 359 935,200	8,910	96 936,181	0,04280	465,642	0	0	80	8703,58528	20	2175,89632	0	0	100	10879,4816	0	0
gypsumboard	5 842,577	4,440	25 941,040	0,209	1 221,098	0,00070	4,090	0	0	100	5842,576531	0	0	0	0	100	5842,576531	0	0
Roof structure																			
greening	39 273,000	0,020	785,460	0,001	39,273	0,00001	0,393	50	19636,5	50	19636,5	0	0	0	0	100	39273	0	0
extruded polystyren	3 831,836	102,000	390 847,272	3,440	13 181,516	0,02110	80,852	0	0	0	0	100	3831,836	0	0	0	0	100	3831,836
waterproofing	3 257,489	77,000	250 826,638	2,020	6 580,127	0,02100	68,407	0	0	0	0	100	3257,4888	0	0	0	0	100	3257,4888
wooden walking coat	7 530,000	2,720	20 481,600	-1,490	-11 219,700	0,00161	12,123	90	6777	0	0	10	753	0	0	100	7530	0	0
trapezoidal sheets	3 276,210	125,000	409 526,250	8,910	29 191,031	0,04280	140,222	0	0	80	2620,968	20	655,242	0	0	100	3276,21	0	0
OSB boards	4 563,293	9,320	42 529,886	-1,168	-5 329,926	0,00603	27,517	80	3650,634	0	0	20	912,6585	0	0	100	4563,2925	0	0
thin walled CW 50 profiles	1 849,655	125,000	231 206,820	8,910	16 480,422	0,04280	79,165	0	0	80	1479,723648	20	369,930912	0	0	100	1849,65456	0	0
gypsumboard	4 241,522	4,440	18 832,357	0,209	886,478	0,00070	2,969	0	0	100	4241,521875	0	0	0	0	100	4241,521875	0	0
Separation walls																			
thin walled CW profiles	15 677,854	125,000	1 959 731,800	8,910	139 689,683	0,04280	671,012	0	0	80	12542,28352	20	3135,57088	0	0	100	15677,8544	0	0
sound insulation - mineral wool	23 614,520	23,300	550 218,309	1,640	38 727,812	0,01050	247,952	0	0	20	4722,90394	80	18891,61576	0	0	100	23614,5197	0	0
OSB boards	10 981,269	9,320	102 345,427	-1,168	-12 826,122	0,00603	66,217	80	8785,0152	0	0	20	2196,2538	0	0	100	10981,269	0	0
gypsumboard	26 118,591	4,440	115 966,543	0,209	5 458,785	0,00070	18,283	0	0	100	26118,59088	0	0	0	0	100	26118,59088	0	0
Windows																			
Wooden with double glazing	388,130	626,700	243 241,071	35,9	13 933,867	0,46560	180,713	25,77	100,021101	68,88	267,343944	5,36	20,803768	53,57	207,921241	43,37	168,331981	3,06	11,876778
Total	**2 399 799,808**	**33 744 652,186**		**1 893 618,486**		**10 490,050**		**61 461,175**		**175 047,259**		**2 163 291,413**		**132 951,494**		**2 036 100,497**		**230 747,816**	
Total floor area [m^2]	**2 363,770**	**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**	
Total per m^2	**1 015,243**	**14 275,776**		**801,101**		**4,438**		**26,001**		**74,054**		**915,187**		**56,246**		**861,378**		**97,619**	
[%]								**2,561**		**7,294**		**90,145**		**5,540**		**84,845**		**9,615**	

Steel structure variant without basement

Type of structure / Used material	Weight [kg]	Embodied energy [MJ/kg]	Embodied energy total [MJ]	Embodied CO_2 emissions [kg/kg]	Embodied CO_2 emissions total [kg]	Embodied SO_2 emissions [kg/kg]	Embodied SO_2 emissions total [kg]	Renewable materials		Recycled materials		Raw materials		Fully recycleable		Partly recycleable		Waste	
Load bearing structure																			
concrete	177 298,474	0,690	122 335,947	0,103	18 261,743	0,00024	42,552	0	0	0	0	100	177298,4736	3,148	5581,355949	96,852	171717,1177	0	0
reinforcing steel	28 367,756	22,700	643 948,056	0,935	26 523,852	0,00567	160,845	0	0	0	0	100	28367,75578	3,148	893,0169518	96,852	27474,73882	0	0
Steel profiles	75 121,940	125,000	9 390 242,500	8,910	669 336,485	0,04280	3 215,219	0	0	80	60097,552	20	15024,388	100	75121,94	0	0	0	0
Ceilings																			
ceramic tiles	26 519,200	13,900	368 616,880	0,717	19 014,266	0,00298	79,027	0	0	0	0	100	26519,2	0	0	50	13259,6	50	13259,6
		3,400	0,000	0,300	0,000	0,00230	0,000	0	0	0	0	100	0	0	0	100	0	0	0
waterproofing	5 091,686	93,400	475 563,510	2,550	12 983,800	0,02530	128,820	0	0	0	0	100	5091,6864	0	0	0	0	100	5091,6864
anhydrite	139 225,800	1,600	222 761,280	0,090	12 530,322	0,00080	111,381	0	0	0	0	100	139225,8	0	0	0	0	100	139225,8
Ethafoam	928,172	102,000	94 673,544	3,440	3 192,912	0,02110	19,584	0	0	0	0	100	928,172	0	0	0	0	100	928,172
trapezoidal sheets	9 281,720	125,000	1 160 215,000	8,910	82 700,125	0,04280	397,258	0	0	80	7425,376	20	1856,344	0	0	100	9281,72	0	0
OSB boards	12 602,909	9,320	117 459,110	-1,168	-14 720,197	0,00603	75,996	80	10082,327	0	0	20	2520,58175	0	0	100	12602,90875	0	0
thin walled CW 50 profiles	5 240,194	125,000	655 024,240	8,910	46 690,128	0,04280	224,280	0	0	80	4192,155136	20	1048,038784	0	0	100	5240,19392	0	0
gypsumboard	12 016,513	4,440	53 353,316	0,209	2 511,451	0,00070	8,412	0	0	100	12016,5125	0	0	0	0	100	12016,5125	0	0
Facade																			
external plaster	4 914,589	1,400	6 880,425	0,140	688,043	0,00130	6,389	0	0	0	0	100	4914,589375	0	0	0	0	100	4914,589375
thermal insulation - mineral wool	21 992,008	23,300	512 413,777	1,640	36 066,892	0,01050	230,916	0	0	20	4398,40152	80	17593,60608	0	0	100	21992,0076	0	0
OSB boards	15 537,097	9,320	144 805,743	-1,168	-18 147,329	0,00603	93,689	80	12429,67752	0	0	20	3107,41938	0	0	100	15537,0969	0	0
vapour barrier	1 010,217	93,400	94 354,223	2,550	2 576,052	0,02530	25,558	0	0	0	0	100	1010,216525	0	0	0	0	100	1010,216525
thin walled CW 80 profiles	10 879,482	125,000	1 359 935,200	8,910	96 936,181	0,04280	465,642	0	0	80	8703,58528	20	2175,89632	0	0	100	10879,4816	0	0
gypsumboard	5 842,577	4,440	25 941,040	0,209	1 221,098	0,00070	4,090	0	0	100	5842,576531	0	0	0	0	100	5842,576531	0	0
Roof structure																			
greening	39 273,000	0,020	785,460	0,001	39,273	0,00001	0,393	50	19636,5	50	19636,5	0	0	0	0	100	39273	0	0
extruded polystyren	3 831,836	102,000	390 847,272	3,440	13 181,516	0,02110	80,852	0	0	0	0	100	3831,836	0	0	0	0	100	3831,836
waterproofing	3 257,489	77,000	250 826,638	2,020	6 580,127	0,02100	68,407	0	0	0	0	100	3257,4888	0	0	0	0	100	3257,4888
wooden walking coat	7 530,000	2,720	20 481,600	-1,490	-11 219,700	0,00161	12,123	90	6777	0	0	10	753	0	0	100	7530	0	0
trapezoidal sheets	3 276,210	125,000	409 526,250	8,910	29 191,031	0,04280	140,222	0	0	80	2620,968	20	655,242	0	0	100	3276,21	0	0
OSB boards	4 563,293	9,320	42 529,886	-1,168	-5 329,926	0,00603	27,517	80	3650,634	0	0	20	912,6585	0	0	100	4563,2925	0	0
thin walled CW 50 profiles	1 849,655	125,000	231 206,820	8,910	16 480,422	0,04280	79,165	0	0	80	1479,723648	20	369,930912	0	0	100	1849,65456	0	0
gypsumboard	4 241,522	4,440	18 832,357	0,209	886,478	0,00070	2,969	0	0	100	4241,521875	0	0	0	0	100	4241,521875	0	0
Separation walls																			
thin walled CW profiles	15 677,854	125,000	1 959 731,800	8,910	139 689,683	0,04280	671,012	0	0	80	12542,28352	20	3135,57088	0	0	100	15677,8544	0	0
sound insulation - mineral wool	23 614,520	23,300	550 218,309	1,640	38 727,812	0,01050	247,952	0	0	20	4722,90394	80	18891,61576	0	0	100	23614,5197	0	0
OSB boards	10 981,269	9,320	102 345,427	-1,168	-12 826,122	0,00603	66,217	80	8785,0152	0	0	20	2196,2538	0	0	100	10981,269	0	0
gypsumboard	26 118,591	4,440	115 966,543	0,209	5 458,785	0,00070	18,283	0	0	100	26118,59088	0	0	0	0	100	26118,59088	0	0
Windows																			
Wooden with double glazing	388,130	626,700	243 241,071	35,9	13 933,867	0,46560	180,713	25,77	100,021101	68,88	267,343944	5,36	20,803768	53,57	207,921241	43,37	168,331981	3,06	11,876778
Total	**696 473,699**		**19 785 063,224**		**1 233 159,072**		**6 885,482**		**61 461,175**		**174 305,995**		**460 706,568**		**81 804,234**		**443 138,199**		**171 531,266**
Total floor area [m²]	**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**
Total per m²	**294,645**		**8 370,130**		**521,692**		**2,913**		**26,001**		**73,741**		**194,903**		**34,608**		**187,471**		**72,567**
[%]									**8,825**		**25,027**		**66,148**		**11,745**		**63,626**		**24,629**

Timber Structure variant

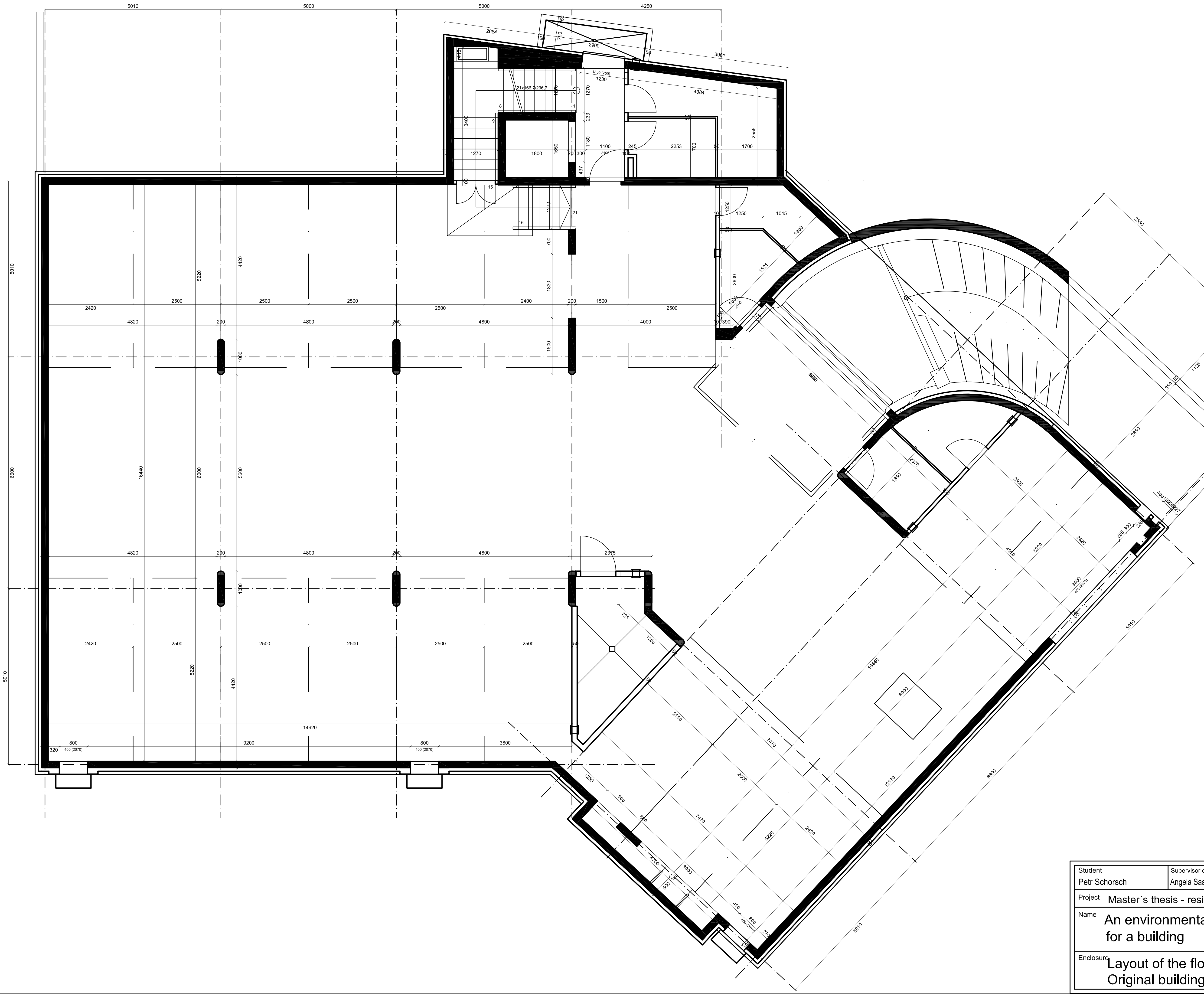
Type of structure / Used material	Weight [kg]	Embodied energy [MJ/kg]	Embodied energy total [MJ]	Embodied CO_2 emissions [kg/kg]	Embodied CO_2 emissions total [kg]	Embodied SO_2 emissions [kg/kg]	Embodied SO_2 emissions total [kg]	Renewable materials		Recycled materials		Raw materials		Fully recycleable		Partly recycleable		Waste	
Foundations																			
concrete	524 058,150	0,690	361 600,124	0,103	53 977,989	0,00024	125,774	0	0	0	0	100	524058,15	3,148	16497,35056	96,852	507560,7994	0	0
reinforcing steel	218 361,000	22,700	4 956 794,700	0,935	204 167,535	0,00567	1 238,107	0	0	0	0	100	218361	3,148	6874,00428	96,852	211486,9957	0	0
waterproofing	4 913,568	77,000	378 344,736	2,020	9 925,407	0,02100	103,185	0	0	0	0	100	4913,568	0	0	0	0	100	4913,568
Garages																			
concrete	396 369,346	0,690	273 494,849	0,103	40 826,043	0,00024	95,129	0	0	0	0	100	396369,346	3,148	12477,70701	96,852	383891,639	0	0
reinforcing steel	183 385,566	22,700	4 162 852,348	0,935	171 465,504	0,00567	1 039,796	0	0	0	0	100	183385,566	3,148	5772,977618	96,852	177612,5884	0	0
extruded polystyren	301,080	102,000	30 710,160	3,440	1 035,715	0,02110	6,353	0	0	0	0	100	301,08	0	0	0	0	100	301,08
poriment	9 729,090	3,400	33 078,906	0,300	2 918,727	0,00230	22,377	0	0	0	0	100	9729,09	0	0	100	9729,09	0	0
impact sound insulation	324,303	102,000	33 078,906	3,440	1 115,602	0,02110	6,843	0	0	0	0	100	324,303	0	0	0	0	100	324,303
anhydrite	48 645,450	1,600	77 832,720	0,090	4 378,091	0,00080	38,916	0	0	0	0	100	48645,45	0	0	0	0	100	48645,45
vapour barrier	0,000	93,400	0,000	2,550	0,000	0,02530	0,000	0	0	0	0	100	0	0	0	0	0	100	0
ceramic tiles	9 265,800	13,900	128 794,620	0,717	6 643,579	0,00298	27,612	0	0	0	0	100	9265,8	0	0	50	4632,9	50	4632,9
mineral wool	3 706,320	23,300	86 357,256	1,640	6 078,365	0,01050	38,916	0	0	20	741,264	80	2965,056	0	0	100	3706,32	0	0
Load bearing structure																			
concrete	138 345,018	0,690	95 458,063	0,103	14 249,537	0,00024	33,203	0	0	0	0	100	138345,0184	3,148	4355,10118	96,852	133989,9172	0	0
reinforcing steel	62 588,879	22,700	1 420 767,552	0,935	58 520,602	0,00567	354,879	0	0	0	0	100	62588,87895	3,148	1970,297909	96,852	60618,58104	0	0
Timber profiles	22 330,612	2,720	60 739,266	-1,490	-33 272,612	0,00161	35,952	100	22330,6124	0	0	0	0	0	0	100	22330,6124	0	0
Glue-laminated timber profiles	51 693,510	8,040	415 615,824	-1,259	-65 082,130	0,00341	176,275	90	46524,15936	0	0	10	5169,35104	0	0	100	51693,5104	0	0
Ceilings																			
ceramic tiles	27 349,600	13,900	380 159,440	0,717	19 609,663	0,00298	81,502	0	0	0	0	100	27349,6	0	0	50	13674,8	50	13674,8
poriment	871,920	3,400	2 964,528	0,300	261,576	0,00230	2,005	0	0	0	0	100	871,92	0	0	100	871,92	0	0
waterproofing	509,169	93,400	47 556,351	2,550	1 298,380	0,02530	12,882	0	0	0	0	100	509,16864	0	0	0	0	100	509,16864
anhydrite	4 359,600	1,600	6 975,360	0,090	392,364	0,00080	3,488	0	0	0	0	100	4359,6	0	0	0	0	100	4359,6
Ethafoam	957,236	102,000	97 638,072	3,440	3 292,892	0,02110	20,198	0	0	0	0	100	957,236	0	0	0	0	100	957,236
OSB boards	51 712,440	9,320	481 959,941	-1,168	-60 400,130	0,00603	311,826	80	41369,952	0	0	20	10342,488	0	0	100	51712,44	0	0
timber joists 60 x 40	2 394,606	2,720	6 513,329	-1,490	-3 567,963	0,00161	3,855	100	2394,606272	0	0	0	0	0	0	100	2394,606272	0	0
gypsumboard	12 016,513	4,440	53 353,316	0,209	2 511,451	0,00070	8,412	0	0	100	12016,5125	0	0	0	0	100	12016,5125	0	0
Facade																			
external plaster	4 914,589	1,400	6 880,425	0,140	688,043	0,00130	6,389	0	0	0	0	100	4914,589375	0	0	0	0	100	4914,589375
thermal insulation - mineral wool	17 654,277	23,300	411 344,665	1,640	28 953,015	0,01050	185,370	0	0	20	3530,855496	80	14123,42198	0	0	100	17654,27748	0	0
OSB boards	9 512,872	9,320	88 659,969	-1,168	-11 111,035	0,00603	57,363	80	7610,29776	0	0	20	1902,57444	0	0	100	9512,8722	0	0
woodenfibre boards	9 288,660	13,700	127 254,642	-0,183	-1 699,825	0,00688	63,906	60	5573,196	40	3715,464	0	0	100	9288,66	0	0	0	0
vapour barrier	975,299	93,400	91 092,964	2,550	2 487,013	0,02530	24,675	0	0	0	0	100	975,2994048	0	0	0	0	100	975,2994048
timber profiles 100 x 60 + joists	10 101,702	2,720	27 476,631	-1,490	-15 051,537	0,00161	16,264	100	10101,70248	0	0	0	0	0	0	100	10101,70248	0	0
gypsumboard	5 842,577	4,440	25 941,040	0,209	1 221,098	0,00070	4,090	0	0	100	5842,576531	0	0	0	0	100	5842,576531	0	0
Roof structure																			
gravel	35 345,700	0,080	2 827,656	0,004	141,383	0,00005	1,767	50	17672,85	50	17672,85	0	0	0	0	100	35345,7	0	0
extruded polystyren	2 796,263	102,000	285 218,826	3,440	9 619,145	0,02110	59,001	0	0	0	0	100	2796,263	0	0	0	0	100	2796,263
waterproofing	3 257,489	77,000	250 826,638	2,020	6 580,127	0,02100	68,407	0	0	0	0	100	3257,4888	0	0	0	0	100	3257,4888
wooden walking coat	7 530,000	2,720	20 481,600	-1,490	-11 219,700	0,00161	12,123	90	6777	0	0	10	753	0	0	100	7530	0	0
thermal insulation - mineral wool	11 520,796	23,300	268 434,557	1,640	18 894,106	0,01050	120,968	0	0	80	9216,637164	20	2304,159291	0	0	100	11520,79646	0	0
OSB boards	15 158,228	9,320	141 274,680	-1,168	-17 704,810	0,00603	91,404	80	12126,582	0	0	20	3031,6455	0	0	100	15158,2275	0	0
timber profiles 60 x 40	1 796,011	2,720	4 885,149	-1,490	-2 676,056	0,00161	2,892	100	1796,010624	0	0	0	0	0	0	100	1796,010624	0	0
gypsumboard	4 241,522	4,440	18 832,357	0,209	886,478	0,00070	2,969	0	0	100	4241,521875	0	0	0	0	100	4241,521875	0	0
Separation walls																			
timber profiles	8 734,871	2,720	23 758,849	-1,490	-13 014,958	0,00161	14,063	100	8734,87104	0	0	0	0	0	0	100	8734,87104	0	0
sound insulation - mineral wool	22 904,816	23,300	533 682,219	1,640	37 563,899	0,01050	240,501	0	0	20	4580,963254	80	18323,85301	0	0	100	22904,81627	0	0
gypsumfibre boards	28 314,347	4,440	125 715,698	0,209	5 917,698	0,00070	19,820	0	0	100	28314,3465	0	0	0	0	100	28314,3465	0	0
gypsumboard	27 316,280	4,440	121 284,283	0,209	5 709,103	0,00070	19,121	0	0	100	27316,28	0	0	0	0	100	27316,28	0	0
Windows																			
Wooden with double glazing	388,130	626,700	243 241,071	35,9	13 933,867	0,46560	180,713	25,77	100,021101	68,88	267,343944	5,36	20,803768	53,57	207,921241	43,37	168,331981	3,06	11,876778
Total	**1 950 089,696**	**16 411 754,286**		**500 463,242**		**4 979,291**		**183 111,861**		**117 456,615**		**1 701 214,769**		**57 444,020**		**1 854 065,563**		**90 273,623**	
Total floor area[m^2]	**2 416,280**	**2 416,280**		**2 416,280**		**2 416,280**		**2 416,280**		**2 416,280**		**2 416,280**		**2 416,280**		**2 416,280**		**2 416,280**	
Total per m^2	**807,063**	**6 792,157**		**207,121**		**2,061**		**75,783**		**48,611**		**704,064**		**23,774**		**767,322**		**37,361**	
[%]								**9,390**		**6,023**		**87,238**		**2,946**		**95,076**		**4,629**	

Timber structure without basement

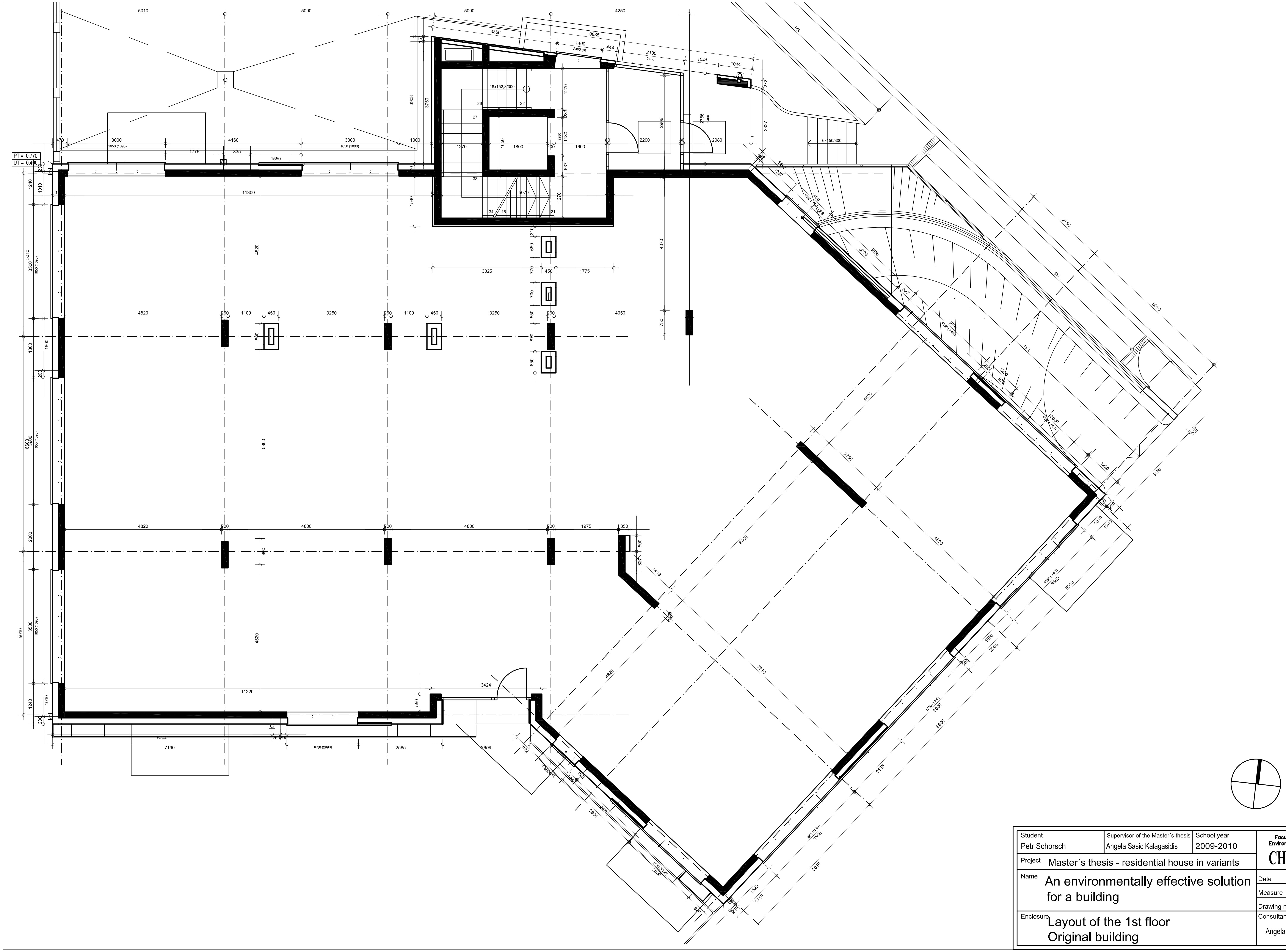
Type of structure / Used material	Weight [kg]	Embodied energy [MJ/kg]	Embodied energy total [MJ]	Embodied CO_2 emissions [kg/kg]	Embodied CO_2 emissions total [kg]	Embodied SO_2 emissions [kg/kg]	Embodied SO_2 emissions total [kg]	Renewable materials		Recycled materials		Raw materials		Fully recycleable		Partly recycleable		Waste	
Load bearing structure																			
		0,690	0,000	0,103	0,000	0,00024	0,000	0	0	0	0	100	0	3,148	0	96,852	0	0	0
		22,700	0,000	0,935	0,000	0,00567	0,000	0	0	0	0	100	0	3,148	0	96,852	0	0	0
Timber profiles	74 024,123	2,720	201 345,614	-1,490	-110 295,943	0,00161	119,179	100	74024,1228	0	0	0	0	0	0	100	74024,1228	0	0
Ceilings																			
ceramic tiles	26 519,200	13,900	368 616,880	0,717	19 014,266	0,00298	79,027	0	0	0	0	100	26519,2	0	0	50	13259,6	50	13259,6
		3,400	0,000	0,300	0,000	0,00230	0,000	0	0	0	0	100	0	0	0	100	0	0	0
waterproofing	5 091,686	93,400	475 563,510	2,550	12 983,800	0,02530	128,820	0	0	0	0	100	5091,6864	0	0	0	0	100	5091,6864
		1,600	0,000	0,090	0,000	0,00080	0,000	0	0	0	0	100	0	0	0	0	0	100	0
Ethafoam	928,172	102,000	94 673,544	3,440	3 192,912	0,02110	19,584	0	0	0	0	100	928,172	0	0	0	0	100	928,172
OSB boards	51 712,440	9,320	481 959,941	-1,168	-60 400,130	0,00603	311,826	80	41369,952	0	0	20	10342,488	0	0	100	51712,44	0	0
timber joists 60 x 40	2 394,606	2,720	6 513,329	-1,490	-3 567,963	0,00161	3,855	100	2394,606272	0	0	0	0	0	0	100	2394,606272	0	0
gypsumboard	12 016,513	4,440	53 353,316	0,209	2 511,451	0,00070	8,412	0	0	100	12016,5125	0	0	0	0	100	12016,5125	0	0
Facade																			
external plaster	4 914,589	1,400	6 880,425	0,140	688,043	0,00130	6,389	0	0	0	0	100	4914,589375	0	0	0	0	100	4914,589375
thermal insulation - mineral wool	17 654,277	23,300	411 344,665	1,640	28 953,015	0,01050	185,370	0	0	20	3530,855496	80	14123,42198	0	0	100	17654,27748	0	0
OSB boards	9 512,872	9,320	88 659,969	-1,168	-11 111,035	0,00603	57,363	80	7610,29776	0	0	20	1902,57444	0	0	100	9512,8722	0	0
woodenfibre boards	9 288,660	13,700	127 254,642	-0,183	-1 699,825	0,00688	63,906	60	5573,196	40	3715,464	40	3715,464	100	9288,66	0	0	0	0
vapour barrier	975,299	93,400	91 092,964	2,550	2 487,013	0,02530	24,675	0	0	0	0	100	975,2994048	0	0	0	0	100	975,2994048
timber profiles 100 x 60 + joists	10 101,702	2,720	27 476,631	-1,490	-15 051,537	0,00161	16,264	100	10101,70248	0	0	0	0	0	0	100	10101,70248	0	0
gypsumboard	5 842,577	4,440	25 941,040	0,209	1 221,098	0,00070	4,090	0	0	100	5842,576531	0	0	0	0	100	5842,576531	0	0
Roof structure																			
gravel	35 345,700	0,080	2 827,656	0,004	141,383	0,00005	1,767	50	17672,85	50	17672,85	0	0	0	0	100	35345,7	0	0
extruded polystyren	2 796,263	102,000	285 218,826	3,440	9 619,145	0,02110	59,001	0	0	0	0	100	2796,263	0	0	0	0	100	2796,263
waterproofing	3 257,489	77,000	250 826,638	2,020	6 580,127	0,02100	68,407	0	0	0	0	100	3257,4888	0	0	0	0	100	3257,4888
wooden walking coat	7 530,000	2,720	20 481,600	-1,490	-11 219,700	0,00161	12,123	90	6777	0	0	10	753	0	0	100	7530	0	0
thermal insulation - mineral wool	11 520,796	23,300	268 434,557	1,640	18 894,106	0,01050	120,968	0	0	80	9216,637164	20	2304,159291	0	0	100	11520,79646	0	0
OSB boards	15 158,228	9,320	141 274,680	-1,168	-17 704,810	0,00603	91,404	80	12126,582	0	0	20	3031,6455	0	0	100	15158,2275	0	0
timber profiles 60 x 40	1 796,011	2,720	4 885,149	-1,490	-2 676,056	0,00161	2,892	100	1796,010624	0	0	0	0	0	0	100	1796,010624	0	0
gypsumboard	4 241,522	4,440	18 832,357	0,209	886,478	0,00070	2,969	0	0	100	4241,521875	0	0	0	0	100	4241,521875	0	0
Separation walls																			
timber profiles	8 734,871	2,720	23 758,849	-1,490	-13 014,958	0,00161	14,063	100	8734,87104	0	0	0	0	0	0	100	8734,87104	0	0
sound insulation - mineral wool	22 904,816	23,300	533 682,219	1,640	37 563,899	0,01050	240,501	0	0	20	4580,963254	80	18323,85301	0	0	100	22904,81627	0	0
gypsumfibre boards	28 314,347	4,440	125 715,698	0,209	5 917,698	0,00070	19,820	0	0	100	28314,3465	0	0	0	0	100	28314,3465	0	0
gypsumboard	27 316,280	4,440	121 284,283	0,209	5 709,103	0,00070	19,121	0	0	100	27316,28	0	0	0	0	100	27316,28	0	0
Windows																			
Wooden with double glazing	388,130	626,700	243 241,071	35,9	13 933,867	0,46560	180,713	25,77	100,021101	68,88	267,343944	5,36	20,803768	53,57	207,921241	43,37	168,331981	3,06	11,876778
Total	**400 281,170**	**4 501 140,054**		**-76 444,551**		**1 862,510**		**188 281,212**		**116 715,351**		**99 000,109**		**9 496,581**		**359 549,613**		**31 234,976**	
Total floor area [m^2]	**2 363,770**	**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**		**2 363,770**	
Total per m^2	**169,340**	**1 904,221**		**-32,340**		**0,788**		**79,653**		**49,377**		**41,882**		**4,018**		**152,109**		**13,214**	
[%]								**47,037**		**29,158**		**24,733**		**2,372**		**89,824**		**7,803**	

G

Basic drawings of the original building



Student Petr Schorsch	Supervisor of the Master´s thesis Angela Sasic Kalagasidis	School year 2009-2010	Faculty of Civil and Environmental Engineering CHALMERS	
Project	Master´s thesis - residential house in variants			
Name	An environmentally effective solution for a building		Date	05/2010
			Measure	M 1:100
			Drawing no.	S 1
Enclosure	Layout of the floor with garages Original building		Consultant Angela Sasic Kalagasidis	



Student
Petr Schorsch

Supervisor of the Master´s thesis
Angela Sasic Kalagasidis

School year
2009-2010

Project
Master´s thesis - residential house in variants

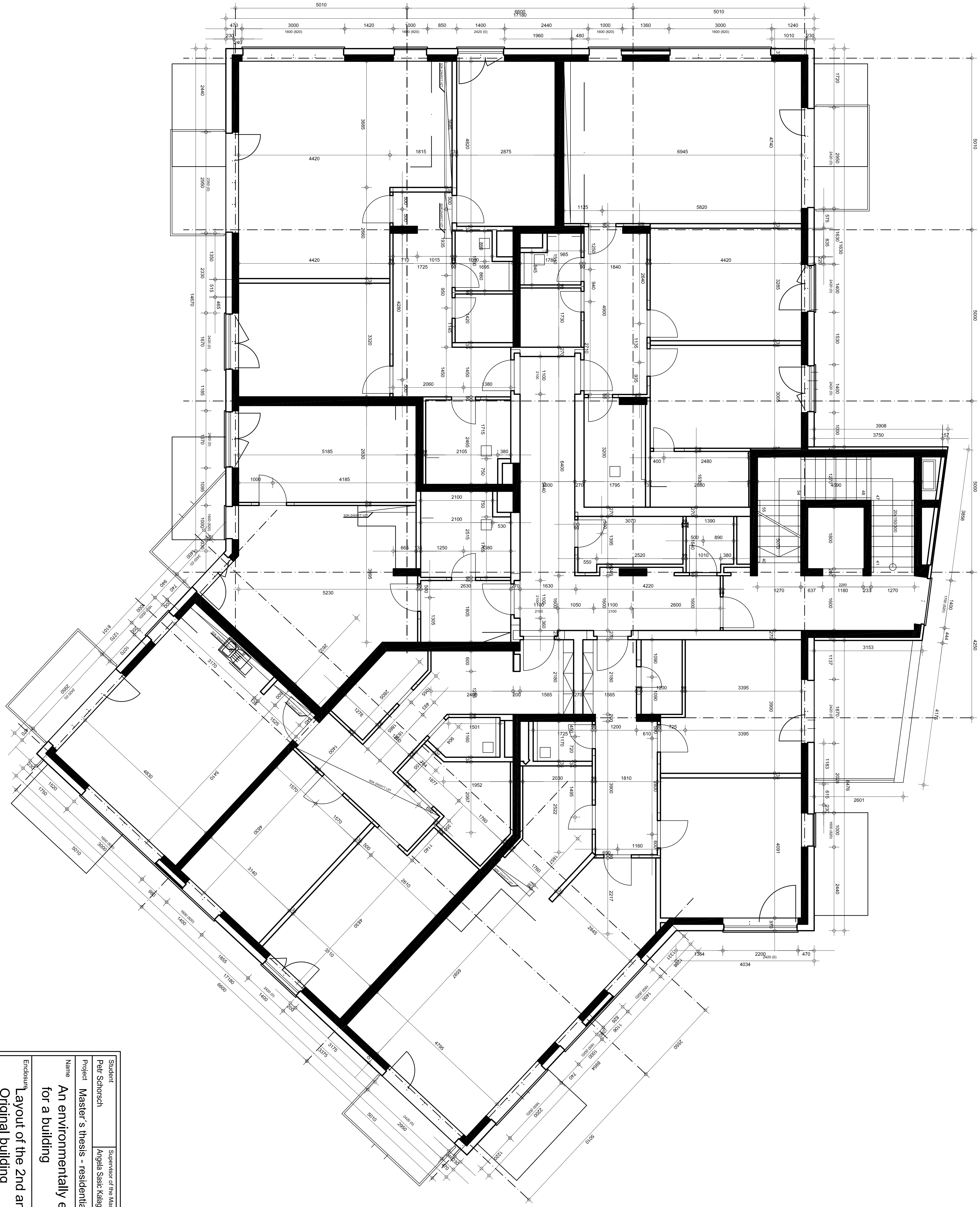
Name
An environmentally effective solution
for a building

Enclosure
Layout of the 1st floor
Original building

Faculty of Civil and
Environmental Engineering
CHALMERS

Date	05/2010
Measure	M 1:100
Drawing no.	S 2

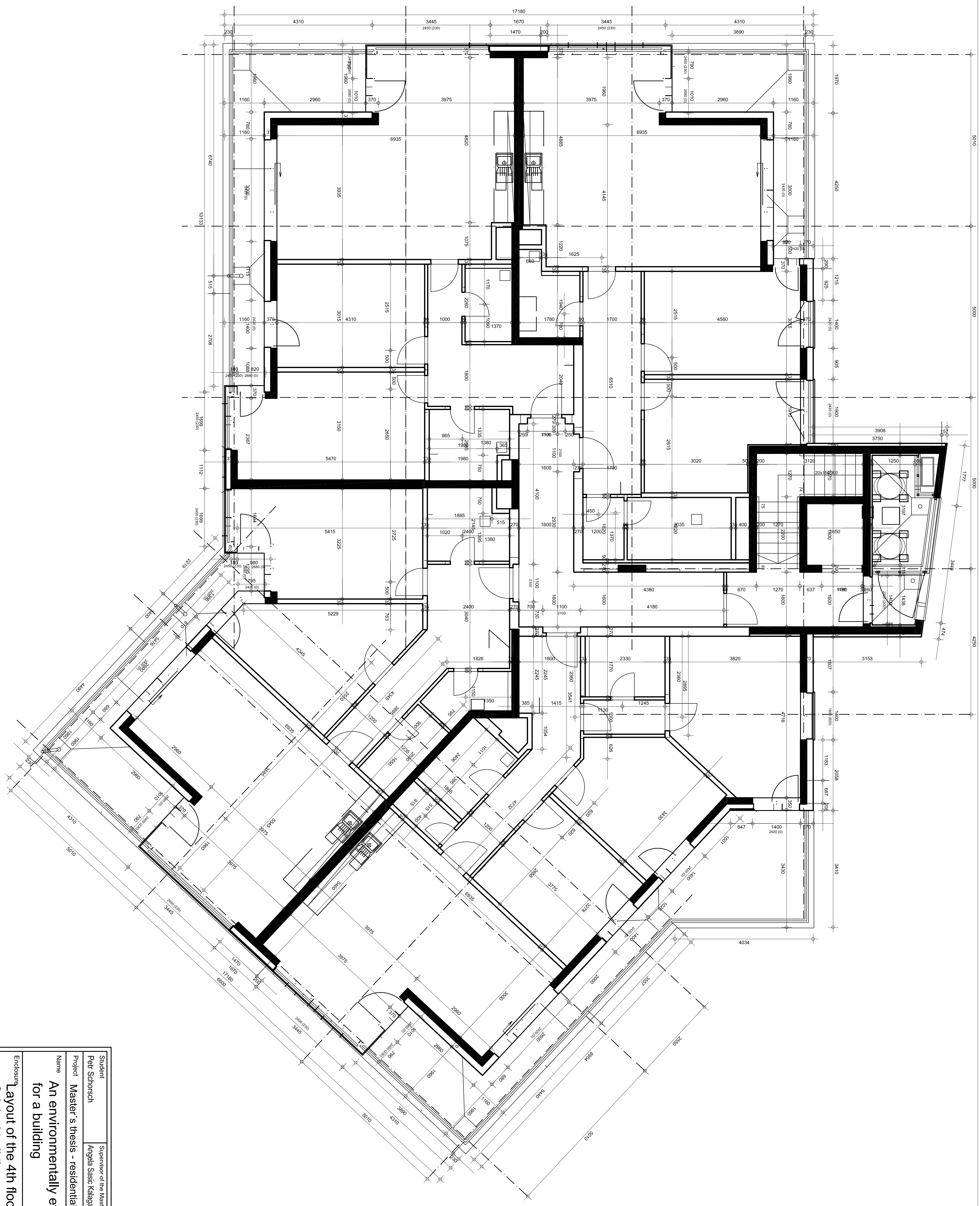
Consultant
Angela Sasic Kalagasidis



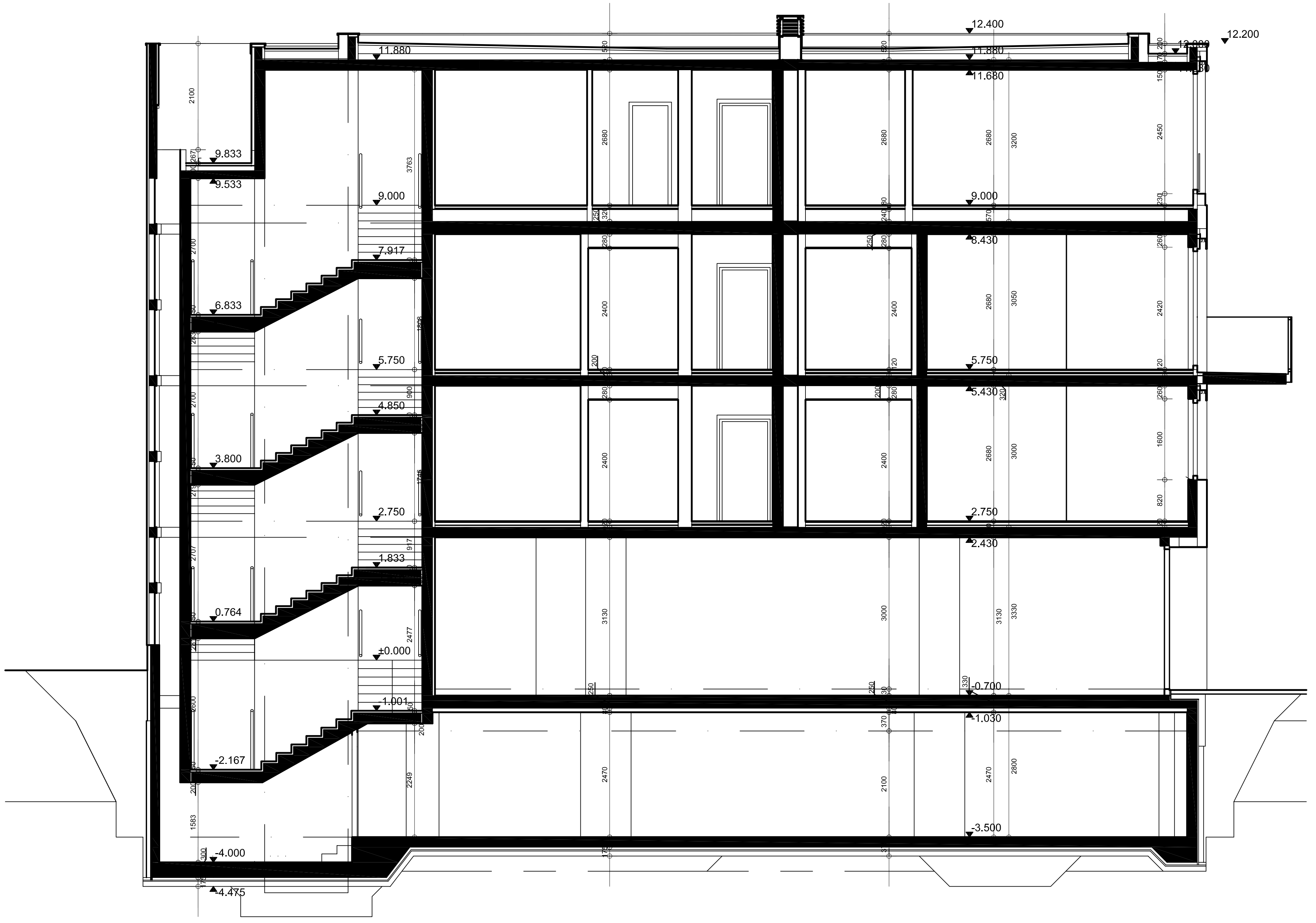
Student	Petr Schorsch
Supervisor of the Master's thesis	Angela Sasic Kalagasidis
School year	2009-2010
Project	Master's thesis - residential house in variants
Name	An environmentally effective solution for a building
Enclosure	Layout of the 2nd and 3rd floor Original building

Faculty of Civil and Environmental Engineering
CHALMERS

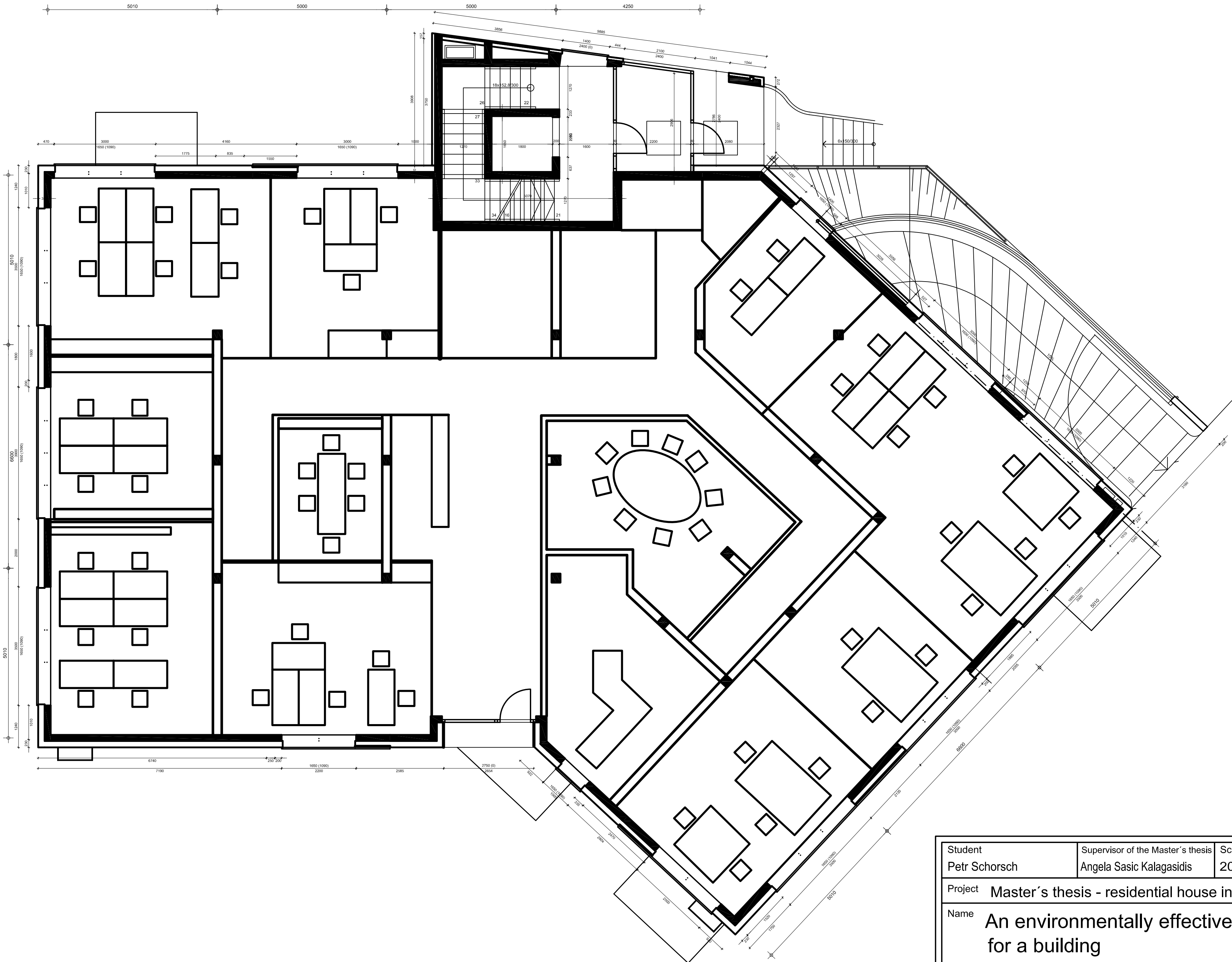
Date	05/2010
Measure	M 1:100
Drawing no.	S 3
Consultant	Angela Sasic Kalagasidis



Student Petr Schorsch	Supervisor of the Master's thesis Angela Sasic Kalagasidis	School year 2009-2010	Faculty of Civil and Environmental Engineering CHALMERS
Project	Master's thesis - residential house in variants		Date: 05/2010
Name	An environmentally effective solution for a building		Measure: M 1:100
Enclosure	Layout of the 4th floor Original building		Drawing no.: S 4
			Consultant Angela Sasic Kalagasidis



Student	Supervisor of the Master´s thesis	School year	Faculty of Civil and Environmental Engineering CHALMERS
Petr Schorsch	Angela Sasic Kalagasidis	2009-2010	
Project: Master´s thesis - residential house in variants			
Name: An environmentally effective solution for a building			Date: 05/2010
			Measure: M 1:100
			Drawing no.: S 5
Enclosure: Section of the original building			Consultant: Angela Sasic Kalagasidis



Student Petr Schorsch	Supervisor of the Master´s thesis Angela Sasic Kalagasidis	School year 2009-2010	Faculty of Civil and Environmental Engineering CHALMERS
Project	Master´s thesis - residential house in variants		
Name	An environmentally effective solution for a building		Date: 05/2010 Measure: M 1:150 Drawing no.: S 6
Enclosure	Changes in the disposition on the lowest floor		Consultant Angela Sasic Kalagasidis