SynEnergy District

Study of the effect of the implementation of electric mobility on the energy behaviour of a newly built district including a performing arts centre

Politecnico di Milano

Polo Territoriale di Lecco
Scuola di Architettura Urbanistica Ingegneria delle Costruzioni
Corso di laurea in Ingegneria Edile-Architettura
Anno accademico 2018-2019

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Un ringraziamento va al nostro relatore Gabriele Masera per la grande disponibilità e per averci spinto ad indagare un tema trasversale e in divenire come è quello della mobilità elettrica.

Ringraziamo inoltre i partecipanti al gruppo di ricerca TRESPASSING per le importanti informazioni forniteci.

Ringraziamo poi tutti i professori del Polo Territoriale di Lecco per la disponibilità a rispondere ai nostri dubbi e per i preziosi suggerimenti.

Un particolare ringraziamento va infine a tutti coloro che ci hanno supportato e accompagnato durante il nostro percorso accademico.

Abstract

The energy issue is becoming nowadays more and more important. The World is facing a growth in energy consumptions rates, as well as a harshening in climatic conditions mainly due to energy production. The possibility to exploit renewable energy sources in order to reduce emissions and at the same time increase our life conditions needs then an important attention.

This research addresses two of the main actors in the energy consumption panorama: buildings and private mobility. Even if today they are seen as energy users, they are experiencing a strong attention from National Authorities and single consumers in order to reduce their impact on the environment.

After a general overview on these two topics, the research tries to define and develop a scientific method to integrate diffused energy production with energy consumption. In order to achieve this goal particular attention is given to the theme of energy storage. Besides already existing technologies, the possibility to exploit the electric vehicles batteries to temporarily store energy is explored. In this way the energy surplus locally produced can be used during non productive hours, such as at night, favouring the consumption of energy on site. The aim is to provide a realistic approach that would help a complete transition towards renewable energies production reducing in this way the interaction with the electricity distribution grid.

At first the method is applied to the development of a new masterplan in the city of Milano. The medium and large scale possibilities and impact can then be analysed and studied. After that, the simulations and energy balances focus on a particular building with well defined functional and architectural requirements. The method is applied to a Performing Arts Center to be located within the previously defined masterplan.

Finally, the analysis goes back to the medium scale, confronting different scenarios of electric vehicles distribution on the territory. The parameters defined during the design of the two case studies are used to simulate a realistic impact of the research on the urban environment.

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CHAPTER 1

Preliminary research

Global and European overview on CO_2 emissions, construction and transport field impact and official policies

An overview on Global CO_2 emission

Understanding the main trends in the overall scenario of energy consumption and CO_2 emissions is fundamental to better understand the reasons behind the new ambitious emerging energy targets defining the base of our research. The following paragraphs will illustrate how the energy consumption framework has evolved throughout the years, the potential risks it leads to, and the vast panorama of policies developed to assess the problem. Large space will be given to the construction and transport sector, leading actors in the energy consumption and CO_2 emissions scenario, and the new emerging policies characterizing them.

The relatively small concentration of carbon dioxide and other greenhouse gas (GHG) existing in Earth's atmosphere is fundamental to guarantee the liveability of the planet, that would simply be too cold without them.[1] However, since the Industrial Revolution, the energy-driven massive consumption of fossil fuels brought to a fast increase in CO_2 emissions, that determined a critical planetary warming impact.

It is important, to better understand the aim of the research, to highlight how CO_2 emissions have evolved throughout the years, how they are distributed, what the driving key elements of the trend are and what we should focus on in order to mitigate the climate change. According to the statistic data collected by the Met Office Hadley Centre in the latest decades, the average global temperature started registering anomalies and the trend especially after 1980. Indeed, considering as reference the average temperature of the 1960-1990 period, in the latest years, global temperatures raised of 0.8°C compared to the base line. When extended back to 1850, temperatures were a further 0.4 degrees colder than they were in the 1960-1990

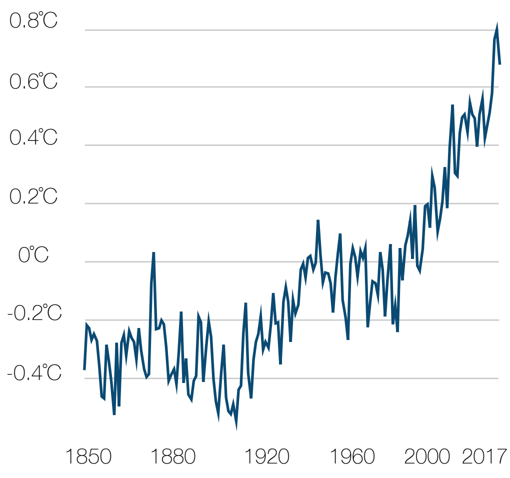


Chart 1: Global average temperature anomaly relative to the 1961-1990 average temperature

baseline. Which accounts for 1.2°C in the overall framework, considering the total temperature increase since pre-industrial period.[2]

Digging into more detailed data, when calculating the cumulative emissions of any country of the World since 1750 until 2016, we see different trends. Due to the Industrial Revolution, the UK has been the first emitter of CO_2, followed by other European regions and North America while other regions such as Asia or India started contributing much later. Today US and EU are leaders in terms of cumulative emissions, immediately followed by China, whose emissions drastically increased in a very few years[3]

The general trend changes when digging into the most recent annual emissions data: trends across many high-income nations have stabilized or even decreased, while a number of low to middle income nations such as China or India are now within the top global emitters.[4] It is predictable that these new top emitters will very probably continue to increase as they undergo development.[5]

However, to make a fair comparison of contributions, it is necessary to compare, more than countries' cumulative data, global emissions in terms of CO_2 emissions per person. The global trend shows how per capita emissions in most countries have continued to increase in line with development,[6] and how big global inequalities still exist.

Global CO_2 emissions might even be divided by sector, where "energy" accounts for the highest percentage. However, "energy" is inclusive of public heat and electricity production, other energy industries, manufacturing and construction.[7] And it is then interesting to see that, when allocating emissions from electricity to consuming sectors, industry is the largest emitter, immediately followed by buildings, whose share increases from 8% to 27%[8]. Indeed, building sector

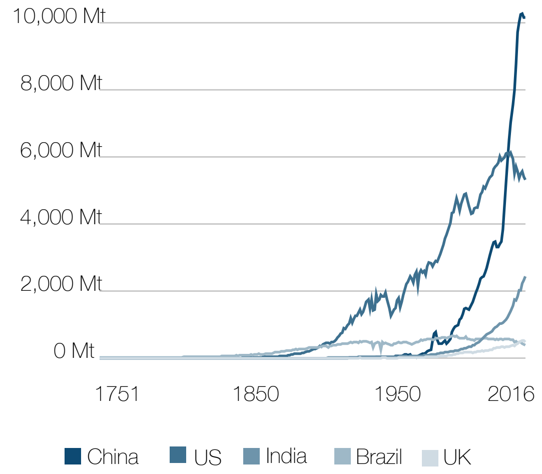


Chart 3: Annual carbon dioxide (CO_2) emissions, measured in million tonnes (Mt) per year

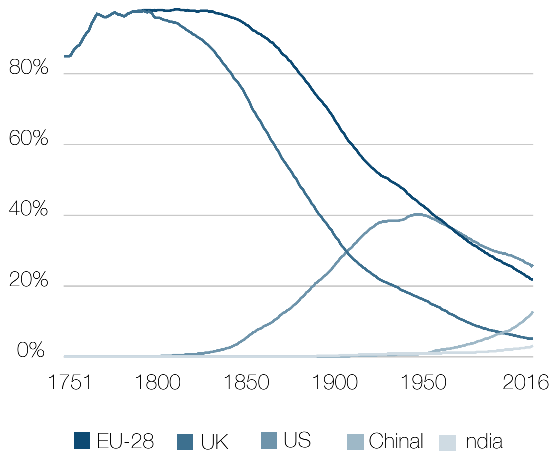


Chart 2: Country or region's share of cumulative global CO_2 emissions, calculated as the sum of annual emissions from 1751 to a given year

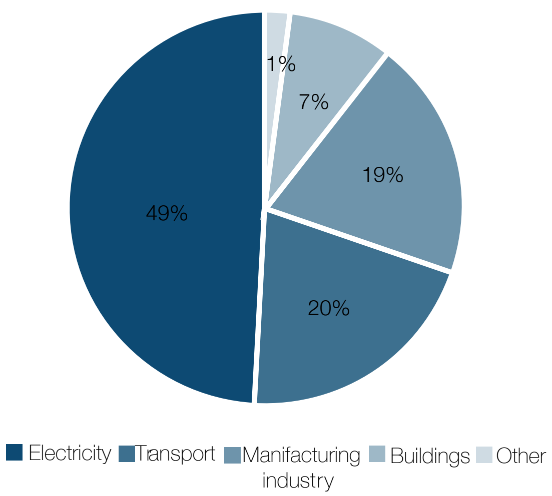


Chart 4: Global carbon dioxide (CO_2) emissions by sector

strongly relies on electricity, especially due to the large contribution of space heating.
Among the main leading actors of global CO_2 emissions there is then for sure the transport sector, whose main contributor is the car mobility.[9]

Why is it important to decrease CO_2 emissions?

The massive increase of CO_2 levels in the atmosphere is the main responsible of global warming and climate change, serious concern for global and European institutions. The current changes in our planet's climate are redrawing the world and magnifying the risks for instability in all forms. The last two decades included 18 of the warmest years on record.[10] Global warming impact is gradually transforming our environment increasing the frequency and the intensity of extreme weather events affecting all regions around the world. Polar ice shields are melting, and the sea level is rising causing flooding and erosion of coastal and low-lying areas. In several regions extreme weather events and rainfalls are becoming more and more common, while others are experiencing more extreme heat waves and droughts. Large parts of Europe suffered from severe droughts while flood events have particularly affected Central and Eastern Europe in recent years. Climate change would also have severe consequences on European economy's productivity, on its infrastructure and on its ability to produce food, on public health, biodiversity and political stability. Weather related disasters caused 283 billion euros of economic damages last year and are very likely to affect two-thirds of European population by 2100, compared to today 5%. The 16% of the Mediterranean areas could become arid by the end of the century and the productivity of several European southern regions might decrease of the 10-15 % compared to the present levels.[11]

Climate policies at global and local levels

In order to asses the climate change, several policies have been developed since the end of the XX century. A wide climate policy framework has been developed, implemented, and revised over the years, and among the most significant events there are:

UN climate convention (1992)

The United Nations Framework Convention on Climate Change (UNFCCC) agreed in 1992 during Rio de Janeiro conference, the main international treaty on fighting climate change. The treaty objective was stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interferences with the climate system.[12] The UNFCCC set no binding limits on greenhouse gas emissions and did not contain any enforcement mechanism.

Conferences of the Parties (from 1995)

The 197 Member States that signed the UNFCCC met again in 1995 during the annual-based Conferences of the Parties (COP) to assess their progress. Later on, State Members began to reunite every year at a Conference of Parties to review the progresses and set up new agreements.

COP3, Kyoto protocol (1997)

The Kyoto Protocol is the first document legally binding obligations to reduce greenhouse emissions between the 192 Members that signed it in 1997. The Kyoto protocol extended the 1992 UNFCCC and according to it, two commitment periods have been agreed:

- 1st period (2008-12): industrialized countries committed to reduce emissions by an average of 5% below 1990 level
- 2nd period (2013-2020): parties who joined this period committed to reduce emissions by at least 18% below 1990 level[13]

However, the protocol did not become international law until 2005, halfway through the 1990-2012 period. And by that point global emissions had risen substantially. Some countries and regions such as EU were on track to accomplish their Kyoto targets, but several others big countries such as United States and China emitted more than enough extra GHG to erase all the reductions made by other cuntries.

COP16, Cancùn (2010)

The 16th Conferences of the Parties took place in 2010 in Cancùn and stated some new good points:

- acknowledged for the first time in a formal UN decision that global warming must be kept below 2°C compared to pre-industrial temperatures
- agreed on stronger rules for the monitoring, reporting and verification of emissions [14]

COP21, The Paris Agreement (2015)

The Paris Agreement is the culmination of years of efforts by the international community to bring about a universal multilateral agreement on climate change. At the Paris climate conference, COP21, held in December 2015, 195 countries adopted the first universal, legally binding global agreement. The agreement sets an action plan in order to avoid dangerous climate change by setting the following:

- a long-term goal of maintaining the global average temperature increase below 2°C above pre-industrial levels
- to aim to limit the increase to 1.5° in order to reduce risks and impacts of global warming
- on the need for global emissions to diminish as soon as possible, considering this will take longer for developing countries

Before and during the Paris conference, countries submitted comprehensive national climate action plans. These are not yet enough to keep global warming below 2°C, but the agreement traces the way to achieve this target.
European Union has been at the forefront of international efforts to fight climate change, being the first major economy to submit its intended contribution to the new agreement in March 2015.

European climate policies

Preventing dangerous climate change is one of the main priorities for the European Union. Europe is working hard to cut its CO_2 emissions and to take the way to achieve the transformation towards a low-carbon economy while encouraging other nations and regions to do likewise. Climate policies in the EU have been developing since 1990, introducing common measures in the areas of greenhouse gas emissions, renewable energies and energy efficiency. An EU-wide climate policy framework has been developed, implemented, and revised over time.

2020 and 2030 energy package

2020 and 2030 goals were set in 2014 and submitted by the European Commission during the 2015 Paris Agreement.
EU targets for 2020, set in the “2020 climate energy package” , involve:

- 20% cut in greenhouse gas emissions compared to 1990
- 20% of total energy consumption from renewables
- 20% increase in energy efficiency*

*Where with “increase in energy efficiency” is intended as using less energy to provide the same service.

EU targets for 2030, set in the “2030 climate energy framework”, involve:

- at least 40% cut in greenhouse gas emissions compared to 1990

- at least 27% of total energy consumption from renewables
- at least 27% increase in energy efficiency[15]

“Cleaned Energy for all Europeans” package

On 20 November 2016 the European Commission presented a measures package named “Cleaned Energy for all Europeans” in order to accelerate the shift to a low-emission economy involving, between the others, the following targets:

- reach the 32% of total energy consumption from renewables by 2030
- reach the 32.5% in energy efficiency by 2030[16]

These measures, beside stimulating European industrial competitiveness, would increase the availability of job positions, reduce the energetic bills and increase the air quality, and will carry to an even major emissions reduction of 45% by 2030 relative to 1990.

European Directive 2018/884

The measures collected in the packages earlier formulated are eventually adopted within the European Directive 2018/884 of May 30, 2018, officially published only in June. It modifies the Directive 2010/31/UE (EPBD) and the Directive 2012/27/UE (EED) respectively on energy buildings performances and on energy efficiency.
Among the aims of the new directive there is:

- Integrate and increase the efficiency of building stock renovation strategies for an ideally de-carbonized sector. And obtain a modest percentage of net zero energy buildings by 2050, mobilizing new investments.
- Encourage the introduction of new and innovative technologies to reach efficiency, comfort and flexibility in the built environment.
- Promote new modes of transports
- Integrate the already existing databases with further monitoring
- Increase the number of consumers, informing about the responsive mechanisms that energy efficient solutions bring to.
- Consider the multiple advantages of refurbishing initiatives, such as air quality, thermal and visual comfort and seismic safety.[17]

2050 Long-term strategy

On November 28, 2018, the European commission presented its long-term strategic vision for a prosperous, innovative, competitive and climate neutral economy. The vision, which is totally in line with the objectives agreed during the Paris Agreement, aims to substantially reduce its gas emissions of 80-95% before 2050 compared to 1990 levels[18] and Transform Europe in a highly energy efficient and low-carbon economy, which will stimulate economy, create job positions and will reinforce Europe competitiveness.[19]
The European directives in force mainly regard the sectors that have a biggest impact on CO_2 emissions. As well as for the global panorama, among the main responsible of European CO_2 emissions are the transport field and the building sector, that when considering indirect upstream emissions attributable to electricity and heat consumption, contributes for about one-third on total CO_2 emissions.

Building sector impact and EU policies

Big percentage of the global greenhouse gas emission is due to the building sector. According to the International Energy Agency (IEA), build-

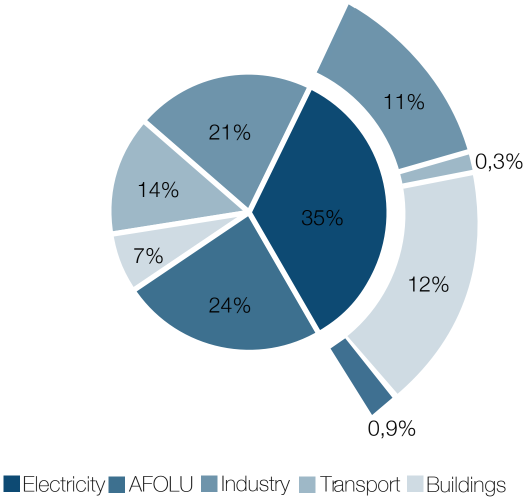


Chart 5: European carbon dioxide (CO_2) emissions by sector

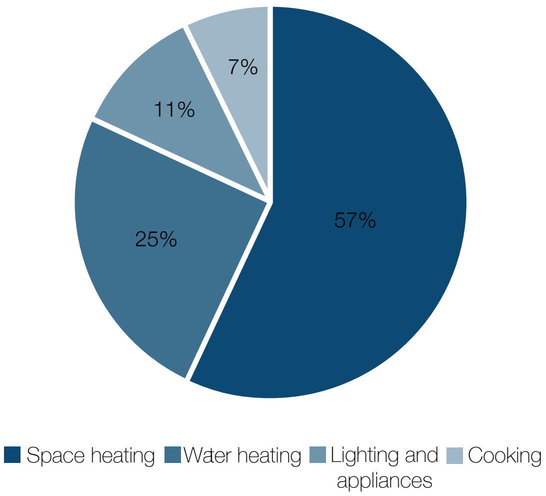


Chart 6: European residential buildings CO_2 emissions

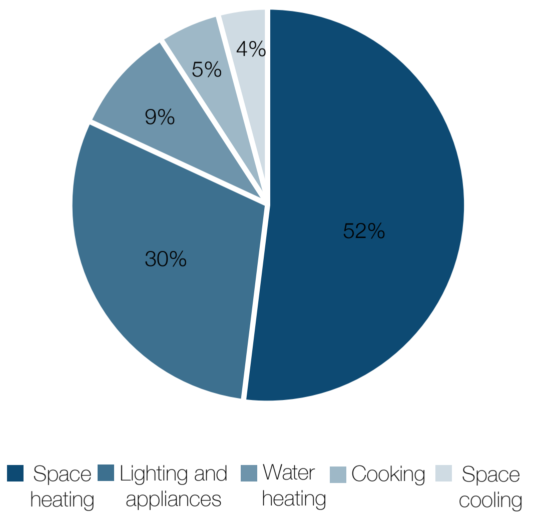


Chart 7: European commercial buildings CO_2 emissions

ings consume 32% of global final energy. Moreover, consumption exceeds 50% if also production of materials and construction process are considered. The European panorama substantially mirrors the global trend. Indeed, according to the European Commission buildings are responsible for the 40% of the European energy consumption and for the 36% of its CO_2 emissions.[20]

It is then fundamental to consider not just the construction phase of a building but also its own life cycle, counting different phases such as the design one, the realization, the operation, maintenance and the dismission one. Each of them has its own environmental impact, and it is then crucial to understand how significant the decisions taken at the very beginning of the design process are. Good choices in the early stage could substantially decrease the operational impact which is the one generating the biggest impact[21] .

Energy Performance of building Directive (2010)

Among the main directives regarding the building sector in terms of greenhouse emissions there is the 2010 Energy Performance of Building Directive (EPBD), which states that EU members should ensure the followings:[22]

- From January 1st, 2018, all new buildings occupied and owned by public authorities have to be nearly zero-energy buildings
- From January 1st, 2021, all new buildings constructed have to be nearly zero energy buildings.[23]

The EPBD and the 2012 Energy Efficiency Directive (EED) are the European Union's main legislative instrument aiming to promote the improvement of energy performance of buildings within the community. Thanks to the introduction

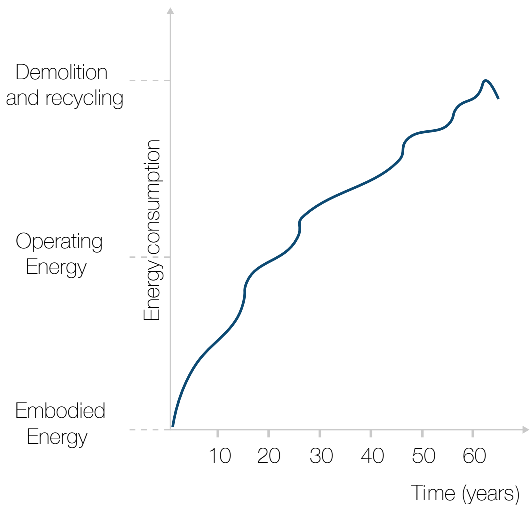


Chart 8: Cumulative energy used in the life cycle of a building (assumed 60 years)

of energy efficiency targets in the national building codes, the new buildings nowadays consume only half of what a typical building from the 1980s consumes.[24]

European Directive 2018/884

Further modifications on the Energy Performance of Building Directive have been added when the European Commission formulated a measures package on November 2016. The measures collected are eventually adopted within the European Directive 2018/884 of May 30, 2018.
The directive involves actions that should accelerate the shift to clean energy production and incentive the renovation of existing buildings. Indeed, considering the great impact that the building sector has on energy consumption, and that the 35% of EU buildings have more than 50 years, more renovation of the existing building stock could lead to significant energy savings.[25]
More precisely the directive claims that:

- EU countries establish stronger long-term renovation strategies, aiming at decarbonising the national building stocks by 2050, and with a solid financial component
- A common European scheme for rating the smart readiness of buildings, optional for Member States, will be introduced
- Smart technologies will be further promoted, for instance through requirements on the installation of building automation and control systems and on devices that regulate temperature at room level.
- E-mobility will be supported by introducing minimum requirements for car parks over a certain size and other minimum infrastructure for smaller buildings
- EU countries will have to express their national energy performance requirements in ways that allow cross-national comparisons
- Health and well-being of building users will be promoted, for instance through an increased consideration of air quality and ventilation[26]

Transport sector impact and EU policies

Transports sector produces almost a quarter of the total European greenhouse gas emissions and it is the main responsible of cities air pollution. While the other sectors, thanks to a low carbon circular economy underway, registered a gradual decline of CO_2 emissions, those due to transports only started to decrease during 2007, remaining higher compared to 1990.[27] Road mobility is by far the biggest emitter accounting for more than the 70% of all the greenhouse gas emissions coming from transports, and the highest percentage is due to cars.[28] Europe action toward a CO_2 reduction in the transport field consists in an irreversible shift to low emission mobility.

European Strategy for low-emission mobility

By 2050 CO_2 emissions due to transport

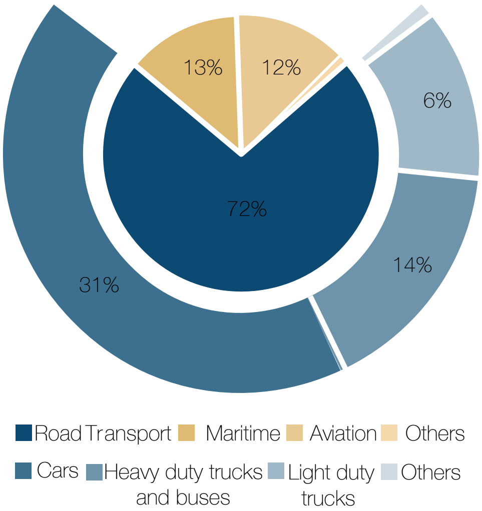


Chart 9: Share of transport greenhouse gas emissions

must diminish at least of a 60% compared to 1990 and decrease until zero. That is why Europe is moving towards 3 main strategies:

- Increase the transport system efficiency by making the most of digital technologies and low-emissions smart transport modes
- Accelerate the introduction of low-emissions alternative energy sources for transports such as electricity or hydrogen instead of fossil fuels, and remove any obstacles to the electrification of transports
- Moving towards zero-emissions vehicles[29]

Cities and local authorities will play a crucial role in delivering this strategy. They are already implementing incentives for low-emission alternative energies and vehicles, encouraging active travel such as cycling and walking, public transport, bicycle and car-sharing to reduce congestion and pollution.

Light-duty vehicles policies

Road transport alone accounts for about one fifth of total EU CO_2 emissions.[30] Light vehicles such as cars and trucks produce 15% of EU carbon dioxide emissions. Even though the CO_2 emissions related to road transport are still 20% higher than 1990, European legislation is working and setting emission targets for new vehicles, reason why the average emissions registered some improvements in recent years. The targets set for 2015 and 2017 have been achieved already and in November 2017 the EU commission presented a new proposal that defines new laws on CO_2 emissions for the period after 2020.[31] The targets set for 2015 have been met: the average level of emissions of a new car sold on 2017 was only 118.5 g of CO_2 per km, significantly lower than the 2015 target of 130 g.
Further targets require that:

- Before 2021, the average emissions of all new cars must be equal or lower than 95 g of CO_2 per km, and than 147 g CO_2 for commercial vehicles Penalty payments to the constructors due to excess emissions are foreseen and incentives for low or zero emission vehicles production are provided
- The average emissions of the EU fleet either of new cars and new trucks must be 30% lower compared to 2021.
- The targets for 2025 are 15% lower compared to 2021, in order to accelerate the emissions reduction[32]

In order to accelerate the uptake of zero and low-emission vehicles, the proposed scenario combines the CO_2 targets with an incentive mechanism for low and zero emission vehicles. The incentive covers:

- zero-emission vehicles such as battery electric or fuel cell vehicles
- low-emission vehicles with emissions lower than 50 g of CO_2 per km, such as plug-in hybrid vehicles with a conventional and an electric motor

The producers that will reach a certain amount of zero and low emission vehicles with a level of emissions even lower than the target (15% by 2025 and 30% by 2030) will be rewarded in terms of a less strict CO_2 target. This proposed framework aims to support a gradual transition from fossil fuel powered vehicles to electric ones in order to provide a sufficient amount of time to those working in the automotive sector.

These strategies will help to meet the objectives set out in the EU 2030 framework for climate and energy, which includes the target of at least 40% cut in domestic EU GHG emissions compared to 1990 levels, improve life quality and air quality, decrease the noise levels and increase safety. The costumers will benefit of vehicles consuming less energy and of better equipped infrastructures for new fuels, better connections and less delays.

Future impact of current EU policies

Europe and its Member States' set of energy and climate policies will strongly impact EU's transformation up to and beyond 2030. For this purpose, European Community developed a "baseline scenario" in order to reflect in the current and future EU de-carbonization trajectory largely based on agreed EU policies and goals. The baseline has been defined specifically for the purpose of reflecting on the EU long-term strategy. The aim of the baseline is then to represent the impact that current and agreed EU energy policies will have on the European scenario, if the States Member policies would adequately reflect them. According to the EC baseline previews, comparing primary energy consumption projections to 2005 levels, the EU energy supply levels evolve either in generic terms either in terms of energy mix. The baseline illustrates an overall reduction

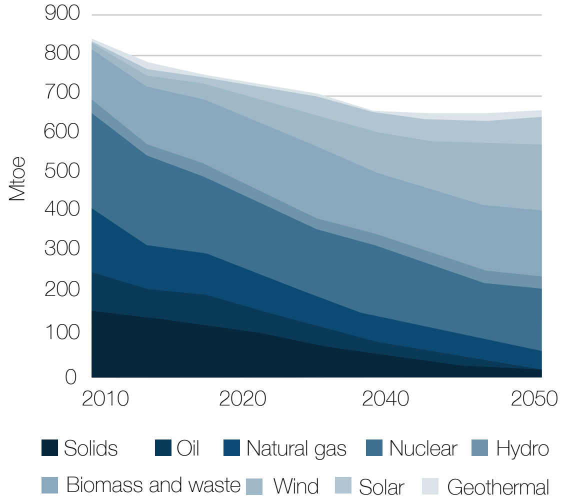


Chart 10: Primary energy production in the baseline

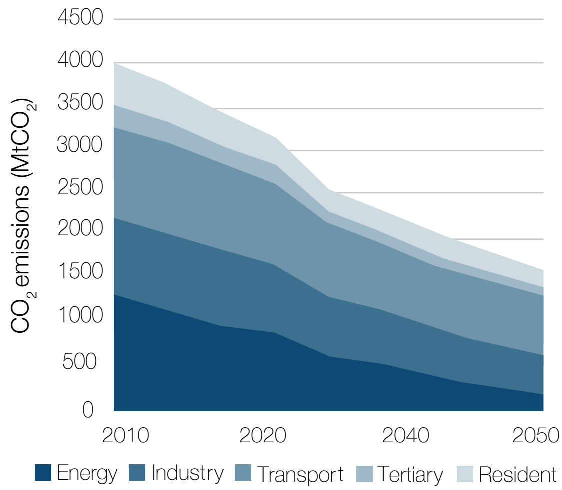


Chart 11: Evolution of CO_2 emissions by sector

of 26% by 2030, in line with the 2030 EU target, and a 35% reduction by 2050; while, by 2070 no reductions are registered due to the counterbalancing effect of economic growth on energy consumption.[33]

Energy supply

According to the EU previsions, the fossil fuel production diminishes of 88% by 2050 and the energy production through renewables more than doubles in the same time. Overall electricity generation is growing strongly. The demand of electricity is led by electrification on heating and cooling systems, from the increase of IT tools and by the gradual penetration of electric vehicles. The EU power generation mix shifts in favours of renewables chiefly driven by wind power. By 2050, 73% of electricity will be generated through renewables sources while oil and solids electricity production become marginal.[34]

Energy demand

The final energy consumption decreases by 26% between 2005 and 2050 thanks to the lower energy demand. The sector that registers more significative results in terms of energy demand are the residential one, accounting for a 38% reduction in 2050 compared to 2005 and the transport one, with a 24% reduction of final energy demand. The decreased demand levels are not only the result of the ambitious EU policies for the various sectors such as the building and transport ones, but also a result of the drastic shift from fossil fuel to RES.

CO_2 emissions

The CO_2 emissions are expected to decrease substantially towards 2050. By 2050 emission level decreases from about 4000 $MtCO_2$ in 2010 to 1600 $MtCO_2$, recording a 65% reduction compared to 1990. The main drivers of the de-carbonization are a higher energy efficiency in every sector and the large introduction of renewables energies. However the transport sector still remain the main source of CO_2 emission, the efficiency gains led by policies carries to a substantial reduction of CO_2 emissions equal to 38% compared to 2005.
Building a low-carbon-impact society is a great opportunity but also a big challenge. Many of the necessary technologies are already existing and the real challenge is to apply them. Studies show that this change is possible and feasible[35] , and that the price that society and economy will need to pay for climate change is much higher than the one they would pay now in order to fight it.

How it is possible to reach better energy performances in buildings and what we are doing today

Parameters and criticalities in the assessment of buildings energy performances

Approaching the matter of minimising the amount of energy consumed by a building in its lifetime is very complicated and multifaceted. The first thing to be considered is that the most environmentally friend way to build and run a building is with no energy at all, as energy production comes with pollution, even if in a small amount. This implies that we not only have to investigate the amount of energy that a building consumes to maintain a comfortable interior environment. We also have to be conscious about the energy embodied during the construction, the dismission, and the sources of all the energy used by a building during its lifespan.

A building lifecycle

At first, it is important to consider the amount of energy embodied by a building. It is defined as the energy required during the entire life cycle of a product, including raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and/or decomposition as well as human and secondary resources. This concept is useful to determine the effectiveness of energy-producing or energy-saving buildings or devices. Notably, the embodied energy is calculated in mass of CO_2 produced, or in MJ, that are then reconducted to equivalent CO_2.

A photovoltaic panel, for example, produces "free CO_2" electricity, but its construction process is particularly energy expensive, so that it has a "payback time" of 2 to 4 years, depending from the geographical area in which it is used.[36] This means that only after this amount of time the produced energy begins to be really "green".

Another important concept is the one of primary energy, intended as the energy found in any natural, raw source, not yet processed by any human intervention. It is important when considering buildings because depending on the kind of energy process used to heat, cool or light it up, the primary energy can differ a lot. Depending on the source, 1 unit of effectively used energy can imply a conversion factor of around 1.05, in case of methane, or around 2.80, in case of electricity.[37] This is caused by the process of energy production, its transport and related losses, and its transformation.

Regarding buildings, it is also important which kind of energy we look at. The term "energy" is being progressively replaced by the term "exergy", when considering high performance build-

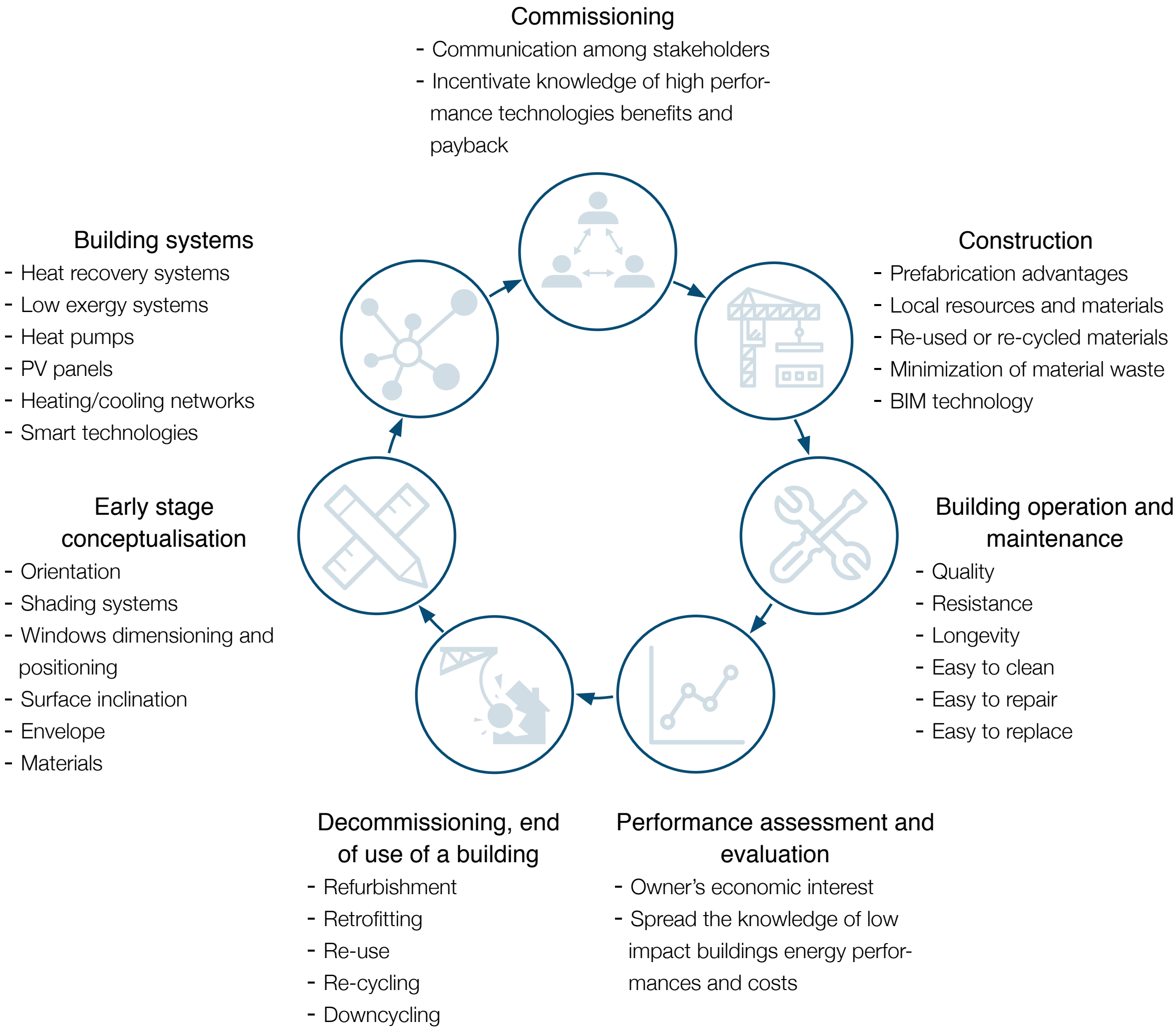


Chart 12: Integration of all sustainability concepts in building design

ings. The exergy indicates, in thermodynamics, "the maximum work potential of a system under determined conditions".[38] This concept is becoming more and more important since high performance buildings need less energy than traditional, or unretrofitted, buildings, and have heating systems that work at lower temperatures. This means that, for example, heating systems don't require anymore temperatures as high as 75 °C, generated by, typically, heating systems that use electricity or fuel in a combustion process that reaches 1500 °C[39] . So, even if the energy conversion is near to 1, its quality is degraded.[40] On the other side the so-called LowEx systems can provide different heating and cooling methods, that exploit more valuable energy sources. In other words, the use, for example, of heat pumps becomes very competitive, considering that their performances can reach a CoP (coefficient of performance) ranging from 6 to 13.[41]

A fragmented energy certifications panorama

What the industry and the research scene have been working on in the recent decades started from the formerly mentioned concepts to begin developing a series of standards and rankings of building performances. The general approach, more or less common, relies on the so-called trias energetica. The term, introduced in 1979 by Kees Duijvestein at TU Delft, wanted to introduce a rule of thumb in the sustainable design of buildings.[42]

More in detail, it states that at first the demand of energy has to be reduced since the beginning, that means that the building has to be designed taking into consideration energetic issues, like insulation, solar gains or natural ventilation. Then, the required energy has to come, if possible, from renewable sources. Finally, the required leftover, coming from fossil fuels, has to be used in the most efficient way. So the three concepts of embodied energy, primary energy and exergy are summed up and try to be minimised.

To give designers, but especially buyers, the certainty of a building's performance, along the years a series of certifications were defined and began to acquire recognizability around the world.

Leadership in Energy and Environmental Design (LEED)

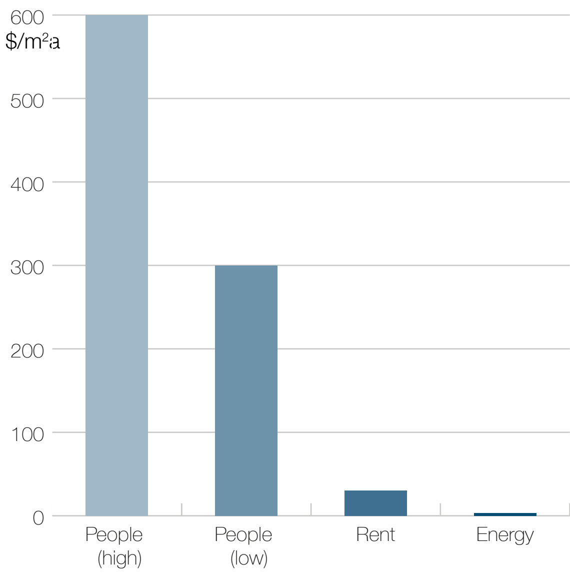


Chart 14: Costs in office building related to floor surface

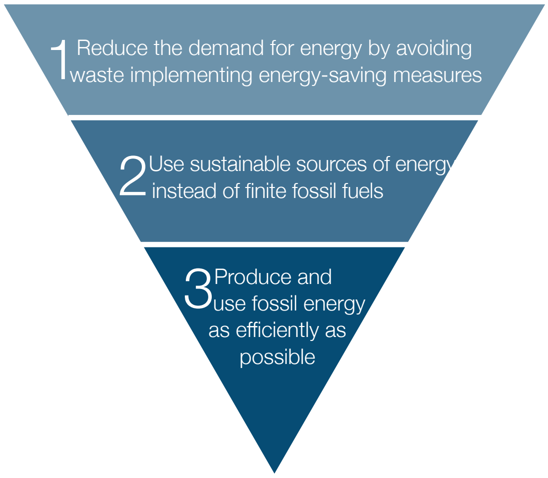


Chart 13: The trias energetica concept

Developed since 1993 by the non-profit U.S. Green Building Council (USGBC), it aims to a comprehensive system of interrelated standards that comprehend aspects from the design and construction to the maintenance and operation of buildings. It applies to different sectors, and mainly focuses on energy consumption and embodied energy. Its grading is nowadays one of the most spread around the world, and kept in high consideration. The assumption is that since the higher costs in an office buildings are staff related, with them are salaries, sick-leave or absenteeism. Studies have shown how there is a 3 to 7% gain in workplace productivity in "green" buildings, and how a 1% productivity increase pays all energy related costs. Moreover, a 10% productivity increase can pay for the entire building technology.[43] On the other side, the average cost increase compared to a normal building is just around 2%.[44]

However, many studies are questioning the effective coherence between the LEED certificate and the effective building performance.

Active House

The Active House certification goes beyond the

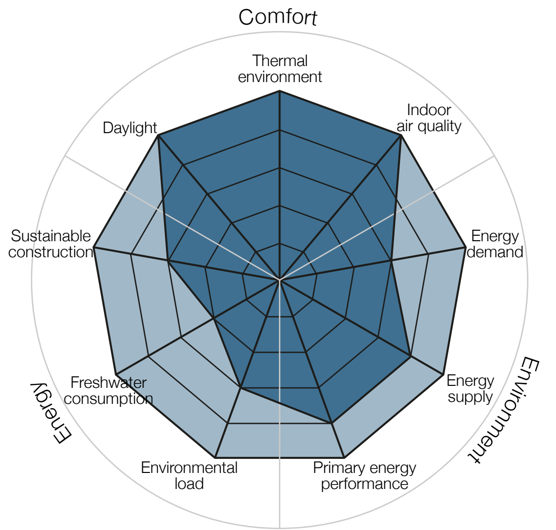


Chart 15: Graphical representation of Active House evaluation

founding principles of LEED. Its approach, promoted by the Belgian non profit association Active House Alliance, "supports the vision of buildings that create healthier and more comfortable lives for their residents without impacting negatively on the climate and environment".[45] It introduces an holistic approach that integrates comfort, environment and energy at the same time. These three parameters are ranked separately 1 to 4 and then compared, following specifical guidelines.[46]
More in detail, the subcriteria are:

- Comfort:
  - Daylight
  - Thermal environment
  - Indoor air quality
- Energy:
  - Energy demand
  - Energy supply
  - Energy performance
- Environment:
  - Environmental loads
  - Freshwater consumption
  - Sustainable construction

The Active House specification does not have rigid limits on any of the single parameters. In fact it considers the overall performance of the building related to human comfort.

Passive House

The Passive House Institute is an independent research institute founded in 1996 by Wolfgang Feist. Unlike the Active House standard, in this case there is a set of precise criteria to be addressed in order to achieve the specifications. The space heating energy demand must not exceed 15 kWh/m^{2}a, and the renewable primary energy has to be lower than 60 kWh/m^{2}a. These targets allow to reach savings of up to "90% compared with typical building stock and over 75% compared to average new builds".[47] Even if it has stricter standards than the previous case, the comfort evaluation is left a bit in the back, losing part of the Active House approach.

Nearly Zero Energy Buildings... and beyond

The next step, nowadays future target of the European building regulations, is the nearly, or even totally, zero energy consumption.[48] The energy

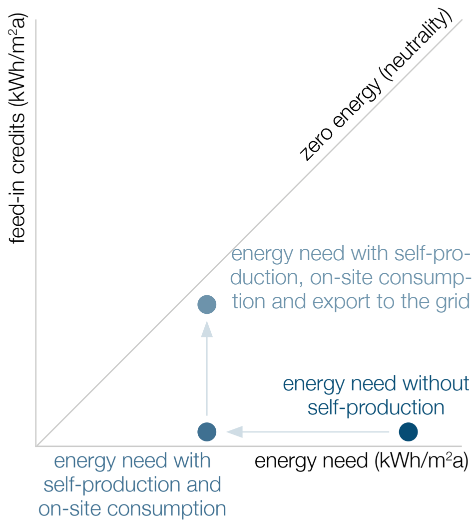


Chart 16: Visual representation of NZEB concept

performance of a building is determined considering the primary energy needed in a year to heat, cool and run its appliances. In this case, the renewable energy is considered as "negative" energy, so that if the building has a self production, this is subtracted from the energy required from the grid. It is important to point out this detail, that means that the building is deemed "zero energy" even if its energy consumption is covered by its self production. Indeed it is sufficient that the total amount of energy bought from the energy supplier on an annual basis is roughly equal to the amount of energy coming from RES (renewable energy sources) sold to the grid.

The definition of NZEB, however, is ambiguous, and there is not a standard that qualifies a building in such a way. EU member Countries are free to set the requirements according to the common basic principles. The actual parameters can vary due to different climate conditions, previous energy efficient buildings panorama, etc.[49]

The same approach brings to the so called "beyond zero energy buildings". They can be defined as buildings that produce an amount of energy from RES which is higher than the one used on an annual basis.

However, before completing the transition towardas a ZEB (or beyond) goal, there are some problems to be solved. The first one is related to the lack of concurrence between the production of renewable energies and their consumption. More in detail, the renewable energy sources are:

- limited (in a unit of time)
- discontinuous (during the day, but also between seasons)
- require conversion

The biggest dilemma to be addressed is then the creation of a temporary energy storage, namely a battery, able to stock and release the energy when respectively produced and required by the user (or users). Instead the only "big battery" that can be today found on the market is the grid itself, that still relays on fossil fuels to accomplish its role.

The second one is to integrate the zero energy concept within a wider "sustainability" concept. Not only the environmental, but also the social and economic aspects have to be addressed at the same time. These topics are not independent, since none of them can exist without the other, especially in a world in which the impact of this approach on the urban realm will get bigger and bigger. Indeed only making people to accept this transition, and making it economically competitive, as it will be explained in the next paragraph, the built environment will be able to become really sustainable.

State of the art of energy efficient buildings

The German case on housing energy efficiency

The European panorama is nowadays populated by buildings of different ages, that span from medieval to contemporary realization. It is then very complicated to make a general consideration on the average energy consumption of European dwellings, considering different techniques, climate conditions, use, appliances, systems and more. However, the European Energy Agency (EEA) tried to give an average overall reference value of per capita final energy consumption in the household sector. In 2016 it was of 6.51 MWh/person (6.16 MWh/person in Italy).[50] This means that, on average, European households consume 195 kWh/m²a (143.2 kWh/m²a in Italy).[51] These values are both very far from the new objectives that EU is self imposing. Then, what can be done to improve the current standards?

Actually, following EU objectives, along with the progress in the buildings design we can say that, nowadays, there is convergence between market, public opinion and energetic concern. The panorama shows a continuous improvement in building performances, that follow the provisions

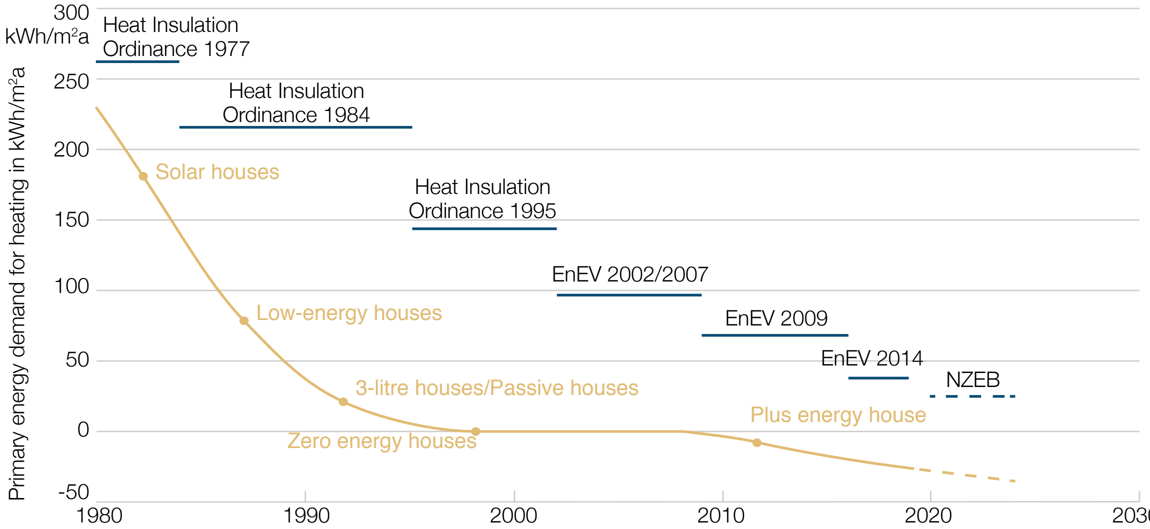


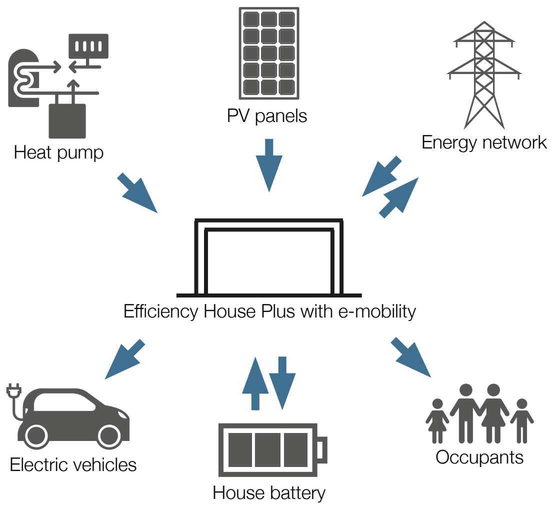
Chart 17: Developmental progress of the primary energy demand of semi detached houses over the last 36 years in Germany

of the previously analysed standards and go even beyond.

To show how these goals can be concretely reached and condensed, the case of Germany is analysed because among the most evident and advanced. So far Germany has indeed assumed a leading role in climate protection. If in the past the subjects of energy saving and energy production were primarily considered from a mere economic perspective, today the ecological perspective is becoming increasingly relevant.[52] One for all, today German population considers the energy efficiency of their house the major parameter to consider when choosing to buy a new house.[53]

The government chose then to start financing a series of projects aiming to reach energetic self sufficiency in buildings, following the progress of the primary energy demand of semi-detached houses of the last decades. In 2007, for example, the Technische Universität (TU) Darmstadt developed a plus energy house as part of the Solar Decathlon competition, winning it and repeating the victory in 2009. The model was used by the federal building ministry (BMVBS) for presentations and exhibitions, and other similar projects followed.

Figures 1 and 2: Demonstration house in Berlin



Gross floor area	181 m2
Net floor area	147 m2
Gross volume	645 m^2
Heating requirement	21.1 kWh/m^{2}a
Heating (air/water heat pump)	5.8 kW
Hot water tank	288 l
Ventilation	400 m3/h
Heating recovery	> 80%
Roof solar cells	98.2 m^2 (14.1 kWp)
Facade solar cells	73.0 m^2 (8.0 kWp)
Projected energy generation	16625 kWh
Projected energy consumption (including 30000 km annually for driving - 2 cars)	16210 kWh
Project balance	+415 kWh

Chart18, table 1: Functioning concept and technical data of the demonstration house in Berlin

The most relevant case so far realised, both for the amount of aspects simultaneously examined and the performance reached, is a demonstration house in Berlin which wanted to put together the efficiency house plus standard[54] with electromobility. The competition, won in 2010 by the University of Stuttgart, the Institut für Leichtbau Entwerfen und Konstruieren (Institute for Lightweight Design and Construction), headed by prof. Werner Sobek, and the Institute for Building Energetics, asked to "define the current state of development of the networking of energy-efficient, sustainable construction and living in the Federal Republic of Germany, using an actually constructed, architecturally attractive pilot research project."[55]

To be defined "Efficiency House Plus" the building has to achieve both a negative annual energy demand and a negative annual delivered energy demand, plus the usual requirement of the Energy Saving Ordinance (EnEV).

The energy efficiency is reached by:

- building design:
  - compact building form: lower A/V ratio are both lower energy demanding and cheaper
  - optimum orientation
  - zoning of the building: bedrooms and kitchen can have lower setpoints than the rest of the rooms
  - building services in the core of the building for lower pipes and to use heat losses from the heating system
- thermal insulation: highly efficient windows and thermal insulation systems for the opaque envelope
- optimised workmanship: no thermal bridges with zero tolerance, airtight structures and structural connections
- energy-conscious behaviour on the part of the occupants: smart metering, energy use displays
- higher occupant comfort: warm surfaces generate a better feeling of comfort
- low system temperatures
- heat recovery systems
- household appliances with the highest energy ratings and efficient room lighting

Additionally, renewable energy can be actively or passively used in the buildings. Solar gains through windows and thermal solar collectors, geothermal heating, photovoltaic panels and wind turbines all concur to help the "plus" side of the buildings.

In the specific case the house was designed with a central energy core and two parts, one private, one public, where a testing family could live and where people could have information about the house. The standalone building has a compact, rectangular shape, and the total amount of PV surface is greater than the actual skin of the habitation module. On the other side, the public part hosts two charging points for cars and one for an e-bike. The energy core hosts all the systems needed for the functioning of the house, comprising a Li-ion battery necessary to store part of the produced energy and to release it during the peak hours.

Thanks particularly to the availability of energy storage this building, as well as others of its kind, is able to reach a higher self-sufficiency from the grid than buildings that only produce energy. Analysing a high number of NZEB houses nowadays built in Germany, it was found that self-sufficiency passes from an average of 26% to 47%, according to the German government, when a battery is used (considering net energy). Notably the amount of PV-produced energy sent to the grid is in general reduced, avoiding excessive stress on the grid.

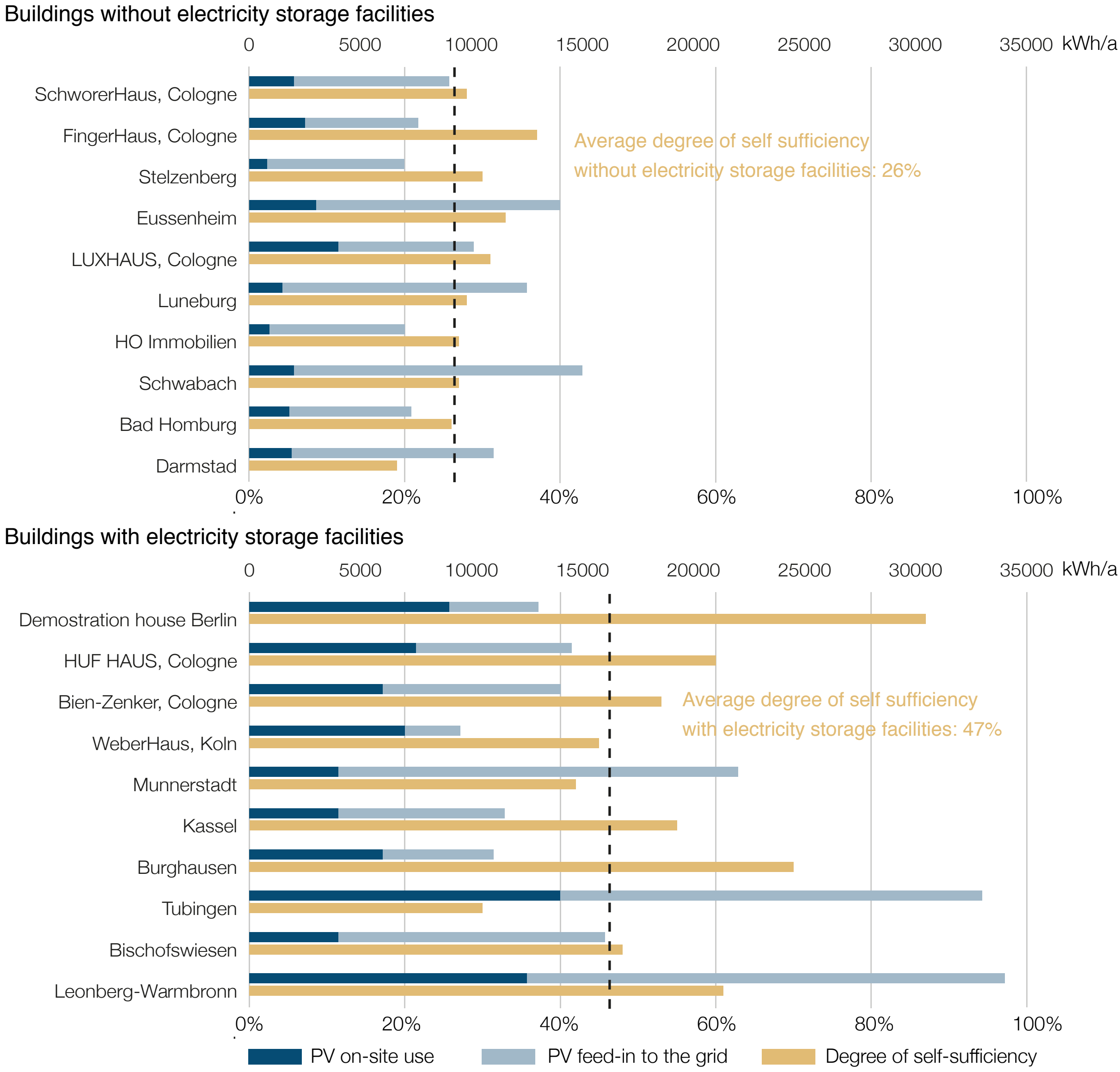


Chart 19: Personal use, feed-in and rate of self-sufficiency of the PV power in the second year of monitoring for projects in Germany with and without electrical storage

The next problem: energy efficiency regarding office buildings

Office buildings represent a different issue, for some aspects, from housing energetic efficiency. Their performance is often left in the background by tenants, since there is less pressure by the personal concern regarding the consumption of the building, like it can happen for houses, as explained in the previous pragraph. Instead the impact of this kind of building is very important, and sometimes it is even bigger than the one related to the residential sector.

Some actions have been taken, like the grading of the already explained LEED certificate. However, there is often less freedom in layout, orientation or design alternatives for this kind of buildings. Very often they have to be mid or high rise, mostly glazed, with mechanical ventilation and have a series of internal loads (workstations, lighting, systems) that make it very difficult to reduce, at first sight, their energy demand.

The University of Washington's Center for Integrated Design tried, however, to overcome these boundaries designing a case study analogous to the demostration house in Berlin, but for office

Figure 3: Bullitt Center, Seattle

Floors	6
Gross floor area	4800 m²
Roof solar cells	1300 m² (242 kWp)
Geothermal wells	26 (120 m deep)
Rainwater tank	200000 l
Heating recovery	65%
Treated water infiltrated to the ground	61%

Table 2: technical data of the Bullitt Center

buildings. The Bullitt Center, located in Seattle, opened in 2013 and was designed to be "the greenest urban office building in the world".[56] The aim was to design a commercial building able to produce more energy than the actually needed, and to inspire a new approach towards truly sustainable design.
To reach these goals the design process focused on four main categories:

- Building life cycle:
  - 250 year designed structure
  - 50 year designed skin
  - 25 year designed technology
- Net zero water
  - Rainwater collection
  - Greywater treatment on site
  - Waste water compost on site
- Net zero energy
  - Renewable energy produced on site (with the grid used as battery)
  - Heat recovery air system
  - Natural ventilation
- Occupants
  - Internal cap on usable energy
  - Incentive on using stairs

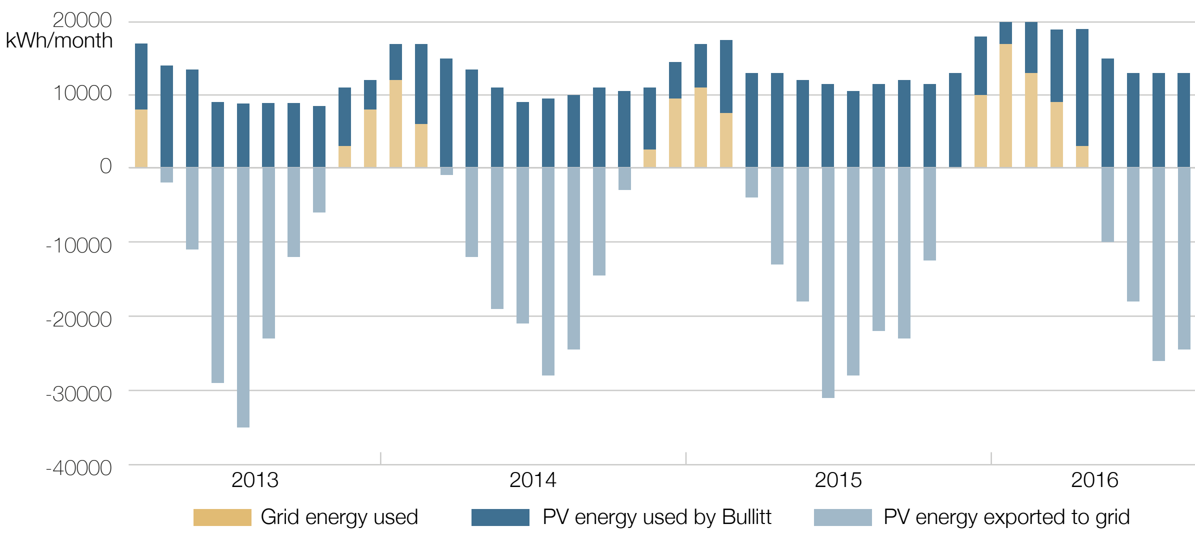


Chart 20: Bullitt Center performance over the first years monitored

This so-called performance-based design approach made it possible to maximize the efficiency through all phases of design. More in detail, the building form, the daylight penetration and control, the building envelope, the windows and exterior shades and the systems were all optimized to work together and to achieve the highest results. Plus, internal loads were reduced by adopting solutions like laptops in place of workstations and using efficient lighting systems.
The result, as showed by the diagram, is that, as in the case of the model house in Berlin, the overall amount of energy produced by the PV panels is higher than the energy required by the building during the year. However, the entire system still relies on the grid as external battery.

Towards an energy integrated system

The shift between energy production and consumption is then an important issue, attracting growing attention as the amount of RES use increases within the energy generation landscape. Renewable energy sources, especially non-programmable ones (photovoltaic and wind power) bring indeed to a decrease in network safety and its reliability.

Charts show how from day to day, or month to month, the percentage of non-fluctuating (from fossil fuels) and fluctuating (from RES) energy can change significantly. Hence the need by the system of becoming as autonomous (off the grid) as possible.

Looking at the photovoltaic production only, it can be assumed that the generation goes with the solar radiation, and then it varies with the seasons, but is more or less stable during a short period (e.g. one week). At the same time, the production has a regular fluctuation during the 24 h of a day, with its peak at noon. This doesn't overlap very well with the energy need of residential buildings, that show several peaks and depressions during the same day, due to different behaviours of the inhabitants. On the other side, office (or retail) buildings show a more regular energy utilization, that has approximately the same fluctuation of the production. If tertiary activities could not need a big energy storage, residential buildings need an adaptation in energy usage.

Since big energy storage are today not available, however, or at least still under development (see next chapter) the answer could go in the direction of creating a so-called smart grid. A smart grid is an electricity system that can integrate the actions of all stakeholders connected to it in order to ensure economically efficient, sustainable, and safe power supply. Its power is that from a mono-directional scheme there is a shift to a bi-directional, or shared, scheme.

Generation>Transmission>Generation>Consumer

↓

Generation<>Transmission<>Generation<>Consumer

This is possible because the final user becomes himself a supplier, even if only during some hours of the day. A smart grid requires, of course, a complex, integrated system able to manage production and demand from different sources and with constantly changing values. Its components then comprehend:

- smart generation: to optimize the operation of

various generation sources depending on network conditions and consumption patterns
- smart network: to ensure reliability, quality and security of the network through action-reaction mechanisms involving both generation and consumption sides
- smart metering and active demand: to make the consumer an active subject into the system, through monitoring and interaction mechanisms with other actors of the system

To be able to do so, it is required to:

- determine the optimal load into different transmission/distribution network sections
- automate maintenance operation
- infrastructure control optimization
- grant bi-directional communication among consumer and electricity system and to have real-time information to consumer about his consumption profile
- elaborate energy consumption forecasts as a function of work program set by the user[57]

The strength of this approach is that energy could be used in a more efficient way, reducing the stress on the grid. The PV energy, for example, could be directly used by an office building, that requires a lot of energy during the day, even if it is produced by the roof of a nearby house. This would avoid (or reduce) the use of the main grid to transfer the energy, resulting in a smaller need of energy to the main supplier (e.g. a fossil fueled power plant) and smaller losses due to energy transport. At the same time, when the house will need energy in the evening, it will have an energy bonus proportioned to the amount of energy provided during the day that it can use at almost zero cost (because paid by the building that used its energy during the day).

The subsequent step is to go towards an ener-

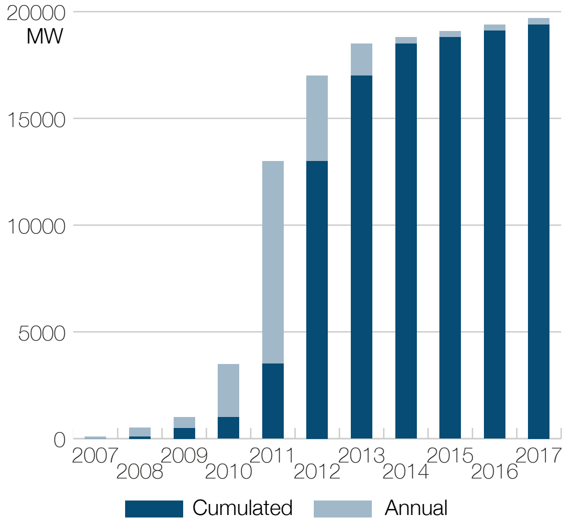
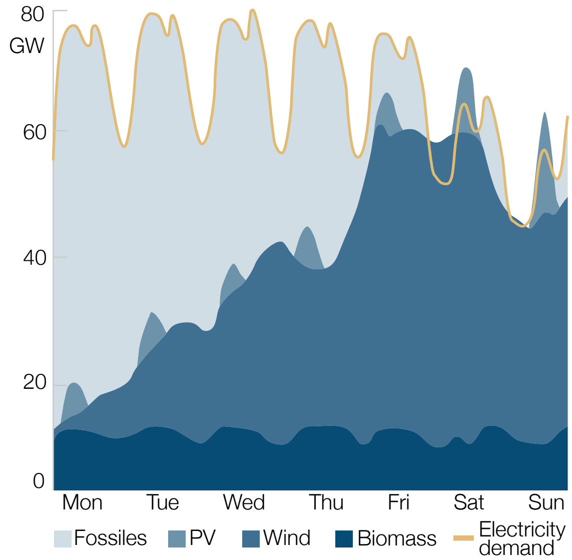
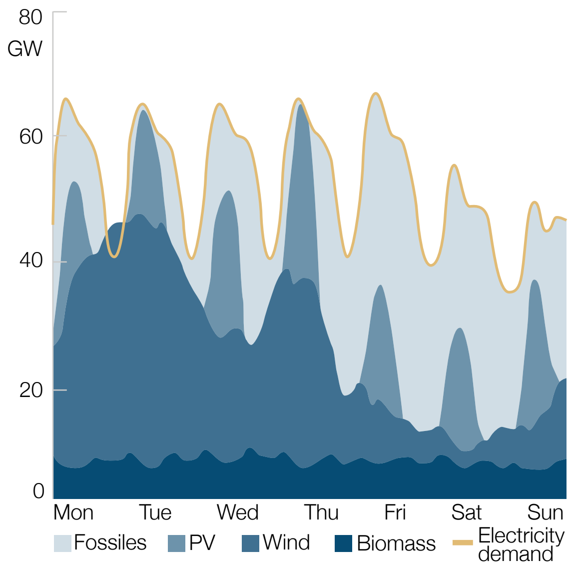


Figure 21: Evolution of Italian cumulative PV installed capacity 2007-2017





Charts 22 and 23: Simulation of German grid in 2022: daily and seasonal fluctuations, February (6th week) and August (33th week) gy community concept. The term refers to a set of consumers who decide to make a common choice regarding their energy need satisfaction in order to maximize the benefits resulting from this kind of "collegial approach", through the implementation of distributed generation and smart energy management solutions. Its stakeholders can be residential, industrial and tertiary buildings, both on-grid, so connected to the main grid, or off-grid. The decentralised production is in this case not only limited to the single buildings, but it can comprehend bigger power plants (however from RES) which property is shared among several users.

One benefit of energy communities is that they can help to increase acceptance of renewable energies, and citizen involvement can overcome resistance to infrastructure development (e.g. big wind turbines).[58] Another positive result is that even citizens that are not able to invest in RES plants, like PV panels, or that lack a suitable surface (such as in ground floor apartments), as happened for example in Malta,[59] can invest in a share of a bigger power plant and benefit from its energy production at lower fares.

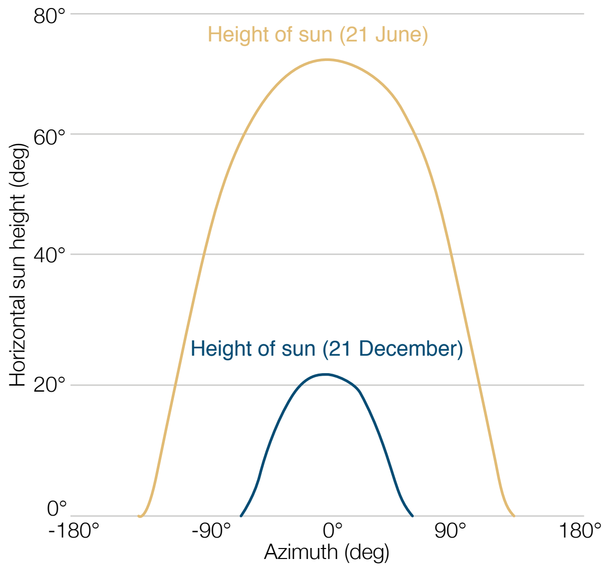
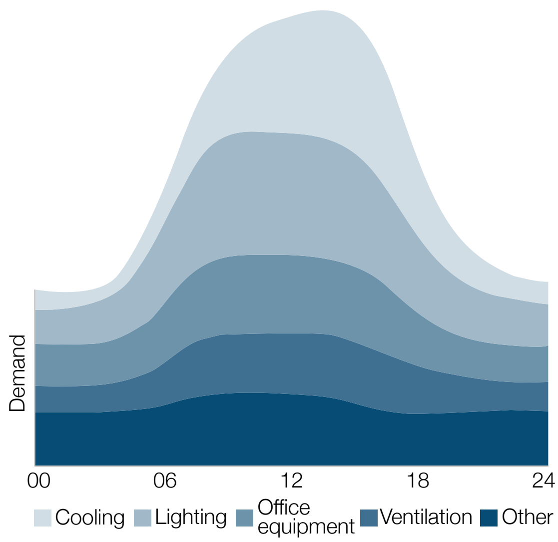


Chart 24: Height of the sun on the horizon in Milano



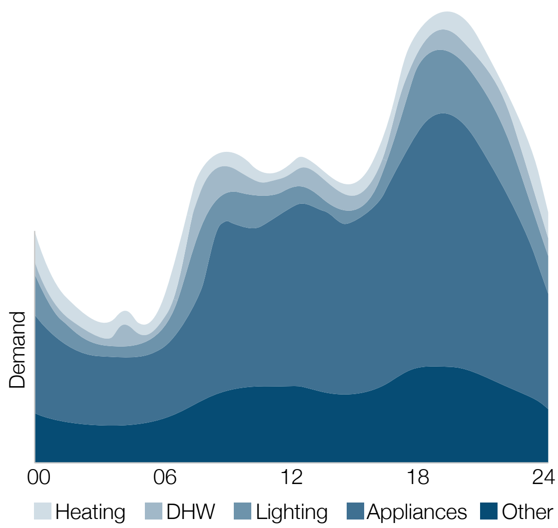


Chart 25 and 26: Energy demand profile in office buildings, Energy demand profile in residential buildings

Plug-in electric vehicles: technology, infrastructures, market and impacts

Technologies, infrastructures and market of electric vehicles

As described in the first part, European and Italian institutions are moving in the direction of electric mobility, giving instructions to countries and organizations. In this part the concept and the implications of electric mobility are going to be analyzed. First of all, to give a general overlook on electric vehicles and infrastructures, it is necessary to explain what electric mobility is.

The FIA, an international association that represent car manufacturers and users, defines e-mobility as "referred to vehicles that use electricity as the main source of energy, with possibility to recharge the battery by connecting with a socket to the grid".[60] The Erneuerbar Mobil (Renewable Mobility) project, sponsored by the German Minister for the Environment, answers to the question saying that e-mobility "comprises all street vehicles that are powered by an electric motor and primarily get their energy from the power grid"[61].

From this sources and from the reading of European and Italian legislation about e-mobility[62,63], we can notice how the definition include both electric vehicles and the infrastructure needed for charging. For this reason this part is divided in four different paragraphs. The first and the

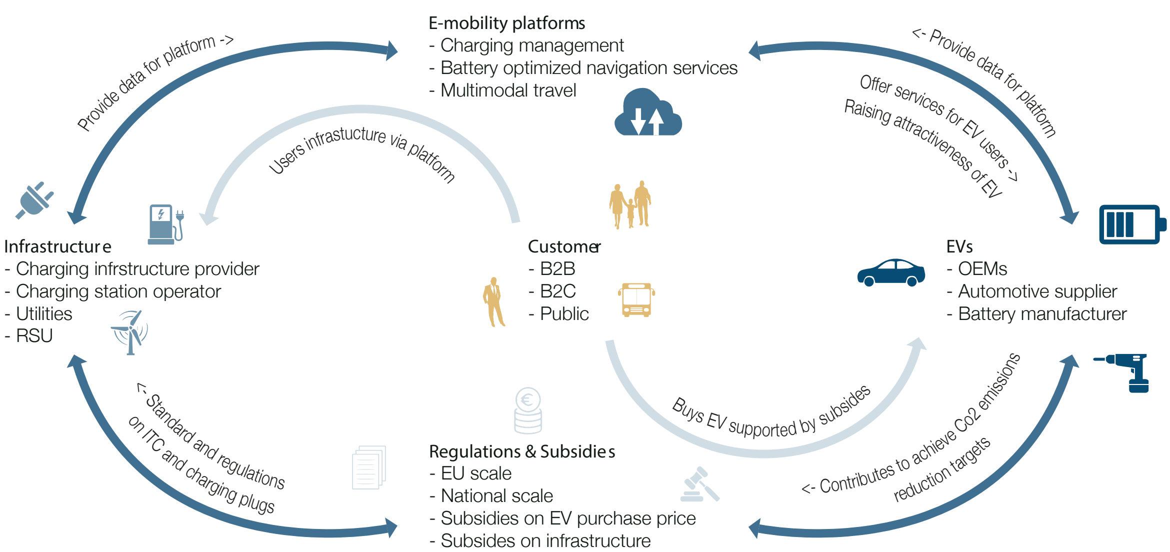


Image 4: The ecosystem related to e-mobility

second parts are about respectively vehicles and infrastructures for charging, introducing different technologies and typologies. Then the market of electric vehicles and its trends will be briefly presented, comparing different geographic areas. The fourth part will introduce the advantages and problems related to the diffusion of electric vehicles. Then the conclusion will present a brief overview on possible future developments of e-mobility.

EVs technologies

Technological elements in EVs may differ in many ways depending on the purpose, the cost and the performances that the manufacturer wants it to have. The biggest issue to be tackled regards the storage of energy to be used by EVs. Traditional cars are powered with an engine that works using fuel kept in a tank. Instead EVs are provided with a motor that needs electricity to function. Its storage becomes even more important considering the need to mitigate the fluctuation of production typical of RES, more and more relevant in today's energy production panorama. The problem is nowadays solved with the use of batteries, that however can vary significantly among them.

Engines

The drivetrain of a typical Plug-in EV is shown in Image 5. PHEVs have larger batteries and more power converters than hybrid vehicles, being electricity the only way to power the motor[64]. The different functionalities of the PHEVs (charging, discharging and propelling) can be controlled by the bidirectional converter. Every function has a power electronic interface (PEI), i.e. the PEI for propelling mainly consist of the motor inverter.

Charging

Image 5 shows two different charging approaches, conductive and inductive. Conductive chargers have wired connections and can be on-board, with internal regulation, or off-board, where the PEI for charging is installed externally guaranteeing a faster charging. Inductive chargers are contactless, using the principle of magnetic induction, and are composed by a transmitter (off-board) and a receiver (on-board) coil.

Batteries

In order to find the best adaptable to EVs, these elements have to fit on the bottom of a car, have low-cost technology and high performances. Technologies such as Compressed air (air compressed and stored into the ground, used with natural gas) or pumped hydro are exceeding dimensions for this purpose. Flywheels (rotors spinning in the void) and superconducting magnets have too high implementation costs to be suitable for a large production market as the EVs one. Then different types of batteries have been adopted in ground vehicles due to their charac-

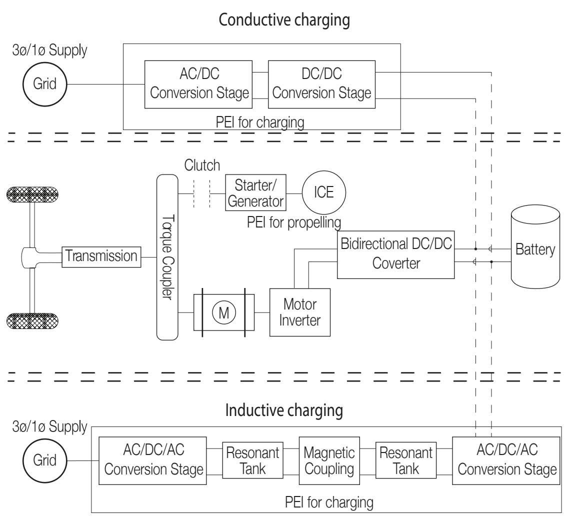


Image 5: Propelling and charging PEI of a typical PHEV

teristics in terms of high energy density, compact size, and reliability.
Most common type of batteries that can be used on EVs have been analyzed in different studies[65,66,67] and are summarized as follows.

- Lead-Acid:
The diluted sulfuric acid is the electrolyte between the spongy lead (negative) and the lead oxide (positive). This type of batteries s available in production volume, guaranteeing a low cost power source. However it has a limited life cycle and low energy and power density.

- Nickel-Metal Hydride (NiMH):
These batteries work using Nickel hydroxide as the positive electrode, an alkaline solution as electrolyte and different metals (Ti, V, Ni, Zi, Cd and others) as the negative electrode. The NiMH batteries have high energy density, recyclable and harmless elements and wide temperature ranges. Depending on the metal paired with Nickel these type of batteries can have low resistance to fast discharges, poor life cycles (Zn) or highly pollutant products (Cd).

- Lithium-Ion:
The lithium-ion batteries have excellent performances in portable electronics and medical devices, they work with oxidized cobalt as positive electrode and a carbon material as negative. The lithium salt in organic solvent is used as the electrolyte. These batteries has high energy and power density, good high temperature performance and are recyclable. The cost is higher than other types of batteries, but recent investments in research have the goal to solve this problem. Lithium-Ion battery is the main technoogy used by car manufacturers at the moment, being it the best option available in the market.

Fuel cells (hydrogen):
The FC generates electricity from the reaction between the fuel (H) and the oxidant (O), with the presence of products of reaction (H_2O). Advantages for the FC include high conversion efficiency, quiet operation, near to zero emissions, flexibility and reliability. Hydrogen is an ideal fuel, having the highest energy density and water as the product of reaction. The main problems are the relatively high cost of the battery, the need of a large tank for hydrogen and water, and mainentance problems (such as the possibility of freezing of the water).

- Flow batteries:
Flow batteries work with the flux of two liquids, one reducing and the other oxidizing, that causes a flow of electrons. The direction of this flows determines the charge or discharge of this type of battery. The low cost and high performances of this type of batteries promote them as the principal competitor of Lithium-Ion battery. A comparison was done in order to determine which is the best choice for EVs batteries[68]. Even if yhe aim of the reference was to determine which suits better for a house battery, the dimensions, the use and the performances needed were comparable with car batteries. The results are in favor of the Lithium-Ion batteries, that bring to more savings in time even with less efficiency.

- Future developments:
Battery technologies are evolving, thanks to the increase of the market and of research on EVs. For example, a paper published by Toyota[69], emonstrated the feasibility of solid state lithium-ion batteries. This technology is seen as the future of EVs batteries, as it has better performance than the one with liquid electrolyte. Up to 23.000 charging cycles, temperature ranges between -30 and 100°C, 70% increase in volu-

metric energy density and 50% less impact on energy demand during the lifecycle are the main advantages of solid lithium-ion batteries[70].
Other possibilities for EVs bateries can be molten-salt batteries (new flow batteries), super-capacitators (batteries with millions of charging cycles) or printed batteries (with a thickness of only 2 mm)[71].
The overall goal is to reduce nowadays consumption of kwh per km. If today the average values (considering inefficiencies) span between 0.3 and 0.18 kWh/km, the aim is to reach performances till 0.15 kWh/km[72] , today reached only by small citycars with small ranges, and beyond.

In the table 3 we can see a comparison between the 10 most sold PEVs in 2017[73] and their technical specifications, plus the Tesla model 3 that reached the sells record in 2018[74]. As we can see in the table, every column has a huge variety of values, meaning that the success of an EV doesn't depend on better performances or lower costs but on the combination of these values. Tesla confirms to have better performance but with higher prices, especially than Chinese competitors. Toyota managed to be on the podium even with lower performances, probably because of good hybrid compromise with combustion engine.

EVs infrastuctures

Infrastructure for EVs is a key factor for its development and diffusion[75]. This includes charging points, energy production and buildings to vehicle connections. Not only car manufacturers are focusing on the theme, also governments and research centres are providing a series of different answeres[76]. For example studies[77,78] financed by energy companies have been developed in order to improve the existing methods or to find new ones, here are summarized some of them.

Out of service interaction

This type of interaction charges vehicles when they are out of service, while they are stopped in a parking or outside the house. This is the most common for passenger vehicles, because it is the closest to the traditional way and the cheapest to install. The charging speed depends on the electric power that a charging station can provide[79]. Higher power means more expensive, bigger

	Sales [/]	Engine [kW]	Battery [kWh]	Range [km]	Charging [max kW]	Cost [k€]
Chevrolet Bolt	27982	150	60	380	36 - 90	34.9
BYD Song EV500	30920	110 - 160	61.9	500	60	24.2
BMW i3	31410	125 - 137	22 - 42.2	130 - 183	7.4	37.5 - 45.8
Renault Zoe	31932	66 - 80	22 - 41	210 - 400	43	27
Zhi Dou D2	42342	30	18	155	\	6
Tesla Model X	46535	193 - 375	75 - 100	383 - 475	22 - 120	96 - 157
Nissan Leaf	47195	110	40	243 - 270	6.6 - 50	31.2
Toyota prius prime	50830	23 - 53	8.8	40	\	35.8
Tesla model S	54.715	581	60 - 100	401 - 539	22 - 120	70 - 146
BAIC EC	78.079	36	22	162	\	7,2
Tesla model 3	1.060*	258 - 340	50 - 75	350 - 500	22 - 120	36 - 87,5

Table 3: technical specification of 10 best car sold in 2017 and Tesla Model 3. **139782 in 2018.*

and noisier equipment required. In table 4 different typologies of charging stations, are explained according to different uses and properties.

Spot interaction

In this case the vehicle is charging only on specific spots positioned on the way and for a limited time. This type of interaction can be used on public transportation, where the stops are fixed, frequent and equally distributed on the route. The vehicles can charge using a moving elements as in Image 7 or wireless connection with the transmitter positioned on the stop. This kind of interaction is cost saving, as the infrastructure do not have to be continuous but can be limited to bus or train stops.

Continuous interaction

In this case the vehicle is continuously taking electricity from the grid, as it happens for trains and trams. The vehicle freedom is limited, having to follow the route imposed by the charging infrastructure. This limitation could be overcome using inductive continuous charging, or vehicles that can attach to the infrastructure just in case of need. Manufacturers imagine vehicle with moving elements that can rise and link to the top infrastructure just when charging is needed. Another option is shown in Image 6, where a specific aisle is equipped to charge wireless cars while they are passing by. However this case is particularly critical, due to high costs of installation and maintenance.

EVs market

The global market of electric vehicles is increasing year by year, exceeding the million cars sold

Use	Type of charging	Power [kW]	Charged range [km]
House	Mono AC	7	30 - 50/h
House	Fast DC	22	100 - 150
Parkings	AC	22 (7)	30 - 50/h
Parkings	Fast DC	25 - 50	120 - 300/h
Charging station	Fast DC	50 - 150	120 - 400 in 30min
Charging station	Ultrafast DC	350 - 500	300 - 400 in 10 min

Table 4: typologies of out of service interaction

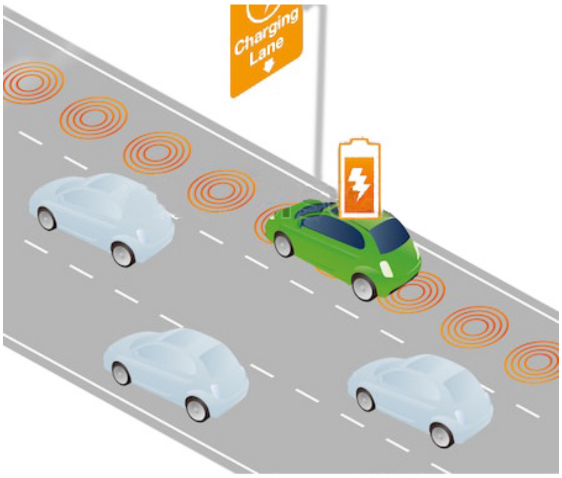


Image 6: highway equipped with charging aisle

Image 7: bus stop with spot interacion

during 2017[80]. A research project made by Cambridge Econometrics[81] foresees that in 2030 the number of electric and hybrid vehicles on roads will be 50% of the total in EU, reaching 100% in 2040. The impact of EVs will soon be relevant in the public and private spheres, modifying our cities and lives.

It is important to note that with EVs it is intended the sum of BEVs and PHEVs. Indeed in the charts we can see a difference between Plug-in Hybrid-Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs), the first paired with a traditional fuel engine, the second working only with an electric motor. However these two typologies work with similar technologies and have same benefits and problems, moreover the Chart 28 is showing how EVs are going to overcome all different types of vehicles in twenty years.

As shown in Chart 27 and 28 the EVs market is quickly increasing, helped by smart policies and a general consciousness about the benefits of using electric cars. Another reason for the quick increase of EVs in the market is the reduction of time needed by people to adopt an innovation[82] .

A huge increase in EVs sales was registered in the United States, with an increase of 63% compared to the same period of 2017[83]. This increase was mainly due to the sells of the Tesla model 3. In the first half of 2018 there were still ramp-up problems, but after that problems were solved Tesla sold began to rise. This increase reflected on the global market and the EVs sales grew quickly in July, August and September, reaching more than 100% of the increase respect the previous year.

At the same time in a report about Europe published at the end of 2018[84], it is shown how the sales are highly increasing every year. The sells are pushed even further by a series of national policies aiming to increase EVs diffusion. Only looking at 2018, the year was eventful regarding

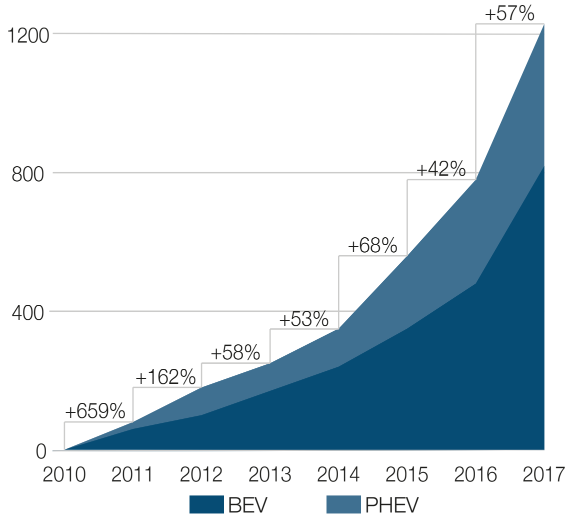


Chart 27: global EV sales in thousands of cars and annual growth rate

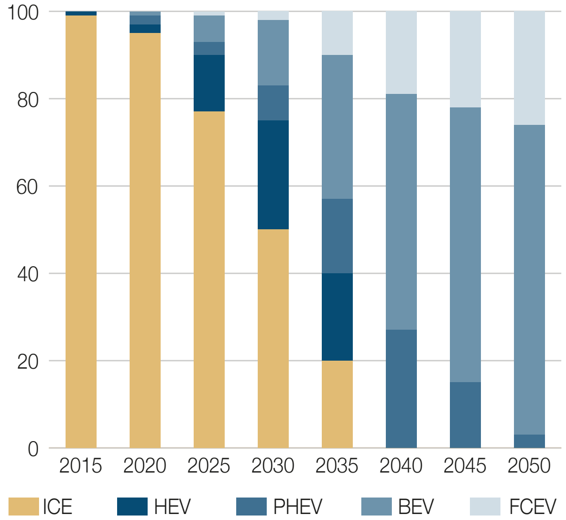


Chart 28: the evolution of new vehicle sales by technology type

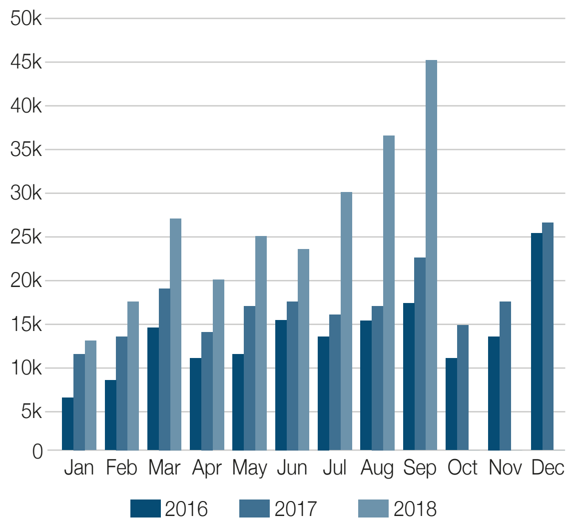


Chart 29: monthly EV sales in USA in 2018

policies. In Sweden the Bonus-Malus taxation system was approved[85], Germany announced the Berlin package[86] and the WLTP certification has been applied from September the 1st[87]. Most European markets showed growth in 2018, with countries such as UK, Germany and Netherlands climbing the charts thanks to a growing consciousness. In total, Europe EVs sales grew by 35% compared to 2017.

On the other side of the world China is shaking the car industry with an increasing uptaking of EVs. The growth in the first half of 2018 reached 114% growth respect the previous year for passengers cars and 60% for electric buses[88]. The EVs share reached the 4.2% of the total, comparable with percentages of most of European countries. This growth is mainly due to the presence on the market of BAIC BJEV, electric vehicle units of Beijing Automotive Group, and BYD that owns the majority of Chinese EVs market. This companies managed to find a good compromise between cost and battery efficiency, focusing on the Chinese market. The expected cars sales at the end of 2018 are about 2.35 million EVs, 90% more than the previous year.

To conclude, global sales in the first half of 2018 are greatly rising, with an increase of 66% over the same period last year and 783000 units sold. China stands for 51% of the global volume, 2 times more than Europe and 3 times more than USA[89]. It needs to be considered that China holds 18% of the world population, while Europe 8% and USA 4%[90], but the Chinese EVs share on total cars (4.2%) is still higher than most European countries and USA. That probably means that a large part of the Chinese population doesn't have a car, but EVs are diffused between the ones that own a vehicle. Regarding car manufacturers, the Chinese companies are leading together with Tesla and BMW, followed by Nissan and VolksWagen. The only country that registered a drop in

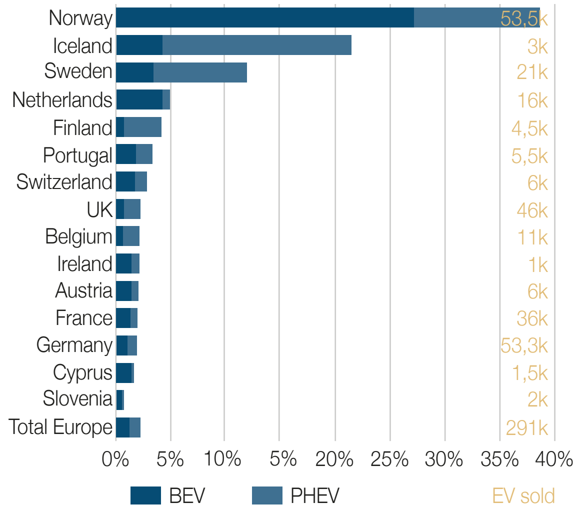


Chart 30: Ev shares of total cars and EV sales in 2018

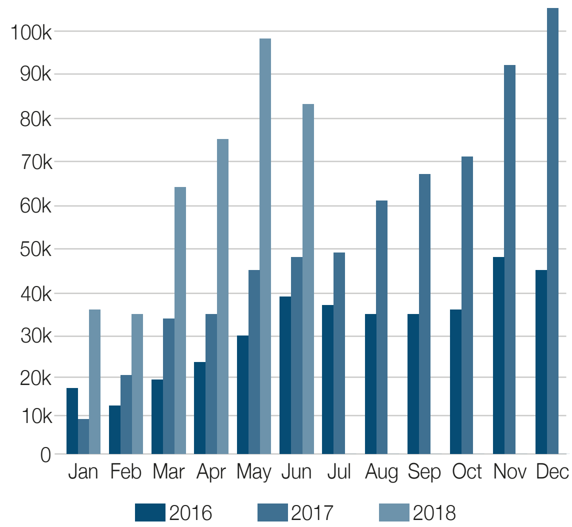


Chart 31: monthly EV sales in China in 2018

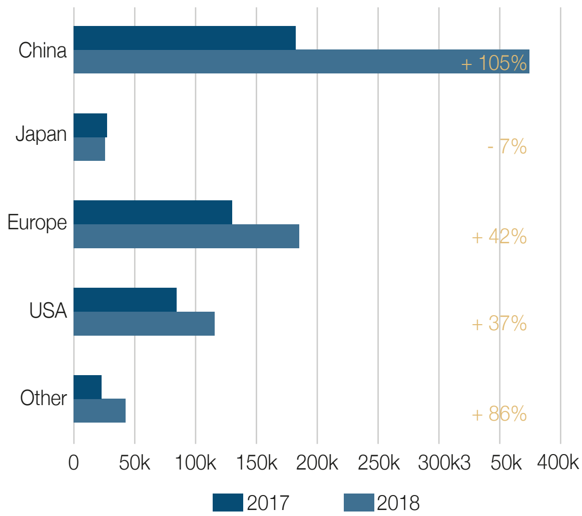


Chart 32: sales and % growth divided by area

Chart 33: Planned investments in the next 10 years by main car manufacturers, grouped by country. The chart doesn't consider investments that are not yet public.

EVs sales is Japan, where the manufacturers and the buyers are focusing more on Hydrogen Electric Vehicles, not taken into account in this graphs.

The future investments regarding EVs also show how the biggest investors are German, Chinese and American car manufacturers. Overall, it is calculated that in the next 10 years 300 B$ will be invested in electric mobility market, only considering public investments. The biggest beneficiary will be China, with contributions coming from most of the Countries investing in e-mobility.

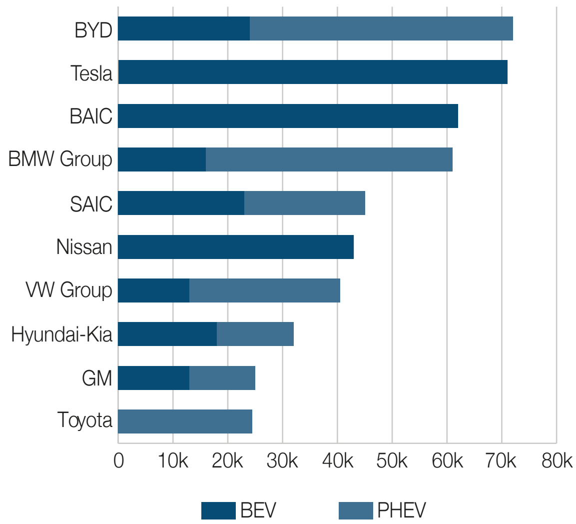


Chart 34: sales divided by car manufacturers

Present and future impact of electric mobility

Environmental impacts

The analysis of environmental impact of e-mobility is complex for many reasons. Firstly, data are missing, as the sales are rising in these last years and not enough time has passed to collect information. Then the complexity and the different typologies of vehicles do not allow researches to make a general conclusion about the impact of EVs on the environment. Most of studies done on the impact of EVs on the environment tries to examine the life-cycle and all different typologies, but in order to draw some conclusions they have to focus on a specific element or type. On one side studies led in Europe on a wide range of EVs[91] demonstrated how electric cars can reduce significantly the environmental footprint, revealing that particularly small-size EVs are useful. Besides that an effective impact can be reached converting used cars from combustion to electric, reducing C02 equivalent emissions by an 80%. The carbon footprint was calculated over 100000 km, comparing a 10 years old Smart with the same vehicle converted to electric.

On the other side researches on Lithium-based batteries life-cycle[92] unveil that the main problem to be solved to guarantee the sustainability of EVs regards the production of Lithium Carbonate (Li_2CO_3). This element is key in the production of EVs batteries, even if it is the 4% of the overall weight of the car battery (12 kg over 300). Natural brines are now used to produce this compound, but it will not be sufficient for a future higher production. In China seawater is used to fulfill the need of Li_2CO_3 and this study supposes that this will be the future way to provide this element on a global scale. Latest news confirm the hypothesis, being USA starting to extract Lithium Carbonate from Bolivian salt desert[93]. Without entering in detail on how this will impact on the environment[94] , the effect of this kind of Li_2CO_3 extraction can be worse than the impact of traditional car engines on natural life. A different way to extract Lithium Carbonate has then to be found in order to guarantee a low environment impact of EVs.

In general, various studies[95, 96] concluded that the main problem of the switch to e-mobility is the life-cycle of batteries. However, the impact on environment is generally better than ICEs, reducing CO_2 emissions, noises and energy losses. Further technology improvements are needed to guarantee a better impact on the environment and better performances[97].

Urban impacts

The International Transport Forum, an intergovernmental organization that counts 57 member countries to manage transport policies, led a study[98] in 2016 where the impact of replacing all car and bus trips has been calculated in a city with mobility provided through fleets of shared vehicles. The consequence was that congestion disappeared, traffic emissions were reduced by one third, 95% less space was required for public parking, and the car fleet needed would be only 3% in size of today's fleet. The adoption of EVs is not directly linked to vehicle sharing, but the trend in all the cities that are adopting sharing policies is to use small electric cars. Less consumption, easy charging and an image of a greener city are the main reasons at the basis of this choice[99]. In a press release of car2go, one of the biggest car sharing companies in Europe and North America, the link between car sharing and e-mobility was highlighted and promoted: "Electric mobility has the potential to significantly change the mobility sector. However, further development is required in order for it to realize its full potential. Carsharing is a huge step ahead in the advancement of electric mobility compared with privately owned vehicles"[100]. Car sharing market is still growing and not enough data were collected to compare its growth with EVs market, but the shared fleet is expected to grow quickly till 2024[101].

Efficiency

Efficiency of EVs is one of the biggest selling point in comparison with ICEs. The official U.S. government source for fuel economy information states that the efficiency (from grid to wheels) of EVs is around 60% while internal combustion engines (ICE) use only 20% of the energy[102]. This portal also ensures performance benefits, with stronger acceleration and less maintenance than ICE[103]. The overall efficiency of the EVs is also improved with systems of energy recover, such as regenerative brake, that can be installed on every EV[104].

Costs

Another important issue in switching to an EV panorama regards the costs that consumers have to face. Its convenience is fundamental to grant that people will leave ICE cars behind them. A research conducted on German possible EVs users[105] concluded that drivers in cities do not profit enough due to short distance of the trip. Instead, drivers living in the suburbs would profit most depending on investment cost, driving distance and the possibility to charge at the workplace. The reason is that short distances do not allow users to have a payback for the higher initial costs, even if EVs have better performances. Another research done on 38000 people living in European cities[106] showed how switching to EVs and car sharing pays off, but only if it has a significant acquisition value. Otherwise, the costs for sharing (staff and control) are higher than the acquisition expenses, that means cars are a good candidates while smaller vehicles (such as bycicle or scooters) aren't.

Social impacts

The diffusion of EVs is changing the life of car users in terms of costs, habits and city landscape, but it also has other social implications. In a future where all vehicles will need this material, the impact on the society and the population of countries where the Lithium Carbonate is abundant (i.e. Bolivia, Chile and Tibet[107]) can be huge, especially on the poorest countries. The new level of richness that petroleum gives to some countries, such as the dramatic events often related, can now be emulated by this new Lithium demand[108].

The path towards energy self-sufficiency

Micro-grid and building-vehicles interactions examples

The first three parts of this chapter provided an overview of the regulatory framework regarding the energy market and future targets in the World and in particular in the EU. The focus was mainly headed to the building, automotive and energy storage sectors, nowadays responsible for the highest amount of energy consumption and related pollution. These sectors, however, show how there is a convergence between technology, market and social concern to evolve towards a more sustainable panorama. There are, of course, some problems that have to be solved in order to achieve this goal, that are related to a specific sector or are shared among them.

The biggest issue, as previously highlighted, is the shift between RES production and energy consumption, that make it difficult to be useful for both the building and the transport sectors over a certain degree of usage. Another big problem, directly related to the previous one, is the struggle in finding a suitable electric energy storage. The requirements of economic competitiveness, high specific energy and small transformation losses have not found common ground yet.

One of the most realistic options could be an integration among these sectors, sharing energy production, consumption and partial storage, for a more competitive and less wasteful system. Then, this section starts from the concept of smart grid, analysing its potential,then investigates further possible developments of this concept. In this way, it establishes a starting point for the future steps of the research.

Smart grids state of the art

The smart grid concept is nowadays a reality. However, it remains circumscribed in a few scenarios, namely R&D departments, research centres (like universities) and energy companies. The investors, instead, are both private and national, and focus in five main application fields:[109]

- Smart network management
- Energy demand management
- Integration of distributed generation and storage
- Electric mobility
- Integration of large scale RES (minor)

Their spread is, on the other side, subject to the market potential, that is the sum of the regulatory framework, the technology development and market factors. The main problem nowadays is related to the return of investment (or Internal Rate of Return), which is the time spanning between the investment itself and the payback of the initial sum of money. Indeed it happens to be largely negative, while to be competitive it should be positive.

Only for the so defined micro grids[110] there is a positive IRR (internal rate of return) of around 1-3%, even if the threshold for this subject is fixed at 6%.[111] So it can't be assumed that the single national bodies or single providers would be willing to pay for a very fast and spread development (up to now). One of the biggest issues to be considered is that who is supposed to invest the money is not the same one that gains the benefits. For example, the installation of smart energy meters, to better manage the energy consumption, will bring advantage to the final user, but not to the energy provider.

On the other hand, energy storage systems begin to be more and more competitive. They would be a fundamental component of a smart grid environment, so their spread would be a fundamental step towards this kind of approach. For instance in Italy they are estimated to have a market potential ranging between 12% and 27% of the overall smart grids market, that is estimated to be between 15 and 60 B€ worth in the next 5 years. Considering that energy transformation and grid inefficiencies cost around 5 B€ per year[112] , the development of smart grids, even if at first sight seems to require huge investments, would anyhow be able to bring long-term advantages.

Smart grid case studies and simulations

Once that a bit of background on smart grids is set, it is fundamental to see what happens when buildings begin to interact among them or with electric vehicles sharing energy. Different projects related to the topic have been going on in the last years, and some of them are more successful or interesting than others.

B10 House

Among them, the B10 House, a research building designed and realised by the University of Stuttgart (ILEK department) together with professor Werner Sobek, completed in 2014. The purpose of the project was to incorporate and improve the experiences previously acquired

Image 8: B10 House

Gross floor area	90 m²
PV panels	65 m²
Installed electric output	10.4 kW_p
House battery capacity	11 kWh
Glazing U_w	0.83 W/m²k
Energy production	8341 kWh
Energy demand	4247 kWh
- of which building servides	1840 kWh
- of which building controls	1208 kWh
- of which household electricity	1199 kWh
Surplus	4094 kWh

Table 5: Technical data of B10 House

with the Efficiency House Plus project in Berlin.[113] An interconnection between built environment, transportation and sustainable energy wanted to be achieved. Moreover, it tried to fulfill the requirements demanded by the Triple Zero standard: zero energy (higher generation than need), zero emissions and zero waste (using renewable or reusable materials).[114]

The single-family demonstrative house was designed taking into consideration several energy savings optimizations like shape, orientation, building envelope, systems etc. It was also provided with PV panels roof and an energy storage of 11 kWh. Moreover, a predictive, self-learning building control system was employed. In this way production, storage and use could be optimised following users habits to have the smaller amount of energy to be exchanged with the grid. After one year of monitoring the house was claimed to generate twice as much energy from sustainable resources as it actually required for its own needs.[115] The surplus energy was used to power two electric cars and, utilizing smart grid technologies, the nearby house designed in 1927 by Le Corbusier, home to the Weissenhof Museum. In this way, it was able to “dovetail energy systems of electro-mobility solutions and buildings to an overarching integral control system”.[116]

Moreover, as shown in the next part of this research[117] , the house was modelled and its interactions with the grid calculated. The results show how it was able to reach an overall self sufficiency of around 38%. This means that half of the energy the building used came directly from the PV panels or from the storage, while the rest came from the grid. However it is important to consider that the house produced a total amount of energy equal to the total energy consumed.

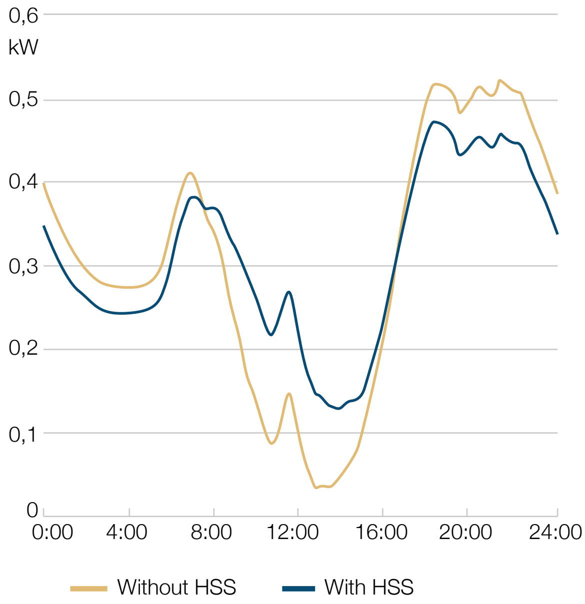


Chart 35: Influence of HSS on the average load per house connection (without BEVs)

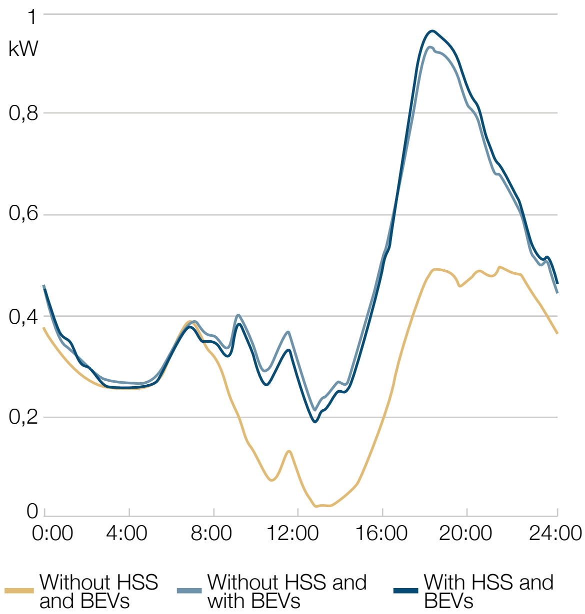


Chart 36: Influence of control and BEVs on the average load per house connection

	Without HSS	With HSS
Connection peak load	163 kW	155 kW
PV internal use	78.5%	87%
District self-sufficiency	23.7%	26%

Table 6: Improvements related to the use of HSS

GP District

Another example on a low voltage distribution grid based on a real grid area was conducted in Garmisch-Partenkirchen (in southern Germany) on a simulation of over one year in 2015. The district counted 202 households with a PV penetration of 18% of the buildings. 30% of these have a home storage system (HSS) with a capacity of 7,5 kWh each.[118] The district had an electric vehicle penetration of 30% on the total amount of cars.[119]

The simulation showed how the HSS had an influence on the overall energy required from the grid, even if only 6% of houses had one. The peak load of the connection between the district and was reduced. At the same time, internal use of PV energy and self-sufficiency significantly grew, as shown in the table.

Moreover, an integration between production and recharging of BEV was carried on. Even if the influence of the HSS was reduced, due to the high amount of energy required by BEV, the optimisation of recharging time showed how there was a reduction of the peak load, typically in evening hours, in favour of around-midday hours. The experiment established, in this way, how storage systems and optimisation can lead to better use of the production and smaller stress on the grid.

Shared energy production in a simulation in Finland

The following step could consist in sharing energy production among buildings. This means that the energy production, coming from RES, is distributed among buildings and not regarded as property of the single ones. Its potential could be to increase energy efficiency, renewable and local resource application and promote energy resilience and security.

The feasibility of this approach was the subject of a research led in a cluster of buildings in Finland.[120] In order to investigate the impact of on-site energy generation and sharing, three cases were set. Case 1 was the base case, following previous measurements. In case 2 the buildings could produce energy (both electricity and heat) but not to share it. In case 3 they could share their production if energy deficits and surpluses occurred.

The optimisation results showed how the primary energy consumption fell to 77% of the base case by distributing on-site CHPs (combined heat

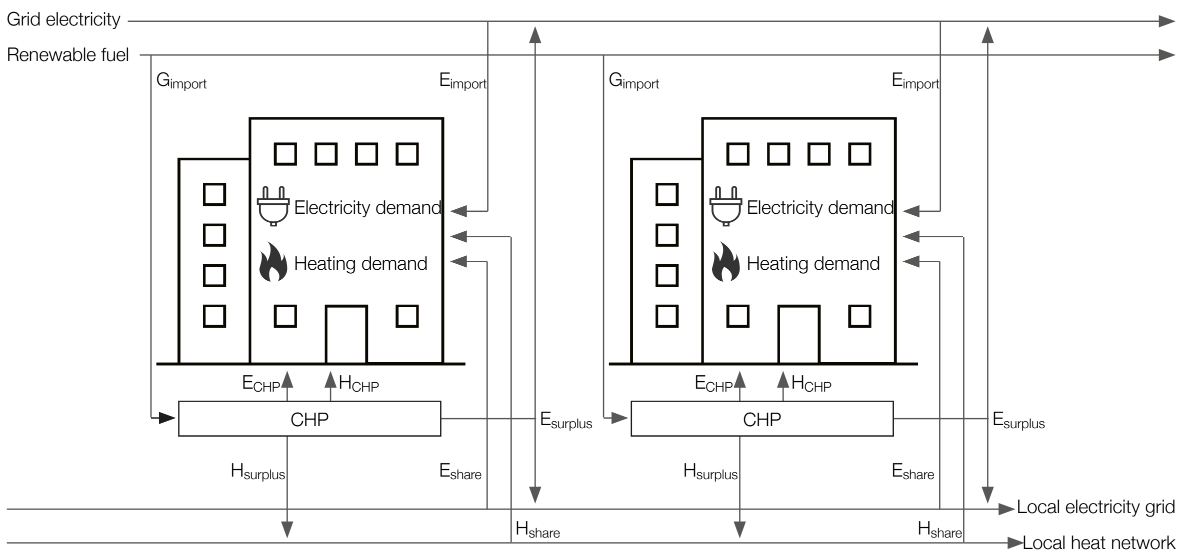


Chart 37: Energy flow in case 3

The next step towards energy self sufficiency

and power) in every building, so confronting case 1 and 2. Moreover, by sharing energy within the four buildings (case 3), the primary energy used resulted to be 65% of the base case. This means that the balances of surplus and deficit of electricity and heat were in some cases managed and at the same time the reliance on the energy grid was reduced.

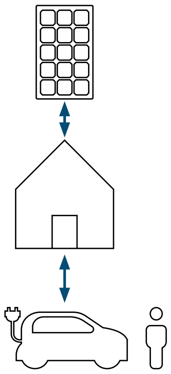
The final objective of becoming completely self-sufficient in the production and use of RES seems to become closer and closer, as shown in the previous examples, but far to reach yet. A breakthrough has still to come, and several authorities and companies are struggling to find the right direction to proceed in. While Governments are mainly responsible of setting new standards regarding the built environment, the single companies are raising the bar about the e-mobility sector.

We can thus see how different scenarios emerge among the visions developed by car producers. One of these, for example, was presented by German carmakers Daimler and BMW and consists in merging their urban mobility services. These include "car-sharing units Car2Go and DriveNow as well as ride-hailing, parking, charging and multimodality services.[121] The aim is to cut expenses related to the development of charging infrastructure, and at the same time to share the energy demand within a smart grid-like system. BMW, by itself, is at the same time developing a series of concepts mainly related to E-mobility and autonomous driving[122] . The system, that would integrate the so-called DriveNow, ParkNow, ChargeNow, and BMW iWallbox would create a forefront in the management of charging systems. Indeed the danger is to have extremely high demand peaks followed by huge depressions, as shown in the previous paragraphs. Having an integrated system able to make cars, parkings and charging points to talk among them will be fundamental in the development of BEV scenario.

A more radical vision, backed up by the Japanese carmaker Nissan, intends to design cars in a way that they would be able not only to receive, but also to supply energy: "electric vehicles, homes, offices, businesses and remote villages would combine to form a smart grid where second life batteries could be used to supply electricity. Clean, recycled energy would be shared, managed and never wasted by the people using it".[123] Even if the statement can seem quite bold, it is however true that the batteries are almost

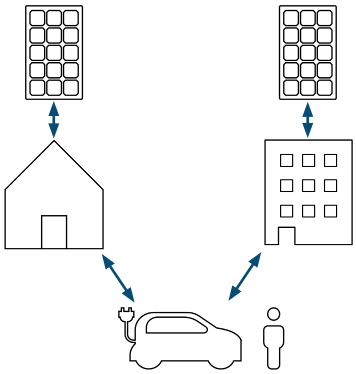
Localized production, private car

In this scenario the cars would be charged and discharged with the energy surplus produced by a single building (e.g. private houses) and would be private themselves. The weak point of this option is that the car could store energy only if it was connected to the building in the moment of surplus production. Otherwise, the energy would be fed-in to the grid or lost.



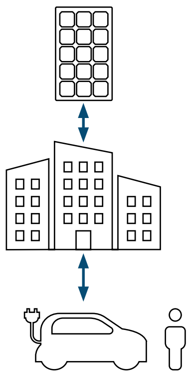
Shared production, private car

In this scenario the cars, again privately owned, would be charged and discharged with the energy surplus produced by a small set of buildings (e.g. private houses, working places). This option would provide more flexibility even if higher complexity. However options like the storage of surplus energy during the day in one building, to be used by night in another building, following people movements, would become possible.



Diffused production, private car

In this scenario the cars, privately owned, would be charged and discharged with the energy surplus produced by buildings to which the car would be connected during the day. Cars, seen as a whole storage system, could recharge or discharge according to the diffused energy sources they would be near to moment by moment. A house, empty during day, could give energy to a car parked in its street, and then take energy during night, when needed, from the occupants' cars. This option would require a high level of integration and precise rules regulating the flows of energy.



Diffused production, shared cars

In this scenario cars would not be private anymore. Instead they would be shared, as the energy production would be. Private energy production or energy storage (i.e. the cars) would not exist anymore. The system should be self learning and able to manage the amount of energy needed in different parts of a built environment according to sudden requests. Cars and energy production would form a complex network able to handle energy requirements in the best way.

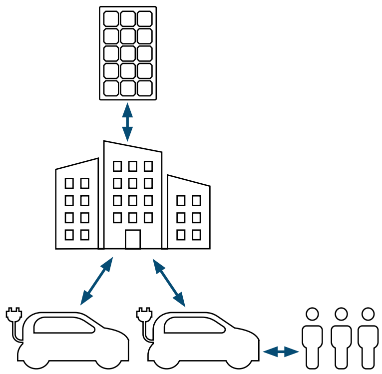


Chart 38: Different alternatives of V2G scenarios

never used at their full potential.

Considering an average distance travelled by car of 12000 km in the EU (9600 in Italy)[124] it means that cars travel on average 33 km per day. Since car batteries now have largely higher autonomy[125] it means that a relevant percentage of their storage capacity is not actually daily used. The number even gets higher considering cities, in which notoriously people rely less on cars in the advantage of public transport. The unused percentage of batteries, already at hand, would then constitute a relatively big amount of energy storage, without the need of any further investment. The new approach should be part of an integrated system, able to charge cars when a surplus in local RES production occurs, or when there is low energy demand, and taking it back when there would be need of energy. This idea would lead to different case scenarios, with increasing complexity, but also benefits.

Nevertheless there are still concerns regarding the so-called vehicle-to-Grid (V2G) economic feasibility. The main ones are related to the degradation of the batteries that undergo frequent cycles of charging and discharging, more than the ones that they would normally undergo in a BEV. Moreover, the batteries couldn't be used at their full potential, since charging at maximum or completely discharging further shorten their lives (they should have a SOC within 15% and 95%). Their value could then decrease faster than the money gained through energy feed-in. Many studies have shown how there is still uncertainty regarding the topic, but there is however much space for improvement.[126] Understanding of the local markets, a sufficient number of vehicles to bid into energy markets, equipment to provide power back to the grid, and an aggregator to manage the project would be needed at the same time to establish the new technology.

The selected scenarios clearly imply the concurrence of intentions, agreement among parties and market feasibility, spanning from statistics to electronics, from automation to IoT technologies, and so on. However, in the next chapter the main purpose will be to define a modelling and simulation method to show the possible advantages of a scenario with diffused production (and storage) but private cars. In fact this seems to be the most promising one. If cars would be charged only at home or at the job place (case scenario 1) they would lose part of the PV production of the buildings. The second case is more promising, as backed up by several studies on PV energy utilization to charge car batteries.[127] The third one is even better, since the options to charge the car grow even further, while the fourth one will be left apart as it comprehends the modelling of complex car sharing scenarios (and for now is the less realistic one).

The third scenario will then be applied to a realistic case study and there further detailed.

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Chapter 1 abbreviations

AC - Alternating current

B2B - Buissness to Buisness

B2C - Buisness to Client

BEV - Battery Electric Vehicle

CHP - Combined heat and power

COP - Conferences of the Parties

DC- Direct current

EEA - European Energy Agency

EED - Energy Efficiency Directive

EPBD - Energy Performance of Building Directive

EU - European Union

EV - Electric Vehicle

FCEV - Fuel Cells Electric Vehicle

FC - Fuel Cells

GHG - Greenhouse Gas

HEV - Hybrid Electric Vehicle

HSS - Home storage system

ICE - Internal Combustion Engine

IEA - international Energy Agency

IoT - Internet of things

IRR - Internal rate of return

LEED - Leadership in Energy and Environmental Design

NZEB - Nearly Zero Energy Building

OEM - Original Equipment Manufacturer

PEI - Power Electronic Interface

PEV - Plug-in Electric Vehicle

PHEV - Plug-in Hybrid Electric Vehicle

PV - Photovoltaic

RES - Renewable Energy Source

RES - Renewable Energy Sources

RSU - Road Side Units

SOC - State of charge

UNFCCC - United Nations Framework Convention on Climate Change

V2G - Vehicle to grid

VPP - Virtual power plant

ZEB - Zero Energy Building

CHAPTER 2

Method definition

Modelling the baseline:
B10 House case study

Project and design

Basic informations

B10 is a research project located in the Weissenhof Estate in Stuttgart, in a plot of land chosen by the City of Stuttgart to be available for an experimental research building[1]. The Weissenhof Estate was opened in 1927 and was a radical development, with houses and apartments designed by architects such as Walter Gropius, Le Corbusier and Mies van der Rohe[2]. The B10, abbreviation from the address Bruckmannweg 10, was designed by Werner Sobek in 2014 and commissioned by the "E-lab Projekt gGmbH" of the University of Stuttgart (ILEK department)[3]. This project is part of a research examining how innovative materials, structural designs and technologies can improve energy performance and sustainability in buildings[4]. In particular B10 house is able to produce twice the energy it consumes on an annual basis using only renewable resources[5]. Moreover, it can be easily lifted on a transporter and moved to different sites, as it happened in August 2019[6].

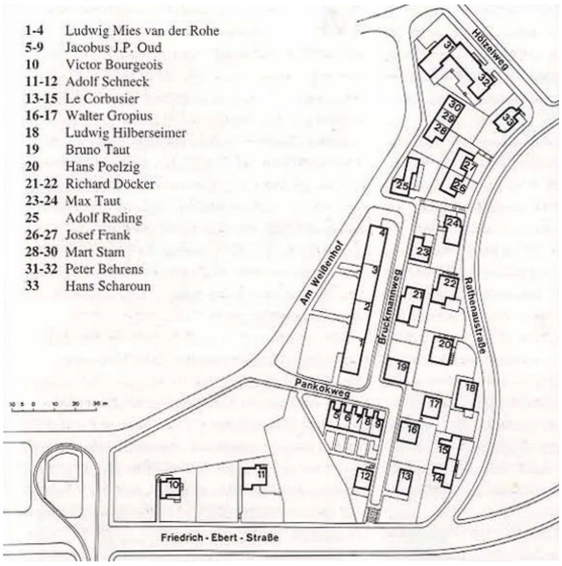

Image 1: Weissenhof Estate


Image 2: B10 House

Design

The building is around 90 m², with a prefabricated timber frame covered in fiberglass fabric[7]. The structure, such as the materials, is studied to be disposed and recycled to leave no waste. For example, the big windows facing West fit into a masonry walls with no use of glue or primer.
The furniture changes following the use: the kitchen can be hidden behind a wall, while the living space is designed for different usage scenarios (office, residential, etc.). The North area is designed as parking for the EV, being the energy flows between the building, the electric vehicles and the district one of the project goals. The terrace is movable, allowing the user to close it in order to cover the windows and save energy.
An important feature of the building is its predictive and self-learning building control system, which is connected to the internet and can be configured using an app. It can predict snow or heat waves, setting the conditioning system in a different way for each room depending on usage or special needs. It also consider changing in natural light and shadows, such as a growing tree, and estimate the annual consumption with 20000 different options and variables[8].
With the photovoltaic panels placed on the roof, the B10 House is able to produce more than 8300 kWh and its energy demand is only 4200 kWh. The surplus is not sold into the national grid, because the price during summer would be too low, but it is used to power a specific house in the neighbourhood. Moreover the little EV is charged using the residual energy, allowing it to run over 100km per day.

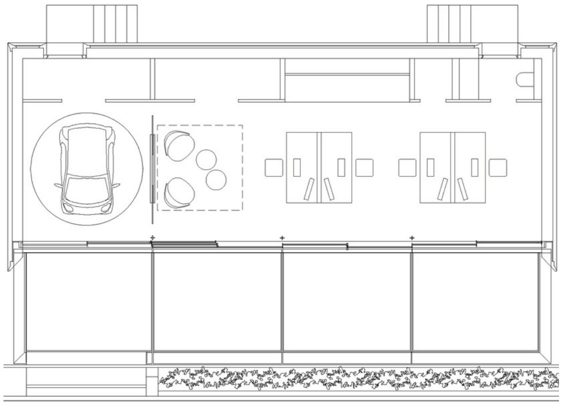

Image 3: plan, office configuration

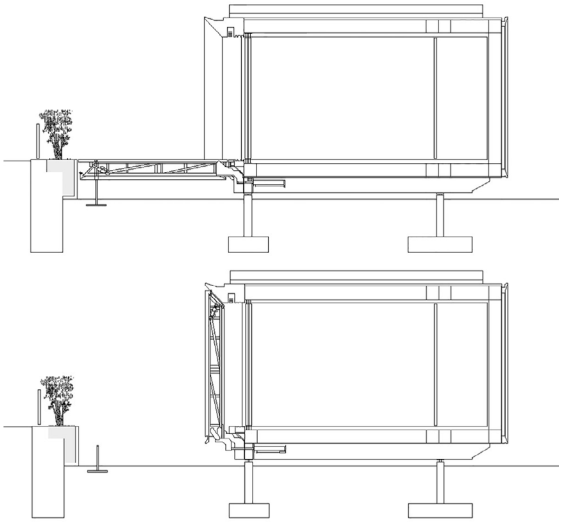

Image 4: sections, open and close terrace

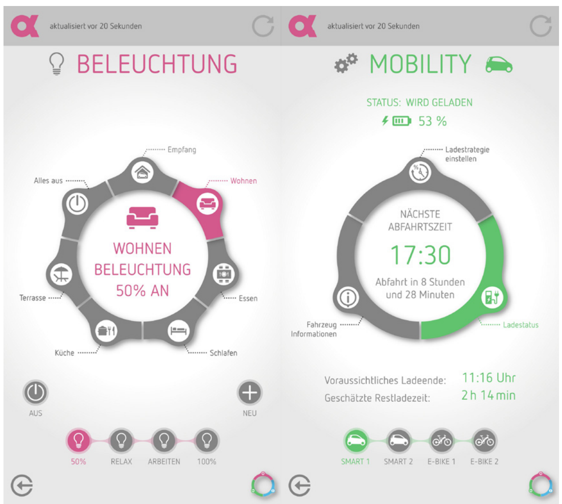

Image 5: system configuration and controls

Simulations

Modelling

Being the B10 house a research project, it is possible to find precise informations about its energy behaviour, as it is shown in Table 1.

The highly insulating walls, roofs and glazings reduce heat losses, while the performing service equipment together with the automated system control reduce the energy waste. These strategies achieve to reduce the energy demand, which is low for a house with all sides exposed to the outdoor space. The consumption can be divided in three groups: one is for the building services, the second for building controls (the monitoring costs energy as well) and the third for lighting and household needs.

These provided values allowed the formulation of a dynamic energy simulation model of the B10, which has been set in order to align the results to the one of the real building. The time schedules and single elements consumption were not provided, so they were assumed and then changed in order to match the real values.

Regarding the PV panels their area and the total production are known, so the power of each panel is calculated in order to have the same production values.

Gross floor area	90 m^2
PV panels	65 m^2
Installed electric output	10.4 kW_p
Installed thermal output	26 kW_p
House battery capacity	11 kWh
Wall U_w	0.11 W/m^2k
Roof U_w	0.133 W/m^2k
Glazing U_w	0.83 W/m^2k
Heat pump	5.9 kW
Heat recovery	80%
Max ventialtion	300m^3/h
Energy production	8341 kWh
Energy demand	4247 kWh
- of which building services	1840 kWh
- of which building controls	1208 kWh
- of which household electricity	1199 kWh
Surplus	4094 kWh

Table 1: Technical data of B10 House

Results

As shown in Table 2 the official values for the B10 performance over an year are very close to the ones obtained through the energy model simulation. This can then be considered a reliable model of the B10, able to be compared with other models through the definition of an independence index that will be introduced later in the chapter.
In Chart 1 all consumptions values are summed and compared to the production of renewable energy. On an annual basis, comparing the consumption and production of every moth, it is visible as for most of the year the consumption is covered by production. However in the remaining months (November-February) the production is not enough, not even with the small storage of 11 kWh placed in B10.
This is a typical problem of energy produced with PV panels, that this performing house is not solving. It is therefore necessary to buy energy from the grid during winter, meaning that the house is not completely independent from the national grid and not completely self-sufficient. What can't be seen from this chart, but will be better analysed later in the chapter, is that also night consumption requires a storage in order to prevent acquisitions from the grid.

B10	Declared [kWh/year]	Simulation [kWh/year]
Production	8341	8312
Consumption	4247	4246

Table 2: Comparison between declared and simulated values

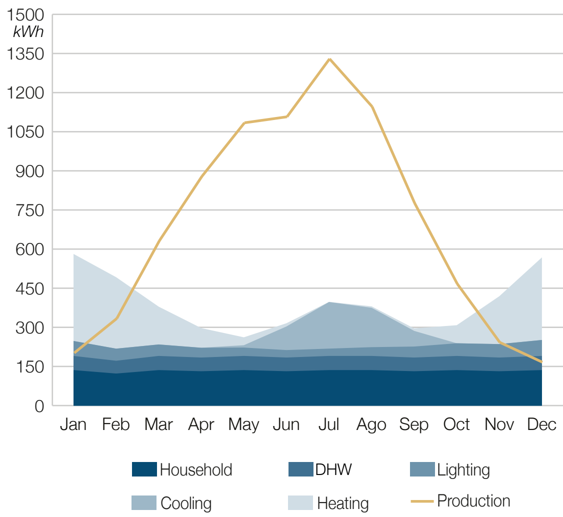

Chart 1: Consumption and production values per month

Definition of the base units and buildings optimisation

Base units definition

Intentions and methods

In order to assess the feasibility of an energy independent building or neighbourhood in a urban area, the most performing building shape has to be found and simulated.
The difference with the B10 House is that this new building has to be positioned in an urban area, that means that it cannot be limited to a single storey wasting too much land. This problem was highlighted right after the construction of B10, as we can see in the Image 6 about future development of the "E-lab Projekt".[9] The final goal of these simulations is to set the parameters and the method for future analysis, which will be inserted in a real urban context and for this reason will be more "realistic".
The method used to find the final shape was developed as following:

- Optimise the shape, the window ratio and the shadings of a base module
- Considering the integration of PV panels in the building design
- Increase the number of floors studying its influence over the total energy surplus
- Considering the amount of EVs for each building


Image 6: Future developments

- Compare efficiency of production and consumption of different layouts and combinations of buildings with different programs (district)
- Considering the presence of fixed (powerwall) or movable (EV) storage
- Calculate the autonomy of the district from the grid

These simulations were run and optimized using DesignBuilder sotware, which is able to perform a series of analysis with different variables, such as the widows to wall ratio for each façade or different shading systems.

Model properties and schedules

The properties and schedules for two kinds of buildings, offices and residential, are the one listed below, according to ASHRAE 90.1-2017 standards.
The schedules for the offices are mainly related to working hours, supposed to be 8:00-18:00 on working days only. The residential schedules are more complicated, being divided in working days, weekends and holidays. In table 3 are presented just the weekdays values, to have an idea of the complexity of the schedules. The lights are active only when needed (to have minimum 300 lux)

Hours	Kitchen	Light	Others
23-7	0	0	0.1
7-8	0.4	1	0.5
8-9	0.6	1	1
9-10	0.4	1	0.5
10-18	0	0	0.1
19-20	0.3	1	0.5
20-22	1	1	1
22-23	0.3	1	0.8

Table 3: Residential schedules for weekdays

Residential	Element	Value
Construction elements	Exterior walls	0.098 W/m²K
	Floors	0.098 W/m²K
	Roof	0.098 W/m²K
	Glazing	0.993 W/m²K
PV panels	Power	300 Wp
	Efficiency	19 %
Glazings	Wtw ratio	S: 80% N: 10% W-E: 20%
Gains	People density	0.002 ppl/m²
	Kitchen	0.2 W/m²
	Lights	7.5 W/m²
	Others	7 W/m²
Cooling	Setpoint	26 °C
	Setback	32 °C
Heating	Setpoint	20 °C
	Setback	13 °C
Ventilation	Fresh air	2.5 vol/h
HVAC	VAV	with HR

Table 4: Residential model properties

Office	Element	Value
Construction elements	Exterior walls	0.098 W/m²K
	Floors	0.098 W/m²K
	Roof	0.098 W/m²K
	Glazing	0.993 W/m²K
PV panels	Power	300 Wp
	Efficiency	19 %
Glazings	Wtw ratio	S: 50% N: 20% W-E: 40%
Gains	People density	0.07 ppl/m²
	Computers	5 W/m²
	Lights	7.5 W/m²
	Others	7 W/m²
Cooling	Setpoint	26 °C
	Setback	32 °C
Heating	Setpoint	20 °C
	Setback	13 °C
Ventilation	Fresh air	2.5 vol/h
HVAC	VAV	with HR

Table 5: Office model properties

Parameters optimisation

Shape optimisation

The optimization process started from the search for the best energy performing shape. The first simulation was set with a box with a suitable floorplan for residential use, following the B10 house, that is a rectangle with sides of 13.5m and 7m. From this starting point two other buildings were simulated with the same floor surface, one closer to a square shape (11.5x8m) and the other further (15x6m). As it is visible in Chart 2, the best shape is 15x6 base module with a total consumption of 106 kWh/m^2. Even if the difference between the shapes may appear little, in the following step where the number of floors is increasing the difference would be more relevant. The results highlighted how a shape nearer to the square has less heating consumptions but more cooling consumption, probably due to the smaller dissipating surface. The bigger difference is made by other consumptions, which are smaller in the 15x6m shape probably due to the big window facing South, which is providing more uniform daylight in the back of the building. The resulting shape has similar proportions to the B10 House, which probably means the designers came to same conclusions.

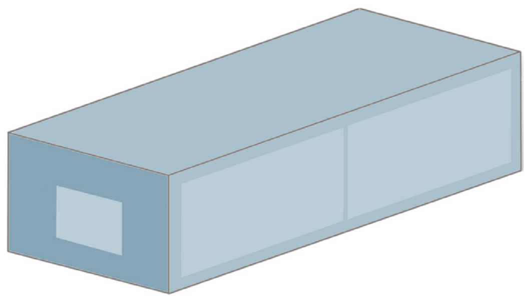

Image 7: Starting point

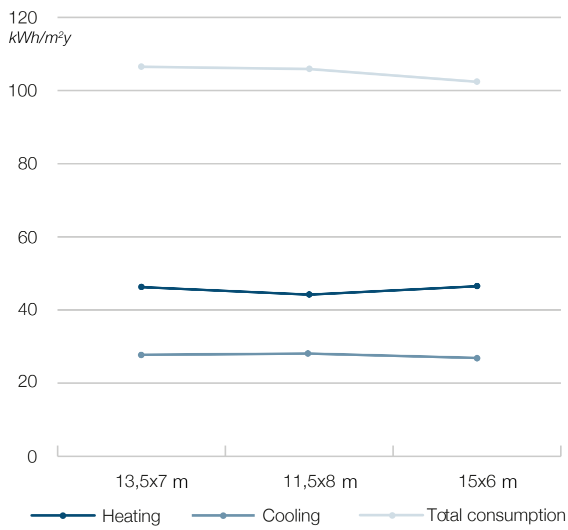

Chart 2: Comparison between different shapes

Glazing optimisation

The optimization went on with the windows to wall ratio and the shading system, which were optimized using the DesignBuilder tool. Regarding the office building a 20x20m shape, which is representative of a minimum office floor, was considered.

Starting with the glazing presented in the previous part, the windows to wall ratio was optimized for each buidling face considering the mutual influence. The same process was applied to the shadings, optimized for each direction.

The results, shown in Charts 3 and 4 and in Table 6 and 7, show how for residential units the shadings have a big impact on the consumptions of the building. It is evident how the total consumption decreases, but the heating load is increasing for the fewer heat load coming from the sun. For the office building the behaviour is the same but, being the total consumption per square meter less than the residential, the effect is less visible.

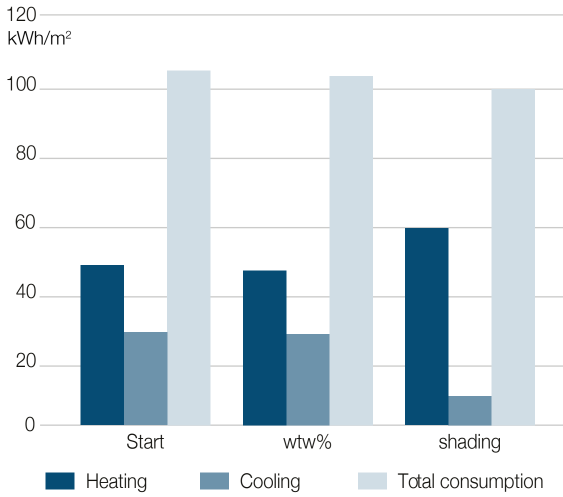

Chart 3: Optimization results for residential units

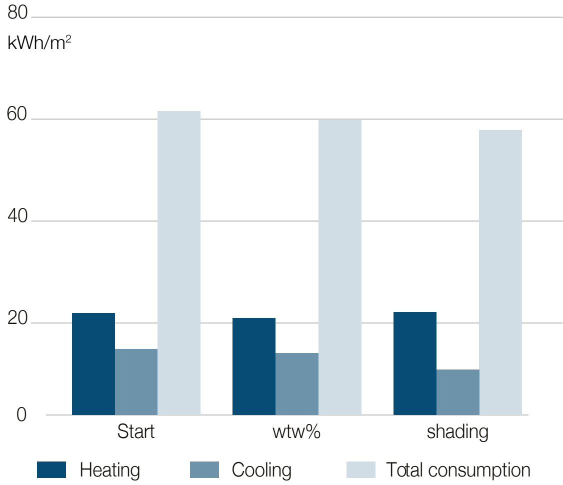

Chart 4: Optimization results for residential units

Residential	Starting point	Optimization
Shape	13.5x7 m	15x6 m
Wtw ratio	S: 80% N: 10% W-E: 20%	S: 60% N: 10% W-E: 20%
Shadings	\	S, W-E: 0.5m overhang
Total consumption	106.5 kWh/m²	97.1 kWh/m²

Table 6: Comparison between starting point and optimization values for residential units

Offices	Starting point	Optimization
Shape	20x20 m	20x20 m
Wtw ratio	S: 50% N: 20% W-E: 40%	S: 70% N: 20% W-E: 20%
Shadings	\	S: 1m overhang W-E: 0.5m louvre
Total consumption	59.6 kWh/m²	55.9 kWh/m²

Table 7: Comparison between starting point and optimization values for office units

Energy production balances

The choice of the PV panels is based on two parameters: maximum power and efficiency. Considering those elements the NeON® Black 2, produced and sold by LG, was chosen among others top products because of its reliability and duration in time.
In order to increase the overall production, the panels are placed on the total surface of the roof with an inclination of 35° to the ground.
Additionally PV panels are placed on the opaque elements of the façade facing South, East and West. In order not to change the façade design of the buildings, they were placed perpendicular lyto the ground (parallel to the façade).
The shading elements were not considered, even if they could have been a good place to position the panels. The reason is that considering 100% of the roof and of the opaque façade is an overestimation of the available surface, then not considering the shading elements as possible areas where to place the panels is considered a good compromise.
The production coming from the roof panels is higher than the one from the walls, so it is probable that with high-rise buildings the production for square meter is going to be less.

Image 8: PV panels, NeON ® Black 2

One floor	Residential	Offices
Roof surface	90 m^2	400 m^2
Wall surface	147 m^2	280 m^2
Wtw ratio	S: 60% W-E: 20%	S: 70% W-E: 20%
Wall surface with PV	S: 21 m^2 W-E: 34 m^2	S: 21 m^2 W-E: 112 m^2
Total energy production	24 MWh/year	111 MWh/ year

Table 8: Sum up of the parameters and energy production of the base units

Medium rise units simulations

Office buildings

In order to assess the feasibility of a multi storey office building several simulations were run stacking office modules on top of each other. For each step the energy consumption and production were calculated, in order to estimate the total energy surplus. At the beginning the simulations were run until the total energy consumption was the same of the energy production. In the office buildings this threshold was reached at 10 storeys, where the surplus energy has a negative value.

From Chart 5 is clear how this process considerably decreases the surplus energy in the first steps, while with a higher number of storeys the difference is smaller and smaller.

The next step was to consider the energy consumption required by electric vehicles. t was considered that an electric car consumes on average 2100 kWh per year (see Chapter 1) and that one car per worker is needed, so that there are 26 cars to be charged per floor.

As it is visible in Chart 5, the only configuration that satisfies these criteria is the one storey office building.

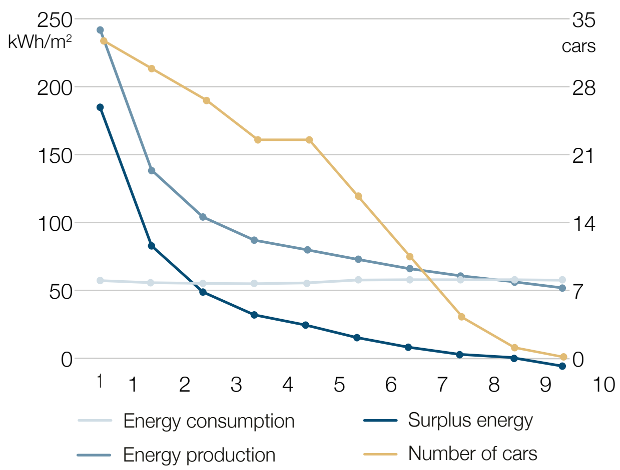

Chart 5: Surplus energy for increasing floors in offices

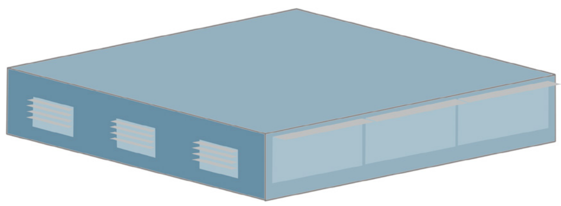

Image 9: stand-alone office configuration

Residential buildings

For the residential buildings the process was similar to the one used for the offices, with an additional variable. In fact the within the possible configurations it was considered the possibility of pairing the base units also on the horizontal direction, creating more than one residential unit per floor.
Starting with the most simple configuration, one unit per floor, several simulations were run increasing the number of floors until there was some surplus left. In residential buildings with one unit per floor, the most suitable situation is the 4 storeys typology, being the highest building with at least one car per unit. The same process was reiterated for a building with two units per floor and fours units per floor. The results are shown in Table 8, with a decreasing optimal number of floor when the size increases.
The best configurations to be tileable on an urban district are shown below. The results shown in Table 8 show how the best performance was reached by the 4 storey building with one unit per floor.

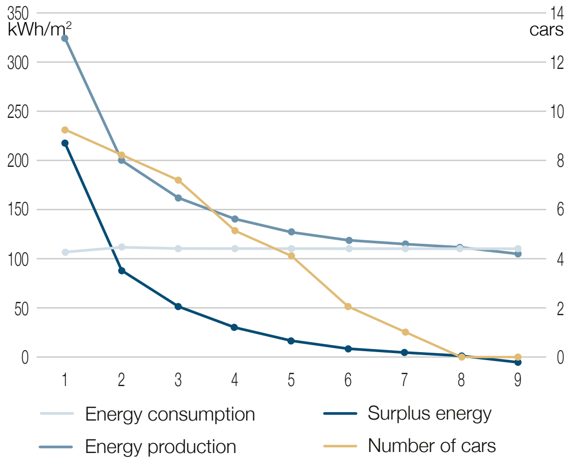

Chart 6: Surplus energy for increasing floors - residential

Units per floor	1	2	4
Storeys per building	4	3	2
Buildings per area	4	2	1
Residential units per area	16	12	8

Table 8: Different residential units combination

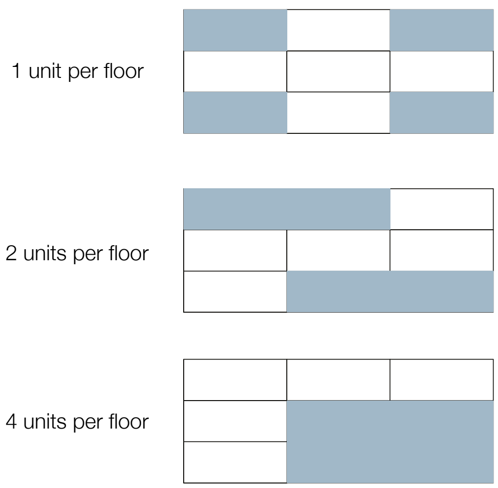

Image 10: Stand alone residential configuration

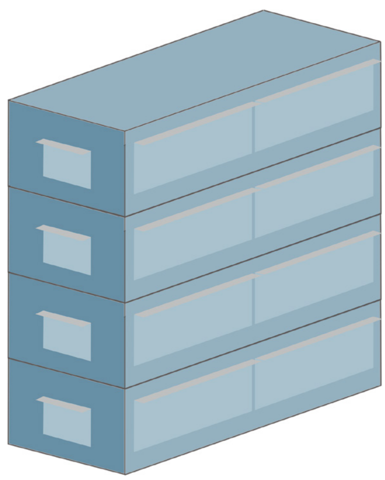

Image 11: Stand alone residential configuration

District simulations

The following step was to combine residential and offices units in order to create an mixed use hypotetical district. A seires of combinations and simulation were then run, following the process exmplained below:

- The residential buildings have 5 storeys, increasing the previous result
- Only one office building is included in the district, preferring a multi-storeys building than multiple buildings with one storey
- The office buildings have more than one storey, increasing the previous result
- The number of people is the maximum between the people working in the offices (26 per storey) and the working people living in the district (1 per unit)
- The number of office storeys and residential buildings have to provide enough surplus to charge at least one EV per person

The results of these simulations are shown in Table 9, showing how the number of residential buildings needs to grow fast in order to guarantee at least one EV per person.
The second set was preferred to the others because it was increasing the previous results without the need of an excessive number of residential buildings per district.
In the following part it will be demonstrated how the creation of a district does not only increase the number of possible storeys, but it improves its energy performances too.

	Set 1	**Set 2**	**Set 3**
Residential storeys	5	5	5
Residential buildings	10	15	20
Offices storeys	2	3	4
Office buildings	1	1	1
People	52	78	104
EVs charged	69	86	102

Table 9: District related office configuration

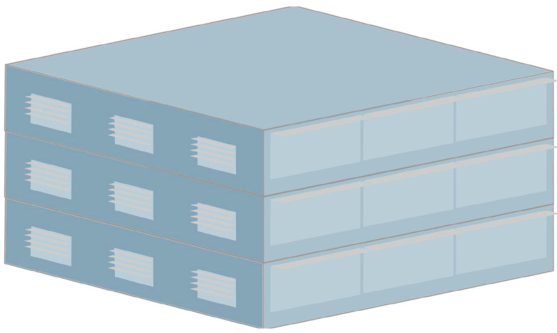

Image 12: District office configuration

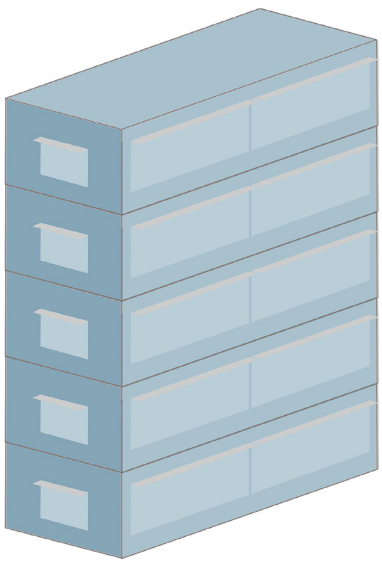

Image 13: District residential configuration

Application and study of energy storage impact on the dependency from the grid

District energy performances and definition of performance indexes

Data analysis

Once established the exact dimensions of residential and office buildings and their number, it was possible to run more specific simulations over the district. The analysis was carried out on an hourly base, which created as an output enough discretized data to be reliable.

In order to prevent anomalies, which may appear because the weather data refer to a specific year, an average of every day in each month was done. Indeed, it is possible that a particular situation occurring a specific day (e.g. a very cloudy day) could affected the whole analysis. This process also reduced the number of data, reducing calculation errors. The data were then interpreted following a methodology that will be explained later in this chapter, in order to obtain the annual net consumption and two performance indexes.

First, the analysis was carried out without the presence of electric vehicles, then the energy loads needed to charge the EV were inserted in the data and finally EV batteries and power walls were used as temporary storage. These steps were studied separately for a residential and an office building, then together in a district simulation in order to show a possible improvement.

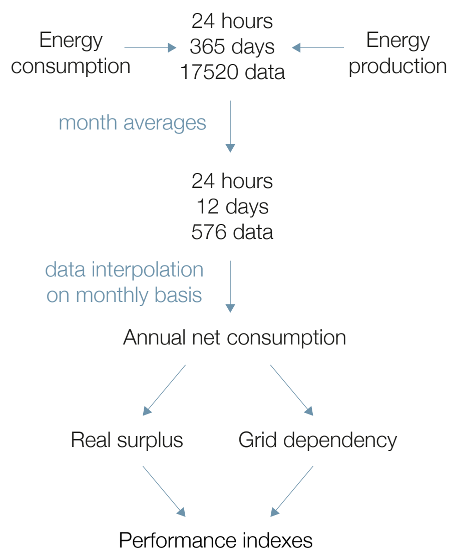

Image 14: Data analysis process

	Loads	Storage
Step 1	Cooling, Heating, Lighting, Equipments	\
Step 2	Step 1 + EVs	\
Step 3	Step 2	EVs, Powerwalls

Table 10: Data analysis process

Energy indexes

To fully understand the data elaboration it was necessary to define a few indexes:

- Hourly consumption (HC): building consumption on a specific hour of the average day
- Hourly production (HP): PV panels production on a specific hour of the average day
- Hourly net consumption (HN): HC - HP (when HC > HP)
- Hourly surplus (HS): HP - HC (when HP > HC)
- Daily consumption (DC): sum of all the HC on the same day
- Daily production (DP): sum of all the HP on the same day
- Daily net consumption (DN): sum of all the HN on the same day
- Daily surplus (DS): sum of all the HS on the same day
- Annual consumption (AC): sum of the DC of every month considering in total 365 days
- Annual production (AP): sum of the DP of every month considering in total 365 days
- Annual net consumption (AN): sum of the DN of every month considering in total 365 days
- Annual surplus (AS): AP - AC which is the energy produced and not used
- Grid dependence (GD): AN / AC which indicates the percentage of energy consumed that is taken from the national grid
- Grid independence (GI): 1 - GD which indicates the percentage of energy consumed that is produced and used on the site
- Production surplus (PS): AS / AP which indicates the annual surplus relatively to the annual production of the building

Performance indexes

The two last indexes are going to be used to compare all the simulations of different buildings or strategies which will be formulated in this research. The choice of these indexes has been made in order to include the different energy aspects of the building, which are compared with the total consumption or production. This particular aspect allows the comparison between buildings with different sizes or energy strategies. The indexes have to consider both the annual consumption and production of the building, then the annual values have to be part of the formulation. Once the EV storage is going to be considered (step 3), it will affect mainly the daily net consumption, that is the reason the annual net consumption is part of the formulation. In order to obtain the percentage of the total consumption that is taken from local renewable energy sources, first the grid dependency (AN / AC) has to be calculated, and then its complementary (1 - GD). This doesn't consider the energy produced and not used, which is represented by the production surplus (AS / AP).

AC	AP	GD	AS	GI	PS
1	2	0.3	1	**0.7**	**0.5**
2	2	0.3	0	**0.7**	**0**
1	1	0.3	0	**0.7**	**0**
1	1	0.6	0	**0.4**	**0**
2	1	0.6	-1	**0.4**	**-1**
1	0.5	0.9	-0.5	**0.1**	**-1**
2	0.5	0.9	-1.5	**0.1**	**-3**

Table 11: Mock examples on performance indexes

Energy balances and introduction of electric vehicles consumption

In these two first steps the storage is not considered, then the only renewable energy used is the one produced in real time. In Chart 7 and 8 are shown the values of Step 1 and 2 considering the district described previously in this chapter. In the charts it can be seen how the surplus energy is strongly decreasing with the application of EV consumption.

In Table 12 the energy indexes are shown both in Step 1 and 2 for residential buildings (5 storeys), office buildings (3 storeys) and the district. Even though in the first simulations the office buildings were decreasing the energy efficiency, it can be seen how they have better performance indexes values than residential standalone ones. This is caused by the higher energy production and complementary occupancy rates, being the offices used when the PV panels are producing energy differently from residential buildings. The biggest impact of EV consumptions is on office buildings, because they are supposed to charge one car each employee. It is clear how the district improves the energy performance of the residential buildings, increasing the performance indexes and decreasing the grid dependence.

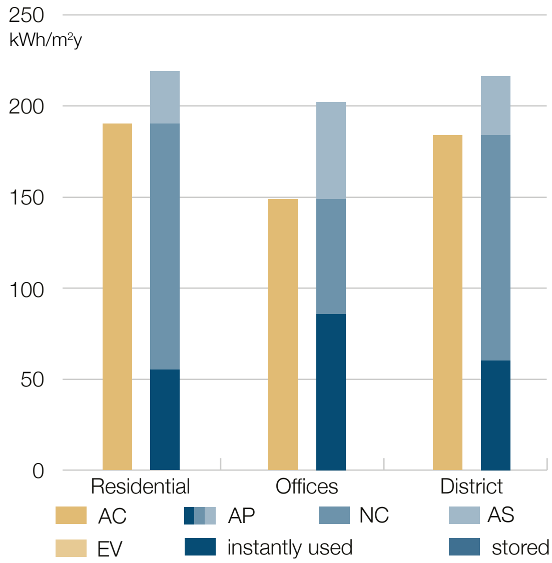

Chart 7: Step 1 simulations on the district

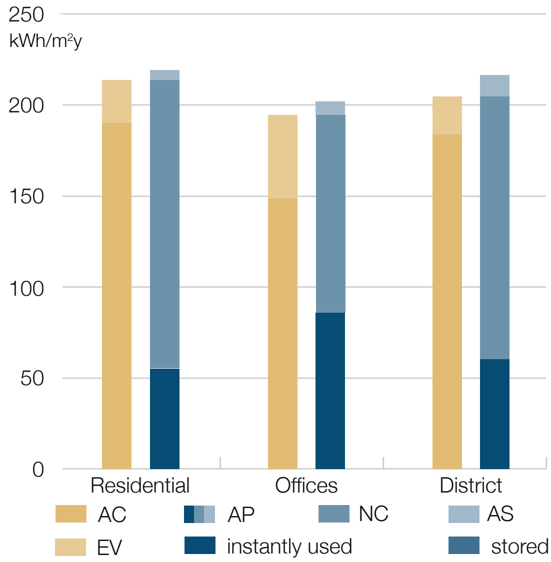

Chart 8: Step 2 simulations on the district

Step / Building	AC [kWh/m²]	AP [kWh/m²]	AN [kWh/m²]	AS [kWh/m²]	GD	GI	PS
1 / Res	180.8	208.2	128.7	27.4	0.71	0.29	0.13
1 / Office	141.4	192.1	60.1	50.7	0.42	0.58	0.26
1 / District	174.8	205.8	117.3	30.9	0.67	0.33	0.15
2 / Res	203.1	208.2	151.1	5.1	0.74	0.26	0.02
2 / Office	184.9	192.1	103.6	7.2	0.56	0.44	0.04
2 / District	194.5	205.8	137.0	11.2	0.70	0.30	0.06

Table 12: Step 1 and 2 results from simulations and analysis on annual basis

Introduction of energy storage

Before analysing the Step 3 values, it is necessary to clarify how the impact of energy storage is simulated.
Image 15 shows the energy production and consumption during an average day in a mild season, used to qualitatively explain this process dividing it in 5 steps:

- 1: Once the hourly data are obtained from the simulations, it is evident how during the day the energy loads can be fulfilled by the PV panels production, while during night this cannot happen
- 2: Some part of this surplus is used to charge the EV with the amount needed to properly work during the day, which is only a part of the total battery capacity
- 3: The remaining battery capacity of the EV is charged during the day, using this extra energy to cover part of the energy needed during the night
- 4: The power walls are then charged during the day, in order to use this energy during the night
- 5: Finally, the remaining energy produced, which could not be placed in EVs or power walls for battery capacity limits, is sold to the grid. During the night, once the energy stored

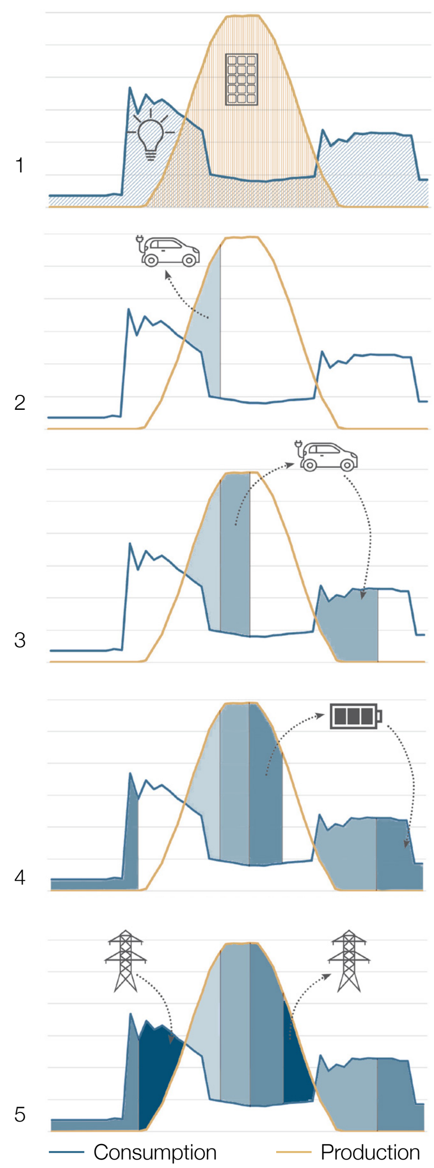

Image 15: Qualitative energy storage steps on an hourly basis

is totally consumed, the building needs to buy some energy from the grid

Once this process is applied to the energy simulations in Step 3, some assumptions have to be made regarding EVs in order to be able to discuss the results with sufficient confidence:

- Every residential unit uses an EV, which means 5 EV per residential building
- Every employee needs to charge an EV, which means 78 EVs per office building
- In the district it is supposed that the number of the EVs is equal to the maximum between the numbers of cars charged with the residential buildings and the offices
- Every EV is used to drive around 11200 km per year[10]
- The EV efficiency is 0.18 kWh/km[11]
- Considering the two precedent assumptions, the EV consumes about 5.5 kWh/day
- The storage for every residential building is 50kWh, for office building is 100kWh
- There are no charge/discharge losses, but the energy stored during one day can't be used for the following day
- For residential buildings the 45%[12] of the EVs, corresponding to the number of people going to work by car in a city such as Milano, are not in the district between 9 a.m. and 6 p.m. so that they can't be used as storage between those hours
- The consumption of EV is calculated on 100% of the actual number, to compensate extra use.
- The energy produced by PV panels is first consumed to fulfil the building consumption, then it is stored in the EV batteries and finally the surplus is stored in powerwalls

With these assumptions it is possible to calculate the annual performance indexes using energy storage.

Energy balances using energy storage

In this step it was considered the presence of storage, both in EVs batteries and power walls. In Chart 9 it is clear the reduction of annual net consumption compared to Step 2 (dash line), which was almost twice as much as Step 3.
In Chart 10, 11 and 12 the daily average values for each month are presented, showing the differences between winter and summer months. It is clear that in most cases the PV panels can completely fulfil the energy demand from April till October, while in the rest of the year it is still necessary to buy energy from the grid. Furthermore, the summer peak of consumption (July) is efficiently mitigated by the peak of production as the surplus continues to grow in most cases. Regarding the peak in winter, it could be mitigated installing a more efficient storage (covering more days) or doing an agreement with the grid in order to exchange the summer sold energy with the winter bought energy.
In Table 13 it is shown a comparison between Stage 2 and 3, with the difference of the presence of storage. It is clear how Stage 3 is highly more efficient than Stage 2, as indicated by the performance indexes. In particular the Grid Dependency in Step 2 is almost twice as much as Step 3, indicating a great improvement. From the table the improvement in the performance indexes can be seen to happen even comparing single buildings to the district, confirming the hypothesis on which the theory is based.
Another result, not visible from the graphs but emerged from the simulations, is that the presence of the power walls are not changing at all the results. This means that the EVs are providing the buildings (stand alone and in the district) with enough storage. This is probably caused by the high number of EVs in the district and may change in further analysis considering smaller amounts of EVs.

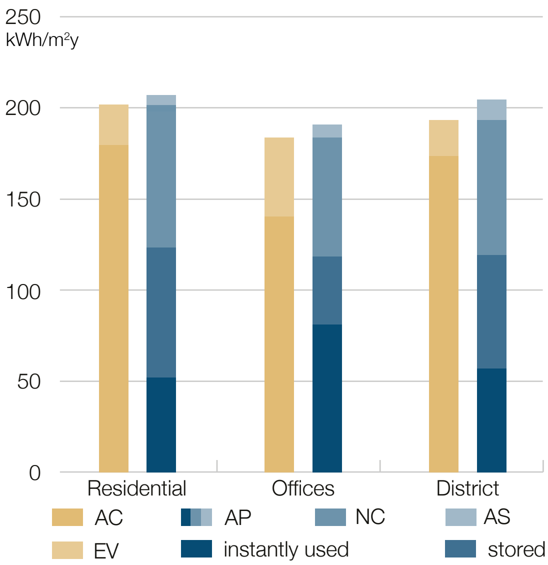

Chart 9: Step 3 simulations on the district

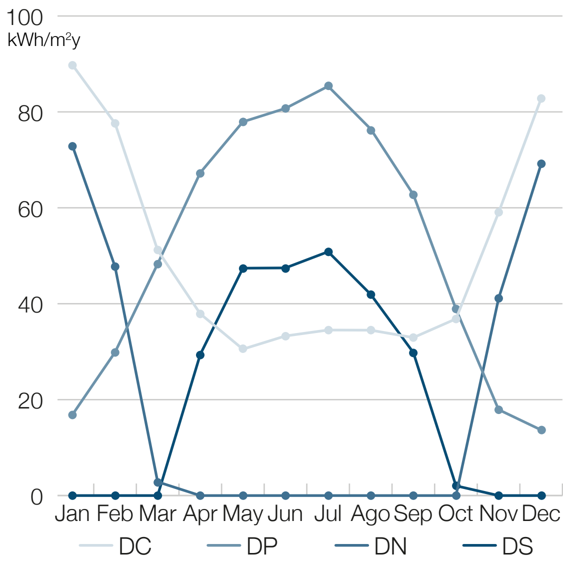

Chart 10: Step 3 daily values of residential buildings

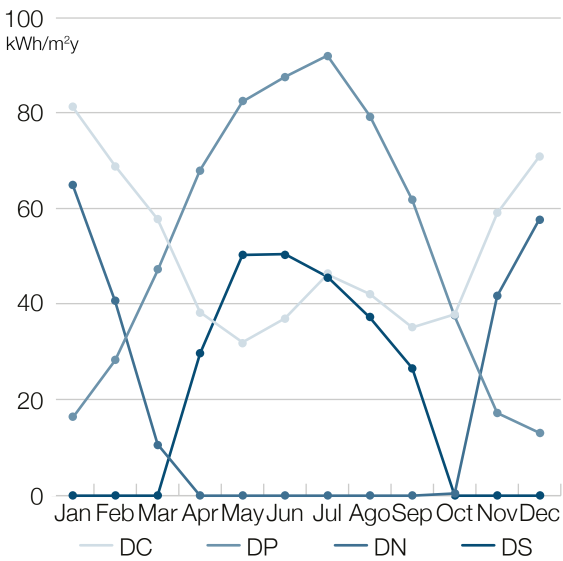

Chart 11: Step 3 daily values of office buildings

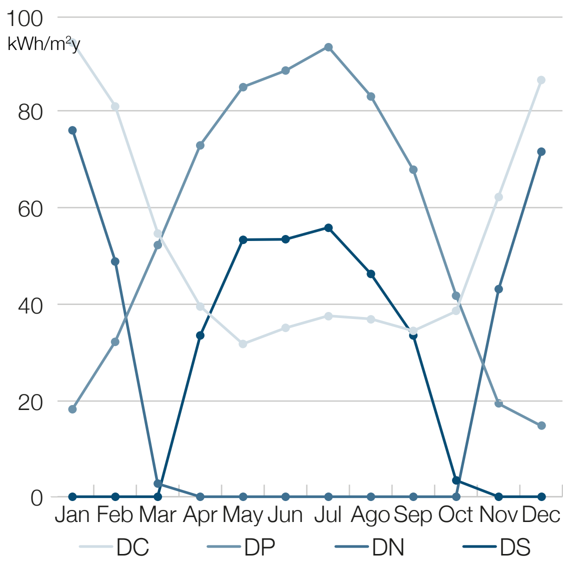

Chart 12: Step 3 daily values of the district

Step / Building	AC [kWh/m²]	AP [kWh/m²]	AN [kWh/m²]	AS [kWh/m²]	GD	GI	PS
2 / Res	203.1	208.2	151.1	5.1	0.74	0.26	0.02
2 / Office	184.9	192.1	103.6	7.2	0.56	0.44	0.04
2 / District	194.5	205.8	137.0	11.2	0.70	0.30	0.06
3 / Res	203.1	208.2	79.0	5.1	0.39	0.61	0.03
3 / Office	184.9	192.1	65.9	7.2	0.36	0.64	0.04
3 / District	194.5	205.8	74.6	11.2	0.38	0.62	0.06

Table 13: Comparison between simulations with storage (3) and without storage (2)

Chapter 2 endnotes

1 The New York Times, “A Glass Box of a House in Germany That ‘Thinks’ for Itself”, accessed November 04, 2019. www.nytimes.com/2015/07/17/greathomesanddestinations/a-glass-box-of-a-house-in-germany-that-thinks-for-itself.html

2 Ibid.

3 WernerSobek.de, “B10”, accessed November 04, 2019. www.wernersobek.de/en/projects/status/completed/b10/

4 Ibid.

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6 Ibid.

7 The New York Times, “A Glass Box of a House in Germany That ‘Thinks’ for Itself”, accessed November 04, 2019. www.nytimes.com/2015/07/17/greathomesanddestinations/a-glass-box-of-a-house-in-germany-that-thinks-for-itself.html

8 Ibidem

9 AHK, “Empowering the environment - Aktivhaus B10”, accessed November 04, 2019. www.aktivhaus-b10.de/home/

10 Quattroruote, “Curiosità - Italiania alla guida”, accessed November 04, 2019. www.quattroruote.it/news/curiosita/2016/02/24/italiani_alla_guida_in_media_percorrono_11_200_km_all_anno_.html

11 Science for Environmental Policy. “FUTURE BRIEF: Towards the battery of the future”, European Commission, Issue 20 (2018).

12 Accordo di programma Comune di Milano

Chapter 2 images

Image 1: University of Hong Kong, “Modern Architecture: A Visual Lexicon”, accessed November 04, 2019. www.visuallexicon.files.wordpress.com/2017/10/251.jpg?w=723

Image 2: www.aktivhaus-b10.de/home/

Image 3, Image 4: Archdaily, “House B10 / Werner Sobek Group”, accessed November 04, 2019. www.archdaily.com/596695/house-b10-werner-sobek-group?ad_medium=gallery

Image 5: Archello, “Active House B10“, accessed November 04, 2019. www.archello.com/project/b10

Image 6: AHK, “Empowering the environment - Aktivhaus B10”, accessed November 04, 2019. www.aktivhaus-b10.de/home/

Chapter 2 tables

Table 1: AHK, “Empowering the environment - Aktivhaus B10”, accessed November 04, 2019. www.aktivhaus-b10.de/home/

Chapter 2 abbreviations

AC - Annual Consumption, sum of the DC of every month considering in total 365 days

AN - Annual Net consumption, sum of the DN of every month considering in total 365 days

AP - Annual Production, sum of the DP of every month considering in total 365 days

AS - Annual Surplus, AP - AC which is the energy produced and not used

DC - Daily Consumption, sum of all the HC on the same average day

DN - Daily Net consumption, sum of all the HN on the same average day

DP - Daily Production, sum of all the HP on the same average day

DS - Daily Surplus, sum of all the HS on the same average day

EI - Efficiency Index, 2 - GD + PS which is a parameter able to compare the efficiency of different strategies or different buildings

EV - Electric Vehicle

GD - Grid Dependence, AN / AC which indicates the percentage of consumption that is taken from the national grid

GI -Grid Independence, 1 - GD which indicates the percentage of consumption that is produced on the site

HC - Hour Consumption, building consumption on a specific hour of the average day

HN - Hour Net consumption, HC - HP (when HC > HP)

HP - Hour production, PV panels production on a specific hour of the average day

HR - Heat Recovery

HS - Hour surplus, HP - HC (when HP > HC)

HVAC - Heating, Ventilation and Air Conditioning

PS - Relative Surplus, AS / AC which indicates the annual surplus relatively to the annual consumption of the building

PV panels - Photovoltaic panels

VAV - Variable Air Volume

CHAPTER 3

Masterplan design

Choice of the project area and design intentions

Choice of the project area

The first step in order to apply the theory proposed (see Chapter 2) is to find a suitable project area. This area should be able to respond to different kinds of requirements at the same time. The relative freedom in the design of buildings should be paired by the possibility to create a micro-grid of a dimension that is enough to study the impact of the electric mobility on the energy behaviour of the district. Moreover the possibility to design a mixed-use area would make it possible to study how different layouts and building densities would affect a such created micro-grid.
To sum up these criteria , the area to be chosen should be:

- big enough to host an entire district, better if newly built
- strategic from a services and economic point of view
- close enough to the city centre to be easily covered by a car sharing system

In this scenario it would be very useful to choose the site within a metropolitan area that could be interested in the development of such a kind of district. This would mean to have the possibility to create more realistic scenarios in the next phase of the research (see Chapter 5).
In these terms, the Metropolitan Area of Milano answers to many of these requests. Its main carachteristics regarding the choice of the project area are:

- To have a high number of commuters from outside Milano, many moving by car
- To have a trend of people living in Milano to work in Milano
- A good development of current public transport system
- A great potential in the future development of public transport
- A combination of circular and linear connections between city center and periphery
- A concentration of e-charging points in the center
- The presence of car sharing services (mostly in the center)
- The presence of big abandoned areas between center and periphery or outside Milano to be redeveloped

Regarding the last point, in recent years much attention has been given to de redevelopment of unused freight yards, left back from the decen-

	Dimen-sions (m^2)	Immi-nence of requalifi-cation	Distance from the centre (km)	Proximity to highly developed areas
Greco-Breda	62000	Long	6	Low
Farini	404000	Short	3.5	High
Porta Romana	187000	Medium	2.5	Medium

Table 1: The three abandoned freight yards that better answer to the area requirements

tralisation of the productive plants. At first they were moved further from the city centres, later in other Countries.

In the city of Milano there are seven of such kind of areas, subject of attention and studies from the municipality of the city together with the national system of railways (Trenitalia) that is the owner of the areas[1]. Among these seven areas, three of them positively answer to the requests listed above.

Among these, Scalo Farini responds positively to all the needs, offering an area for the most part not built and at the same time being in close connection with the tertiary pole of Porta Nuova and the residential neighborhoods that surround it. Moreover, it is not only near the Milan ring road, but also crossed by a railway line and one of the Passante lines, which offer further opportunities for the energy integration of these infrastructures with the built area. The nearby university campuses of Politecnico di Milano (Bovisa and La Masa) give a further opportunity to the design options in order to offer even wider services.

But the most important characteristic of this are is its imminent riqualification project, with a competition called by the main stakeholders of the area. Its brief is particularly interesting in its requests for innovation, integration, reconnection and presence of green areas.[2] These requirements are well related and directly lead to the design intentions.

Project requirements and design intentions

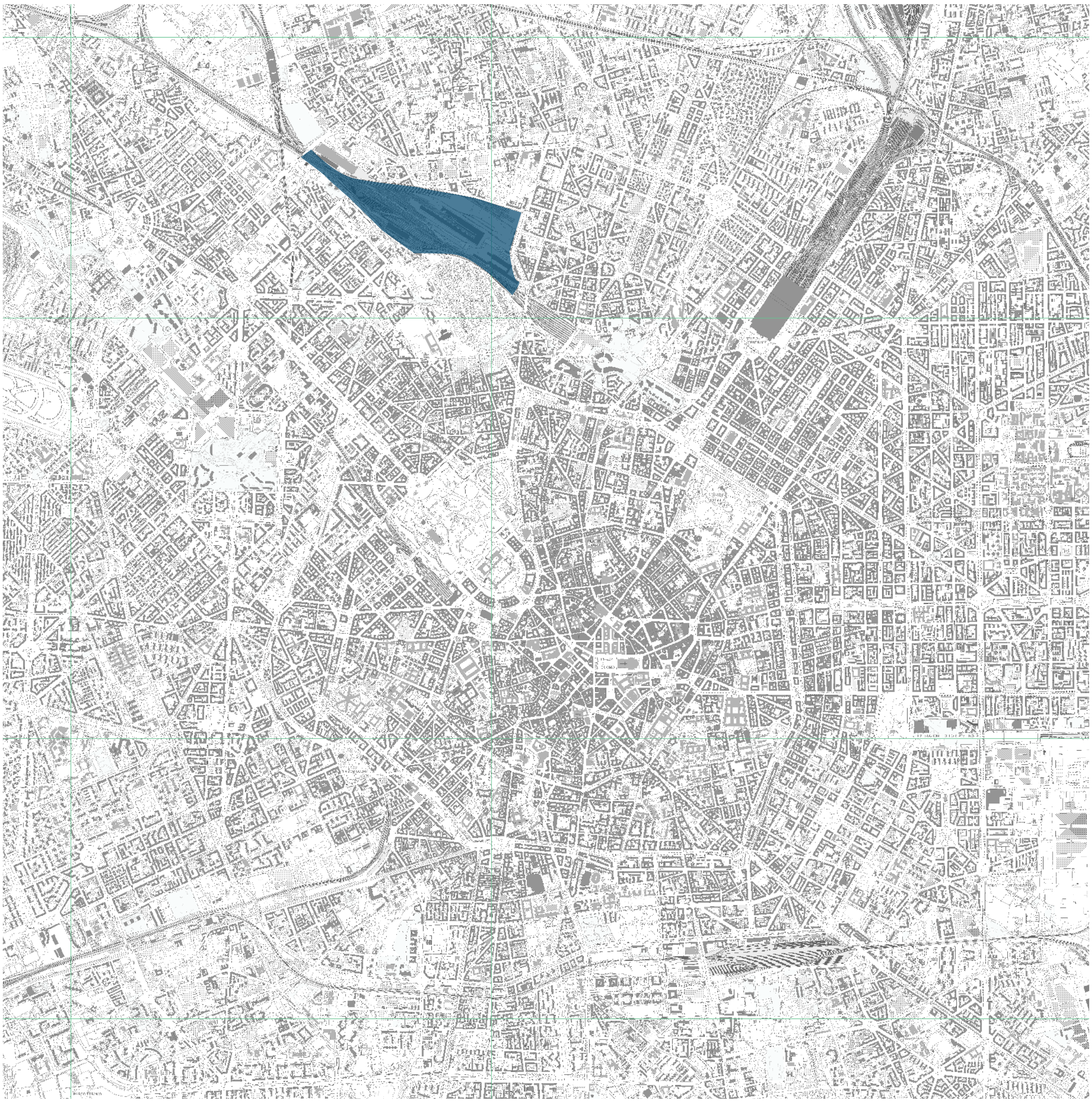


Image 01: Scalo Farini in Milano

Scalo Farini area is located in the first belt of Milano, between the historical city centre and the nearest periphery. Looking at a map of Milano, it is easy to see it thanks to its almost completely empty area, in the North West direction from the city centre. It is only crossed by railways that connect the station of Porta Garibaldi to the surrounding transport network. Its area, counting roughly 400000 m^2 of unused space, is the subject of an international competition held by Comune di Milano and Ferrovie dello Stato, that selected its winner in April 2019.

The area, left unused for several decades (see next part), contains some functional buildings that are nowadays underused and in some cases host squatters that can freely enter and exit the area. Its position, among higher class districts, in the southern direction, and lower class ones, in its northern direction, is particularly challenging for its imminent redevelopment. Moreover it is very near to the successful recent development of Porta Nuova, that created one of the economically most productive areas in Europe in place of an unused and abandoned area till one decade ago.

The brief of the competition contains at the same time all these themes, integrating them with the growingly important one of the necessity of green spaces and green axis.

These intentions have to deal with practical limits and needs, defined by historical or infrastructural constraints. First of all, the railway that will remain active crossing the site in its longitudinal direction. Then, the seniorities that surround the site and the listed buildings that are present inside of it, like the famous Cimitero Monumentale. At the same time, the active and lively infrastructural systems that surround the area will need to be reconnected, crossing the site.

A further difficulty is represented by the mixing of needs and expectations of the people living in the nearby districts. These, summed up in the brief of the competition, will have to deal with the heterogeneity of the services that already surround Scalo Farini.

In general, the masterplan design will have to take into consideration the effervescent, dynamic social and cultural society that will interact, use or live in the area. The economic and demographic trends of the city of Milan show how the requests of the population vary significantly according to geographic, economic or age distribution.

Then the challenge of the future designers will be to tackle all these inputs, to plan a functioning and proactive environment from every point of view.

In addition to these requirements, the simulation of a micro-grid within the area could be enriched by additional actors. The overground and underground trains, for example, could play a role in the energy storage or consumption. Moreover the intention of the municipality to distribute on its area medium-sized bus depots could create the chance to integrate this transport system into the micro grid too.

But the most interesting aspect of developing a masterplan in this area is that ultra-efficient buildings, typically residential, could be coupled by a few big public buildings, with strong and important functions. In this case it could be difficult to reach energy surplus in their energy balances, since big public buildings typically produce less energy than the one produced. High occupancy rates, long opening hours, mechanical ventilation and big openings are some of the reasons that often affect the design of such buildings, reducing their energy performances. The huge area of Scalo Farini could host both kinds of buildings, giving the possibility to study the energy relationship between different uses.

Urban and local analysis of Scalo Farini

Historical analysis of Scalo Farini and railway network of Milano

Historic urban development of Milan

The city of Milan is in a strategic position, at the centre of roads and rivers interconnecting the North are of Italian peninsula. For this reason the trading of goods has always been one of the biggest income for the city, and the development of national and international market brought to a fast development of the city in XIX century.[3] To solve the problem of the increasing number of factories and the need of new residential districts, the city government was in need of a new urban development plan.

In 1884 the Beruto plan was completed and its criteria were applied to new districts: the central-based geometry of the city hadn't been changed, creating ring roads to connect the radial historical ways. This plan was providing the city with a possible infinite way of expansion, limited only by the railway belt that was bonding its growth. Indeed, the rails system was growing in parallel with the city development, with the construction of new railways and train stations.

The development of the Italian railway network started around 1840[4], 15 years after the inauguration of the first railway in the UK[5]. By 1861, right after the Italian nation was born, all the mayor cities of northern Italy were connected by railways, even passing the Austrian border.

The first railway in Milan was built in 1840, connecting to the city with Monza, guaranteeing the connection with the rich towns and cities in the North. The station was built outside the city walls, near Porta Nuova, but in 1850 it was moved in Via Melchiorre Gioia. This bigger station was used in 1859 to create a new railway on the way to Turin.

In 1857 the construction of a new station on the East border in Porta Tosa connected the city to Venice and, in 1861, to Piacenza and Pavia.

To manage this market expansion a Central station was build connecting the two original stations with the centre of the city. The construction of the new station in 1864 modified the old urban design, with the creation of Via Turati that allowed a direct connection with the city centre.

The expansion of the city to the countryside made a change in the railway system necessary, but the Beruto plan failed to be effective.[6] The plan only set the position of new freight yards, replicating the same urban geometry to the suburbs.

With time, Beruto plan showed its limits. The ring roads were not enough to reduce the traffic in the city centre, caused mainly by the daily movements of workers, made worse by the lack of public transport. The development of railways and freight yards created a separation with the suburbs, which started to grow without following the designed plan.

To solve these mayor problems, in 1909 the city government promoted the creation of a new urban plan. The Pavia-Masera plan led to the construction of a new central station, moved away from the city centre but connected to it through a large avenue. This new central station allowed to move the railway belt, restoring the connection with the North-Eastern suburbs. The same problem was solved also on the West side of the city, were the improvement of Scalo Farini allowed the dismission of the Sempione freight yard behind the Sforzesco castle and its relative rails. The World War in 1916 and the epidemy in 1918 stopped the city expansion and did not allow to solve the city problems. The following urban plans (1934, 1953, 1976) couldn't solve the mayor problems of the city neither.

The advent of prefabrication led to the construction of the post-war residential district, in order to solve the most quickly ad possible the demographic emergency caused by the economic "boom". This quick expansion of the city wasn't controlled by a proper urban plan, creating a fragmented reality where the new districts resulted separated from the city.

While the prevalence of economic reasons over urban planning was evident, the public transport managed

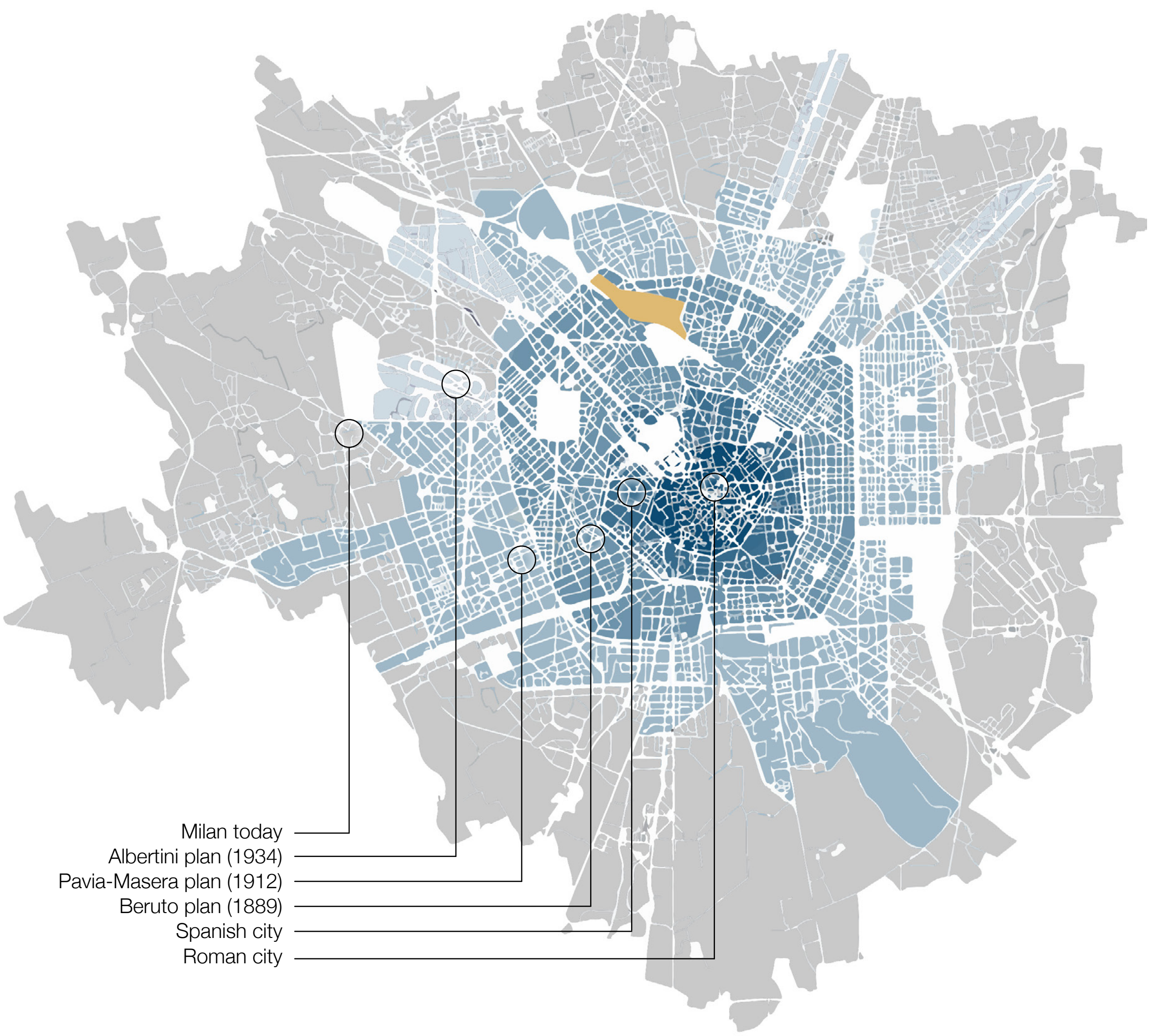


Image 02: Evolution of Milan through urban plans

to be improved. The construction of the subway system and the Passante, an underground railway connecting directly the West stations with the East ones, guaranteed a good connection throughout the city.
Furthermore, at the end of the century the city government started a new program of restoration of the city centre. The new philosophy was to restore and improve the old buildings, avoiding the demolition process.
The PGT (Territory government plan), introduced in 2009 to provide the city with a flexible instrument of urban planning, went on the same direction. Indeed, the restoration of industrial and abandoned areas and the introduction of urban green were the guidelines provided by the city government.
The program of restoration of old freight yards is moving in this direction. Seven large unused areas near to the city centre with a high potential in a new vision of urban planning. The hope is that these projects will be able to fill the gaps created by railway infrastructures, improving the global urban connections and infrastructure. The government has already set competitions for the projects of these areas, such as Scalo Farini.

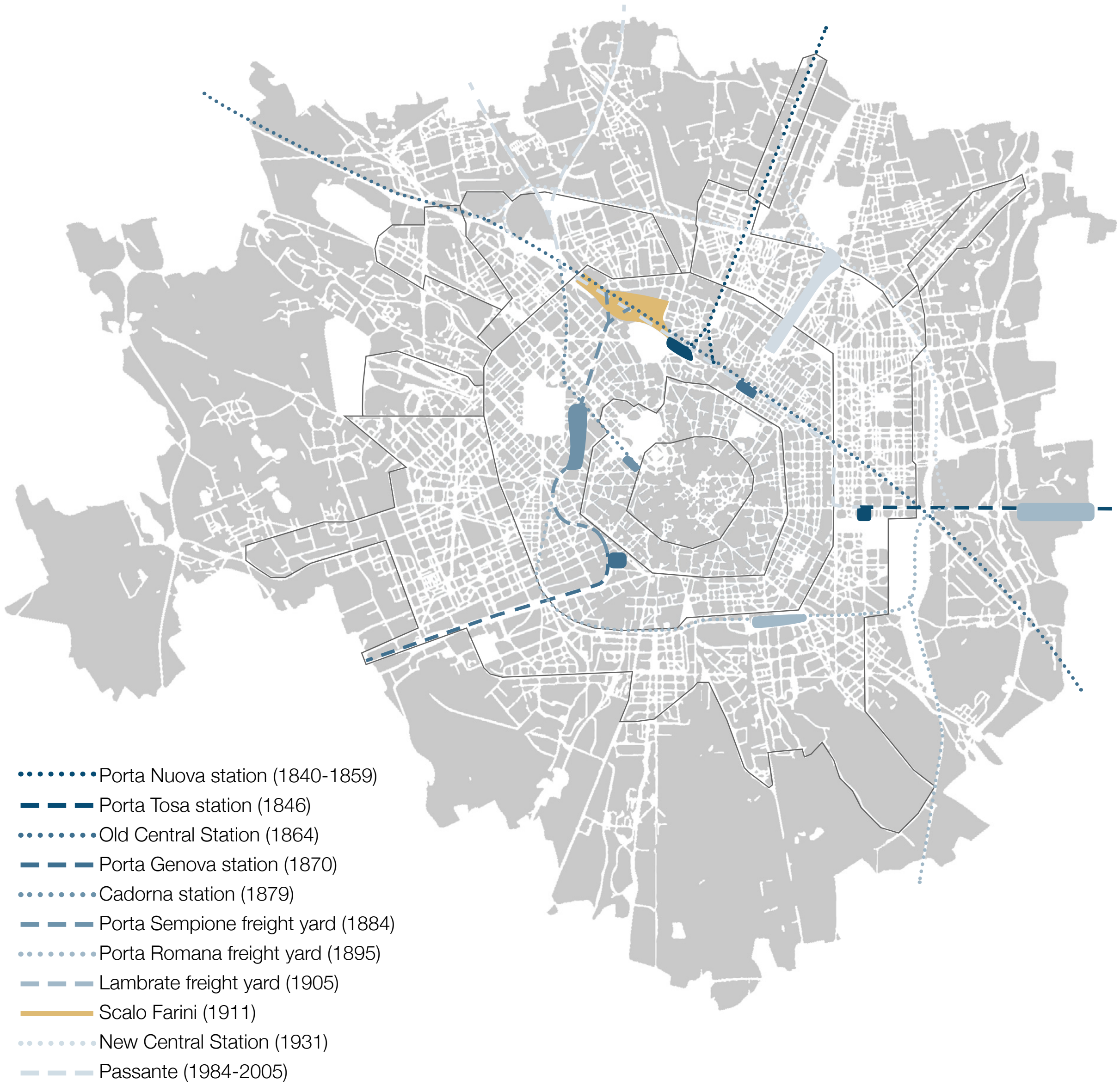


Image 03: Evolution of railways in Milan

History of Scalo Farini

The area, mainly occupied by fields and farmer's houses, wasn't under any urban development before the advent of the railway. Till the 19th century there were little towns developing near the main roads, such as Comasina, Varesina and Sempione. This little towns were the starting points of the current Milan districts, such as Bovisa or Dergano. The land planning was set by the rural divisions, aligned to waterways or main roads.

From the second half of the 19th century, the need of new building sites brought the city expansion outside the walls. The new railway connecting Milan to Turin was introduced in this strategic area, which allowed the connection with the South of the city.

The Beruto Plan provided the are with a connection to the city, creating a contrast between the old constructions and the new rational plan. This plan was relying on the axle created by the monumental cemetery, in order to connect the ring roads to the centre.

The improvement of the railway system led to the realization of Scalo Farini, a strategic point of connection with the rich cities in the North and in the West of Milan. The Pavia-Masera plan confirmed this direction, moving the Sempione freight yard and the Customs to Farini.

This led to an increase in the fragmentation of the area, separated by the city centre and used for industrial purposes. The empty areas in the North were filled with warehouses or industrial sheds, not controlled by any urban planning. Even the monumental cemetery and Villa Simonetta were excluded from the urban planning. In 1960 the new Porta Garibaldi station was build, providing Scalo Farini with new infrastructures and factories.

Even if for logistic and structural reasons Scalo

Image 04: Farini area in 1865

Image 05: Farini area in 1930

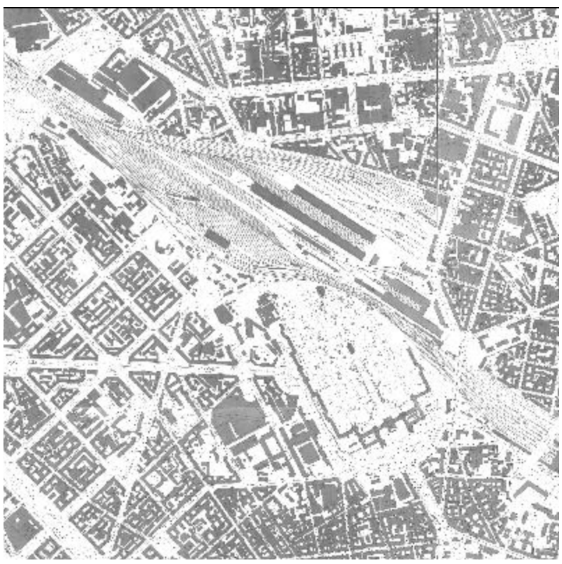


Image 06: Farini area in 1972

Farini was never used at full capacity[7], this area was excluded by the city urban planning and expansion. This led to an abandoned area, surrounded by districts with different origins and functions.

In the map below it is evident how the freight affected the city expansion. Via Valtellina, the eastern limit of the area, was part of the Beruto plan but it had to change its direction due to the presence of Scalo Farini. The axle of the cemetery is still visible in Via degli Imbriani in the North, but the freight completely avoided this connection. The same happened to Via Francello Caracciolo on the West border, probably planned to be connected with the other side of the freight. The industrial buildings in Bovisa area improved the fragmentation and the irregularity of the urban design, stepping out from the city planning.

A project of urban restoration of the area should take in account this interrupted connection, in order to preserve and reinforce the historic urban planning of the city of Milan.

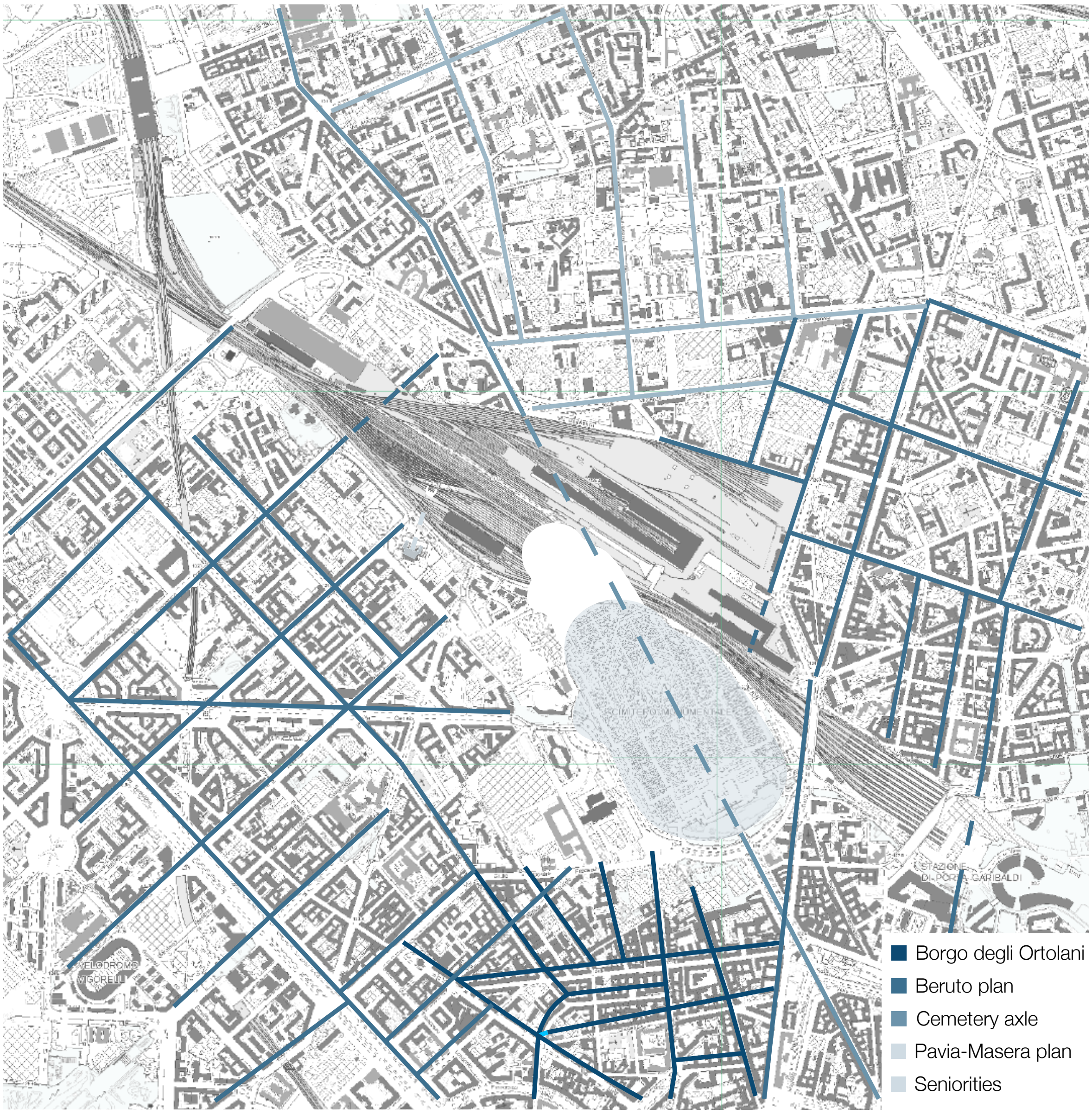


Image 07: urban plans and connections in Farini area - Scale 1:15000

Historical seniorities

Some buildings in the area of Scalo Farini have a significant historical value, so that they have to be considered in the analysis of the area.

Cimitero Monumentale

The most important historical building is the Cimitero Monumentale, South form Scal Farini, that covers an area of 250,000 m^2 facing the city center with an entrance 260 m long.[8] It was build in the XIX century because of the "Edict of Saint-Cloud", that obliged all the cities under Napoleonic domination to move the cemetery outside the city walls. The construction started in 1863, oriented to Porta Volta in order to create a direct connection to the city. This axle, even though is interrupted by the railways, is still visible in Via degli Imbriani and Via Ceresio.
The internal organization is build on two main orthogonal axis which, intersecting with secondary ways, create a front where the main architectures are placed. The monuments are different for style and religion, defining an eclectic language that refers to the medieval tradition and its black-white duotone.[9] The importance of the cemetery is not only related to its dimension and history, but also to the importance of the people that were buried there and of the authors of the beautiful monuments.

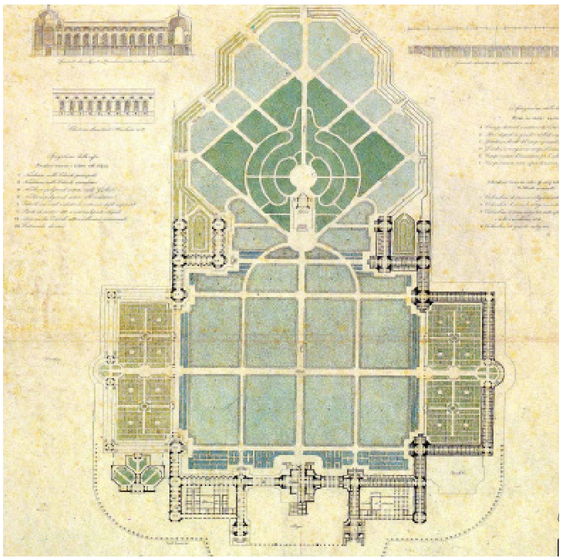


Image 08: The original project of the cemetery


Image 09: The entrance to the cemetery (Famedio)

Villa Simonetta

Another historical building in the area is Villa Simonetta, one of the most important example of Reinaissance suburban villa in Milan. The villa is interesting for the architecture and for the bond that it created with the territory. Even though it's no longer visible, in XVI century the orientation of the villa modified the surroundings, aligning rural


Image 10: Villa Simonetta and surroundings in 1889

roads and canals to it. Built in 1502 by Ludovico il Moro's chancellor, the villa changed many owners, until the city planning of XIX century completely changed the surroundings. The villa was abandoned, then used as candle factory, garage, social house, barrack, carpentry and tavern.[10] In 1960 the municipality bought it and restored, using it as music school until now.

The building is a Renaissance villa, organized by a sequence of rooms and spaces that opens to the garden ad the landscape. In the refurbishment of 1547 two volumes were added to the initial core, creating a U-shape building that surrounds the internal square. This solution is oriented to the creation of a functional distinction of the wings, where the offices were placed, from the residential core. Moreover, the old core was preserved and distinguished from the new intervention. The principal façade is introduced by a porch, composed of 9 arcs at the ground floor and two levels of loggias. The relationship with the surroundings was underlined with the implementation of two fish pond, a light border that was dividing the villa from its garden.

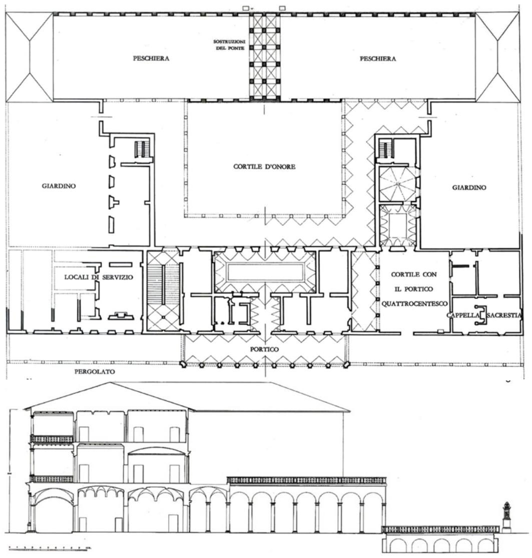


Image 11: Villa Simonetta plan and section

The Customs and train facilities

Scalo Farini was the centre of goods moving in the North of the city, being connected to the main railways. For this reason the Government established here the Customs in 1914, expanding the number of tracks and placing more commercial buildings in the area.

The composition and the geometry of the area affected the placement of that buildings, such as the direction of the tracks and Via Valtellina on East. The building facing the road and the cemetery are isolating the area from East and South, a missing connection that should be restored.

The entrance to the area is protected as cultural heritage, and the only used buildings are the barrack (now occupied by Guardia di Finanza) and the Offices, while the other facilities are mainly abandoned.

The entrance was build in the first implementation stage of Scalo Farini, being the most representative and with the most valuable design. This avoided the building to be neglected, and even nowadays it is well preserved in comparison to other facilities and buildings. The entrance is composed by three defined volumes: the central one has most decorations and traffic of goods and people, while the lateral are hosting the Guardia di Finanza.

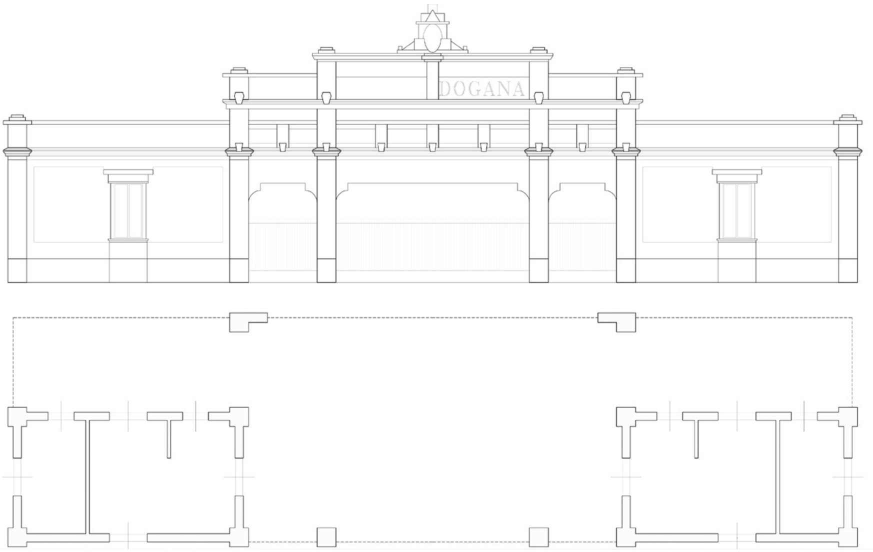


Image 12: Custom entrance, elevation and plan

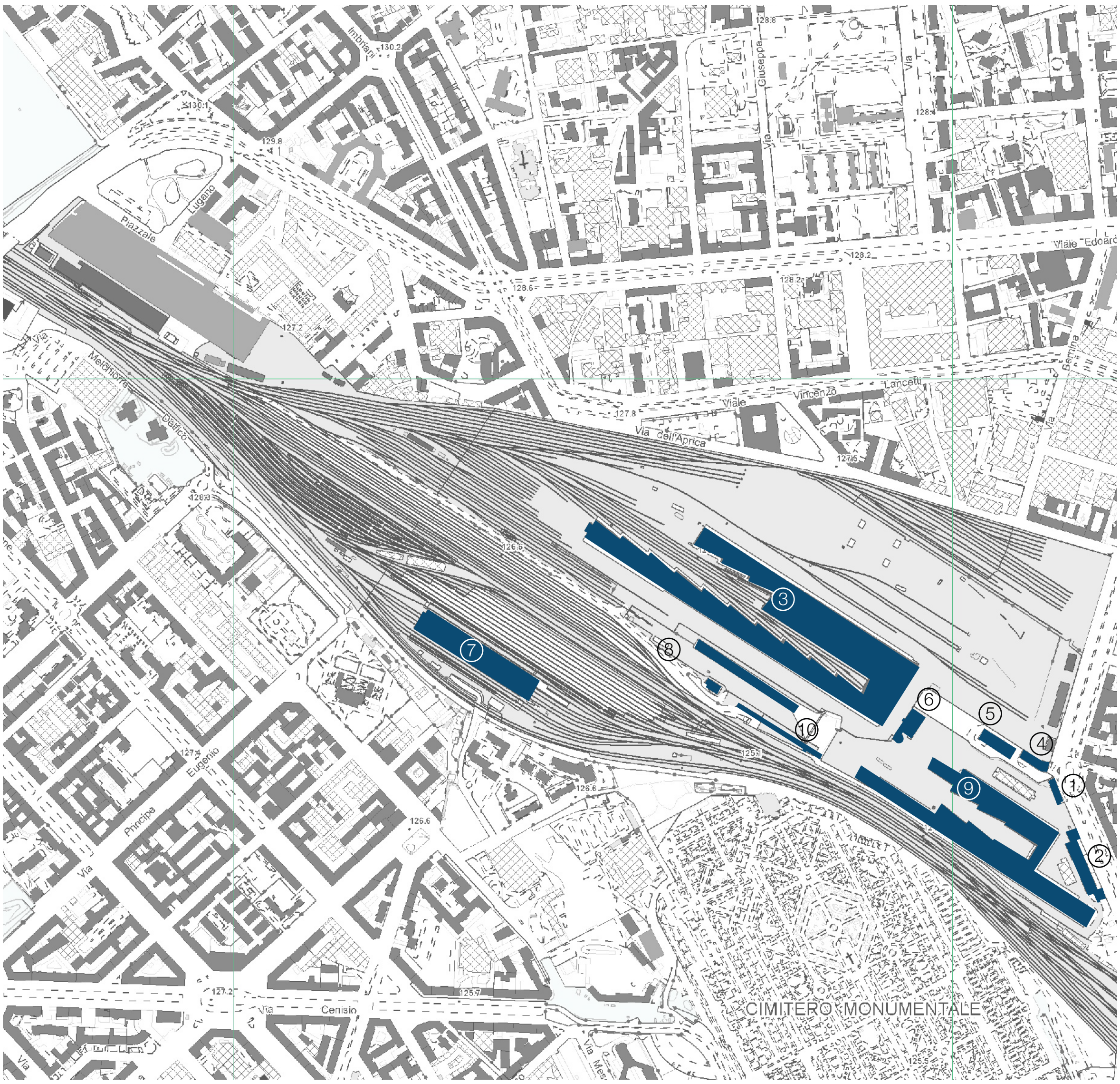


Image 11: Scalo Farini plan, with highligthed the train facilities - Scale 1:10000.
1: Entrance to the Customs; 2: Offices; 3: Warehouse; 4: Customs for packages; 5: Barracks; 6: Little deliveries; 7: Warehouse; 8: Warehouse; 9: Offices for border crossing; 10: Scale.

Morphological and typological analysis of the area

Image 12: Urban morphology

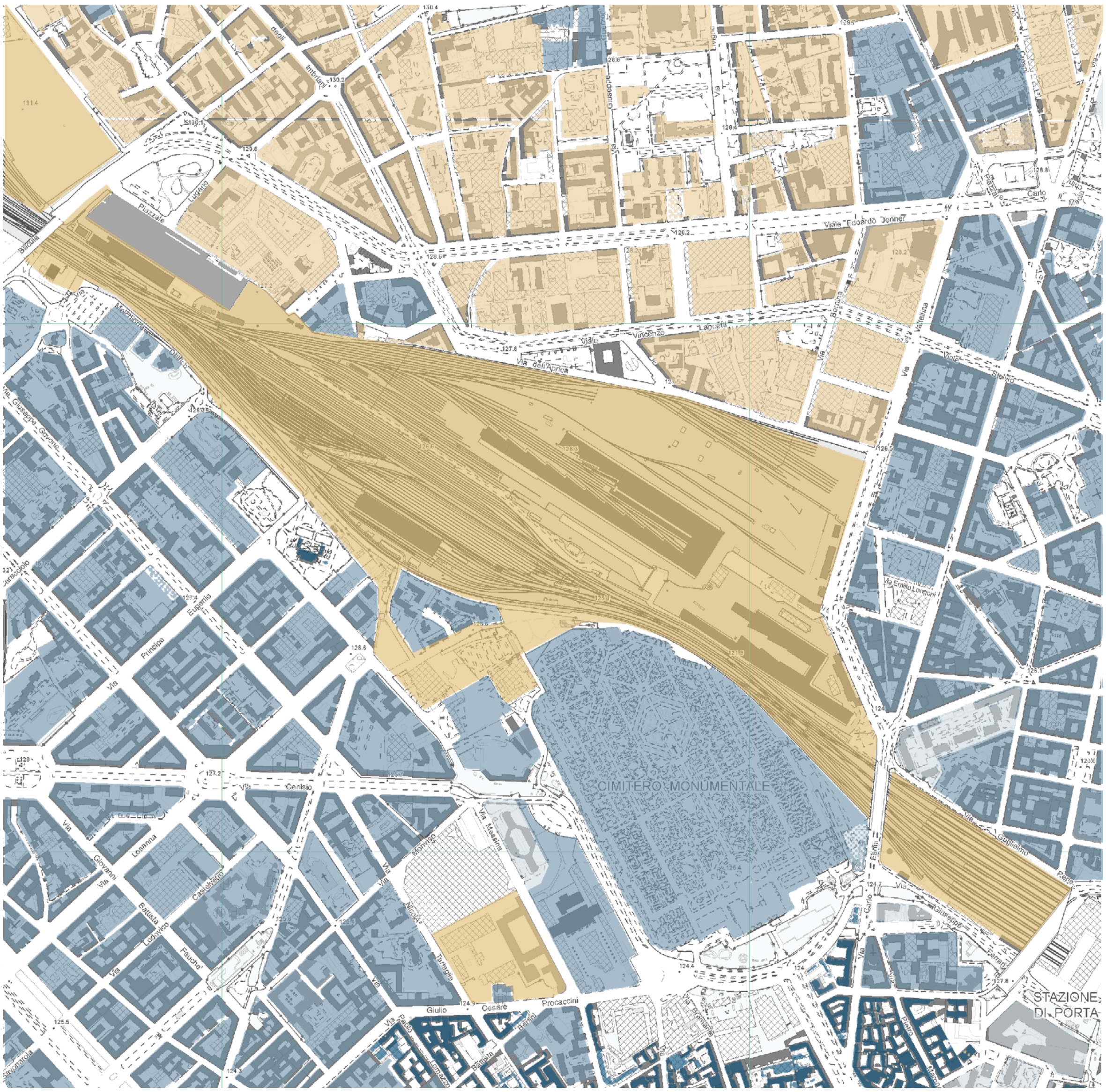
The morphological map is able to highlight the relationship between full and empty areas, built and not built spaces. The shapes also show the uniform, or not, urban fabric, built following the shape of streets, roads and railways.

The area can be easily divided in groups of blocks, which boundaries are the biggest carways. In the same way, the railway track splits this part of the city, leaving a very evident scar in the fabric.

While the thinner and articulated shapes represent residential buildings, the big filled areas mainly refer to productive buildings. They can be mainly be found in the northern part, where residential and productive (mainly unused today) buildings are mixed up. The same division occurs in dimension and grid of roads. They are wider and more diffused in the southern part, while fewer and irregular in the northern one.

The former railway track shelter is very evident in the centre of the free space of Scalo Farini, while the rest of the area is completely free. Its space does not have a fixed order and is free from urban seniorities.

This dualism can also be found in the identifications of urban areas by the PGT. The regulatory plan identifies two main distinctions: established



Historical buildings | Dense urban fabric | Open urban fabric | Urban renewal area | Urban transformation area

Image 13: Planning prescriptions from PGT urban fabric and renewal or transformation areas. The southern and the city centre areas are made of dense or open urban fabric, in some cases even historical. The plan identifies these areas as established and not to be changed very soon. On the opposite, the northern area is subject to urban transformation. It means that it could change in the next years or decades, and that its process is not set yet. In the middle, Scalo Farini is an urban renewal area, that means that there will be precise plans and programs to further develop the area. In this case, the Accordo di Programma and the competition brief, in which both Milano municipality and Ferrovie per l'Italia took part in the writing (see part 7 - Plans, programs and constaints).

A similar division between the southern and northern areas can be also found in the programs of the buildings. While in southern part residential and cultural buildings are more present, the northern one is more dominated by productive (active or inactive) buildings. These will be the first subject of urban reuse and transformation that a winning project on Farini area could contribute to start.

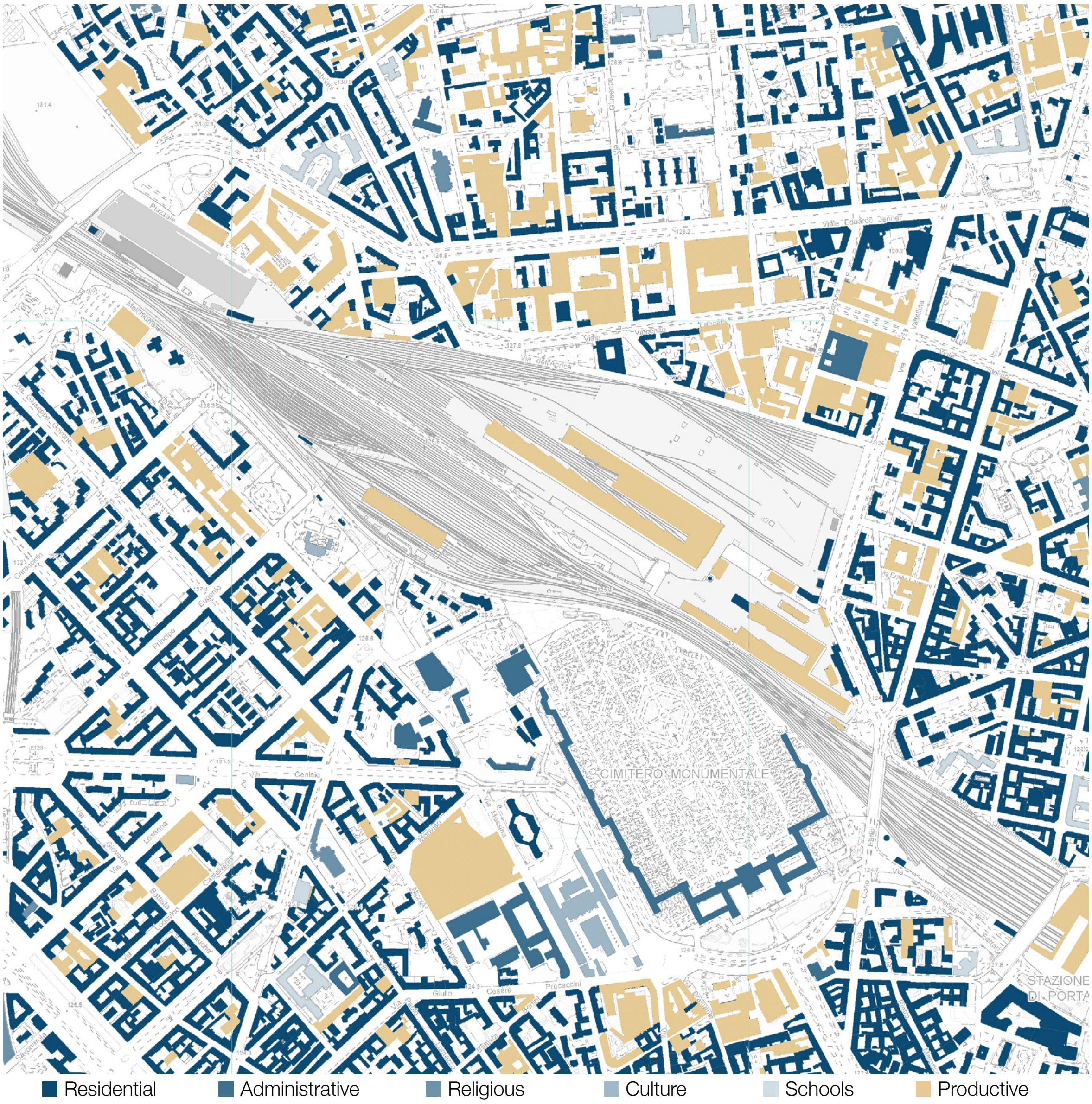


Image 14: Buildings programs

Urban systems and facilities network

Scalo Farini is surrounded by a dense and packed built environment, where a huge amount of public functions finds place. On both sides of the area, towards North and South, more or less the same public services are present.

High schools (the only one represented in the map) are well distributed and sorted, offering different options. Always on the instruction and cultural field, many libraries are distributed on the surrounding area. They are both public and local, that means that they are archives or thematic libraries.

In the North-West direction Politecnico di Milano, one of the most important universities in the city, has some of its city campuses: Bovisa, Durando and La Masa. The entire area of Bovisa (called la Goccia) has been the subject of many proposals for its reuse in the second half of 20th Century. However the space mainly remains like it was some decades ago, dominated by two abandoned huge gasometers. This means that even if Politecnico invested a lot in the area, it still lacks a functioning system at the service of the students. Affordable housing and restaurants would be more than welcome in the immediate surrounding area.

Moreover, the concentration of cultural public services in the area gives it a big potential both for families that want to establish here to raise their children, and in possible student population. Culture is also boosted by the presence of several cultural institutions. Among these there is Fabbrica del Vapore. A former trains and tram factory, it was converted into an art complex embracing music, theatre and dance, plus a cinema. The site provides permanent and temporary exhibitions to visitors that come also from outside Milano, and provides space for artists to create and show their works. The nearby Cimitero Monumentale represents the other big historical and artistic element, filled with a wide range of contemporary and classical sculptures. The presence of mausoleums makes it an institutional and memorial site, visited every year by a big number of tourists.

Regarding free time, the area offers several sport facilities, allowing people to enjoy the activities without moving far from their homes. At the same time a discrete presence of theatres and cinemas, mostly toward the city centre, makes the area enjoyable also at night time. Hospitals are not very present in the area, because of its old origins, that makes it difficult to fit them into the urban fabric interstices. However Niguarda hospital, the biggest public one of Milano, is on the North East side, creating a potential for the area in terms of temporary hostels for people that are being treated in the hospital or their relatives. Finally, police and firefighters are present, but more towards the city centre. Indeed there is a lack of local stations in the upper part of the area, leaving it empty from this point of view.

Zooming to a smaller scale the scene gets more pixelated. In this case, a radius of approximately fifteen minutes walk from the border of Scalo Farini was chosen, and only social services were considered. Indeed their presence and relative density on urban scale can give important informations regarding the life quality of its residents. Four categories were considered: sport facilities, free time spaces, cultural spaces and social services and associations. These are quite diffused and in relationship among them. The "Allegato K" of AdP for the redevelopment of Scalo Farini also contains important informations regarding the needs and wills of the local population. These are strictly related to the public services previously analysed in the area, and also help to depict the social mix that populates the area. More in detail, this kind of services is

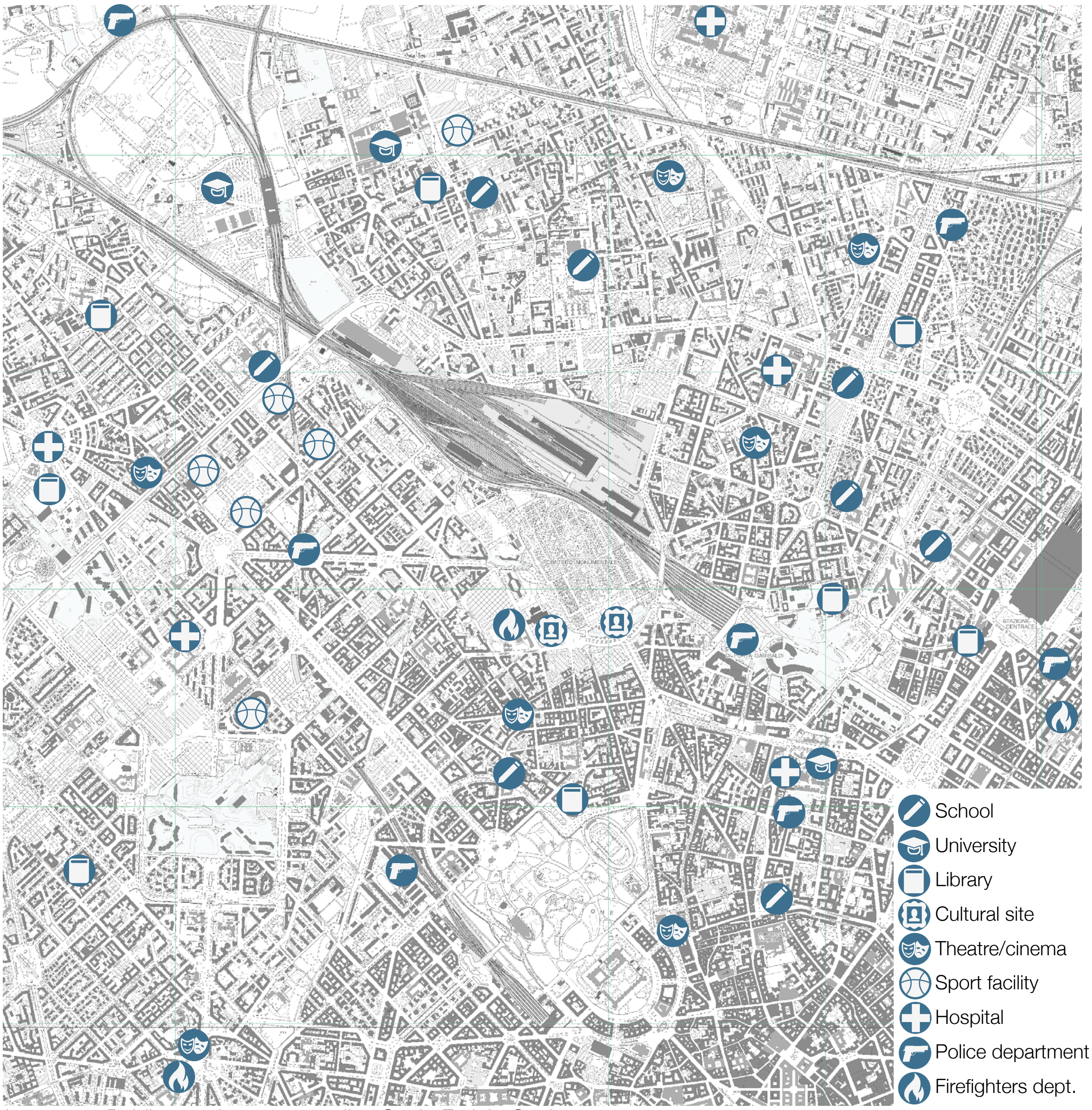


Image 15: Public functions surrounding Scalo Farini - Scale 1:25000

concentrated in the upper and lower bands surrounding Farini. The local associations “GAIA” and “Associazione cittadini zona 9” are two of the many taken into consideration by the local administration.
Finally, the realationship between Farini area and its surrounding has been summed up in a chart that shows the relative distance from different levels of services. If green facilities or retail can be found on a local dimension, instruction or metro stops can only be found on a neighbourhood scale. Going further, train stops, libraries, and theatres can be found on a district level. Finally, health care services and universities can be find on a town level, while major public functions and connections only operate at a city level.

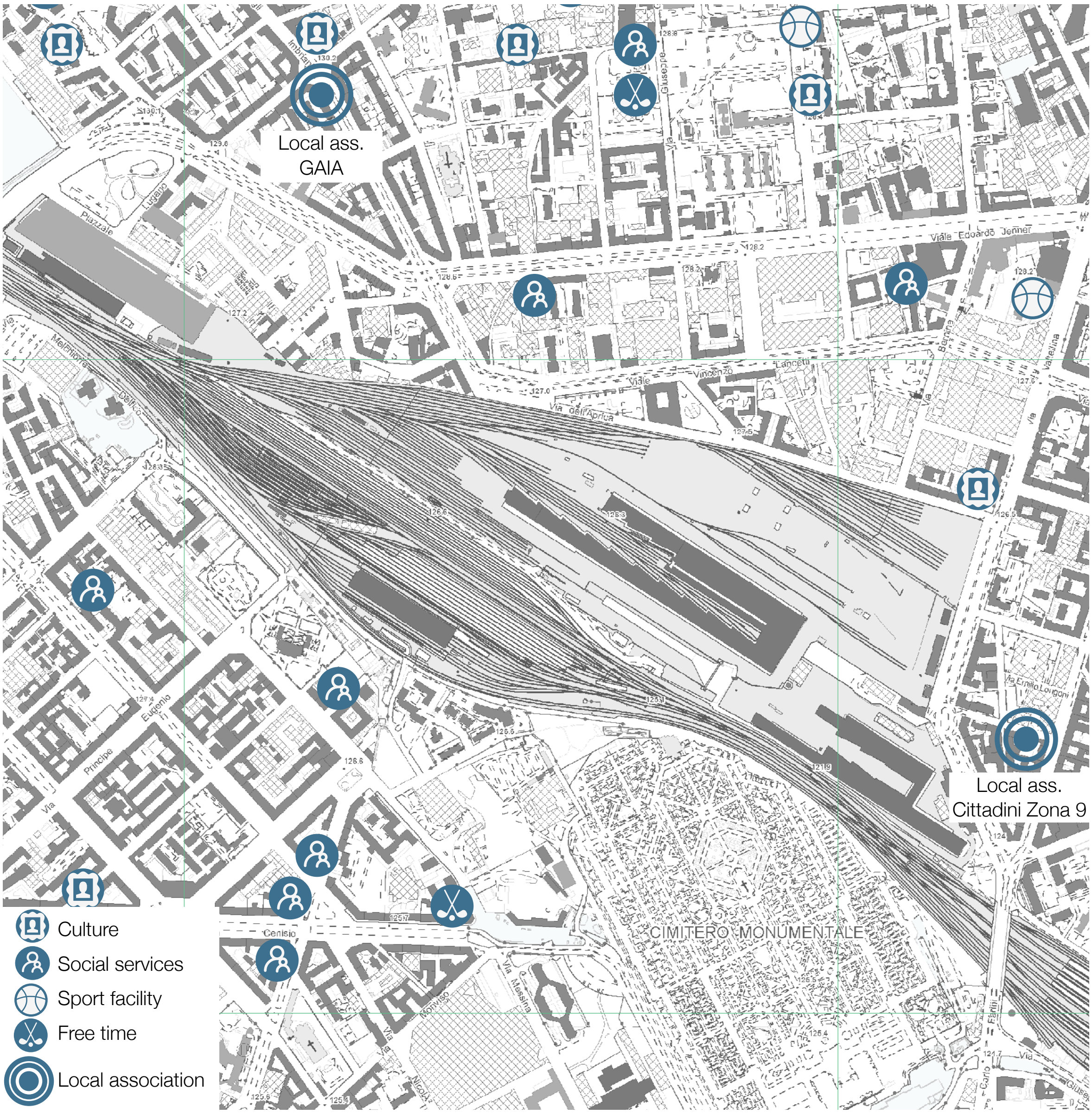


Image 16:Social services surrounding Scalo Farini - Scale 1:10000

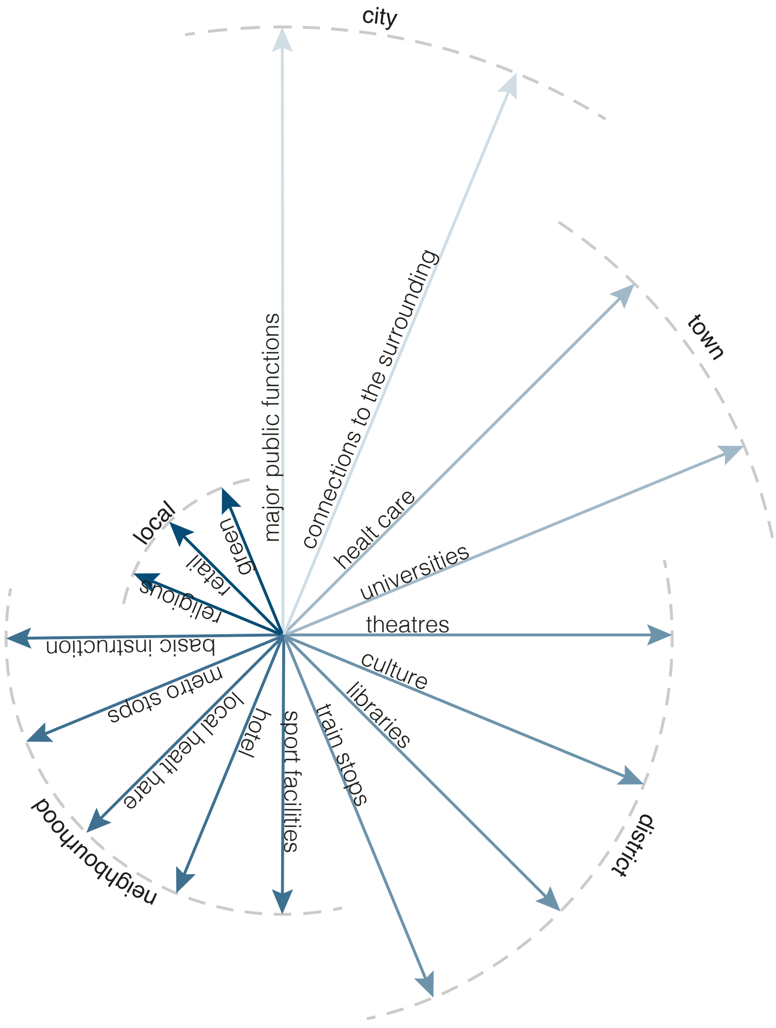


Chart 1: Distance from Farini area to main public facilities on urban scale.

Mobility and public transport

Milan mobility system is the core of an urban region that is extended far beyond the municipality borders. People and goods move both in the municipality network of competence and in the regional, provincial or national ones. Milan is also the central node, historically consolidated, of long distance infrastructures and transport networks either by rail and by road.

The city is infrastructurally well connected to the main nothern cities such as Varese, Como, Lecco, Monza, Bergamo, Torino, Venice or the southern Genoa. Everyday about 850 000 people enter the city to work, study or access primary and secondary services. About 270 000 residents in Milan leave the city every day towards other municipalities as well, and overall, 5,3 millions of people movements affect the municipality.[11] Within the city of Milan, the movements made by people take currently place around 37% by car or motorbike and 57% by public transport, and this data, although still improvable, is one of the most positive among those recorded in biggest Italian cities. Instead if the exchanges between Milan and the other cities are considered, the percentage of trips by motorized private vehicle increases to 62%, indicating the need of improving accessibility to the public transport network in

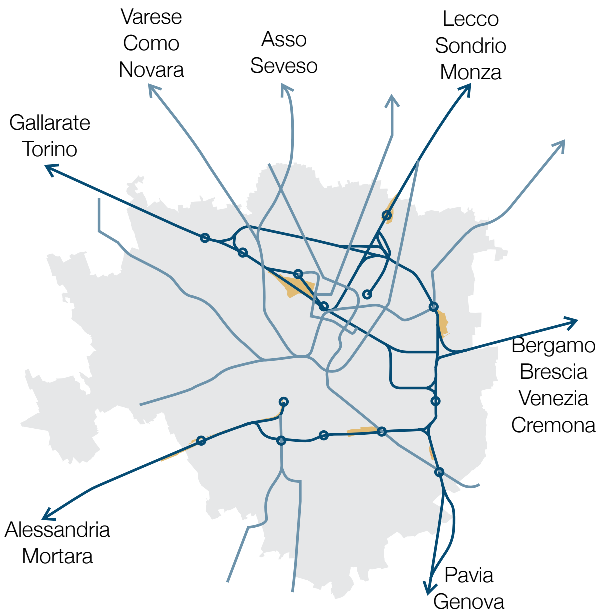


Image 17: Intercommunal connections

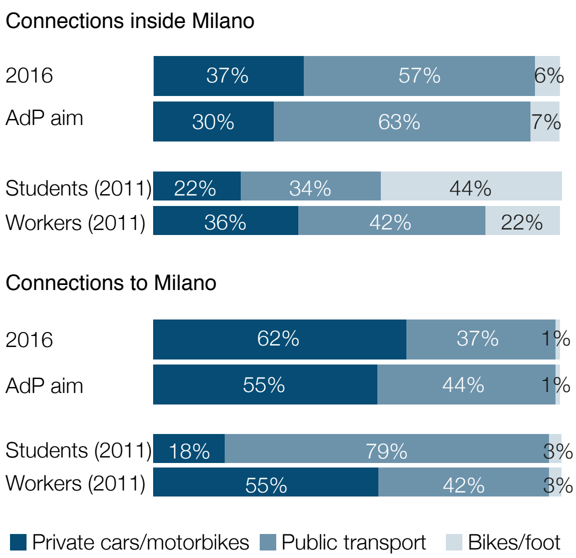


Chart 2: Connections in and to Milano

the urban and extra-urban area.[12]

Public transport network

The city offers an efficient network of public transport that integrates urban and inter-urban overground transport services: the 4 metro lines, operated by ATM and other operators, and the 12 suburban railway lines of Trenord. The Milan subway consists of four lines already working, plus an additional one opening soon. The public surface service of the urban area of Milan consists of a dense and widespread network covering a consistent part of the city: 18 tram lines, 4 trolley lines and over 110 urban and suburban bus lines.[13] According to the Urban Mobility Plan analysis of public transport passengers flows, it is clear how the intensity of movements through public transport is much higher in the city core than in its suburbs. The reason is clearly related to traffic restriction determining many areas of the inner city part.

The Area C was inaugurated in 2012 and encloses 8,2 km^2 of traffic restricted zone. In early 2019 the Area B restricted the access to most of urban area to particularly polluting vehicles.

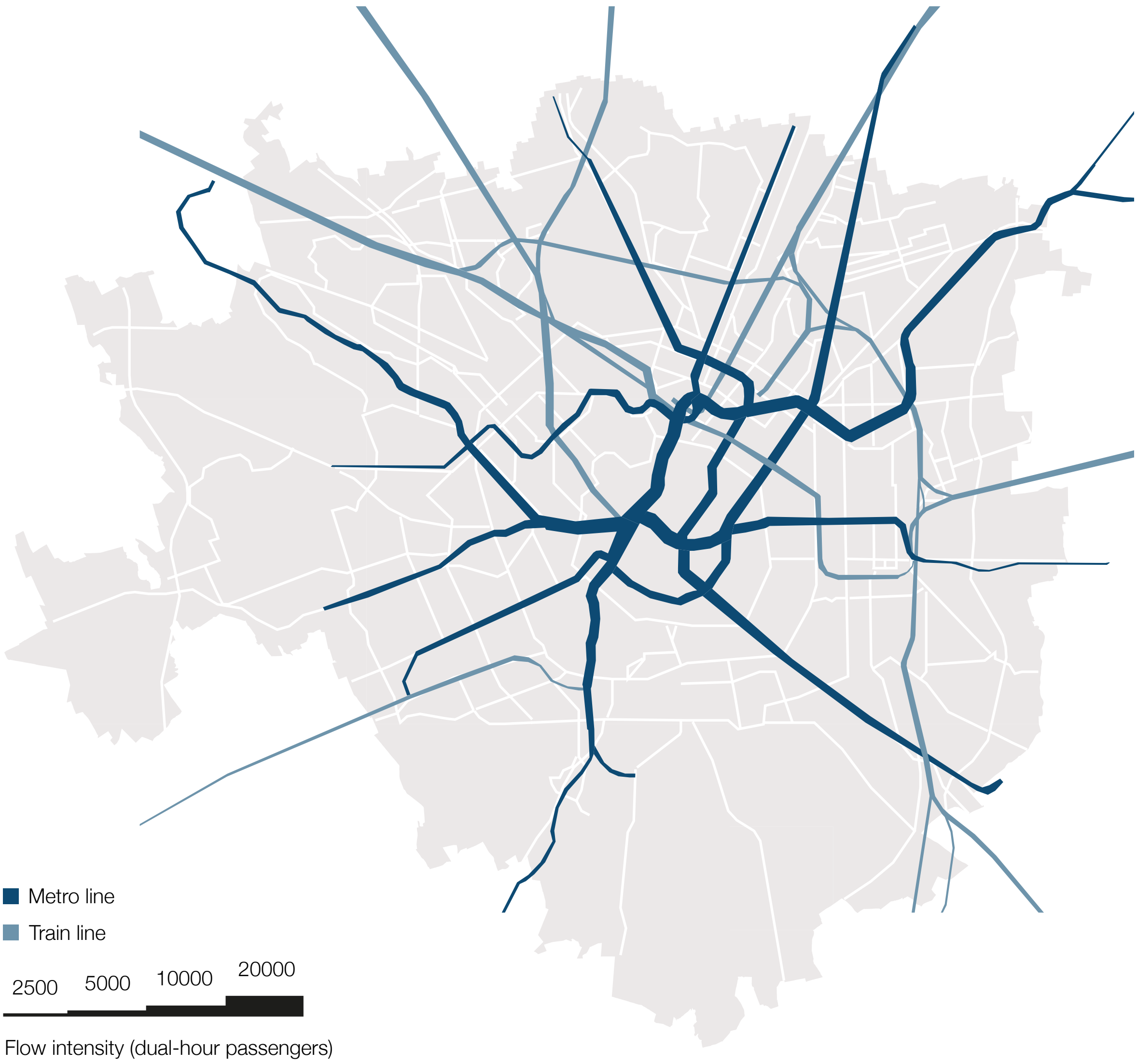


Image 18: Public transport network of Milan and passengers intensity flows

Road network

The PUMS (Urban Plan of Sustainable Mobility) identifies different streets hierarchies. While the main network of highways connects Milan to the big Italian northern cities, sliding roads link the outskirts to the inter-city ones. Indeed interzonal and local streets radially surround the city centre. In this case private vehicles flows are particularly high in the ancient walls outer perimeter. In particular in correspondence of the interzonal roads in which users coming from areas outside the city converge as well as those that are leaving it.

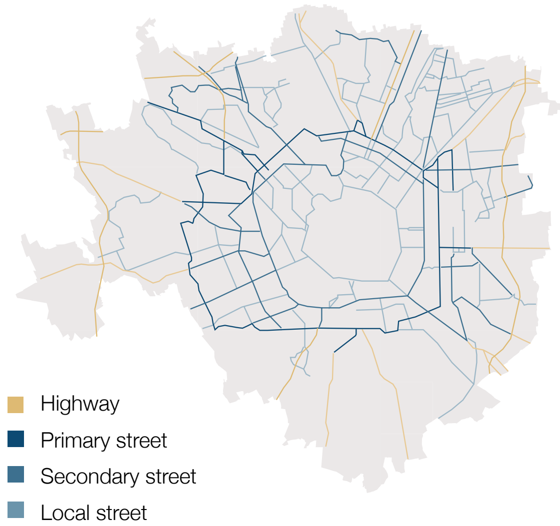


Image 19: Roads network of Milan

Image 20: Roads network of Milan and passengers intensity flows

Public parkings

Public parking areas are quite many. The abundant offer, mainly concentrated around the city centre, answers a still very high demand. In fact, even if Milan is one the Italian cities with the lowest motorization rate, it still remains well above the average of large European cities.[14]

Car sharing and bike sharing

Through the implementation of the new services of car and bike sharing the city continues its path towards sustainable mobility. These services include a fleet of vehicles that can be used for short periods, in time and/or kilometres. Among the reasons why the citizens are shifting towards a car sharing mobility there are either economic and social ones. Indeed, except the annual fee, there are no purchase costs and annual fixed costs, insurance costs, stamp duty, parking or garage rent. In this way car sharing services extend the possibility for citizens to renounce to private cars in favour of a more sustainable mobility. Cars shared can enter freely in Area C and park in special parking spaces thanks to an annual contribution paid by the companies to the City of Milan. Among the main companies offering the service, there are: Car2Go, Enjoy, E-vai, Share'Ngo, Ubeeqo and Drive-Now.[15]

Also the panorama of the bike sharing offer consists both of station-based services (based on stationary pick-up and drop-off stations) and free floating services. In this case bicycles can be unlocked via smartphone and can be freely released within the operating area, at any public rack or in locations that do not impede pedestrian and vehicle traffic.

So far, both of the services operate mainly the city centre and the immediate surrounding areas, while they struggle to spread in the suburbs due to longer distances and less demand.

Image 21: Public parkings of Milan

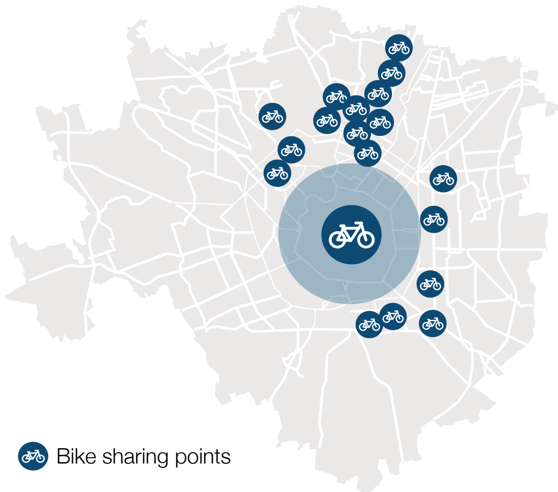


Image 22: Bike sharing points in Milan

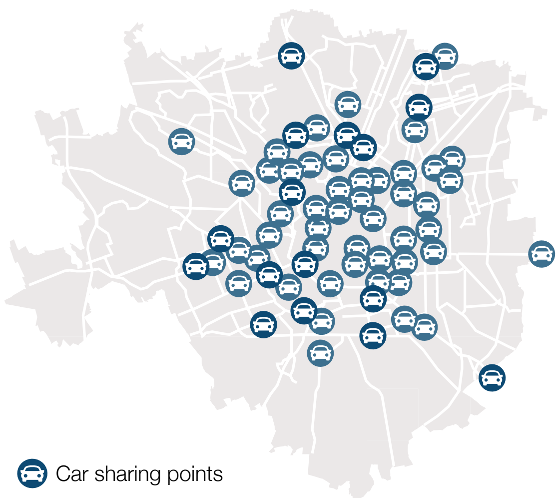


Image 23: Car sharing points in Milan

E-charging points

The diffusion of car sharing is also moving towards hybrid or electric solutions as well as the European vehicles market. Since of the main reasons in the struggle for electric vehicles to spread is the lack of charging points the theme is particularly important. However driving an electric car in Milan is becoming easier and easier. In fact, during 2013 charging points within city borders doubled, to a total of 110 stations.[16] The panorama is getting even wider in the last few years.

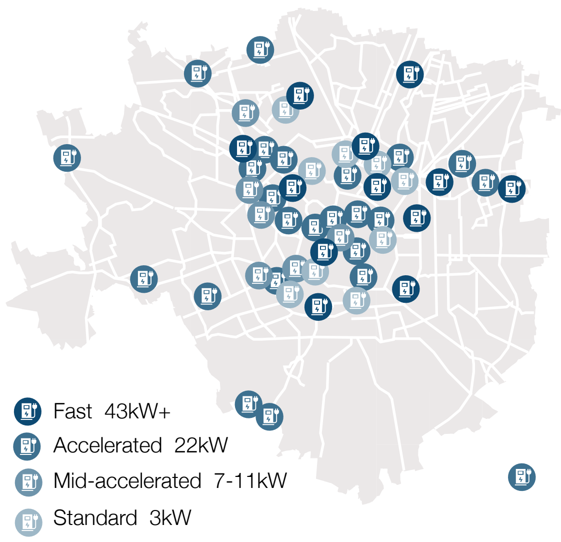


Image 24: Charging points in Milan

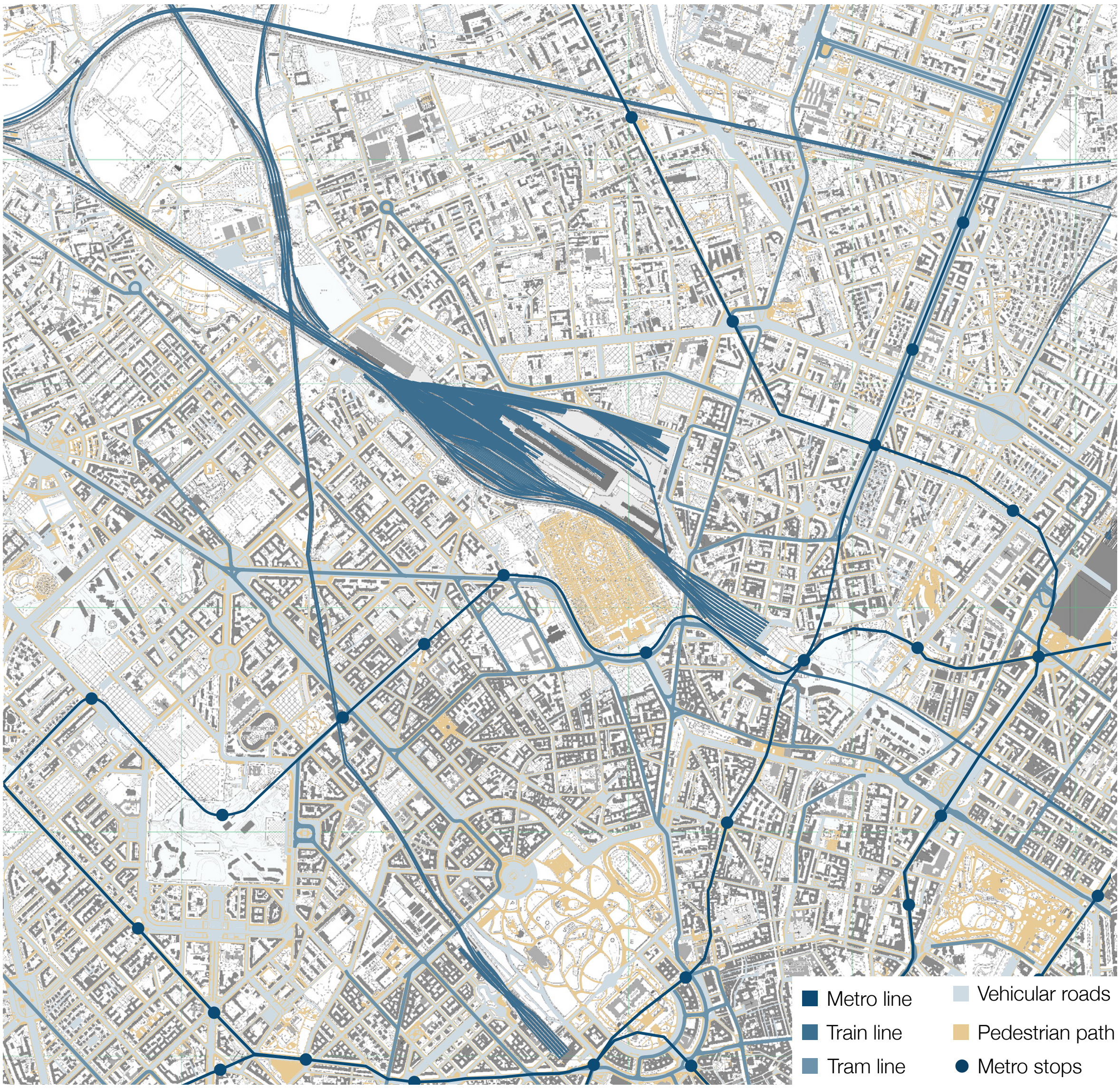


Image 25: Mobility networks in in the sorrounding area of Scalo Farini - Scale 1:25000

Focus on the area of Scalo Farini

The abandoned railway station of Scalo Farini is positioned in a strategic area of the city crossed by railroad and underground local tansport tracks. It is located nearby a M5 line subway station (Porta Garibaldi) and several bus stops , bike and car sharing stations. The area, located in near to one of the roads with the highest flow intensity, also counts many public parkings and a few already available charging points for electric vehicles. It is also well served by tramways and secondary streets, both equipped for vehicular and pedestrian transit.

It is however important to note how, despite the high number of bike sharing posts, bike lanes are missing, as in most of the rest of the city.

Image 26: Mobility networks in in the sorrounding area of Scalo Farini - Scale 1:10000

Natural components

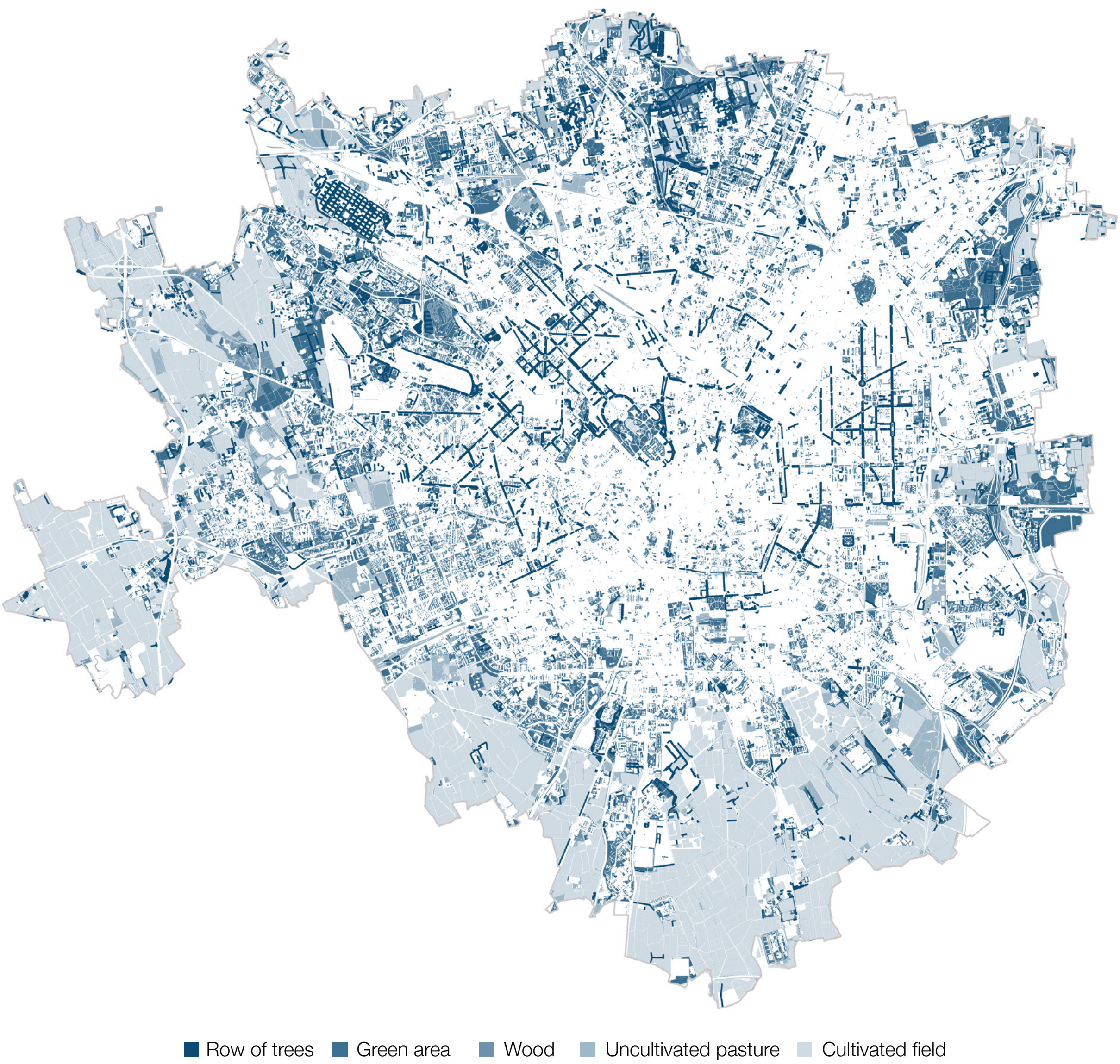


Image 27: Classification of green areas of Milan

Milan has a public green area of around 24 million square meters in approximately 3,000 censorship locations. These include historical parks, parks, gardens, green roads and squares. The arboreal heritage consists of over 220 thousand trees, of which at least 17 are monumental. 60% of trees are distributed in parks and gardens, 29% along road rows and the remaining, 11% in schools or green areas belonging to municipal buildings.[17] Milan is permeated by a large system of parks crossed by the waters of the canals and its rivers (Olona, Seveso, northern Lambro and southern Lambro). The fundamental role of green areas is urban drainage and stormwater absorption. The green structures are mainly agricultural for what concerns the perimetral parts of the city, flowerbeds and rows of trees in the metropolitan ones. However, there are also several green areas such as parks, among the main ones: Parco Lambro, Parco Forlanini and Parco Sempione, closer to the core of the city. The area of Scalo Farini, not far away from Parco Sempione, is characterized by the presence of the monumental cemetery of the city, which surface is mainly green, and rich in trees and vegetation. There are also some minor green areas surrounding the site.

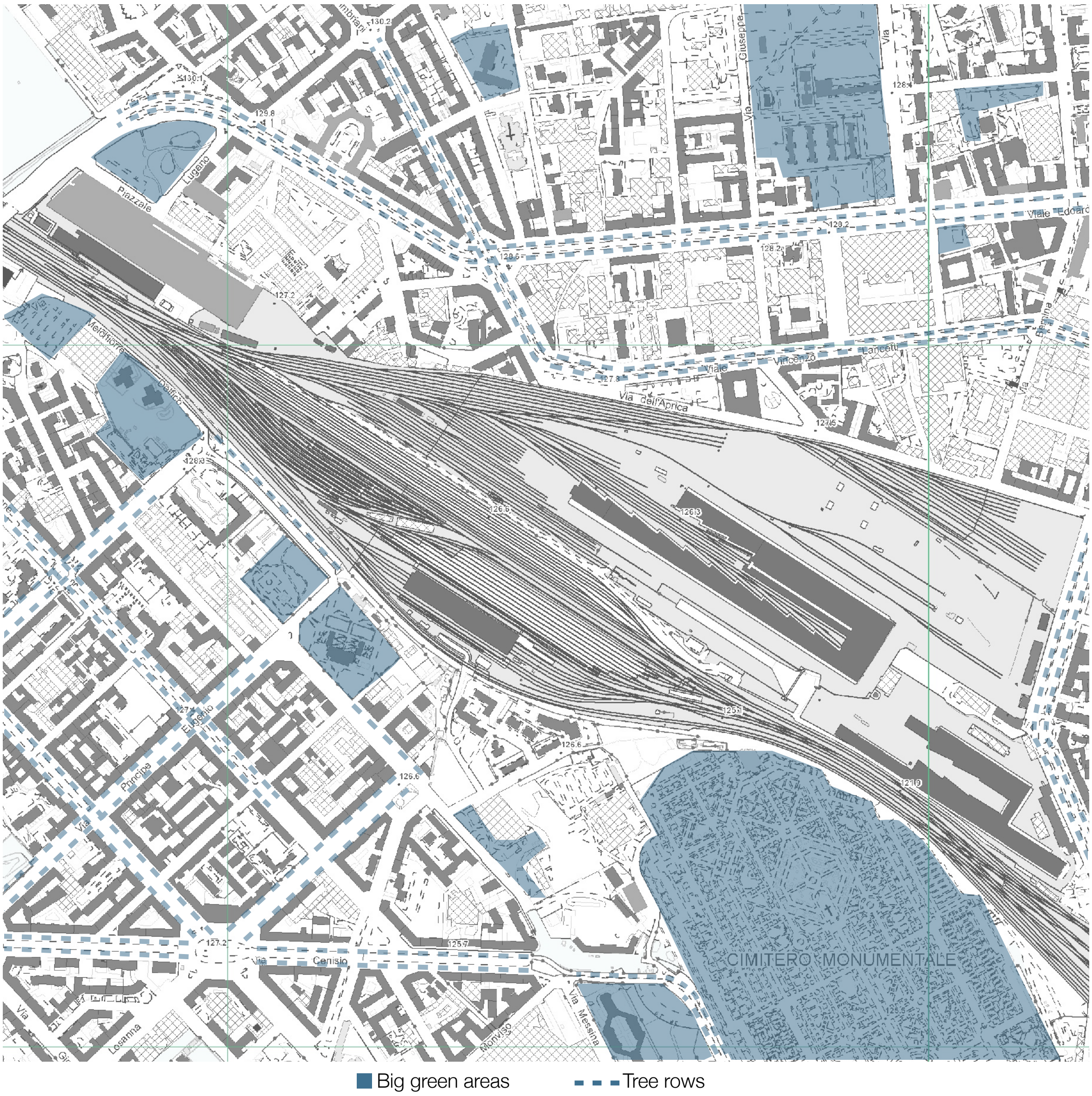


Image 28: Green systems surrounding Scalo Fraini - Scale 1:10000

Demographic and economic trends

In the last years Milano has experienced a huge phenomenon of growing population. If, until a few year ago, people tended to move from the city to the surrounding, looking for better living conditions related to life quality, from 2003 there has been an opposite trend. Higher salaries, increasingly good living environment and immigration all concurred to make urban population start growing.

As shown by ISTAT data Milano population grew of 72000 inhabitants in the last decade. This could seem weird if compared to the trends of births and deaths over the last decade. If in 2007 approximately 13000 people were born and died in the same year, nowadays the difference between births and deaths is around 3000 people per year. The trend also shows how this situation is expected to worsen in the future.

The reason is in migration towards the metropolitan city. Indeed every year from 2009 showed more people registered at the registry office than the ones that left it. This flux is fed both by people coming from other cities in Italy and by people that come from out of Italy, that count for 19% of the total population. The peak was in 2013, in which there were 65000 more registered people than the ones that de-registered (that were

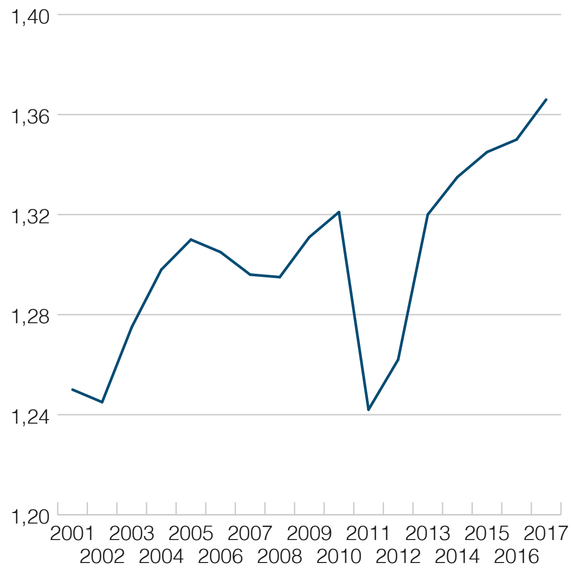


Chart 3: Trend of people living in Milano

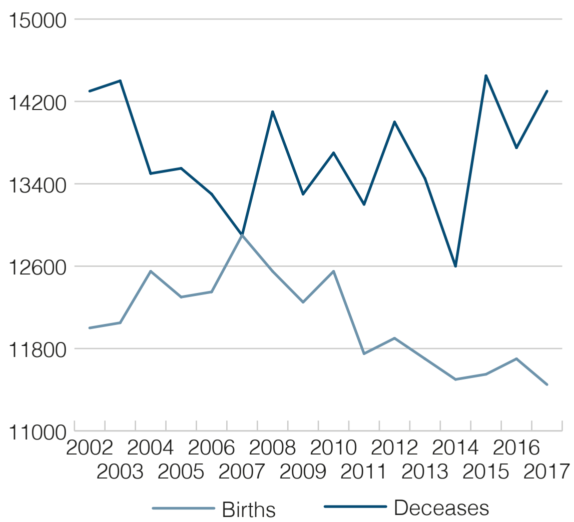


Chart 4: Trends of births and deceases in Milano

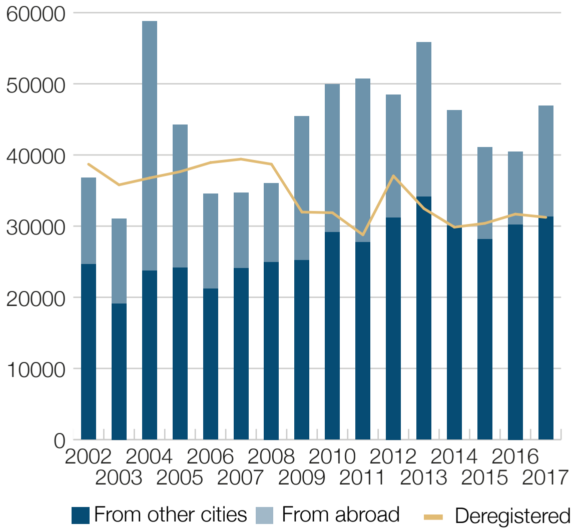


Chart 5: Immigration and emigration trends in Milano

51000) for a total of 119000 people coming from outside Milano.

The attractiveness of the city can be listed separately for the different population sections. If for working people it is mainly due to the economic growth (and well being) that the city is experiencing, for students it is the number of universities that stand out in international rankings.

According to Assolombardia[18] Milano grew of 6,2% in four years (2014-2017) and is today the third richest city in Europe according to Eurostat[19], after London and Paris, with a GDP of 671 B€/year. The main sector, that is leading the economic growth, is the one of services, that grew of 7,6% in the last four years. Thanks to this push, nowadays Milan GDP is higher than pre-crisis level of 3,2%, while Lombardia is at -1,1%, and Italy at -4,4%. However it is important to consider that not all the city has the same productiveness, and indeed there are some districts, like the one of Porta Nuova, that was considered, in 2017, Europe's richest and most productive area in any city.

On the other side, universities are expanding and getting higher and higher recognition around the world. In 2019 Politecnico di Milano was listed seventh in the three fields of architecture, engineering and design together, while Bocconi was listed eighth among business and finance schools.[20] The main reasons are related to the ability to attract international students and teachers, to offer entire course taught in english and to connect very effectively to the working world, through startup incubators or similar investments. This is why 13% of the total population is made of students, that count 171000 people living in the city. The trend shows also here growing rates, with 4% students increase between 2014 and 2016.

This is why, of the 1,5 million people that is expected to live in Milano in 2025[21], a big part will be made of young or immigrant people. In addition to this data, ISTAT shows how new generations are less likely to marry, or to go to live together, than older ones. This, together with high prices of housing, means that a growing part of the population will be living alone and will need cheap living solutions. At the same time, there is a spread between the number of young people and older people, with 114000 people between 45 and 49 years old, and only 56000 people between 15 and 19 years old.

Despite these indicators building industry is now focusing on high-price residential and offices

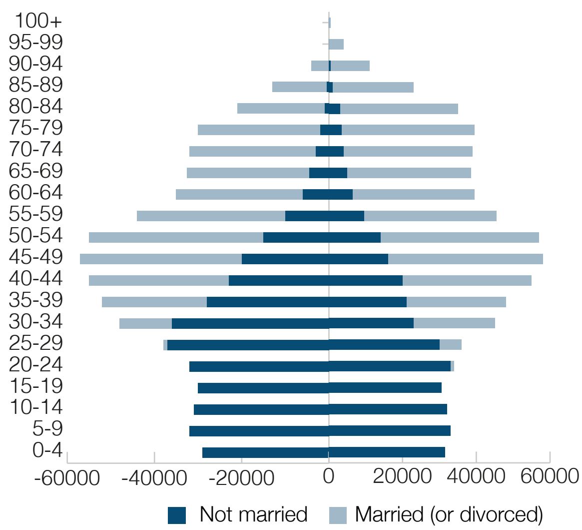


Chart 6: Age of residents in Milano

buildings. In 2018 the sells of houses was 32% higher than the year before, for a total of 1233 units.[22] This pushes enterprises and investments funds to invest even more on newly built buildings, with a growing lack of low priced, or social, housing.
The mayor, Beppe Sala, recently highlighted the issue, claiming that there is no more space for big housing speculations.[23] Instead the attention should shift towards social housing solutions that offer lower revenues, but safer. Social housing represents nowadays only 15% of total housing in the city, and it should be expanded, as it already happens in other European capitals.
Instead, new developments are mainly related to high to super high quality buildings. The newly built areas of Porta Nuova and Quattro Torri have prices that overcome 10000 €/m2, reaching the prices of the old city center. For the rest of the city, prices decrease as one moves from the center to the periphery. Something similar happens to average income per person, with more than 50000 euros/year for people that live in the center, till less than 20000 euros/year in the periphery. But if these two datas more or less overlap, population density follows different paths. Most of the people live in the first belt of the city, between the city center and the periphery, with some small part that are less inhabited.In this panorama the area of Scalo Farini has a fundamental role, and a very high potential. It is located between low and high income areas, but in the densely populated area. This means that it could represent a very strong element of reconnection within the urban fabric. Its nearest surrounding are social housing districts in the North and North West direction, while established, wealthy districts in the South East direction, and the super expensive district of Porta Nuova in the East direction. The possibility of building in the Farini area could have very good or very bad consequences. On one

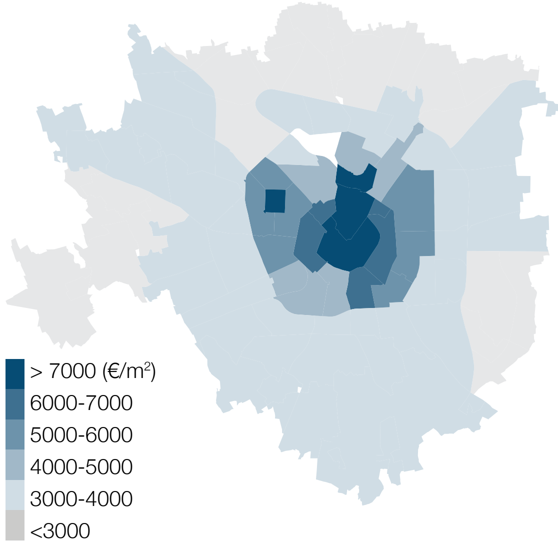


Image 29: Housing prices per square meter

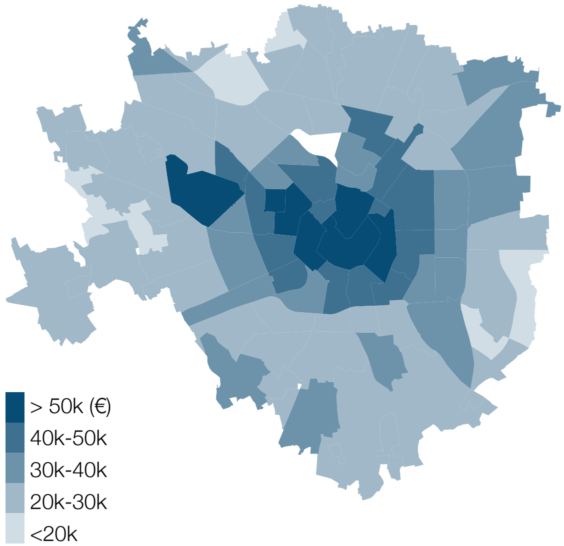


Image 30: Average yearly income per capita

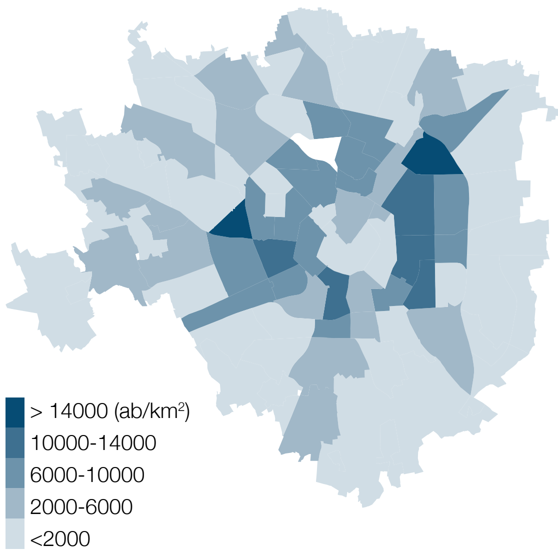


Image 31: Population density

hand, there would be the chance to finally reconnect the urban fabric after decades of division, mixing high and medium income population and making them to create a new urban identity. On the other hand, the risk is the one of segregation, if a not wise masterplan is developed. Putting all social housing requested by the brief near to the North West border of the area, while gathering offices and high quality residential buildings in the South East area would avoid any conflict between different kinds of population. However these people would never meet, and there would not be any occasion of integrating the different needs and strengths. The challenge would be to fill the white gap into the income map with a color that remains in the middle of the range, meaning that the integration is ongoing, and that the redevelopment of this area could bring to a positive spinoff for the surrounding districts. The district of Dergano could positively mix with richer areas like Mac Mahon and Cagnola, today mainly residential, and that would go to look for social life or services in other areas of the city. Scalo Farini could then represent a good candidate, in which social mix and services would find place and bring to a real urban regeneration.

Plans, programs and constraints

Image 32: Map of disused Milan freight yards

Scalo Farini is one of the key elements of the recent review of the "Accordo di Programma Scali Ferroviari" (agreement on the program for freight yards) in which the municipality, together with Ferrovie dello Stato, agreed on redeveloping the areas of seven disused freight yards of Milan.
Once fundamental elements for the city economy, working as infrastructural connections of the city, today these areas are elements of discontinuity in its fabric.
The AdP lists a series of objectives in reusing these areas:
- Reconnect and regenerate through green infrastructures creating an ecological connection between the abandoned railway stations
- Integrate and link through the rails in order to implement the transport connections, creating a railway system with characteristics similar to those of the subway system. Among the intentions, indeed, the areas must host public and private services, strongly attractive.
- Think about the areas as social innovation and new economic centres, to create new job positions and to harmonically dialogue with the city of sciences that will take life in the Expo area and in Sesto San Giovanni one.

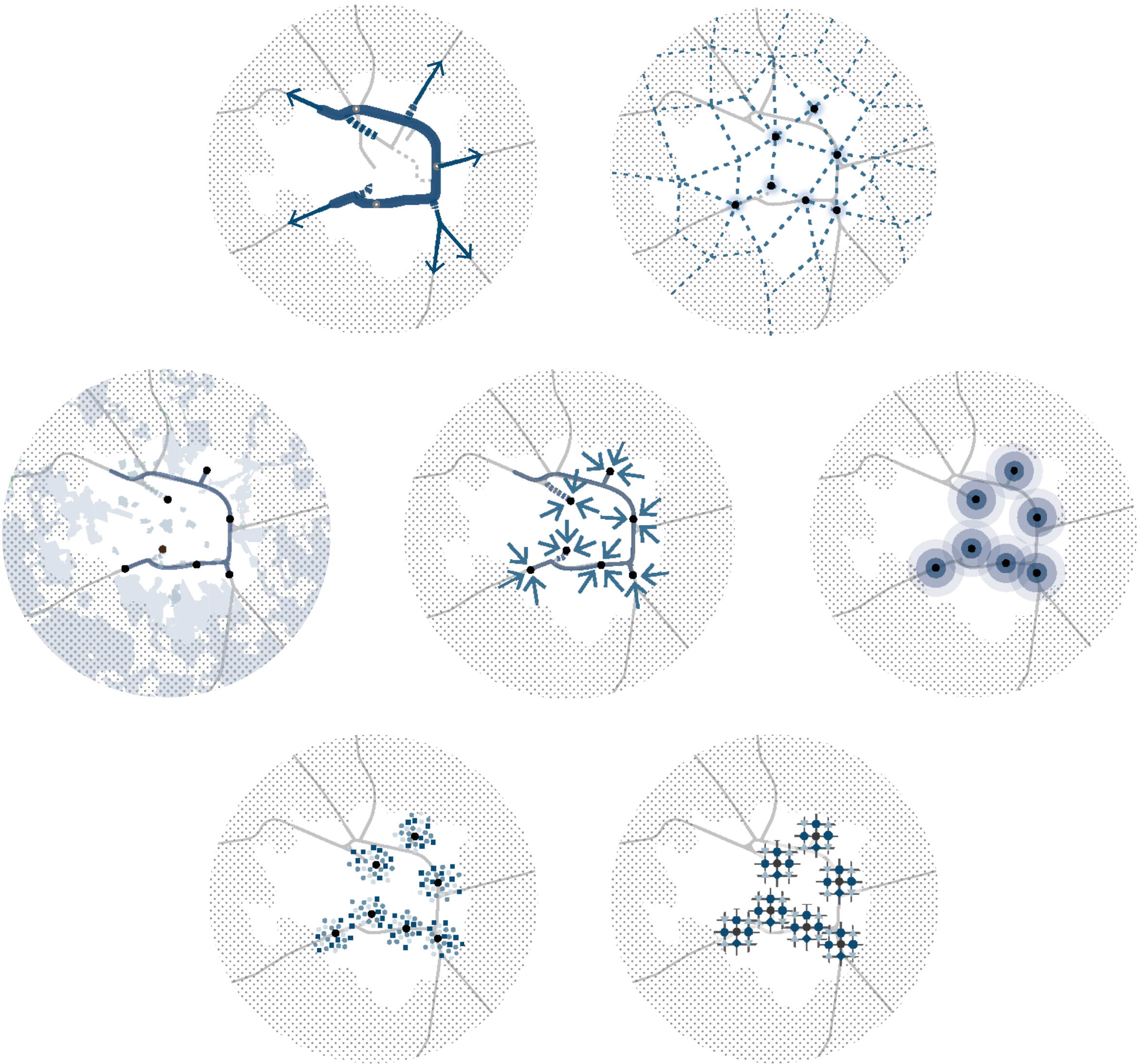


Image 33: AdP scenario of the redevelopment of Milan disused railway stations. Top to bottom, left to right: New connections to peripheries, New connections to the city center, Green belt, New attractive poles, New identities, Mix of functions, Reconnecting urban fabric.

- Invest in younger generations and on the peripheries generating houses for any type of possibility, improving social conditions in these areas and eliminating the physical barriers, bringing the freight yards “closer” to the city centre.[24]

The competition on Scalo Farini

In the “Documento di visione strategica” (Strategic planning document) schematic approaches to each of the abandoned freight yards are summed up. The main aims are the relationships that the transformed areas should have with the surrounding area and with the urban context. In the case of Scalo Farini the regeneration project should strongly consider the preexisting elements enhancing their original meaning as well as the surrounding green areas. The documents explicitly invite to create a strong relationship between the area, which at the moment is almost inaccessible, and the surrounding, opening it up to the rest of the city.

A direct connection should be created between the area and the one of Bovisa, the area of Isola, Porta Nuova and with the northern one of Dergano. The aim is to reconnect the urban fabric that is physically cut by the railway at the moment. Among the requirements, green and public spaces need are on top. The importance of crossings of the area directly follow, in order to enhance the connection between different districts.

Moreover, requests from the neighbourhood showed the necessity of libraries, high schools, structures for elders and youngster as well as aggregation centres such as cinemas or theatres. The area of Scalo Farini is made of two different areas. Farini area is owned by Ferrovie dello Stato and will partially continue to host the railway. The “Unità Valtellina”, instead, is property of Coima Mistral Fund and hosts the building of the

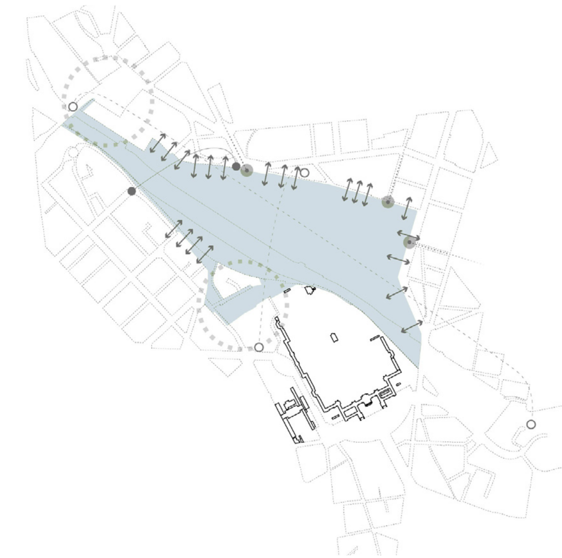


Image 34: Connectivity strategy

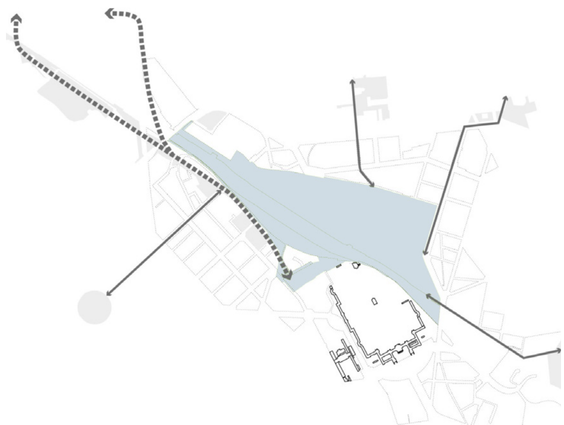


Image 35: Strategy for a green public space

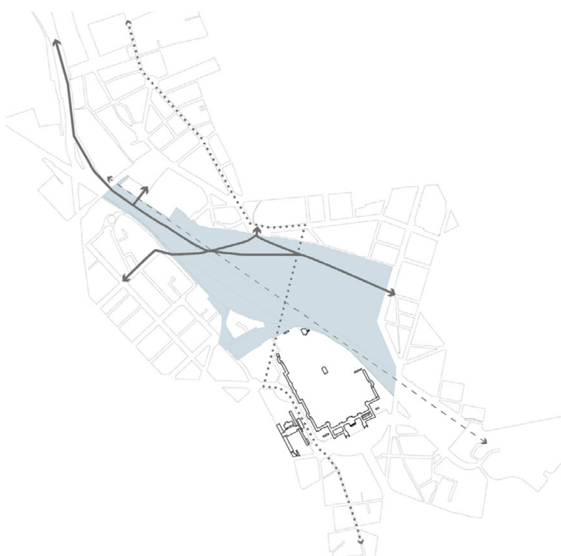


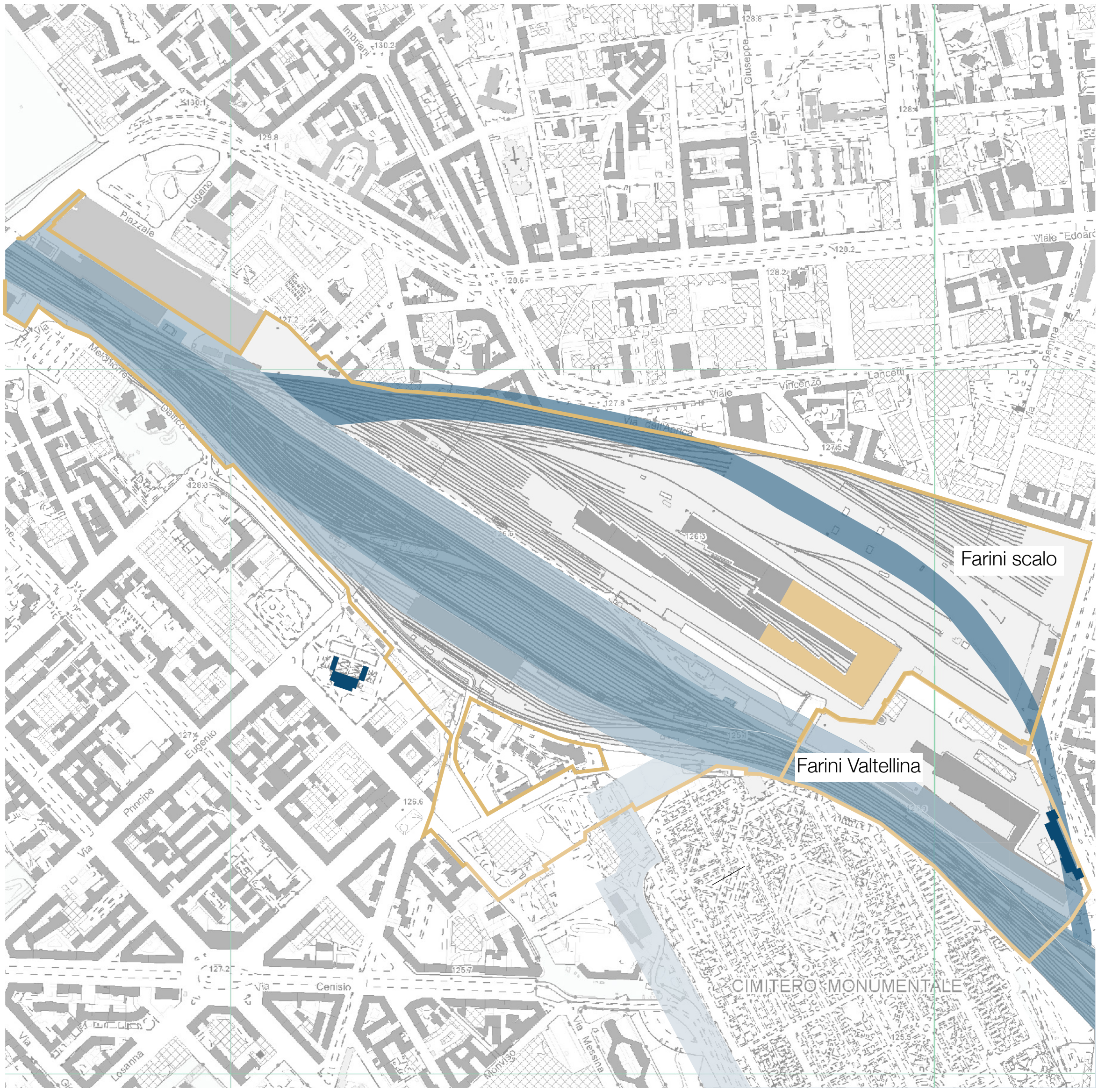
Image 36: Stategy for a crossable area

old customs, subjected to monumental heritage constraint.

The two Units are in any case part of the same “Special Zone” and as such, subject to a unitary Masterplan, which constraints are summed up as follows.

	Scalo	Valtellina
Total surface	550478 m²	
Construction area	400046 m²	
Max gross floor area	362947 m²	39513m²
Floor area ratio	0.90	
Green surface	> 65%	> 70%
Non residential	> 30%	> 50%
Social housing	> 52170 m²	> 9878 m²

Table 02: Requirements from the brief



Listed buildings | Passante line (underground) | Technical area | Forbidden railway area | Forbidden cemetery area | Project site boundaries | Buildings with already a project

Image 37: Limitations of the area

Concept formulation and precedent case studies

SWOT analysis: Strenght, Weaknesses, Opportunities, Threats

Strategic planning is a useful tool in the development of the project idea, being comparable to a systematic process for the development of the city. The SWOT analysis defines the strengths, weaknesses, opportunities and threats that can influence the design choices, such as the definition of objectives and strategies. In this way it is part of the planning process, being a powerful synthesis tool for the city and its components.

The SWOT analysis was carried out for Scalo Farini taking into account internal and external factors of the project area, in order to facilitate the realization of a sustainable project with respect to the rest of the city of Milan. The relationship with the adjacent areas and the rest of the city was of fundamental importance for the realization of this analysis, in such a way as to widen the area of impact of the intervention.

Each of the elements of the SWOT analysis was studied according to four criteria, with the intention of facilitating the reading and extrapolation of information for the subsequent planning phases. These criteria were chosen based on the urban environment that characterizes the area and its main characteristics, together with the city development plans and the previously defined project requirements.

The urban regeneration of Scalo Farini is a strong opportunity for connecting previously separated areas within the city of Milan. For this reason one of the criteria used is urban mobility, which aims to facilitate accessibility to the area and the connection with the inside and outside of the city. The presence of metropolitan (M3, M5) and railway stations is certainly a force that can be used in the development of project actions related to mobility. With regard to connectivity within the city, an urban transformation intervention is already planned within the Milan PGT in the area north of the Scalo, which will also cover an infrastructural penetration within Scalo Farini.

The elements that can have a negative impact from the point of view of urban mobility are mainly linked to the historical isolation of the airport in relation to the surrounding area. The lack of access due to the presence of the tracks and the Monumental cemetery have been aggravated by the impossibility of access to the public to the whole area, eliminating any connection with the outside. Furthermore, the lack of an appropriate cycling infrastructure within the city of Milan is a threat to the connection of the area, which must also favour this type of mobility.

In the urban plans foreseen for the area of Scalo Farini present within the PGT and in the project announcement there is the need to realize a series of useful services to the city, both cultural and for aggregation. The second criterion is in fact related to the elements that can promote or slow down the development of new services in the area, as well as the effect on those existing or being created in the surrounding areas.
The proximity to the Bovisa campus of the Politecnico di Milano, as well as the plan to build a new campus of the Brera Academy within the airport can attract users and users of services, such as residences, cultural centers and nightclubs. Also the proximity to the Niguarda hospital, the largest in Milan, can be an element of strength for services to users in the area.
The main problems in this case are also related to the lack of services in the proximity designed to serve the area, as it has historically been excluded from the planning of urban functions and services. This could cause an overload of services in the area, or on the contrary an effect of gentrification and polarization towards those areas with more developed and attractive services.
Within an urban regeneration plan, the landscape plays a fundamental role, as it brings the project back to the human scale by relying on the territory. The historical component is important inside and outside the project area. Industrial archaeology, Villa Simonetta, the Monumental Cemetery and the Dogana are buildings that reflect the historical importance of the districts adjacent to the area and their urban routes. The vegetation inside the area is characterized mainly by trees and shrubs of a spontaneous nature, while outside there are already gardens and parks that represent a force of the area. The landmarks in the vicinity, which undoubtedly help to increase the quality of the spaces, are also important for the characterization of the landscape. Finally, the Municipality of Milan has included the project on Scalo Farini within a project to upgrade rail yards, proposing the creation of a “Green Line” that would connect Milan’s green areas.
The isolation from the city and the non-use of the area led to a general degradation of the buildings and infrastructures inside, while externally the buildings have never sought a direct relationship with the airport. This lack of relation is an intrinsic weakness of this abandoned area, which can affect the perception from the inside towards the borders of the airport. Finally, the presence of numerous green areas, imposed by the project announcement, can lead to a crime and degradation effect in public spaces, if they are not used and cared for.
The economy and the social characteristics of the surroundings are always of primary importance within an urban analysis. The main economic centers present are Porta Nuova and the City Life district, objects of recent interventions that have been included in the urban fabric. These, in addition to all the Urban Transformation Areas that have been identified around the area, can guide the design towards services offered or missing in these realities. Furthermore, the level of densification and the social mix of adjacent neighborhoods can be an index of a wide range of different users, to whom effective and sufficient services must be provided for their needs.
The absence of an identity of the project area is an element that can hinder the social and economic component within the project, as it will probably take time to be developed within the mentality of the users. Furthermore, the presence of a high economic and social difference between the different areas separated by the airport can lead to gentrification phenomena, distorting the nature of the neighborhoods and preventing communication between different social realities.

	Positive	*Negative*
Internal	**Strenghts** Mobility & connectivity - Presence of railways passing through the site. - Presence of the Passante under the site. - Closeness to train stations (Lancetti and P.ta Garibaldi) and subway station (Monumentale M5 and Maciachini M3) that improve the accessibility. - Between the West ring road (A4) and the city center, allowing the inner and outer connection to the city. Services - Closeness to Bovisa campus of Politecnico di Milano, presence of students, professor and workers. - Closeness to Niguarda metropolitan hospital, the biggest hospital facilities in Milan. Landscape & environment - Presence of industrial archaeology in the site. - Historical component of surroundings. - Closeness to Villa Simonetta garden. - Presence of spontaneous and local vegetation. - Presence of “GIardino comunitario Leo Garofalo” with a lot of active users. - Direct view on Porta Nuova landmarks. - Significant sun exposure due to the low rise buildings in the surroundings. Economy and demography - Variety of social mix and social functions in the area.	**Weaknesses** Mobility & connectivity - Lack of entrances to the area and impossibility of penetration for pedestrians and bikes to the surroundings and to the site. - Difficulty to acces from South due to the cemetery and a difference in height. Services - No services in the site. - Lack of communication with the services in the surroundings. Landscape & environment - Presence of industrial archaeology in the site to main- tain. - Isolated from the surroundings, due to historical separation. - Widespread decay due to neglect and abandonment. - The site is limited by the presence of rails and its forbidden area. - No significant natural landscape visible from the ground floor. - Noise and air pollution due to industrial buildings and railways. Economy and demography - Lack of local identity in the site. - The surroundings have areas with great differences in terms of richness and functions.
External	**Opportunities** Mobility & connectivity - Penetration in the area due to an urban development in the North part of the site (Poste Italiane group). Services - Plan to place a campus of Accademia di Brera inside the site. - Plan to place new residential and offices in the North part of the area (Poste Italiane group, Esselunga). - The brief provide a typological and functional mix in the development of the site. Landscape & environment - Plan to link the masterplans of the renovated freight yards (Green Line). Economy and demography - Close to Porta Nuova and City Life districts, two main centers for buisness in Milan. - New urban development plans given by PGT in the North area. - Highly densificated areas next to the site.	**Threats** Mobility & connectivity - The infrastructure for car mobility is the main purpose for the ongoing projects in the surroundings. - The bycicle lanes near the center of the city of Milan are few and not used. Services - The project can create polarization and gentrification effects in the area and the surroundings. - Landscape & environment - Possibility of development of crime and decay in the large green areas. - Possibility to increase the car flows in Via Carlo Farini and Via Valtellina. Economy and demography - Risk to create phenomena of gentrification and polari- zation of activities. - The site have to deal with a heterogenous social mix that can create social conflicts.

Table 03: SWOT analysis

Opportunities and constraints maps

Map of opportunities

The area of Scalo Farini is located in a decidedly strategic fraction of the city of Milan, tram connections, and high-speed road circumscribe the area. Although its original use has meant that the area has been physically isolated from the rest of the city, the presence of a limited number of blind fronts or impassable barriers, makes it still potentially potentially permeable. The northern project area, which due to its considerable extension best lends itself to hosting most of the activities, has the possibility to dialogue well with the surrounding fronts. The southern area, on the other hand, of limited extension due to the presence of the instrumental area of the airport still used, is divided from the rest of the city by a wall and surface used as green, therefore draining.

A small amount of neighboring road courses offers the possibility to stitch up the road jersey by extending the existing avenues. The area also ranks among important areas of current and future urban regeneration, of which the main ones are certainly those of Porta Nuova and Bovisa. To the south there is also a new “Cittadella degli Uffici” which is an extension of the economic hub of Porta Nuova. The north-west front is instead characterized by a further project in progress: the area, owned by the post offices and today characterized by a disused building, will be reclaimed and will become the seat of residential buildings. A great further opportunity is the presence of an existing project by the Milanese University of Brera to redevelop and use for cultural purposes, part of the abandoned building located in the central part of the area, thus providing an important starting point for cultural activities. The key position is therefore the location of the airport, intermediate with respect to urban areas that are particularly active from an economic point of view and cultural areas such as the Monumental Cemetery and the Fabbrica del Vapore. The surrounding fabric is full of services, scholastic, sports, hospital and catering, ready to host a new community that would be established in the Farini area. The recent construction of the lilac line of the Milan subway has also led to the determination of new stops close to the area itself, such as that of Cenisio, Gerusalemme and Monumentale, defining an important opportunity to connect the area with the rest of the city.

Even closer is the stop of the passer-by, almost tangent to the perimeter of the northern front of the airport. Key is the connection of the exit of the stop and the tracks themselves, which, developing below the airport, offers the opportunity to create a potential future exit in the same.

The neighboring area is also well supplied in terms of car sharing and bike sharing stations, which determine the opportunity for users to be able to use them in potentially designed public spaces.

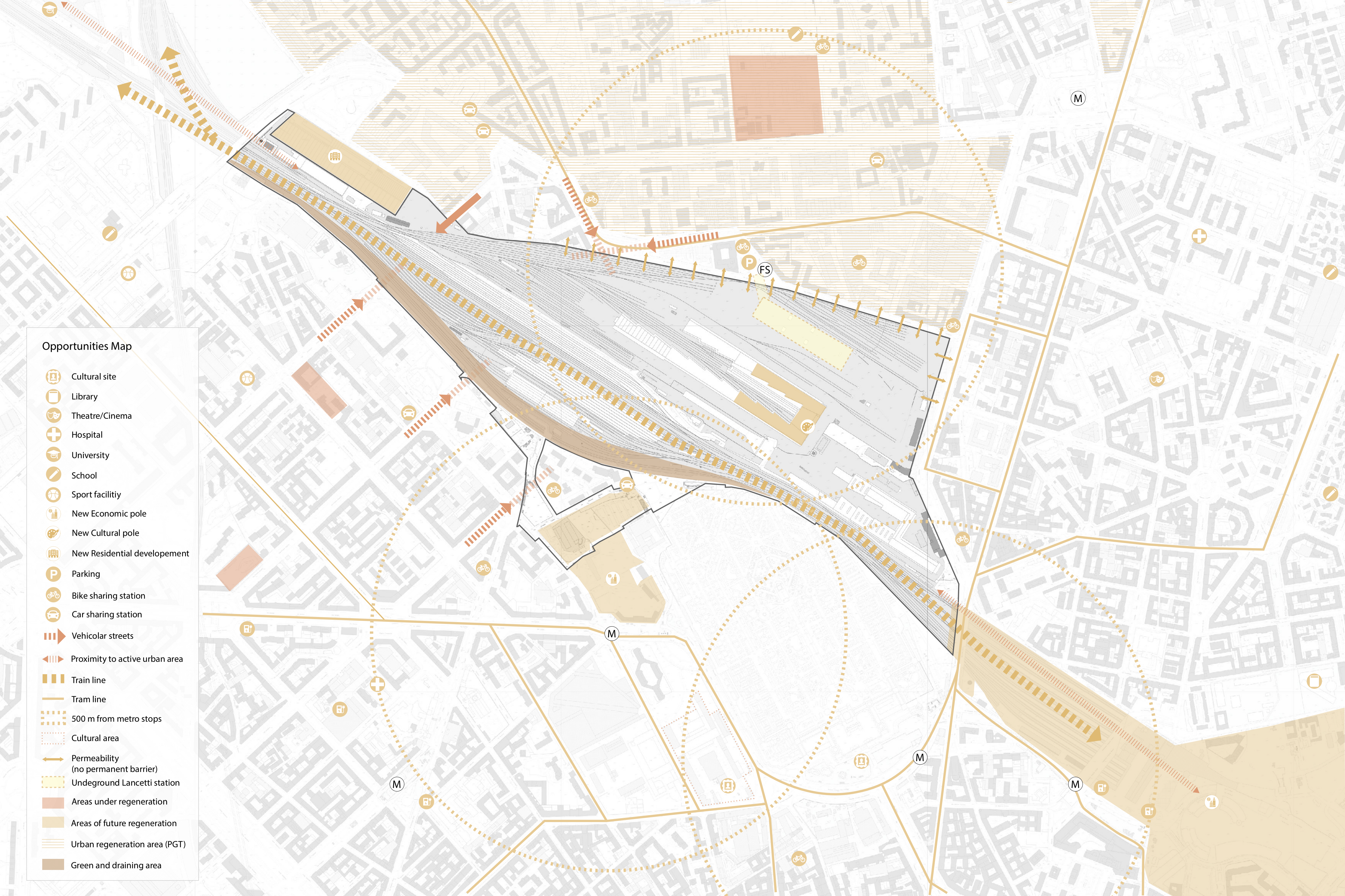
The presence of public car parks not only allows workers or users coming from neighboring cities to go directly to the area by private means, but at the same time gives the possibility to those who need to go to the city center to stop their car in a less congested area and free from limited traffic areas, to then travel by public transport.

Map of Constraints

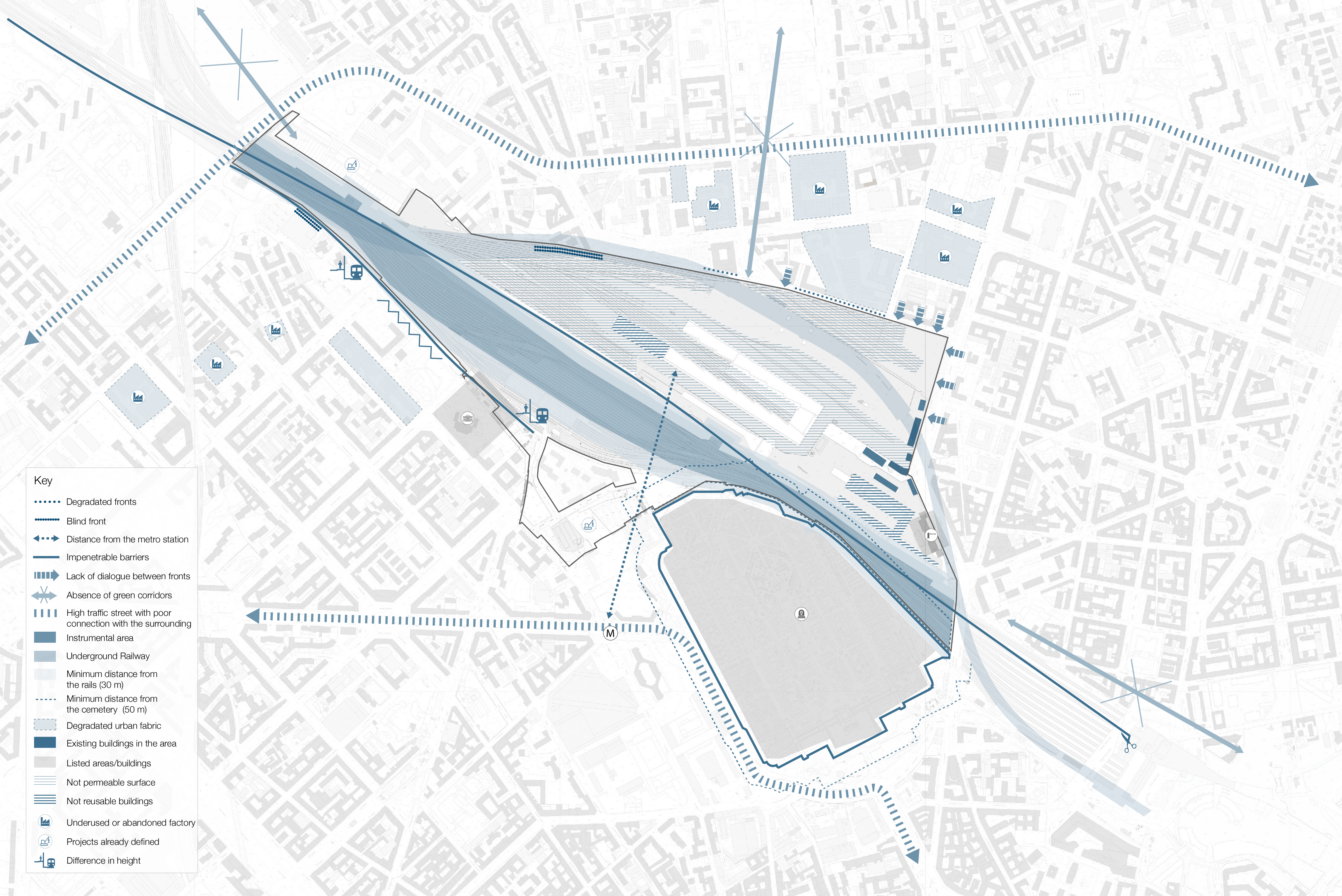
The biggest limitation found within the area is certainly the passage of the railway tracks, which goes as to divide the inner part of the city, with the more peripheral, preventing any connection to the human scale. The constraint outlined by the buffer zone of the instrumental area and the monumental cemetery means that the area of intervention is considerably reduced, necessarily leading to excluding the possibility of densifying the southern area of the masterplan. The site is configured as a large void within the town's mesh, almost completely impenetrable, especially with regard to the front adjacent to the monumental cemetery, and the northern one which, in addition to being characterized by a jump in altitude, foresees a wall separation beyond which sight is impossible.

The presence of high-speed roads in particular with regard to Viale Edoardo Jenner in the north, determine a scarce possibility of dialogue with the built-up area but above all with the human dimension, which, with the scarce presence of cycle and pedestrian connections , is strongly threatened. Moreover, the absence of corridors connecting the greens of the city is sometimes, due to the presence of high-speed roads, sometimes due to the passage of the tracks itself.

OPPORTUNITIES MAP



CONSTRAINTS MAP



Vision: objectives, strategies and actions to define the design intentions

The project vision is first of all divided into four main objectives. They are clearly distinct, but at the same time closely interconnected. In fact many of the actions they propose may look similar, but are actually originated from different strategies. This means that many of the actions that will actually be implemented in the design phase will simultaneously respond to multiple objectives.

The first of these is that of grid independence. Given the large size of the project area (400000 m^2) the intention is to reduce the interaction with the electricity grid as much as possible, if not totally. This need stems from the problems linked to the increasingly widespread use of renewable energy. They are in fact unpredictable, and have fluctuations in production that do not reflect those of user consumption. Photovoltaic panels, for example, generate energy by day, but the inhabitants of residential buildings consume more during the morning and evening. The different strategies therefore derive from this, namely to reduce energy consumption, favour production but also energy consumption. While the first two lead to actions that are now frequent in the design of new buildings, to guarantee energy consumption it is necessary to favour energy storage and energy exchange between buildings, as well as between buildings and vehicles.

The second objective focuses instead on intermodality. Indeed, by integrating the different means of transport, both public and private, both with single and multiple users, efficiency in the use of electricity can be further increased. To make this possible, first of all it is necessary to facilitate the passage between the different means of transport, reducing the distance between the stations and concentrating them in the same place. At the same time, it is essential to guarantee the passage of public transport in the area, reducing the importance of the routes that are exclusively driveways. Finally, in order to guarantee the use of electric means of transport, the support infrastructure must be well structured and spread over the area. In this sense, both the recharging points and the technologies must be at the forefront, allowing the exchange of energy in the most efficient and fast ways for the various needs.

The third objective focuses on the identity of the area. In this way it is possible to distinguish it from its surroundings, however without cutting any

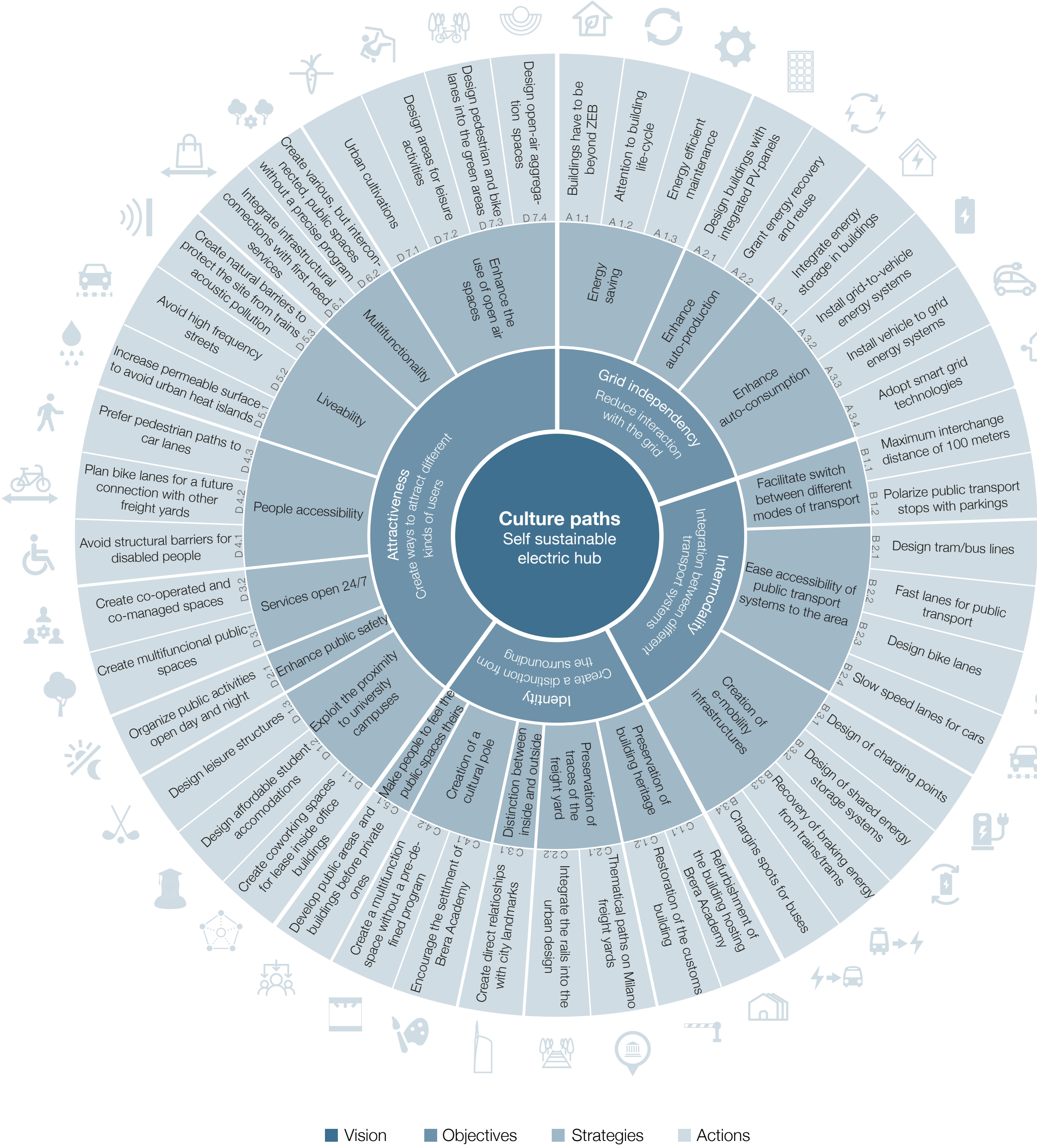


Chart 07: Masterplan vision

contact with it. However Scalo Farini requires the structuring of elements of distinction, not having existing ones. The area, abandoned for several decades, appears as almost completely unbuilt, or with dilapidated buildings, only partially recoverable. At the same time, being the first of Milan's abandoned freight yards to be reused, it would be very interesting, if not necessary, to preserve the memory of its construction, structure and relationship with the other Milan airports. For this reason we intend to maintain some iconic buildings and at the same time design spaces or cultural paths of memory of the productive nature of the site. In this way the future users of the area will be able to perceive it as their own and not use it exclusively for functional activities. Moreover, the exploitation of the existing buildings, that will be used for social functions, would create a completely new panorama into the milanese cultural and social spaces. The chance to reconnect unused areas, and design entirely new experiencial paths in the city, in a strict relationship with the surrounding, would create a new point of attraction and valorisation in the urban fabric.

The fourth objective focuses on attractiveness. In close relationship with the previous one, the intention is to attract users of various origins and make them interact through the functions present in the area. First, the strategies consist in exploiting the proximity of Scalo Farini to fundamental functions already present in the surrounding area, such as the Politecnico di Milan, in the Bovisa/La Masa area. For this reason we propose to allocate part of the residential buildings to student accomodation. At the same time, accessibility is a fundamental strategy, to allow all types of users to access the area. Furthermore, since the goal is to be able to use the area at its top, both the multi-functionality of the services offered and their 24-hour operation are listed among the strategies. In this regard, part of the spaces of the buildings will be allocated to spaces without a single destination of use, so that they can be used at different times of the day by different groups of users.

This programmatic intention is also reflected in the use of open air spaces, with a prominent green vocation. The large green covered surfaces, as required by the brief at least 70% of the surface, will have to be accessible, usable and used, as well as being able to be maintained at low cost. For this reason, even in the green areas there are various points that offer services or that remain without a predefined program, to encourage spontaneous and shared uses.

Finally, the two strands transversally affecting all the actions listed are those of the use of the green and that of favouring slow and public mobility over the fast one of cars. Regarding green, its integration with the built environment, its use in various ways, its maintenance, its public safety and the possibility of using it to create a green axis that connects areas already destined to green have been considered in the immediate surrounding area.

Concept: strategic design vision and design intentions for the implementation of the urban masterplan

Following the definition of objectives, strategies and actions that have to be implemented in the project, the design process requires a graphic representation that can put the results into a spatial dimension. This is called concept, that is the identification of a series of ideas or concepts that help, later in time, to define the final design choices. The types of representation used were selected to clearly and concisely define the project objectives, and then to create a preliminary project.

The first graphic design is the so-called “concept plan”, that is a schematization of the ideas that the designers intend to pursue within the project. Within this map, the elements that are considered the most important for the definition of the project on Scalo Farini have been reported. The use of colours, symbols and arrows does not allow a precise location of the elements on the map, as the concept plan wants to represent a series of ideas and not a definite zoning.

In the centre of the concept plan there is the cultural hub, which represent the main attraction in the area and will provide a series of services and functions to the users. This attracts people to use public spaces and green areas, creating a path that connects the two part of Milan once separated by the railways. This cultural hub is reinforced by the presence of Brera Academy and Villa Simonetta music school, which will guarantee art pieces performances. This area will be accessible thanks to the pedestrian, bike and tram paths that are linking to existent roadways. Lancetti station has a close relationship with this area and will improve the accessibility and the services on the path, creating a mutual collaboration.

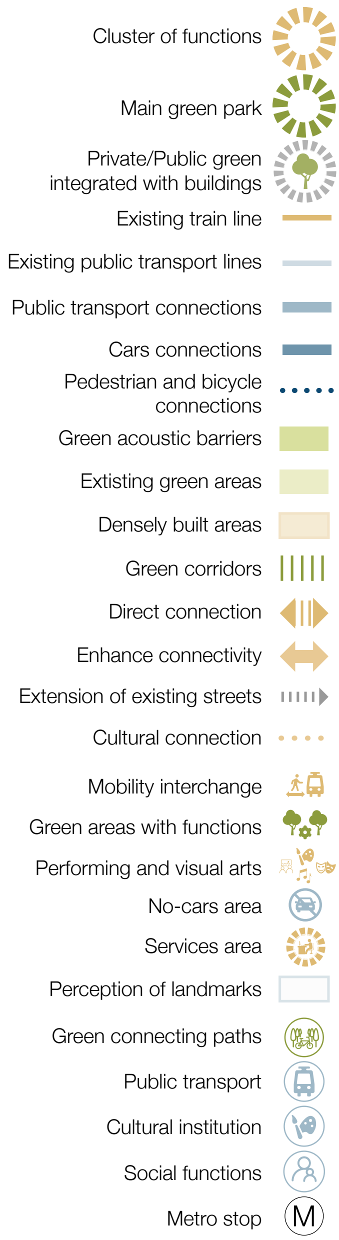
The mobility of the area becomes very important within the project, as can be seen from the numerous road connections present within the concept plan. The arrows present only indicate the main ideas regarding the mobility of the project, not limiting itself to them. Looking at the legend, we understand that car traffic is limited to two main axes, an elevated road to the north and a low-speed network within the area.

Public transport, on the other hand, is more widely distributed within the area, as it deals with connecting to existing city routes by entering the airport within them. These are also on the surface and allow users to be able to move quickly without the use of the machine. Cycle and pedestrian paths are also widespread in the area, connecting the area to the main points of interest and service (subway stations, meeting areas, etc.), as well as connecting the main parks in the area. The importance of these paths is high, as the regeneration of the area also aims to change the lifestyle of the citizen trying to promote a slow and sustainable mobility.

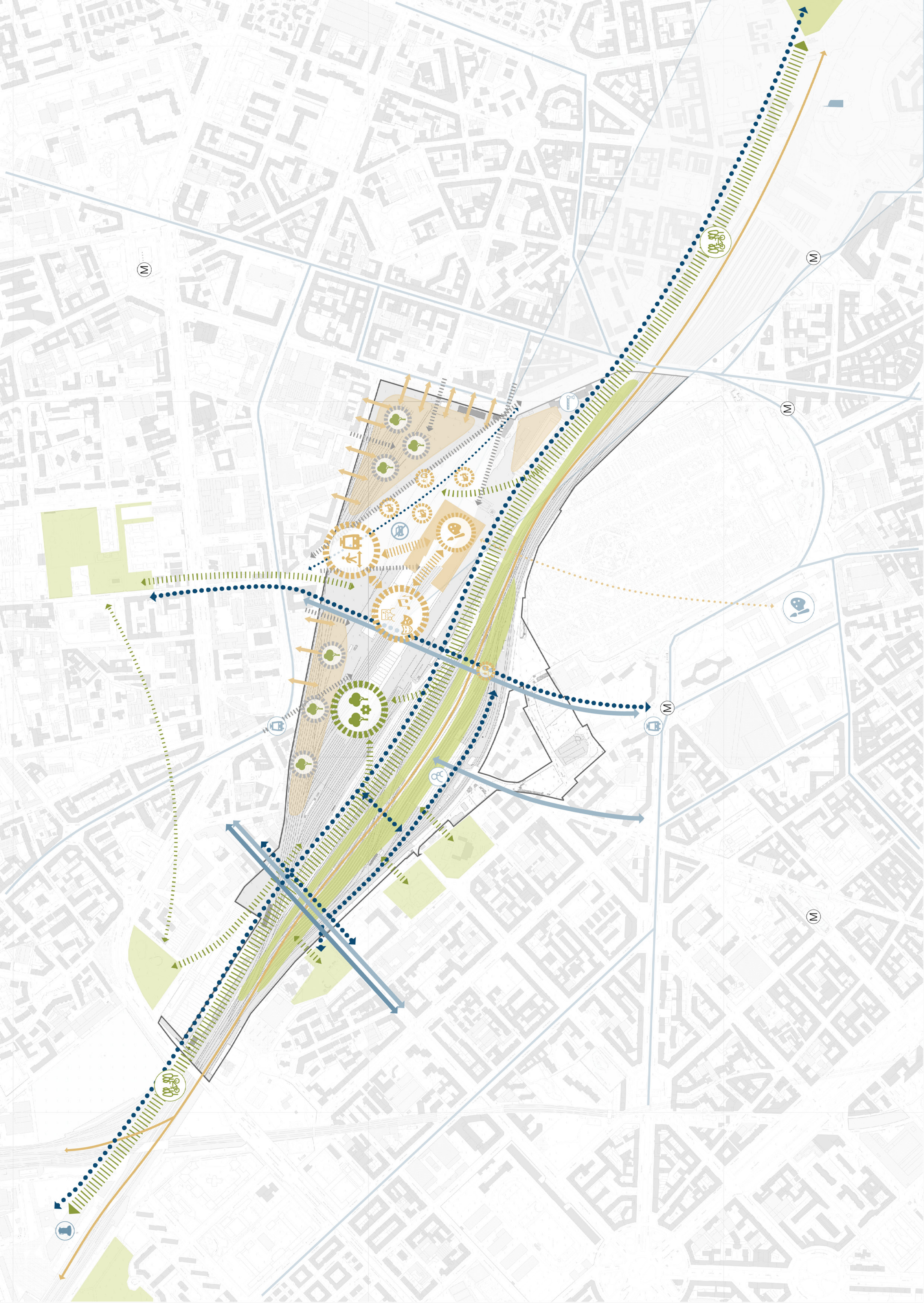
In the area there are car parking areas with electric recharging infrastructures, a direct connection with the train stations, bus and tram stops, bicycle storage, bus deposits, carsharing, and a series of accessory services useful to the user. In this way it will be possible to leave the car and move within the area (or the city itself) using public transport or moving on foot or by bicycle, as the dense network of pedestrian and cycle paths allows it. This interconnection will allow the services that develop around it to interact with the services of the area, creating a mutual collaboration. This is allowed by the connection with other focal points present in the area, characterized by attractive elements and a greater concentration of services.

A further evident element within the concept plan is urban green, not only seen as an ecological resource but also as an opportunity to create points of aggregation and use of services. The green surrounding the area wants to be well connected to it, avoiding barriers or obstacles to the path. Furthermore, the relationship with these green areas is supported by pedestrian and cycle infrastructures, which will be integrated into the green routes. The main green axis is the connection with "La Goccia" to Bovisa and Porta Nuova, foreseeing a future connection also with the other projects of regeneration of Milan railway stations.

Of great importance within the project idea is the relationship with the urban environment, seeking a direct relationship of mutual collaboration. The main ones are with the built fronts of Via Valtellina and Via dell'Aprica, in addition to the green spaces further west. The connection to the urban surroundings is also defined by the perception of the symbolic places, or landmarks, present in the territory. In this case it is important to underline the presence of the nearby Famedio, inside the monumental cemetery, and the skyscrapers of Porta Nuova, the new unmistakable symbol of the Milanese city. A further elaborate that summarizes the concept represents the green strategies, that is the approaches towards the green areas present within the area and the relationships with the external ones.



Concept plan key



Design examples: case studies on an urban scale and local design references

Following the analysis carried out on the project area and around it, it was considered appropriate to carry out an interpretation of executed projects, in order to use them as references. Each project was chosen as it relates to an important aspect that will also be addressed in subsequent analyzes. For this reason the synthesis of the references was carried out by analyzing the project actions, selecting the components that can also be applied to the case of Scalo Farini.
The Porta Nuova project in Milan was selected mainly due to its proximity to the airport area, but numerous elements were found in common with the project intentions. They concern the desire to regenerate an area that was previously abandoned by creating environments designed for the individual, such as squares or parks, in which the user can appreciate the quality of the services provided.
King's Cross in London was chosen for the economic and social development that led to the area, relying on the present industrial archeology. This last factor has also characterized the area, creating a local identity and remaining faithful to the history of the place.
The intervention in Paris regarding the Clichy Batignolles district became famous as it managed to create a series of services suitable for users from different social backgrounds. It is in fact present in the references above all due to its high social diversity, but also for the goal of eliminating CO_2 emissions while maintaining good service quality.
The creation of a green corridor within the intervention on the La Segrera neighborhood in Barcelona not only provides a green lung for the urbanized area, but allows a transversal connection between the areas previously separated by the railways (now underground). The ability to create a strong connection between the different green components of the city through the use of bicycle and pedestrian paths was the main motivation for which it was selected as a project reference.
After a table that sums up the various masterplan actions, more detailed analysis are carried out.[25]

Masterplans	Objectives	Strategies	Actions
Porta Nuova, Milano	New centrality	Enhance of local life	Design open-air aggregation spaces
		Create a dynamic and stimulating environment	Design area for leisure activities
		Reconnect surroundings existing neighbourhoods	Create direct relationships with city landmarks
	Pedestrian connections	Create safe area for people to walk	Prefer pedestrian paths to car lanes
		Integrate with car parking, metro and trains	Polarize public transport stops with parkings
		Create new aggregation points with green areas	Create multifunctional public spaces
	Remove cars	Limit the number of car	Slow speed lanes for cars
		Design the spaces for a low mobility	Avoid high frequency streets
King's cross, London	Economical rebirth	Grant accessibility to the area and connect it to the rest of the city	Maximum interchange distance of 100 meters
		Promote flexibility and mixed use	Create various, but interconnected, public spaces without a precise program
		Attract dwellers with new services	Integrate infrastructural connections with first need services
	Industrial heritage	Enhance of historical buildings	Restoration of historical buildings
		Make them to host important institution	Hosting the St. Martins Art School
Clichy Batignolies, Paris	Social mix	Promote social mix and integration	Create a multifunctional space without a pre-defined program
		Connect to the neighbourhoods	Develop public areas and buildings before private ones
		Promote attractive services and activities	Design leisure structures
	Social housing	Create affordable houses in are not too far from city center	Design affordable student accomodations
		Give high standards homes to people	Buildings have to be beyond ZEB
		Combine with strong accessibility to public transport	Fast lanes for public transport
Sagrera, Barcelona	Green corridor	Combination of surface and underground car ways	Avoid high frequency streets
		Strengthen public transport accessibility	Design tram/bus lanes
		Buildings on the side	Design pedestrian and bike lanes into the green areas
		Creation of a green corridor	Plan bike lanes for a future connection with other freight yards

Porta Nuova

Milano - Italy

In 1873 Garibaldi station was built as a freight yard near to Stazione Centrale. In 1934 Piano Albertini suppressed the two stations of Garibaldi and Sempione, trying to reconnect the city with its surrounding territory. In their place, a new station, Scalo Farini, was built, while Scalo Garibaldi was abandoned.

In 2004, after the approval of the extensive use of the area, the project was led by the international real estate giant Hines and featured a team of 25 architects coming from 8 different countries. Its main characteristic is that it is not accessible by cars and it is raised over the existing car streets of about 6 meters. In this way the pedestrian scale is the leading one, allowing people to circulate with no barriers for all the 700 meters length of the area. The area gained very quickly the capacity to concentrate an astonishing number of big companies. Porta Nuova district had in 2017 a GDP of around €400 billion, that made it Europe's richest and most productive area in any city. Around 4% of all businesses that can be found in Italy is in this area. But the area was not only successful from the economic point of view. Environmentally it achieved very high goals and was thus internationally promoted as an example to follow.

Image 38: View of Porta Nuova

Dimensions:

Area:

290000 sqm

GFA:

347000 sqm

Mobility:

Before:

After:

Program:

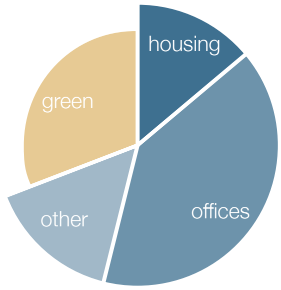


Image 39: Porta Nuova concept

Image 40: Porta Nuova masterplan

Strategies and actions

New centrality

- Bring people back to the focus of local life
- Create a dynamic and stimulating environment
- Attract tourists
- Reconnect surrounding existing neighbourhoods

Pedestrian connections

- Create safe areas for people to walk
- Integrate with car parking, metro and train stations
- Create a new green park to allow people to spend some time there
- Connect the area with existing pedestrians surrounding streets

Remove cars

- Limited number of car parkings
- Lift the walking level over the existing streets
- Create bike sharing stands
- Design the spaces for a low mobility (pedestrians, bikes)
-

King's Cross

London - UK

The area, that comprehends the two stations of St. Pancras and King's Cross, is located in the center-north of London. Formerly an industrial site, from the '70s it experienced a declining period. The surrounding area was not further renovated, so that the buildings remained the same for all the century. As a consequence, the rent prices were among the lowest of London at the end of the '90s. In 1996 the decision to create the Channel Tunnel Rail Link, that connects the two stations to the Channel Tunnel with a new Eurostar line, brought back the attention on the area.

The new development focuses especially on public and shared spaces, and on building flexibility. Indeed the 20% of the building volumes was left undefined, to be able to choose later what to dedicate it to. A network of public open spaces permeates the urban blocks and creates connections across the site. At the same time the industrial heritage is taken in high consideration, creating astonishing new public areas, like the already famous Granary square. The cars can hardly penetrate in the area.

Thanks to the redevelopment of this part of the neighbourhood also the surrounding experienced a raise in value.

Image 41: View of King's Cross

Dimensions:

Area:
270000 sqm

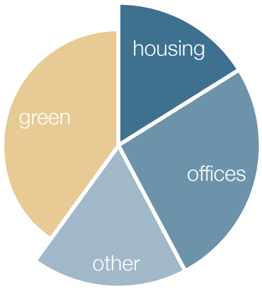
GFA:
740000 sqm

Mobility:

Before:

After:

Program:



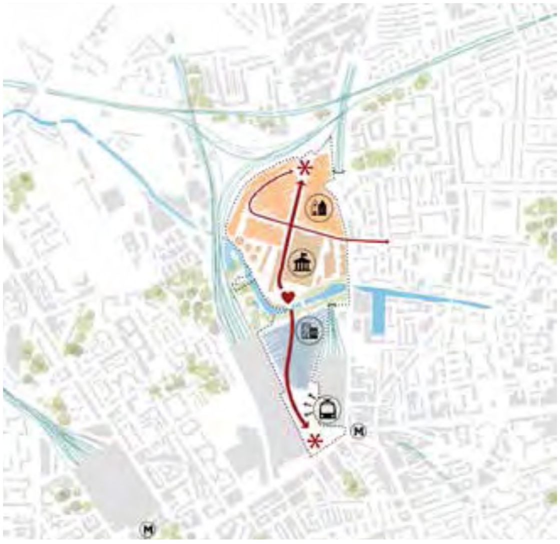


Image 42: King's Cross concept

Image 43: King's Cross masterplan

Strategies and actions

Economical rebirth
- Grant accessibility to the area and connect it to the rest of the city
- Promote flexibility and mixed use
- Exploit the industrial heritage
- Attract dwellers with new services

Flexibility
- 20% of the site without any precise function at the time in which works started
- Define only paths, connections and maximum allowed heights
- Choose in a second moment part of the functions

Industrial heritage
- Enhancement of historical buildings
- Use existing listed buildings as a frame for the new public areas
- Make them to host important institutions (like the St. Martins Art School)

Clichy Batignolles

Paris - France

The masterplan promotes a new eco-friendly neighbourhood on a precedent railyard located in the 17th Paris arrondissement. The project is divided in three different sectors to be built in consequent phases to make it possible to adapt the design during its construction. The ownership is split between the local administration, private investors and the national railay company.
In the middle of the area there will be a big park of 100000 m^2, the heart of the masterplan. Around it there will be mixed function buildings. The accessibility is a key factor, with the extension of the metro line to connect it to the economical district of La Defense and to the city center. In fact the area is strategical for the city, being at the center of a triangle connecting La Défense, the economicdistrict and the station of Mairie de Saint-Ouen. Despite this, half of the dwellings will be of social housing, making it affordable for everyone and to promote the creation of a diffused social mix.
The energy issue is taken in great consideration, anticipating to 2008 the new standards that from 2020 the entire France will have to adopt, following Kyoto agreements. It means reuse of water, generation of electricity and heating through renewable sources.

Image 44: View of Clichy Batignolles

Dimensions:

Area:
540000 sqm

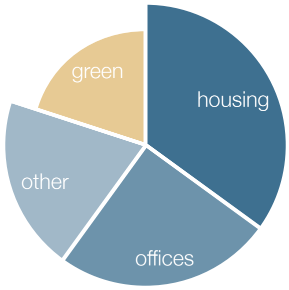
GFA:
450000 sqm

Mobility:

Before:

After:

Program:



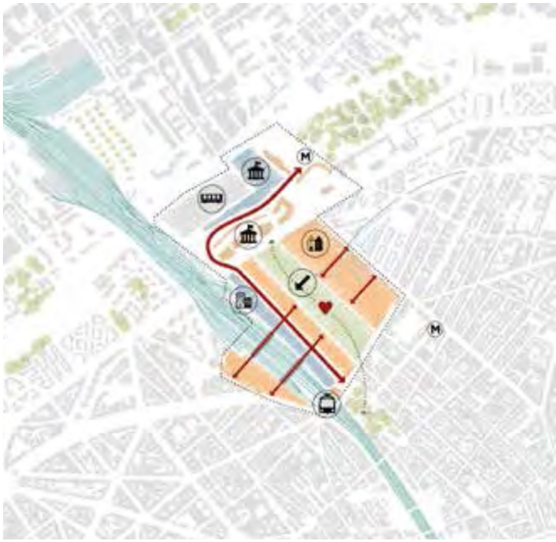


Image 45: Clichy Batignolles concept

Image 46: Clichy Batignolles masterplan

Strategies and actions

Social mix
- Promote social mix and integration
- Connect the neighbourhoods
- Promote attractive services and activities
- Promote slow mobility and public transport

Social housing
- Create affordable houses in an area not too far from the city centre
- Give high standard homes to people
- Combine it with strong accessibility to public transport

Target: zero CO_2 emissions
- Innovative techniques to collect waste
- Reuse of water
- Geothermal energy
- Diffused use of PV panels

Sagrera

Barcelona - Spain

The masterplan is part of the will to extend the city center towards the North-East. The development of the high-speed train line was the opportunity to restore this area, abandoned in the '90s following the moving of industries and of the freight yards. The 380000 m^2 of railway still active were moved underground, freeing a much bigger area, longer than larger, creating new connections between the two separated parts of the city. A new intermodal link area would find place in the newly designed masterplan.
At the same time, a linear park was designed, gaining new permeable ground. At the same time new public mobility lines were deisgned. On the sides, mainly residential functions find place, while the services and offices concentrate around the new train station in the center. These would be of medium and high-rise buildings, to exploit at maximum the new value of the area. However they would live the huge are aamong them completely free.
The project, approved in 2004, has slowed down because of economical crisis that reduced the public budget. Indeed the approval is dated back to 1976, but economic recession made it deifficult to finance the project.

Image 47: View of La Sagrera

Dimensions:

Area:
1640000 sqm

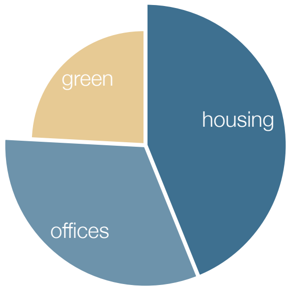
GFA:
1658000 sqm

Mobility:

Before:

After:

Program:



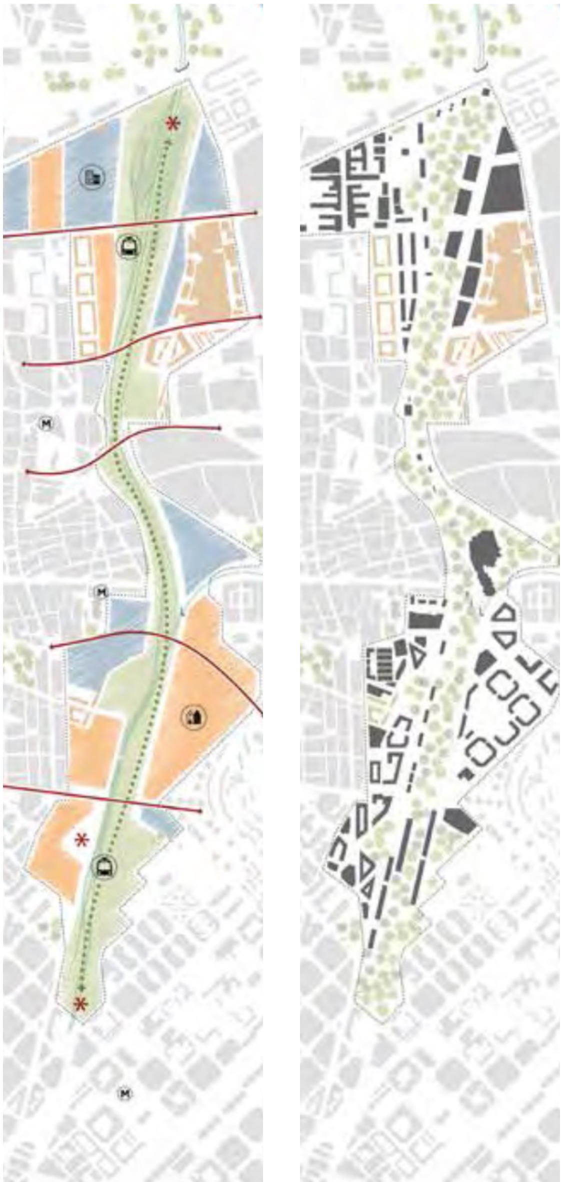


Image 48, 49: Sagrera concept and masterplan

Strategies and actions

Green corridor
- Buildings on the sides
- Strengthen public transport accessibility
- Creation of a new modal train station
- Move infrastructure underground

Permeability
- Connect the two sides of the city with car but also pedestrian streets
- Allow people to freely access to the new park

Infrastructure strengthening
- Development of high speed train line
- Creation of a new train station
- Combination of surface and underground car ways

“A Thousand Yards” Botanical Pavilion - Beijing, China - Chris Precht - 2019

“A thousand Yards” is the project for the Vanke Pavilion for the Beijins Expo of 2019. The site’s 30,000 sqm masterplan is a set of modular blocks, containing five functions. Each block connects to its neighbours, offering a continuous space inside and an area of “urban gardening” connected to the roof. The pavilion, which after the end of the fair would be used as a residential district, is located at the extremes of the dense city of Beijing that is rapidly growing. In this context, the Horticultural Expo aims to promote a healthy and ecological coexistence with the natural environment.
Like a chessboard, the building blocks and the green alternate with each other to create a symbiosis between architecture and nature. Various functions alternate, from table tennis tables to playgrounds to benches for visitors.

Image 50: A thousand yards botanical pavillon

Stockholm Continental - Stockholm, Sweden - 3XN - 2017

The Stockholm Continental is a multi-purpose building located in a central location in the city of Stockholm consisting of a subway station, a hotel, a conference centre and a series of apartments. By dividing the building volume into four smaller sections of different heights, the building is able to connect different road levels and nearby buildings to 360 degrees.

Image 51: Stockholm continental by 3XN

Office Building - Paolo Venturella - 2014

The project regards an office building modelled through a parametric rotation of the blocks that compose it. By rotating, the blocks give a better

Image 52: Office building by Paolo Venturella

perception of what lies beyond the building, almost inviting the visitor to go beyond it.
The shapes and volumes develop in height while maintaining a strong link with the human dimension at the base. Indeed thanks to the progressive slope the horizontal surfaces, from the roof, become terraces, and from terraces they turn into what is pedestrian crossing, going to define not only the built but also the external public space.


Image 53: A park to unify Montreal by Mandaworks

A park to unify a divided Montreal - Mandaworks - 2018

The bridge, with a circular plan, allows the interlocking of the interrupted pedestrian network and the continuity of the green, creating an amusing union between park and public space. The duality of the project is inspirational.

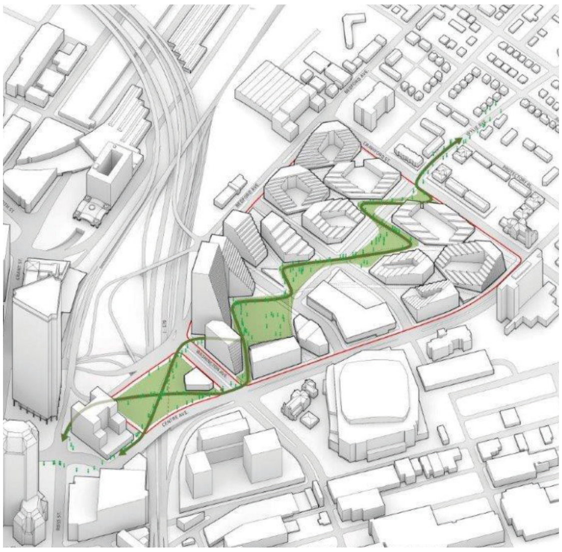


Image 54: Masterplan by BIG and West8

Masterplan for the Lower Hill district of Pittsburgh - BIG, West8 - 2015

The project develops around a double slope of the buildings. The first, from right to left, guarantees a better view and allows an optimal sun exposure; the second one is from the margins of the project site towards the inside. The action somehow breaks down the clear boundaries of what is built and what is central public space. Buildings are getting closer to the human dimension as they approach pedestrian crossings and internal public spaces.

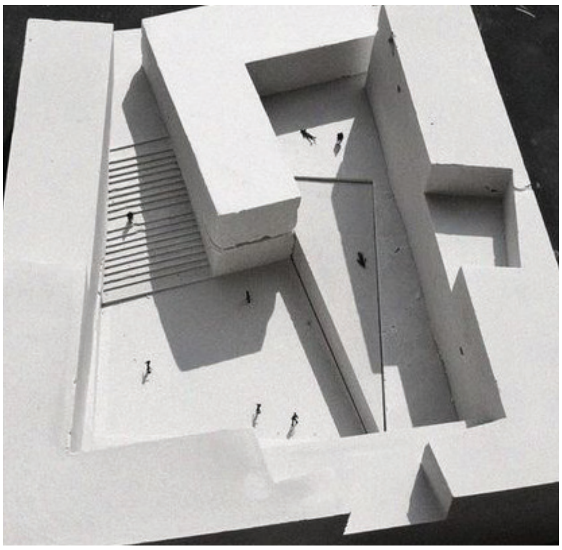


Image 55: Atacama Regional Museum proposal

Proposal for the Atacama Regional Museum - David Rodriguez Arquitectos - 2013

Through a game of extrusions the project creates a new connection between the level zero

and the underground level which not only offers a simple passage but it also guarantees access to buildings in the surrounding at different levels. The atmosphere that is generated is not at monotonous but articulated and dynamic.
The case study is of strong inspiration for what will be the access to the Lancetti station located at level -1.

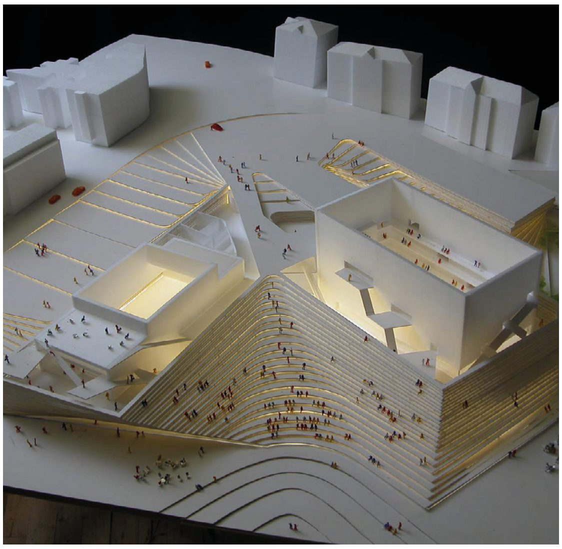


Image 56: Stavanger concert hall proposal by BIG

Stavanger Concert Hall - BIG - 2004

The project represents an interesting alternative to the previous case study, where attention is more focused on the underground station rather than on adjacent buildings. In this case the space in front of the buildings is generated more clearly and less cryptic, in favour of a greater dynamism of the station building itself.

Image 57: Rebel morphology by Studioninedots

Rebel - Studioninedots - Amsterdam - 2017

The project is useful for what the morphology of the buildings of the lots could be. The strong dynamism recalls a further materials evolution of the project for the Beijing Expo Pavilion by Precht. The modularity of the elements allows greater design freedom in terms of needs, functions and for the creation of passages among the buildings. Moreover it makes it possible to design elements that do not shade each other, thus optimizing the building also from an energy point of view.

Masterplan design and implementation

Creating a new city urban fabric

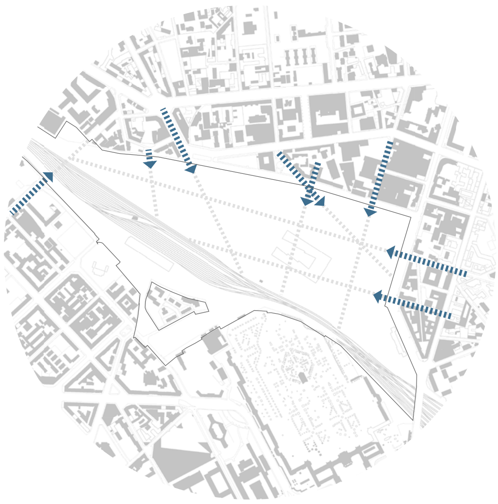


Image 58: Extension of the existing streets to reconnect the urban fabric

Image 59: Unitary green between the rails and the urban fabric, densification of the blocks confining with the existing

The new urban fabric has been defined according to a careful evaluation of the existing one. Farini freight yard nowadays creates in fact a big laceration of the city urban fabric that needs to be reconnected properly, being respectful of the pre-existing but being able, at the same, to satisfy the current and future city needs.

The main existing streets have been extended in order to provide a certain continuity between the new and the old urban fabric. The interruption inevitably created by the railway has been associated to a green path connecting the closer big green areas: the "Biblioteca degli Alberi" of Porta Nuova and the one of Bovisa, that is itself area of next future regeneration. The resulting green corridor also meets the need coming from the respect distance of 30 meters from the railway highlighted in the PGT. Moreover the extensions of the existing roads have been interrupted in order to allow the creation of the requested "unitary green".

At the same time, a built urban fabric on the edge of the upper perimeter of the freight yard protects the big resulting park, relating at the same time with the confining residential existing fabric. The identification of the historical and future mean of the already existing buildings in the area has been been given a central role in the definition of the new public spaces. In particular they are Villa Simonetta, the Edificio delle Dogane and the wide building situated in the central part of the area that will be occupied by Brera University of Art.

Another important defining element was the underground station of Lancetti, that represents a big opportunity to reconnect the area with the public transport system through underground accesses.

In order to enhance these key elements the project has carries out new strategic areas physically connected to them by the main pedestrian axis, coupling them with new functions. Their functions want to implement the existing functions with complementary urban services and infrastructural connections of these areas to lead the implementation stages of the masterplan. Villa Simonetta will host in fact a music school, the old warehouse building local associations and market spaces; the Edificio delle Dogane will be used as a library and the central building already belonging to Brera University will be the new heart of the district. The newly built urban services comprehend a new offices district for the municipality, new administrative centres, a cultural pole such as a museum in front of Villa Simonetta and a multifunctional Performing Arts Center in front of Brera Academy (see Chapter 4).

Image 60: Valorisation of the existing elements with high social and cultural functions

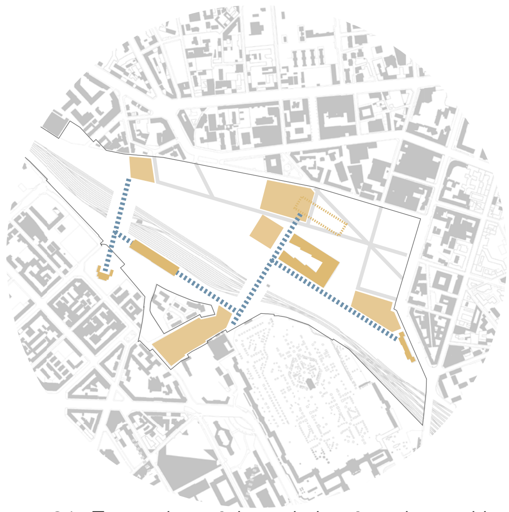
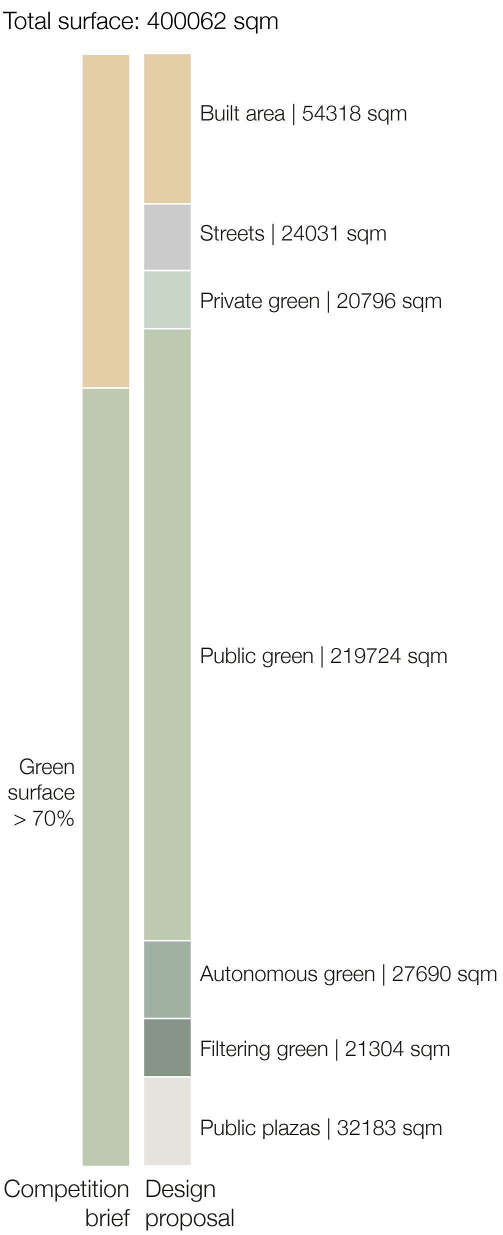


Image 61: Expansion of the existing functions with complementary urban services and infrastructural connections

Programmatic functions and connecting systems



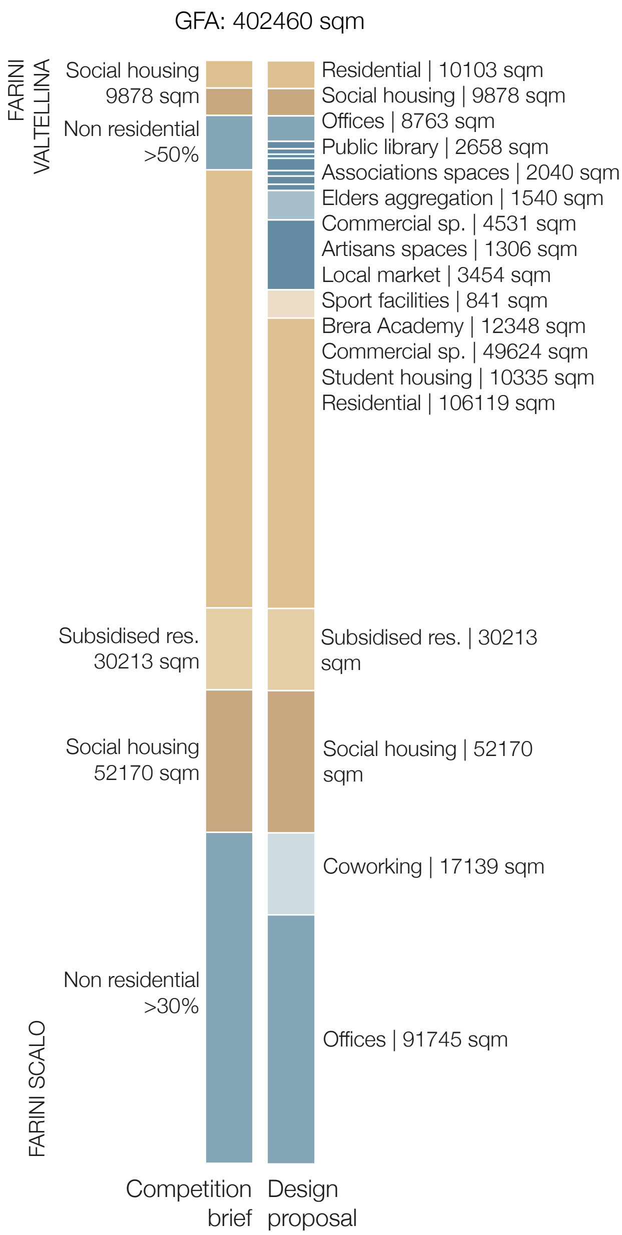


Chart 08: Comparison between the competition brief requirements and the design proposal

The program of the area has origin from the competition brief requirements, and is then further developed. The proposed masterplan satisfies either the expectations in terms of minimum green surface percentage, and the built GFA ratios required.

In fact the brief requires a percentage of green surface higher than 70% of the total surface, counting roughly 400000 sqm. The design proposal distinguishes different kinds of green: it proposes filtering green areas in order to guarantee the hydraulic invariance on the city water collection system, autonomous vegetation areas in order to guarantee a minimum intervention in terms of maintenance and private green areas. The highest percentage of green, accounting to 219724 sqm is public, and hosts multiple activities freely accessible by the users. Other areas accounting among the public realm consist in paved public plazas and streets.

On top of this, 402460 sqm of GFA are built on the remaining surface. The built area, requested to be partially non residential and partially dedicated to social housing and subsidised residential units, meets the requirement and is organized around activities such as private residential social housing and subsidised units as well as students accommodations, offices, coworking and association spaces, a public library, elderly people aggregation spaces, retail and craftsmanship ones.

In order not to avoid creating mono functional clusters the density of functions has been calibrated according to the needs and the intention, avoiding any zoning action. The residential unities intensity is higher in the upper perimeter blocks, due to their proximity to existing residential buildings, while lower in those areas identified as being the ones of higher density and denser in activities due to their proximity to the pre-existing. On the other hand the intensity of services dedicated spaces is higher where the residential one is lower, and lower, but not absent where the residential one is higher. The aim is to create more attraction poles in proximity of the existing elements that achieve a high social and cultural function in the area, with the opportunity to generate a higher amount of activities and functions.

The third of the main programs identified regards retail spaces, which distribution is denser around the poles mentioned above. In this way the user are pushed in passing from one pole to the another, crossing in this way the hybrid generated blocks, that can offer different kinds of services.

Eventually, the cultural programs are concentrated in the already existing buildings becoming the new hearts of the urban fabric. Social activities of public interest are located in these areas, offering public services to users of different ages, spanning from education to amusement, from temporary exhibition spaces to elders' spaces.

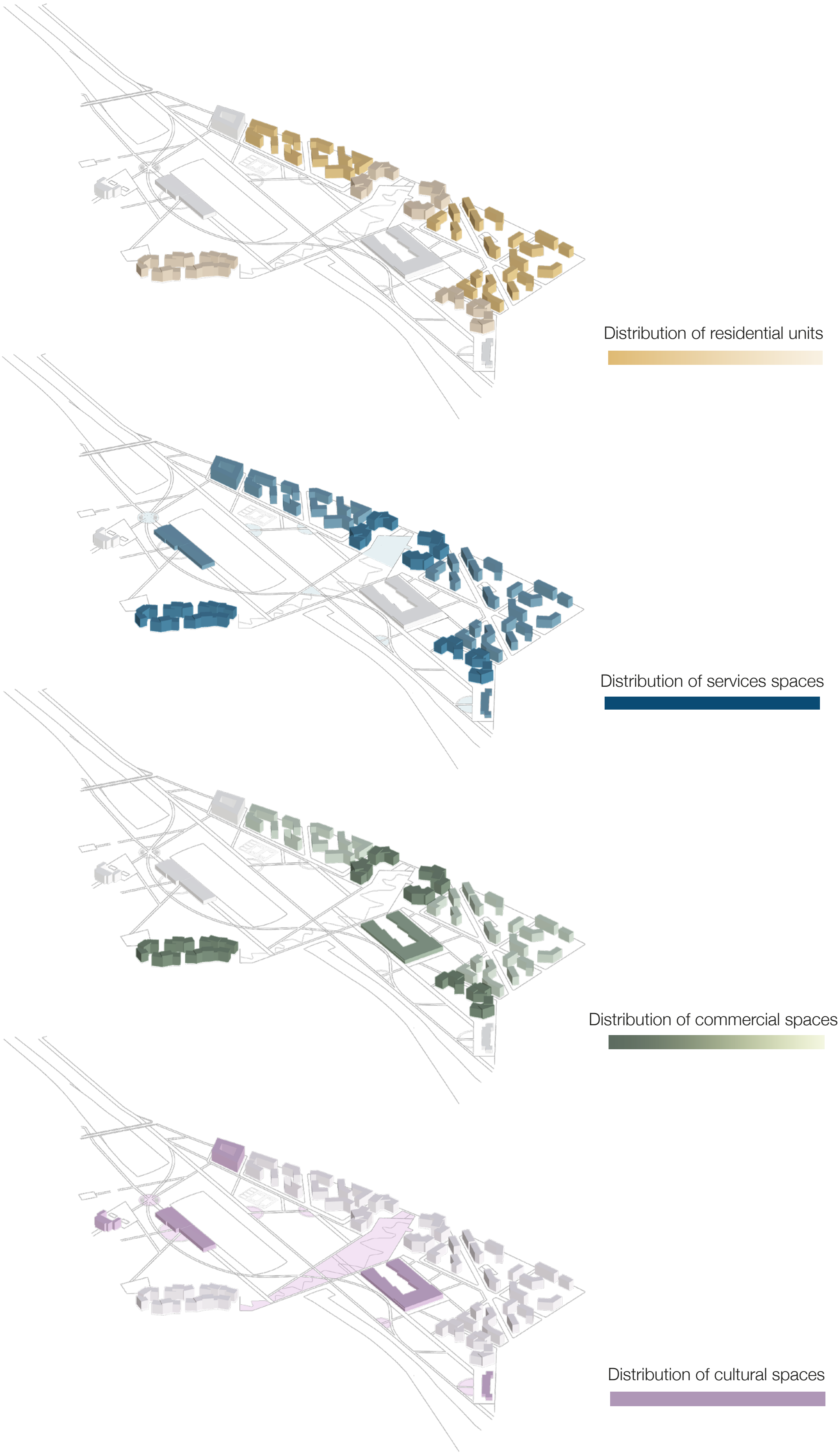


Image 62: Schematic representation of programmatic distribution of functions within the masterplan area

Urban blocks typologies

The volumes of the buildings that shape the masterplan proposal are determined, in its first preliminary phase, by a few but simple rules.
The urban blocks are determined by a first grid dedicated to vehicular transport, which is then combined with a more irregular sub-grid, which favours pedestrian and bicycle connections.
The importance of allowing cycling and pedestrian permeability from outside the area to the inside of the area has led to the creation of street level openings in the outer perimeter of the lots. As for the internal connections, on the other hand, in many cases the volumes have been completely separated to allow greater permeability, even visual. Moreover, the large internal courtyards, for public and private use, reduce the mutual shadowing of the buildings and invite the people to use these spaces.
The buildings composing the masterplan project can be summed up into two main functional block types:

The medium-density fabric block, in which buildings of simple volumes, mainly positioned on the outer edges of the lots, create green and mineral spaces within them, favouring pedestrian crossing. The first typology characterizes the blocks previously identified as being higher in residential unities density, even though still having a minor density of services and retail activities in the lowest floors, such as local retail spaces, sport facilities, minor supermarkets, shops, restaurants, cafes and so on. Within the residential program different sub-programs are identified as private residential units, subsidised residential spaces, social housing, and students accommodation units.

The second typology, the high density fabric, accounts for buildings of about ten floors alternated with green pedestrian zones. Thanks to their target, they reinforce the attractiveness of the historical cultural centres identified, generating an urban synergy. This typology is characterized by a higher density of services and retail programs even if it does not lack of residential units. Shopping area, shared facilities, commercial activities characterize the lowest levels while offices and residential ones the upper ones.

The masterplan is generally regulated by the existence of a series of poles identified as being the preexistent buildings and the high density blocks, that, thanks to a correct disposition of the functions, make the district to work on functional, economic, and human scale. In this sense, the disposition of the buildings in the blocks is spontaneous but not casual. Indeed it generates a certain continuity but at the same time, throught a differentiation of paving, through the shaping of the buildings and through the green islands disposition, it leads the user to follow certain paths, which will be more served in terms of services and retail spaces than others.

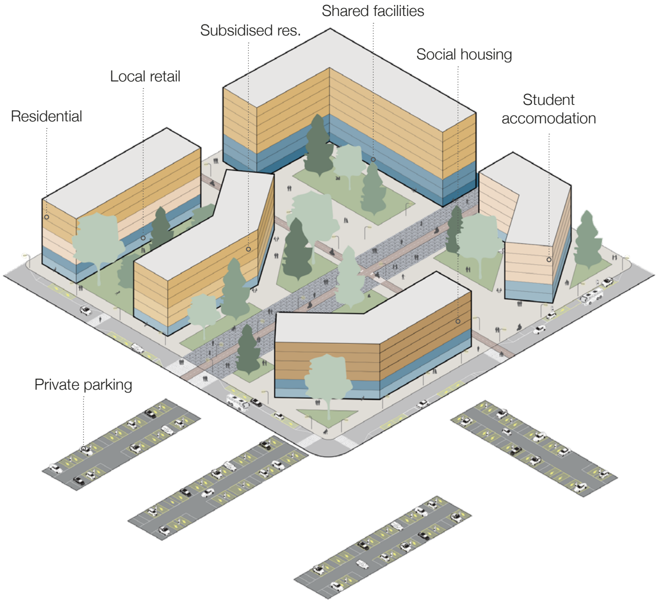


Image 63: Medium density block typology

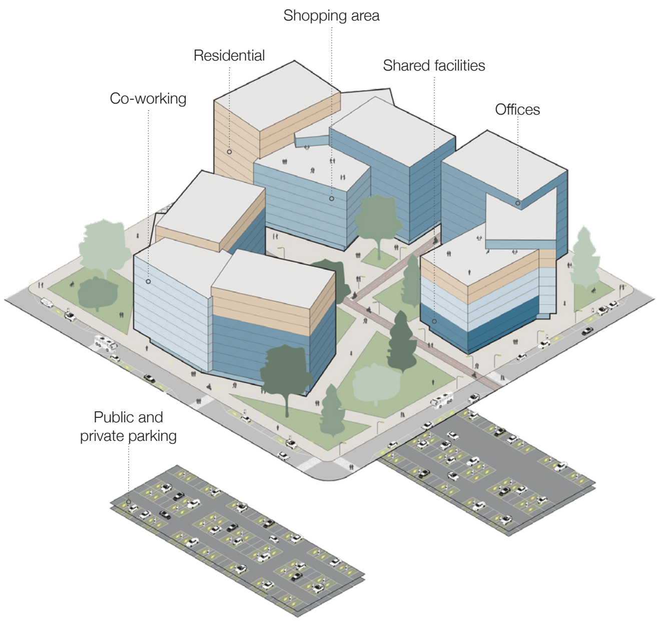


Image 64: High density block typology

Green areas design and program

Green areas represent a fundamental component in the new Scalo Farini masterplan project, as more than 70% of the area will be free from construction. The majority of these public spaces are placed in a unitary park, which works as a buffer space between the railways and the urban fabric.

At first a series of so-called "green strategies" were developed. These would be applied to all the green areas present within the masterplan, especially focusing on their relationships with the exterior. Main strategies applicable to the green present within the area are coupled with objectives and strategies previously mentioned. First of all, the relationship between the green and the built is defined, defining the vegetation as a continuous element, which penetrates inside the layout of the buildings and guarantees access and opening to the public. Furthermore, the building itself will interact with the vegetation, as it can be found in balconies, roofs or atria.

The green will then also be used as protection, both against road and rail pollution and natural elements, such as the wind. In addition, vegetation can contribute to the mitigation of heat islands, reducing the emissivity of surfaces, and creating a proper drainage of rainwater.

Vegetation planning can also be used to define paths, design shapes and connect elements in an intuitive, natural and high quality way. Furthermore, green can guide the user, explaining the concept of the master plan on a human level, modelling the environment based on the paths and connections.

It is important for the maintenance and the good conservation of the city green is the use, for this reason have been thought of different ways of using public parks, such as urban gardens. In this way there is a continuous relationship between user and public space, from which both can obtain benefits regarding health and liveability of the environments.

Green has also been analysed in its relationship with the surroundings and with the functions found within the same areas. In this case the green corridor La Goccia-Scalo Farini-Biblioteca degli Alberi was represented, representing the extension of the green areas and the functions related to them. The creation of this corridor allows a communication not only at the level of the greenery, but also cycle-pedestrian as the two infrastructures will be closely linked together. Furthermore, the functions presented here are not only born but developed parallel to vegetation,

Image 65: Green strategies representation

creating a collaboration and a strong bond at masterplan level.
The buildings around the central park create a boundary to the surrounding area, allowing accessibility to pedestrians, bikes and public transportations. This allow a high level of accessibility to every side of the central park, which is interconnected with internal paths. The park roads are classified following their importance and the type of connection that they are creating.
The importance of the paths is related to the connection to the main masterplan elements, represented by public transportations, services and seniorities. The main paths are connecting the Customs entrance with Brera Academy, Lancetti station with Città degli Uffici, Città degli Uffici with the associations house and Villa Simonetta path. This roads have the function of connecting this elements, so they have to guarantee a fast and straight connection with no interruptions. The main path is the longitudinal road, following the green corridor La Goccia-Scalo Farini-Biblioteca degli Alberi with a broken line that connects the main internal functions of the masterplan.
Paired to the fast paths are the slow connections, represented by a curve that is linking different functions and services. They connect the for sides of the area, a long and longitudinal path connecting the seniorities, and two transversal paths that contribute to the connection on an urban scale. This slow paths are passing trough the park, exploring different types of vegetation, pavement, activities and functions.
The vegetation varies along the park, providing an heterogeneous mix of plants, trees and flowers. The spontaneous vegetation doesn't need a lot of maintenance around the year, providing a friendly habitat for the local fauna, such as bees and other insects. Trees are usually placed in order to guarantee shadow, colourful flowers and also edible fruits that can be a source of attraction and relief. The position of trees also create some buffer zones towards the surroundings or the railways, in order to guide the user and allow him to stay in the park. Bushes are also populating the area, which are flowering in different period of the

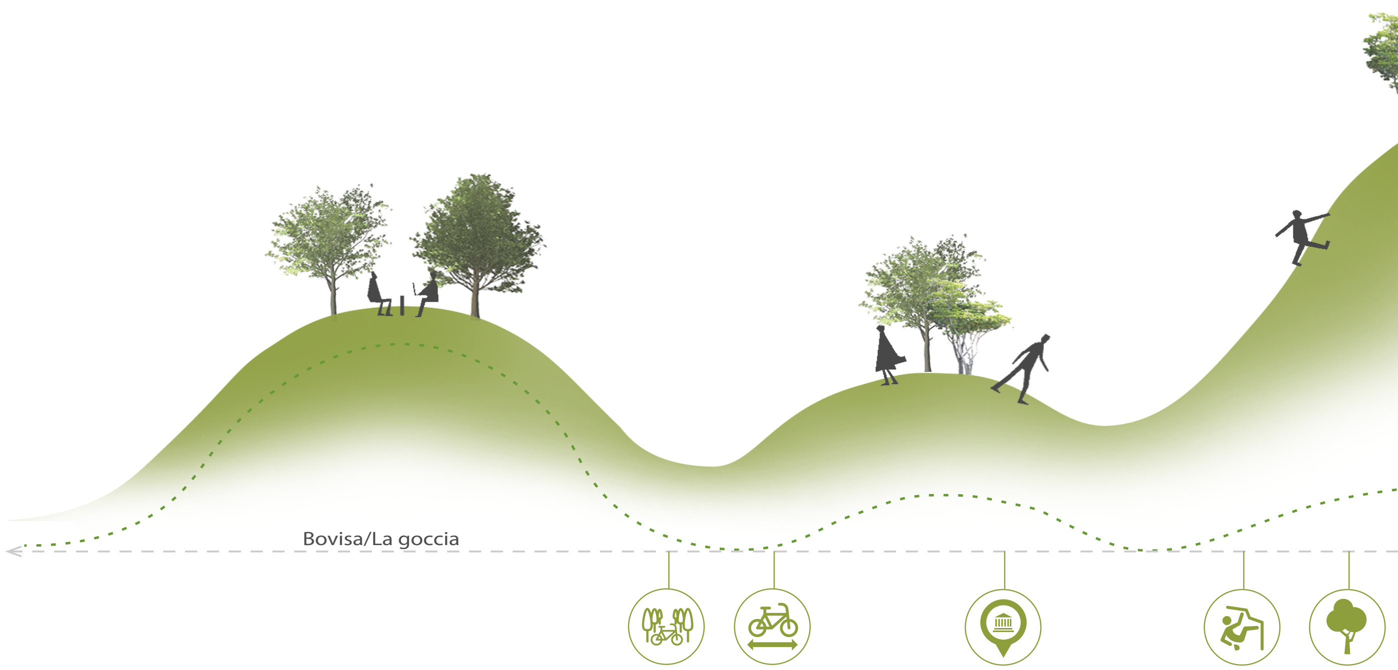


Image 66: Schematic representation of the green corridor, with the activities that would be placed in its various parts

year to guarantee a precious atmosphere during the whole year. Some green areas are used as flood areas, that can fill with water during long or violent rains. These are paired to main squares or not permeable areas, in order to guarantee a sufficient resilience against weather conditions.
The activities placed in strategic points all around the central park are important points of attraction for users and residents, as we can see in the map. These activities are mainly related to culture, such as an open-air theatre, a music school, visual and performing art exhibitions, a public library and a museum. Also sports and open-air activities have a central importance in the park with playgrounds for children from different ages, a skatepark, sport facilities and picnic areas. Aggregation spaces for adults and elder people are important for the masterplan, such as a designed space for associations a local markets. Also urban cultivation are seen as aggregation spaces, which attract and provide users with activities and natural food.
Vegetation is also placed in between the buildings, in order to guarantee private gardens for residences and public green areas where to stop, rest or play. These elements are also improving the liveability of public spaces, against pollution and overheating, promoting the commercial activities facing those spaces.
All these elements are creating a safe natural environment, where the users can easy orient, find services and cultural attraction or meet with acquaintances. The attractions are also providing services and functions needed by the surrounding areas, which emerged in the early stages of participatory planning with local associations and organizations. The open-air activities are promoted and encouraged, in order to guarantee an healthy lifestyle of residents and users.
The design of the park also promotes the creation of green corridors, besides the La Goccia-Scalo Farini-Biblioteca degli Alberi one, also other parks are likely to be connected with the area, on a local and urban scale (Villa Simonetta, Castello Sforzesco, Cimitero Monumentale, community gardens etc.).

The culture path: a new infrastructural, green and cultural connection

In the middle of the green park, that follows the railway with a mainly East-West orientation, a transversal, dynamic shape crosses the Masterplan, connecting Lancetti station with the new administrative centre of the Milano administration.

Its reasons are first of all infrastructural. The new offices, developed by the Milano administration, would be in a way isolated from their surrounding, being on the Southern border of Scalo Farini, cut away by the railway line. On the other side, the potential of the existing Passante station of Lancetti would be only partially exploited, being connected only on the upper area of the urban fabric in which Farini is. So a straight and fast connection is needed, not only for public transport services, but also for pedestrians and bikes. The two lines that connect Lancetti, Brera and the “Cittadella degli Uffici” are the ones that allow this fast path, and are doubled by the presence of a tram line, that runs parallel to the path. In particular, near to Lancetti a new entrance is carved into the ground, creating a hypogeum plaza that allows a direct and fast access to the trains level. From this one, different stairways lead to the street level, in the Northern direction as well as the East and West directions. In this way the high flows of commuters coming to Lancetti would directly arrive in a functionally dense area, where they would find useful services at hand. Instead towards the Southern direction a series of sloped planes would bring the visitor to cross one of the first transversal pathways, that belong to the drawing of the bigger park. Beyond this point, a

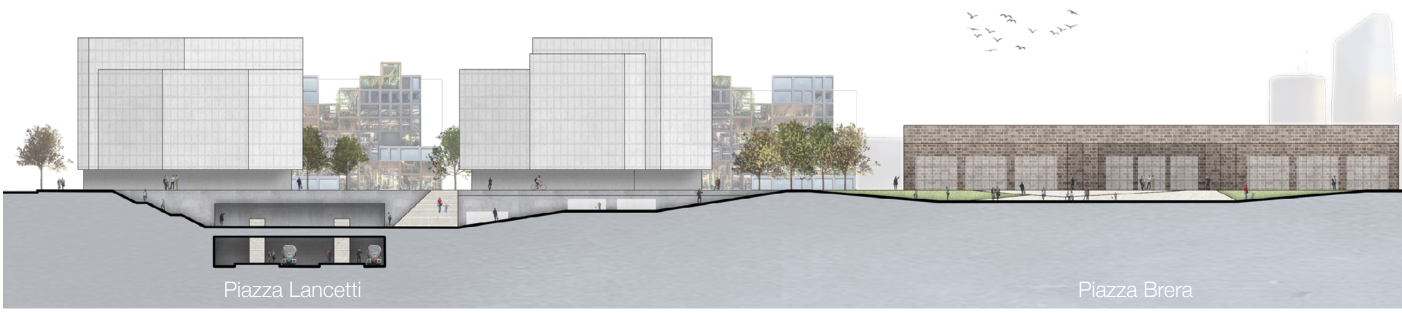
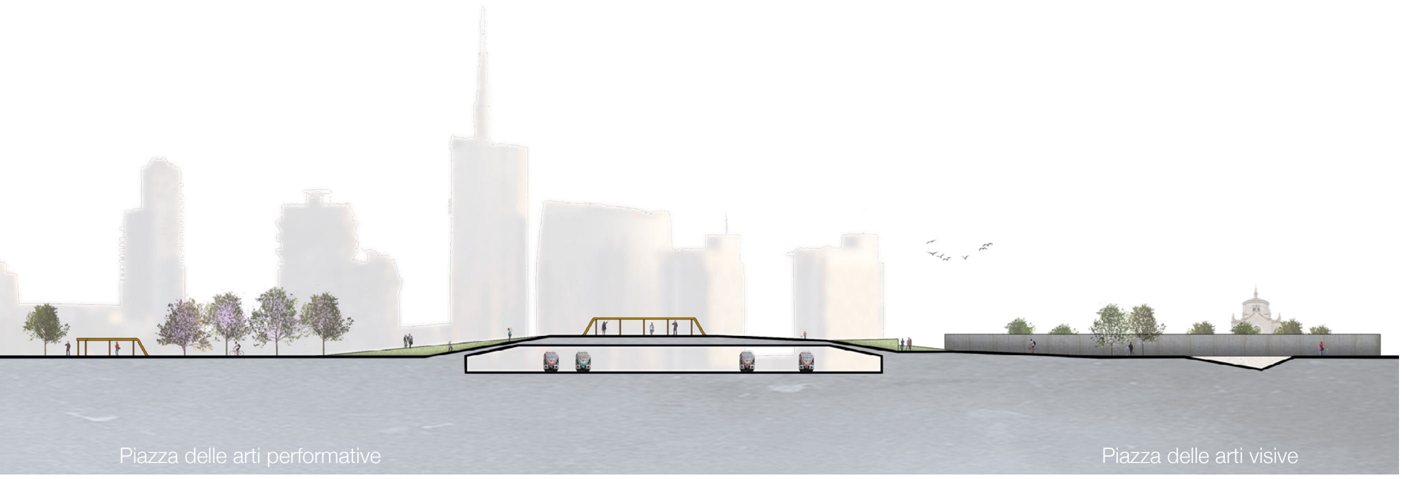


Image 66: Site section of the culture path with its sries of plazas

new slowing down area would be formed in front of Brera Academy.
This second square, slighlty under the ground level, would condensate the main flows intertwining in this point. The ones coming from Lancetti, from Brera, from the park and from the other side of the masterplan. The big open space could be used for gatherings of people, urban great events, exhibitions, concerts, using the building of Brera as a background, and looking at the park. Moreover it would directly face the new Performing Arts Center, becoming in certain conditions an extension for the activities happening in its spaces.
After the crossing of the second of the main transversal connections that this path encounters, a new panorama begins. The bridge that crosses the railway would create a new tectonic, creating the possibility of carving or extruding smaller volumes to give place to temporary activities, stand up performances, or yearly events. A criss-cross path would double the two main direct ones, giving the possibility to the user to wander around, experiencing this natural and artificial mixed up environment.
Finally, a new landing is possible when arriving to the “Cittadella degli Uffici”, on the other side of the masterplan where at a short distance there is a metro stop and the new social aggregation space in the Villa Simonetta area.

The green and mineral panorama

The fast and slow paths are surrounded by pavements and green areas, that are aligned to complete the fast and slow parts of the main path. Where there are areas of slowing down and rest, they are mainly mineral, with permeable and absorbing surfaces. Where paths have to be crossed green areas surround these ones, creating spaces both for nature and for leisure, to be populated as further discussed.
More in detail, the green panorama is dominated by different species of plants that are grouped on different basis. The self-sustainance and self-maintenace of the plants is one of the criteria. The less they have to be cared, the more it is probable that will remain in their shape and will not create excessive costs of maintenance and replacement. At the same time, they would be able to slow down the run of the water and to absorb the biggest majority of the rain that not only will fall on them, but also on the surrounding, impermeable pavement areas. Moreover, they are grouped in a way to have similar colours during the bloom so to create islands of colours clearly recognisable in the panorama of the entire park. In the same way, plants with different blooming moments are grouped together so to have the colour to last for the longest time possible.
The groups are shown in the right column, to-



gether with their blooming time.

Together with this distribution, also the pavement techniques are planned to allow the activities to take place, but also to deal with the management of water collection. Filtrating paving is planned in the hypogeum areas, and should be coupled with water collecting systems able to store temporarily the water and to infiltrate it in the ground slowly. Photocatalitic pavings are instead used in the most exposed areas, on which the flows of people would probably be bigger and that would require a cleaner air surrounding. Finally, gravel is used in the paths that criss cross the green areas.

The culture path

The slow path, here described, is in the design intention remarked by a continuous, sinuous element, that distributes itself into the biggest connection, leading from point to point the visitor. Its shape could change, passing from a simple difference in the paving typology to become a bench or a pergola, to shade the visitor and to host climbing plants. Its function would be always changing and would act as a local landmark, able to attract and gather people.

Its path would not only connect existing attraction points, such as Brera or Lancetti, but also new areas with specific or undefined functions. These would be juxtaposed according to a cultural path, that would start in Piazza Lancetti, would develop in Piazza Brera, and continue through the Piazza delle Arti Performative (Plaza of Performing Arts) and Piazza delle Arti Visive (Plaza of Visual Arts). These last plazas would have different functions, however not clearly defined. Their function could change and develop through time, exploiting those only partially designed stops. Simple pedestals, foldings of the ground, carved window into the soil could generate space for temporary exhibition, formal or informal events, stand up events, concerts, gatherings, open air activities. The proximity to culturally dense areas such as Brera or the new Performing Arts Center, as well as Villa Simonetta, would strengthen this path and make it to develop along time, creating a new element of local recognition and distinction from the surrounding. The spaces would address different and diverse band of the population, from young to elder ones.

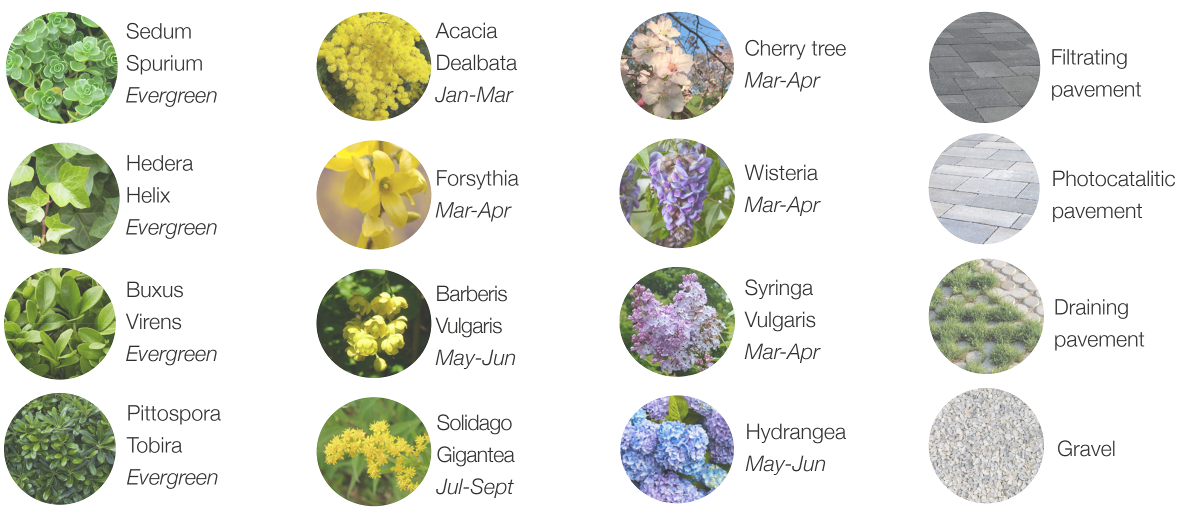


Image 68: Abacus of some of the green species and paving systems

Image 69: Examples of the activities that could take place along the Culture Path

Implementation stages: economical, ecological and cultural development of the masterplan

A masterplan of a huge dimension such as Farini would need a very careful attention during the phases of implementation. Economically speaking, it would need a very huge investments, that will probably take place only in a very large span, of years if not decades. So it is very important to consider the programming of the successive stages in which separate parts of the masterplan will be actually implemented.

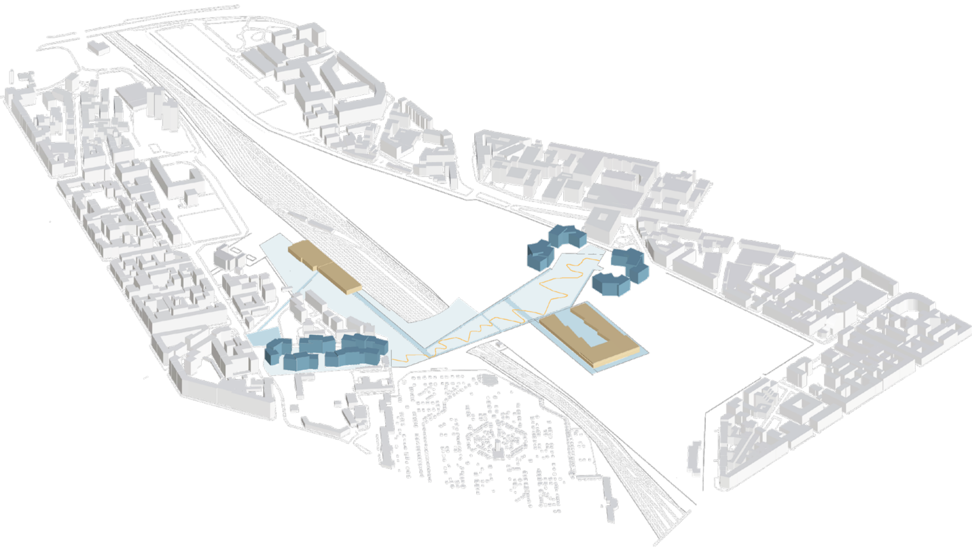
More in detail, it is wise to suggest that to every private investment, the implementation of a public area would have to correspond. In fact local administrations do not have the money required to design and to maintain these huge surfaces, that would then have to be sustained by the private investors. Moreover, it is important to grant the soonest possible the most strategic infrastructural connections, to provide the city new spaces and systems to be really used. In this way, even the public spaces would become fully accessible and implemented, granting that the vast majority of people living in the surrounding would become to benefit from these new spaces.

In order to follow these guidelines, three main stages were designed. At first, Brera would be refurbished, as already planned, acting as a private investors. At the same time, the Cittadella dei Servizi would be built, paid by the local administration. Together with this, the buildings surrounding Lancetti would be built, granting in this way also the implementation of the main strategic connection into the park and the refurbishment of the future house of the associations.

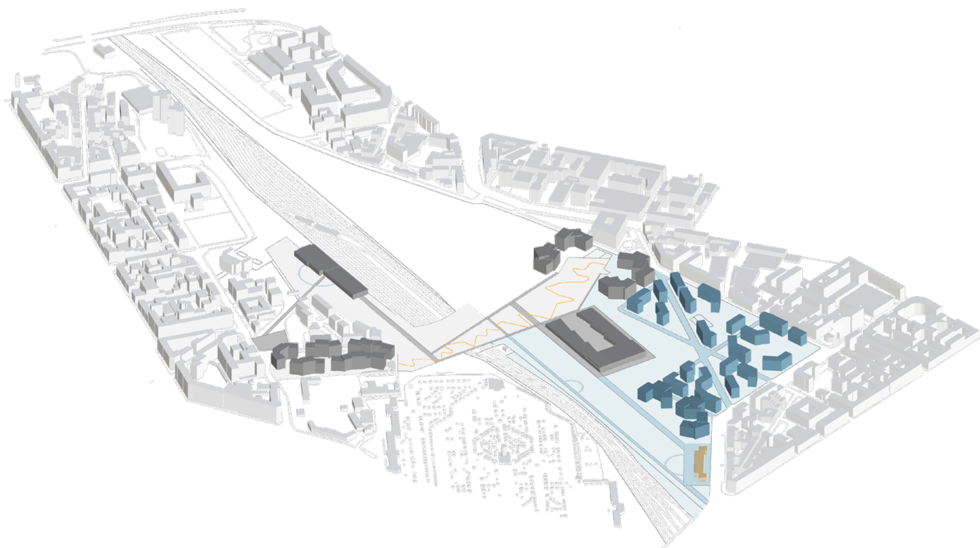
The second step foresees the development of the North-East part of the masterplan. The huge private investments required in this phase would also be able to pay the right side of the park, together with the Customs building and its new public library.

Finally, the Western part of the masterplan would be built, completing the public park and reconnecting Villa Simonetta with the general drawing. The second bridge over the railway would also be built, and the green ray connecting Biblioteca degli Alberi to Bovisa would be completed.

Implementation stage I



Implementation stage II



Implementation stage III

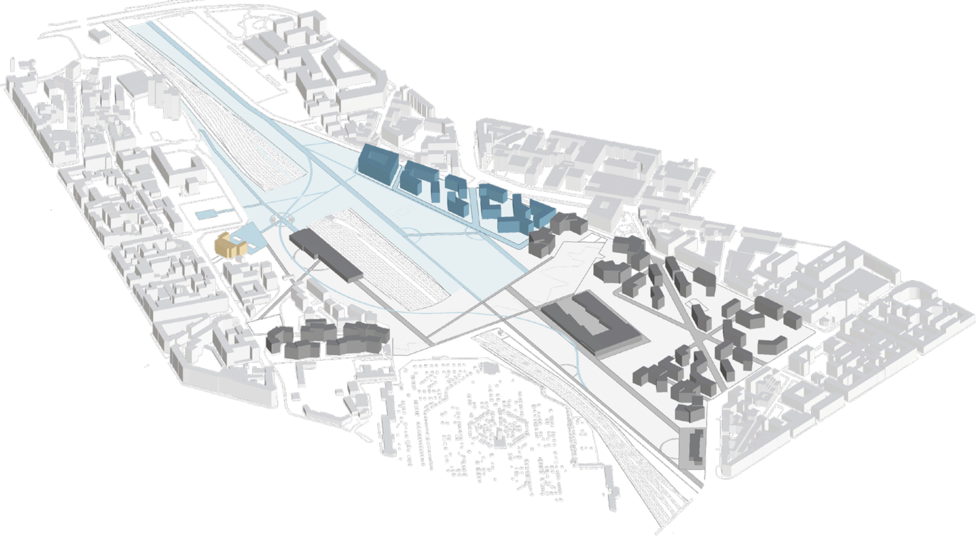


Image 70: Schematic implementation stages

District energy balance

As presented in the design intentions, the buildings composing the Scalo Farini masterplan are built in order to achieve high energy performances. This requirement has been fulfilled choosing, after proper analysis and simulations, high performance stratigraphies and HVAC system, using heat recovery and a ground source heat pump. The parameters and schedules used for the simulations are similar to the ones used for the "base units" presented in Chapter 2, and are summarised her in Table 03.

The district was designed in order to avoid as possible the mutual shading, in order to improve the PV panels efficiency during the day. This parameter is fundamental for these simulations, because the energy produced by PV panels has to be maximised in order to achieve the best results possible.

The particular district represented in Image 71 was chosen as it represents a good model for the whole masterplan, for the number of buildings, the built area and the spatial distribution and orientation. The percentage of transparent surface is the result of energy optimisations carried out with the energy simulation software DesignBuilder, simulating all the possibility in a range and confronting the obtained results.

	Element	**Value**
Total surface	Residential	13550 m^2
	Office	5800 m^2
Construction elements	Exterior walls	0.098 W/m^2K
	Floors	0.098 W/m^2K
	Roof	0.098 W/m^2K
	Glazing	0.993 W/m^2K
Glazings	Wtw ratio	S: 80% N: 10% W-E: 20%

Table 03: District buildings parameters

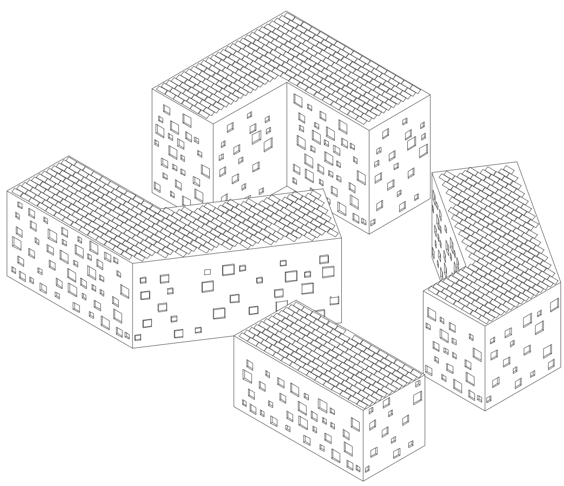


Image 71: District blocks for energy simulation

The annual simulation of the whole district shows an important amount of produced energy, which is higher than the consumption for most of the time as visible in Chart 07. The general results are very good, considering that the total consumption is only 27.6 kWh/m²y, which is an optimal value for mixed use buildings. Being the total production 40.2 kWh/m²y, the district can be considered as "active", meaning that the buildings produce more energy than it consumes.

The summer peak of consumptions, due to increasing use of energy for cooling, is offset by an important increasing in production. On the other hand, the winter production can be enough for the consumption during the day, while during winter nights the energy will have to be taken from the grid. During an average day the production reaches higher values then the consumptions, as represented in Chart 08, providing an important surplus during daytime. The presence of different functions in the district allows a more uniform distribution of the consumptions during the day, which improve the effectiveness of the energy strategy.

The excessive energy needs a storage to be effective, which can make it available for consumptions during night hours. This storage should be enough to store as much energy as it is needed to fulfil the consumption not covered by production. Both electric vehicles and power walls can be good ways to store energy, but both have problems in relation to their availability and additional costs.

The simulations showed an important amount of excessive energy, which can be useful to charge EVs or to provide passive buildings with renewable energy. In last chapter this possibility has been analysed, using EVs as storage and means of energy transporting in order to increase the grid independence of the district.

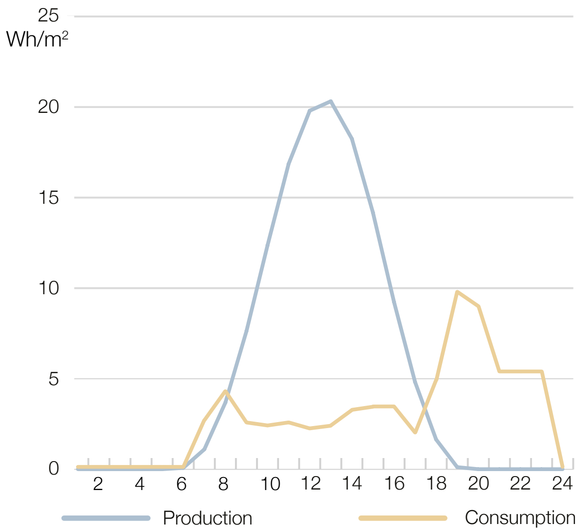


Chart 08: Daily energy analysis during equinox

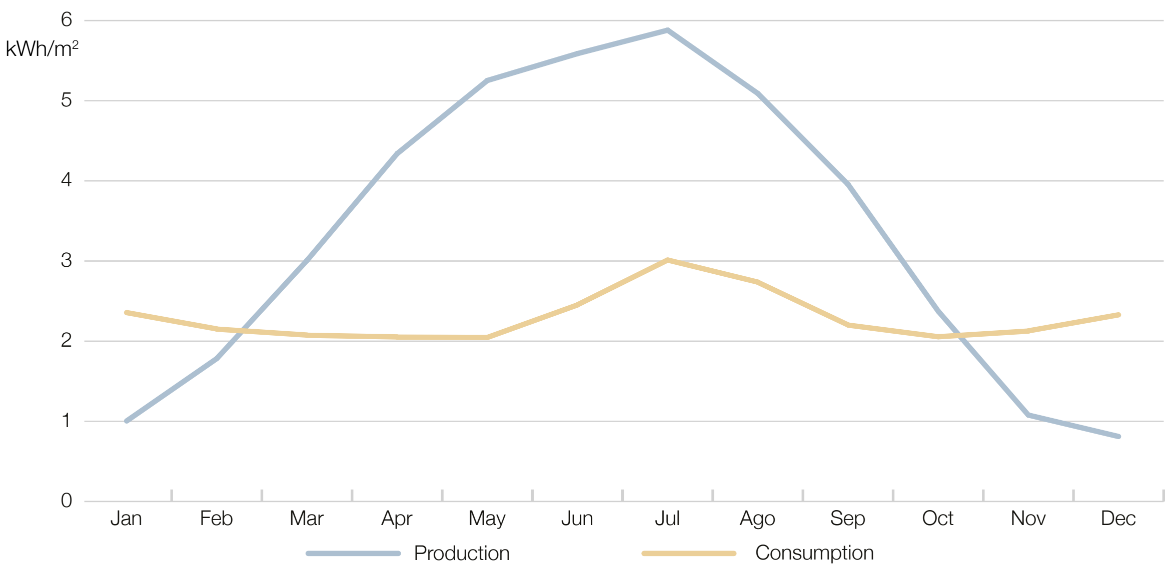


Chart 07: Monthly energy analysis of the analysed district

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Image 06: CTR 1972.

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Image 13: PGT Milano

Image 14: CTR Lombardia

Image 16: AdP, Allegato K

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Image 35: www.scalimilano.vision/concorso-scalo-farini/

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Image 37: Farini competition brief

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Chapter 3 charts

Chart 2: Accordo di programma Comune di Milano

Chart 3,4,5: ISTAT 2016

Chapter 3 tables

Table 01: www.scalimilano.vision

Table 02: Farini competition brief

Chapter 3 abbreviations

AdP - Accordo di programma

CTR - Carta tecnica regionale

EV - Electric vehicle

PGT - Piano di governo del territorio

PUMS - Piano urbano di mobilità sostenibile

CHAPTER 4

SynEnergy Hall

Concept and design

Design intentions

The choice of a representative and outstanding building to be realised at the heart of the new masterplan started from a few requirements, coming both from the design process and the masterplan intentions. The intention to create a new landmark inside of the area, that for the rest remains of low profile buildings, was a key motif. This meant that both the shape of the building and its program had to be relevant. From a programmatic point of view, particularly relevant building would characterise the new district since the first moments, relating the new development with a new function of the area. In Milano, for example, the same happened with he recently developed districts of Porta Nuova or City Life. Here the skyscrapers of the "Bosco Verticale", of the Unicredit Tower and of Tre Torri respectively created the association between the new, contemporary buildings and their correspondent developing area.

On the local dimension the leading motifs were the will to strengthen the so called "Cultural Path" with a relevant building and to relate the latter both with the built environment and the big urban park. Indeed the position of the building is very relevant into the masterplan urban fabric, at the border dividing the mixed-use district, the more residential area and the green area. Moreover it is positioned on the same axis of the new Accademia di Brera, that being misaligned to the rest of the masterplan is easily recognisable into its general drawing and urban system. Finally, the nearby infrastructural connections, to the Passante on the North-East direction, with the station of Lancetti, and to the new tram line in the South-West direction make this position particularly strategic as attraction and crossing point.

Image 1: Design are within the masterplan

The new building would also represent a very interesting case-study regarding the dependence and independence from the electricity grid. On

Image 2: Schematic representation of the design intentions

one hand it would have a great potential, considering the strategies and the theory explained and developed in the Chapter 2. It could have a variable, however big, PV panels surface, it could host a great number of electric vehicles, could have energy storage and to relate with other electricity-powered "subjects" such as trams and trains. On the other hand it would be really interesting (as stated before, at the beginning of Chapter 3) to understand how a building with this kind of requirements could be helped by the rest of the district in becoming energy-independent from the grid. In fact it is not difficult to suppose that a such-designed building, with a strong public function requirement, would not be able to completely satisfy its energy requirements. The energy interaction with the surrounding area and actors could then be deeply analysed, guessing different possible scenarios (see Chapter 5). The new building could help the surrounding constructions when having a surplus and temporarily storing electric energy through its energy storage or parked cars, and it could be helped by the rest of the district when requiring high energy loads due to intensive energy-consuming activities.

This said the program of the building was chosen also analysing the area of Milano on a local and urban scale. At the same time, a research on the trend in new, important public realisations in other big cities and capitals of the future was run. A multi-functional building, however with a main program, was chosen. Moreover a new protagonist into the cultural panorama of the city of Milano was the ideal subject. Indeed the city is facing today a various and super active panorama regarding the cultural activities, starting from temporary and experimental projects till the most renowned yearly events such as the Design or Fashion Weeks. The intention was then to create a building able to attract both users just interested in its main function as well as users more used to it, that require a higher level of spaces and program offer. At the same time a building opened most of the day, able to welcome day and night users, coming from the train station, from Brera Academy as well as the ones just crossing the new park.

The hypothesis of a Performing Arts Center was the most suitable one, and the one with the best motivation and design alternatives. Many municipalities around the world are investing in this kind of building, because they can accommodate different kind of functions and activities within their spaces. Indeed they could host people that came to attend a specific event as well as pass-byers, that wanted to explore the area by chance. Moreover they often create the possibility to observe the surrounding area and the city landscape just climbing the building and using it as an observation point (through elevated open levels or rooftops and sky bars). Their program remains partially defined and partially not, leaving space for experimental and temporary uses of the spaces. They give the possibility to fully express and convey a new message of modernity, where functions and people are mixed and able to freely interact. At the same time, it requires high functionality and efficiency in spaces and systems, to avoid confusion and grant the full enjoyment of the user's experience.

Building program

The building would have the performing arts as main functions. The main ones are music, theatre and dance, plus a sum of secondary ones. Their common characteristic is to express one's emotions and feelings, and to try involving the spectator in this process. This means that the spaces that are supposed to host these activities have to be able to properly host the performer and the spectators to maximise the mutual involvement. In designing the building program then the main functions were separated in different spaces, but at the same time coupled with ancillary and complementary spaces that can work as intermediate spaces between the main ones.

The three main spaces would be performance-hosting theatres. The biggest one would be a concert hall able to welcome more than one thousand spectators (around 1400). The second one, a theatre for performances requiring a stage with wings. A third one would be a more generic, experimental space, where there could be more flexibility both in spaces and performances. The distribution between these spaces and to the outer space would happen through dedicated, yet open, foyers, and ancillary spaces. These would at the same time work as main distribution spaces and clustering spaces for other functions that could be accessed using the open and public spaces. In fact receptions, cloakrooms, cafes all contribute in providing support to the visitor. Moreover a conference hall, a space dedicated to temporary exhibitions and a gift shop would complete the panorama of main functions. Finally a rooftop restaurant and terrace would give the possibility to the visitors to overlook the surrounding panorama, given the good location into the Milanese urban fabric. At the same time the restaurant could serve both temporary visitors and spectators attending performances. Servant spaces would complete the picture, granting space use efficiency and functioning. Backstage spaces would take most of these areas, coupling the three main halls. Dressing rooms, rehearsal rooms and storage spaces would form the backstage. Parking spaces would also give the possibility to workers and visitors to park their cars in order to assess the theory explained in Chapter 2 regarding energy exchange between the building the the electric vehicles. A kitchen for the restaurant and in general system spaces would also contribute to the functioning of the building.

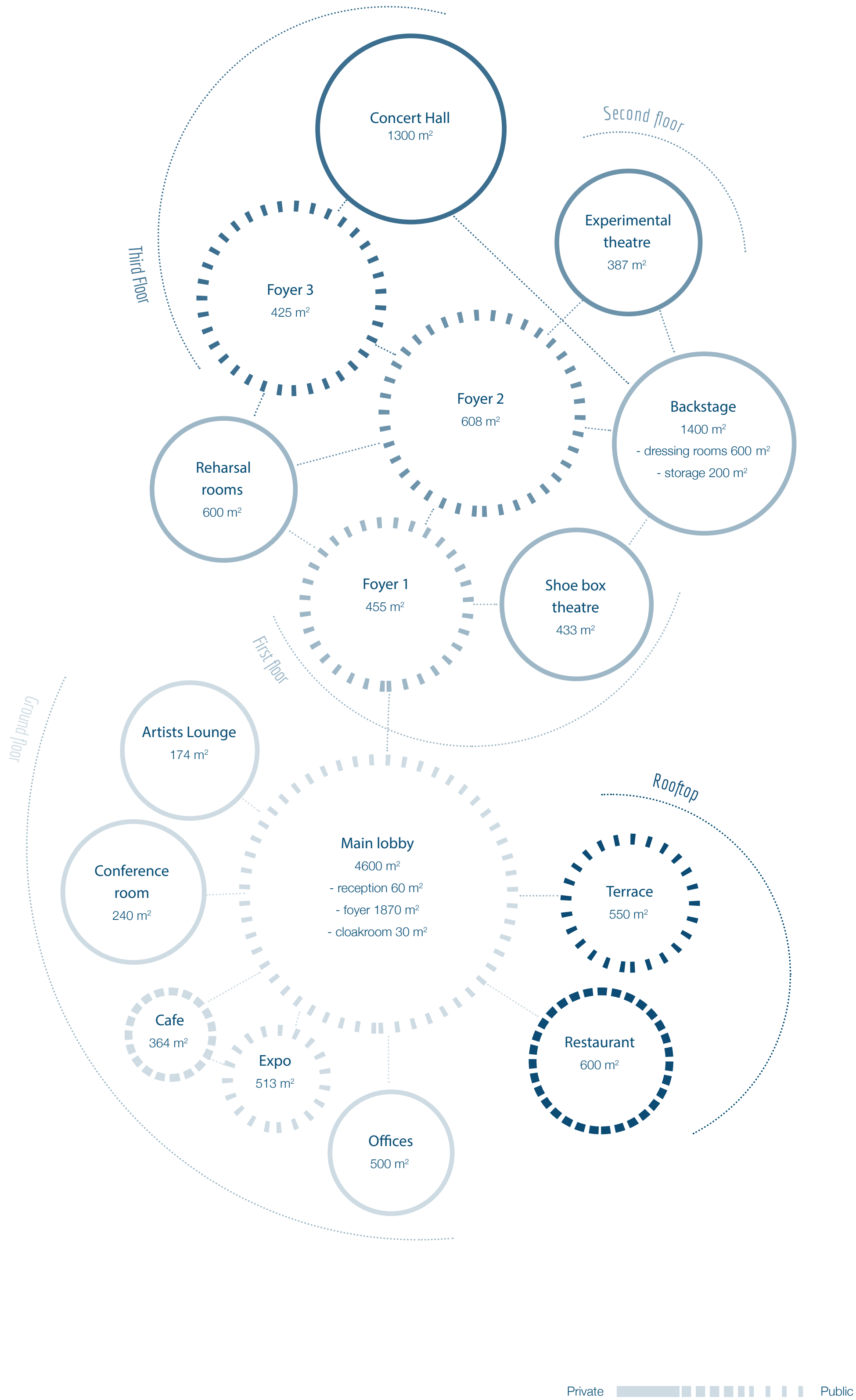


Image 3: Visual representation of the building program distribution

References

The development of the architectural design followed the study of different case studies that somehow already answered to similar needs and intentions that emerged in the masterplan developed.

Elbphilharmonie, Herzog & de Meuron Hamburg, 2016

Among the case studies analysed the Hamburg Elbphilarmonie answers to the need of revitalizing an area of the city that most people in Hamburg know about but have never really noticed becoming a real landmark. The area is now set to become a new centre of social, cultural and daily life for the people of Hamburg and for visitors from all over the world. This action mirrors one of the main intentions of defining a new landmark able to characterize Scalo Farini, giving birth to a new vibrant neighbourhood. The way the Hamburg Philarmonie engages in the site is overbearing and outstanding. It strongly differs from the surrounding building morphology denouncing its innovative character. It answers to a the need of a new kind of cultural centre not catering only to the privileged few. Aiming

Image 5: Hamburg Elbphilarmonie section showing the vertical development of the functions

to make the new Philharmonic a genuinely public attraction, Herzog & de Meuron provided not only an attractive architecture but also an attractive mix of urban uses. The building complex accommodates a philharmonic hall, a chamber music hall, restaurants, bars, a panorama terrace with views of Hamburg and the harbour, apartments, a hotel and parking facilities. At the same way, the new Milan Performing Art Centre aims to define an urban attraction for a wide range of potential users. The offer of different attractions and activities, as well as the indoor architectural arrangement aims to create a cosy environment which would be used throughout the whole day by users of different ages and interests. Culture and art are the key words in an harmonic whole. The Hamburg Philarmonie, responding to the need of marking the area, develops vertically emerging from the urban fabric and offering a view over the city. The same behaviour is assumed by Scalo Farini new Performing Arte Centre that wants to define a strong landmark emerging vertically, offering a series of spaces outlining throughout its verticality. As well as in the Herzog & de Meuron building, multiple theatres of different entity and character emerge from the section differentiating from the public spaces.

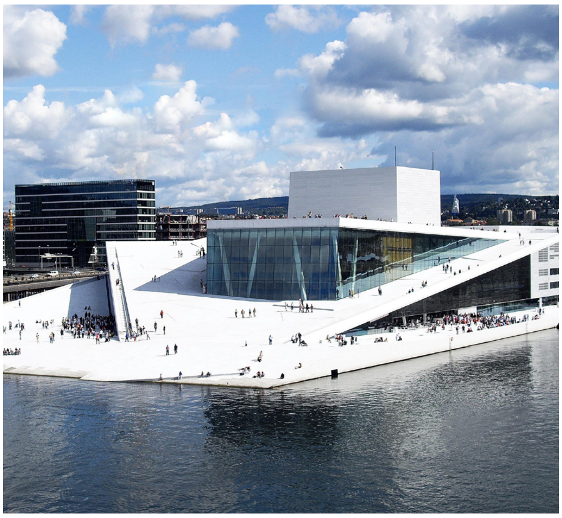


Image 6: Oslo Opera House picture showing the strong relation with the ground level

Opera House, Snøhetta
Oslo, 2008

Permeability is the answer that studio Snøhetta gave when realizing one of the most relevant landmarks of the Norwegian capital. The Oslo Opera House answers to the city need of hosting a new cultural centre that could be a symbol for the city but, most of all, part of the city. The vertical development of the building is fiercely connected with the human dimension and with the ground level. Indeed, it allows visitors to freely walk on it throughout the whole day and night, during summer and winter months. At the same way the project wants to be strongly permeable for the whole community, offering direct access from the ground floor to the first floor's green roof and becoming a sort of continuum of the surrounding park.

Taipei Performing Arts Centre, OMA
Taipei, under construction

The new Taipei Performing Arts Centre has somehow been a reference for what concerns the massing of the building. Oma's TPAC consists of a cube with hanging volumes, containing the different functions that are quite clear. In this way the building is clearly readable as a pure geometric diagram. At the same time, it becomes a very layered building: a very public part with a very private part, too. It is made from a cube with three volumes that, apart from the main exclusive functions, give the possibility to play with the public space. The concept of **recognizability** clearly and effectively adopted by OMA for the TPAC has been a key factor also for the project. Scalo Farini new Performing Art Centre wants to

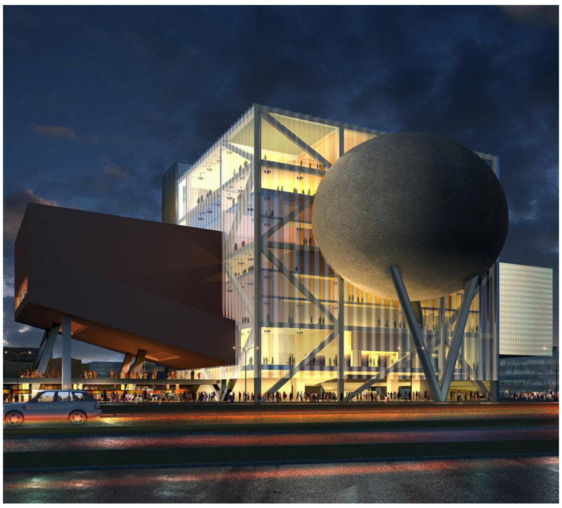


Image 7: TPAC view showing how the three volumes are clearly visible and readable

explore the morphology of a pure form, such as the cube, but at the same time wants an indoor space in direct contrast with the simplicity of the outer. The indoor space is dominated by the main functions that, as well as in OMA project in Taipei want to be recognizable, clear, and easily identifiable in the indoor space. While the intersection between this functions defines fluid and organic public spaces.

Royal Danish Opera, Henning Larsen Architects Copenhagen, 2005

A further inspiration has been the elegance with which Henning Larsen highlighted the importance of the main hall function in their Royal Danish Opera. The volume of the concert hall dominates the great open-space as a huge volume of a warm wooden colour almost floating in a white luminous and peaceful container. The surrounding space is characterized by simplicity and light colours in order to make the central volume to appear completely detached by any other structural components. The access to the hall is allowed only by suspended floors, connecting it punctually to the areas dedicated as foyer.

Similarly, the project of the new Milan Performing Art Centre wants to emphasize the importance of its main hall that wants to appear, as well as in the Copenhagen Opera, almost floating in the great open-space. Once again, the main hall wants to appear completely detached by any other structure, in order to seem a standalone volume. For this purpose, the audience access is allowed through punctual galleries suspended in the bright open-space.

Image 8: Royal Danish Opera inside view showing the bright internal space dominated by the mail hall

Design concept

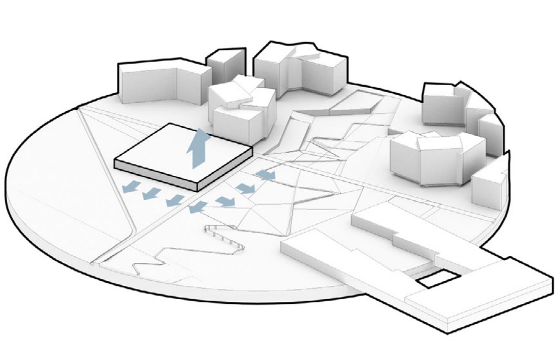
In order to maintain a strong relationship with the ground level and the human dimension, the first level of the building follows the adjacent streets orienting itself according to the new masterplan design and defining new fronts in the urban asset. The lowest level spreads horizontally with transparent facades in order to enhance the concept of permeability to the public and to any pedestrian. The concept of permeability is also translated in a vertical manner. The roof of the lowest level is modified in order to allow the park and the flows to spread over the lowest part of the building defining an outdoor public informal space accessible at any time of the day. Moreover its shape enhances and highlights the entrances and defines clear attractive points that would canalize the flows, oriented to the main access directions.

Then, in order to define a urban landmark, able to be clearly visible within the new masterplan and from any of its points, the groundfloor footprint is extruded in order to provide a certain verticality where the main functions will take place. The vertical volume is then pushed back from the outermost perimeter in order to allow again green public spaces over the roof.

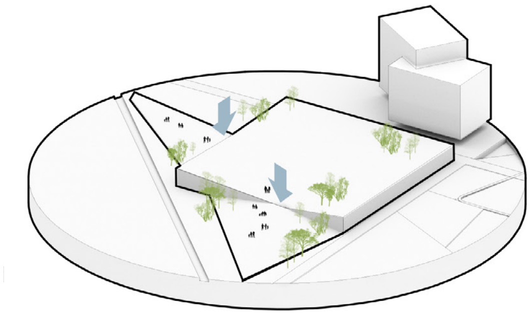
The volume is then rotated in order to create a visual connection with the building hosting Brera and allow further natural light in the ground level. Moreover this orientation is related to the main axis drawing the park landscape and that directly connect the buildings hosting the most public functions.

Instead the vertical volume hosts the three main functions that purposely are disposed vertically and connected by a suggestive path. In this way their disposition helps characterising every main level with one of the three halls, giving the possibility to serve them with the necessary ancillary functions. Moreover at every level the shape of the fopenspace floor is defined by a direct view to a relevant point. In this way a direct relationship with the surrounding is created and enhanced. The first level opens up towards the main entrance and Brera direction, the second one towards the new green bridge and the third one towards the park.

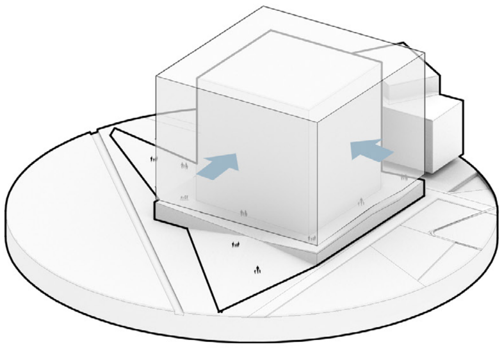
Finally, the rooftop hosts the restaurant and the terrace from which any visitor can enjoy the view of the landscape of Milano, spacing from the new district of Porta Nuova to City Life, passing throght the city iconic Duomo, Castello Sforzesco and Torre Velasca.



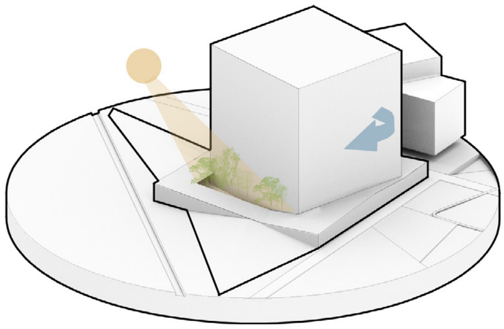
1 - Identification of ground plot



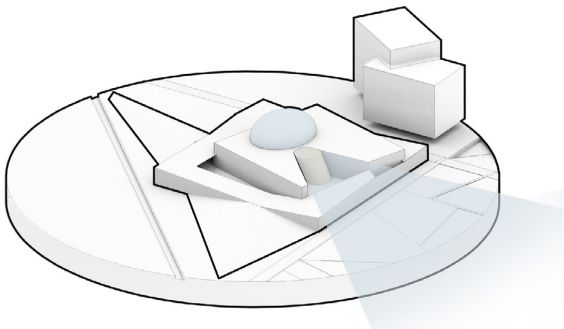
2 - Fusion with the park



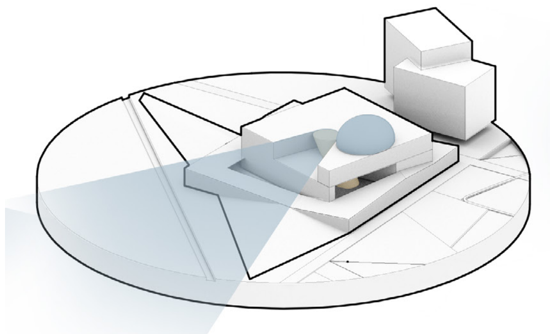
5 - Massing



6 - Rotation according to the seniorities

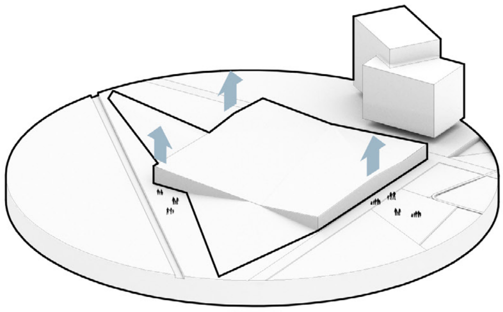


9 - Traditional theatre foyer cut

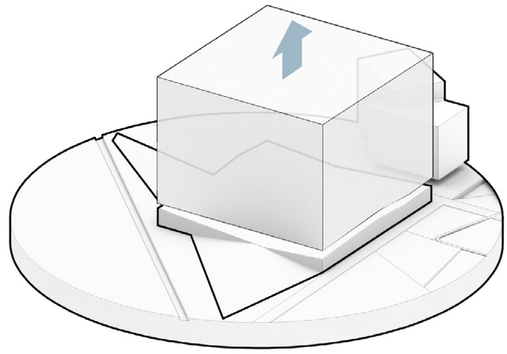


10 - Experimental theatre foyer cut

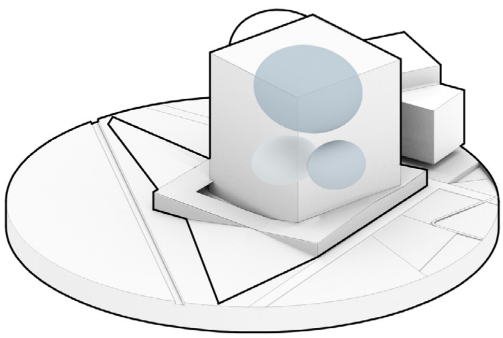
Image 9: Concept steps



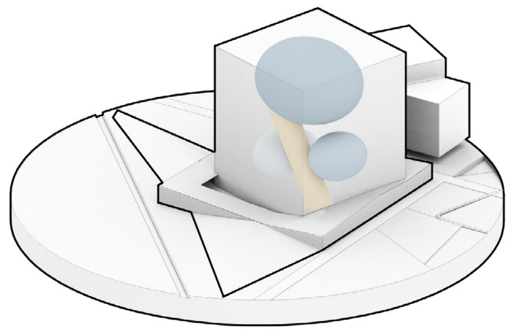
3 - Strengthening of the entrances



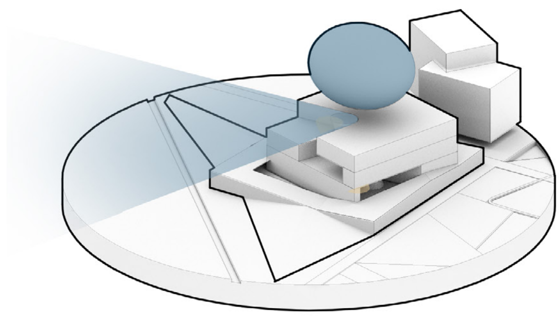
4 - Identification of the upper volume



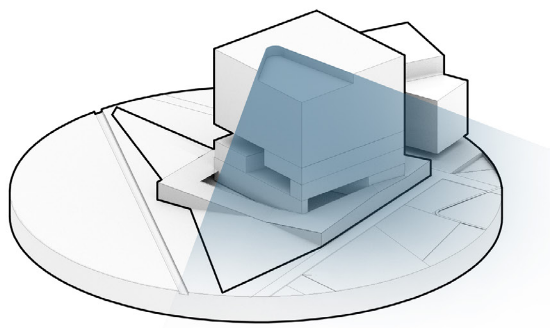
7 - Carving of the three halls



8 - Connection of the volumes



11 - Main hall foyer cut



12 - Rooftop cut

The relationship with the outdoor space

The relationship between indoor and outdoor spaces is really strong and a key point in the design of the building. In fact the position of the building within the masterplan general design makes it a cross point that, if well exploited, can generate a huge flux of visitors and users, even temporary. In the North-West direction there is the Passante station of Lancetti, which entrance is carved into the ground by the new public plaza. Around that one of the high-density blocks (explained in Chapter 3) host a big number of users, bot inhabitants and daily workers, as well as visitors and temporary users. Directly in from of the building, in the East direction, the Brera Academy collects a big number of students and professors that could be really interesting in exploiting the new building spaces and opportunities. In the South-East direction, instead, the new park would create a natural extension of the indoor space. Finally in the North-East direction the road and the walkable path, that are part of the new masterplan, would represent one of the main direction that the visitor would come from. The main accesses are also furnished with bike stands to allow bikers to easily park before entering.

The boundary conditions are exploited in two ways: granting the visitor to easily access and cross the building, and using its plinth as an extension of the park. The ground floor is accessible from all of the previously listed direction, making it easy for the user to access the building. Three main doors would face respectively the Culture Path, the park with its tram stop and the walkable path into the North-East direction. The indoor flows would then be headed to the centre of the floor plan, where the reception and info point would welcome and distribute the visitors. Moreover the main staircase, leading to the upper levels, is accessible from this point, enabling the building security to easily check the people that access the upper floors (even if freely accessible). At this level an exhibition space, a cafe and a bookshop find place, located in the free corners of the building. At the same time a conference hall and an artists' lounge take the upper-left corner. Finally, a cloakroom and the entrance for the restaurant and terrace are in the upper-right corner. Here the space is shared with the offices and with the artists entrance.

Inside of the building two inner courtyards convey light into the floor plan and help orienting the visitors. Generated by the rotation of the main volumes upon the plinth they have a trapezoidal shape and host green and paved areas. The bottom can be used as an expansion of the cafe spaces, while the upper one works as division between the private artists area and one of the main entrances. Moreover the latter also gives light to the conference hall. The presence of the green inside of the building continues through drawings on the floor, that host earth and greenery, as a fictitious continuation of the outdoor park.

The park itself does not stop at the doors of the building. It also climbs up the plinth through two main planes that from the South and East directions allow the visitor to walk on the ground floor roof. The roof, completely green, is shaped through inclined planes studied to highlight the main entrances and to help the visitor to climb up the plinth. Moreover the triangular shape of the single planes resembles the drawing of the nearby Culture Path and of the bridges crossing the railway.

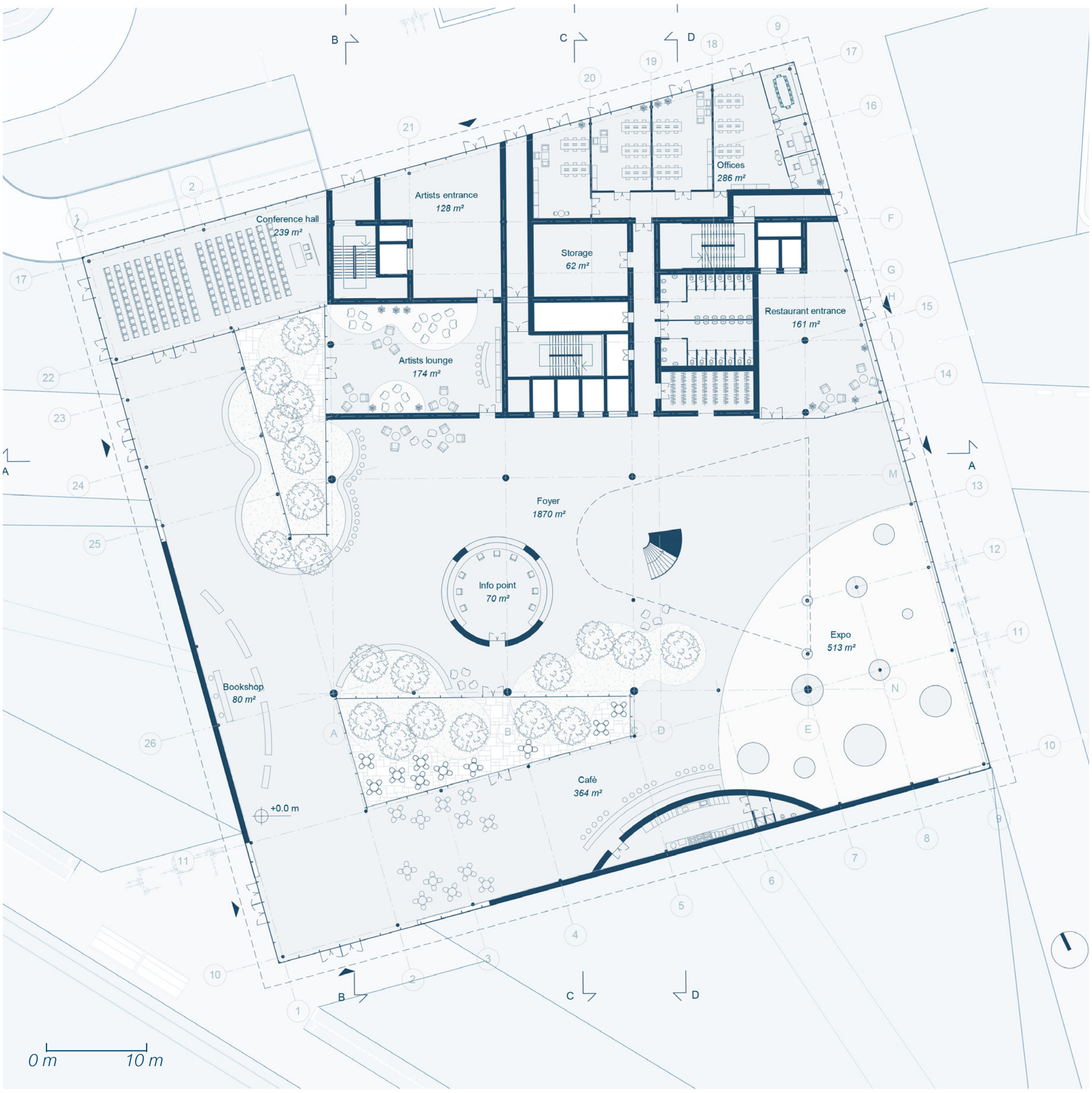
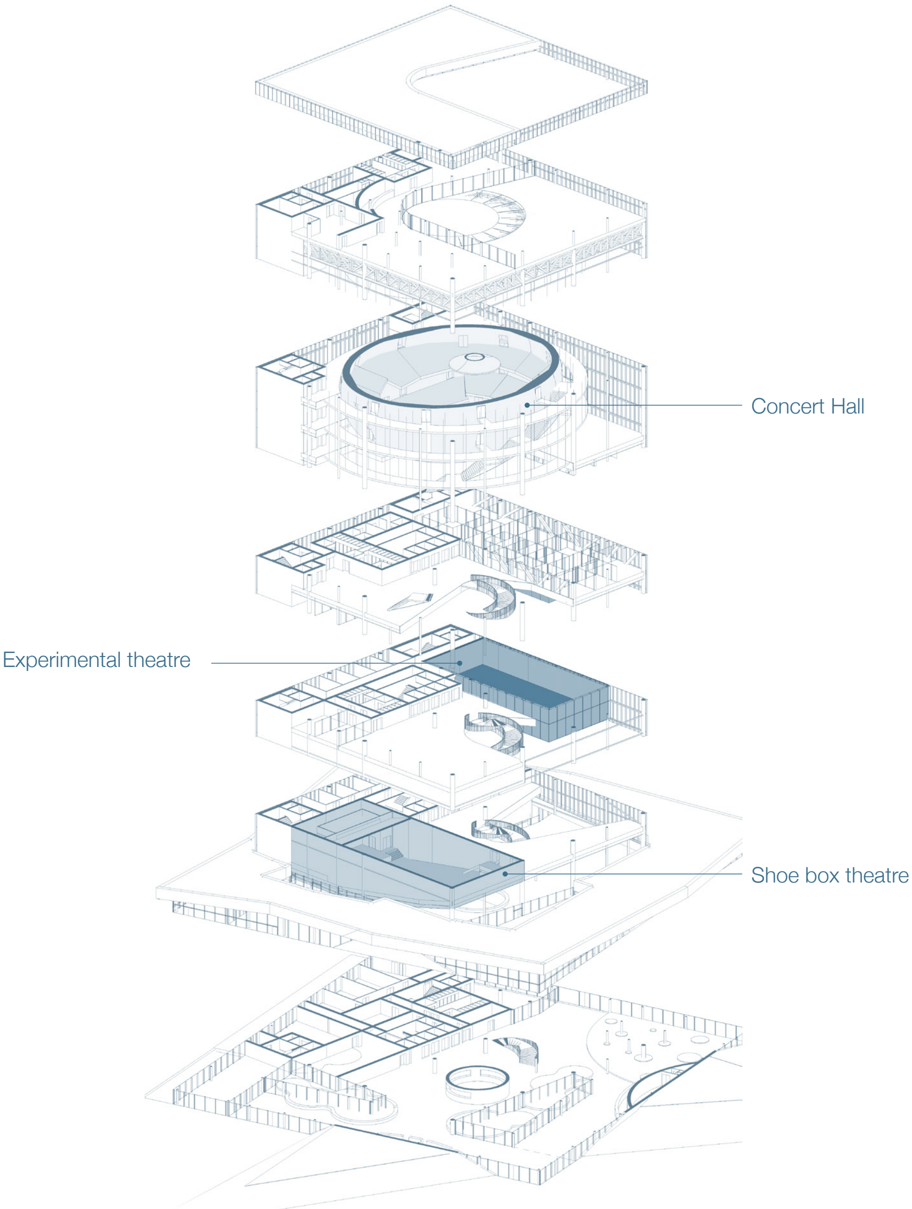


Image 4: Ground floor plan

The theatres design



The traditional theatre

The first of the theatres, counting bottom-up, is a regular shoe-box shaped one. Its primary function is to host different kinds of plays that require an average amount of spectators and a typical stage with wings and the possibility to change scenography. Its inclined floor allows the audience to see the stage more easily and helps the flows inside of the space.

Indeed the entrance is from the back of the parterre, which is accessible from the foyer at level 2 (+10 m). Here a U-shaped floor allows visitors to enter the parterre using two stairs on the sides of the floorplan. There 420 seats allow the audience to enjoy the play. They are separated in sectors that respect the requirements for the safety of theatres. The stage counts roughly 160 m^2 of open space and another 150 m^2 of wings, that allow actors to enter and exit the stage, as well as to direct lights and objects onto the stage.

From the back and the floor of the theatre floorplan there is a difference of five meters, while the stage is one meters above the bottom level of the parterre. This allows the actors to directly access the backstage that is located at level 1 (+6 m). This level is only accessible from the service elevators and the bottom of the theatre, while it is completely inaccessible by the general public. This level is also important because from the parterre one of the safety escape routes is passing through the backstage, arriving to the fire safety stair.

The shape of the theatre is clearly recognisable from the groundfloor, where its outer form is left untouched to create a clear statement in the interior panorama. Moreover to highlight its shape the two walls along the long sides of the theatre host two wall-high trusses that avoid the need of columns directly below them. In this way the access from the West side of the building remains free from big columns.

The experimental theatre

The second theatre is an even more regularly-shaped spaces than the first theatre, but its function is different. In this case the shape is a simple rectangle, both in floorplan and in section. The reason behind this form is because the function of this space is to host more experimental acts and plays, without a superimposed plan arrangement. In fact no seats nor a stage are represented in its floorplan, because both of them can change for every play or exhibition that takes its place.

The entrance is located on the left side, looking at the plan, facing the foyer number 2, at level 4 (+16.5 m). Instead the main level of the theatre is located at level 3 (+14.5 m). This difference in level allows the floorplan to be rearranged according to the use and the activity, creating a sloped floor, a convergent parterre, a theatre-like arrangement of seats, and much more. The artists and technicians entrance is located in the back of the space, at level 3.

The outer skin of the space is made of a double curtain wall treated with fritted glass. This doesn't make the sound and the eyesight to penetrate inside it, but allows diffuse light to leak out of its walls. In this way, according to the time of the day and the activity carried on inside of the theatre its skin will change, partially showing what is happening inside or allowing part of the sunlight to enter it. The same skin is used to visually distinguish this volume from the rest of the building even from the foyers. Moreover its volume extrusions is clearly recognisable from the levels below (foyer 1 and groundfloor) following the design intentions and concept.

The experimental theatre is in a direct relationship with the space that can be found on the other side of the its foyer, where a so-called "informal theatre" takes part of the space of the floorplan.

This space has a more generic program, leaving its users to arrange its layout in different ways according to the use time by time. It can be used as waiting area, catering, temporary exhibition, open-air theatre, stand-up performances, or even joined with the space of the experimental theatre for a shared exhibition need.

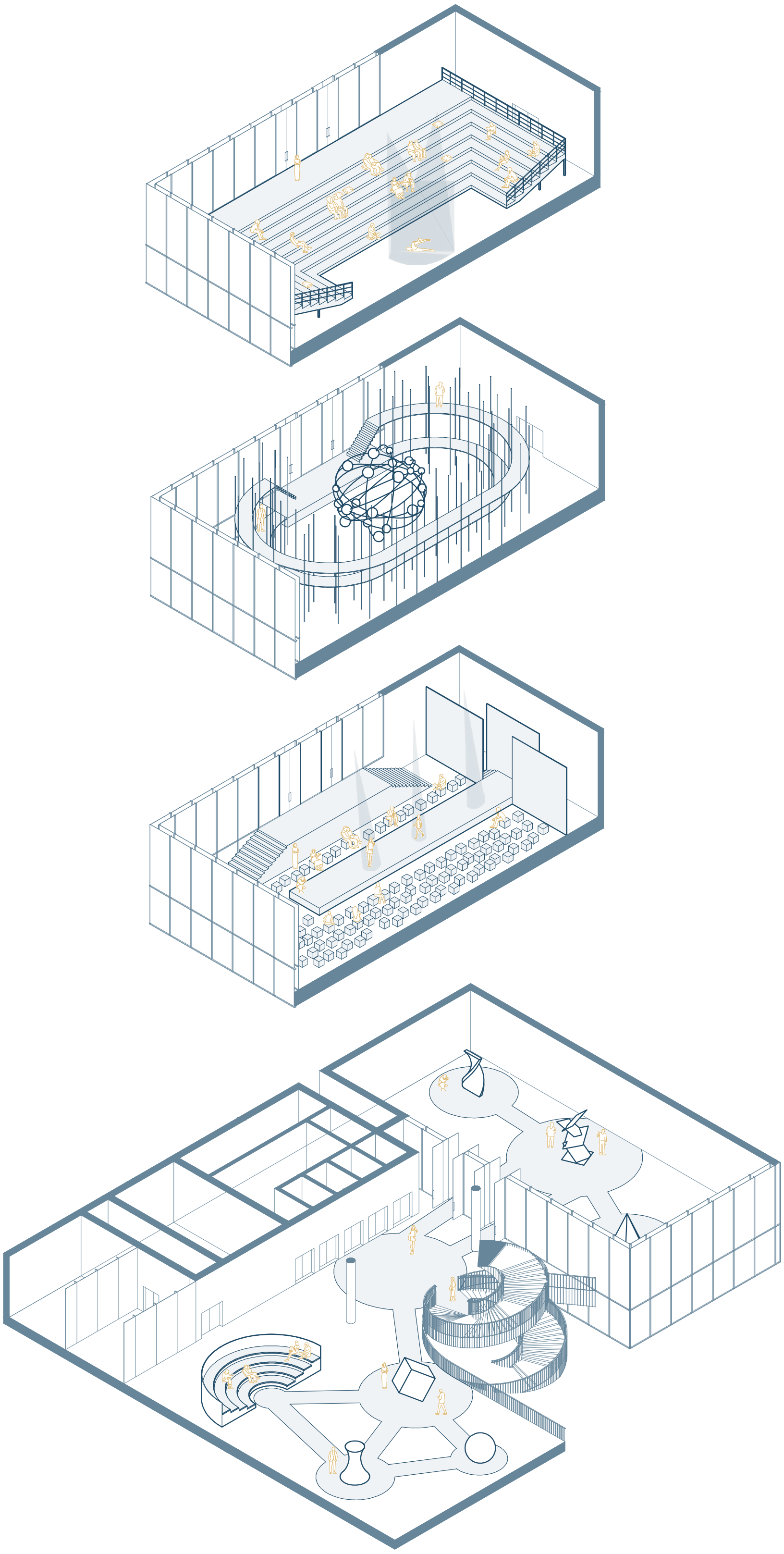


Image 10: Schematic representation of possible floorplan arrangements and uses of the experimental and informal theatres

The main hall

The main hall purpose is to host concerts. From one pianist to an entire orchestra, its shape is designed to diffuse and reflect the sound waves in the best possible way. The ovalized shape is studied to accommodate the highest number of seats possible, without limiting the audience experience. In fact the configuration that follows a vineyard scheme avoids the need of electric systems to amplify the sound. Its base principle is that placing the seats all around the stage the round sound wave will be exploited in the best way. To enhance even more the sound strength and clarity an acoustic baffle helps teflecting the sound waves directed from the stage upwards.

The configuration and the high number of seats (around 1350) requires a complex system of ancillary spaces, such as corridors and stairs, to access them. For this reason the main hall is surrounded by three round aisles that make a 360° revolution around its centre. They allow not only an easier access to the hall, but also facilitate the escape in the direction of the fire safety stairs.

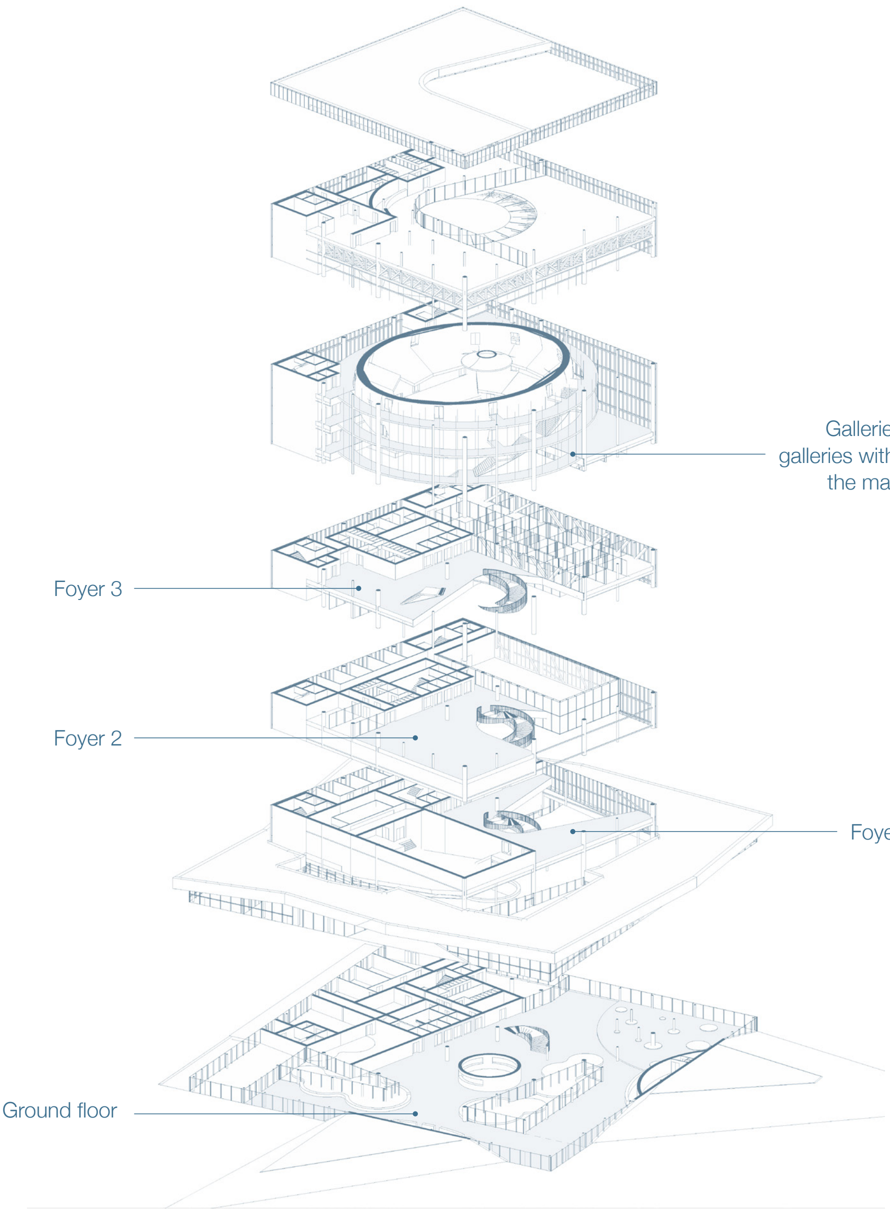
Once entered the hall the seats are arranged with different layouts according to their position in floorplan. The parterre is quite regular, with seven sectors in total, with two accesses from the bottom and 5 from the top. The first round of galleries runcs semi-circular around the stage and suspended of a couple of meters from it. It hosts five sectors and has five accesses from its back. Finally the second round, that changes inclination and riection for every of its galleries, hosts eleven sectors and has nine entrances in total.

From the outside the main hall is clearly recognisable for its shape both from the bottom and from the side. The regularity of the outer volume was achieved by approximating the shapes of the galleries and of the relative corridors. Moreover its form is kept autonomous from the rest of the building as much as possible. When arriving to the upper ceiling a cut into the opaque layers allows the eye-sight to see the continuation of the volume. Even from the terrace there is the possibility to see part of the volume through a glass transparent floor into the floor.

In the inside of the hall volume the upper part is cut by a false ceiling that is studied to absorb the sound, avoiding reflection that would create echo. Moreover it prevents from seeing the spatial truss that sustains the roof floor.

Image 11: Impression of the galleries leading to the main hall (on the left)

The open spaces



As previously mentioned the building wants to be the sum of private and exclusive spaces such as the three theatres and the auxiliary spaces serving the main functions, and open, public areas. These areas are intentionally opened and accessible in order to define areas for the community, different users, and different programs. These spaces do not host a specific function but are intended to be flexible, mutable, defining auxiliary spaces whether needed, becoming for examples foyer for the three main halls, or else, becoming attraction point for the community during open conferences, meetings and so on.

The opens spaces define an organic and fluid whole connected by a suggestive path, an elegant stair, designed parametrically in order to be able to connect the functions vertically.
The open spaces develop fluidly from the ground floor, where the main flows, and most of the public function occur, until the great void embracing the central main hall. The ground floor hosts a cafe, a temporary exhibitions area, a lobby, and distribution cores leading to the upper floors. The distribution elements divide between fast and slow ascent, while it is only fast when reaching the roof top restaurant and terrace.

Image 12: Impression of the ground floor openspace with the staircase leading to upper levels

Image 13: Impression of the experimental theatre and the foyer of the traditional theatre

The ground floor offers then many informal spots where any user can sit down and work at the computer, read a book or simply hang out with a friend. Green indoor areas are provided in order to enhance the space and air quality. Once reached the first level, the visitor finds himself in a big void from where he can entirely perceive the building asset. Indeed, he can be able to admire the overlying main hall wooden skin through the double height and the apparently hanging structure of the experimental theatre.

The first level occasionally becomes a proper foyer, offering a suggestive space where to organize catering and hospitality for the first level theatre spectators.

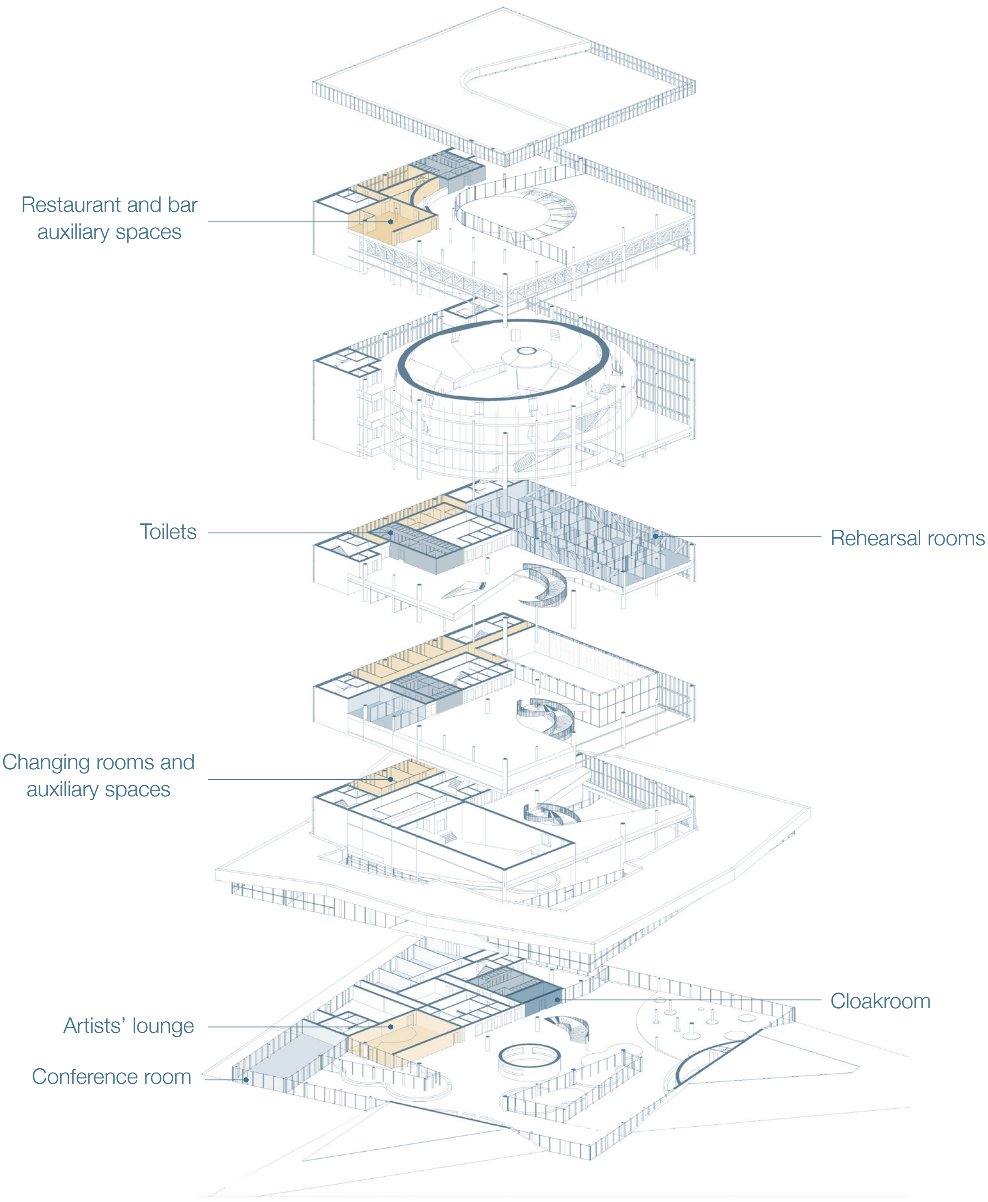
The panorama changes when arriving at level 2, hosting the experimental theatre. Here the space, occasionally used as a foyer, hosts otherwise an informal area where to organize open conferences, meetings, catering, or shows. The furniture, consisting of cubic elements of different dimensions is movable and re-arrangeable. The third level opens up in the park direction defining the most suggestive of the foyers, from where, at sunset time it is possible to enjoy a natural spectacle. Level 3 offers then a wide area where to arrange catering and meeting before accessing to the main hall for a concert, but at the same time might define an open and public space for those practicing music, dance or acting in the rehearsal rooms.

The open space culminates with the area embracing the main hall and with a series of gangways that allows the access to the concert hall and that appear like floating in the bright open space.

The common leitmotiv of the open spaces is that even if they serve separate spaces and are functionally designed in order to answer to this need, however they visually and spatially connected so that the activities that happen can be seen and joined by different kinds of users. The structure was carefully studied in order to leave these spaces the most free as possible, to remove any possible physical constraints in rearranging and temporarily furnishing the spaces. At the same time the natural light can spread across the spaces and minimise the need of artificial lighting. In this way, through the huge transparent façades it is possible to enjoy the panorama of the new urban park and to perceive the public space, at openair as well as indoor, as a whole.

Image 14: Impression of the first foyer and of the overhanging main hall, through the space of the foyers 2 and 3

The closed spaces



Auxiliary closed spaces are complementary to those hosting the main functions and the public open spaces. In this case the auxiliary spaces are in most levels located in the back part of the building. The reasons are to stack them one on top of the other, for an easier vertical connection, and to place them in the least important facade. Indeed the Northern facade is the less exposed to the sun and the only one that does not face the park.

At the ground floor offices, an exclusive conference room, as well as a hospitality room dedicated to the artists find place. Indeed the artists entrance is in the North side of the buildings, where also service entrances find place.

The next levels offer auxiliary spaces and room for the theatres, as well as dressing or changing rooms for the artist, distribution cores that do not intersect with the public flows for the machineries movements as well as for those of the artists or of the employees. In these cases a long corridor connects the different spaces, distributing the flows.

Another fundamental function takes space in the so called private spaces. A few rharsal rooms are in fact located at the boundary between open and closed spaces, where they can be accessed by both classes of users. Their translucent walls allow the necessary privacy, without limiting the natural light too much. Their particular position within the building system allows them to be used by the general public during the day, such as music, dance or theatre students, as well as by professionals. The third floor in particular hosts a series of rehearsal rooms for the public and the performers, where ballet, music or acting companies can train.

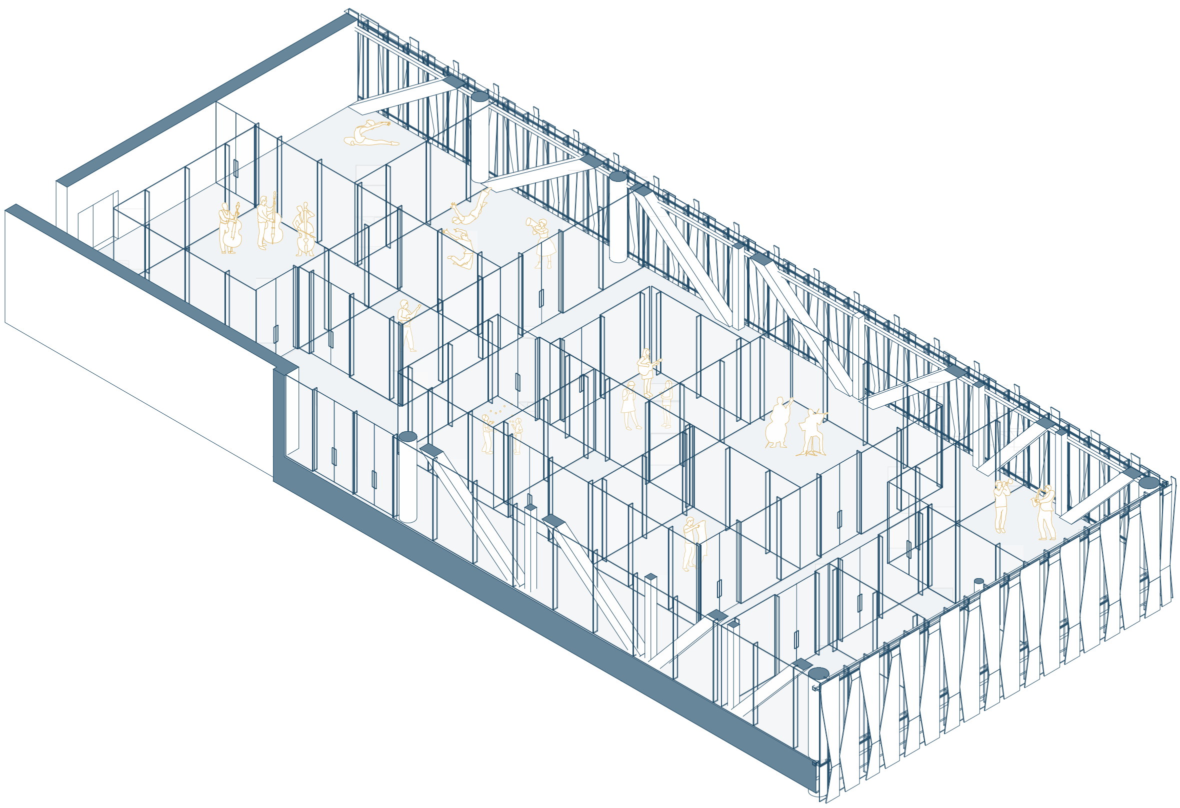
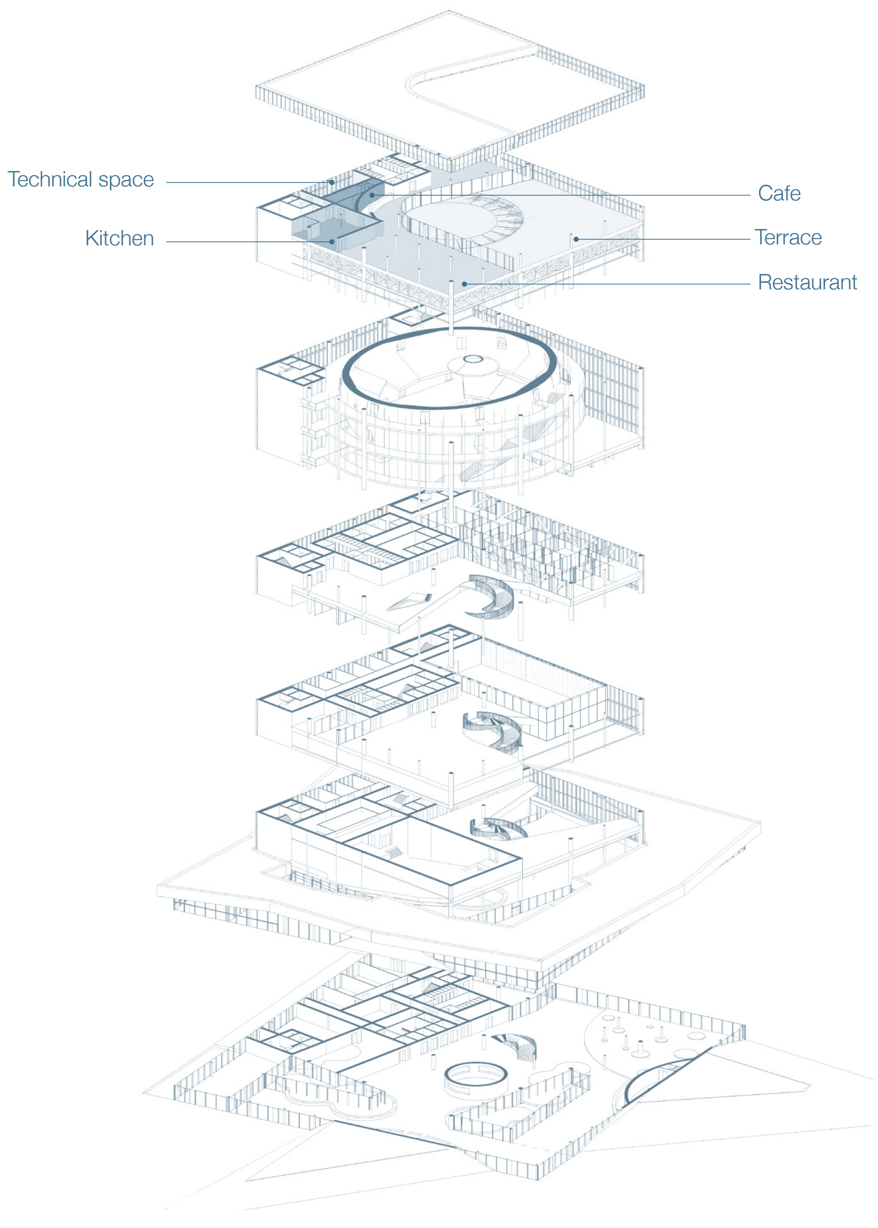


Image 15: Axonometric view of the reharsal rooms located besides the third foyer

Restaurant & terrace

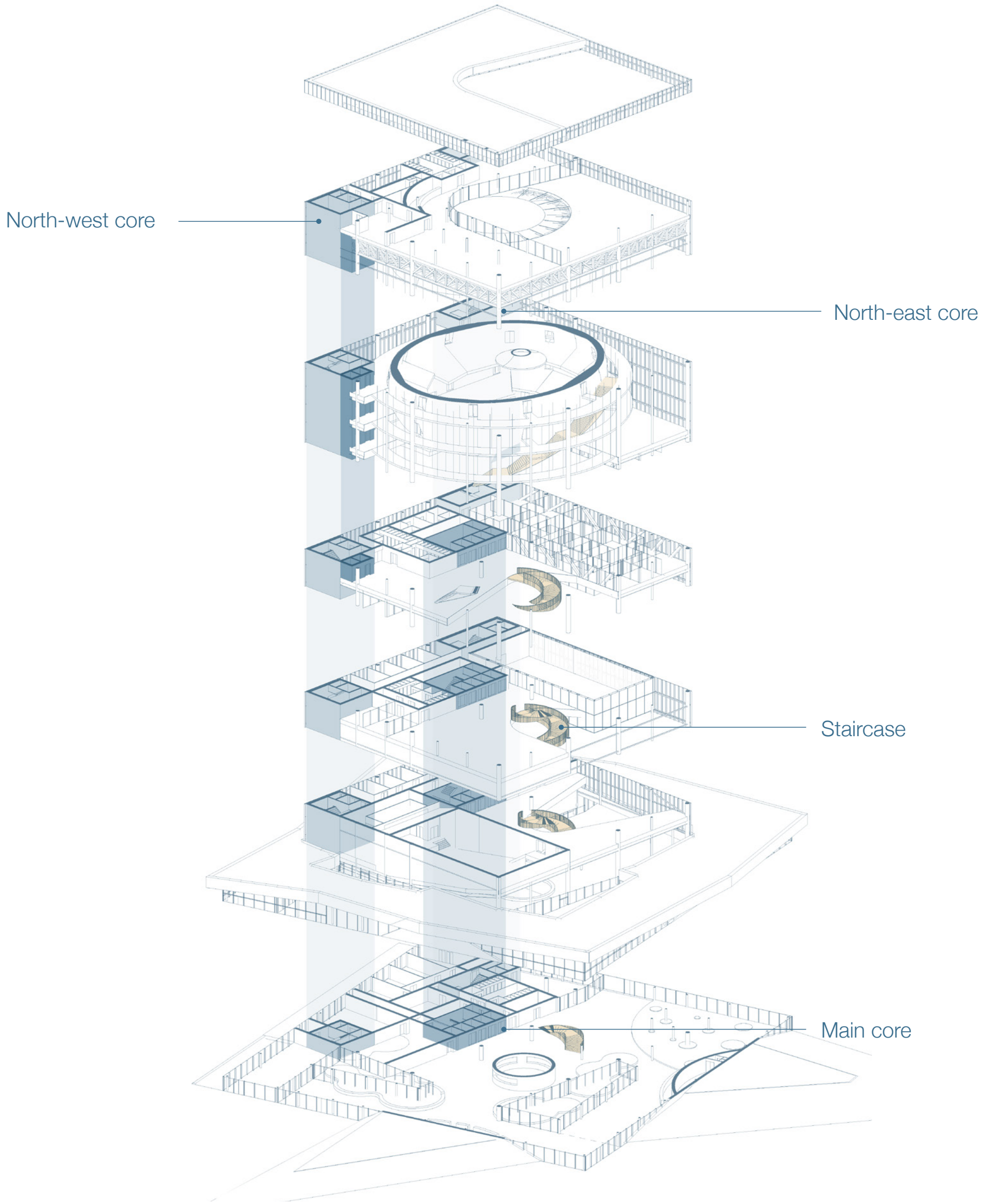


The roof top level hosts a wide restaurant and bar that in the summer months might host outdoor tables and activities. A great terrace anyone could have access to from the ground floor entrance overlooks the city especially towards the nearby area of Porta Nuova.
The rooftop is indeed reachable from a distribution core positioned in the North-East side of the plan and accessible from the ground floor from an exclusive access. In this way it can remain open even when the other spaces of the Performing Arts Centre are closed. Moreover in this way it allows a higher control of the users directed to the roof terrace.
On the restaurant floor plan the majority of the space is taken by the restaurant room. The 400 square meters room is served by a kitchen that is located in the back of the floorplan, where the freight elevator can be freely accessed.

The outdoor space instead is located in the southern side of the floorplan, where the view on the skyline of Milano is the best. In particular the floor hosts a glazed surface, which allows the visitors to see the main hall shape beneath it. The reasons are first of all to leave the shape of the main hall as free as possible from the levels it encounters. In this way the autonomy and supremacy of the volumes of the halls within the main squared shape is once again exploited. The second reason is to leave a part of natural light to spread within the open space inside of the building from a zenital direction.
The fence surrounding the terrace is glazed in order to allow the view of the surrounding area, but at the same time it provides a safe barrier against falls and accidental falling objects. Indeed it is 1.8 meters tall.

Image 16: Impression of the view from the rooftop

Distribution systems



The elevators

The distribution inside of the building happens through three main cores and one staircase. The biggest core is the central one and it has the function of distribution the public till the foyer of the main hall (level 5, +23 m). In order to do that four elevators, each one able to carry till 30 people, run from the level -2 to the level 5, disembarking on the foyers. Behind them one of the three fire-safety stairs allows to escape from the levels entering the staircase from the side of the elevators shaft. Its exit corridor is then at the groundfloor, on the North plinth facade. The core is completed by a technical shaft that distributes the majority of air ducts to the levels. The second core is in the North-West corner of the building. It is used as a service distribution core and hosts two elevators. The first one is a regular elevator, while the second one is a freight elevator used to move stage equipment and so on, and can carry one piano. In the same way of the first core, a fire safety stairs allows the safe escape to the ground floor and then to the outside through a corridor into the plinth. From the main hall foyer a sub-core is attached to this one, hosting to smaller elevators open to the public but restricted to the audience of the main hall events. In fact they allow the visitor to go from level 5 (+23 m) to level 8 (+38 m), disembarking on the rounded suspended aisles. The third core is in the North-East corner of the building and hosts two elevators. In this case they are shuttle elevators that only have two stops. One is at the groundfloor level, and the other one at the terrace level. Indeed they only serve the restaurant and the rooftop, allowing them to be used even when the rest of the building is closed. To enhance this possibility the entrance to this ground floor area can happen in two ways: from the main foyer and directly from the outdoor space. This also allows to have a security that checks the people going to the rooftop and to the restaurant. Also in this case the elevators are paired with a fire safety stair and a technical shaft for ventilation purposes.

The main staircase

The helical staircase at the center of the building has a key role in the functioning and the distribution among the levels. Not only it has to be clearly recognisable to convey the visitors to the upper floors, but it also shapes the indoor panorama, cutting the floors that it encounters (see the building concept). In order to realize these design intentions a uniform shape of strong visual impact had to be designed. The shape chosen was a helical stair, that well approximates the shape of the inclined cylinder that cuts the floors. To choose the right dimensions, inclination and rise and tread of the steps a parametric software was used. The width of the stair was fixed to 3 meters, accordingly to the flow of people it has to accommodate. Then the number of consecutive steps was fixed at a maximum of 12, and the threads to a minimum of 32 cm. Finally the railing was fixed to a minimum height of 120 cm from the walking level.

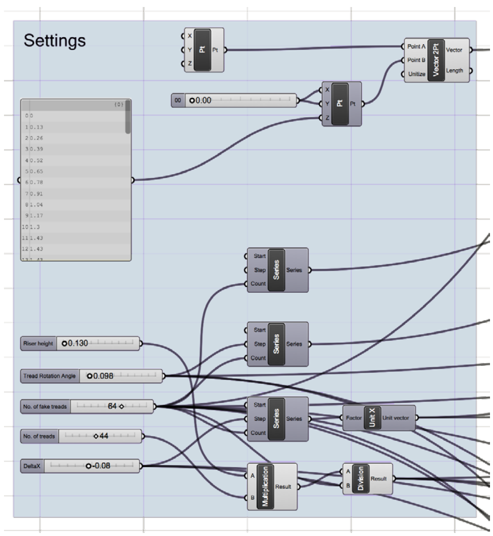


Image 17: Parameters controlling the staircase form

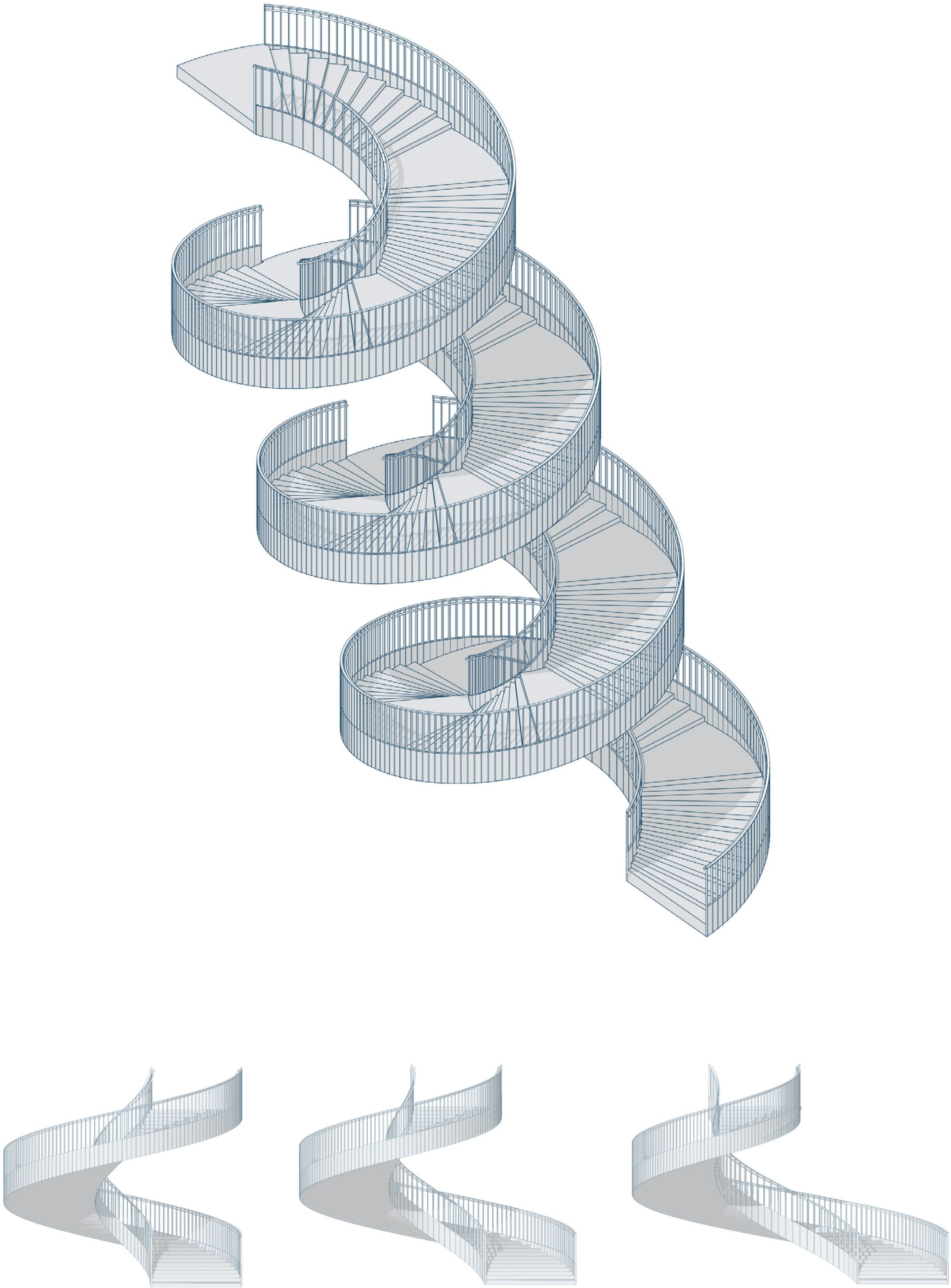


Image 18: Stair design options with incremental axis inclination and axonometric view of the final result

Interior finishings

The interiors finishing and materials were carefully chosen in order to convey the right mood and atmosphere to the users. The materials chosen for the main spaces were then translated in material moodboards.

Open spaces

The ground floor open spaces are characterized by a warm light birch wooden pattern that clearly differs from the main hall one. Stairs and string-course are characterized by the same texture as well as floors. Ceilings and walls are made of a bright white plasterboard texture.

The opened spaces, in particular the ground floor, host green peninsulas hit by natural light where plants and trees are grown in order to improve air quality and space quality. Among the plants species chosen there are the philodendron and kenzia, plants with e a good life expectation in the indoor spaces. The furniture preferred is very minimal, characterized by tubular elements and light colours such as wood or beige, that well marries floor and walls colours and textures. Lights hanging from the ceiling help diffusing a warm light to the spaces.

Traditional theatre

The theatre at level one is characterized by a traditional theatre configuration. The chromatic and materials arrangement continues being characterized by timber for what concerns the pavements and the furnitures. The walls are characterized by a 3D texture that beside reminding the external facade configuration, it offers a very effective sound absorbing surface.

Seats are characterized by a grey velvet that marries the light wall and ceiling. Led spotlights dot the ceiling and black tubular parapets the stairs while a black and heavy curtain hides the scenography before the show.

Experimental theatre

The theatre at the second level is characterized by an extremely free configuration. Indeed, it wants to be a neutral space where a new kind of theatre, exhibition or spectacle can be conceived and allowed. In order to be as neutral as possible the chromatic identity and materiality is kept very anonymous on purpose. Timber continues being a constant in the floor and the ceiling, while the walls

Image 19: Moodboard of the opened spaces

Image 20: Moodboard of the traditional theatre

Image 21: Moodboard of the experimental theatre

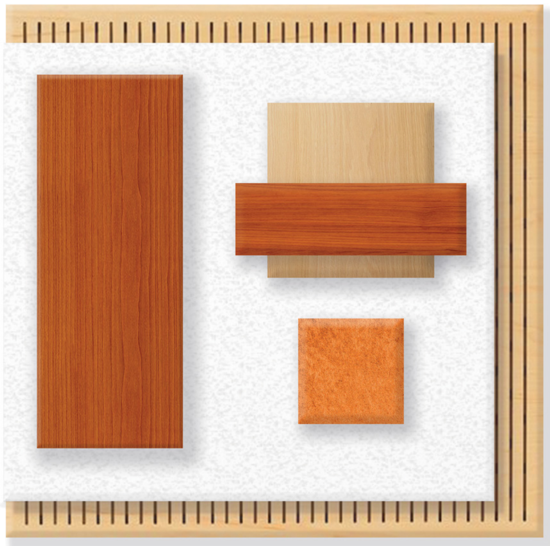


Image 22: Moodboard of the main hall

are characterized by a double layer of fritted glass. This kind of choice is made to let anyone glimpse what happens in the inside of the theatre but not completely reveal it. Colours are very neutral and light, either for the spotlights and for the railings.

Main hall

The main hall distinguishes itself from the surrounding environment either morphologically either chromatically. It appears like a floating element over the great open space characterized by quite light colours. Contrarily, the main hall is painted of a warm and polished cherry wood. The warm orange shades of its envelop is re-proposed in the internal details. Walls and stands are in fact characterized by a light wood material, by the way warmer then the one used in the other areas of the building. Sound proof panels are installed vertically in order to improve the internal acoustic while a white raw textures characterizes the ceiling. A very warm colour is proposed again for what concerns the seats: a cosy orange velvet welcomes the spectators of the elegant main hall.

Exterior finishings

The exterior outcome of the project derives from a strong architectural intention. The desire was to delineate an univocal volume that could be able to contain a great diversity of functions and further volumes. The facade has to deal then with a very simple and regular structure, it has then the responsibility to characterize such a simple shape, but at the same time not to deny it. The choice of a monochromatic, monomateric and simple morphology of the facade panels answers to the need of asserting the unity of the project. The monotony of the unity is however avoided by the rhythmic scan of the facade. Nevertheless the monomateric and monochrome character, the continuous envelope is treated as a great curtain that fluidly opens in strategical points in order to allow natural light and a greater permeability.

To achieve these particular requirements a long and complicated trial and error process was run. More in detail factors such as architectural expression, daylight requirements, technical feasibility and energy performances were all taken into consideration and condensed in a parametric designed. The topic has been studied in deep in the next section of the chapter.

Image 23: Visual representation of the facade

Technical detailig

Performance requirements and strategies

Choice of requirements assessment

In order to optimize the energy performance and comfort of the building, it is necessary to establish some requirements to be achieved. The most common way to find objective and reliable requirements is to follow the guidelines of energy certifications. While most of those are only dealing with residential buildings, the LEED certificate considers also non residential ones. LEED certificate differs for building types and phase of construction, including new construction, interior fit outs, operations and maintenance, core and shell[1]. For the requirements it was considered the category LEED v4 BD+C: New Construction, which can score up to 110 points. The points are attributed using a "project checklist" which is divided in different categories:

- Integrative process (max 1 point)
- Location and transportation (max 16 points)
- Sustainable sites (max 10 points)
- Water efficiency (max 11 points)
- Energy and atmosphere (max 33 points)
- Materials and resources (max 13 points)
- Indoor environmental quality (max 16 points)
- Innovation (max 6 points)
- Regional priority (max 4 points)

Image 24: LEED certification badges

Every category includes also some prerequisites, which does not add any point but has to be fulfilled in order to get the certification[2].

From the project checklist only two credits are considered in this part, Optimize Energy Performance (Energy and atmosphere) and Daylight (Indoor environmental quality). The goal is after all not to obtain a certification but to establish some requirements in order to set the optimizations parameters. Here the two credits are going to be explained in detail, later in this chapter they will be fulfilled with proper simulations.

Optimize energy performance (0-18 points)

The intent is to achieve increasing levels of energy performance to reduce environmental and economic harms associated with excessive energy use. The procedure is to analyse efficiency measures during the design process and account for the results in design decision making. The decisions should focus on load reduction and HVAC-related strategies (passive measures are acceptable) appropriate for the facility.[3]
To assign the relative points it has to be build an energy baseline model with the same shape, windows to wall ratio and schedule then the proposed building. The building envelope (opaque and transparent), lighting and the HVAC system of the baseline model has to match the LEED baseline parameters. The proposed building has to be compared with the baseline through two different simulations, calculating the percentage of improvement. The points are awarded according to the Table x+1.

% of improvement	Points
6 %	1
8 %	2
10 %	3
12 %	4
14 %	5
16 %	6
18 %	7
20 %	8
22 %	9
24 %	10
26 %	11
29 %	12
32 %	13
35 %	14
38 %	15
42 %	16
46 %	17
50 %	18

Table 1: Points for percentage improvement in energy performance

Daylight (0-2 points)

The intent is to achieve a good visual comfort on the majority of regularly occupied floor area, in order to prevent glaring or excessive darkness. This also prevent the use of artificial lighting during the day, improving the energy saving of a building.
The procedure is to demonstrate through computer modelling that illuminance levels will be between 300 lux and 3000 lux for 9 a.m. and 3 p.m., both on a clear-sky day at the equinox, for the floor area indicated in Table 2. The points are awarded according to the average of the values obtained for the two equinoxes.

Percentage of regularly occupied floor area	Points
75 %	1
90 %	2

Table 2: Points for daylight floor area: illuminance calculation

Strategies

Once the requirements are set, it is necessary to analyse and set the strategies considered during the building design. It is important to highlight that the elements discussed in this part have been developed in conjunction with the architectural and structural design, in order to optimize the process and make the final result work better. The strategies have been summarised in Table 3 and 4, divided following the different goals and requirements.

Heating and cooling loads

The realization of a building able to reduce at minimum the heating and cooling load is not only a requirement given by national legislations or certifications, but also the central aim of the research. The first step is to use the building design in order to decrease the heating loads entering the building during summer. For the ground floor, the hanging roof on the external perimeter is a perfect shading system for this purpose. It blocks the sun rays during peak hours, preventing them from entering the building, while it allows diffuse light and sun rays in milder hours. In addition to this system, movable shadings are added on the transparent curtain wall, providing an additional protection if needed. Also the seasonal trees, placed in the interior gardens on the ground floor, can be considered as effective shading devices, filtrating the sunlight during hot seasons. The shading system for the main part of the building is, on the other hand, composed of a parametric façade which blocks sun rays, allowing light to enter and a clear visibility from inside. The geometry of this shading devices and its performances will be further investigated in this chapter.
Other important strategies concern the reduction of heat exchange through opaque and transparent elements, which is mainly faced decreasing the thermal transmittance. Besides the design of high performance stratigraphies for the building envelope, as triple glass glazings, highly insulated opaque elements or green roofs, another strategy appeared to be effective for the purpose. While the majority of the units that are composing the unitised façade are transparent in order to allow the view from inside to outside and viceversa, the units corresponding to the theatres don't have this requirements and can be installed opaque. Being the thermal transmittance of the opaque units less than one third of the transparent ones, this choice greatly reduces the total consumptions.

Daylight comfort

The daylight improvement is crucial for two main reasons: the increase of visual comfort and the reduction of the impact of artificial lighting load on the total consumption. The strategies applied on the building are mainly concerning the reduction of glare or darker areas, which have been spotted through daylight simulations. Accurate openings in the opaque roofs have been created, in order to prevent the creation of areas without enough natural light. The biggest openings are the internal gardens which allows daylight to intern in the ground floor central area, together with the glass floor on the terrace which illuminates the external surface of the main hall from outside. The rehearsal rooms floor is made with high-reflectivity materials, in order to enhance the natural light entering from the perimeter windows.
The strategies developed for preventing the glare due to excessive sunlight are mainly relative to external shadings, such as seasonal green, movable shadings and the parametric façade.

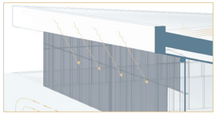
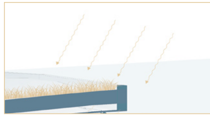
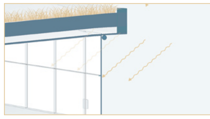
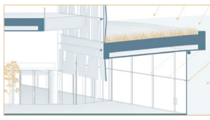
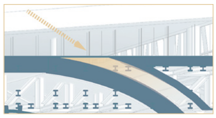
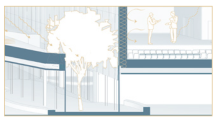
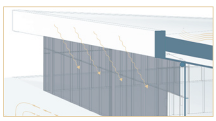
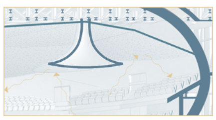
Category	Strategy	
	Parametric façade to stop solar radiation allowing quality sights	
	Unitised system façade with opaque panels outside the theatres to reduce energy consumption	
	Movable shadings to improve thermal performances and daylight comfort	
Decreasing heating and cooling loads	Hanging roof to stop direct solar radiation during peak hours	
	Hanging roof allows diffuse solar radiation	
	Green roof for better thermal comfort and air quality	
	Green seasonal shading to stop solar rays during summer	
	Roof windows to improve daylight quality and visual comfort	
	Internal courtyards to bring light in central areas of the ground floor	
Improving daylight comfort	Reflecting surface on rehearsal rooms' floor to improve daylighting	
	Green seasonal shading to stop solar rays during summer	
	Movable shadings to improve thermal performances and daylight comfort	
Improving sound quality in theatres and common spaces	Sound reflecting surfaces in theatres to improve the acoustic	
	Sound absorbing surfaces to reduce the reverberation	

Table 3: Building strategies

Acoustic comfort

The presence of big open spaces and full heights atria can create acoustic discomfort for excessive noise and sound reverberation. Besides the acoustic insulation provided by floating floors, it is important to cover the internal surfaces of these big spaces with sound absorbing surfaces. Moreover, it is necessary to provide specific acoustic performance for the three theatres, distributing the sound equally in the whole room. To achieve this performance it is necessary to insert sound reflecting surfaces with designed shapes and materials.

Rainwater collection

The collection of rainwater on the roof and terrace have been committed to the elevators cores, which are the only elements passing through the whole building from top to the ground. The presence of vegetation on the accessible roof is highly decreasing the need of water collection, which in any case has been committed to the internal gardens due to its inclination. The collected water, after purification or filtration phases, can be reused in many ways, such as flushing or watering.

Space quality

The creation of quality spaces is one of the main goals of architecture, trying to provide the visitor with visual and spatial comfort. The presence of specific types of interior green provides many benefits to people living that space, depending on the kind of environment the architect prefers[4]. Also the material colours and texture, beside the furniture, can impact on the people perception of a space[5]. For these reasons during the project development "moodboards", which are boards indicating the elements placed in a specific space, were designed following the space function and dimensions.
Space quality is also affected by quality views, which allow the visitor to understand the architecture and orient himself[6]. In the project the three theatres are considered as the main elements, so that from every floor they are fully visible without obstructions. In particular the main hall is fully visible, trying to prevent the occlusion of stairs or slabs. Moreover, the experimental theatre is made with a translucent material which allows the visitor to understand if a performance is occurring and to orient with it.

HVAC system

The usage of performing system to provide the required thermal and humidity comfort is very important for energy savings. A heat pump with a high efficiency, together with a heat recovery system, reduces the waste of energy and consequently the energy consumption or air conditioning. The reduction of periodic costs for HVAC is mainly committed to the use of renewable energy, which has to be maximised to reduce the environmental pollution caused by non renewable sources. The panels on the roof has to be inclined to a specific degree (depending to the season) to the ground in order to maximise their production, as their orientation towards South. The use of geothermal energy helps the energy reduction, mitigating the input temperature of the water entering the heat pump.
The use of electric vehicles as storage for the renewable energy produced with photovoltaic panels is greatly reducing the energy consumptions, as it is visible in Chapter 2 and 5.

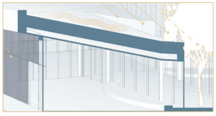
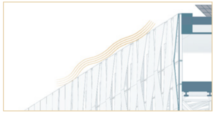
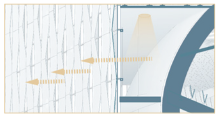
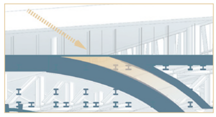
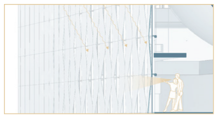
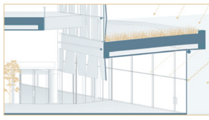
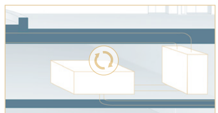
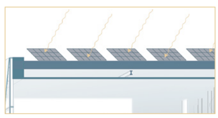
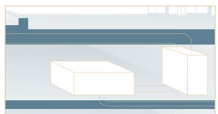
Category	Strategy	
Rainwater collection	Rain water is collected in the back of the building and brought to the ground using the stairs cores	
	Internal courtyards are also used to collect rainwater, which can be reused for different purposes	
Improving space quality and visual comfort	Interior green to improve air comfort and space quality	
	Openings in the parametric façade allow visibility from outside during night	
	The visibility of the main hall volume is guaranteed from every point in the building	
	Translucent soundproof internal wall to highlight the presence of a performance	
	Roof windows to improve daylight quality and visual comfort	
	Parametric façade to stop solar radiation allowing quality sights	
	Green roof for better thermal comfort and air quality	
Performing HVAC system and production	Heat recovery system reduces waste of energy, reducing energy consumption for A/C	
	Electric vehicles can also work as storage in order to reduce the dependence from the grid	
	Ground Source Heat Pump reduces energy consumption for air conditioning	
	PV panels on the roof facing South to maximize energy production	
	HVAC is positioned in the basement in order to save quality space for the building	

Table 4: Building strategies

Daylighting analysis and façade implementation

The daylight optimization has been part of the preliminary design of the building, because the visual comfort is central in the definition of public spaces. The presence of both large atria and small rehearsal rooms forced to have two different approaches in the design optioneering for daylight. Several daylight simulations have been run in order to evaluate the effectiveness of these approaches, using specific softwares and parameters. The main software used is Autodesk Insight®, a Revit plug-in designed for energy and daylight simulations. This software allows to run the simulations directly on the architectural model, with the exact materials, dimensions and building orientation. Using a precise and detailed 3D model it is then possible to run accurate daylight simulations, exporting the results in order to compare the different steps. The optimization process followed four steps:

- Glazing reduction through shading panels parametrisation
- Dark areas reduction through the increase of floor reflection
- Glazing reduction inserting movable shadings
- Glazing reduction using high performance translucent panels (optional)

In order to the check if the final result meets the requirements established in the previous part, the simulations were run for 9 a.m. and 3 p.m., both on a clear-sky day at the equinoxes. The results are then calculated according to the average of the values obtained for the two equinoxes, calculating the percentage of regularly occupied floor area matching the standards. The standards refers to LEED certification, considering as acceptable values the one between 300 and 3000 lux (from blue to green) and discarding below (red) and above (yellow) values.

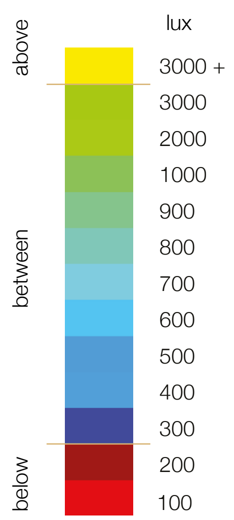


Image 25: Colour legend for daylight maps

Starting point (step 1)

The first simulation was run on the 3D model with no type of shadings and an entirely glazed facade with exception to the theatres ones, highlighting the presence of a lot of area with glare. The images are indicating the Foyer 1 floor plan at 9 a.m. on the September equinox. It is visible as the glare problem is not only present in the foyer, but also in the rehearsal rooms. It is then necessary to apply a strategy that can reduce the area with a level of illuminance above the standards.

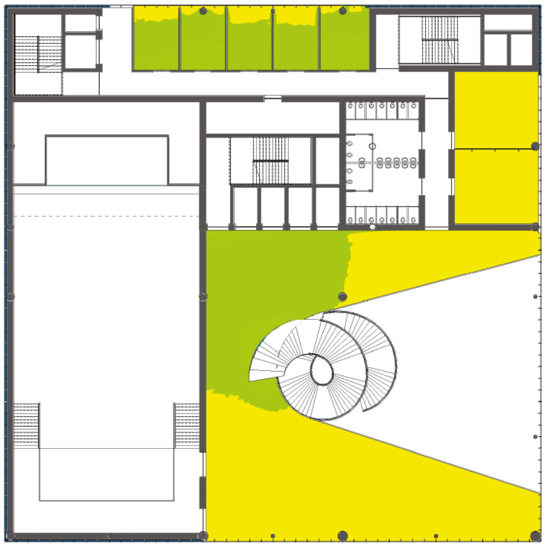


Image 26: Step 1, starting point (22%), 21/09 9:00

Phase 1: shadings parametrization

In order to reduce the glare areas, it was necessary to reduce the quantity of light entering the building. The shadings that have to be placed need to match different criteria:

- The building has to be permeable to the eyes of the people, in order to guess the function and the volumes from outside
- The visitors living the internal spaces have to perceive the surroundings, orienting in the masterplan and enjoying the view
- The shading has to block a part of sun rays which creates glare near the windows, without creating too many dark areas in the centre
- The distribution of the shading on the façades has to characterize the faces of the building, modifying its perception following the concept
- The shading has to vary depending on the specific function, geometry and orientation of the space in order to match excellent performances.

A shading panel was then created following these criteria, choosing parameters which can vary following the specific needs of a space. These parameters are then following both aesthetic and

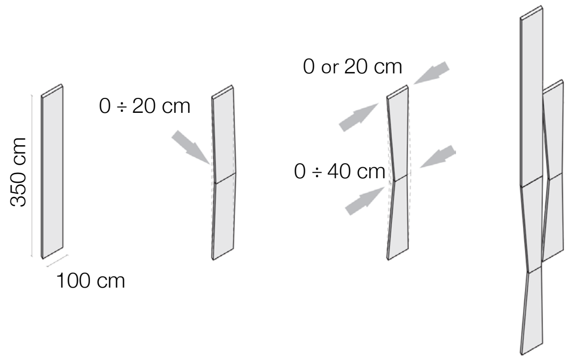


Image 27: Shading panel parameters and pairing

functional criteria. The starting point is a rectangular panel, having the dimension of 3.25x1m, a proper sub-multiple of the whole façade, matching the majority of slabs, roofs and corners. This panel is then folded in the half in order to create a space where the light can enter the building. To increase the amount of light the central part of the panel is reduced, as the upper part in order to improve visibility. The panels are then paired horizontally with an offset of half a module, in order to match the hanging part with the plane part. The parameters have been set following the results of the daylight analysis.

Basic shading panels (step 2)

The first simulation with shading panels shows an important reduction in glare in the whole building, but in central areas some dark corner starts to appear. The parametrization of the façade should solve this problem, such as the amount of glaring present in the area.

Adding side piece (step 3, rejected)

An hypothesis was to add a side piece to the shading panel in order to decrease the amount of light entering the building. This option has been rejected because the daylight simulation was not improving, while the visibility from inside was greatly reduced.

Increasing shading surface (step 4)

As a replacement to the previous step, the shading surface was increased reducing the parameter values. This reduction is not visible in this specific plan because it didn't have a big impact on the Foyer 1.

Panels parametrisation (step 5)

To optimize the shading effectiveness it was created a parametrised model in Rhino, using Grasshopper functionalities. The parametrisation is based on 6 different steps (matching 6 colours), from totally closed (black) to the panel with less shading surface (white). The colours were placed following all the criteria explained previously, trying to obtain the best results from daylight simulations. It is important to highlight how the façade optimization only include a part of the whole floor area, so the impact on the total percentage may appear low. The most evident effect of the parametrisation is the reduction of dark areas.

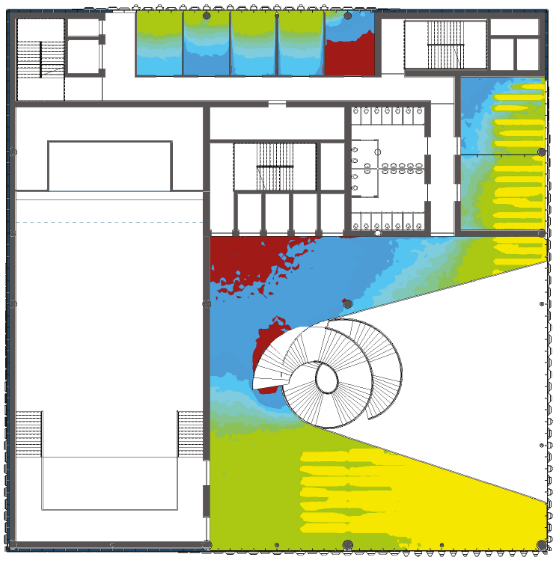


Image 28: Step 2, shading panels (32%), 21/09 9:00

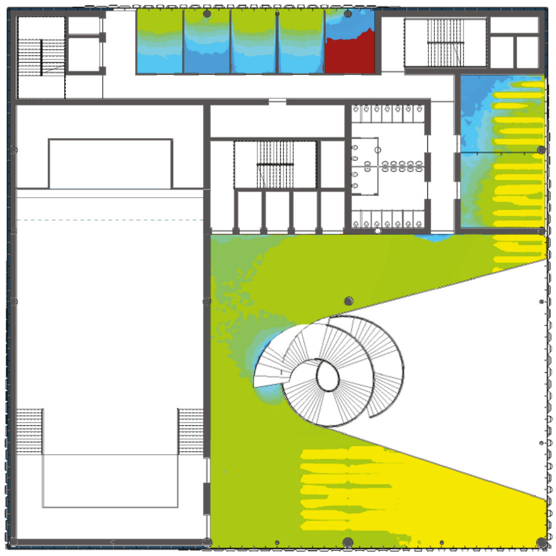


Image 29: Step 5, parametrisation (37%), 21/09 9:00

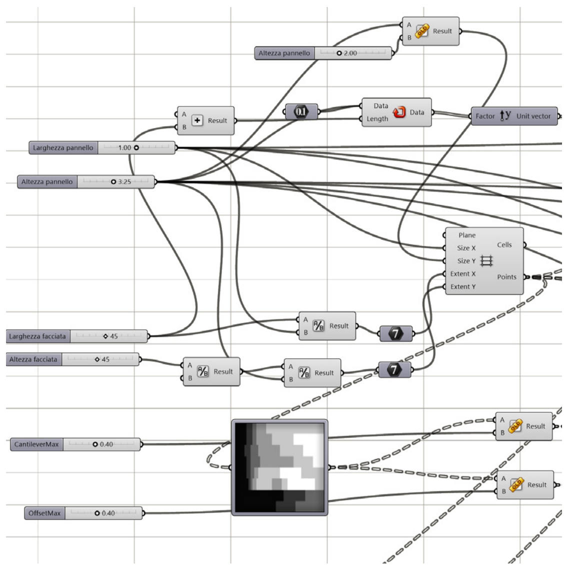


Image 30: Grasshopper parametrisation

Phase 2: rehearsal rooms optimization (step 6)

In order to reduce the dark areas, it is necessary to increase the light distribution in the rehearsal rooms. To reach better levels of illuminance it is necessary to increase the reflectance of floor surfaces. This goal has been reached placing a finishing surface with brighter colours and a reflective top layer, in order to increase the amount of light reaching the inner areas. This strategy turned out to be really effective, increasing the percentage of area matching the requirements.

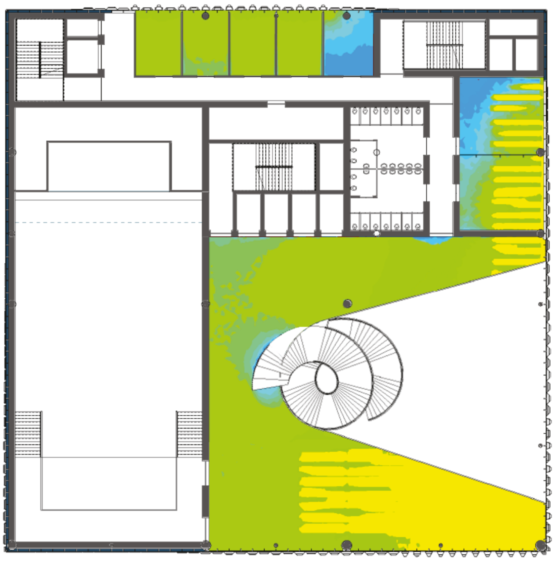


Image 31: Step 6, floor reflectance (51%), 21/09 9:00

Phase 3: movable shadings

To decrease the areas with glare in the levels not protected by the parametric façade and to optimize the daylight in the whole building movable blinds are introduced in the simulations.

First floor and restaurant (step 7)

Movable blinds were introduced in the levels not reached by the parametric shadings, in order to prevent glare. These blinds are guided by a smart system which adapt to the outside weather and the inside daylight conditions. The blinds are semi transparent, in order to stop excessive light without increasing dark areas. This system can be override by the users, for private spaces such as conference room or offices, or by the personnel for public spaces.

Foyers and rehearsal rooms (step 8)

In order to reach a level of illuminance able to reach higher requirements, the smart movable blinds are placed also in the rest of the building. This system, pared with he previous, managed to reduce the glare level to almost zero.

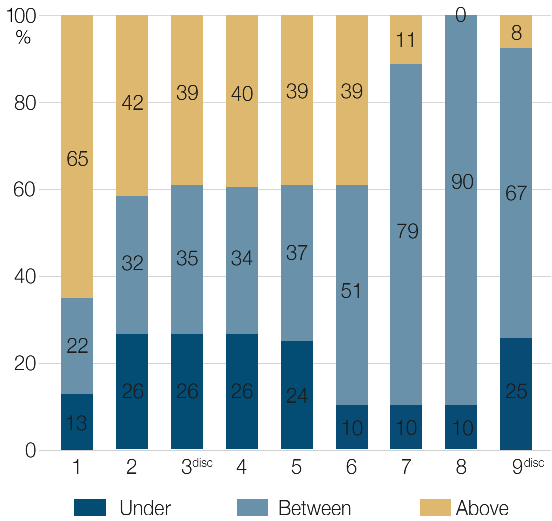


Chart 1: Comparison between different steps in daylight optimization

Percentage of regularly occupied floor area	Points
75 %	1
90 %	2

Table 5: Points for daylight floor area: illuminance calculation

Phase 4: translucent panels (step 9, rejected)

In order to reduce the level of glare in the building, reaching better results without the use of movable shadings, new translucent panels were introduced. The properties of these elements are explained in table 6, where the high insulation and low light transmission are evident. These performance are achieved using a specific type of aerogel, created preserving larger porous air-filled hydrophobic structures than normal silica sol gel. The panels are good thermal and acoustic insulators, allowing a reduced amount of light to enter.

The panels are placed where they are not blocking the view to the surroundings, which means on the façade levels in between the Foyers.

The simulation results are worse than the previous ones, which do not justify the use of this type of panels. The amount of dark areas is, in fact, increasing and the increase of floor reflectance is not solving the problem. However, this option is improving a little the thermal performance (5%) as it is explained in the following part. After analysing the pros and cons, this option has been discarded and only opaque or transparent panels have been used.

Data	Value
Heat transmittance	0.05 W/m²K
Visible Light Transmission	20 %
Solar Heat Gain Coefficient	0.27

Table 6: Tanslucent panels tecnical data

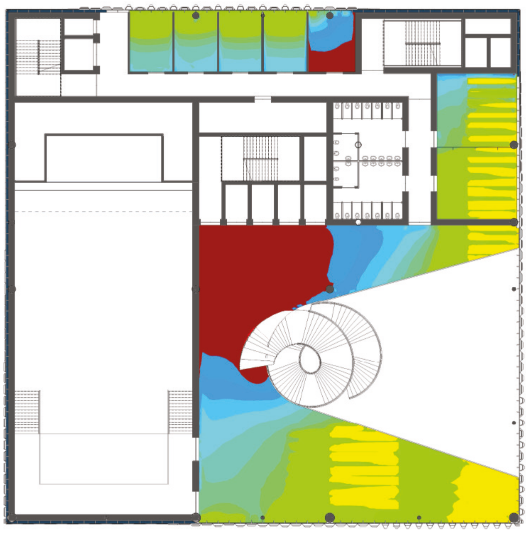


Image 32: Step 9, translucent panels (68%), 21/09 9:00

Energy performance

The energy performance of the building has been analysed with DesignBuilder simulations, in order to be able to confront with previous analysis.
The strategies for the optimization of the energy performances have already been presented in the previous part, including shadings, technical detailing, high thermal performances. The simulation on the building followed a process similar to the one described in Chapter 2, with a difference relatively to the schedules. Indeed, the spaces in the analysed building have very different type of usage, which determine a variation in the schedule for every function. In Table 7 it is summarized the different values used to simulate a realistic behaviour of the building. The category named "atria" includes corridors, foyers and open spaces, while the category "rehearsal" includes also the changing rooms. The lighting schedule is the same as occupancy, with an exception for the theatres where the light are on only the first and last hour. The light schedule does not correspond to the time lights are on (except to theatres), but to the moments where, if the sensors measure an insufficient illuminance level, the light will turn on. These schedules are used both for baseline and proposed building, in order to make the comparison for effective.

Space	People	Occupancy	Equipments	Air exchange
Atria	0.1 ppl/m^2	9:00-24:00	3 W/m^2	8 l/s m^2
Conference Hall	1.37 ppl/m^2	9:00-21:00	3 W/m^2	5.5 l/s prs
Restaurant	0.33 ppl/m^2	9-14/17-24	1 W/m^2	10 l/s prs
Kitchen	0.2 ppl/m^2	6:00-23:00	16 W/m^2	16.5 l/s m^2
Office	0.05 ppl/m^2	7:00-18:00	16 W/m^2	11 l/s prs
Theatre	1.37 ppl/m^2	16:00-24:00	1 W/m^2	5.5 l/s prs
Rehearsal	0.2 ppl/m^2	11:00-24:00	5 W/m^2	8 l/s prs
Toilets	0.1 ppl/m^2	9:00-24:00	1 W/m^2	6.7 l/s m^2

Table 7: Parameters used for energy simulations

Comparison with the baseline

To set the values for the baseline it was considered the values already present in the software, relative to the LEED certification. The chosen set was "performing reference", with values visible in Table 8. The values which are not inserted in the table are supposed to be the same for both models, such as geometry, orientation or windows to wall ratio.
Once the schedules and parameters are set, the simulations relative to the baseline model and the proposed building are run and the results compared. The improvement of the proposed building is higher then 50%, which means that the energy performance requirements have been fulfilled.

	Baseline	**Proposed**
Exterior walls	0.365 W/m²K	0.199 W/m²K
Floors	0.273 W/m²K	0.101 W/m²K
Roof	0.273 W/m²K	0.101 W/m²K
Glazing	1.990 W/m²K	0.640 W/m²K
HVAC	VAV	GSHP with HR
CoP Cooling	?	?
CoP Heating	?	?
Heating set-point/setback	20/13 °C	20/13 °C
Cooling set-point/setback	26/32 °C	26/32 °C
Total conditioned area	13000 m²	13000 m²
Energy consumption	3.994.266 kWh	1.274.419 kWh
Energy consumption	307.3 kWh/m²	99.9 kWh/m²
Improvement	\	- 68%
Points	\	18/18

Table 8: values for baseline and proposed building

Energy consumption

Once the comparison with the baseline has been successful, in the building model the production of energy has been included. The PV panels used are the same as Chapter 2, with a maximum power of 300 Wp and a module efficiency of 19%. The positioning of PV panels follows three different steps, trying to increase the production and reduce the net consumption of the building:

- On top of the restaurant roof, with a variable inclination following the direction perpendicular to the sun (option showed in the architectural boards)
- On top of the roof and on the upper part of the façade panels, the parts inclined towards the sky (better angle)
- On top of the roof and on the whole façade panel, both facing downwards and upwards

The different results are shown in table 9, showing as the production of the PV panels placed on the upper part of the panels produces almost the double then the lower one.

	Roof	**Roof + top**	**Roof + panel**
Total consumption		1.274.419 kWh	
Total production	227955 kWh	324168 kWh	376467 kWh
Total production	17.54 kWh/m²	24.94 kWh/m²	28.96 kWh/m²

Table 9: values for three PV panels positioning

In Chart 2 the different consumptions and the production (roof only) of the building are compared on a monthly basis. It is visible as the production is not enough to cover the energy need, not even in summer because of the cooling consumption peak. This is not a problem relative to the high consumption of the building, because the value per m^2 is low for a non residential building, but for the reduced number of PV panels. The building has an important number of storeys above-ground, with only half of the roof available for positioning of PV panels. This is the reason why during the energy analysis the three different positioning were formulated, trying to increase the energy production.

This problem is going to be solved in Chapter 5, where the application of energy storage (electric vehicles and power walls) on the designed district, is going to improve the energy efficiency of the whole district. The presence of a parking for electric vehicles in the underground levels and a tram stop in the next park is then helping the energy efficiency of the building.

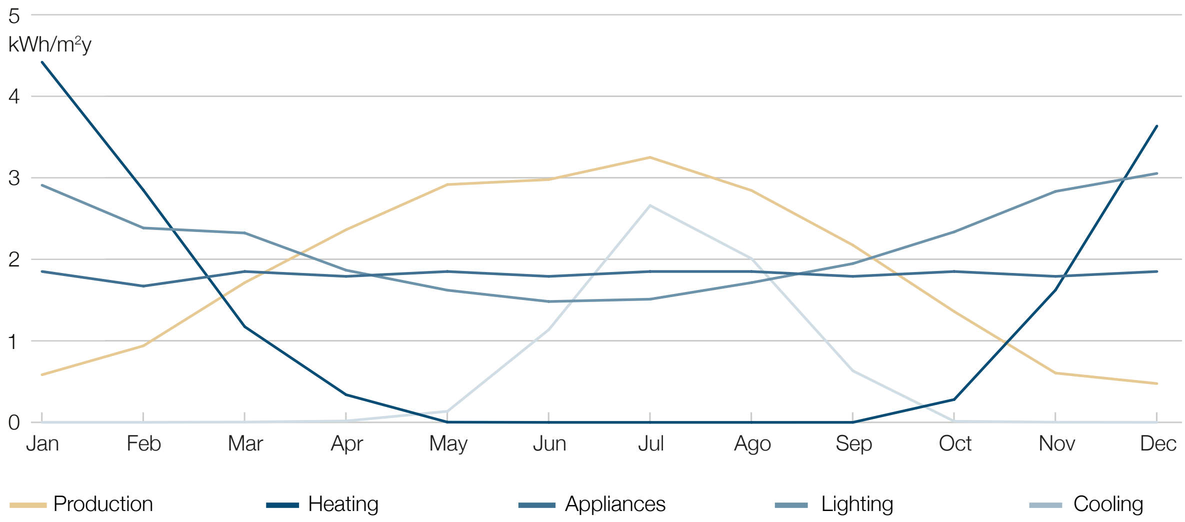


Chart 2: Monthly energy analysis of the proposed building with a production related to a PV panels system only applied of the roof

Technological detailing

Once the energy and lighting requirements were defined, the next step was to choose the right technologies for the purpose. In order to do this, a series of factors were considered at the same time:

- Satisfaction of the physical thermal requirements
- Easiness of construction or assembly
- Dimensions flexibility
- Dimensions adaptability
- Easiness of transport
- Easiness of supply
- Minimum toxic waste generation
- Longest life span possible
- Compatibility among materials
- Safety during usage (e.g. behaviour under fire load)
- Minimum embedded energy
- Easiness and non-toxicity of the disposal

In order to do this the technologies, for example, were chosen among the ones that are already available in the surrounding area of Milano, to minimise the transport environmental costs. Other materials were chosen in place of others thanks to their resistance to fire, such as the rock wool, that is more resistant than fibreglass (that is cheaper), burning at 1000 °C instead of 550 °C. In some cases panels were chosen in place of loose fills, such as for the hard insulation materials, that made it possible to have a faster assembly process.

The highest attention to the assembly process was given to the unitized system facade, that made it possible to assemble it without the use of an external scaffolding (see further in the chapter).

Once the stratigraphies were designed, their performance was assessed calculating the overall U-value to obtain the required characteristics. Moreover a Glazer analysis verified the absence of moisture between the layers of the stratigraphy. Comparing the vapour pressure inside of the element compared with the air dew point it is possible to check if the stratigraphy needs a vapour barrier or is already ok.

Finally the most critical details of the building were checked in order to asses the absence of thermal bridges and the compatibility among the various layers. Using a software it was possible to run a further check into the details analysis.

Opaque horizontal closures

The opaque closures are mainly horizontal and have a series of characteristics in common, while they differ for the most external layers. In most of the cases the bearing layer is made up by the bubble deck concrete system, that allows to have slabs spanning great spans. The only case in which the bearing layer is different is for the upper roof structure, that can be found both on the terrace floor and on the restaurant roof. In this case a metal-concrete deck was used, since in this case a column-beam system was used. This also helps for the smaller amount of concrete that has to be pumped at this height compared to the amount per square meter used in the other floor slabs.

The insulation layer is mainly composed by XPS panels, chosen for their great thermal performance and for the possibility resist compressive forces. Indeed the outer finishing varies according to the position of the closure. For non-practicable roofs a simple ballasting layer made of gravel was used. For practicable areas green roofs or tiled roofs were used.

For the interior finishings a quite standardised system was used. C-shaped galvanised steel profiles and a double plasterboard layer make the structure, while rock wool is used for sound insulation purpose. A gap of roughly 60 cm is left between the false ceiling and the bearing layer, leaving space for air ducts and other systems.

The only closure that differs from the rest is the water resistant ground flooring, that has to resist the water pressure and at the same time work as a loads distribution layer able to convey the load of the building to the foundation piles. In this case an underwater concrete floor has been used. Indeed it can be used even if the building pit is filled with water, that can be easily expected since the level -2 floor is near or beyond the water level (depending on the season).

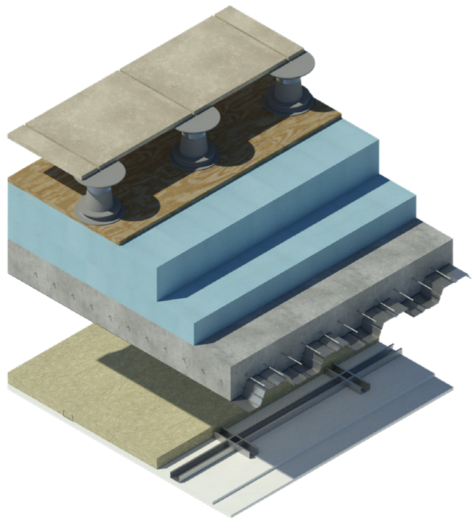


Image 33: Green roof stratigraphy with composite metal deck technology

Opaque horizontal partitions

The opaque horizontal partitions have a bearing structure similar to the horizontal closures in most of the cases. However they differ regarding the upper finishing layer. In this case a sound insulation mat is placed below a loads distribution concrete layer. Over that, a porcelain or wood finishing completes the stratigraphy, answering to the architectural interior design requirements. The false ceiling is made in the same way as previously described.

The only horizontal partitions that differ from the

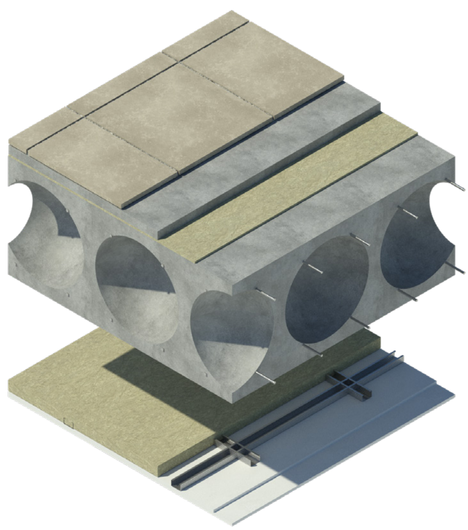


Image 34: Interior horizontal partition with Bubbledeck technology

others are the suspended floors that lead to the main hall entrances and the main hall stratigraphies. In the first case the light weight was a key requirement, since they are hung to the spatial truss that shapes the building roof. A cross system of steel profiles, C shaped, was used, in order to grant maximum shape flexibility and assembly velocity.
Instead the main hall stratigraphies have to combine flexibility, performance and aesthetics. The outer shell of the main hall is made up of plasterboard panels and insulation rock wool for acoustic reasons. The interior galleries are instead made of timber panels, for structural and acoustic reasons. Finally the ceiling finishing is made of fibre-reinforced polymers that limits sound reflections but at the same time has a pleasant finishing.

Opaque vertical partitions

The opaque vertical partitions can be clustered depending on their function. They can be structural one, sound proofed ones or they have to host systems. In the first case, the bearing layer is made up of pure concrete cast in place. In the second and third case, the bearing layer is made up of crossed C-shaped galvanised steel profiles and a double plasterboard finish. Rock wool sound insulation is put between the profiles. The difference between case 2 and 3 is that in case 3 the bearing layer is doubled in order to leave space in the middle to host the necessary systems.
These last partitions can be found both in the main spaces walls, such as theatres, as well as used as fire compartmentalisation. In fact their performance is even higher compared to the single-layered partitions.

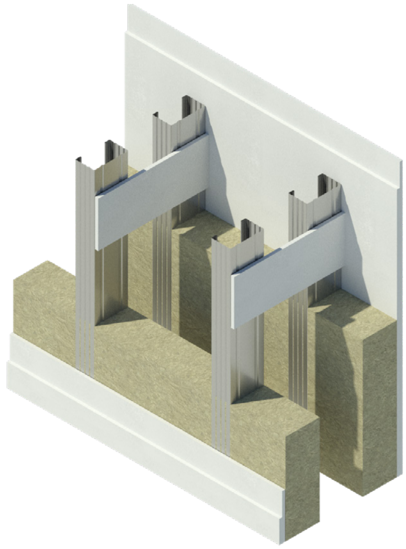


Image 35: Vertical compartmentalisation

Transparent horizontal closures

There is only one horizontal closure that is transparent, and it can be found int the terrace floor. Here, following architectural reasons, a part of the terrace allows to see the main hall shape below it. To do that, a glazed floor has been studied. The floor is made of three layers of glass for safety reasons (the first one is sacrificial) and than coupled with another layer to have insulating properties. To enhance the transparency at it maximum, the sub structure is made of structural glass fins that span till roughly 6 meters. In this

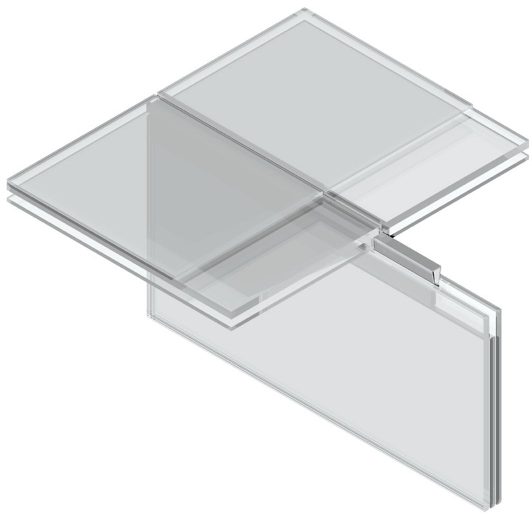


Image 36: Transparent flooring

case a triple glass layer coupled witha PVB film allows the fin to transfer the loads to the main structure.

Transparent vertical closures and partitions - Curtain walls

Curtain walls systems can be found as vertical closure at the ground floor and as vertical partitions inside of the buildings. In the first case there is the necessity to have an almost completely transparent wall, that clashes with the above thick and massive green roof. In order to do that, structural glass mullions were used, and no metal frame is visible from the outside. The glazed layer has a triple low-e glass to minimise energy transmittance.
The transparent vertical partitions have a similar structure, but the mullions are less thick (15 cm instead of 30 cm) since the windload is absent indoor. Moreover the glazed panels are only double layered since they have only acoustic insulation requirements instead of acoustic+energy insulations requirements.

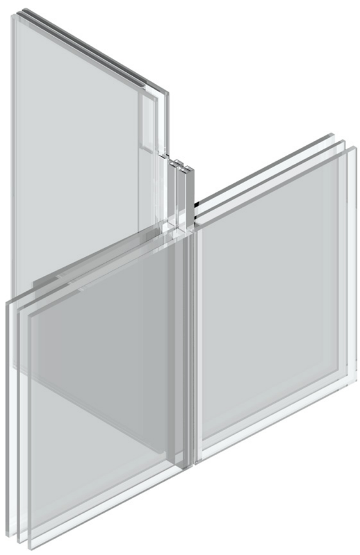


Image 37: Curtain wall with glass mullions

Transparent and opaque vertical closures - Unitized system

To realize the outer skin of the main volume of the building two alternatives were considered. Curtain walls and a unitized system pros and cons were discussed and summed up:

- Curtain walls: They could provide big glazed surfaces, but the mullions have to resist the wind load and where the atria are 30 m high they would become big as columns. However they would allow to have a mixed technology of closures, using regular opaque closures where transparency is not needed. Then the higher cost of the transparent parts would be balanced by the low cost of opaque parts.
- Unitized system: In this case the modularity of the panels would generate smaller frames than in the previous case. Moreover, the chance to have opaque panels too would uniform the technology used as vertical closure, reducing risks coming from the use of different technologies (compatibility of materials, junctions, dilatations). However the panels would need a sub structure able to carry their load to the main structure and eventually till the ground.

In the end the second alternative was chosen. In fact it allowed a more uniform facade technology, especially considering that the facade finishing is modular and spreads all around the façades, even in front of opaque parts. This characteristic was fundamental, because it meant that the facade (both the panels and the shading system) could be assembled without using a scaffolding system. The substructure, necessary to attach the panels, was calculated and resulted to be not excessively big, not disturbing the aesthetic of the interior space.
The dimension of the panels was the next step

to be considered. A 3.25 x 1 m panel was chosen. Indeed this dimension corresponds to half of the floor-to-floor height of the first levels (till the foyer of the main hall). After this point most of the space is a huge, full-height atrium. The only exception is made at the level of the spacial truss (just below level 9) where the panels are split in two to allow a better weather proof connection. The 1 m dimension followed instead the requirement of the shading system, to have a more gradual transition between the opaque elements, parametrized as explained before.

The panels would then rely on concrete or steel supports. This varies according to the point of the facade. Where there are concrete slabs, steel plates will be inserted into the formwork. Of course the necessary tolerances have to be accounted. Where the facade is self standing, the steel plates will be already welded to the steel substructure. It is important to note how these plates have slotted holes that allow for two dimensional adjustments. The third one (in the direction perpendicular to the facade) can be done adjusting the connection between the vertical hook and the panel itself.

Unitized system technology

The panels itself have two different alternatives. The transparent one has to provide transparency as well as super-high thermal performances, since the transparent surfaces are relevant on the total facade surface (around 70%). Do to that a four-layered low-e glass was chosen. This allows the panels to reach U of 0,64 W/m^{2}k, very competitive compared to traditional double or triple layered glasses. The outer frame is made from extruded aluminium, bringing the approximative weight of the panel to around 250 kg (without considering the shading system, that is however almost not relevant).

The opaque panels have an outer glazed layer, that appears similar to the one of the transparent panel, but is not see-through. Behind it an insulating panel makes the unit to reach a U of 0,199 W/m^{2}k. The inner face would be however coupled with a sound insulating partition, in order to avoid relying just on the outer panels.

Shading system choice and detailing

The shading system technology had to follow a series of requisites.

- Respond to architectural requirements, in shape and finishing
- Be light weight
- Be resistant to weather (wind force, rain, sunlight)
- Be easily assembled

The choice fell on anodized aluminium panels. They can be very thin, with easy connections and are compatible with the thermal expansions of the unitized frames (that are in aluminium too). Moreover it is a durable material that would last for a long time without deteriorating, that would happen in case of painted materials.

These panels, in shape of thin foils curved on the sides to give resistance against the wind pressure, would be connected to the unitized system panels by means of horizontal metal hooks. The hooks, that would vary the depth according to the local position required by the shading system, would be connected to the main panels through bolts inserted on the side of the single panels.

Assembly process

The assembly would start from the shipping of the system panels to the site. Here the metal hooks connecting the shading system to the main panels would be mounted. The shading panels would then be positioned and mounted. Then the single panels would be hoisted in position with a crane, without the use of scaffoldings. The assembly process would proceed in a bottom-up direction and from right to left. This is because the weather proof connections are shaped in a way to joint without the need of additional fixings. The relative positioning of the panels would be constantly monitored with the correct laser sensors in order to have a perfect planarity between the panels, according to the architectural design.

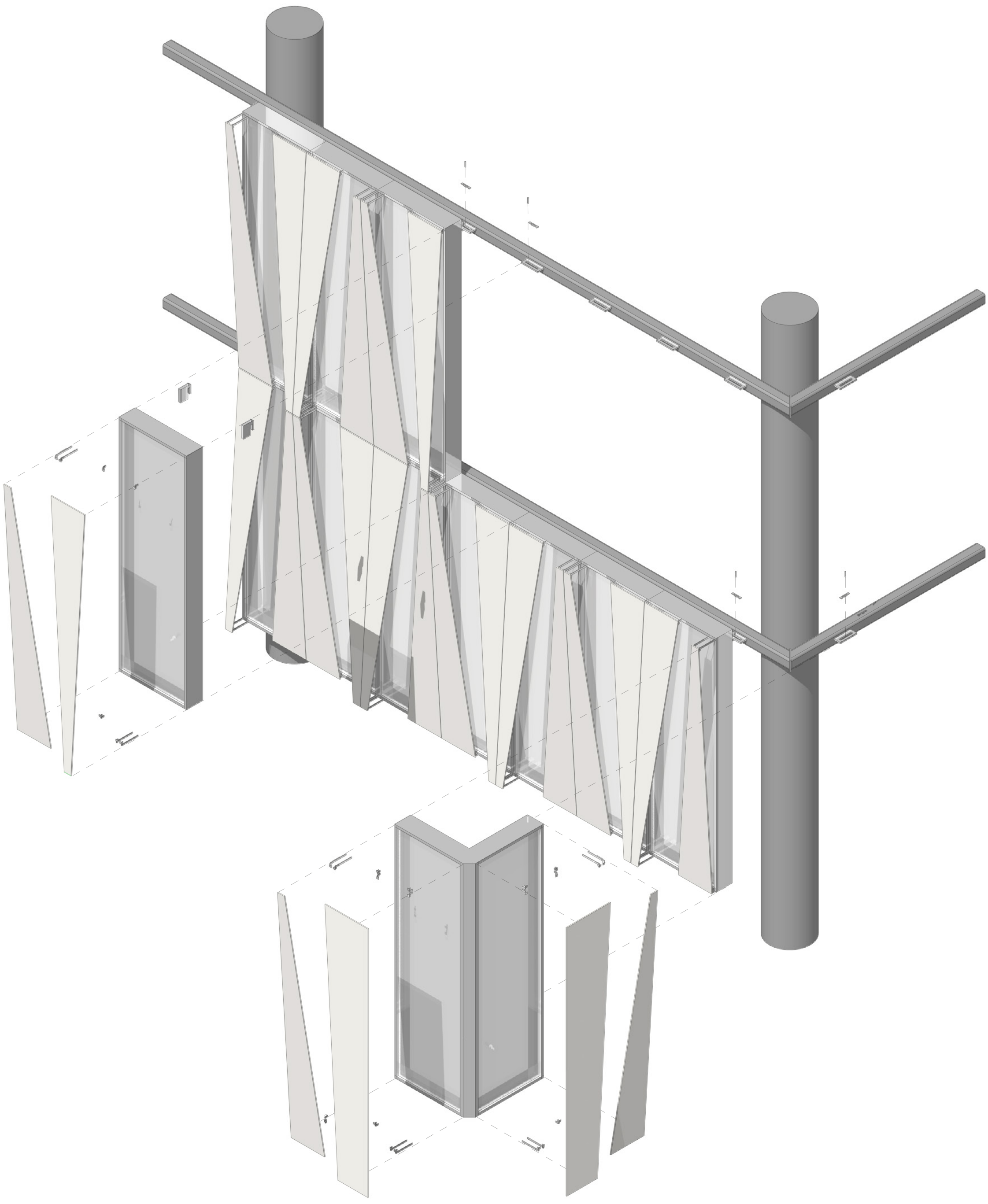


Image 38: Blow-up of the unitized system facade technology and assembly process

Systems design and implementation

A building of the size of the one designed cannot rely just on natural ventilation. The big spaces (often open spaces), the high occupancy and the requirements of thermal comfort make it necessary to rely on an air conditioning system. Moreover the big glazed walls, even if well insulated, also contribute with big solar gains values to the internal energy equation. Another important factor is represented by the presence of performance halls (namely the three theatres) that even if for a few hours a day are occupied by a huge amount of people, that need the necessary air change, both for thermal and ventilation reasons. In order to assess the position and distribution of the air conditioning systems, the following process has been followed. At first the minimum air changes required by the Italian legislation have been respected. Then following the energy balances the air supply air volumes have been confronted with the previous value. The maximum between the two has been taken.
Then the building volume has been divided in sub-volumes accordingly to their function, in order to be able to switch on only the necessary systems during the use of the building and to limit energy waste. The Air Handling Units (AHU) have been then placed in the most suitable position accordingly to the proximity of the conditioned area. Next the dimensions of the main air ducts have been calculated using a software (see the next paragraphs). Finally the ducts have been placed into the technical shafts in order to assess their dimension and to run a preliminary clash detection.

The Italian legislative reference and the choice of the systems

The Italian government requires a minimum of air changes per conditioned space for health and well being reasons.[7] This value changes according to the function of the space, and can be calculated starting from the crowding of the space, the surface or the volume of the space. The spaces that can be found in the designed building have the following requirements:

Conditioned space			Minimum air change		
			l / s m²	*vol / h*	*l / s pers*
Public buildings	Cinemas, theatres	Halls			5.5
		Stages			12.5
		Waiting rooms, open spaces		8	
		Services		8	
	Cafes, restaurants	Cafes			11
		Restaurant room			10
		Kitchens	16.5		
		Services		8	
Offices		Open spaces			11
		Services		8	

Table 10: Minimum air changes per conditioned space

Following the table the spaces were grouped according to their use, since they will require different air volume changes. At the same time a suitable system has been chosen.

A general air handling unit has been selected. The unit would be made up of different parts that would carry out various functions. Fans, filters, silencer, cooling and heating batteries, post-heating batteries, humidifiers all find place into the AHU sections. Moreover a heat exchanger is able to retrieve about 80% of the energy that the air is carrying, reducing the energy waste and increasing the battery efficiency.

Even if the precise dimensions of the units have not been calculated, the dimension of some of the biggest units that can be found on the markets have been considered, as conservative approach. These are roughly 9x2.5 meters in plan and about 5 meters high. In this way they could treat till about 7000 l/s, leaving space for small tolerances in the preliminary drawings.

The air treatment inside the AHU varies from winter to summer and follows the environmental conditions. During winter the boundary conditions considered are:

- Outdoor temperature: -4 °C
- Indoor temperature: +20 °C
- Outdoor RH: 75%
- Indoor RH: 50%

Once the intake air has been partially mixed with the extract air inside the heat exchanger, it is heated up till 24 °C and then it is humidified to reach the indoor setpoint.

During summer the boundary conditions are:

- Outdoor temperature: +31 °C
- Indoor temperature: +26 °C
- Outdoor RH: 75%
- Indoor RH: 50%

In this case the heat exchanger reaches a nominal efficiency of about 75%. Once the air has been partially mixed with the extract air, it is cooled till 13 °C and is then post-heated to reach the correct values of the indo0r setpoint.

The heating and cooling are provided by a heat pump that has a calculated coefficient of performance (COP) of 3,5 for heating and 4,5 for cooling. The heat pump would work through the heat exchange between water and ground, that remains at a steady temperature along the year.

AHUs distribution

The spaces have been then grouped on the basis of their function and the necessary air exchange volumes.

AHU code	Space function	Floor	Volume (m^3)	Load per Area (W/m^2)	Air Flow per space (m^3/h)	Air Flow per AHU (m^3/h)
01; 11	Groundfloor	0	21551	49.67	32422	32422
02; 05	Theatre 1	1	7411	287.38	34614	34614
3	Back 1	1	3793	159.66	10062	16729
	Reharsal rooms 1	1	461	892.15	6667	
4	Conference Hall	0	1599	170.55	8269	26849
	Artists Area	0	3950	112.72	12197	
	Offices	0	2194	96.05	6383	
6	Back 2	2	2677	114.37	8201	14342
	Reharsal rooms 2	2	1637	123.86	6142	
7	Foyer 3	3	5491	55.91	10850	23800
	Foyer 4	4	17539	431.99	12950	
8	Reharsal rooms 3	3	5702	254.60	23587	23587
9	Foyer 1	1	9259	104.92	16535	26770
	Foyer 2	2	6175	54.74	10235	
10	Experimental theatre	2	3018	265.35	20030	20030
12; 13	Main Hall	4	16404	212.99	35780	35780
14	Restaurant Corridor	5	827	52.66	1706	16715
	Restaurant	5	2717	147.62	15008	
Exhaust	Toilets	0	1244		9952	
	Toilets	1	1034		8272	
	Toilets	2	450		3600	
	Toilets	3	787		6296	
	Toilets	5	309		2472	
	Kitchen	5	2096		24901	

Table 11: AHU list with relative air flows (N.B. For the distribution spaces a volume of 3 m height has been considered to calculate the minimum air changes since these can reach 20 m of height, that are instead considered for the internal loads coming from the energy simulations)

Once the number of air handling units has been cleared, their position inside of the building has been defined in order to minimise the distance from the conditioned volumes. At the same time the possibility to cluster the units together, for an easier maintenance program, has been fully exploited. In this way there are three main location for the AHUs to be put.

The first and biggest one is at the level -1, where most of them (from AHU 01 to AHU 11) find place. This place is strategical since it doesn't take space from the floors out of the ground and at the same time is easily accessible by trucks for maintenance and check up activities. In fact the technical room is near to the underground parking lot. Moreover, this area is next to the main technical shaft, that makes it possible to asily distribute the conditioned air into the building through the air ducts.

The second area is located at the level 07, next to the main hall. In fact there the AHUs 12 and 13 find place. Their proximity to the main hall reduces at maximum the distance that the air has to cover, reducing pressure losses along the path. Even if this location is less optimal than the first one, it is however good since the AHU extract and intake ducts can be directly headed to the North-East facade, well hidden behind the shading system.

Finally the AHU 14, that serves the restaurant, is located in a back position looking at the restaurant floor. Also in this case the extract and intake ducts would head directly to the North-West facade.

The extraction systems, responsible of the exhaust coming from the services (toilets and kitchen), follow a slightly different organization. First of all the extraction ducts are located in a secondary shaft, in the North corner of the building, and go till the roof. Here independent extraction engines suck the air outside the building. Similarly, the exhaust coming from the restaurant and its kitchen is heade directly outside thourgh engines located on the roof above the restaurant.

Ducts dimensioning and checking

Once the position of the AHUs has been defined, the dimension of the main air ducts has been calculated. Since it is a preliminary design, the secondary ducts and the air terminals have not been calculated, considering only one air terminal for every air duct.

The maximum velocity inside of the main ducts, made in galvanised steel, has been set to 6 m/s in order to avoid excessive vibrations that could not be stopped by the false ceilings. The velocity in the secondary ducts would be instead of 4,5 m/s in order to have an optimal distribution of the air through the air terminals.

In order to calculate the dimension of the ducts the method of constant pressure loss has been used. This states that, given a starting pressure provided by the AHU, the total pressure losses are given by:

$$\text{Total losses} = p * L + p_{loc}$$

Where :

p: pressure given by the AHU

L: equivalent length of the duct, given by the air velocity and the duct properties such as dimension and roughness

p_{loc}: localised pressure loss, given by the formula $C * \gamma * v^2 / 2g$

C: given by the localised condition (angle dimension, restriction)

γ: the air density

v: air velocity

g: gravity acceleration

AHU code	Main duct dimensions (mm)
01	750 x 750
02	800 x 800
03	800 x 800
04	1000 x 1000
05	800 x 800
06	750 x 750
07	950 x 950
08	950 x 950
09	1150 x 1150
10	850 x 850
11	750 x 750
12	800 x 800
13	800 x 800
14	750 x 750

Table 12: Main ducts calculated dimensions

Given the big dimension of some of the ducts, they have been placed into the shafts trying to optimise the space available and leaving enough space for inspection and maintenance. The most critical point is the horizontal section just above the ground floor. Indeed the ducts coming from the underground technical room have to be arranged in order to distribute on the floors above. After this point, going up in the building, the number of ducts is reduced, since they little by little end up in the conditioned spaces.

The second main problem is related to the distribution of the air through the false ceiling. A preliminary clash detection has been run using a 3D model of the entire system. As can be easily noticed from the schematic representation of the system distribution (where are however shown only the supply ducts and not the exhaust one, to avoid confusion) the arrangement is not effortless.

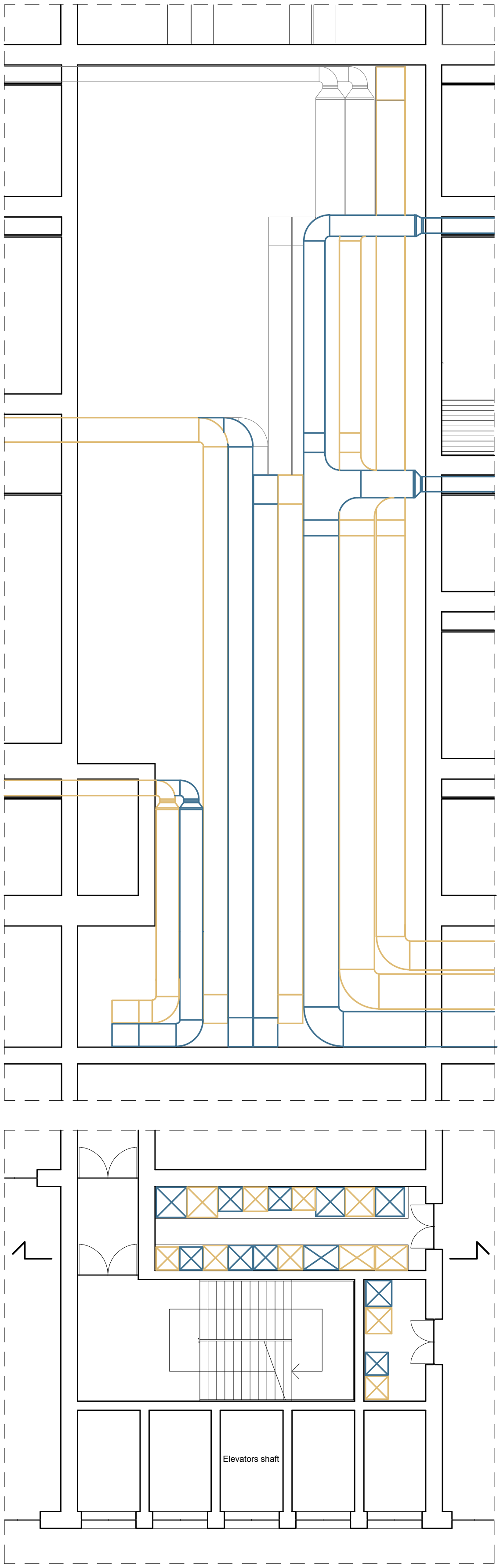


Image 39: Main shaft arrangement: ground floor plan and cross section

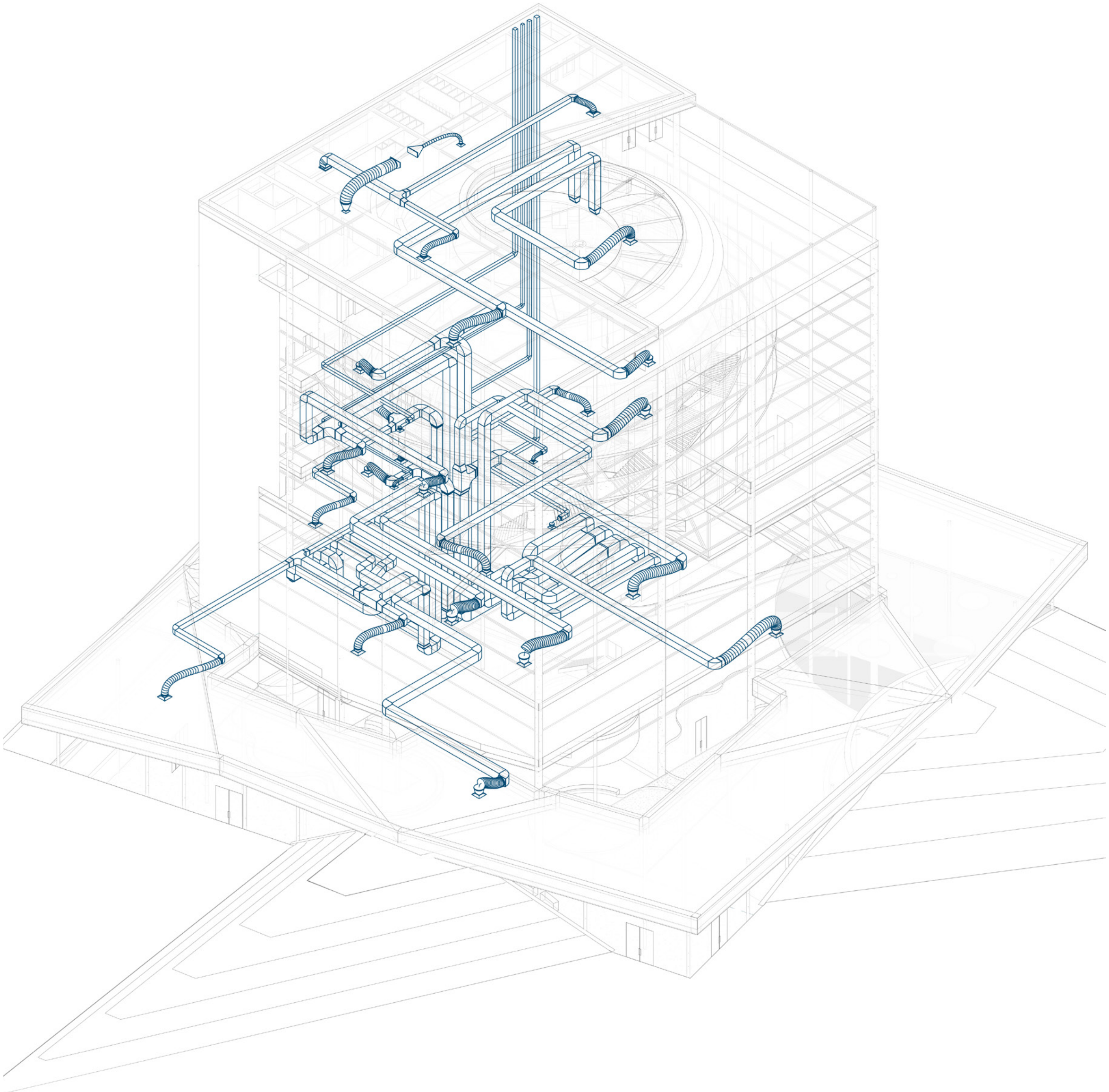


Image 40: Axonometric representation of the main supply and extraction air ducts

Structural design

Loads analysis

Loads classification

An action is defined as any cause or set of causes capable of inducing limit states in a structure. Throughout the following report the following actions will be considered:

- Norme Tecniche per le Costruzioni, D.M., 17/01/2018;
- Circolare ministeriale esplicativa n.617, 02/02/2009;
- Eurocodes EC1 (Actions on structures) and EC3 (Design of steel structures).

In this section there is a classification of actions based on the variation of their intensity over time:

a) Permanent (G)

Actions that act throughout the nominal life of the construction project, whose variation of intensity over time is very slow and of modest entity:

- Dead load of all structural elements; ground weight, when applicable; ground-induced forces (excluding the effects of variable loads applied to the ground); forces resulting from water pressure (when configured over time) (G1);
- Dead load of all non-structural elements (G2);
- Impressed displacements and deformations, including withdrawal;
- Pre-stress (P).

b) Variables (Q)

Actions that act with instantaneous values that can be significantly different from each other during the nominal life of the structure:

- Overloads;
- Wind actions;
- Snow actions;
- Temperature actions.

Variable actions are called long-term actions if they act with a significant intensity, even not continuously, for a period not negligible with respect to the nominal life of the structure. They are called short-term if they act for a short period of time with respect to the nominal life of the structure. Depending on the site where the construction is located, the same climatic action can be long or short.

c) Exceptional (A)

Shares that occur only exceptionally during the nominal life of the structure:
- fires;
- explosions;
- impacts and impacts;

d) Seismic (E)

Actions deriving from earthquakes.

Analysis of permanent loads (G)

As specified in the regulations, permanent loads act throughout the nominal design life of the building and require different operations to be calculated.

Permanent Structural Loads

The permanent gravitational actions associated with the weights of structural materials are derived from the geometric dimensions and density of the materials of the structural parts. We assume the values of the density listed in the table contained in Chapter 3.1.I of the NTC 2018[8]. On the other hand, the structural materials not included in the table refer to documents of proven validity by treating the nominal values as characteristic values.

Permanent Non-structural loads

Permanent non-structural loads are considered as non-removable loads during normal operation of the building. Among these: vertical and horizontal internal partitions of which we do not consider the load-bearing elements, screeds, insulating states, floors and walls, plasters, false ceilings and systems.

They are evaluated by the geometric dimensions and the density of the materials of which the parts are made. The densities of non-structural materials have been taken from the specific table in chapter 3.1.I of the NTC 2018[9], from the Eurocode[10], or, if necessary, from documents of proven validity, such as specific technical data sheets, treating the nominal values as characteristic values.

The reference stratigraphies and the related calculation tables are shown in the following pages.

This value, calculated for each layer, is obtained from the following relation:

γ_i

P_a weight per unit area of the material making up the i-th layer [kN/m2]

sp_i thickness of the i-th layer [m]

γ_i specific weight of the material [kN/m3]

n number of layers present

Vertical closures

The weight of the external closures weighs only and directly on the edge beams and on the perimeter walls and should therefore not be distributed over the floors. Then it is defined the inter-floor value net of the floor height, at this point the total weight per linear meter of wall is defined.

Internal vertical partitions

For the calculation of the internal vertical partitions, the legislation[11] requires a different approach than the one described above, since it is necessary to consider the linear load of the technological package (kN/m). The weight of the stratigraphy of each wall carried by the floor is calculated using the formula:

$$G_2=P_a \cdot h$$

where:

G2 : linear load of the partition (kN/m)
P_a : weight per unit area of the material making up the i-th layer (kN/m^2)
h : height of the partition wall (m)

For the horizontal layouts of residential buildings, such as those for offices, the weight of internal dividing elements can be compared to a uniformly distributed permanent load g2, provided that constructive measures are taken to ensure adequate load distribution. The uniformly distributed load g2 may be related to the weight per unit of length G2 of the partitions as follows[12]:

- for dividing elements with G2 ≤ 1.00 kN / m: g2 = 0.40 kN / m^2;
- for dividing elements with 1.00 <G2 ≤ 2.00 kN / m: g2 = 0.80 kN / m^2
- for dividing elements with 2.00 <G2 ≤ 3.00 kN / m: g2 = 1.20 kN / m^2
- for dividing elements with 3.00 <G2 ≤ 4.00 kN / m: g2 = 1.60 kN / m^2
- for dividing elements with 4.00 <G2 ≤ 5.00 kN / m: g2 = 2.00 kN / m^2

The internal dividing elements with a dead load greater than 5.00 kN/m, however, must be considered in the design phase, taking into account their actual positioning on the floor.
The reference stratigraphies and the calculation tables are shown in the following pages.

H.C.01 - Horizontal closure: not practicable roof - U = 0.101 W/m²K

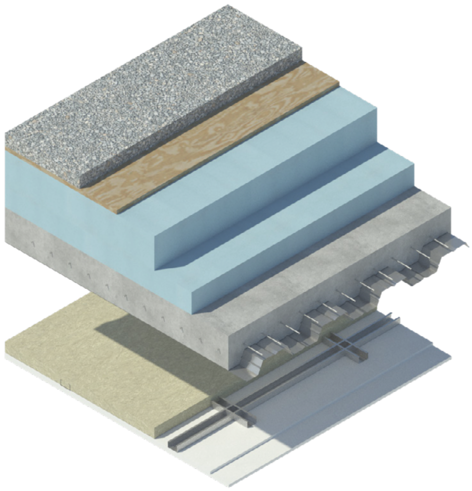


Image 41: horizontal not practicable roof layers

1. Ballasting layer: polished white gravel
2. Protection layer: draining and filtering membrane in high density polyethylene
3. Water-tight layer: breathable waterproofing membrane in polypropylene and non-woven fabric
4. Load sharing layer: OSB chipboard panels
5. Slope and thermal insulation layer: XPS panels
6. Vapour barrier: aluminum foil with glass felt
7. Bearing layer: prefabricated BubbleDeck slab, height 65 cm, spheres diameter 54 cm
8. Sound insulation layer: rock wool panels
9. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers
10. Finishing layer: double plasterboard panel

Layer	Thickness [cm]	Density [kg/m³]	DensitY [kN/m³]	Loads [kN/m²]
Gravel	5	-	19.0	0.95
High density polyethylene membrane	0.5	-	-	0.03
Polypropylene membrane	0.9	-	-	0.03
OSB chipboard panels	2	660	6.47	0.13
XPS panels	16 + 10	33	0.32	0.08
Rockwool panels	5	40	0.39	0.02
C-shaped profiles and plasterboards	5	-	-	0.27
TOTALE (G2) [kN/m²]				1.51

Table 13: horizontal not practicable roof layers properties

H.C.02 - Horizontal closure: practicable green roof - U = 0.099 W/m²K

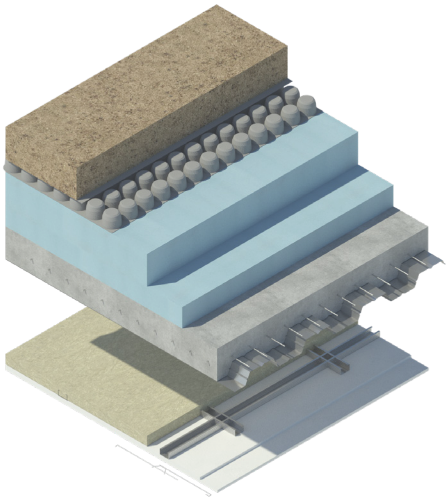


Image 42: practicable green roof layers

1. Soil layer for extensive cultivation
2. Anti-root filtering layer, non-woven polyester fabric
3. Retention layer: compression-resistant polyethylene storage elements
4. Protection layer: geotextile membrane with polypropylene fibers
5. Watertight layer: waterproof and desolidarizing sheet in PVC reinforced with glass fibers
6. Thermal insulation layer: XPS panels
7. Vapour barrier, aluminum foil with glass felt
8. Bearing layer: prefabricated BubbleDeck slab, height 65 cm, spheres diameter 54 cm
9. Sound insulation layer: rock wool panels
10. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers
11. Finishing layer: double plasterboard panel

Layer	Thickness [cm]	Density [kg/m³]	Densità [kN/m³]	Loads [kN/m²]
Green roof storage system	23	834.78	8.19	1.88
PVC reinforced with glass fibers	0.6	-	-	0.03
XPS panels	16 + 10	33	0,32	0.08
Rockwool panels	5	40	0.39	0.02
C-shaped profiles and plasterboards	5	-	-	0.27
TOTALE (G2) [kN/m²]				2.29

Table 14: practicable green roof layers properties

H.C.03 - Horizontal closure: practicable roof - U = 0.100 W/m²K

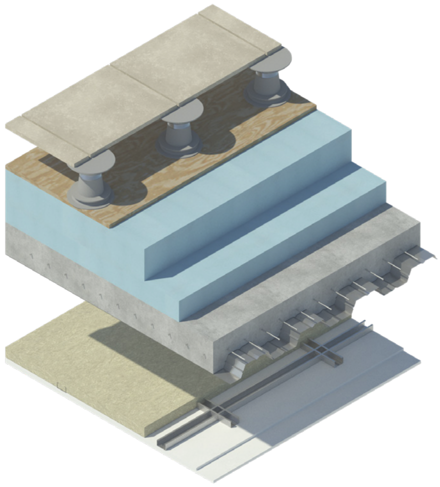


Image 43: horizontal practicable roof layers

1. Finishing layer: simil wood porcelain stoneware
2. Bearing elements for outdoor flooring
3. Watertight layer: elastomeric bituminous membrane
4. Load distribution layer: OSB chipboard panels
5. Slope and thermal insulation layer: XPS panels
6. Vapour barrier: aluminum foil with glass felt
7. Bearing layer: prefabricated BubbleDeck slab
8. Sound insulation layer: rock wool panels
9. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers
10. Finishing layer: double plasterboard panel

Layer	Thickness [cm]	Density [kg/m³]	DensitY [kN/m³]	Loads [kN/m²]
Simil wood porcelain stoneware	2	2300	22.56	0.45
Bearing elements for outdoor flooring	21.5	2.33	0.023	0.49
Elastomeric bituminous membrane	0.5	-	-	0.03
OSB chipboard panels	2	660	6.47	0.13
XPS panels	16+10	33	0.32	0.08
Rock wool panels	5	40	0.39	0.19
C-shaped profiles and plasterboards	5	-	-	0.27
TOTALE (G2) [kN/m²]				1.64

Table 15: horizontal practicable roof layers properties

H.I.P.01 - Horizontal internal partition

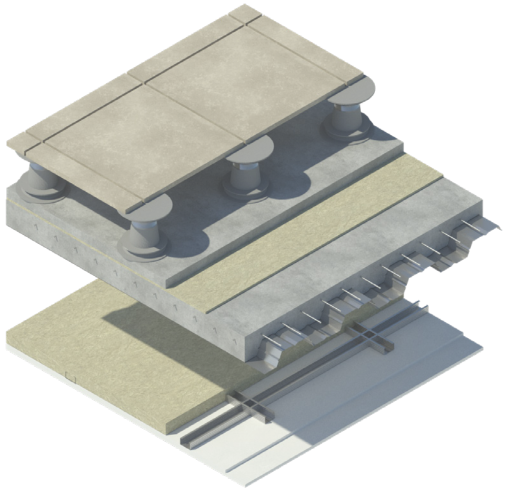


Image 44: horizontal interior partition layers

1. Finishing layer: simil wood porcelain stoneware
2. Load distribution layer: slightly reinforced concrete
3. Sound insulation layer with impact noise: polymer-bitumen elastoplastic membrane coupled with a layer of polyester fiber
4. Bearing layer: prefabricated BubbleDeck slab, height 65 cm, spheres diameter 54 cm
5. Sound insulation layer: rock wool panels
6. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers
7. Finishing layer: double plasterboard panel

Layer	Thickness [cm]	Density [kg/m^3]	DensitY [kN/m^3]	Loads [kN/m^2]
Simil wood porcelain stoneware	2	2300	22.56	0.45
Slightly reinforced concrete	4	340	3.33	0.13
Polymer-bitumen membrane	1.3	30	0.29	0.0038
Rock wool panels	5	40	0.39	0.19
C-shaped profiles and plasterboards	5	-	-	0.27
TOTALE (G2) [kN/m^2]				1.06

Table 16: horizontal interior partition layers properties

V.P.02 - Vertical partition: soundproofed not equipped wall

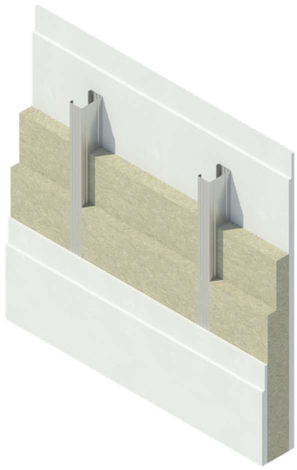


Image 45: vertical partition layers

1. Cladding layer: double plasterboard sheet, with a leveling and finishing layer
2. Support layer: vertical frame of C-shaped profiles
3. Sound-insulation layer: rock wool panels
4. Support layer: vertical frame of C-shaped profiles
5. Sound-insulation layer: rock wool panels
6. Cladding layer: double plasterboard sheet, with a leveling and finishing layer

Layer	Thickness [cm]	Density [kg/m³]	Density [kN/m³]	Loads [kN/m²]	Height [m]	Loads [kN/m]
Plasterboard panels	1.25 x 2	760	7.45	0.19	5.5	1.02
C-shaped alluminium profiles	10	-	-	0.01	5.5	0.055
Rock wool panels	6	40	0.39	0.19	5.5	0.13
C-shaped alluminium profiles	10	-	-	0.01	5.5	0.055
Rock wool panels	6	40	0.39	0.19	5.5	0.13
Plasterboard panels	1.25 x 2	760	7.45	0.19	5.5	1.02
TOTALE (G2) [kN/m²]						2.42

As mentioned before, with vertical partition loads of 2.00 < G_2< 3.00 kN/m, si considera g_2 = 1.20 kN/m

Table 17: vertical partition layers properties

Analysis of variable loads (Q)

The overloads are linked to the intended use of the building including the ordinary dynamic effects. The models of these loads, divided by intended use, are shown in the table below[13] divided by:

- Uniformly distributed vertical loads [q_k]
- Concentrated vertical loads [Q_k]
- Linear horizontal loads [H_k]

Cat.		Room	q_k [kN/m²]	Q_k [kN]	H_k [kN/m]
A		Rooms for domestic activities and residential	2	2	1
		Commons stairs, balconies, galleries	4	4	2
B	1	Offices not opened to public	2	2	1
	2	Offices opened to public	3	2	1
		Common rooms, balconies, galleries	4	4	2
C	1	Areas with tables, such as schools, cafes, restaurants, banquet halls, reading and reception	3	3	1
	2	Areas with fixed seating, such as churches, theaters, cinemas, conference and waiting rooms, university classrooms and lecture halls	4	4	2
	3	Environments without obstacles to the movement of people, such as muse-ums, exhibition halls, office access areas, hotels and hospitals, railway station lobbies	5	5	3
	4	Areas with possible physical activities, such as ballrooms, gymnasiums, stages	5	5	3
	5	Areas susceptible to large crowds, such as buildings for public events, concert halls, sports arenas and related stands, tiers of seats and railway platforms	5	5	3
	6	Common rooms, balconies, galleries	according to category, with the following limitations:		
			≥ 4	≥ 4	≥ 2
D	1	Shops	4	4	2
	2	Shopping centers, markets, department stores	5	5	2
		Common rooms, balconies, galleries	according to category		
E	1	Areas for accumulation of goods and relative access areas, such as libraries, archives, warehouses, warehouses, manufacturing laboratories	≥ 6	7	1
	2	Industrial areas	to consider case by case		
F		Remittances, areas for traffic, parking and parking of light vehicles (full weight up to 30 kN)	2.5	2x10	1
G		Areas for traffic and parking of medium vehicles (weight at full load between 30 kN and 160 kN), such as access ramps, goods loading and unloading areas.	≥ 5	≥ 2x50	≥ 1
H		Accessible covers for maintenance and repair only	0.5	1.2	1
I		Practicable covers of environments of use category between A and D	according to category		
K		Covers for special uses, such as installations, helipads	to consider case by case		

Table 18: NTC 2018 overload values for the different categories of building use

Atypical overloads

For what concerns atypical loads, the results have to be calculated case by case according to the following modalities[14]:

- In case of overloads q_k acting on a single structural element forming part of a horizontal element (eg: beam) can be reduced according to the coefficient α_A, based on the area of influence A [m2]:

$$\alpha_A = \frac{5}{7}\psi_0 + \frac{10}{A} \leq 1{,}0$$

- In the case of overloads q_k acting on vertical elements (eg: pillars or cores) of a building with more than 2 floors, based on the number of floors n :

$$\alpha_n = \frac{2 + (n-2)\psi_0}{n}$$

- Q_k overloads apply only for local checks, that differ from total building checks. For simplicity it can be considered a square shape of 50x50 mm.

- the H_k overloads are applied only for local checks, distinct from the total checks of the building. They are applied to the non-mobile two-dimensional vertical elements (eg: walls) at a height of 1,20 m from the floor level and to the parapets or handrails on the upper edge.

Snow overload

The load due to presence of snow on the roofs is given by the expression[15]:

$$q_s = q_{sk} \cdot \mu_i \cdot C_E \cdot C_t$$

where:

q_{sk} is the reference value of the snow load on the ground

μ_1 is the shape coefficient of the roof

C_E is the exposure coefficient

C_t is the thermal coefficient

The snow load is assumed acting in vertical direction on the horizontal projection of the roof.
In the absence of adequate statistical surveys, and since the building is located at an altitude of less than 1500 meters above sea level, the values necessary for calculating the snow load will be obtained in the following ways[16].

Reference value of the snow load on the ground q_{sk}

The snow load on the ground depends on the local climate and exposure conditions, considering the difference in snowfall between the different areas of the Italian peninsula.
According the NTC 2018, for the calculation of q_{sk}, being the building at a height a_s < 200m

Image 46: NTC 2018 snow load areas and q_{sk}

a.s.l., we can refer to the following map:
Setting the value a_s = 120 m a.s.l. we refer to the area of Milan: 1. Consequently to the associated q_{sk} value is $\mathbf{q_{sk} = 1.5}$.

Roof shape coefficient μ_1

The shape coefficient of the roof depends on its shape and inclination relatively to the horizontal, in addition to its component parts and climatic conditions. The value of the μ_1 coefficient can be obtained from the following table:

Roof shape coefficient	0° ≤α ≤ 30°	30° ≤ α ≤ 60°	α ≥ 60°
μ_1	0.8	$\frac{0,8\,(60 - \alpha)}{30}$	0

Table 19: NTC 2018 roof shape coefficient

Since the roof of the building is flat, the value of the coefficient will be **μ1 = 0.8.**

Exposure coefficient C_E

The exposure coefficient takes into account the characteristics of the project area and its surroundings. The value of the C_E coefficient can be obtained from the following table:
Since the area in a city context is not excessively sheltered by trees or taller buildings, a "Normal" topography and the relative exposure coefficient C_E = 1,0 are considered.

Thermal coefficient C_t

The thermal coefficient takes into account the loss of load of the snow due to its dissolution, relative to the heat loss of the building itself. As no specific studies have been carried out in this regard, a value of the thermal coefficient C_t = 1.0 is considered.

Snow load q_s

Following the analysis and calculation of the necessary coefficients, it is possible to calculate the snow load that must be applied to the building for a return period of 50 years[17].
This value, relative to the building and the project area, will be $\mathbf{q_s = 1.29\ kN / m^2}$.

Topogaphy	Description	C_E
Windy	Unobstructed flat areas exposed on all sides, without taller buildings or trees	0.9
Normal	Areas where there is no significant snow removal on the building produced by the wind, due to the terrain, other buildings or trees	1.0
Sheltered	Areas where the construction considered is significantly lower than the surrounding land or surrounded by taller buildings or trees	1.1

Table 20: NTC 2018 exposure coefficient for snow analysis

Wind load

The pressure that the wind exerts on the building is given by the expression[18]:

$$p = q_r \, c_e \, c_p \, c_d$$

where:

q_r is the reference kinetic pressure
c is the exposure coefficient
c_P is the pressure coefficient
C_t is the dynamic coefficient

The load caused by wind pressure is assumed to act in horizontal direction, exerting generally dynamic effects. Furthermore, wind actions consist of pressures and depressions acting on surfaces, both internal and external. The action of the wind on the individual elements must therefore be determined on the basis of the most severe combination of the pressures acting on the two faces of each element. The action of the wind on the building will instead be considered as the result of the actions of the single elements, considering as wind direction the one corresponding to one of the main axes of the plant (in this case N, E, W, S).
The NTC 2018 standard defines the values necessary for the calculation of the wind load which, having the building a regular form, will be obtained in the following ways.

Reference basic velocity and reference velocity v_b ,v_r

The base reference velocity v_b is the average value calculated over a period of 10 minutes, at a height of 10 m above the ground on a level II exposure ground, referring to a return period of 50 years.
It, as there are no adequate analises in this regard, is defined by the expression:

$$v_r = v_b \cdot c_r$$

where is it:

$v_{b,0}$ is the base reference velocity at sea level, depending on the area in which the building stands; in the case of our project area (in Lombardy) we obtain $v_{b,0}$ = 25 m / s

c_a is the altitude coefficient; in the case of our project area (as <1000 m a.s.l.) we get c_a = 1

From these values we obtain that v_b = 25 m/s.
Following the NTC 2018 standard it would be necessary to also calculate the reference speed, correction of the base reference speed as a function of the return period, used if this is different from 50 years. However, the return period considered for the building in question is 50 years, so the reference speed will coincide with the base reference speed.
Thus, **$v_r = v_b$ = 25 m / s**.

Reference kinetic pressure q_r

The reference kinetic pressure q_r is given by the expression:

$$q_r = \frac{1}{2} \rho v_r^2$$

where:

v_r is the reference speed of the wind, in our case considered equal to v_b

ρ is the density of the air, assumed constant and equal to 1.25 kg / m[3]
In the considered building, the value of the reference kinetic pressure will be **q_r = 390.63 Pa**.

Exposure coefficient

The exposure coefficient takes into account the height z on the ground of the point where the value of c_e is to be calculated, the topography of the land and the category of exposure of the land. As there are no specific analyses in this regard, these values are defined by the following expression and related images:

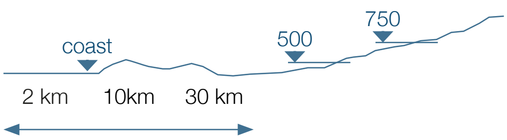
$$c_e(z) = k_r^2 c_t \ln(z/z_0)\left[7 + c_t \ln(z/z_0)\right] \quad \text{per } z \geq z_{min}$$
$$c_e(z) = c_e(z_{min}) \quad \text{per } z < z_{min}$$

where:

k_r, z_0, z_{min} are assigned in the table to the right, depending on the category of exposure of the site
c_t is the topography coefficient, generally considered with a value of 1.

To determine the exposure category of the site it is necessary to identify the class of soil roughness, and being Milan an urban area we consider a class A. With this data, knowing that Milan is in zone 1 (Lombardy), at a height of 120 m a.s.l. and at a distance from the sea greater than 30 km, it is possible to define the zone from the following image:

Zones I, II, III, IV, V



A	-	IV	IV	V	V	V
B	-	III	III	IV	IV	IV
C	-	*	III	III	IV	IV
D	I	II	II	II	III	**

* Category II in zone 1,2,3,4
Category III in zone 5

** Category III in zone 2,3,4,5
Category IV in zone 1

Image 47: wind zones parameters

Exposition category of the site	K_r	z_0 (m)	z_{min} (m)
I	0.17	0.01	2
II	0.19	0.05	4
III	0.20	0.10	5
IV	0.22	0.30	8
V	0.23	0.70	12

Table 21: exposure classes according to site

The exposition class will be then **class V** and the relative values:

$K_r = 0.23$, $z_0 = 0.70$ m, $z_{min} = 12$m

Pressure coefficient

The pressure coefficient depends on the type, geometry and orientation of the building. In the absence of specific studies carried out in the wind tunnel, a unitary value is assumed, therefore we will have that $c_P = 1$.

Dynamic coefficient

The dynamic coefficient takes into account the reductive effects related to the non-contemporaneity of the maximum local pressures, in addition to the amplification effects due to the response of the structure. As no specific study has been carried out in this regard and the building does not exceed 80 m in height, it is assumed to be cautiously unitary, so that we will have that $c_d = 1$.

Action of the wind

Following the analysis and the calculation of the

necessary coefficients, it is possible to calculate the wind pressure that must be applied to the building relative to a return time of 50 years. This value, relative to the building and the project area, will be a maximum of **p = 530,89 Pa**.
Considering c_{pe} , global aerodinamic coefficient and the EC 2018 directive, we define the values associated with the upwind, downwind and lateral facade relatively to the h/d ratio.
The analysis allowed to evaluate and dimension the facade structural profiles.
Considering h = 53 m, d = 46 m, the selected c_{pe} are highlighted in the following table:

Windward facade
h/d ≤ 1: c_{pe} = 0.7 + 0.1 h/d
h/d > 1: c_{pe} = 0.8
Downwind facade
h/d ≤ 0,5: c_{pe} = - 0.5 - 0.8 h/d
h/d > 0.5: c_{pe} = - 0.9
Lateral facade
h/d ≤ 1: c_{pe} = - 0,3 - 0,2 h/d
1 < h/d ≤ 5: c_{pe} = - 0.5 - 0.05 (h/d - 1)

Table 22: aerodinamic coefficient according to h/d ratio

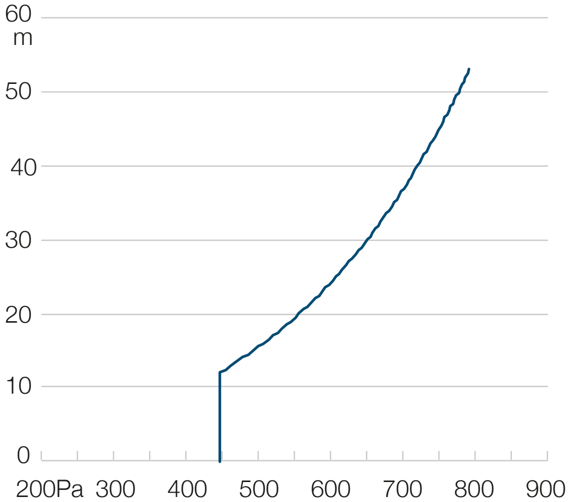


Chart 03: wind pressure on windward facade according to height

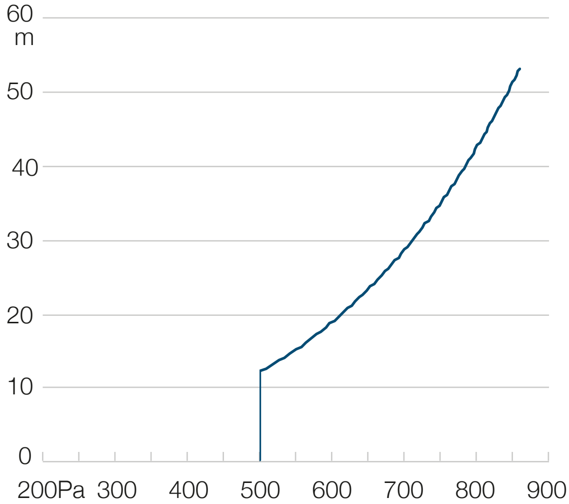


Chart 04: wind pressure on leeward facade according to height

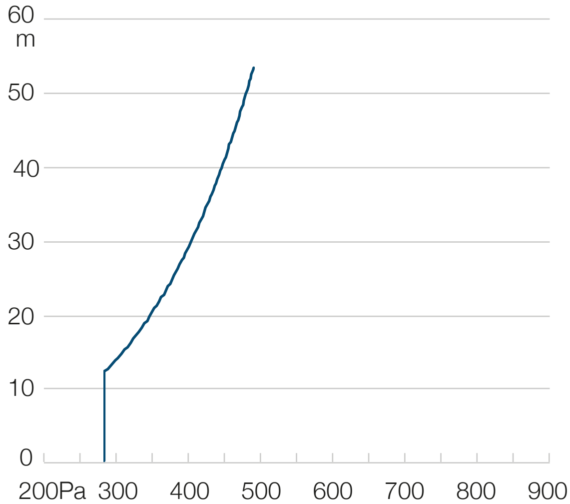


Chart 05: wind pressure on lateral facade according to height

In addition, the following rule applies to roofs:

$c_{pe, A}$ = - 0.80 (applied for a depth equal to the minimum between b / 2 and h, with respect to the wind direction)

$c_{pe, A}$ = 0.20 (applied to the remaining areas)

Material specifications

Concrete

In the following chapter the characteristics of the materials used in the structure are specified with reference to the following regulatory sources:

- Eurocode 2 § 3.1, for concrete
- Eurocode 2 § 3.2, for reinforcing steel
- NTC 2018 § 11.2, for concrete
- NTC 2018 § 11.3, for reinforcing steel

For the purposes of assessing the behaviour and strength of concrete structures, this is identified by the class of resistance, which is represented by the characteristic values of cylindrical and cubic uni-axial compression resistances, measured respectively on cylindrical (or prismatic) and cubic specimens, expressed in MPa.

For the project case, reference is made to a concrete class 25/30, considering an indicative weight of 2500 kg/m^3. The characteristics of the concrete can be derived, in the design phase, from the formulas provided by the standard (ref. § 11.2.10 NTC).

Structures type	Minimum resistance class
For unarmed or low-reinforcement structures	C 8/10
For simply reinforced structures	C 16/20
For pre-compressed structures	C 28/35

Table 23: different resistance classes implementation

Compression characteristic resistance

The characteristic compressive strength is defined as the resistance for which there is a 5% probability of finding lower values. In the present standards the characteristic resistance designates that deduced from tests on specimens having the characteristics referred to in § 11.2.4, performed at 28 days of maturation.

From the characteristic compression resistance R_{ck} it is possible to obtain the characteristic cylindrical compression resistance to be used in the formulas, through the expression:

$$f_{ck} = 0.83 \times R_{ck}$$

Still in the context of project forecasts, it is possible to pass from the characteristic value to the average value of the cylindrical resistance through the expression:

$f_{cm} = f_{ck} + 8$ [N / mm^2]

Referring to the project values:
$R_{ck} = 30$ N / mm^2
$F_{ck} = 25$ N / mm

Traction characteristic resistance

The tensile strength of the concrete can be determined by means of direct experimentation, carried out on specially packaged specimens, according to the UNI EN 12390-2: 2009 standard, by means of the following tests:

- Direct traction tests;
- Indirect traction tests: (according to UNI EN 12390-6: 2010 or equivalent proven method);
- Tensile tests for bending: (according to UNI EN 12390-5: 2009 or equivalent proven method).

In the design phase, the value (in N/mm^2) of concrete can be assumed as a simple average (axial) tensile strength:

$f_{ctm} = 0.30 \times f_{ck}$ for classes ≤ C50 / 60
$f_{ctm} = 2.12 \times \ln [1 + f_{cm} / 10]$ for classes> C50 / 60

The characteristic values corresponding to 5% and 95% fractiles are assumed, respectively, equal to 0.7 f_{ctm}, and 1.3 f_{ctm}.
The average value of the bending tensile strength is assumed, in the absence of direct experimentation, equal to:

$$f_{cfm} = 1.2\, f_{ctm}$$

Referring to the project values we will have:

$f_{cfm} = 2.62$ N / mm^2
$f_{ctk,\,5\%} = 1.82$ N / mm^2
$f_{ctk,\,95\%} = 3.38$ N / mm^2
$f_{cfm} = 3.12$ N / mm^2

Compression and traction project resistance

The mechanical properties of the materials must be reduced by multiplying by partial coefficients so as to be able to consider the variability due to the duration of application, to the design situation. (ref. § 4.1.2.1.1).

The f_{cd} compression design resistance is defined as (ref. § 4.1.2.1.1.1):

$$f_{cd} = \alpha_{cc} f_{ck} / \gamma_c$$

where:

α_{cc} is the coefficient that considers the reduction of resistance due to the long duration of application of the load or to the modalities of its application;

γ_c is the partial safety coefficient for concrete;
f_{ck} is the characteristic compressive strength on cylindrical specimens;

The design tensile strength, f_{ctd}, is valid (§ 4.1.2.1.1.2):

$$f_{ctd} = f_{ctk}/\gamma_c c$$

where:

γ_c is the partial safety coefficient related to concrete already defined in § 4.1.2.1.1.1;
f_{ctk} is the characteristic tensile strength of concrete (§ 11.2.10.2):

In the present case:

f_{cd} = 14.2 N/mm^2

Elastic module

$$f_{ctd} = 1.2 \text{ N/mm}^2$$

For instant elastic modulus of the concrete, the secant one must be assumed between zero and 0.40 f_{cm}, determined on the basis of specific tests, to be carried out according to the UNI EN 12390-13: 2013 standard.

At the design stage, the value can be assumed:

$$E_{cm} = 22000 \times [f_{cm} / 10]\ 0.3\ [\text{N/mm}^2]$$

which must be reduced by 20% in the case of the use of large recycling aggregates within the limits set by Tab. 11.2.III.

For the project:
E_{cm} = 31476 N / mm^2 ≈ 31500 N /mm^2

Poisson coefficient

For the Poisson coefficient, a value between 0 (cracked concrete) and 0.2 (non-cracked concrete) can be adopted, depending on the state of stress. (ref. § 11.2.10.4 NTC 18)

Thermal expansion coefficient

During structural design, in the absence of a direct experimental determination, an average value of 10 x 10^{-6} °C^{-1} can be assumed for the thermal expansion coefficient of the concrete. The quantity depends on the type of concrete considered (aggregate / binder ratio, types of aggregates, etc.) and can consider values that are significantly different from the one indicated. (ref. § 11.2.10.5 NTC 18)

Viscosity and withdrawal

The viscous deformations and the shrinkage of the concrete depend mainly on the humidity of the environment, the size of the element and the composition of the concrete. The viscosity is also influenced by the degree of maturation of the concrete at the time of the first application of the load, as well as by the extent and duration of its application.
The viscous deformations correlate with the persistence of a condition of compression that is invariable over time; the deformation of the element gradually increases and in the long term value may be greater than the initial one.

Referring to EC2 § 3.1.4, the viscous deformation of the concrete has been analysed at an infinite time t_∞ produced by a compression tension σ_c invariable in time and applied at the time t_0.
It is $\varepsilon_{cc\ (t\infty,t0)}$ (where the first subscript indicates “concrete” and the second “creep”, or viscosity),

which is given by the expression:

$$\varepsilon_{cc\ (\infty,t0)} = \phi_{(\infty,t0)} \cdot (\sigma_c\ E_c)$$

$\phi_{(\infty,t0)}$ is the viscosity coefficient referred to E_c, a tangent module that can be assumed equal to 1.05 x E_{cm}.

Appendix B of the EC2 contains detailed information on the evolution of viscosity over time.
The negative deformation due to the withdrawal can instead be made to correspond to two contributions:

$$\varepsilon_{cs} = \varepsilon_{cd} + \varepsilon_{ca}$$

where:

ε_{cs} is the total deformation for withdrawal (s stands for shrinkage);
ε_{cd} is the deformation by drying shrinkage, which develops slowly over time, being a function of the migration of water from the hardened concrete;
ε_{ca} is the deformation due to self-generated withdrawal, which develops in the first days after casting.
In cases where high accuracy is not required, and for concrete and common project situations, it is possible to refer to the indicative values provided by the Eurocode, for the evaluation of the final viscosity coefficient $\phi_{(\infty,\ t0)}$ and of the final deformation of withdrawal ε_{cs} (ref. § 3.1.2.5.5-EC2), for a concrete packaged with normal aggregates, subject to axial tension not greater than |0.45 fck| at time t_0 of the first load. For a more accurate evaluation, see Appendix 1 of the Eurocode.

where:

A_c is the area of the concrete cross section
u is the perimeter of the section

The following considerations apply:
- The values indicated in the tables below refer to the temperature range between 10 °C and 20 °C. However they can be accepted for seasonal temperature excursions between -20 °C and 40°C. Likewise, the same values as in tables above can be accepted in the relative humidity range between RH = 20% and RH = 100%.
- The values in tables below are applicable to concretes which, when fresh, have a plastic consistency of class S2 and S3. For concretes

Concrete age at t_0 instant of the loads application	**Nominal dimension 2 A_c/u (mm)**					
	50	150	600	50	150	600
	Dry atmosphere (indoor) RH = 50%			Humid atmosphere (outdoor) RH = 80%		
1	5.5	4.6	3.7	3.7	3.2	2.9
7	3.9	3.1	2.6	2.6	2.3	2.0
28	3.0	2.5	2.0	1.9	1.7	1.5
90	2.4	2.0	1.6	1.5	1.4	1.2
365	1.8	1.5	1.2	1.1	1.0	1.0

Table 24: final value of the viscosity coefficient φ (∞, t_0) of a concrete of normal volumetric mass

Positioning	Relative humidity (%)	Nominal dimension 2 A_c/u (mm)	
		≤ 150	600
Indoor	50	-0.60	-0.50
Outdoor	80	-0.33	-0.28

Table 25: final value of the shrinkage deformation $\varepsilon_{cs}\infty$ (in% o) of a concrete of normal volumetric mass

of different consistency the values will be multiplied by 0.70 (rigid consistency S1) or by 1.20 (fluid consistency S4).
- For concretes containing superplasticizers, the evaluation of the viscosity and shrinkage coefficients using tables 4.2 and 4.3 will refer to the consistency before the addition of the superplasticizer.

Reinforced concrete steel

The reinforcement steel admitted by the Eurocode design rules and the NTC 18 is qualified according to the procedures described in § 11.3.1.2 and checked in the manner described in § 11.3.2.11.

The project used B450C type steel (ref. § 11.3.2.1), characterized by the same nominal values of yield strength and maximum load voltage of the B450A, but with higher characteristic resistance and greater elongation.

$f_{tk} \geq 540$ N / mm^2

$f_{yk} \geq 450$ N / mm^2

$\varepsilon_{uk} \geq 0.075$

All steels for reinforced concrete must have improved adherence, having a surface with transverse ribs or indentations, uniformly distributed over the entire length, suitable to guarantee adequate adherence between reinforcement and cement conglomerate.

B450C steels, referred to in § 11.3.2.1, can be used in bars with a diameter Ø between 6 and 40 mm. The use of steel supplied in rolls is allowed, exclusively for structural uses, for diameters less than 16 mm.

The design values provide a characteristic yield stress of:

$f_{yd} = f_{yk} / \gamma_s = 391$ N / mm^2

where

γ_s is the safety coefficient for the ultimate limit states, equal to 1.15.

The recommended ε_{ud} value is 0.9 ε_{uk}. The elastic module Es is assumed equal to 200000 N/mm^2.

Structures durability

The durability of concrete can be defined as the ability to preserve the characteristics (physical and mechanical) and performance of structural elements during the nominal life of the building, without resorting to extraordinary maintenance. "Nominal life" means the time during which the structures and / or materials retain their initial performance, while maintaining the level of safety and functional efficiency of the project, for any action and expected environmental condition (except for the period of reference for seismic actions § 2.4.3. NTC).

The structural designer is required to analyse the design environmental conditions and identify the corresponding exposure class for concrete, followed by the definition of both the characteristics of the concrete to be used (in terms of constituent materials and mechanical strength) and of the value of the cover plates suitable for facing environmental aggressions, fully ensuring the durability of the work.
Here it is just defined the strength properties of the concrete and the concrete cover distances, leaving out the prescriptions of the mixture and the correct execution of the works. Generally good durability can be matched to compact concrete, low porosity and low permeability.

Prescription of the exposure class

With reference to Schedule 1 of UNI 11104, the exposure class of the work and each of its components is identified, depending on the mechanisms of environmental degradation on the structures. All the underground structures belong to the XC2 class. All the internal structures of civil constructions refer instead to class XC1.

Denominazione classe	Descrizione dell'ambiente	Situazione d'esempio
	1. Assenza di rischio di corrosione o attacco	
X0	Per calcestruzzo privo di armatura o inserti metallici: tutte le esposizioni dove c'è gelo e disgelo, o attacco chimico. Calcestruzzo con armatura e inserti metallici: in ambiente molto asciutto	Interno di edifici con umidità relativa molto bassa. Calcestruzzo non armato all'interno di edifici
	2. Corrosione indotta da carbonatazione	
XC1	**Asciutto o permanentemente bagnato**	**Interni di edifici con umidità relativa bassa**
XC2	Bagnato, raramente asciutto	Parti di strutture di contenimento liquidi, fondazioni
XC3	Umidità moderata	Superfici esterne riparate dalla pioggia, o in interni con umidità da moderata ad alta
XC4	Ciclicamente asciutto o bagnato	Superfici esterne soggette ad alternanza asciutto ed umido
	3. Corrosione indotta da cloruri esclusi quelli provenienti dall'acqua di mare	
	4. Corrosione da cloruri presenti nell'acqua di mare	
	5. Attacco di cicli gelo/disgelo con o senza disgelanti	
	6. Attacco chimico	

Table 26: classification of exposure classes according to the environmental conditions (extracted from UNI 11104)

Prescription of the resistance class

The quality and type of concrete used influence the resistance of the concrete to external agents and the preservation of the reinforcement inside the concrete itself. It is important to choose a suitable concrete strength class so that the compression requirement is respected, in addition to the protection requirements against the corrosion of the reinforcements and the durability of the concrete (in the presence of attacks by external agents). The table shown below, taken from UNI 11104, lists some of the classes of resistance that must be adopted.

Prescription of the reinforcement covering layer

The concrete cover in the structure plays the fundamental roles of protecting it against infiltration, fire, corrosion of the reinforcement; just the latter depends on the compactness of the concrete and also on the thickness of the concrete cover.
Through § 4.1.3.3 of Eurocode 2 the minimum concrete cover is defined, which must be greater than the Φ12 bar diameter to correctly transmit the adhesion forces and ensure adequate compactness.
Referring to the NTC 18 4.1.2.2.4.2 the exposure class XC2 is identified relative to ordinary environmental conditions which corresponds to a minimum concrete cover of 25 mm.
To this value 10 mm are added to guarantee the tolerance of the concrete cover. A design concrete cover of 35 mm is thus obtained.

Denominazione della classe	Minima classe di resistenza
X0	Nessuna prescrizione
XC1 XC2	C25/30
XC3	C28/35
XC4	C32/40
XD1	C28/35
XD2	C32/40

Table 27: minimum concrete requirements for each exposure class (UNI 11104)

Concrete plates

Concrete plates represent a typology of structural bi-dimensional elements, flat and of limited thickness. They can be easily applied for a big variety of alternatives and can be realized with different materials: reinforced concrete, steel or mixed solutions like steel-concrete or wood-concrete. However, reinforced concrete, offering numerous benefits in terms of formwork simplicity and consistency, represents the optimal solution for our needs. The building, characterized by large spans and a square base structure, is suitable for bidirectional slabs. By definition, the behaviour of a slab is bidirectional if the disposition of the constraints is a grid, it is instead unidirectional if these are aligned in parallel. The proposed slab solution has been chosen of constant thickness and placed on columns, in order to exploit as much as possible the space below. This construction technique turns out to be simplest and fastest, and can be implemented, as in our case, by prefabricated systems such as the Bubble-Deck technology, which allows a lightening of the supporting structure as well as a minimal implementation of material.

The use of continuous solid plates on columns represents a particularly simple solution, suitable for medium-small square or rectangular fields up to 20 m. This scheme is particularly advantageous for covering large areas (several thousand square meters), maintaining great freedom in using the space in the plan (eg parking lots, shopping centres, hospitals). However, in the case of a continuous plate on columns, a slightly larger thickness is required compared to the case of a single plate on beams or walls (between 1/20 and 1/30 of the light). It is necessary to place a dense reinforcement on the supports because of the local bending and punching stresses (shear). A further subdivision is between the standard plates and the lightened ones, very suitable for medium-large lights. Respectively for bidirectional and unidirectional cases, the orthotropic solutions are well known, with ribbing arranged in a grid (coffered floor), and with a hollow-core core, with voids arranged inside the thickness (hollow core slab). Both solutions represent an effective compromise between stiffness and lightness.

Choice of the plate type: The BubbleDeck system

In order to find a good compromise between structural performances and lightness of the system, the proposed solution implies a semi-prefabricated solution of reinforced concrete slabs lightened with crossed reinforcement: the BubbleDeck® system.

BubbleDeck® is a system that allows to obtain a hollow core slab in reinforced concrete with crossed reinforcement through the interposition of recycled plastic material balls. The BubbleDeck® system is the only one that is completely comparable to a massive slab since the balls remove the concrete from the areas where it develops its least effect, leaving the behaviour to the Ultimate Limit State unchanged.

Whether, due to excessive shearing stress, it is necessary to restore the full floor, the spheres can be removed. As with any slab with two directions of reinforcement, the ideal condition of using a BubbleDeck® slab is given by a deck configuration, where the free inflection spans in the two directions are generally almost comparable and therefore it induces a clearly bidirectional tension state. In relation to the loads involved, the technical and economic advantages are increasing in direct proportion to the thickness of the floor itself, since in fact the incidence of lightening increases with height. Among the technical advantages there are the absolute design freedom, as well as maximum security to local punching shear, and many others. These improvements consequently lead to verified savings in construction costs.

On-site supply consists of lightening modules of size 2.5 m. These modules are built in the field through the assembly of two electro-welded meshes separated by lattice girders, also electro-welded, with the spherical lightening elements in HDPE (high density polyethylene) interposed, which therefore remain confined to their operating position by the meshes of the grid. The preparation of the deck and the installation of a BubbleDeck® slab is identical to that of the massive slabs with crossed reinforcement. The difference consists in the insertion of the lightening modules in substitution of the classic spacers for the suspension of the upper layers of reinforcement and in the concrete casting that, in the areas where the lightening is present, must necessarily take place in two phases (Fig. 1).

In the design phase, the wide range of lightening elements allows obtaining thickness of floors between H = 25 ÷ 70cm. A constant dimensional

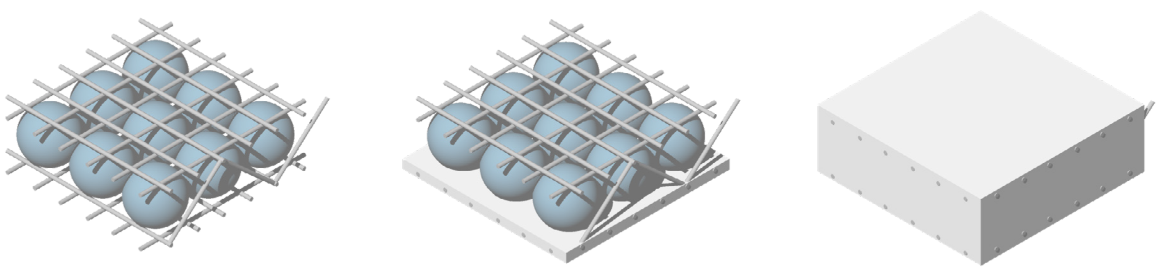


Image 48: BubbleDeck plate construction phases

value for all floors is the ratio between the wheelbase "i" and the diameter "D" of the lightening spheres used, given by the formula
i = D: 0.9. Depending on the lightening class, the reduction in the weight of the floor is between 191 and 573 Kg / m^2.

Characteristics and advantages

Sustainability

The BubbleDeck® system fully focuses on the objective of the conscious and sustainable use of resources. The reduced use of concrete and consequently the reduction of cement production, offers a significant contribution in the reduction of CO2 emissions. The spheres themselves are also produced from recycled material, increasing the overall sustainability of the system. In the event of a possible renovation or demolition of the building, the synthetic material can easily be detached from the rest of the material, allowing a recycling of the same and ensuring a further contribution to the reduction of CO^2.[19]

TABS systems

The BubbleDeck® system offers the possibility of being able to take advantage of the floor slab as a heat accumulator in order to achieve thermal comfort, especially in summer, when it is in fact difficult to release heat during daylight hours. The TABS (Thermal Activation Building System) system has the characteristic of keeping the slab at a controlled temperature through a constant heat exchange with the foundation (a place where temperatures are throughout the year under the 13 ÷ 14 ° C) through PEHD pipes whose circuits are located approximately 5 ÷ 7cm from the intrados of the floor. The system therefore works almost in a Free-Cooling condition, that is without the contribution of additional expensive and energy-consuming cooling devices, but with the simple recirculation of the fluid in the circuit[20].

Technical specifications

The structural behaviour of the system has been widely examined due to innumerable research and laboratory experiments. One of the fundamental characteristics of a slab equipped with BubbleDeck® technology is that its load-bearing capacity corresponds in practice to that of a massive floor. The adequacy and applicability of the system to national technical regulations has also been demonstrated. The results report documents and the test certificates always available for consultation on any request.

Bending

Specifically and within well-defined limits, the flexural behaviour in terms of resistance to ULS (Ultimate Limit State) on specific samples constructed according to BubbleDeck® recommendations, has shown the perfect correspondence in terms of flexural strength in analogy to massive floors[21].
It has also been ascertained that the deflection arrow of a lightened floor with BubbleDeck® technology, for the same load, is 15% higher than that of a massive floor of the same thickness; this both in cracked condition and in non-cracked condition. In any case, taking into account the weight reduction of the BubbleDeck® floor and making the appropriate numerical evaluations, it can be stated that up to a value of 1.5 of the ratio between overload and own weight of the massive floor of equal thickness, the deflection arrows of the floor constructed with the BubbleDeck® system are always lower and therefore always

more advantageous in the direct comparison with the massive floor[22].

Shear Resistance

In a similar way, the determination of the shear resistance of the BubbleDeck® slab was calculated on the basis of a series of diversified tests with simulations designed to represent every possible stress state that may occur in relation to the ULS per cut[23]. The tests allowed to deduce a residual shear strength factor with respect to a massive floor with lower threshold given by the parameter ∑Q, r = 0.55 (55% of the resistance of a massive slab of equal thickness). In fact, therefore, it is certified that the BubbleDeck® floor has a significantly higher shear strength than the one that would be obtained by using the minimum rib width which would be about 10% of the massive section.

Punching applied vertically to the slab

The phenomenon of the shear / punching stress state in the areas close to the vertical support elements is already widely foreseeable in the design phase. It can be adequately solved by removing the spheres from these sections to restore 100% resistance to the massive one. This strategy is not possible for loads applied locally, because it acts punctually with small load marks. It can be transmitted for example by the same props in the phase of support during the construction phase, or by feet of heavy shelving, rather than by industrial machines in the exercise phase located on the deck. This phenomenon is systematically undervalued and is almost always the cause of cracking or even small local breakthroughs of the hoods that do not have the shear stress resistance sufficient to contain these efforts. The BubbleDeck® technology in this sense, due to the specific shape of the lightening cavities, enjoys a tangible advantageous position due to the arc effect that is created adjacent to the spheres under localized pressure. Through internal mechanisms with connecting rods and struts that create a sort of truss effect, it is possible to achieve resistances to these pressures that are not comparable to the floors constructed with the usual lightening systems. These traditional elements generally have bodies with a flat surface parallel to the faces of the floor and therefore subject the hoods to a job for which they are not designed.

Dimensioning

The calculation of a BubbleDeck® slab, with the exception of some particular cases, takes place in a completely similar way to the calculation of a traditional floor in reinforced concrete with crossed reinforcement. The phases can be represented schematically in the following flow chart:

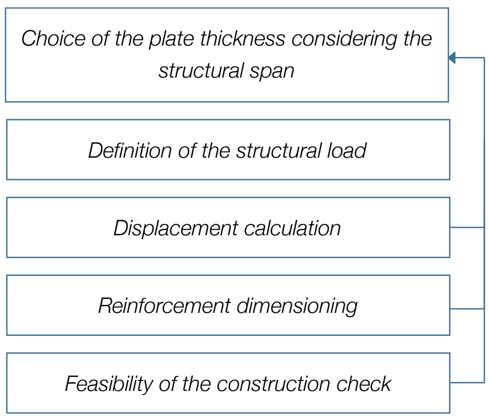


Chart 06: Flowchart of the calculation process

Pre-dimensioning

A good principle for pre-dimensioning concrete plates is to initially hypothesize as a minimum thickness the 1/25 of the maximum grid maximum span.

h_{min}= 1/25 * 16.5 m = 0.65 m

Determination of the slab weight

Table 28 has been used in order to determine the proper weight of the BubbleDeck® slab. Depending on the thickness of the hypothesized floor, together with the associated lightening elements, it is possible to determine the global weight, as well as the weight reduction compared to a massive floor slab of equal thickness (generally this weight reduction is between 29 ÷ 35%). In the case analysed the plate's weight is 1052 kg/m², corresponding to the hypothesized thickness. The hypothesizes thickness has been subsequently reduced whether the verifications were largely satisfied not to generate an excessive waste of material.

Calculation of the displacement

The displacement of the BubbleDeck® plates has been studied with the support of a Finite Elements Software: Robot Structure. The analysis of the plates have been carried out using an equivalent specific weight γ_{eqv} that can be determined based on the weight of the BubbleDeck® floor chosen ($\gamma_{eqv} = PP_{BD} / H$).
At this point, knowing the displacement results, due to the lower equivalent stiffness of the BubbleDeck plate J_{BD} compared to the one of the full slab J_{MD}, the displacements are determined by increasing them with an appropriate factor (w_{BD} / w_{Mass}). For simplicity, in a completely precautionary manner, this increase has been set of around 15%.

$$f_{BD} = f_{MD}(\gamma_{BD})\ (w_{BD}/w_{Mass}) \leq f_{MD} \quad \text{or}$$
$$f_{BD} \approx f_{MD}(\gamma_{BD})\ 1.15 \leq f_{MD}$$

where:

BD = BubbleDeck
MD = full concrete plate
f = displacement
γ_{BD} = specific weight of the BD lightened plate

Bubble Deck	Φ (mm)	Volume sphere (dm³)	PP reduction (kg/m²)	h plate (cm)	PP - Mass (kg/m²)	PP - BD (kg/m²)	Saving (%)
BD - 270	270	10.3	286	35	875	589	33%
BD - 315	315	16.4	334	40	1000	666	33%
BD - 360	360	24.4	382	45	1125	743	34%
BD - 450	450	47.7	477	55	1375	898	35%
BD - 540	540	82.4	573	65	1625	1052	35%

Table 28: Producer given BubbleDeck plates characteristics table

The European legislation allows omitting the calculation and verification of displacements if the plate elements do not exceed a value of the ratio between span and thickness (EC 7.4.2). Similar requirements are given by the current Italian law (DM 9.1.1996, 4.3.3): it is not necessary to check the displacements in simply supported plates with a span/ thickness ratio lower than 20. When the structure has a slenderness greater than these limits, the displacement need to be calculated. The limits to be respected are generally provided in terms of the ratio between the maximum displacement f_{max} and the light between the supports. A f_{max} / l ratio lower than 1/250 generally ensures the functionality and aesthetics of the structure under the action of almost permanent loads (SLS), while respecting the limit of 1/500 in the most common cases integrity is ensured (ULS)[24]. Furthermore, it is possible to consider the relative displacement between the centre of the plate and its edges (which is lower than f_{max}) relative to a span equal to the side of the plate. The maximum displacement on this strip corresponding to the median of length L is equal to 0.75 fmax.

The procedure of calculation has been carried out for the four main floor characterized by BubbleDeck plates of a not completely regular frame:

- Level 1
- Level 2
- Level 4
- Level 5

The calculation has been carried out on a standard concrete C25/30 plate, which has been assigned a weight corresponding to the one of the BubbleDeck slab of the same thickness. The calculation procedure has been re-iterated until acceptable values of displacement have been obtained. Minor thickness have been tested in order to ensure the material implementation optimization and whether verified, adopted. This occurred especially in the case of Level 1 and Level 2 where, thanks to minor spans, a thickness of 55 cm instead of 65 cm resulted acceptable in terms of displacement.

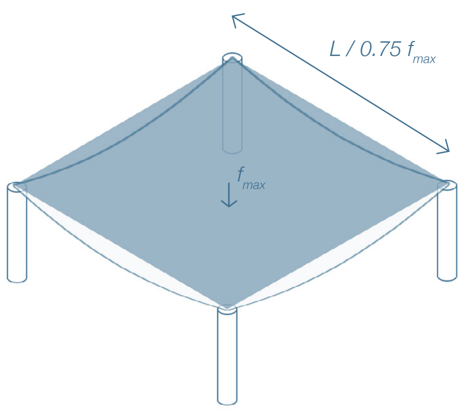
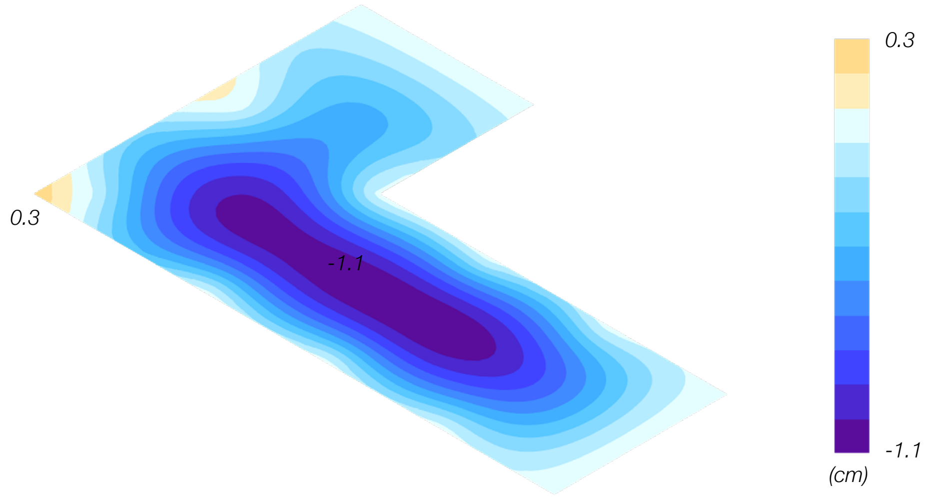


Image 49: Maximum displacement reduction

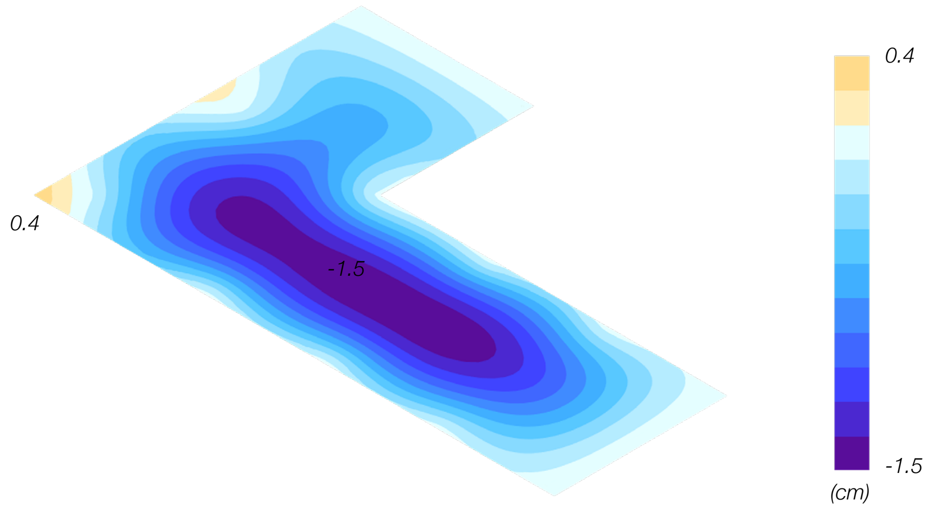
L	h (cm)	G_1 (kN/m²)	G_2 (kN/m²)	Q_1 (kN/m²)	Q_2 (kN/m²)
1	55	8.81	2.29	5	1.29
2	55	8.81	2.26	5	-
4	65	10.32	2.26	5	-
5	65	10.32	2.26	5	-

Table 29: Levels plate thickness and loads

Level 1



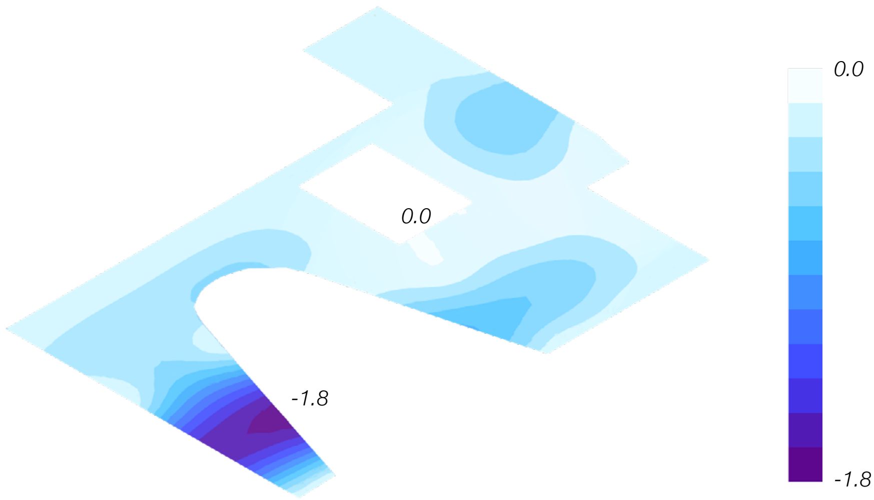
	f_{max} (cm)	f_{min} (cm)	x 0.75	x 1.15	L_{max} (cm)	f_{max}*/L	
SLS	-1.1	0.3	-0.825	-0.94875	1130	-0.00084	< 1/250



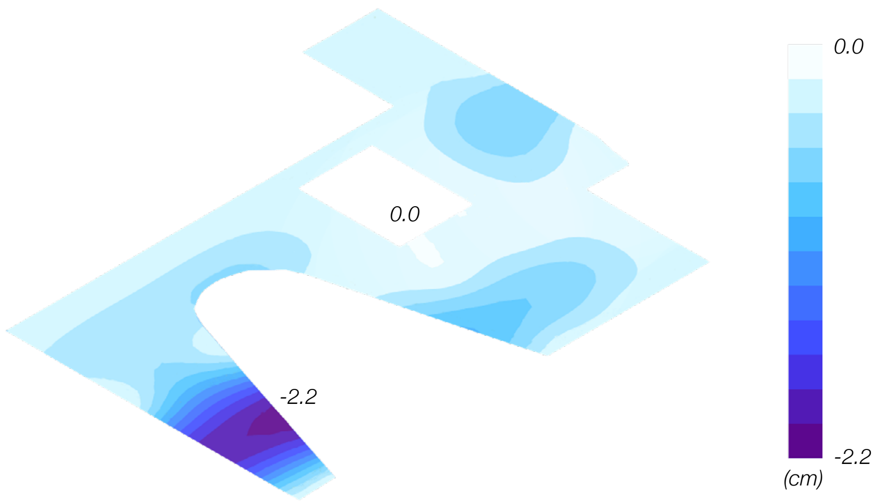
	f_{max} (cm)	f_{min} (cm)	x 0.75	x 1.15	L_{max} (cm)	f_{max}*/L	
ULS	-1.5	0.4	-1.125	-1.29375	1130	-0.00114	< 1/500

Image 50: displacement analysis of Level 1, SLS and ULS analysis

Level 2



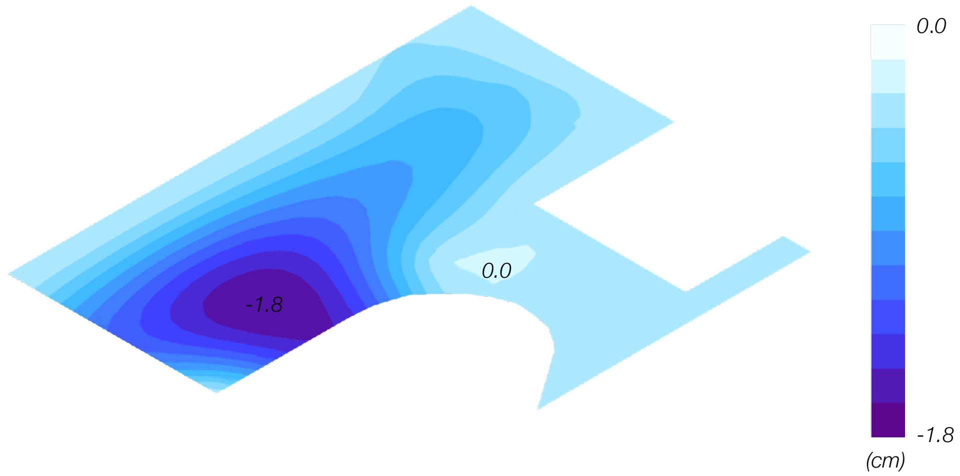
	f_{max} (cm)	f_{min} (cm)	x 0.75	x 1.15	L_{max} (cm)	f_{max}*/L	
SLS	-1.8	0	-1.35	-1.55250	1650	-0.00094	< 1/250



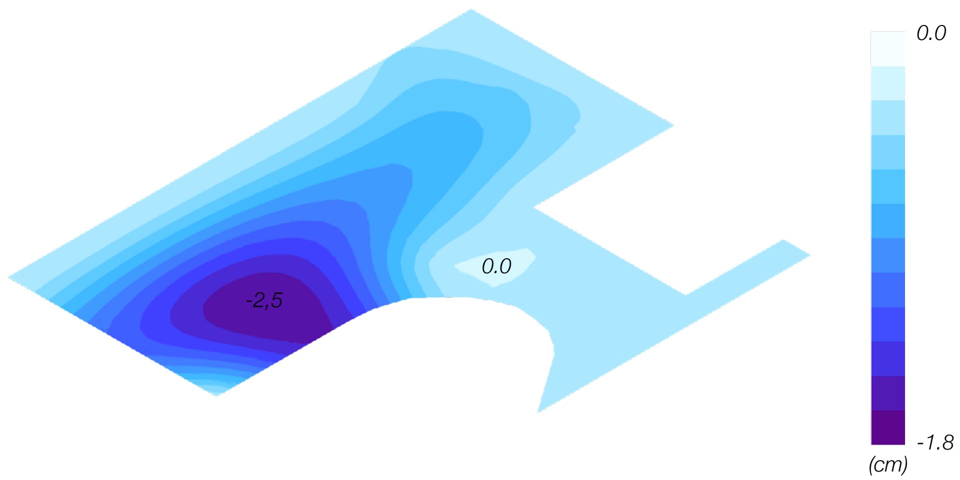
	f_{max} (cm)	f_{min} (cm)	x 0.75	x 1.15	L_{max} (cm)	f_{max}*/L	
ULS	2.2	0	-1.875	-2.15625	1650	-0.00131	< 1/500

Image 51: displacement analysis of Level 2, SLS and ULS analysis

Level 4



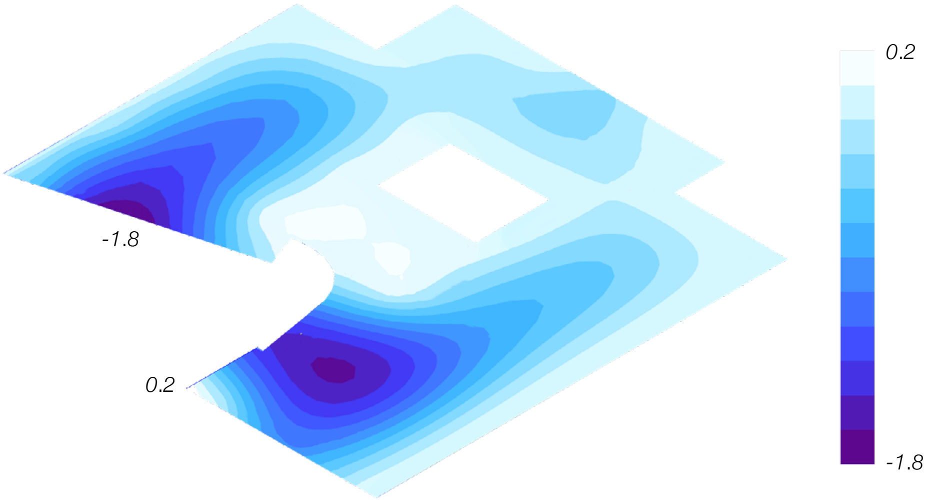
	f_{max} (cm)	f_{min} (cm)	x 0.75	x 1.15	L_{max} (cm)	f_{max}*/L	
SLS	-1.8	0	-1.35	-1.55250	1650	-0.00094	< 1/250



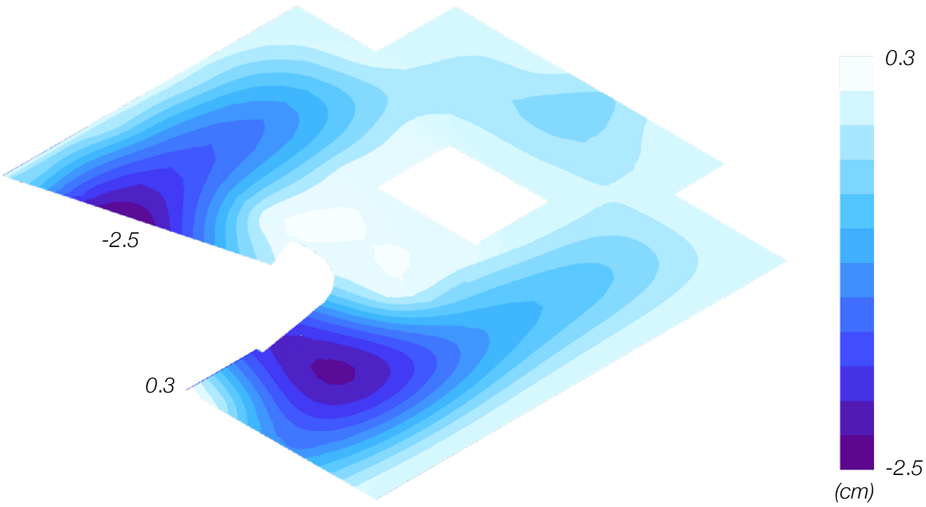
	f_{max} (cm)	f_{min} (cm)	x 0,75	x 1,15	L_{max} (cm)	f_{max}*/L	
ULS	-2.5	0	-1.875	-2.15625	1650	-0,00131	< 1/500

Image 52: displacement analysis of Level 4, SLS and ULS analysis

Level 5



	f_{max} (cm)	f_{min} (cm)	x 0.75	x 1.15	L_{max} (cm)	f_{max}*/L	
SLS	-1.8	0.2	-1.35	-1.55250	1650	-0.00094	< 1/250



	f_{max} (cm)	f_{min} (cm)	x 0.75	x 1.15	L_{max} (cm)	f_{max}*/L	
ULS	-2.5	0.3	-1.875	-2.15625	1650	-0.00131	< 1/500

Image 53: displacement analysis of Level 5, SLS and ULS analysis

Reinforcement dimensioning (ULS)

In order to pre-dimension the reinforcement of the adopted plates, the identification of points associated to critical values of moments has been necessary. In order to simplify the process, the research has been supported, once again by Robot Structure. The points identified are the ones highlighting the extreme values of bending moments. Once identified the critical points and the relative m_{xx} m_{yy} and m_{xy} values, the procedure shown in the following flowchart has been carried out for each one of the studied plate.

- The input data are represented by the internal bending and torque actions, in which the bending moments have a positive sign if the lower fibres tend, and the sign of the torques is irrelevant.
- The reinforcement is calculated at each point both at the lower edge (at "positive") and at the upper edge (at the "negative")
- The output values (m_{xx}* and m_{yy}*) represent the resistant moments required by the reinforcement in case of dimensioning.

The procedure of calculation has been carried

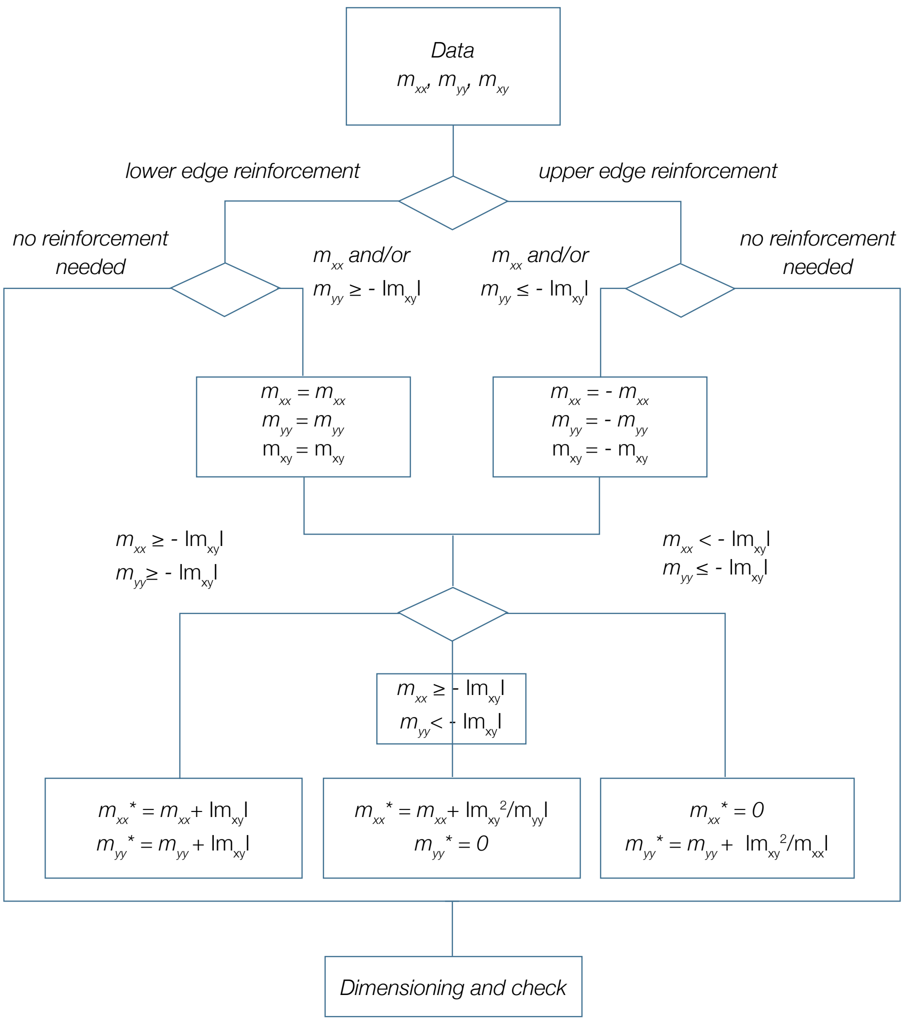


Chart 07: Flowchart explaining the procedure carried out to dimension the reinforcement bars

out for the four main floors with a not completely regular frame or particularly critical:

- Level 2
- Level 4
- Level 5

Level 2

The nodal points in which the terns of values m_{xx} m_{yy} and m_{xy} represent the significant cases are indicated in the drawing and reported in the following tables. The significant cases have been identified as those highlighting the most critical values of m_{xx} and m_{yy}, either negative and positive.

- Table 30 shows the m_{xx} m_{yy} and m_{xy} results of the structural analysis
- Table 31 relates to the lower edge with the values of m_{xx}, m_{yy} and m_{xy} and the corresponding values of m_{xx} * and m_{yy} *
- Table 32 is similar to Table 2, for the upper edge

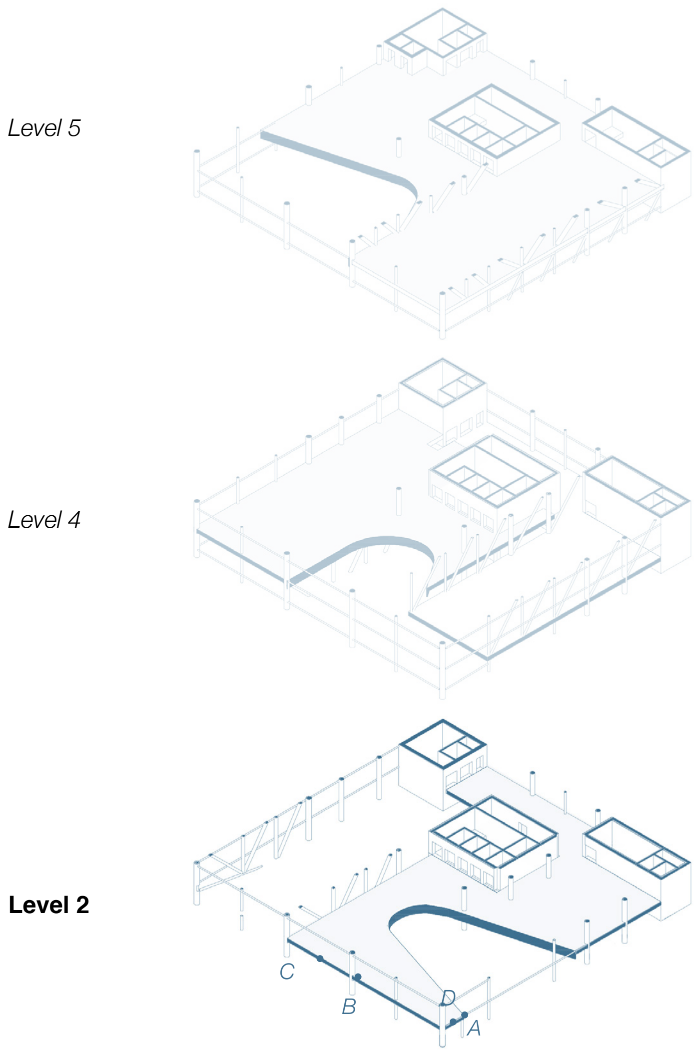


Image 54: Blow-up showing the levels studied and the critical points identified for Level 2

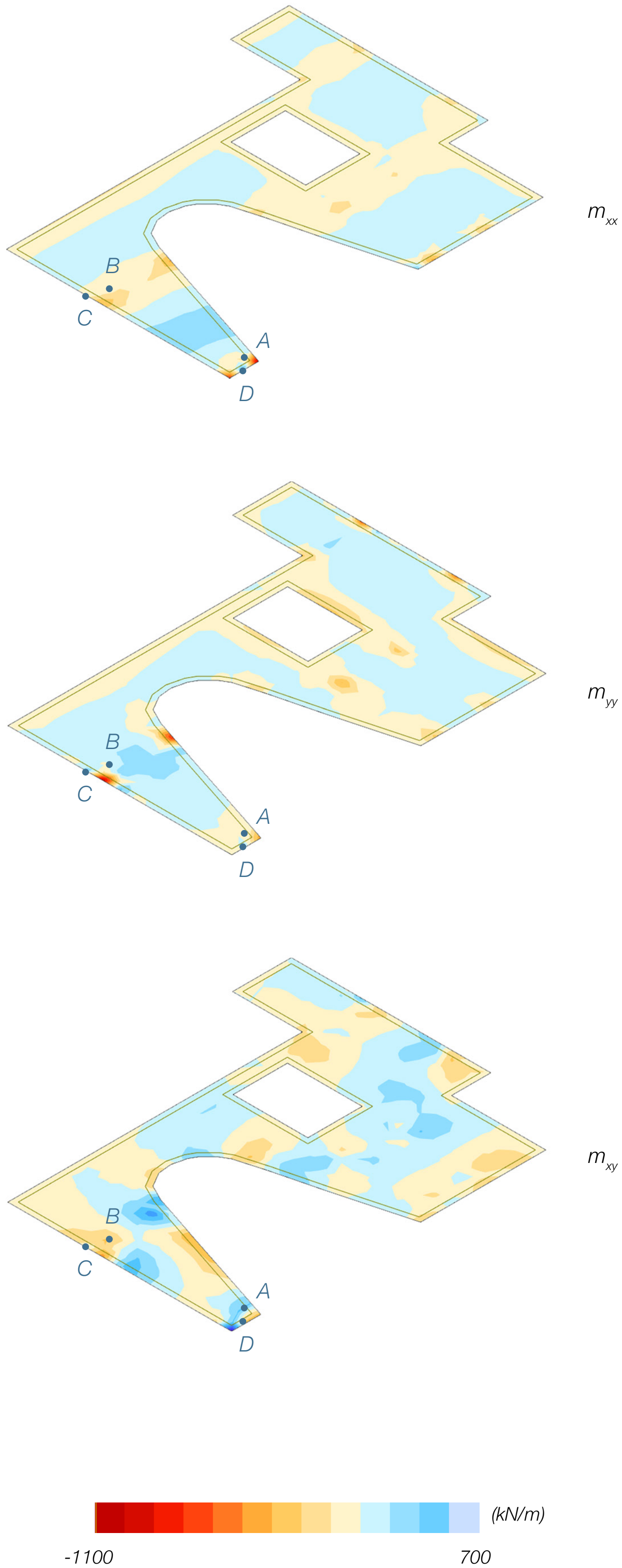


Image 55: Map results of the moments m_{xx} m_{yy} m_{xy} resulting on Level 2

node	m_{xx} (kNm)	m_{yy} (kNm)	m_{xy} (kNm)
A	-1080.44	-320.14	-100.27
B	-544.54	-768.89	-300.05
C	5.51	490.21	137.44
D	653	57.29	99.19

Table 30: Level 2 m_{xx} m_{yy} and m_{xy} results of the structural analysis

Lower edge						
node	m_{xx} (kNm)	m_{yy} (kNm)	$\lvert m_{xy}\rvert$ (kNm)	case	m_{xx}*	m_{yy}*
A	m_{xx} o m_{yy} < - | m_{xy} | no lower reinforcement needed					
B	m_{x} o m_{yy} < - | m_{xy} | no lower reinforcement needed					
C	5.51	490.21	137.44	2	44.04	0
D	653	57.29	99.19	1	909.03	539.96

Table 31: m_{xx}, m_{yy} and m_{xy} values and the corresponding values of m_{xx} and m_{yy}* for the lower edge*

Upper edge						
node	m_{xx} (kNm)	m_{yy} (kNm)	$\lvert m_{xy}\rvert$ (kNm)	case	m_{xx}*	m_{yy}*
A	1080.44	320.14	100.27	1	1180.71	420,41
B	544.54	768.89	300.05	1	844.59	1068.94
C	-5.51	-490.21	137.44	2	33.02	0
D	-653	-57.29	99.19	1	-553.81	41.9

Table 32: m_{xx}, m_{yy} and m_{xy} values and the corresponding values of m_{xx} and m_{yy}* for the upper edge*

The sizing of the reinforcement grid both on the lower and upper edge, is carried out by selecting as critical points those highlighted situations of maximum positive bending and negative bending. At this point we proceed to a calculation at the ultimate limit state; the reinforcing steel is B450C and therefore the design tension is equal to:

$$f_{yd} = 450 \text{ MPa} / 1.15 = 391.30 \text{ MPa}$$

The lever arm of the internal pair z is assumed, approximately, to be 0.8 times the thickness of the plate[25]:

$$z = 0.8 \times 55 \text{ cm} = 44 \text{ cm}$$

Considering the following formula for the determination of the required reinforcement area,

Given the soliciting moment m_{xx}* in x direction:

$$A_{x,theoreticall} = m_{xx}^* / (z \times f_{yd})$$

And the soliciting moment m_{yy}* in y direction:

$$A_{y,theoretical} = m_{yy}^* / (z \times f_{yd})$$

Lower edge				
	m_{xx}^* (kNm)	m_{yy}^* (kNm)	$A_{x,theo}$ (cm^2)	$A_{y,theo}$ (cm^2)
C	44.04	0	2.56	0
D	909.03	539.96	52.80	31.36

Table 33: Critical values of m_{xx} and m_{yy}* and definition of $A_{x,theo}$ and $A_{y,theo}$ needed at the lower edge*

Upper edge				
	m_{xx}^* (kNm)	m_{yy}^* (kNm)	$A_{x,theo}$ (cm^2)	$A_{y,theo}$ (cm^2)
A	1280.71	420.41	68.58	24.42
B	844.59	1068.94	49.05	62.08

Table 34: Critical values of m_{xx} and m_{yy}* and definition of $A_{x,theo}$ and $A_{y,theo}$ needed at the upper edge*

At the lower edge it is necessary 52.8 cm^2 of reinforcement in x direction. While 31.36 cm^2 is required in y direction.

At the upper edge it is necessary 74,38 cm^2 of reinforcement in x direction. While 62,08 cm^2 is required in y direction.

The longitudinal reinforcement grids are considered for the whole extension of the Level 2 plate.

Furthermore, it is verified that the area of the longitudinal reinforcement $A_{s,theoretical}$ in the tense area in each of the two directions is higher than the minimum value provided by the NTC 2018 § 4.1.6.1.1.

$A_{s, min}$ is given by the following formula:

$$A_{s,min} = 0.26 \, f_{ctm}/f_{yk} \, b_t \, d = 7.39 \text{ cm}^2$$

or, however, not less than:

$$A_{s,min} = 0.00013 \, b_t \, d$$

where:

- b_t is the length of the tense area;
- d is the useful height of the section equal to 50 mm;
- f_{ctm} is the average value of the axial tensile strength equal to 2.56 N / mm^2;
- f_{yk} is the characteristic value of the tensile strength of the original reinforcement equal to 450 N / mm^2.

Moreover, considering it is good practice to leave 7-8 cm between the reinforcement bars to allow concrete vibrations[26], we defined the upper and lower grids arrangement as follows:

Lower edge					
	A_{req} (cm^2)	n°	Φ (cm)	d (cm)	A_{real} (cm^2)
x	52.80	10	2.6	7.4	53.09
y	31.36	10	2	8	31.42

Upper edge					
	A_{req} (cm^2)	n°	Φ (cm)	d (cm)	A_{real} (cm^2)
x	68.58	10	3	7	70.69
y	62.08	10	3	7	70.69

However, the required longitudinal reinforcement diameters exceed the hypothesized thickness of the lower and upper concrete layers. Consequently, the overall plate thickness has been increased according to the needs and to the minimum reinforcement covering.
According to the product specification, whether the thickness increases compared to the one given by the producer chart, it will be necessary to add Δ_{PP}=25Kg/m^2 per each cm of increase.

The Level 2 plate, that started with and hypothesized thickness of 55 cm, has been implemented with a 62 cm plate in order to ensure the either the displacement verification and the correct positioning of the bars as well as the minimum required reinforcement covering of 3.5 cm. Simulations have been carried once again with the increased slab weight and thickness and displacement and bending moments verification checked one more time.

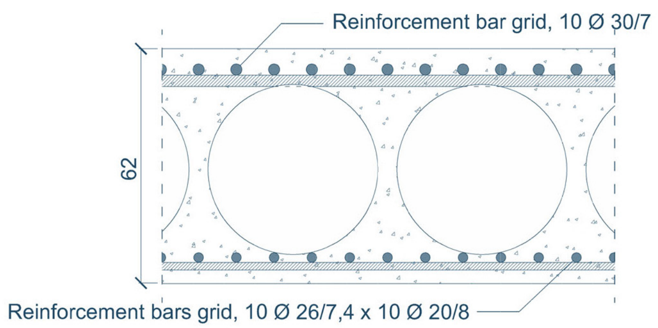


Table 35, 36: upper and lower reinforcement grids properties
Image 56: representation of Level 2 plate

Level 4

The procedure has been reiterated for the next critical levels. Once again, for what concerns Level 4, the nodal points in which the terns of values m_{xx} m_{yy} and m_{xy} represent the significant cases are indicated in the drawing and reported in the following tables. The significant cases have been identified as those highlighting the most critical values of m_{xx} and m_{yy}, either negative and positive.

- Table 37 shows the m_{xx} m_{yy} and m_{xy} results of the structural analysis
- Table 38 relates to the lower edge with the values of m_{xx}, m_{yy} and m_{xy} and the corresponding values of m_{xx} * and m_{yy} *
- Table 39 is similar to Table 38, for the upper edge

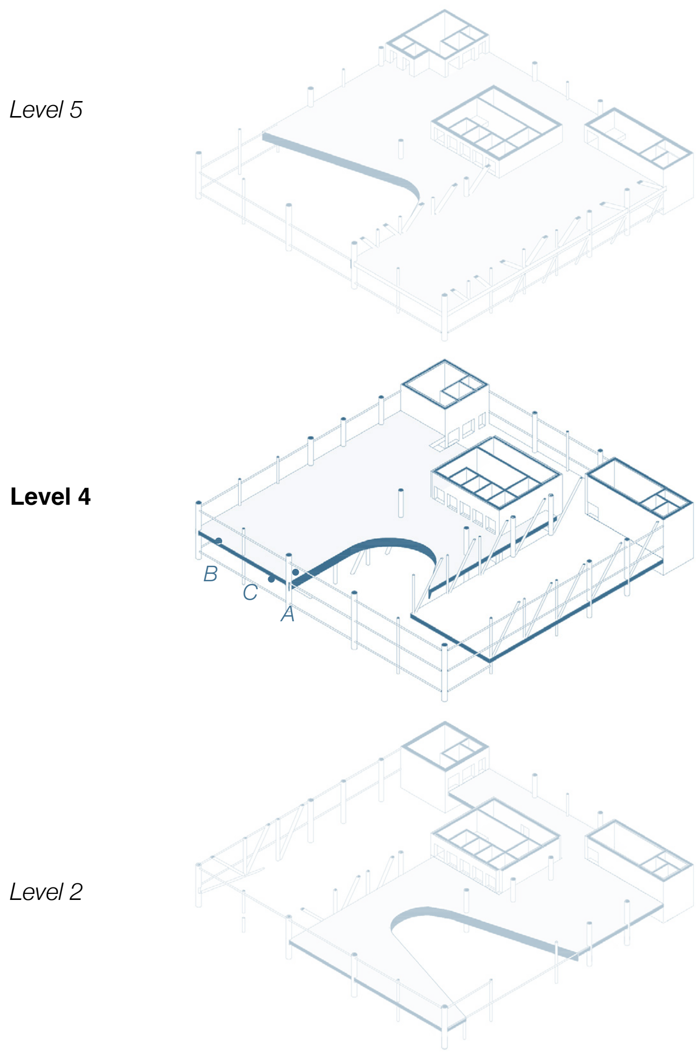


Image 57: Blow-up showing the levels studied and the critical points identified for Level 4

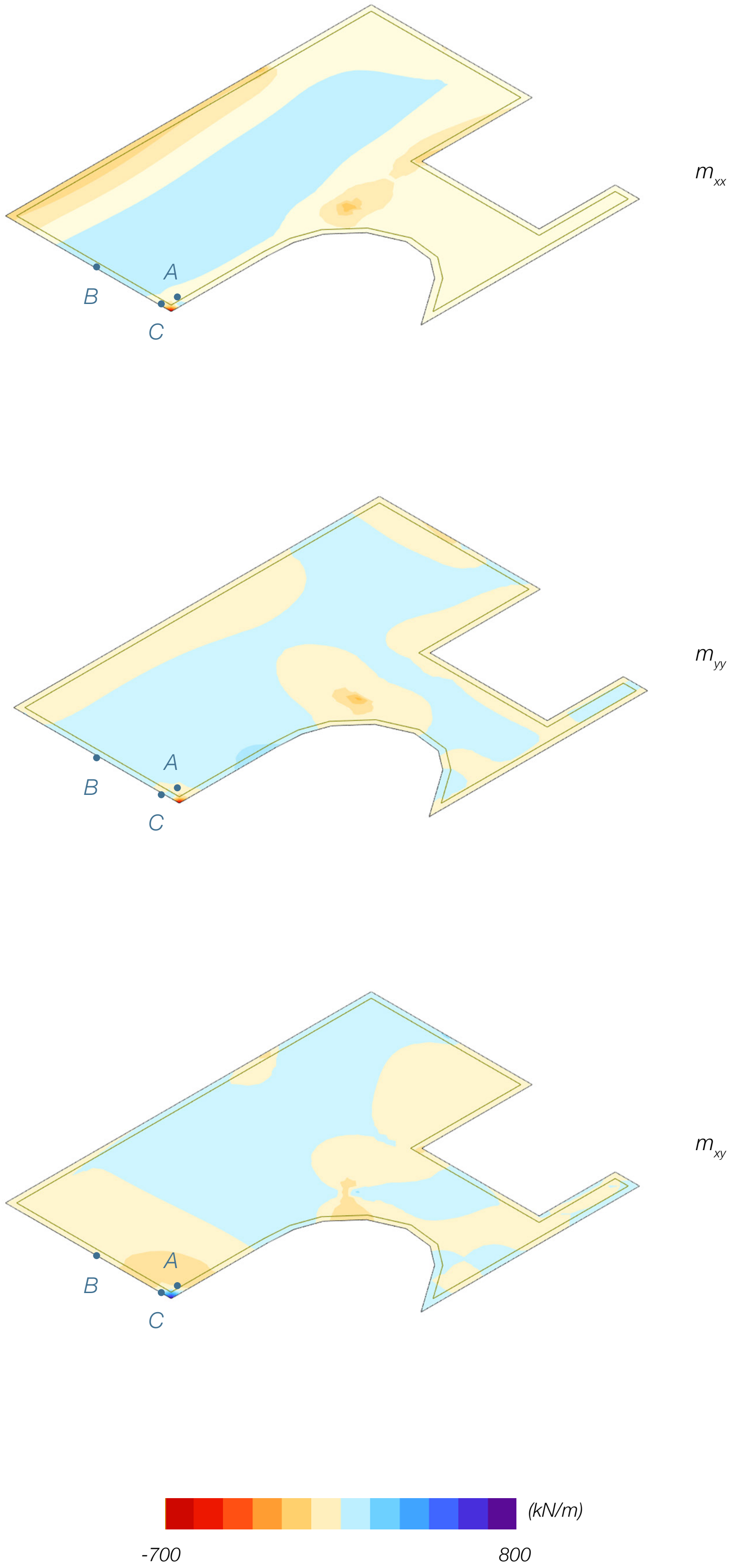


Image 58: Map results of the moments m_{xx} m_{yy} m_{xy} resulting on Level 4

node	m_{xx} (kNm)	m_{yy} (kNm)	m_{xy} (kNm)
A	-655.16	-679.66	709.65
B	456.41	9.14	-120.7
C	-282.65	611.53	225.51

Table 37: Level 4 m_{xx} m_{yy} and m_{xy} results of the structural analysis

Lower edge						
node	m_{xx} (kNm)	m_{yy} (kNm)	$\|m_{xy}\|$ (kNm)	case	m_{xx}*	m_{yy}*
A	m_{xx} o m_{yy} < - | m_{xy} | no lower reinforcement needed					
B	456.41	9.14	120.7	1	577.11	129.84
C	-282.65	611.53	225.51	3	0	791.45

*Table 38: m_{xx}, m_{yy} and m_{xy} values and the corresponding values of m_{xx} * and m_{yy} * for the lower edge*

Upper edge						
node	m_{xx} (kNm)	m_{yy} (kNm)	$\|m_{xy}\|$ (kNm)	case	m_{xx}*	m_{yy}*
A	655.16	679.66	709.65	1	1364.81	1389.31
B	-456.41	-9.14	120.7	3	0	22.78
C	282.65	-611.53	225.51	2	365.81	0

*Table 39: m_{xx}, m_{yy} and m_{xy} values and the corresponding values of m_{xx} * and m_{yy} * for the upper edge*

The sizing of the reinforcement grid both on the lower and upper edge, is carried out by selecting as critical points those highlighting situations of maximum positive bending and negative bending.
At this point we proceed to a calculation at the ultimate limit state; the reinforcing steel is B450C and therefore the design tension is equal to:

$$f_{yd} = 450 \text{ MPa} / 1.15 = 391.30 \text{ MPa}$$

The lever arm of the internal pair z is assumed, approximately, to be 0.8 times the thickness of the plate:

$$z = 0.8 \times 55 \text{ cm} = 44 \text{ cm}$$

Considering the following formula for the determination of the required reinforcement area,

Given the soliciting moment m_{xx}^* in x direction:

$$A_{x,theoreticall} = m_{xx}^* / (z \times f_{yd})$$

And the soliciting moment m_{yy}^* in y direction:

$$A_{y,theoretical} = m_{yy}^* / (z \times f_{yd})$$

Lower edge				
	m_{xx}^* (kNm)	m_{yy}^* (kNm)	$A_{x,theo}$ (cm^2)	$A_{y,theo}$ (cm^2)
B	577.11	129.84	28.36	6.38
C	0	791.45	0	38.89

Table 40: Critical values of m_{xx}^* and m_{yy}^* and definition of $A_{x,theo}$ and $A_{y,theo}$ needed at the lower edge

Upper edge				
	m_{xx}^* (kNm)	m_{yy}^* (kNm)	$A_{x,theo}$ (cm^2)	$A_{y,theo}$ (cm^2)
A	1364.81	1389.31	67.07	68.28

Table 41: Critical values of m_{xx}^* and m_{yy}^* and definition of $A_{x,theo}$ and $A_{y,theo}$ needed at the upper edge

At the lower edge it is necessary 52,8 cm^2 of reinforcement in x direction. While 31,36 cm^2 is required in y direction.

At the upper edge it is necessary 74,38 cm^2 of reinforcement in x direction. While 62,08 cm^2 is required in y direction.

The longitudinal reinforcement grids are considered for the whole extension of the Level 4 plate.

Furthermore, it is verified that the area of the longitudinal reinforcement $A_{s,theoretical}$ in the tense area in each of the two directions is higher than the minimum value provided by the NTC 2018 § 4.1.6.1.1.

$A_{s, min}$ is given by the following formula:

$$A_{s,min} = 0.26\, f_{ctm}/f_{yk}\, b_t\, d = 7.39 \text{ cm}^2$$

or, however, not less than:

$$A_{s,min} = 0.00013\, b_t\, d$$

where:

- b_t is the length of the tense area;
- d is the useful height of the section equal to 50 mm;
- f_{ctm} is the average value of the axial tensile strength equal to 2.56 N / mm^2;
- f_{yk} is the characteristic value of the tensile strength of the original reinforcement equal to 450 N / mm^2

Moreover, considering it is good practice to leave 7-8 cm between the reinforcement bars to allow concrete vibrations, we defined the upper and lower grids arrangement as follows:

Lower edge					
	A_{req} (cm^2)	n°	Φ (cm)	d (cm)	A_{real} (cm^2)
x	28.36	10	2	8	31.42
y	38.89	9	2.4	8,7	40.72

Upper edge					
	A_{req} (cm^2)	n°	Φ (cm)	d (cm)	A_{real} (cm^2)
x	68.58	10	3	7	70.69
y	62.08	10	3	7	70.69

However, the required longitudinal reinforcement diameters exceed the hypothesized thickness of the lower and upper concrete layers. Consequently, the overall plate thickness has been increased according to the needs and to the minimum reinforcement covering.

According to the product specification, whether the thickness increases compared to the one given by the producer chart, it will be necessary to add Δ_{PP}= 25Kg/m^2 per each cm of increase.

The Level 4 plate, that started with and hypothesized thickness of 65 cm, has been implemented with a 72 cm plate in order to ensure the either the displacement verification and the correct positioning of the bars as well as the minimum required reinforcement covering of 3.5 cm. Simulations have been carried once again with the increased slab weight and thickness and displacement and bending moments verification checked one more time.

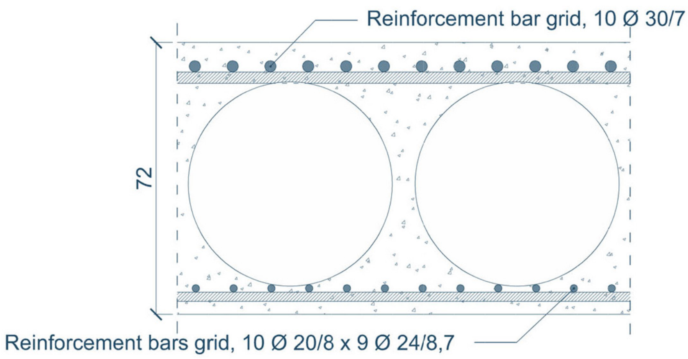


Table 42, 43 upper and lower reinforcement grids properties
Image 59: representation of Level 4 plate

Level 5

The procedure has been reiterated for the next critical levels. Once again, for what concerns Level 5, the nodal points in which the terns of values m_{xx} m_{yy} and m_{xy} represent the significant cases are indicated in the drawing and reported in the following tables. The significant cases have been identified as those highlighting the most critical values of m_{xx} and m_{yy}, either negative and positive.

- Table 44 shows the m_{xx} m_{yy} and m_{xy} results of the structural analysis
- Table 45 relates to the lower edge with the values of m_{xx}, m_{yy} and m_{xy} and the corresponding values of m_{xx} * and m_{yy} *
- Table 46 is similar to Table 45, for the upper edge

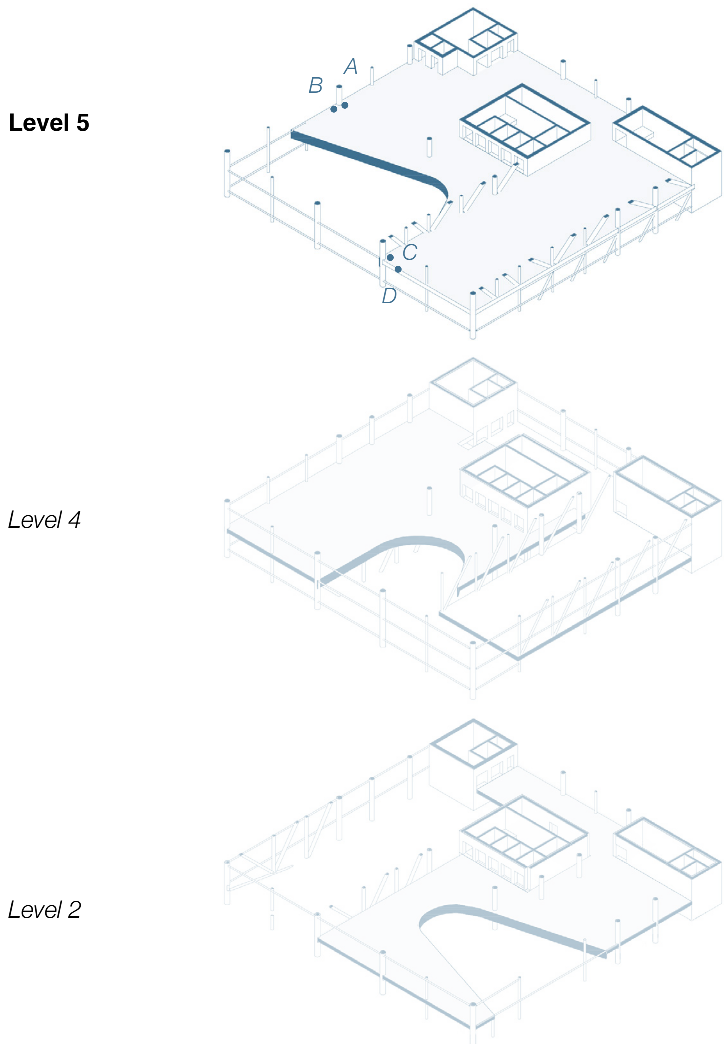


Image 60: Blow-up showing the levels studied and the critical points identified for Level 5

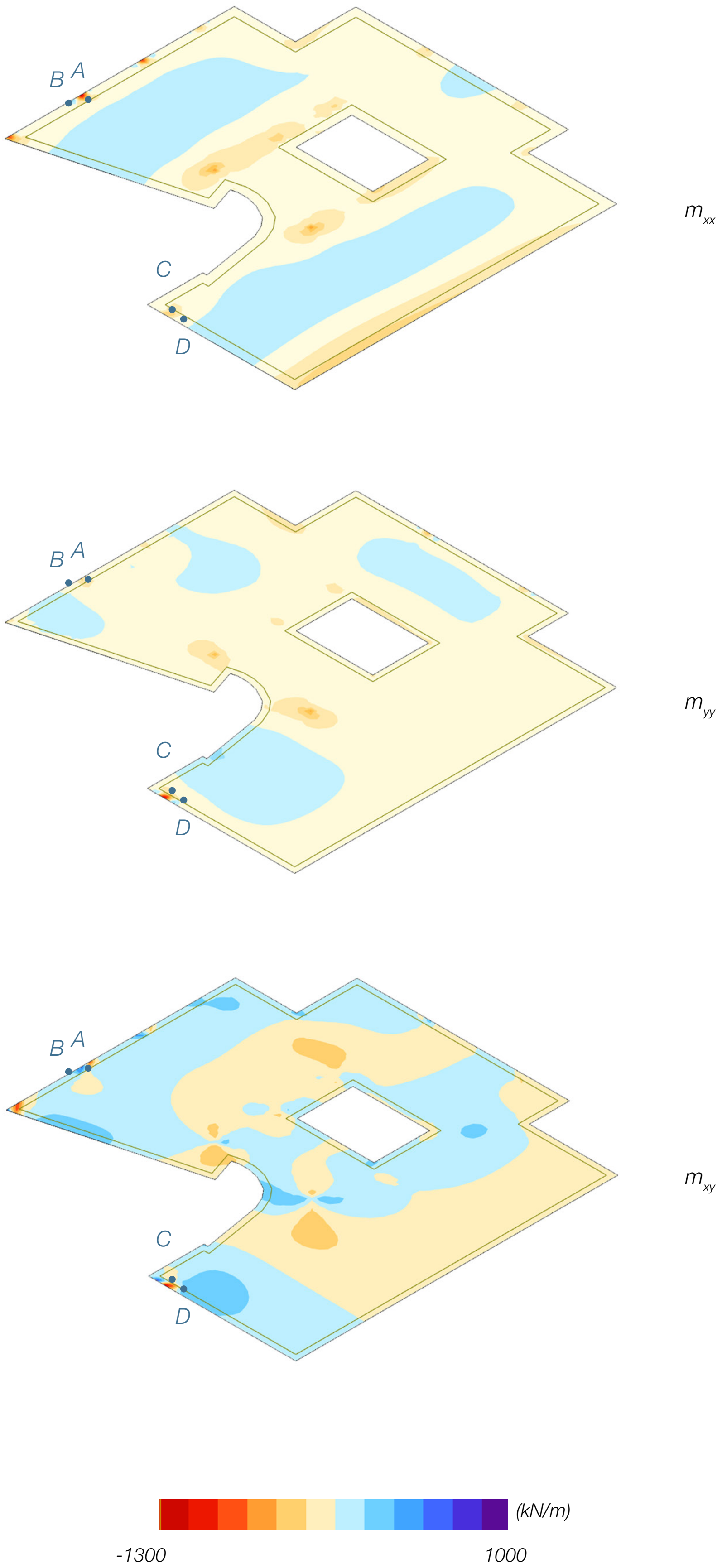


Image 61: Map results of the moments m_{xx} m_{yy} m_{xy} resulting on Level 5

node	m_{xx} (kNm)	m_{yy} (kNm)	m_{xy} (kNm)
A	-1265.86	-613.89	98.23
B	858.63	96.43	199.88
C	-776.6	-1120.55	-263.13
D	-243.78	909.69	-123.73

Table 44: Level 5 m_{xx} m_{yy} and m_{xy} results of the structural analysis

Lower edge						
node	m_{xx} (kNm)	m_{yy} (kNm)	$\lvert m_{xy} \rvert$ (kNm)	case	m_{xx}^*	m_{yy}^*
A	m_{xx} o m_{yy} < - $\lvert m_{xy} \rvert$ no lower reinforcement needed					
B	858.63	96.43	199.88	1	1058.51	296.31
C	m_{xx} o m_{yy} < - $\lvert m_{xy} \rvert$ no lower reinforcement needed					
D	-243.78	909.69	123.73	3	0	972.49

*Table 45: m_{xx}, m_{yy} and m_{xy} values and the corresponding values of m_{xx} * and m_{yy} * for the lower edge*

Upper edge						
node	m_{xx} (kNm)	m_{yy} (kNm)	$\lvert m_{xy} \rvert$ (kNm)	case	m_{xx}^*	m_{yy}^*
A	1265.86	613.89	98.23	1	1364.09	712.12
B	-858.63	-96.43	199.88	3	0	-49.900046
C	776.6	1120.55	263.13	1	1039.73	1383.68
D	243.78	-909.69	123.73	2	260.61	0

*Table 46: m_{xx}, m_{yy} and m_{xy} values and the corresponding values of m_{xx} * and m_{yy} * for the upper edge*

The sizing of the reinforcement grid both on the lower and upper edge, is carried out by selecting as critical points those highlighting situations of maximum positive bending and negative bending.
At this point we proceed to a calculation at the ultimate limit state; the reinforcing steel is B450C and therefore the design tension is equal to:

$$f_{yd} = 450 \text{ MPa} / 1.15 = 391.30 \text{ MPa}$$

The lever arm of the internal pair z is assumed, approximately, to be 0,8 times the thickness of the plate:

$$z = 0.8 \times 55 \text{ cm} = 44 \text{ cm}$$

Considering the following formula for the determination of the required reinforcement area,

Given the soliciting moment m_{xx}* in x direction:

$$A_{x,theoreticall} = m_{xx}^* / (z \times f_{yd})$$

And the soliciting moment m_{yy}* in y direction:

$$A_{y,theoretical} = m_{yy}^* / (z \times f_{yd})$$

Lower edge				
	m_{xx}* (kNm)	m_{yy}* (kNm)	$A_{x,theo}$ (cm^2)	$A_{y,theo}$ (cm^2)
B	1058.51	296.31	52.02	14.56
D	0	972.49	0	47.79

Table 47: Critical values of m_{xx} and m_{yy}* and definition of $A_{x,theo}$ and $A_{y,theo}$ needed at the lower edge*

Upper edge				
	m_{xx}* (kNm)	m_{yy}* (kNm)	$A_{x,theo}$ (cm^2)	$A_{y,theo}$ (cm^2)
A	1364.09	712.12	67.04	35.00
C	1039.73	1383.68	51.10	68.00

Table 48: Critical values of m_{xx} and m_{yy}* and definition of $A_{x,theo}$ and $A_{y,theo}$ needed at the upper edge*

At the lower edge it is necessary 52.8 cm^2 of reinforcement in x direction. While 31.36 cm^2 is required in y direction.

At the upper edge it is necessary 74.38 cm^2 of reinforcement in x direction. While 62.08 cm^2 is required in y direction.

The longitudinal reinforcement grids are considered for the whole extension of the Level 5 plate.

Furthermore, it is verified that the area of the longitudinal reinforcement $A_{s,theoretical}$ in the tense area in each of the two directions is higher than the minimum value provided by the NTC 2018 § 4.1.6.1.1.

$A_{s,min}$ is given by the following formula:

$$A_{s,min} = 0.26\, f_{ctm}/f_{yk}\, b_t\, d = 7.39 \text{ cm}^2$$

or, however, not less than:

$$A_{s,min} = 0.00013\, b_t\, d$$

where:

- b_t is the length of the tense area;
- d is the useful height of the section equal to 50 mm;
- f_{ctm} is the average value of the axial tensile strength equal to 2,56 N / mm^2;
- f_{yk} is the characteristic value of the tensile strength of the original reinforcement equal to 450 N / mm^2

Moreover, considering it is good practice to leave 7-8 cm between the reinforcement bars to allow concrete vibrations, we defined the upper and lower grids arrangement as follows:

	Lower edge				
	A_{req} (cm^2)	n°	Φ (cm)	d (cm)	A_{real} (cm^2)
x	52.02	10	2.6	7.4	53,09
y	47.79	10	2.5	7.5	49,09

	Upper edge				
	A_{req} (cm^2)	n°	Φ (cm)	d (cm)	A_{real} (cm^2)
x	67.04	10	3	7	70.69
y	68.00	10	3	7	70.69

However, the required longitudinal reinforcement diameters exceed the hypothesized thickness of the lower and upper concrete layers. Consequently, the overall plate thickness has been increased according to the needs and to the minimum reinforcement covering.

According to the product specification, whether the thickness increases compared to the one given by the producer chart, it will be necessary to add Δ_{PP}= 25 Kg/m^2 per each cm of increase.

The Level 5 plate, that started with and hypothesized thickness of 65 cm, has been implemented with a 73 cm plate in order to ensure the either the displacement verification and the correct positioning of the bars as well as the minimum required reinforcement covering of 3,5 cm. Simulations have been carried once again with the increased slab weight and thickness and displacement and bending moments verification checked one more time.

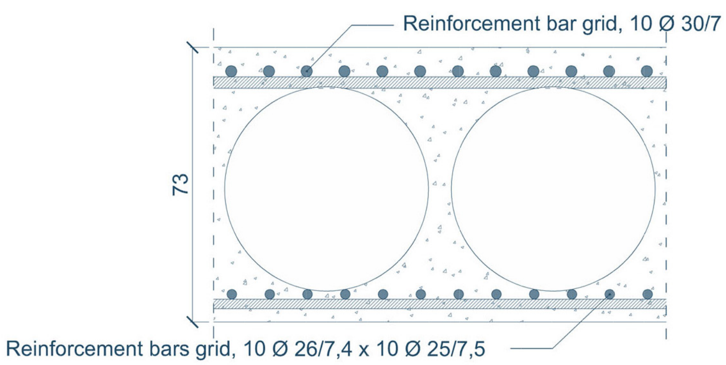


Table 49, 50: upper and lower reinforcement grids properties
Image 62: representation of Level 4 plate

Punching shear

Although the bending stresses have been central in the discussion up to this point, another component is dominant in influencing the plate design: the shear stress. The shearing stresses are maximum corresponding to the columns, other supports or where concentrated vertical loads are applied.
Considering a plate on columns, the entire reaction coming from the vertical element has to be distributed in the concrete at the interface between plate and column. Here there are considerable shear stresses, as well as high negative moments. Consequently, due to a great concentration of stresses, a sudden breakage collapse might occur due to penetration through the plate, with the formation of diagonal cracks that cross the concrete thickness. This type of collapse is called punching.
Reinforcement bars, arranged to resist bending in the upper and lower layers, partially opposes the development of these phenomena. In some cases a too small percentage of bending reinforcement at the column might lead to the collapse. It is therefore necessary to dimension the reinforcement in these areas also considering punching shear danger. In order to avoid the risk of fragile collapse, special punching shear reinforcements which cross vertically the breaking cone are used to absorb the tensile stresses through the crack.
The punching shear analysis has been carried out for simplicity with the support of a further software: Peikko Designer®. The reaction coming from the bearing column on the plate is calculated with the support of Robot Structures. And the punching shear reinforcement is dimensioned for the element identified having the highest shear stresses.

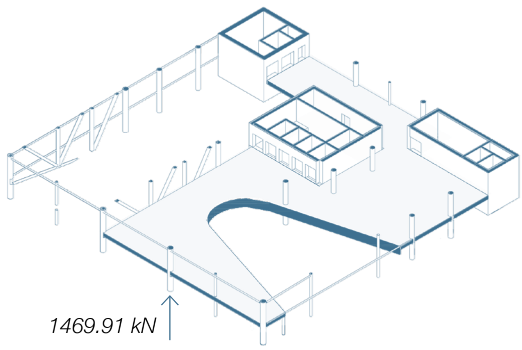


Image 63: identification of the highest shear stresse

With the following input data, and the aid of the software, a punching shear reinforcement system of 7xPSB Φ 25/535-2/800 has been designed.
The input and the output data are reported in the tables below and a graphical representation is reported as well.
It is important to consider that the area of the plate surrounding the column is not provided with the lightening component for a an area defined by a 30° oriented guideline.

Geometry		
thickness (mm)	$h_d = 610$	
useful thickness (mm)	$d_x = 525$	$d_y = 525$
bars covering (mm)	$c_u = 40$	$c_o = 40$
% longitudinal reinforcement	$p_x = 1.17$	$p_y = 1.17$
column (mm)	d = 750	

Table 51: geometrical input data

Materials			
Material	Class	f_{cd} (N/mm^2)	ref.
Concrete	C25/30	$\alpha_{cc} = f_{ck} / \gamma_c = 14$	EN 206-1
Steel	B450	$f_{yd} = f_{yk} / \gamma_s = 391$	EN 10080

Table 52: materials imput data

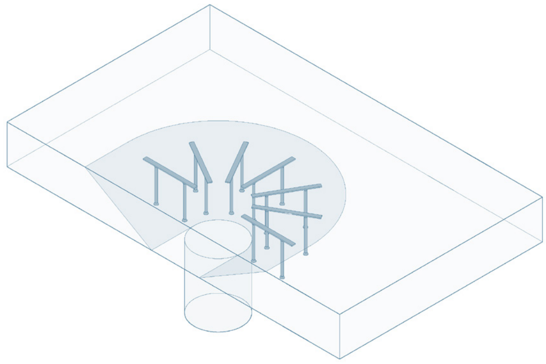


Image 64: representation of the punching shear reinforcement

Loads	
punching shear stress (kN)	V_{ed} = 1469.4
load increase factor	β = 1.4

Table 53: loads imput data

Punching shear reinforcement	
design	7xPSB-25/535-2/800(200/400/200)
reinforcement bearing capacity (kN)	2229.8

Table 54: reinforcement dimensioning output data

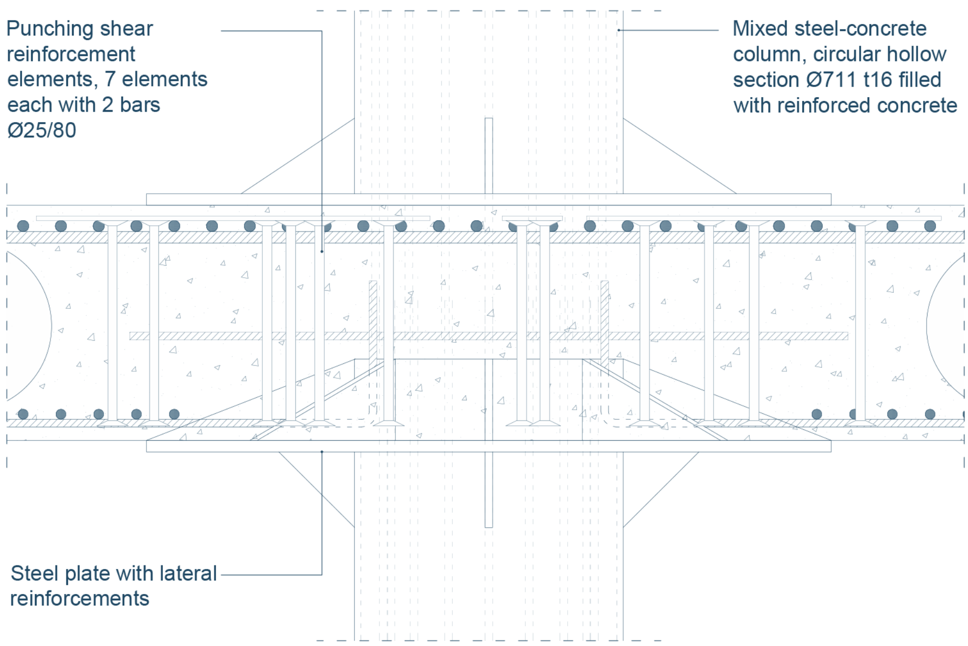


Image 65: Intermidiate connection between column and plate highligting the the punching shear reinforcement

Columns

Concerning the design of structural columns in the building, two critical columns were analysed:

- one column on the perimeter that reaches the structure on the roof, supports the intermediate slabs and takes the loads on the façade.
- one column in the centre of the building that supports the main hall and intermediate slabs

It was chosen the worst case for both of the columns type, so the ones with more area of influence and receiving more loads from other structures. The columns were designed for the ground floor, bearing the highest loads from the upper floors. The structures for the parking spaces were not designed here, considering the absence of particular aesthetic and spatial requirements.
The structural scheme used for the analysis includes continuous columns and beams/slabs interrupted at the intersections. The constraints are designed as hinges both to the ground and at the top, considering also the link between beams/ slabs and the columns as hinges. The β coefficient (that influence the calculus of the buckling length) is then considered as 1.

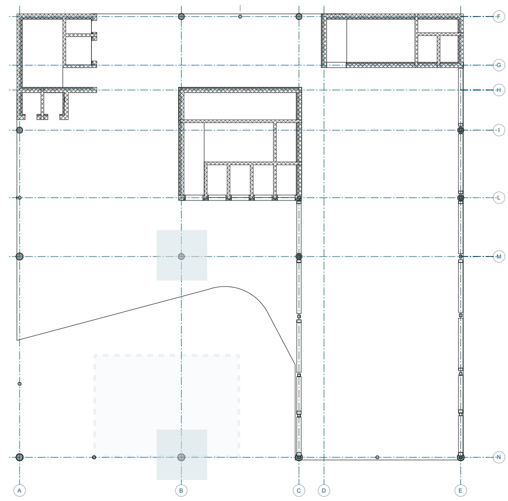


Image 66: columns identification on level 5 and identification of the perimeter one's influence area

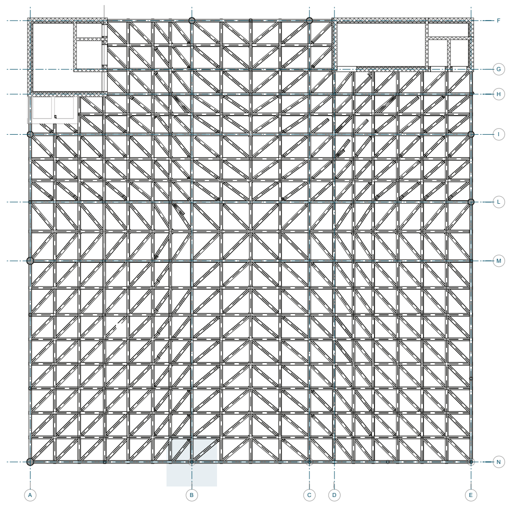


Image 67: columns identification on level 6

Column design

The loads were calculated considering an area of 14.25x9.35 m^2 for the perimeter column and 14.25x8.00 m^2 for the internal one.
For the perimeter column it was considered just one slab, because of the double height at each floor, the roof structure and the façade dead loads. For the inner column it was considered the main hall load and three more slabs. It was then necessary to add the dead load of the columns, considering the specific weight of the materials and the overall height. Considering the large loads bearing on the columns it was used a mixed system, with a core in reinforced concrete and a tubular steel element. The longitudinal reinforcement bars are designed using the minimum values provided by the 2018 NTC (§ 4.1.6.1.2).
The profiles used are a Ø711 t16 steel tubular filled with concrete reinforced with 16ϕ20 bars for the perimeter columns and a Ø610 t16 steel tubular filled with concrete reinforced with 16ϕ30 bars for the inner columns. To verify these profiles it was considered the compression stress at ULS and SLS other than the local and global instability at SLS. It can be interesting to notice that, even if the axial load is higher on the internal column, the higher buckling length of the perimeter column leads to an higher risk of instability which makes it necessary to increases its diameter, exciding the other. For simplicity the calculations have been carried out only for the two most critical columns, a perimeter one and an internal one. All the remaining components have been assumed of the same dimension of the verified ones.

Perimeter column

Definition of internal loads

To calculate the influence area of the columns it was taken into account half of the distances from the structural grid.
For the perimeter column it is 8,25 m on the left, plus 6 m on the right and 9,35 m on the back, that considering a static indetermination bi-dimensional coefficient of 1,4, makes an area of:

$$14.25 \times 9.35 \times 1.4 = 186.5 \text{ m}^2$$

	Type of load	Value (kN/m²)	SLS (kN)	ULS (kN)
G1	Slab (1)	10.2	1891.95	2459.54
G2	Floor	1.06	197.73	296.59
G2	Walls	1.2	223.84	335.76
G2	Façade	\	663.91	863.09
qk	People	5	932.66	1398.99
R	Roof	\	7566.39	8407.10
	Total		11060.15	13136.57
G1	Column	\	828.35	1076.85
	Grand total		11888.49	14213.42

Table 55: loads definition both for SLS and ULS

Reinforcement bars

To dimension the reinforcement bars it is used the 2018 NTC (§ 4.1.6.1.2) where the minimum areas are examined:

- Geometric limit: $A_s \geq 0.3\% \ A_c = 1561 \ mm^2$
- Mechanic limit: $A_s \geq 0.1 \ N_{Ed} / f_{yd} = 3635 \ mm^2$
- Technological limit: $A_s \geq A_{min} = 452$ mm

A_{min} as the area of 4 ϕ12

To satisfy those requirements it was chosen 16ϕ20 with a total reinforcement area of

$$A_s = 5026{,}55 \ mm^2$$

To verify the reinforcement bars at SLS, it is going to be used the formula

$$N/A_{ie} = \sigma_c < \sigma_{c\ adm}$$

where:

$\sigma_{c\ adm} = 0.6 \ f_{ck}$
$A_{ie} = A_c + \alpha_e A_s$
$\alpha_e = 15$

Using the values relative to the perimeter column it is obtained:

$$A_{ie} = A_c + \alpha_e A_s = 0.96 \ m^2$$

$$\sigma_c = N/A_{ie} = 11888.49 / 0.96 = 12136.68 \ kPa = 12.14 \ N/mm^2 < 14.2 \ N/mm^2$$

The verification at ULS is based on the formula

$$\gamma = N_{Rd} / N_{Ed} > 1$$

$$N_{Rd} = 0.8 \times A_c \times f_{cd} + A_s \times f_{yd} = 19738.24 \ kN$$
$$\gamma = 29273.54 / 19738.24 = 1.42 > 1$$

Compression and stability

To define the mixed columns resistance to compression (ULS) it was calculated the value of $N_{pl,Rd}$ trough the formula:

$$N_{pl,Rd} = f_{cd} \times A_c \times (0.8 + 1.6 \ w_w + w_L)$$
$$w_s = (f_{yd} \times A_s) / (f_{cd} \times A_c) = 0.38$$
$$w_w = (f_{yd} \times A_w) / (f_{cd} \times A_c) = 2.66$$

It can be verified that $N_{pl,Rd} > N_{Ed}$

$$N_{pl,Rd} = 27933.87 \ kN > 14213.42 \ kN$$

For the stability test on SLS it is assumed that the value of the inertia moment I is a combination of the three values:

$$I_{eff} = 0.6 \ I_c + I_W + I_S = 837089 \ cm^4$$

Following the § 4.2.4.1.3.1 in 2018 NTC:

$$N_{B,Rd} = \chi \times N_{pl,Rd}$$

χ depends on the type of section and the type of steel; it derives from the following values:

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \bar{\lambda}^2}} \leq 1$$

Φ is given by the following formula:

$$\phi = 0.5\left[1 + \alpha\left(\bar{\lambda} - 0.2\right) + \bar{\lambda}^2\right]$$

α is the imperfection factor (Tab. 4.2.VIII NTC2018) and for mixed profiles α = 0.21.

λ is the dimensionless slenderness:

$$\bar{\lambda} = \sqrt{\frac{A * f_{yk}}{N_{cr}}}$$

N_{cr} is the Eulerian critical load:

$$N_{cr} = \pi^2 * E * \frac{I}{l_0^2}$$

l_0 is the buckling lenght, which depends on the type of constraints.

It is then verified that $N_{brd} > N_{ed\,(SLS)}$ demonstrating the stability of the column.

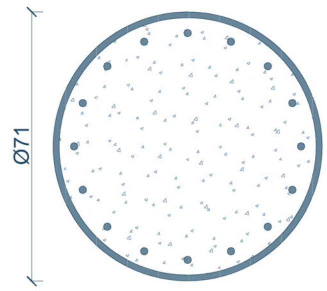


Image 68: rapresentation of the perimetral column

	Concrete	Reinforcement bars	Tubular steel profile
Areas	A_c = 2623.89 cm²	A_s = 113.10 cm²	A_w = 298.58 cm²
Inertia	I_c = 547874 cm⁴	I_s = 63.61 cm⁴	I_w = 131781 cm⁴

SLS (kN)	l_0 (m)	λ' (/)	α (/)	Φ (/)	χ (/)	N_{brd} (kN)
11888,49	21	1.4	0.2	1.6	0.4	12022.3

Table 56, 57: Input values used in the calculations

Internal column

The same procedure has been followed for the internal column, with an influence area of:

$$14.25 \times 8.00 \times 1.4 = 159.6 \text{ m}^2$$

For the reinforcement bars:

- Geometric limit: $A_s \geq 0.3\%\ A_c$ = 877 mm²
- Mechanic limit: $A_s \geq 0.1\ N_{Ed} / f_{yd}$ = 4498 mm²
- Technological limit: $A_s \geq A_{min}$ = 452 mm²

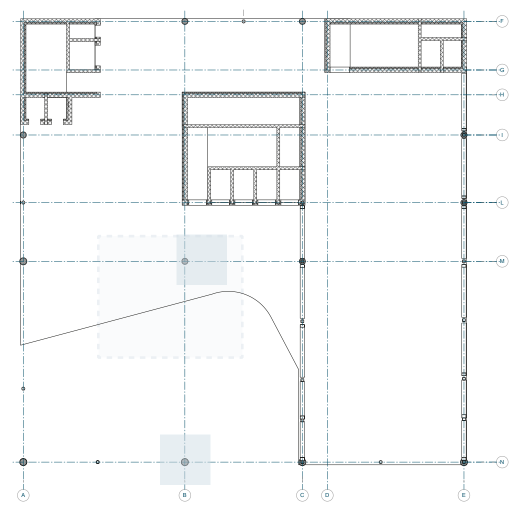


Image 69: columns identification on level 5 and identification of the internal one's influence area

To satisfy those requirements it was chosen 16ϕ30 with a total reinforcement area of

$$A_s = 11309.73\ mm^2$$

For SLS: σ_c = 14.1 N/mm² < 14.2 N/mm²

For ULS: N_{Rd} = 19077.20 kN > 17588.29 kN

For the compression:

w_w = 3,13; w_l = 1.19

$N_{pl,Rd}$ = 26081.82 kN > 17588.29 kN

For the stability:

N_{bRd} = 23887.53 kN > 12409.59 kN

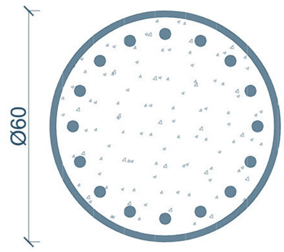


Image 70: rapresentation of the internal column

	Type of load	Value (kN/m²)	SLS (kN)	ULS (kN)
G1	Slab (1)	10.2	1618.78	2104.42
G2	Floor	1.06	169.18	253.76
G2	Walls	1.2	191.52	287.28
qk	People	5	798.00	1197.00
R	Main Hall	\	4850.00	7275.00
	Total		12135.43	17231.88
G1	Column	\	274.16	356.40
	Grand total		12409.59	17588.29

Table 58: loads definition both for SLS and ULS

	Concrete	Reinforcement bars	Tubular steel profile
Areas	A_c = 2623.89 cm²	A_s = 113.10 cm²	A_w = 298.58 cm²
Inertia	I_c = 547874 cm⁴	I_s = 63.61 cm⁴	I_w = 131781 cm⁴

SLS (kN)	l_0 (m)	λ' (/)	α (/)	ϕ (/)	χ (/)	N_{brd} (kN)
12409.59	6.5	0.53	0.2	0.7	0.9	23887.53

Table 59, 60 : tables collecting the input values used in the calculations

Trusses

Three trusses were introduced in order to cover the 20,5m span in the part of the plan facing South. The need of truss is the result of the architectural will of defining clearly outstanding volumes detached from the rest of the building. This avoids the presence of columns in the foyers or in the floor cuts, that would be both an architectural and a functional mistake.
The shape of this trusses is designed in order to bear the diagonal elements with tension axial forces, avoiding the instability due to compression.

Definition of internal loads

The internal loads were defined for both the lower and the upper slabs bearing on the trusses, except for the second truss (experimental theatre) that has no upper loads.
To these loads it was also added the weight of the façade and the dead load of the top columns.
It was then distinguished between the distributed load for the slab (kN/m) and the punctual loads (kN) caused by the columns.
The profiles are squared steel tubular:

Truss	**1_Theatre 1**	**2_Theatre 2**	**3_Reharsal rooms**
Top	D350 t16	D220 t16	D400 t20
Bottom	D220 t16	D300 t16	D350 t16
Vertical	D350 t16	D220 t16	D300 t16
Diagonal	D350 t16	D220 t16	D450 t20

Table 61 : classification of the profiles used for the three different truss

Profile	h (cm)	t (cm)	A (cm^2)	I (cm^4)	W_{pl} (cm^3)
D 220 t16	22	1.6	128	8730	968
D 300 t16	30	1.6	179	23824	1894
D 350 t16	35	1.6	211	38912	2629
D 400 t20	40	2.0	300	71468	4245
D 450 t20	45	2.0	334	98550	4920

Table 62 : characteristics of the different profiles used

The internal loads were defined for both the lower and the upper slabs bearing on the trusses, except for the second truss (experimental theatre) that has no upper loads.
For the calculations of loads, stresses and displacements of the trusses the software "Ftool" to obtain the normal stresses of the elements.

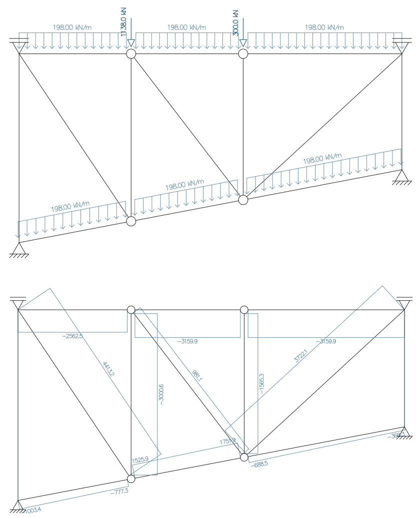


Image 71: 2D discretization of the first theatre truss

First theatre truss

The uniform loads were calculated for half of the span for each truss, that means for 8,25m.

The concentrated loads on the first column were calculated using an influence area of

$$A = 4 \times 8.25 \times 1.4 = 46.20 \ m^2$$

Second theatre truss

For the second column it was considered an height of the facade of 30.5m.
The uniform loads were calculated for half of the span for each truss, that means for 7m. There are not concentrated loads for this truss.

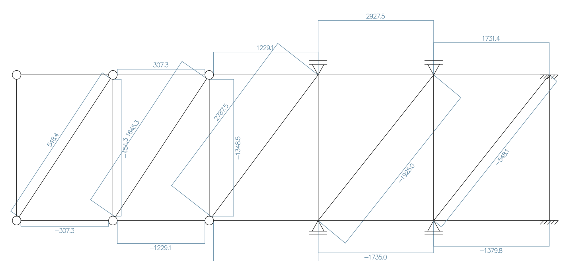


Image 72: 2D discretization of the second theatre truss

Reharsal rooms truss

The uniform loads were calculated for half of the span for each truss, that means for 8.25m.

For the concentrated loads it was considered an height of the facade of 25m and a different length of influence (10 and 9m).

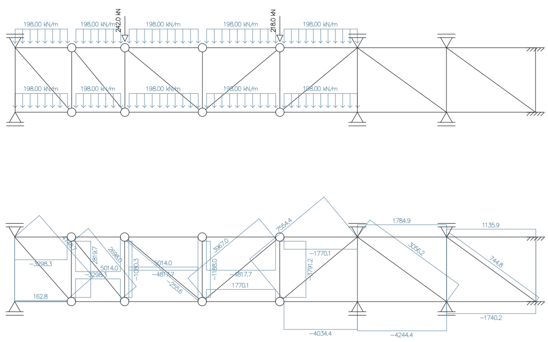


Table 63: 2D discretization of the rehearsal rooms

T1	Type of load	Value (kN/m²)	SLS (kN/m)	ULS (kN/m)	ULS (kN)
G1	Slab (1)	10.2	83.68	108.78	\
G2	Floor	1.06	8.75	13.12	\
G2	Walls	1.2	9.90	14.85	\
qk	People	5	41.25	61.88	\
	Total distributed	\	132.41	198.62	\
	First column	\	\	\	1137.42
	Second column	\	\	\	299.14

Table 64: loads definition both for SLS and ULS

T1	N_{ed} (kN)	A_{min} (cm²)	A_{real} (cm²)	I (cm⁴)	l_0 (m)	N_{cr} (kN)	N_{brd} (kN)
Top	-3159.9	132.1	211	38912	8.5	11162.6	3932.8
Bottom	1751.9	73.3	115	6377	7	\	\
Vertical	-3000.6	125.5	211	38912	9	9956.8	3786.2

Table 65: data relative to the first theatre's truss profiles

T2	Type of load	Value (kN/m²)	SLS (kN/m)	ULS (kN/m)	ULS (kN)
G1	Slab (1)	10.2	71.00	92.30	\
G2	Floor	1.06	7.42	11.13	\
G2	Walls	1.2	8.40	12.60	\
qk	People	5	35.00	52.50	\
	Total distributed	\	121.82	168.53	\

Table 66: loads definition both for SLS and ULS

T2	N_{ed} (kN)	A_{min} (cm²)	A_{real} (cm²)	I (cm⁴)	l_0 (m)	N_{cr} (kN)	N_{brd} (kN)
Top	2927.5	122.4	128	8730	6.9	\	\
Bottom	-2921.1	122.2	179	23824	6.5	11687.1	3544.1
Vertical	-1348.5	56.4	128	8730	8.5	2504.4	1477.5
Diagonal	2787.5	116.6	128	8730	10	\	\

Table 67: datas relative to the second theatre's truss profiles

T3	Type of load	Value (kN/m²)	SLS (kN/m)	ULS (kN/m)	ULS (kN)
G1	Slab (1)	10.2	83.68	108.78	\
G2	Floor	1.06	8.75	13.12	\
G2	Walls	1.2	9.90	14.85	\
qk	People	5	41.25	61.88	\
	Total distributed	\	132.41	198.62	\
	First column	\	\	\	241.35
	Second column	\	\	\	217.19

Table 68: loads definition both for SLS and ULS

T3	N_{ed} (kN)	A_{min} (cm²)	A_{real} (cm²)	I (cm⁴)	l_0 (m)	N_{cr} (kN)	N_{brd} (kN)
Top	-4817.7	201.5	300	71468	7	30229.8	6524.4
Bottom	-4244.4	177.5	211	38912	7	16459.1	4360.6
Vertical	-3791.2	158.6	179	23824	5	9956.8	3786.2
Diagonal	7539.4	315.3	334	98550	9	\	\

Table 69: data relative to the third theatre's truss profiles

Main hall structure

The structure for the main hall represented an important challenge for the design, due to its volume and shape.
The criteria for the design choices are as follow:

- the volume has to be clearly recognizable so the structure has to be detached from the external frame.
- the internal loads of the main hall shouldn't increase the stress on the roof, already overloaded by the very large span.
- the structure should not be visible at all from the inside in order to guarantee a good quality of the space and sound.
- the number of columns under the main hall should be reduced at the minimum not to affect the open plan scheme.
- the structure of the main hall has to allow the circulation around it and the access trough it.
- the structure should follow the main hall shape in order to optimize the space and use of material.

Because of those criteria an usual orthogonal frame was excluded, as well as a structure hanging from the roof. Another option was an ovoid geodesic dome but, apart from the complexity

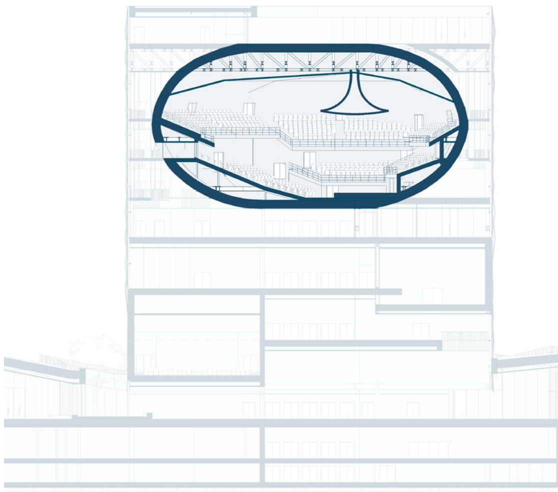


Image 73: identification of the main hall

of the shape and charges, the intersection with the structure on the roof would have been impossible.

The best option was to create curved vertical elements on the external part of the main hall, bearing the internal loads and transferring them to the central plate on the bottom of the structure. This plate is then supported by two columns on the front and the elevators core on the back. The vertical elements are supported by two horizontal trusses that prevent an excessive displacement and transfer the horizontal loads on the two structural cores in the back of the building.

The analysis and study of this structure followed different steps:

- the definition of the internal loads
- the creation of analytical 2D models of each element, in order to size the profiles and understand the main difficulties
- the creation of a 3D model of the structure, simulating a realistic behaviour of the whole structure
- the dimensioning of the bottom plate and columns which are the final load bearing elements.

Definition of internal loads

In order to define the internal loads it has been necessary at first to create a simplified version of the real structure and identify the highest load.
The main hall was then divided in 13 "slices" each one supported by one curved vertical elements placed in the centre of it. The number of the slices and the relative elements was chosen in order to not have an excessive area bearing on the element and guarantee the access trough it

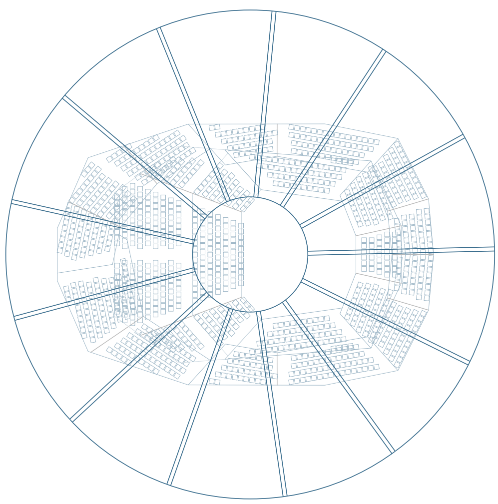


Image 74: projection of the 13 slices

in different points on different levels.
The vertical elements were then divided in 3 types depending on the disposition of the slabs and seats inside the main hall (4 on the left, 3 on the right, 3+3 top and bottom). Each type was then simplified in a dashed line which follows the external shape of the main hall and change direction on the points were the internal loads are positioned (trough columns). These points were identified on the same height for the three types, in order to simplify the realization of the 3D model.

To calculate the highest load on the vertical elements it was considered the largest "slice" of slab and simplified in a rectangular shape (5x5 m). Considering the permanent and variable loads it was then calculated the load on each column and then, adding the weight of the column, the punctual load on the vertical elements. The result was two values of loads, one with half of the slab (205 kN) and one simulating two halfs (330 kN).

For the calculations of internal loads of the main hall it was considered a light slab, supported by steel profiles (11,4x11,4 cm) and made of XLAM (4 cm). The total load has been calculated adding the internal partitions, the accidental loads, and the weight of the columns that are transferring the loads to the curved vertical elements. To define the columns it was calculated the minimum area trough the formula.

$$N_{pl,Rd} = (f_{yk} / \gamma_{M0}) \times A$$

f_{yk} is the yield point of steel (275 MPa);
γ_{M0} is the safety factor (1st class 1,05);
A is the gross section.

It is assumed that the plastic resistance $N_{pl,Rd}$ equals the axial design force N_{ed}, in order to find the gross section.

It is analysed a squared tubular section of 114.3x4.5 mm

To verify the instability it is going to be used the § 4.2.4.1.3.1 in 2018 NTC:

$$N_{B,Rd} = (\chi\, A\, f_{yk})/\gamma_{M0}$$

χ depends on the type of section and the type of steel; it derives from the following values:

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \bar{\lambda}^2}} \leq 1$$

Φ is given by the following formula:

$$\phi = 0.5\left[1 + \alpha\left(\bar{\lambda} - 0.2\right) + \bar{\lambda}^2\right]$$

α is the imperfection factor (Tab. 4.2.VIII NTC2018) and for I profiles α = 0.49.

λ is the dimensionless slenderness:

$$\bar{\lambda} = \sqrt{\frac{A * f_{yk}}{N_{cr}}}$$

N_{cr} is the Eulerian critical load:

$$N_{cr} = \pi^2 * E * \frac{I}{l_0^2}$$

	Type of load	H (m)	B (m)	ρ (kN/m³)	Value (kN/m²)	A (m²)	SLS (kN)	ULS (kN)
G1	Slabs	0,04	\	6	0,24	35	12,6	16,4
G1	Frame	0,1	0,1	78,5	\	5 m	0,4	0,5
G2	Floor	\	\	various	1,1	35	37,1	48,2
G2	Walls	\	\	various	1,2	35	42,0	63,0
qk	People	\	\	\	5	35	175	262,5
	Total						225,4	328,9
G1	Column	0,1	0,1	78,5	\	6 m	1	1.3
	Grand total						226,4	330,2

Table 70: loads definition both for SLS and ULS

ULS (kN)	A_{min} (cm²)	E (MPa)	I (cm⁴)	A_{real} (cm²)	β (/)	l_0 (m)	N_{cr} (kN)
329,5	10,6	210000	234	15,5	1	3	538,9

Table 71: data relative to the column verifications (ULS)

SLS (kN)	A_{min} (cm²)	A_{real} (m²)	λ' (/)	α (/)	Φ (/)	χ (/)	N_{brd} (kN)
225,9	10,6	15,5	0,9	0,5	1,1	0,6	246,2

Table 72: data relative to the column verifications (SLS)

l_0 is the buckling length, which depends on the type of constraints.
It is then verified that $N_{brd} > N_{ed\ (SLS)}$ so the pillar is stable.

Creation of analytical 2D models

With the geometry and the loads it was possible to analyse the elements trough a 2D model made using the software "Ftool".
Simulating the behaviour of the vertical elements, it was placed an hinge at the bottom simulating the plate, and a roller at the top in order to prevent any vertical load on the structure of the roof. Also the horizontal trusses were simplified as rollers, in order to establish the stress on them, find the section of the truss elements and their displacement. With these values it was possible to determine the rigidity of the horizontal trusses (k=F/d) and replace the rollers with springs.
It was then possible to determine the section of the vertical elements verifying the compression stress at ULS and the global instability at SLS.
The chosen profiles are extra wide flange beams HL 920x449 for the vertical elements and HE 550 M for the horizontal trusses.

The schemes and results for the three types of curved vertical elements and the horizontal trusses are presented as follows:

The chosen profiles are extra wide flange beams HL 920x449 for the vertical elements and HE 550 M for the horizontal trusses. These choices are oriented on not having a large displacement, so the profiles are bigger than the minimum for the internal stresses.
In the table 74, 75 are represented the maximum values of axial, shear and bending moment for the three curved vertical elements and for the elements in the trusses.

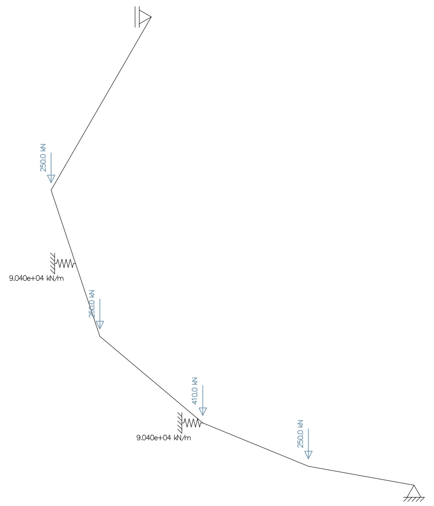


Image 75: 2D discretization of a main hall beam

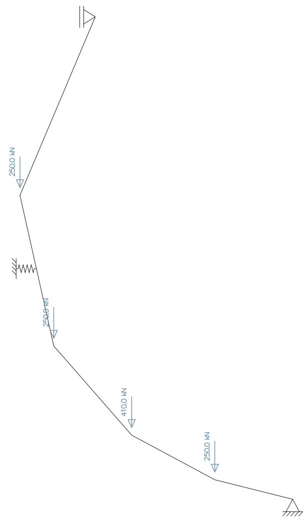


Image 76: 2D discretization of a main hall beam

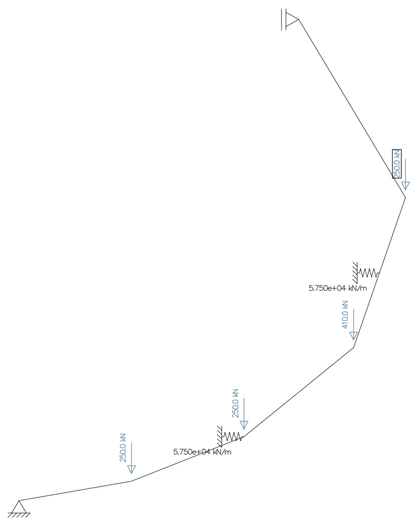


Image 77: 2D discretization of a main hall beam

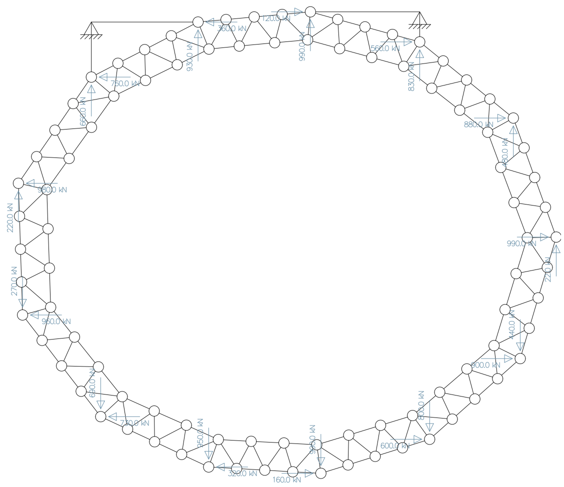


Image 78: *2D discretization of the horizontal truss*

Axial load

To verify the axial load it was calculated the minimum area and the stability of the compressed elements trough the formulas presented for the column:

$$A_{min} = N_{pl,Rd}\, \gamma_{M0} / f_{yk}$$
$$A_{real} > A_{min}$$
$$N_{brd} > N_{ed\,(SLS)}$$

Profile	h (cm)	b (cm)	t_w (cm)	t_f (cm)	A (cm^2)	I (cm^4)	W_{pl} (cm^3)
HL 920x449	94.8	42.3	2.4	4.27	571,4	874700	20950
HE 550 M	57.2	30.6	2.1	4.0	354.4	198000	7933.0

Table 73: Main hall structure profiles used

Element	N_{ed} (kN)	I (cm^4)	A_{min} (cm^2)	A_{real} (cm^2)	l_0 (m)	N_{cr} (kN)	N_{brd} (kN)
Vertical	-2553.6	966300	105.9	571,4	17	69300.0	13785.7
Truss-external	2477.6	198000	103.6	354.4	9	\	\
Truss-internal	2386.1	198000	99.8	354.4	8	\	\
Truss-diagonal	-489.4	198000	20.5	354.4	3	455975	9539.0

Table 74: Profiles axial loads

Element	V (kN)	M (kNm)	A (cm^2)	A_v (cm^2)	$V_{c,Rd}$ (kN)	$W_{pl\,min}$ (cm^3)	$W_{pl\,real}$ (cm^3)
Vertical	807.8	2853.7	571,4	536.5	8112.1	10896.0	23000.0
Truss-links	82.9	180.6	354.4	318.3	4812.7	689.6	7933.0

Table 75: Profiles shear loads

Bending moment

Following the NTC, § 4.2.4.1.2, to verify the bending moment it is necessary:

$$M_{Ed} \leq M_{c,R}$$

Being the profiles in 1st class 1 it would be:

$$M_{c,Rd} = (W_{pl\ real}\ f_{yk}) / \gamma_{m0}$$
$$M_{Ed} = (W_{min}\ f_{yk}) / \gamma_{m0}$$
$$W_{pl\ min} < W_{pl\ real}$$

Shear

To verify the shear force on the profiles, the NTC, § 4.2.4.1.2, has to be respected:

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

Being the profiles in 1st class 1 it would be:

$$V_{c,Rd} = (A_v\ f_{yk} / (\surd 3\ \gamma_{m0})$$

For IPE profiles loaded in the weld plane, it can be assumed that:

$$A_v = A\text{-}2b_{tf} + (t_w + 2r)\ t_f$$

Being $V_{Ed} \leq 0{,}5\ V_{c,Rd}$, the NTC, § 4.2.4.1.2, states that the shear won't have any influence on the bending resistance of the elements.

Creation of 3D model

To control the behaviour of the whole structure working together, a 3D model was created using Autodesk Robot Structural Analysis. This software allows to check the maximum displacement of the structure, using as inputs the 3D geometry, the profiles, the loads and the constraints. The maximum displacement of the elements was 0,054m that, considering the large span, allows the connection with the outside slabs and stairs.

After the creation of a 3D model with the correct 3D geometry, profiles, loads and constraints, it was possible to calculate accurately the maximum axial force, bending moment and displacement.
The results were higher than the 2d analysis, but the profiles remains still verified.

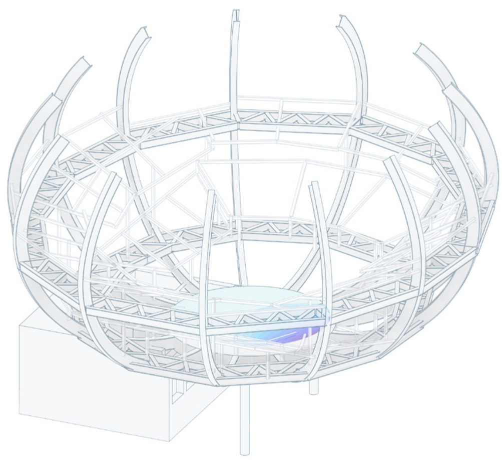


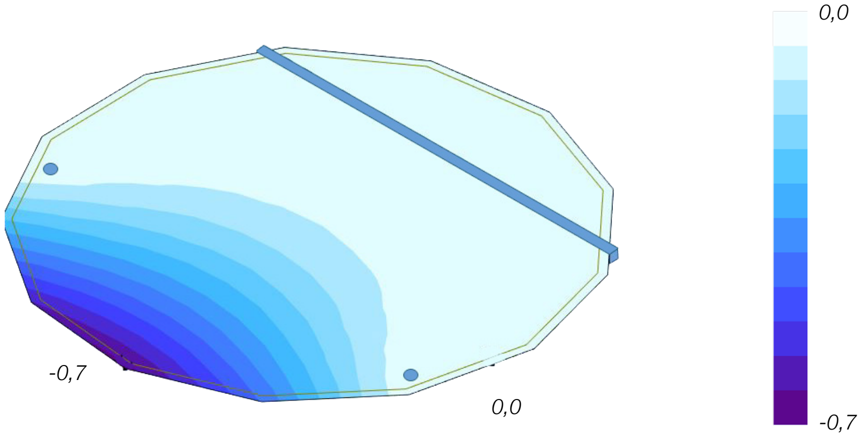
Image 79: 3D model of the main hall structure

Vertical	N (kN)	A_{min} (cm^2)	A_{real} (cm^2)	M (kNm)	$W_{pl\ min}$ (cm^3)	$W_{pl\ real}$ (cm^3)	d (cm)
Max	4509.9	188.6	571.4	3368.9	12863.1	23000.0	5.4

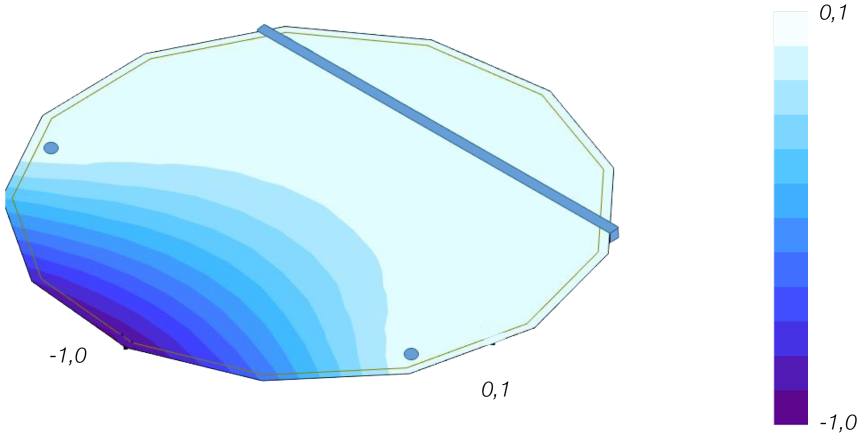
Table 76: Maximum values related to the FEM analysis of the 3D vertical elements

Calculation of the displacement of the Main Hall concrete plate

After hypothesizing a full reinforced concrete plate of an initial thickness of 110 cm, a displacement verification has been carried to confirm the feasibility of the hypothesize thickness.



	f_{max} (cm)	f_{min} (cm)	x 0,75	x 1,15	L_{max} (cm)	f_{max}*/L	
SLS	-0.7	0	-0.525	-0.60375	1000	-0.00060	< 1/250



	f_{max} (cm)	f_{min} (cm)	x 0,75	x 1,15	L_{max} (cm)	f_{max}*/L	
ULS	-1	0.1	-0.75	-0.86250	1000	-0.00086	< 1/500

Image 80: Displacement analysis of the main hall plate

Dimensioning of the reinforcement (ULS)

The nodal points in which the terns of values m_{xx} m_{yy} and m_{xy} represent the significant cases are indicated in the drawing and reported in the following tables:

- Table 77 shows the m_{xx} m_{yy} and m_{xy} results of the structural analysis
- Table 78 relates to the lower edge with the values of m_{xx}, m_{yy} and m_{xy} and the corresponding values of m_{xx} * and m_{yy} *
- Table 79 is similar to Table 78, for the upper edge

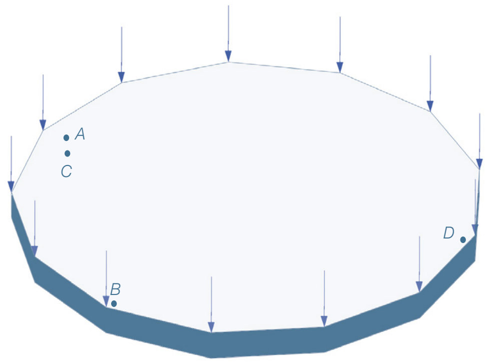


Image 81: critical points identified a

node	m_{xx} (kNm)	m_{yy} (kNm)	m_{xy} (kNm)
A	-1096.84	-1942.07	749.42
B	1511.99	241.95	86.67
C	-472.79	-2027.03	684.3
D	354.57	796.44	244.58

Table 77: Level 5 m_{xx} m_{yy} and m_{xy} results of the structural analysis

Lower edge						
node	m_{xx} (kNm)	m_{yy} (kNm)	Im_{xy}I (kNm)	case	m_{xx}*	m_{yy}*
A	m_{xx} o m_{yy} < - | m_{xy} | no lower reinforcement needed					
B	1511.99	241.95	86.67	1	1598.66	328.62
C	-472.79	-2027.03	684.3	2	-241.78	0.00
D	354.57	796.44	244.58	3	599.15	1041.02

Upper edge						
node	m_{xx} (kNm)	m_{yy} (kNm)	Im_{xy}I (kNm)	case	m_{xx}*	m_{yy}*
A	1096.84	1942.07	749.42	1	1846.26	2691.49
B	m_{xx} o m_{yy} > | m_{xy} | no upper reinforcement needed					
C	472.79	2027.03	684.3	1	1157.09	2711.33
D	m_{xx} o m_{yy} > | m_{xy} | no upper reinforcement needed					

*Table 78, 79: m_{xx}, m_{yy} and m_{xy} values and the corresponding values of m_{xx} * and m_{yy} * for the upper and lower edge*

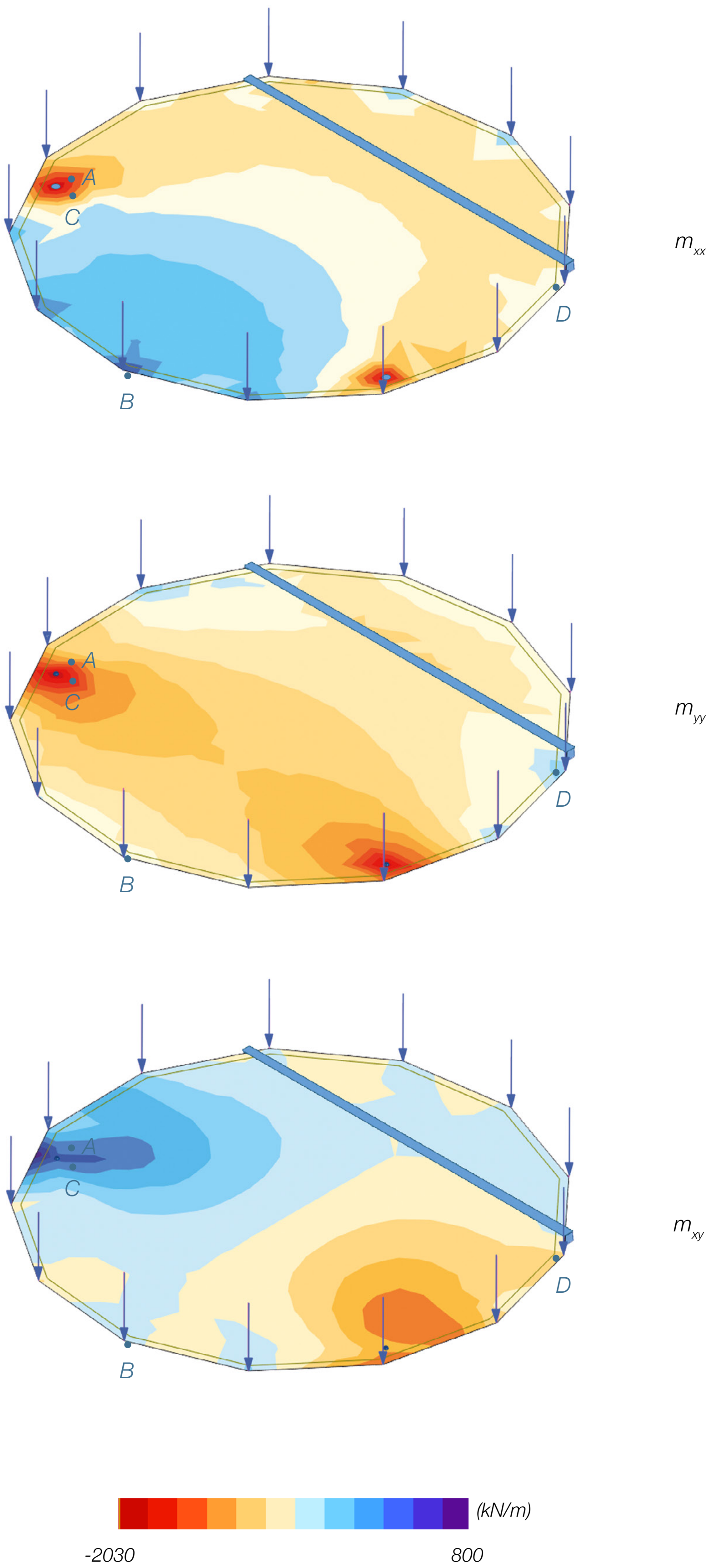


Image 82: Map results of the moments m_{xx} m_{yy} m_{xy} resulting on the main hall plate

The sizing of the reinforcement grid both on the lower and upper edge, is carried out by selecting as critical points those highlighting situations of maximum positive bending and negative bending.
At this point we proceed to a calculation at the ultimate limit state; the reinforcing steel is B450C and therefore the design tension is equal to:

$$f_{yd} = 450\ MPa / 1.15 = 391.30\ MPa$$

The lever arm of the internal pair z is assumed, approximately, to be 0,8 times the thickness of the plate:

$$z = 0.8 \times 55\ cm = 44\ cm$$

Considering the following formula for the determination of the required reinforcement area,

Given the soliciting moment m_{xx} in x direction:*

$$A_{x,theoreticall} = m_{xx}^* / (z \times f_{yd})$$

And the soliciting moment m_{yy} in y direction:*

$$A_{y,theoretical} = m_{yy}^* / (z \times f_{yd})$$

Lower edge				
	m_{xx}^* (kNm)	m_{yy}^* (kNm)	$A_{x,theo}$ (cm^2)	$A_{y,theo}$ (cm^2)
B	1598.66	328.62	56.74	11.66
D	599.15	1041.02	21.26	36...95

Table 80: *Critical values of m_{xx}* and m_{yy}* and definition of $A_{x,theo}$ and $A_{y,theo}$ needed at the lower edge*

Upper edge				
	m_{xx}^* (kNm)	m_{yy}^* (kNm)	$A_{x,theo}$ (cm^2)	$A_{y,theo}$ (cm^2)
A	1846.26	2691.49	65.53	95.37
C	1176.55	2695.88	41.76	95.68

Table 81: *Critical values of m_{xx}* and m_{yy}* and definition of $A_{x,theo}$ and $A_{y,theo}$ needed at the upper edge*

At the lower edge it is necessary 56.98 *cm^2 of reinforcement in x direction. While* 38.28 *cm^2 is required in y direction.*

At the upper edge it is necessary 74.38 *cm^2 of reinforcement in x direction. While* 62.08 *cm^2 is required in y direction.*

The longitudinal reinforcement grids are considered for the whole extension of the Level 2's plate.

Furthermore, it is verified that the area of the longitudinal reinforcement $A_{s,theoretical}$ in the tense area in each of the two directions is higher than the minimum value provided by the NTC 2018 § 4.1.6.1.1.

$A_{s,\ min}$ is given by the following formula:

$$A_{s,min} = 0,26\ f_{ctm}/f_{yk}\ b_t\ d = 7.39\ cm^2$$

or, however, not less than:

$$A_{s,min} = 0.00013\ b_t\ d$$

where:

- b_t is the length of the tense area;
- d is the useful height of the section equal to 50 mm;
- f_{ctm} is the average value of the axial tensile strength equal to 2.56 N / mm2;
- f_{yk} is the characteristic value of the tensile strength of the original reinforcement equal to 450 N / mm^2

We *defined then the upper and lower grids arrangement as follows:*

Lower edge					
	A_{req} (cm^2)	n°	Φ (cm)	d (cm)	A_{real} (cm^2)
x	56.74	10	2.8	7.2	61.58
y	36.95	10	2.4	7.6	45.24

Table 82: lower reinforcement grids properties

Upper edge					
	A_{req} (cm^2)	n°	Φ (cm)	d (cm)	A_{real} (cm^2)
x	65.53	10	3	7	70.69
y	95.68	12	3.2	5.13	96.51

Table 83: upper reinforcement grids properties

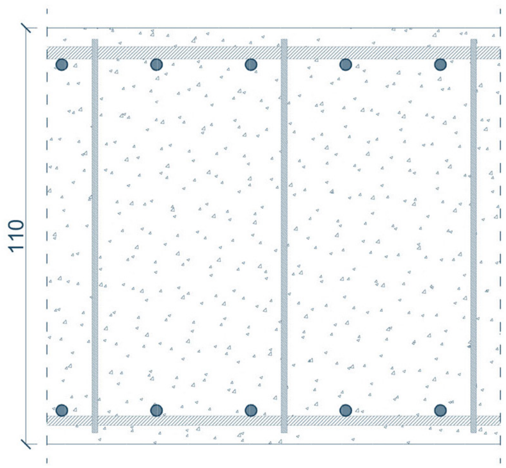


Image 83: representation of the main hall plate

Roof spatial truss

The structure for the roof has to cover a very large span (45m) in order to avoid any column to bear on the main hall structure or to pass trough it. The best option to cover a span that large without an excessive dead load for the structure is a 3D truss. This truss is composed by a series of 2D trusses repeated on the two main axes, creating a complex structure bearing only on the outer columns and cores.

The analysis and study of this structure has followed two steps:

- the creation of an analytical 2D model of a single truss, in order to size the profiles and the total height
- the creation of a 3D model of the structure, simulating a realistic behaviour of the whole structure

Creation of analytical 2D models

The loads were established considering the roof of the restaurant as accessible only for maintenance, while the whole restaurant and

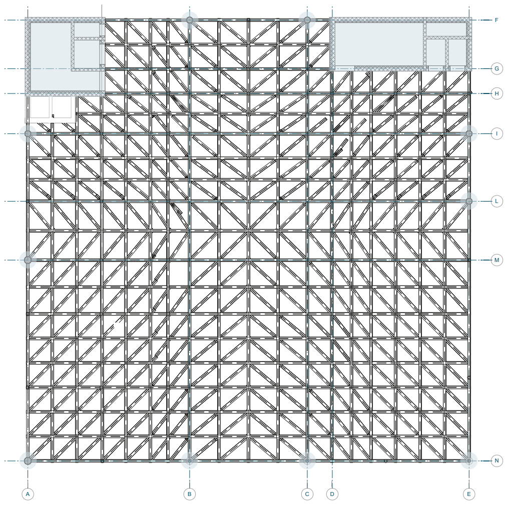


Image 84: identification elements bearing the load of the spatial truss

terrace floor as accessible for the public. With the geometry and the loads it was possible to analyse the elements trough a 2D model made using the software “Ftool”.
Simulating the behaviour of the 2D truss, it has been possible to determine which was the best compromise between the total height of the truss and the dimensions of the single profiles. The height of the truss was then selected to be 2.5m, considering it to be the distance between the centres of the top and bottom horizontal profiles.

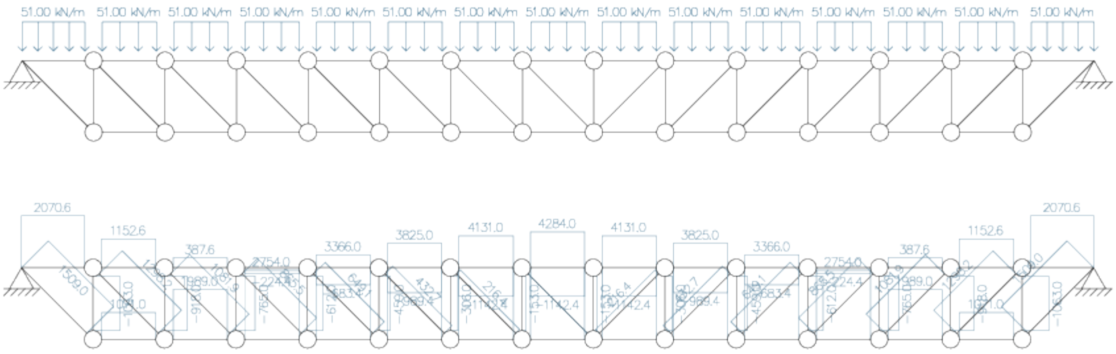


Image 85: 2D discretization of the roof spatial truss

Creation of 3D model

A 3D model was created using Autodesk Robot Structural Analysis, in order to analyse the behaviour of the 3D truss.

Two different types of 3D truss were analysed, one composed with “pyramids” which should reduce the bending moment on the supports, one with “cubes and diagonals” which should reduce the size of the profiles. To obtain the profiles from the axial loads it was used the same method already treated for the main hall structure.

After the comparison between the two simulations, the second shape was preferred because the profiles for the first option would have been too big and difficult to install.

Once the internal stresses have been verified, the profiles had to be increased because of the vertical displacements that were too high. The maximum displacement was calculated as 1/500 of the maximum span (45m) that is 0.09m.

With the new profiles (HD 260x172 for the diagonals and HD 260x299 for vertical, top and bottom elements) the maximum displacement was 0.08m.

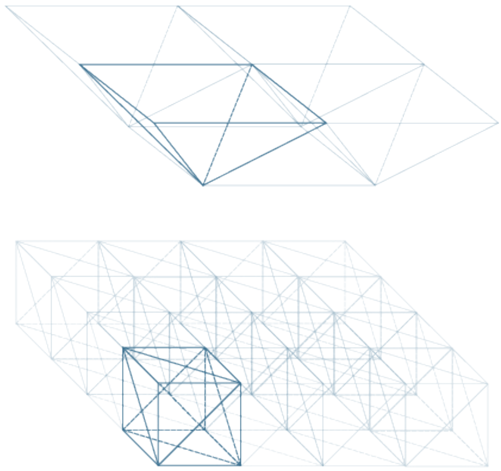


Image 86: 3D discretization of the two truss schemes tested

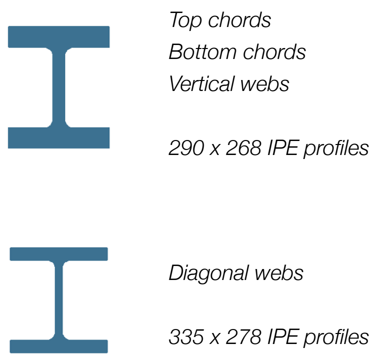


Image 87: profiles used in the spatial truss

For the calculations of loads, stresses and displacements of the roof structure it was used the same method as the main hall structure. Here it follows the data used for and extracted from the analysis of the roof structure.
To calculate the total load it was considered the number of floors (45x45m) of the single load. If the load was relative to the 9th floor (restaurant and terrace) it was counted as 1, if it was only related to the restaurant's floor it is counted as 0.5, if both 1.5.

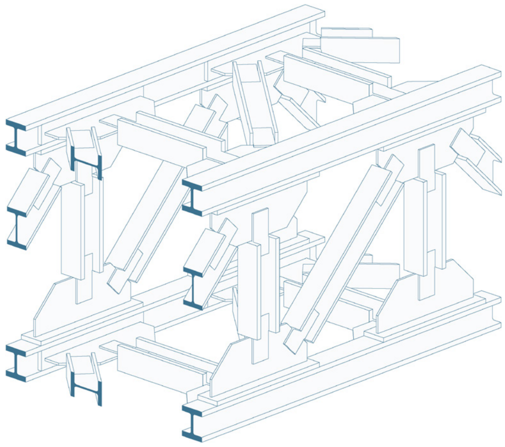


Image 88: part of the spatial truss 3D representation

	Type of load	H (m)	B (m)	ρ (kN/m^3)	Value (kN/m^2)	Floors (\)	SLS (kN/m^2)	ULS (kN/m^2)
G1	Slabs	0.11	\	\	2.15	1.5	3.3	4.2
G1	Profiles	\	\	78,5	\	1.5	software	software
G2	Floor	\	\	various	1.64	1,5	2,46	3.69
G2	Walls	\	\	various	1.2	1	1.2	1.8
qk	People	\	\	\	5	1	5	7.5
qk	Maintenance	\	\	\	0.5	0.5	0.25	0.38
qk	Snow	\	\	\	1.29	1	1.29	1.94
	Total						13.50	19.51

Table 84: Loads definition both for SLS and ULS

Element	N_{ed} (kN)	I (cm^4)	A_{min} (cm^2)	A_{real} (cm^2)	l_0 (m)	N_{cr} (kN)	N_{brd} (kN)
Top	-2428.1	64220	101.5	380.5	2.5	212965	9855.5
Bottom	-5542.3	64220	231.8	380.5	2.5	212965	9855.5
Vertical	-7412.5	64220	309.9	380.5	2.5	212965	9855.5
Diagonal	5095.9	31310	213.1	219.6	2.5	/	/
Diagonal top	-3384.1	31310	141.5	219.6	2.5	103830	5630.9
Diagonal bottom	-2502.5	31310	104.7	219.6	2.5	103830	5630.9

Table 85: Classification of the different profiles used

Profile	h (cm)	b (cm)	t_w (cm)	t_f (cm)	A (cm^2)	I (cm^4)	W_{pl} (cm^3)
HD 260x299	33.5	27.8	3.1	5.5	380.5	64220	2524.0
HD 260x172	29.0	26.8	1.8	3.3	219.6	31310	4727.0

Table 86: Profiles chosen characteristics

Chapter 4 references

1 U.S. Green Building Council, “A LEED for every project”, accessed November 07, 2019. https://new.usgbc.org/leed

2 Ibid.

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8 Norme Tecniche per le Costruzioni, D.M., 17/01/2018

9 Ibidem

10 Eurocodes EC1 (Actions on structures)

11 Norme Tecniche per le Costruzioni, D.M., 17/01/2018

12 Ibid.

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15 Ibid.

16 Ibid.

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18 Ibid.

19 Bubbledeck, "Il solaio senza travi", accessed November 23, 2019. http://www.bubbledeck.it/

20 Ibid.

21 Ibid.

22 Ibid.

23 Ibid.

24 Gambarova P. G., D. Coronelli, P. Bamonte. “Linee guida per la progettazione della piastre in c.a.”, Pàtron, (2008)

25 Ibid.

26 Ibid.

Chapter 4 images

Image 5: www.floornature.it/elbphilharmonie-di-amburgo-di-herzog-de-meuron-12365/

Image 6: www.archdaily.com/440/oslo-opera-house-snohetta

Image 7: www.chinadenmark.com/royal-danish-opera-house/

Image 8: www.buro-os.com/projects/taipei-performing-arts-center

Image 24: U.S. Green Building Council, “A LEED for every project”, accessed November 07, 2019. https://new.usgbc.org/leed

Images 46, 47: Norme Tecniche per le Costruzioni, D.M., 17/01/2018

Chapter 4 charts

Chart 06 : Gambarova P.G., D. Coronelli, P. Bamonte. “Linee guida per la progettazione della piastre in c.a.”, Pàtron, (2008)

Chart 07: Gambarova P. G., D. Coronelli, P. Bamonte. “Linee guida per la progettazione della piastre in c.a.”, Pàtron, (2008)

Chapter 4 tables

Table 1, 2: U.S. Green Building Council, “A LEED for every project”, accessed November 07, 2019. https://new.usgbc.org/leed

Table 10: UNI 10339:1995, 30/06/1995, “Impianti aeraulici ai fini di benessere. Generalità, classificazione e requisiti. Regole per la richiesta d’offerta, l’offerta, l’ordine e la fornitura”

Tables 18 - 27: Norme Tecniche per le Costruzioni, D.M., 17/01/2018

Chapter 4 abbreviations

AHU - Air Handling Unit

COP - Coefficient of Performance

EV - Electric Vehicle

HVAC - Heating Ventilation AIR Conditioning

HR - Heat Recovery

PV panels - Photovoltaic panels

RH - Relative Humidity

CHAPTER 5

Future scenarios and conclusions

Definition and analysis of electric vehicles diffusion scenarios

Scenarios definition

In order to assess the realistic influence and impact of the use of electric vehicles as temporary energy storage a few scenarios have been researched and defined. In fact the market is still relatively young (see Chapter 1) and there is not yet a completely reliable set of data on which the balances can be done. On one side the car makers are investing a lot of money on the research and development of this sector, trying to push the limits and creating car with bigger and bigger batteries. On the other side the consumers also require cheap vehicles, that typically have smaller energy storage, that is one of the bigger terms in the price of an electric vehicle.

Another big term of the equation of the diffusion of EVs on the market is the relative infrastrucure. With a capillar system of charging stations smaller batteries authonomy is still acceptable. On the other side, if this does not happen the car authonomy becomes a very relevant detail.

Among all the terms and pros and cons, however, a sum up has been done, identifies three main scenarios that differ among them for area of influence, for time of realisation and for the concept regarding private transport in general. Next the already defined and simulated mixed use district and the SynEnergy Hall energy balances have been coupled with the number and kind of use of electric vehicles. Finally the different subjects have been studied together in order to assess and highlight the difference between a so-called “zero energy district” and a really grid-independent district. In order to compare among them all the cases, the two performances indexes (Grid Independence and Production Surplus) have been used, as explained in Chapter 3.

Scenario 0: Italy 2019

The first scenario regards Italy nowadays. The number of electric vehicles is nearly zero for a series of reasons. Small or totally absent infrastructure, low state subsides, general lack of confidence in electric vehicles. This scenario is used as starting point. Some of the parameters chosen in this scenario are however used in the other scenarios to rely on the most realistic data possible.

The city taken as example is Milano, as explained in the Chapter 3. The number of workers using the car every day to go to work is around 45%.[1] This means that even in a scenario in which the electric vehicles are the totality of the cars, they will never all be used every day.

Scenario 1: Italy 2030

The first scenario considering the presence of electric vehicles considers as location the Italy but in ten years from now. In this scenarios there will be around one million electric cars over a total amount of 49 million cars. This means that it is roughly the 2% of cars. The scenario however still considers the city of Milano as baseline, with its rate of daily car use and number of kilometers covered every day. The number of electric cars on the total comes from a research by the Urban Studies Department of Politecnico di Milano on the future deployment on EVs.[2]

Scenario 2: EU 2030

In this case the amount of electric private vehicles was set to the 23% of the total amount of vehicles. Even if the location for the scenario simulations was still Milano, its reference panorama was the perspective for the European Union elaborated by Cambridge Analitica[3]. In fact the polices and subsidies at European level will most probably create a higher diffusion of electric vehicles than the one expected at Italian level. This is partially already happening in some countries such as the Netherlands and Norway, where the electric cars and their related infrastructure already have a relevant market.

Scenario 3: Shared mobility

The last scenario still refers to an hypothetical Italian situation in 2030, with around 2% of electric cars on the total amount of vehicles. However in this case the idea is that a certain amount of cars will be shared. This scenario is also realistic in a city such as Milano. Nowadays there are already a certain number of car sharing companies that offer the use of electric cars.[4] This happens because electric cars are already competitive on short distances, because problems such as battery authonomy and lack of infrastructure roblems are minimised compared to private use standards. moreover car sharing is often used for short distance trips and cannot exit the borders of the city.

In this case even if the amount of total electric vehicles is the same of Scenario 1, their use profile changes. The idea is that they would be connected through a district micro-grid. This means that on one side their use "per-car" would be higher than for private transport. In fact a car could be used by different people within the same day (and even within the same hour). On the other side the amount of cars always on the site, for simulation reasons, is higher than in the previous scenarios. In this way assuming a higher number of cars that can be charged and un-charged, also the virtual energy storage can be higher, through more cycles per day. On the other hand, of course, the number of kilometers that the cars have to cover every day will be higher.

The amount of cars shared in this scenario is as-

Performance indexes

In order to compare and discuss the buildings performances in the four scenarios the mixed use urban block coming from the design of the masterplan and the SynEnergy Hall were analyzed following the same processes. Once the energy simulations of their final configurations were run, their energy production and consumption were summed up. Then, considering different amounts of electric cars and use profiles, the performance indexes were computed separately. In the following table the two indexes are summed up and compared.

The different case-scenarios were divided in three sub-scenarios according to the amount of photovoltaic panels that the buildings have: In fact this gives an impression of the different possibilities and consequences that a designer and a developer would have deciding to have more or less PV panels, together with the electric mobility scenario.

The results shown how the urban block has very high indexes. This was expected since the blocks are very high performing and not only their technology is optimized, but also their shape, orientation, window-to-floor ratio, etc. The Grid Independence index is maximum in the scenario

	Scenario 0: Italy 2019		**Scenario 1: Italy 2030**		**Scenario 2: EU 2030**		**Scenario 3: shared mobility**	
	GI	PS	GI	PS	GI	PS	GI	PS
PV on the roof	0.41	0.36	0.62	0.34	0.78	0.15	0.71	0.34
PV on roof and South facades	0.42	0.44	0.64	0.43	0.82	0.26	0.74	0.43
PV on roof and facades	0.44	0.54	0.66	0.53	0.85	0.39	0.78	0.53

Table 1: Performance indexes of the different scenarios regarding the mixed use urban blocks

	Scenario 0: Italy 2019		Scenario 1: Italy 2030		Scenario 2: EU 2030		Scenario 3: shared mobility	
	GI	PS	GI	PS	GI	PS	GI	PS
PV on the roof	0.25	-0.64	0.32	-0.65	0.42	-0.70	0.32	-0.65
PV on roof and face-up facade	0.29	-0.51	0.42	-0.52	0.51	-0.58	0.38	-0.51
PV on roof and all facades	0.31	-0.45	0.45	-0.45	0.54	-0.53	0.41	-0.45

Table 2: Performance indexes of the different scenarios regarding the SynEnergy Hall

number 2, where the number of electric vehicles is maximum and then the chance to use self-produced energy is enhanced. The maximum Production Surplus index is instead in the case where there are no electric cars. This is understandable, but it is very interesting to see how even a small number of electric cars, as in scenario 1, the PS index is almost the same (0.53 instead of 0.54) while the GI index is much higher, 0.66 instead of 0.44. This means that even a small amount of energy storage is able to affect consistently the interaction with the grid.

On the other side, the SynEnergy indexes show poorer performances. In fact there is no surplus production, and consequently the PS indexes negative in all cases. However the Grid Independence index reaches very good values with the introduction of electric vehicles. With PV panels on all exposed surfaces and only a 2% of electric vehicles the building reaches a grid independence similar to the one of the urban blocks without the use of sotorage. This means that even if applied to just a few buildings into an urban context, local temporary energy storage could have really good benefits.

In general it is important to note how car sharing helps reducing the interaction with the grid. However even if considering 66% of the cars as shared EVs the GI indexes are slightly worse than a 2% of privately owned EVs. In fact the amount of parked cars of Scenario 1 is better from a performance point of view than having shared electric cars.

Simulating a "zero energy district"

Once the typical urban block from the masterplan and the SyEnergy Hall were compared, the simulations went on running a few simulations with the two kinds of constructions together. The reason was to assess the reciprocal energy influence, in a similar way as it happened in Chapter 2, where residential and office buildings were simulated together. The creation of a micro grid already showed how the energy could be used more efficiently in this way than considering the buildings alone. The difference from that comparison is that in this case one of the two subjects (or of the three, if considering the block as already made of two different kind of buildings) is passive, meaning that it consumes more energy than the one that it produces annually.

The starting parameter to study the reciprocal energy behaviour of the two kinds of building was then to create a "zero energy district". That means that considering all the buildings, their annual consumption has to be the same of their annual consumption. The equation is possible because the blocks have a net surplus, while the Performing Arts Centre has a deficit. This means that, taking the dimension of the SynEnergy Hall as fixed, the dimension of the urban blocks changes till the total production is the same of the total consumption. In the table 3 it can be seen how the values change according to the amount of PV panels installed. In the case in which the PV panels are less, the urban block surface will be bigger, to sustain the energy requirements of the Hall, while increasing their surface the urban block surface is smaller.

This condition would be enough to define the entire district as "zero energy", following nowadays regulations and classifications, as explained in Chapter 1. However the interaction with the grid is neglected, because most of the energy produced is not used on-site.

	Urban blocks surface [m^2]	**SynEnergy Hall surface [m^2]**
PV on the roof	18570	
PV on roof and South facades	10390	12758
PV on roof and all facades	6210	

Table 3: Square meters of Urban Blocks to sustain the SynEnergy Hall energy demand

	Scenario 0: Italy 2019		Scenario 1: Italy 2030		Scenario 2: EU 2030		Scenario 3: shared mobility	
	GI	PS	GI	PS	GI	PS	GI	PS
PV on the roof	0.33	0	0.48	-0.02	0.62	-0.25	0.53	-0.02
PV on roof and South facades	0.34	0	0.50	-0.02	0.64	-0.19	0.54	-0.02
PV on roof and all facades	0.35	0	0.51	-0.02	0.63	-0.18	0.51	-0.02

Table 4: Performance indexes of the different scenarios regarding the Zero Energy District

Once the equation between the building surfaces was done in a scenario without the presence of cars, the three scenarios that comprehend their presence were analysed using the GI and PS indexes. The Production Surplus is then negative in the three scenarios because the introduction of the energy load due to electric vehicles would affect the total energy requirements. However the data are important because through them the scenarios can be compared, on a basis of a pre-EVs and post-EVs possible future introduction. Instead the Production Surplus is zero in Scenario 0 because it is the starting point for the district simulation. This means that it doesn't produce more or less than the amount of energy needed.

The GI indexes are quite similar inside of the same scenario. This is because the total production is normalised on the amount of square meters that it has to "sustain". This means that the capability of using the energy produced on-site does not depend on the amount of urban block square meters compared to the dimension of the SynEnergy Hall. The buildings have then a similar energy behaviour that is not affected by their reciprocal proportions.

Instead the GI indexes significantly change among the different scenarios. Even with a small energy storage available, such as in Scenario 1, the interaction with the grid is significantly reduced. This is something that was already noticed in the previous case analysed, but it is important how the index is much more favourable compared to the one of the Performing Arts Centre alone. It is however lower than in the case of the urban blocks alone, but this change can be expected since the blocks are super-efficient buildings with a high energy surplus per square meter.

The GI index is much higher in case of a higher electric cars diffusion scenario, such as in Scenario 2. However the PS index is less optimistic because the energy production remains unchanged through the scenarios. It is however important to note that in this case there are only roughly 6000 sqm of urban blocks to "sustain" more than 12000 sqm of Performing Arts Centre.

In case of the car sharing scenario the values are similar to the Scenario 1, however slightly more optimistic. This is because, as previously discussed, the higher presence of electric vehicles in the area is more useful in order to exploit the EVs batteries as temporary storage.

How to use the performance indexes

Almost at the end of the research, it is important to understand how the data could be efficiently used in a real case scenario of the new construction of a high efficient urban district. In fact the last analysis carried on, mixing active and passive buildings, could represent a realistic case. The passive building could be a public building, such as in this case, or also a refurbished building, that reaches good energy performances and through the installation of PV panels can partially produce the energy consumed, without hoeveve reach the active standards. Another realistic comparison could be in a near future in which the renewable energy sources, due to their unpredictability in their production profiles, will become less convenient for the energy providers, arriving to a point in which the energy will have to be "given" for free, without any reward like it happens today.

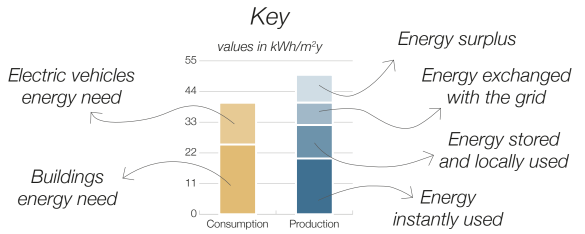
In these scenarios the designers and the urban developers will have to face choices on how much PV power to install, or if to invest money in the creation of a micro-grid within the district, or if investing in house energy storage. The future probable diffusion of electric vehicles, starting from the most populated cities, will represent a new tem into this equation. On one side it will require more electric energy, on the other side it will represent an opportunity to use the energy produced on-site, without wasting or giving it for free to other users. In case of the presence of the necessary technology, of course, the possibility will also be to use the EVs batteries as temporary energy storage.

This is why it is important to focus on the second column of every one of the three scenarios compared to the Scenario 0. Even if the total energy requirement will be higher, the amount of energy used on-site will be much higher. An hypothetical developer could start from the first line (installing PV panels only on the roof) and after the introduction of a consistent amount of electric vehicles in the district move downwards into the table, producing more energy per square meter and at the same time augmenting the energy efficiency of the entire district.

Even if nowadays it is much optimistic, it can be than in the future we will face scenarios of this kind, where the buildings and the cars will not be seen as just energy "consumers" but also producers and energy managers.

ENERGY BALANCES

OF DIFFERENT POSSIBLE SCENARIOS

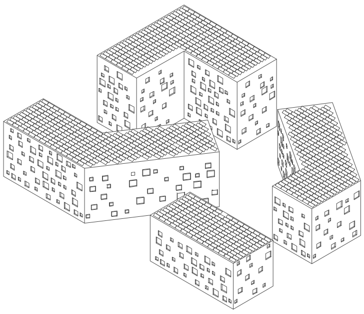


SCENARIO 0: ITALY 2019

45% PEOPLE

GOING TO WORK BY CAR

IN MILANO

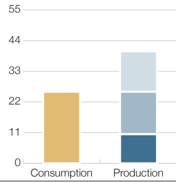


MIXED-USE URBAN BLOCK

SURFACE: 19358 m²

OPTION 1:

PV PANELS ON THE ROOF

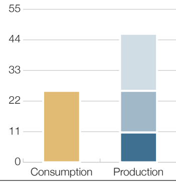


GI: 0.41

PS: 0.36

OPTION 2:

PV PANELS ON THE ROOF
AND SOUTH FACADES

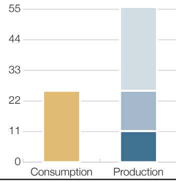


GI: 0.42

PS: 0.44

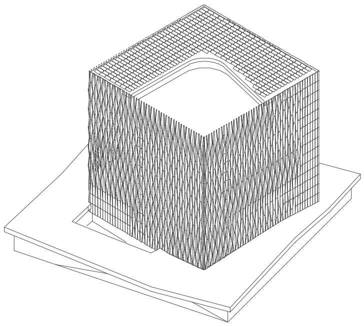
OPTION 3:

PV PANELS ON THE ROOF
AND SOUTH, EAST AND WEST FACADES



GI: 0.44

PS: 0.54



PERFORMING ARTS CENTER

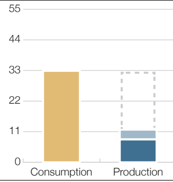
SURFACE: 12758 m²

OPTION 1:

PV PANELS ON THE ROOF

GI: 0.25

PS: -0.64

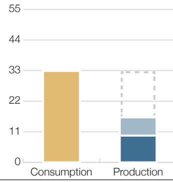


OPTION 2:

PV PANELS ON THE ROOF
AND HALF OF THE FACADE

GI: 0.29

PS: -0.51

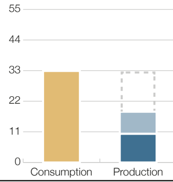


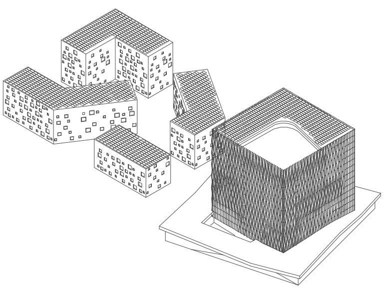
OPTION 3:

PV PANELS ON THE ROOF
AND ALL OF THE FACADE

GI: 0.31

PS: -0.45





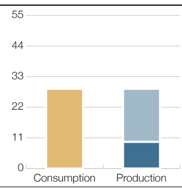
ZERO ENERGY DISTRICT

ANNUAL ELECTRIC PRODUCTION
=
ANNUAL ELECTRIC CONSUMPTION

OPTION 1:

PV PANELS ON THE ROOF

URBAN BLOCKS
SURFACE:
18570 m²



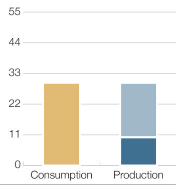
GI: 0.33

PS: 0

OPTION 2:

PV PANELS ON THE ROOF
AND SOUTH FACADES

URBAN BLOCKS
SURFACE:
10390 m²



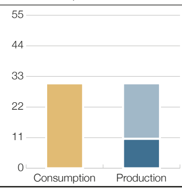
GI: 0.34

PS: 0

OPTION 3:

PV PANELS ON THE ROOF
AND SOUTH, EAST AND WEST FACADES

URBAN BLOCKS
SURFACE:
6210 m²



GI: 0.35

PS: 0

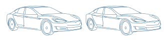
SCENARIO 1: **ITALY 2030**

1 MILLION
ELECTRIC VEHICLES
OVER 49 MILLION CARS

2%

SCENARIO 2: **EU 2030**

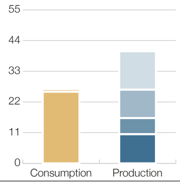
23%
ELECTRIC VEHICLES
AND PLUG-IN HYBRID VEHICLES



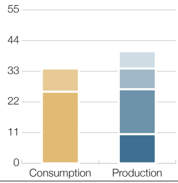
SCENARIO 3: **ITALY 2030**
WITH SHARED MOBILITY

66%
SHARED
PRIVATE MOBILITY

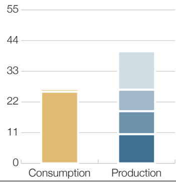
2%



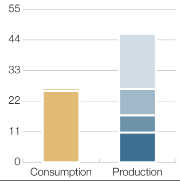
GI: 0.62
PS: 0.34



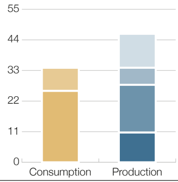
GI: 0.78
PS: 0.15



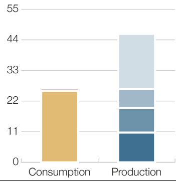
GI: 0.71
PS: 0.34



GI: 0.64
PS: 0.43



GI: 0.82
PS: 0.26



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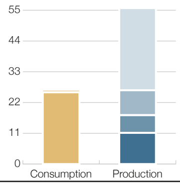
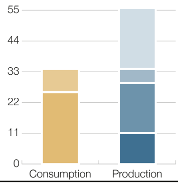
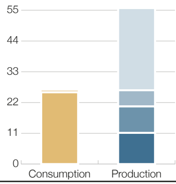
PS: 0.43



GI: 0.66
PS: 0.53

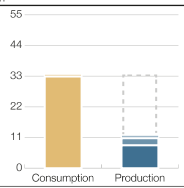


GI: 0.85
PS: 0.39

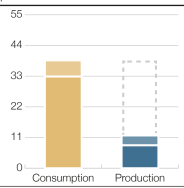


GI: 0.78
PS: 0.53

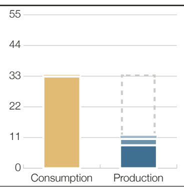
GI: 0.32
PS: -0.65



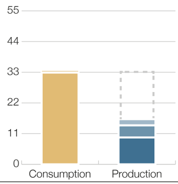
GI: 0.42
PS: -0.70



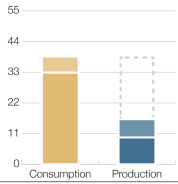
GI: 0.32
PS: -0.65



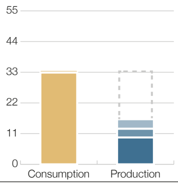
GI: 0.42
PS: -0.52



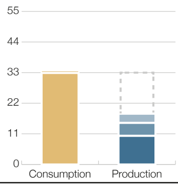
GI: 0.51
PS: -0.58



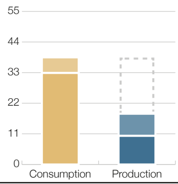
GI: 0.38
PS: -0.51



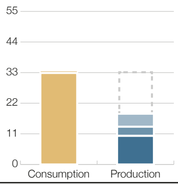
GI: 0.45
PS: -0.45

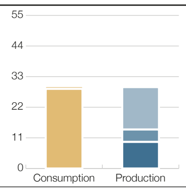


GI: 0.54
PS: -0.53

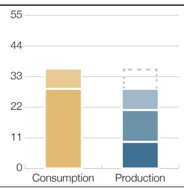


GI: 0.41
PS: -0.45

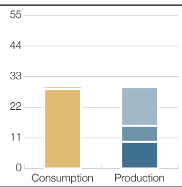




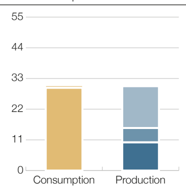
GI: 0.48
PS: -0.02



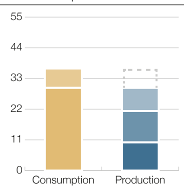
GI: 0.62
PS: -0.25



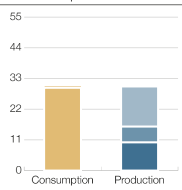
GI: 0.53
PS: -0.02



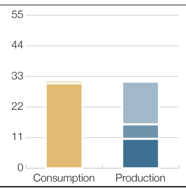
GI: 0.50
PS: -0.02



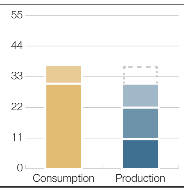
GI: 0.64
PS: -0.19



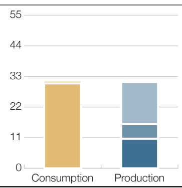
GI: 0.54
PS: -0.02



GI: 0.51
PS: -0.02



GI: 0.63
PS: -0.18



GI: 0.51
PS: -0.02

Conclusions

The results obtained from energy simulations showed how the worldwide penetration of electric vehicles in cities could improve the energy performance of buildings. They could not only be considered as energy consuming subjects, but as a way to improve the effectiveness of the use of renewable energy. To achieve these results it is necessary to create a collaboration between the buildings and the vehicles trough the creation of a proper infrastructure, evenly distributed on the territory.

This new urban system could work using buildings as energy producers, while the vehicles could store the excessive energy and fulfil the needs of the buildings at night. With the diffusion of car sharing the vehicles could also be used to store and distribute the energy trough the city, without the need of a big national grid anymore.

The research developed on the state of art of buildings and electric vehicles stressed the need of a change in the energy system, with a necessary use of renewable energy. Nowadays these strategies are still being developed, with some technical and cultural issues which have to be overcome together with the need of new international legislations.

The hypothesis of the creation of a local grid which would be able to share the energy and the analysis of a few case studies helped developing basilar criteria used to improve energy use efficiency. The application of this criteria to base units led to the creation of an analysis method and performance indexes, which were then used to compare the following simulations.

Pushing the approach further, applying it to a realistic case scenario within an area with given requirements enhanced the comparison with the Italian condition, analysing opportunities and constraints of a given territory. This analysis was carried out in relationship to our vision, including energy objectives, in order to assess the strategy feasibility. This confrontation with a real situation was necessary in order to relate the energy criteria with urban constraints, such as green areas requirements, infrastructural standards and urban priorities. Once these constraints were respected, the properties of the chosen area allowed the creation of a district with features necessary for our purpose, such as high building performances and a good connection with the surrounding area.

The design of a building in the analysed area allowed to carry out a more detailed development of the energy strategy. It was possible to create a building with a public use, big open spaces but high energy performances. The impact of this building on the overall balance of the district was in fact reduced thanks to the use of different energy strategies, which were developed during the design process.

The analysis of the consumption profiles of the different buildings and the modelling of an energy integrated district improved the final result, proving the feasibility and the economic benefits of such strategy.

At the end of the discussion, it was evident how the penetration of EVs in urban areas could bring a lot of benefits for both the people and the environment. The most important advantages which emerged in the discussion were summarised below, clustered following the different scales of their impact. It is clear how the energy strategy which has been developed could increase the grid independence, with a greater impact on bigger areas. This could allow the reduction of the stress on the grid, besides a cost reduction for energy consumption. The benefits would also regard the people comfort, with a reduction of noise and air pollution, as well as an increase of green public areas.

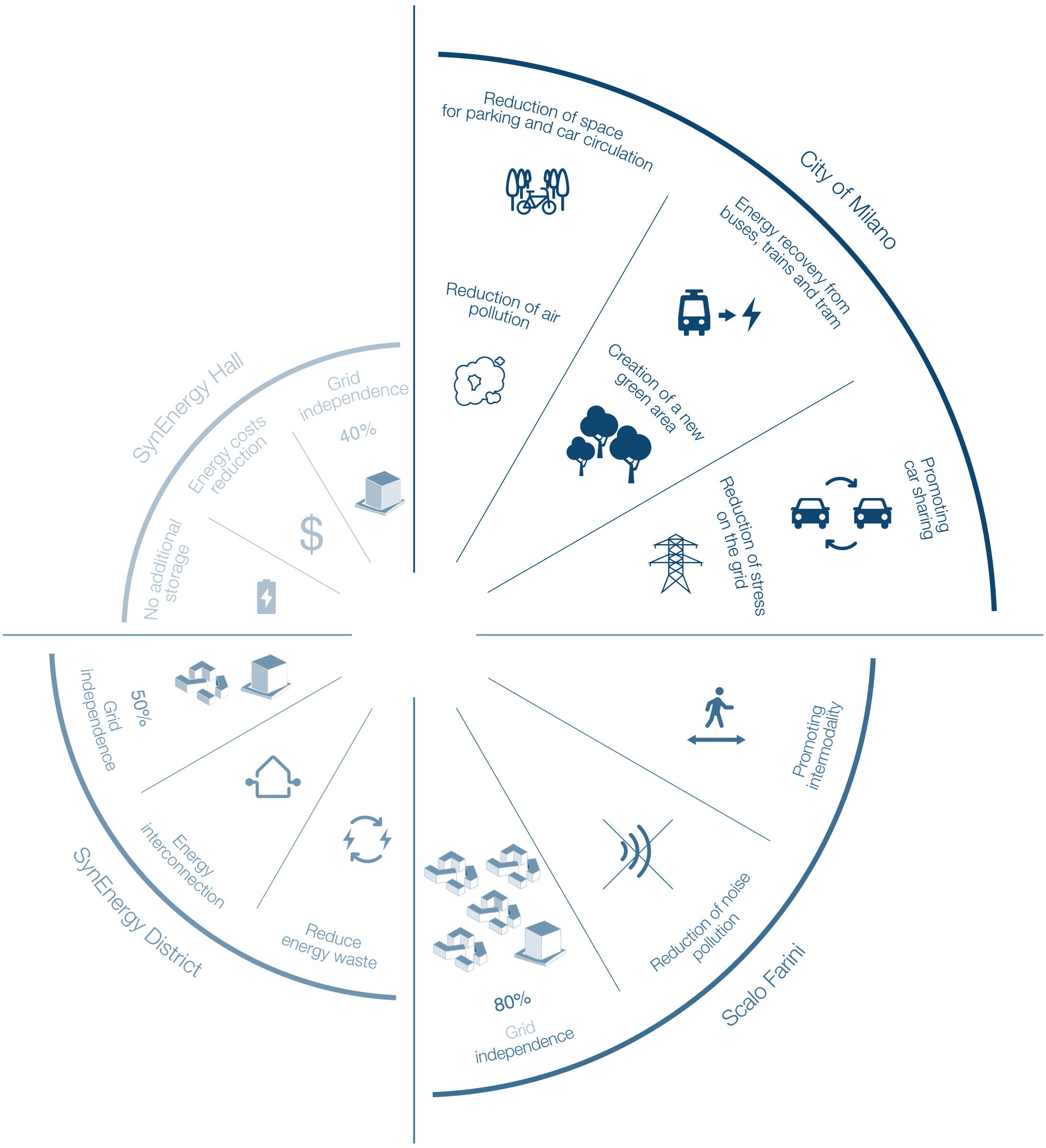


Image 01: Effect of EVs on different urban scales

Chapter 5 endnotes

1 Accordo di programma Comune di Milano e Ferrovie dello Stato

2 DASTU Department, Politecnico di Milano, 10/12/18

3 Harrison P., "Fuelling Europe's Future: How the transition from oil strengthens the economy". Cambridge Econometrics, 2018

4 Car2Go, Share 'N Go, DriveNow

5 EY mobility think tank 2018, www.ey.com

Chapter 5 abbreviations

AC - Annual Consumption, sum of the DC of every month considering in total 365 days

AS - Annual Surplus, AP - AC which is the energy produced and not used

EV - Electric Vehicle

GI -Grid Independence, 1 - GD which indicates the percentage of consumption that is produced on the site

GD - Grid Dependence, AN / AC which indicates the percentage of consumption that is taken from the national grid

PV panels - Photovoltaic panels

RS - Relative Surplus, AS / AC which indicates the annual surplus relatively to the annual consumption of the building

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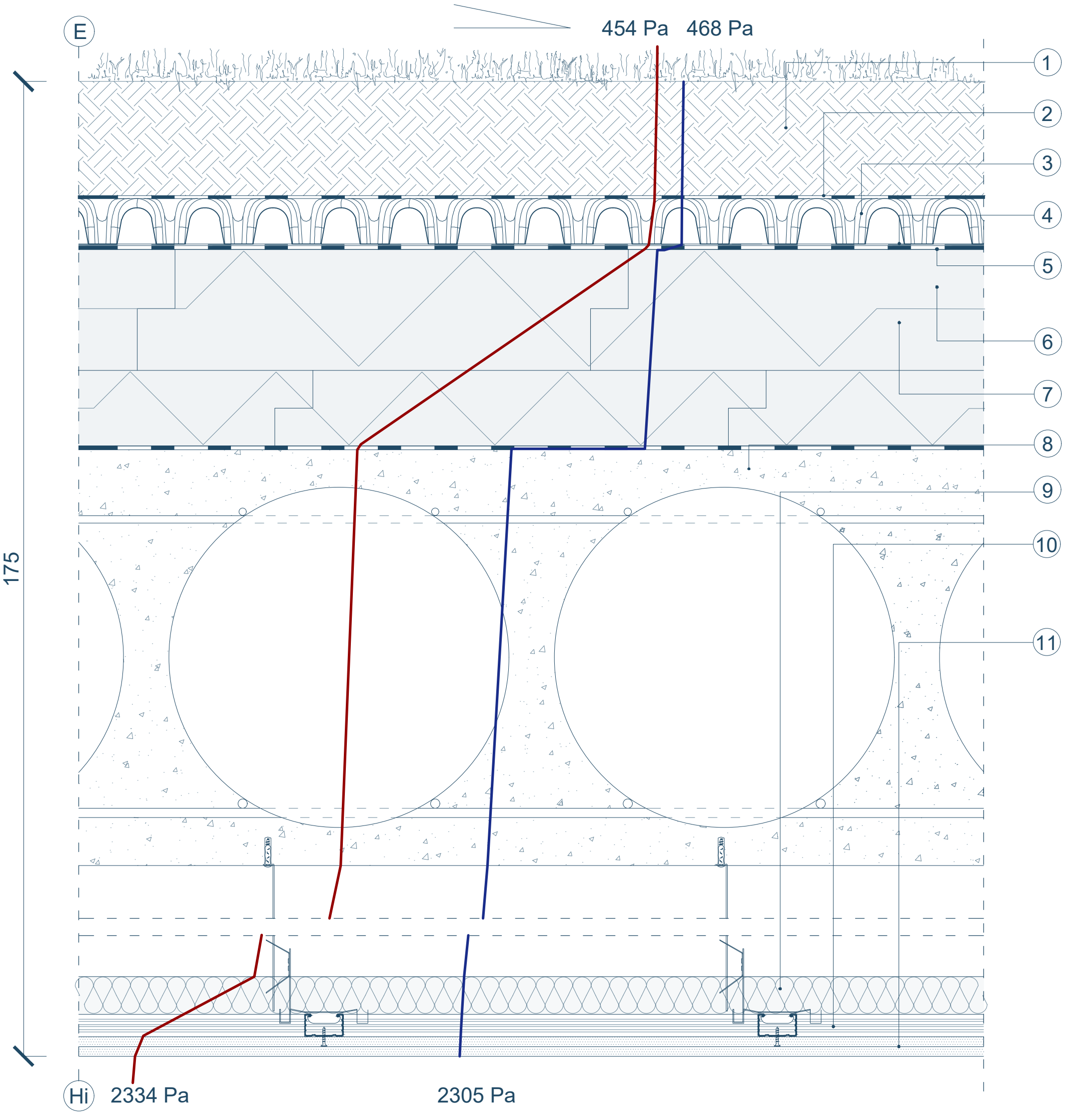
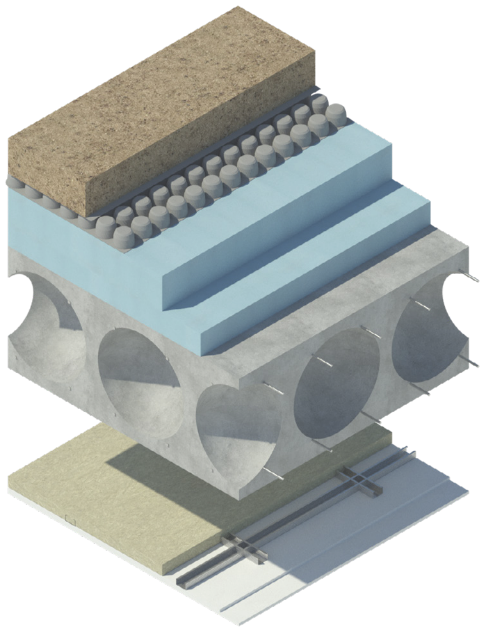
ANNEXES

Annex A
Stratigraphies

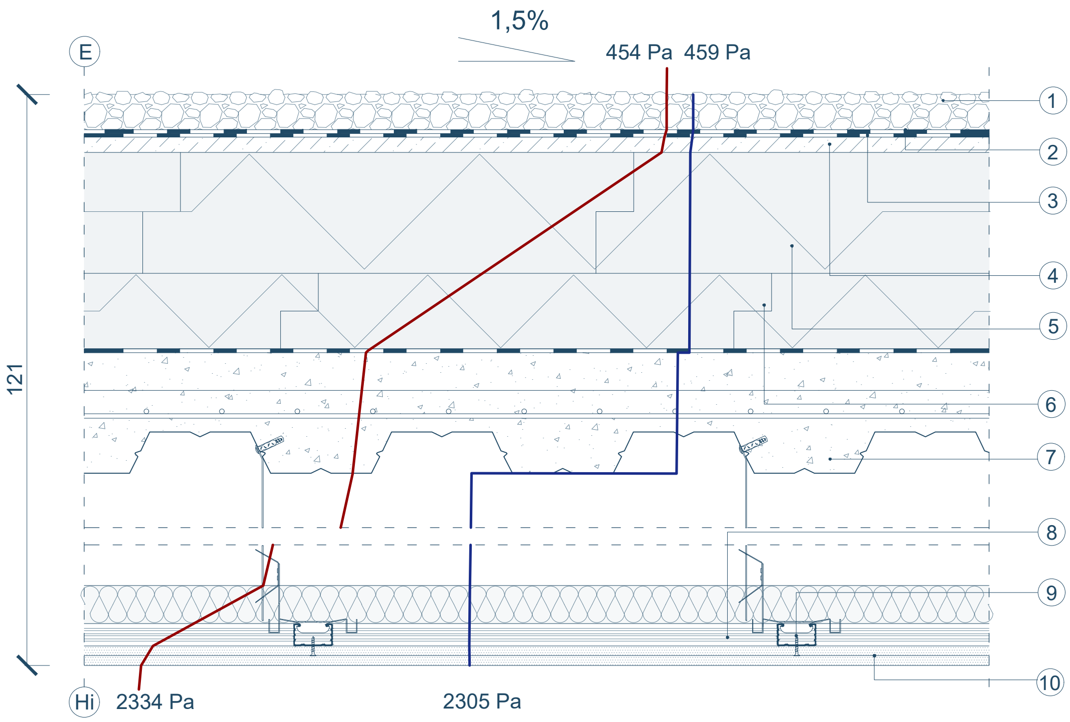
H.C.01 - Horizontal closure: practicable green roof - U = 0.103 W/m²K

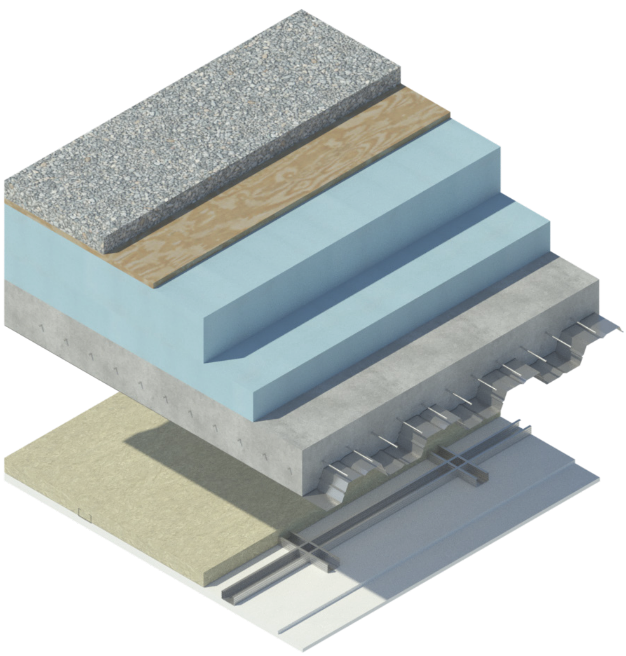




1. Soil layer for extensive cultivation th. 15 cm
2. Anti-root filtering layer, non-woven polyester fabric, th. 0.4 cm
3. Water collection layer: compression-resistant polyethylene storage elements, th. 6 cm
4. Protection layer: geotextile membrane with polypropylene fibers, th. 0.13 cm
5. Watertight layer: waterproof and desolidarizing sheet in PVC reinforced with glass fibers, th. 6 mm
6. Thermal insulation layer: XPS panel, th. 16+10 cm, λ = 0.033 W / mK, ρ = 33 kg / m3
7. Vapour barrier, aluminum foil with glass felt, th. 0.04 cm
8. Load bearing layer: prefabricated BubbleDeck slab, height 55 cm, spheres diameter 45 cm
9. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
10. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
11. Finishing layer: double plasterboard panel, th. 1.25 cm

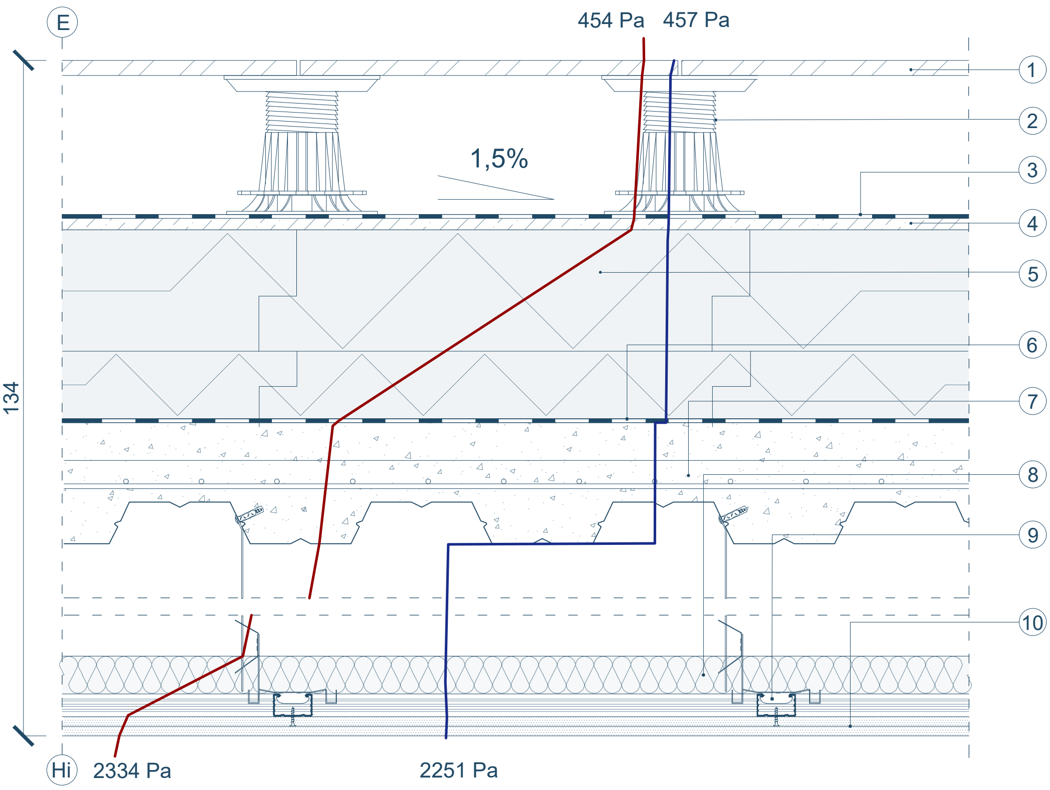
H.C.02 - Horizontal closure: not practicable roof - U = 0.102 W/m²K

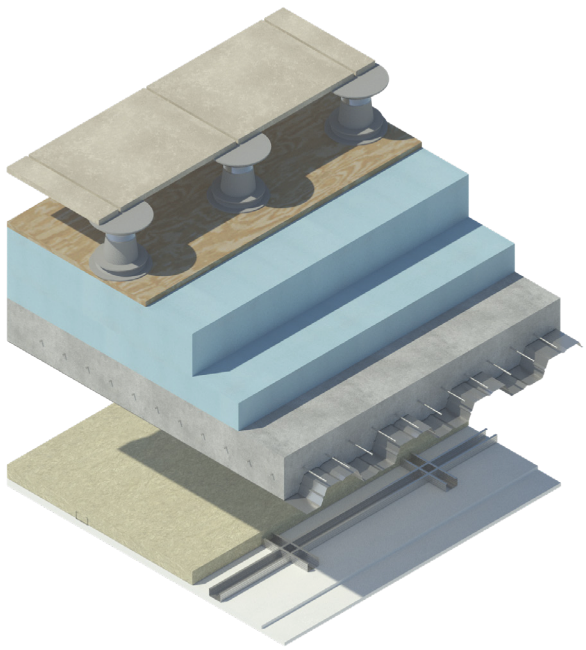




1. Ballasting layer: polished white gravel, th. 5 cm
2. Protection layer: draining and filtering membrane in high density polyethylene, th. 0.5 cm
3. Water-tight layer: breathable waterproofing membrane in polypropylene and non-woven fabric, th. 0.9 mm
4. Load sharing layer: OSB chipboard panels, dim. 125x200 cm, th. 2 cm
5. Slope and thermal insulation layer: XPS panels, th. 16+10 cm, λ = 0.033 W / mK, ρ = 33 kg / m3 , slope 1.5%
6. Vapour barrier: aluminum foil with glass felt, th. 0.04 cm
7. Load bearing layer: metal deck with reinforced concrete, th. 5,5+5,5 cm, with 5 cm of low density concrete for loads distribution
8. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
9. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
10. Finishing layer: double plasterboard panel, th. 1.25 cm

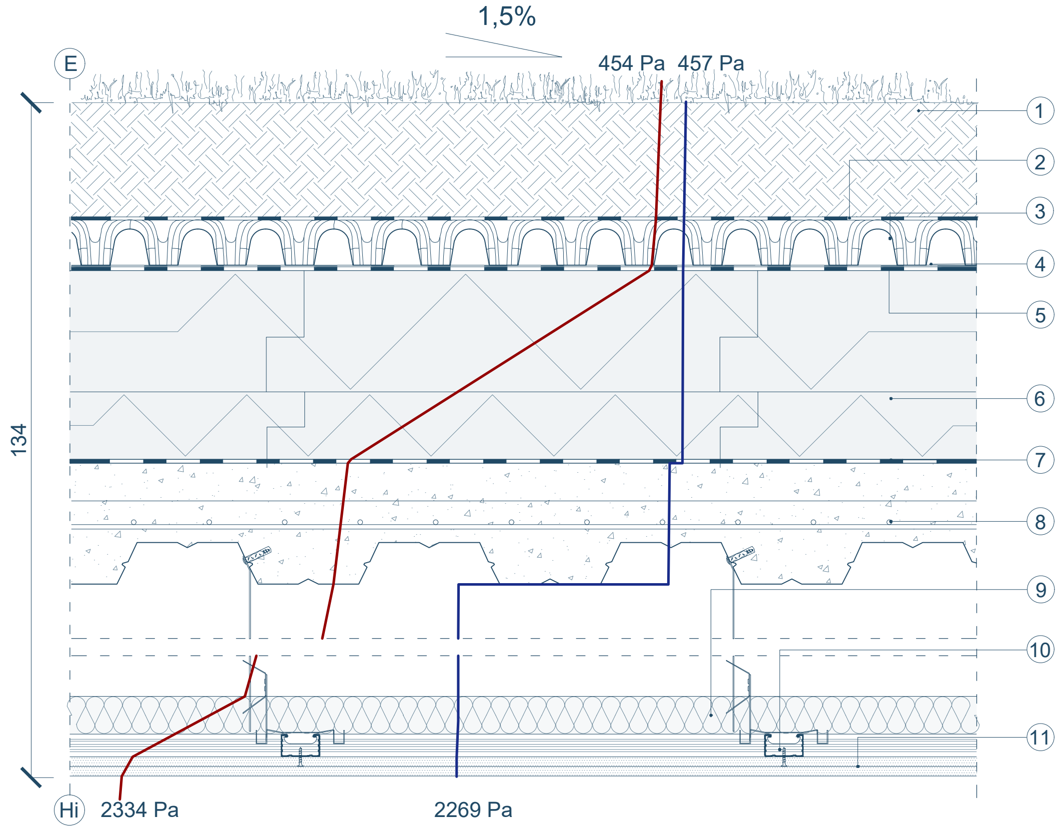
H.C.03 - Horizontal closure: practicable roof terrace - U = 0.101 W/m²K

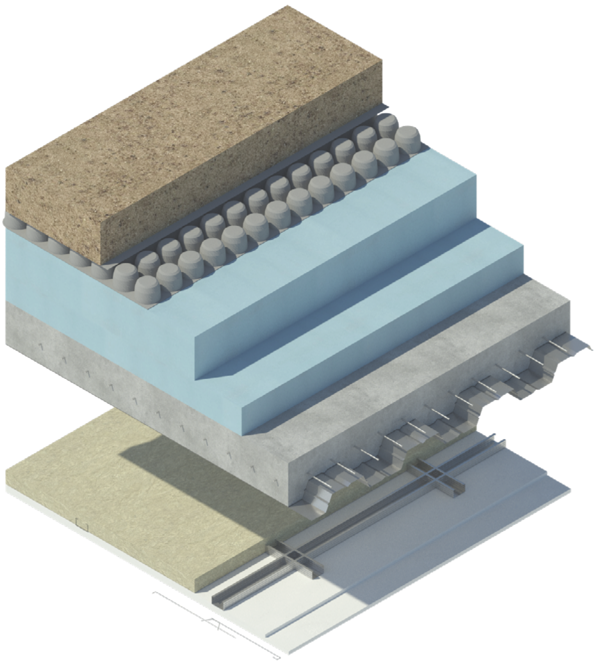




1. Finishing layer: simil wood porcelain stoneware, dim. 60x120 cm, th. 2 cm
2. Bearing elements for outdoor flooring, height 21.5 cm
3. Watertight layer: elastomeric bituminous membrane, sp. 0.5 cm
4. Load distribution layer: OSB chipboard panels, dim. 125x200 cm, sp. 2 cm
5. Slope and thermal insulation layer: XPS panels, th. 10+16 cm, λ = 0.033 W / mK, ρ = 33 kg / m3, slope 1.5%
6. Vapour barrier: aluminum foil with glass felt, th. 0.04 cm
7. Load bearing layer: metal deck with reinforced concrete, th. 5,5+5,5 cm, with 5 cm of low density concrete for loads distribution
8. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
9. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
10. Finishing layer: double plasterboard panel, th. 1.25 cm

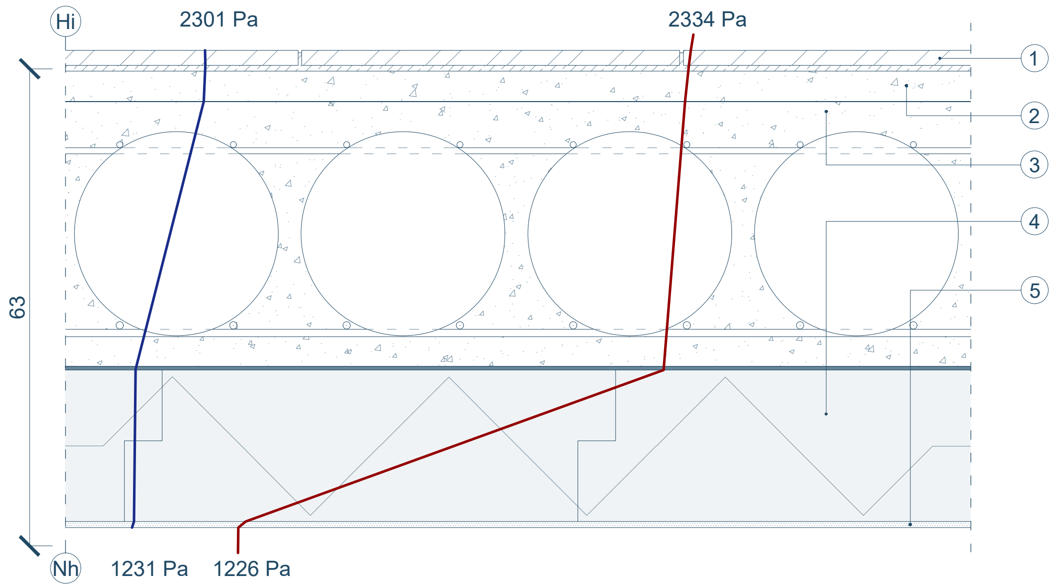
H.C.04 - Horizontal closure: practicable green roof terrace - U = 0.103 W/m²K

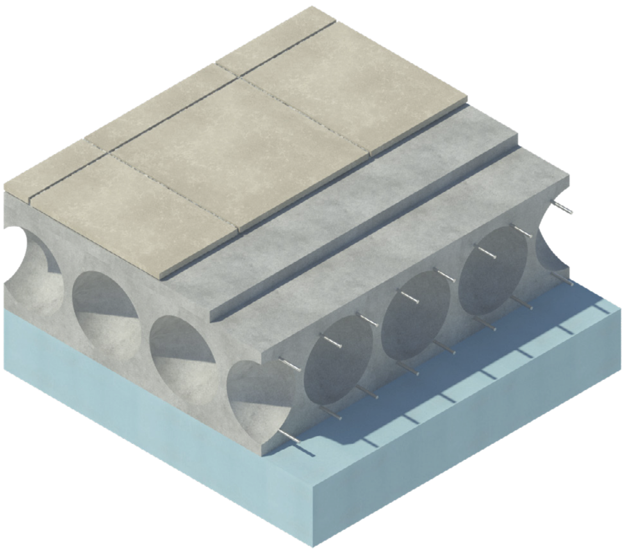




1. Soil layer for extensive cultivation th. 15 cm
2. Anti-root filtering layer, non-woven polyester fabric, th. 0.4 cm
3. Water collection layer: compression-resistant polyethylene storage elements, th. 6 cm
4. Protection layer: geotextile membrane with polypropylene fibers, th. 0.13 cm
5. Watertight layer: waterproof and desolidarizing sheet in PVC reinforced with glass fibers, th. 6 mm
6. Slope and thermal insulation layer: XPS panels, th. 10+16 cm, λ = 0.033 W / mK, ρ = 33 kg / m3, slope 1.5%
7. Vapour barrier: aluminum foil with glass felt, th. 0.04 cm
8. Load bearing layer: metal deck with reinforced concrete, th. 5,5+5,5 cm, with 5 cm of low density concrete for loads distribution
9. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
10. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
11. Finishing layer: double plasterboard panel, th. 1.25 cm

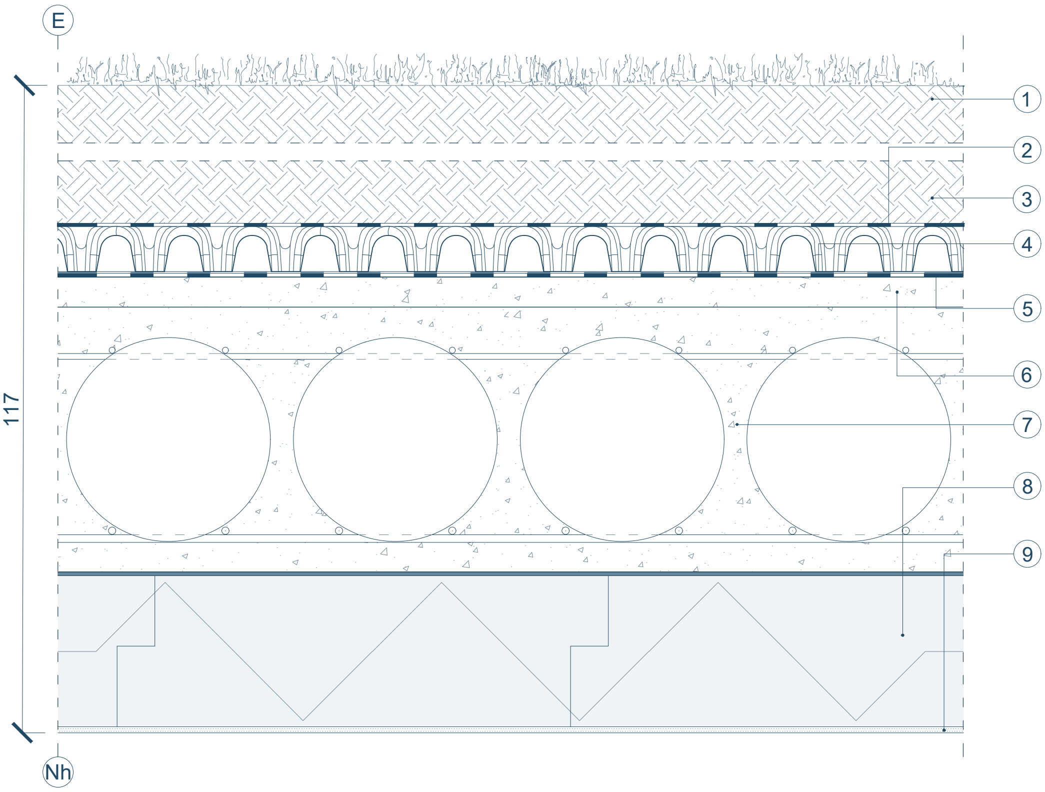
H.C.05 - Horizontal closure: ground floor/parking lot - U = 0.152 W/m²K

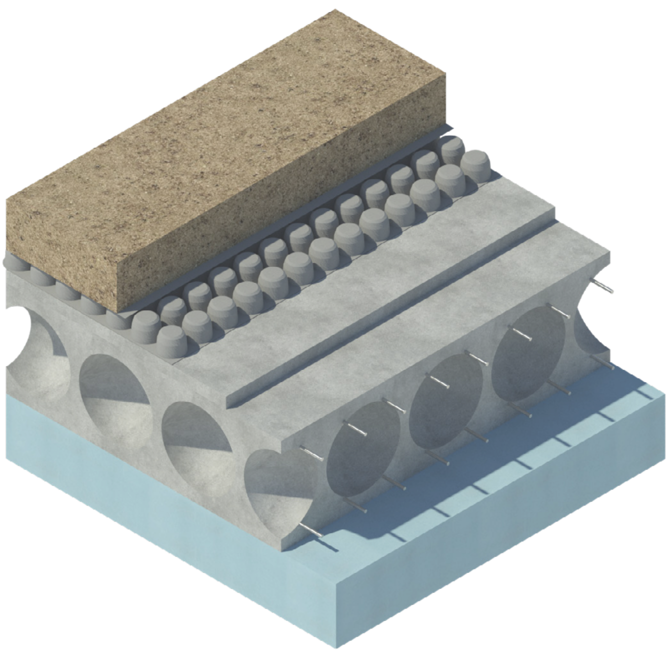




1. Finishing layer: simil wood porcelain stoneware, dim. 60x120 cm, th. 2 cm
2. Load distribution layer: slightly reinforced concrete, th. 4 cm
3. Load bearing layer: prefabricated BubbleDeck slab, height 35 cm, spheres diameter 27 cm
4. Thermal insulation layer: EPS panels, th. 20 cm, λ = 0.033 W / mK, ρ = 33 kg / m3, glued to the bearing layer
5. Finishing layer: plaster, th. 0.4 cm

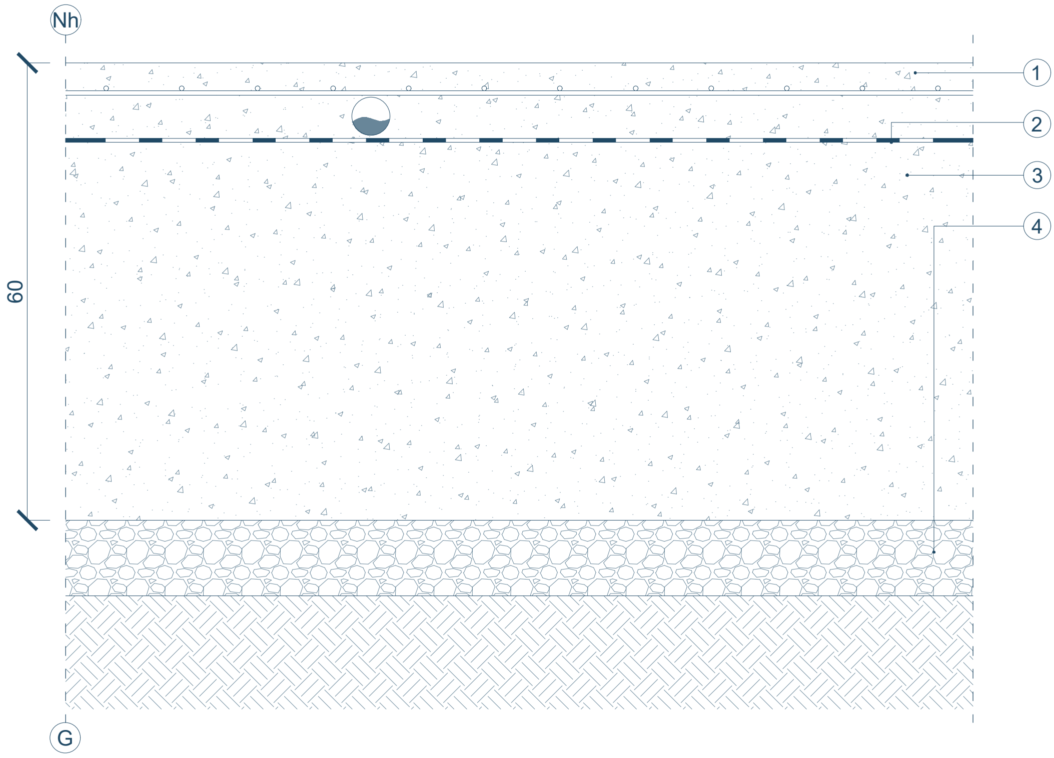
H.C.06 - Horizontal closure: green ground floor/parking lot - U = 0.148 W/m²K

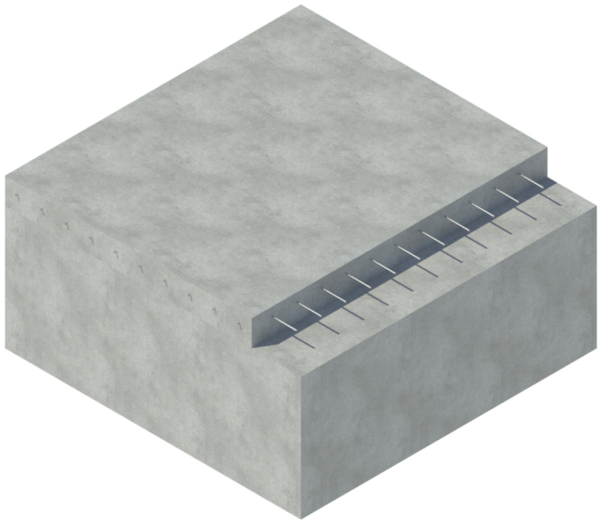




1. Soil layer for extensive cultivation th. 50 cm
2. Anti-root filtering layer, non-woven polyester fabric, th. 0.4 cm
3. Water collection layer: compression-resistant polyethylene storage elements, th. 6 cm
4. Protection layer: geotextile membrane with polypropylene fibers, th. 0.13 cm
5. Watertight layer: waterproof and desolidarizing sheet in PVC reinforced with glass fibers, th. 6 mm
6. Load distribution layer: slightly reinforced concrete, th. 4 cm
7. Load bearing layer: prefabricated BubbleDeck slab, height 35 cm, spheres diameter 27 cm
8. Thermal insulation layer: EPS panels, th. 20 cm. λ = 0.033 W / mK, ρ = 33 kg / m3, glued to the bearing layer
9. Finishing layer: plaster, th. 0.4 cm

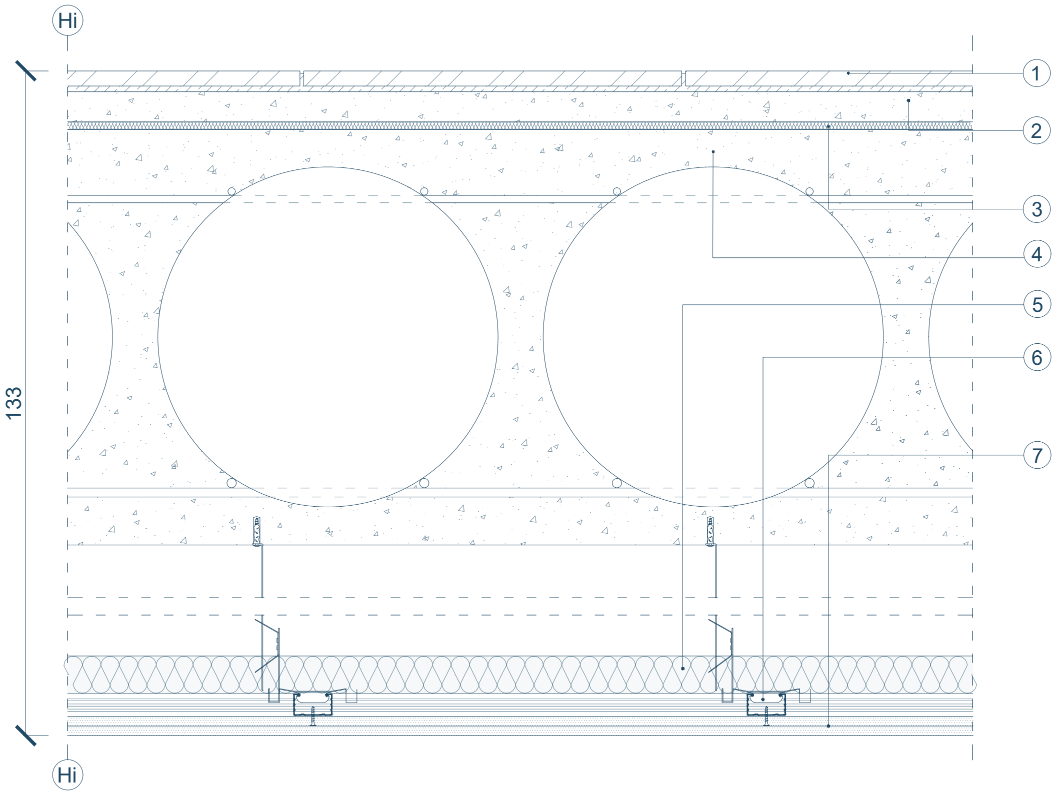
H.C.07 - Horizontal closure: water resistant ground flooring

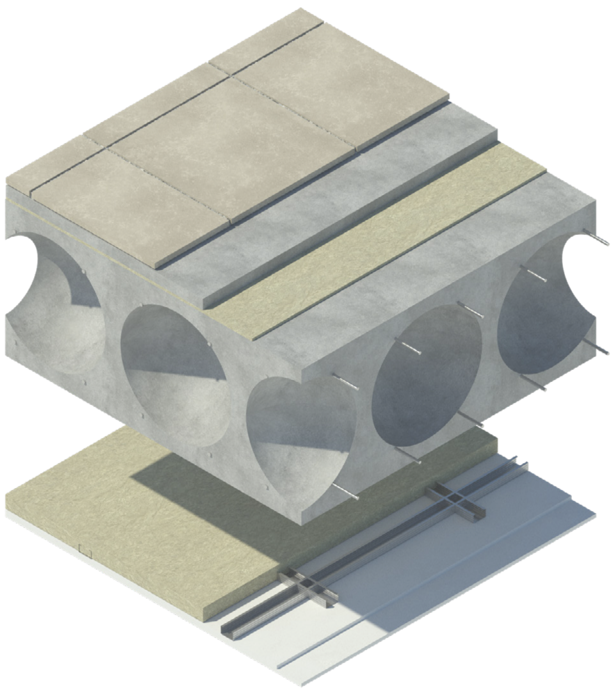




1. Loads distribution layer: low density reinforced polished concrete, th. 10 cm
2. Watertight layer: waterproof sheet in PVC reinforced with glass fibers, th. 6 mm
3. Underwater concrete floor, th. 50 cm
4. Levelling layer: gravel with variable thickness

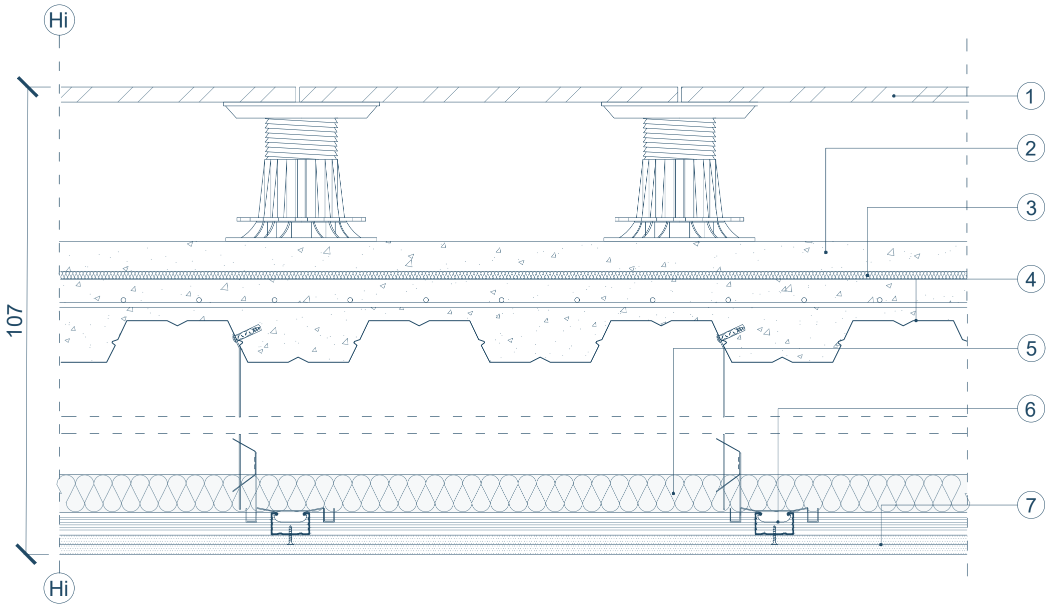
H.I.P.01 - Horizontal internal partition

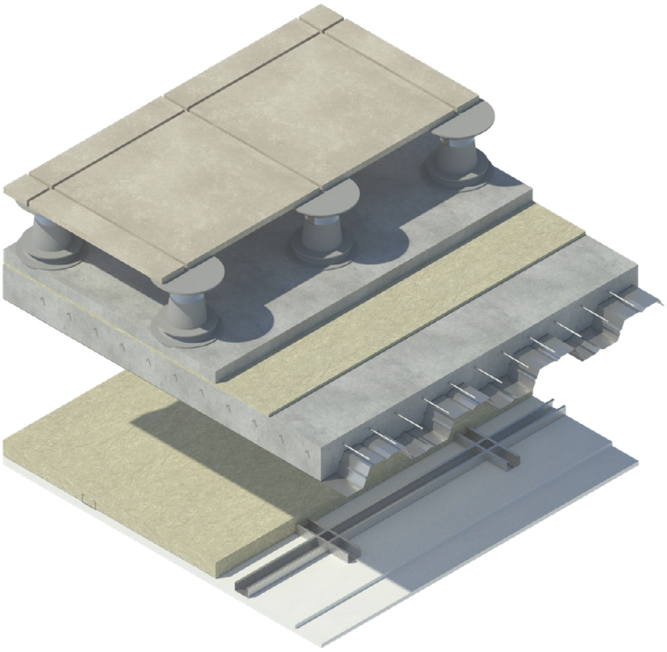




1. Finishing layer: simil wood porcelain stoneware, dim. 60x120 cm, th. 2 cm
2. Load distribution layer: slightly reinforced concrete, th. 4 cm
3. Sound insulation layer with impact noise: polymer-bitumen elastoplastic membrane coupled with a layer of polyester fiber, dimensions: 1x1 m, th. 1.3 cm, λ = 0.032 W / mK
4. Load bearing layer: prefabricated BubbleDeck slab, height 55 cm, spheres diameter 45 cm
5. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
6. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
7. Finishing layer: double plasterboard panel, th. 1.25 cm

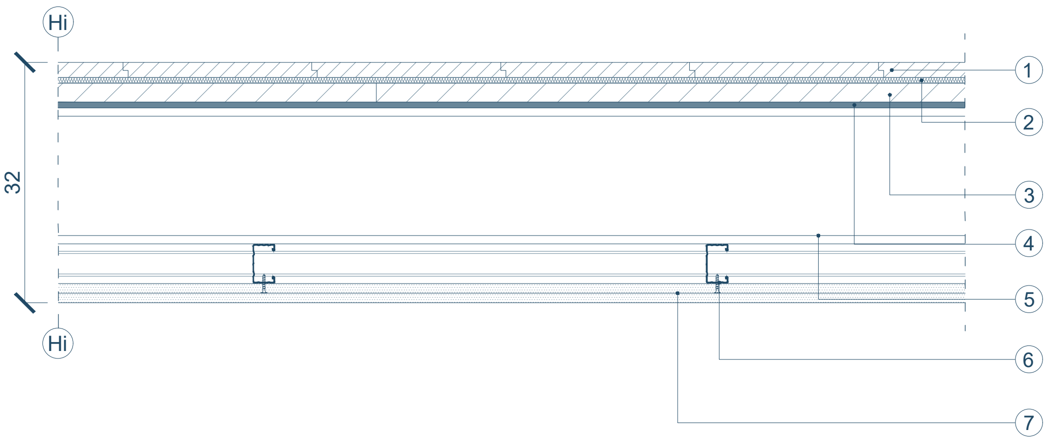
H.I.P.02 - Horizontal internal partition - Restaurant flooring

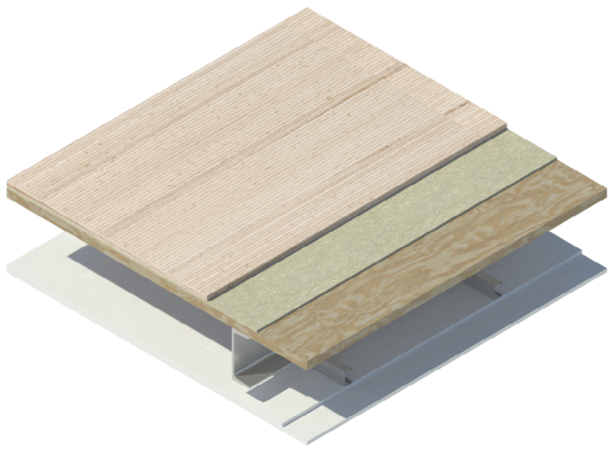




1. Finishing layer: simil wood porcelain panels, dim. 60x60 cm, th. 2 cm
2. Load distribution layer: slightly reinforced concrete, th. 4 cm
3. Sound insulation layer with impact noise: polymer-bitumen elastoplastic membrane coupled with a layer of polyester fiber, dimensions: 1x1 m, th. 1.3 cm, λ = 0.032 W / mK
4. Load bearing layer: metal deck with reinforced concrete, th. 5,5+5,5 cm, with 5 cm of low density concrete for loads distribution
5. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
6. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
7. Finishing layer: double plasterboard panel, th. 1.25 cm

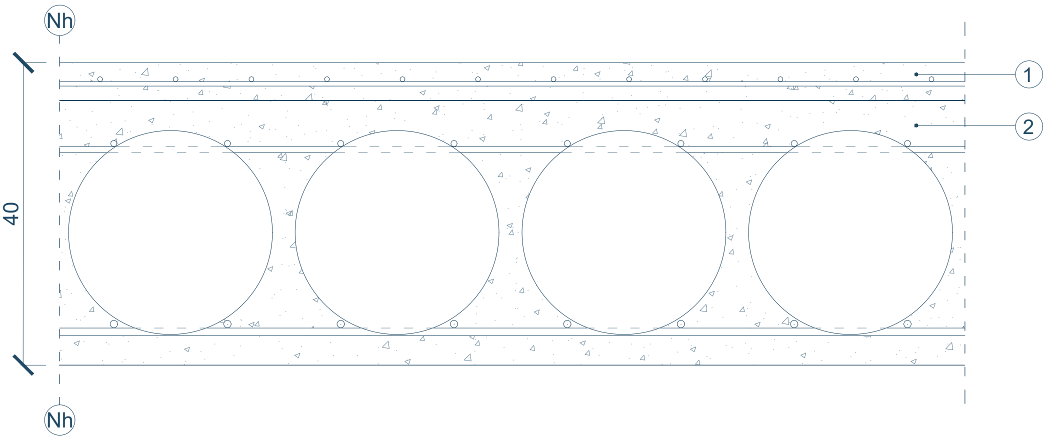
H.I.P.03 - Horizontal internal partition - Suspended flooring

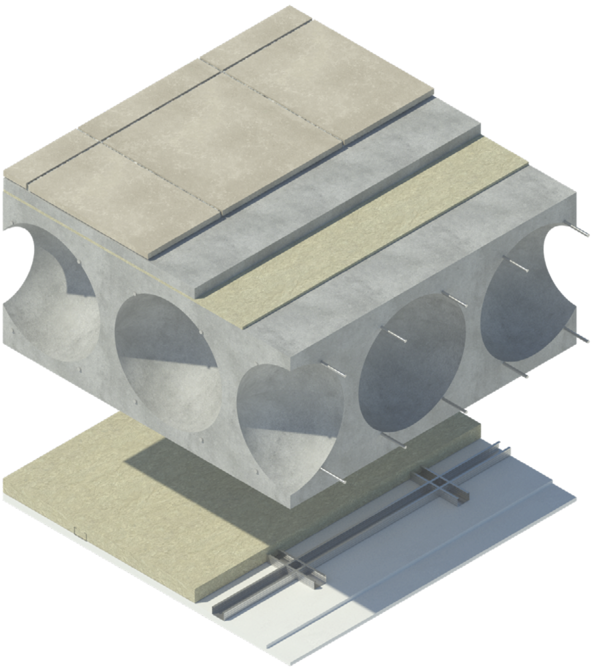




1. Finishing layer: wooden flooring, dim. 25x120 cm, th. 2 cm
2. Sound insulation layer: polymer-bitumen elastoplastic membrane coupled with a layer of polyester fiber, dimensions: 1x1 m, th. 1.3 cm, λ = 0.032 W / mK
3. Load distribution layer: laminated timber panels, dim. 120x300 cm, th. 4 cm
4. Connection layer: high density foam
5. Bearing layer: UPN180 profiles, steel S275
6. C-shaped load-bearing profiles crossed with appropriate orthogonal union hook, dim. 50x27 mm, thickness 0.6 mm
7. Finishing layer: double plasterboard panel, th. 1.25 cm

H.E.P.01 - Horizontal exterior partition - Parking lot flooring

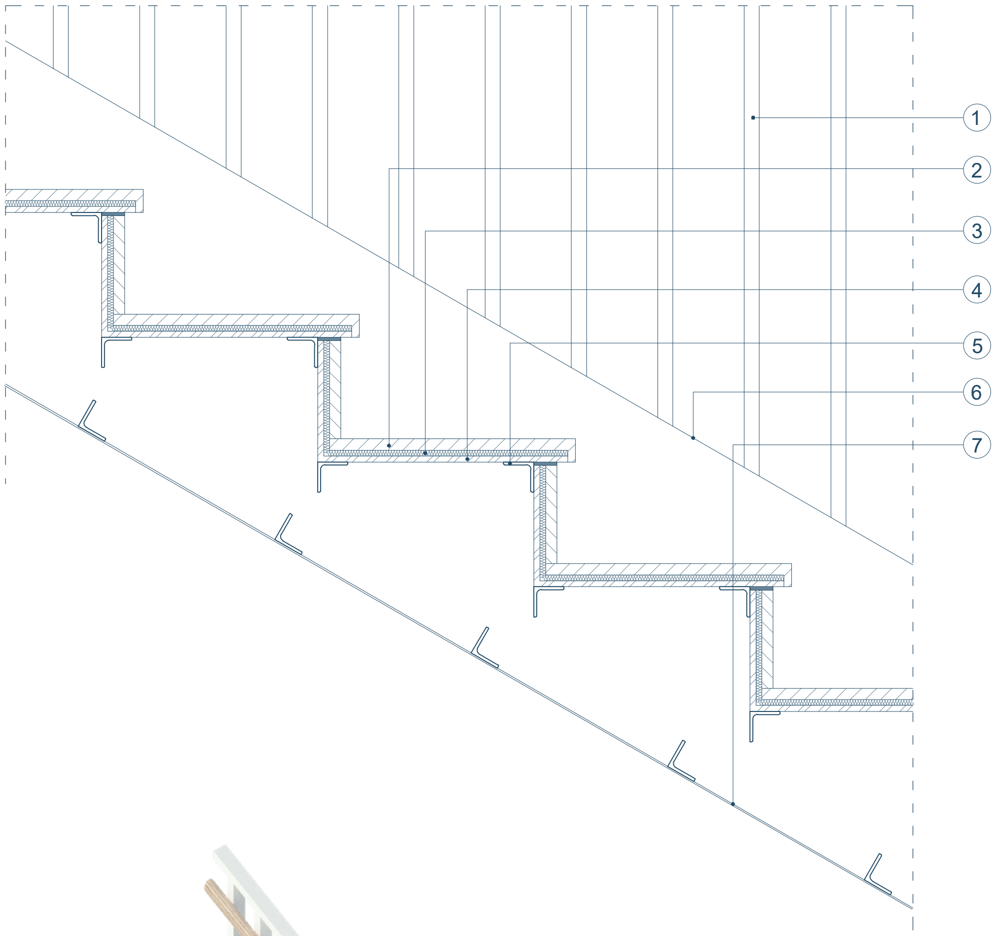


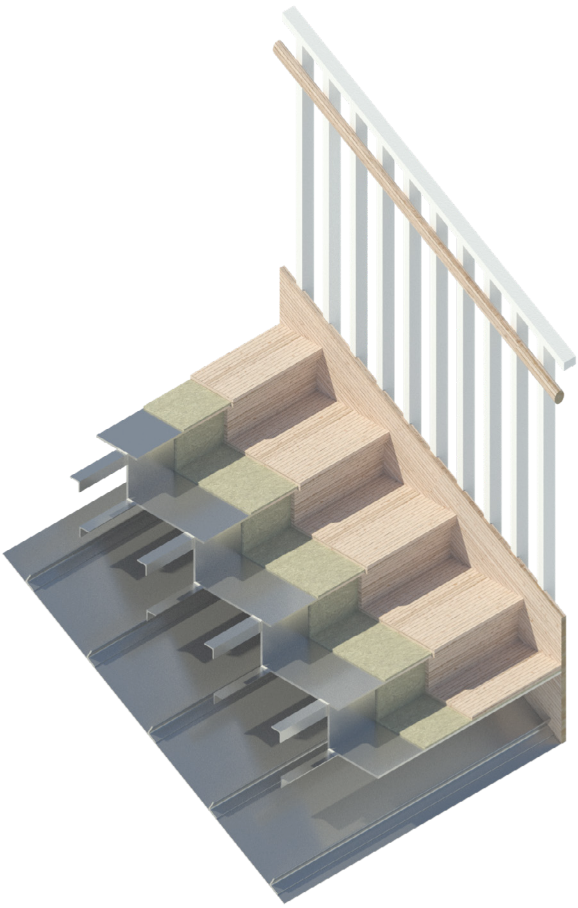


1. Loads distribution layer: low density reinforced polished concrete, th. 5 cm

2. Load bearing layer: prefabricated BubbleDeck slab, height 35 cm, spheres diameter 27 cm

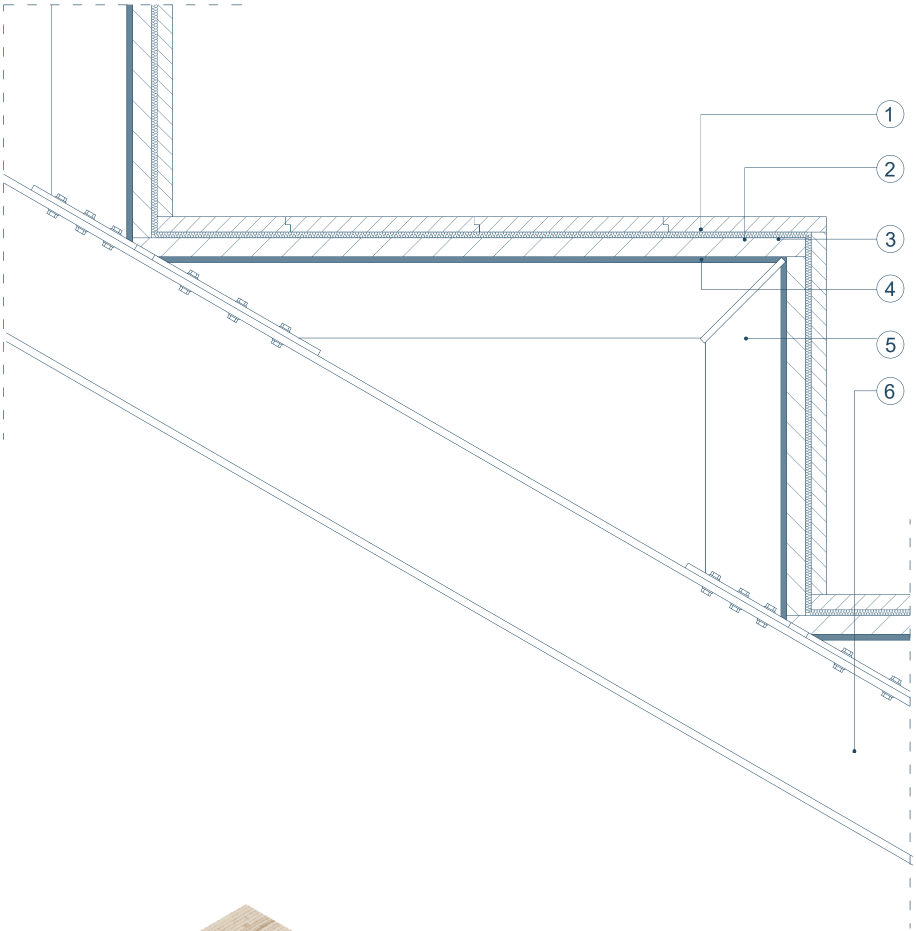
H.I.P.04 - Main stairs





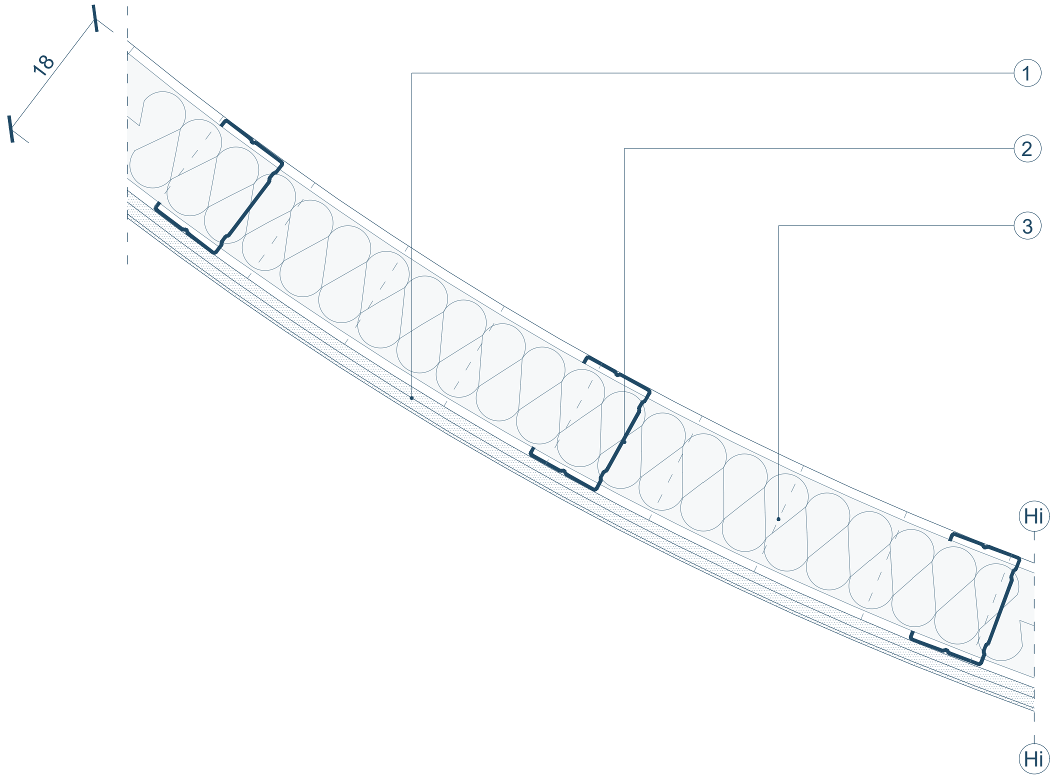
1. Railing, dim. 2.5x5 cm, welded to the bearing structure
2. Finishing layer: wooden flooring, th. 1.5 cm
3. Sound insulation layer: polymer-bitumen elastoplastic membrane coupled with a layer of polyester fiber, dimensions: 1x1 m, th. 1.3 cm, λ = 0.032 W / mK
4. Steel plate, "L" shaped, th. 8 mm
5. Steel profile, "L", shaped, dim. 4x4 cm, th. 4 mm
6. Bearing structure, steel plates, th. 2 cm
7. Bottom finishing, steel plate, th. 2 mm, with outer coating and finished painted

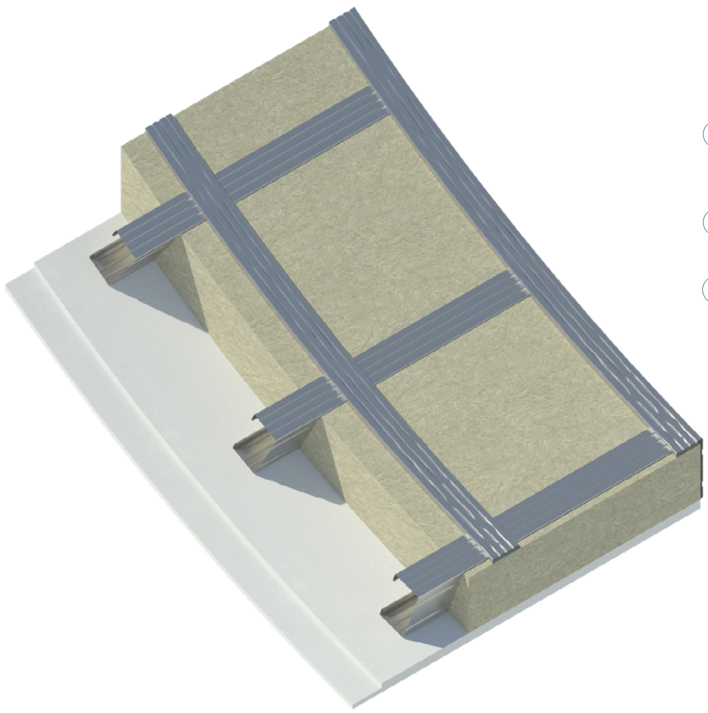
H.I.P.05 - Theatre halls flooring



1. Finishing layer: wooden flooring, dim. 25x120 cm, th. 2 cm
2. Sound insulation layer: polymer-bitumen elastoplastic membrane coupled with a layer of polyester fiber, dimensions: 1x1 m, th. 1.3 cm, λ = 0.032 W / mK
3. Load distribution layer: laminated timber panels, dim. 120x300 cm, th. 4 cm
4. Connection layer: high density foam
5. Bearing layer: squared hollow sections, dim 100x100 mm, S275, welded together
6. Bearing layer: HEA200 profiles, dim. 200x190 mm, S275

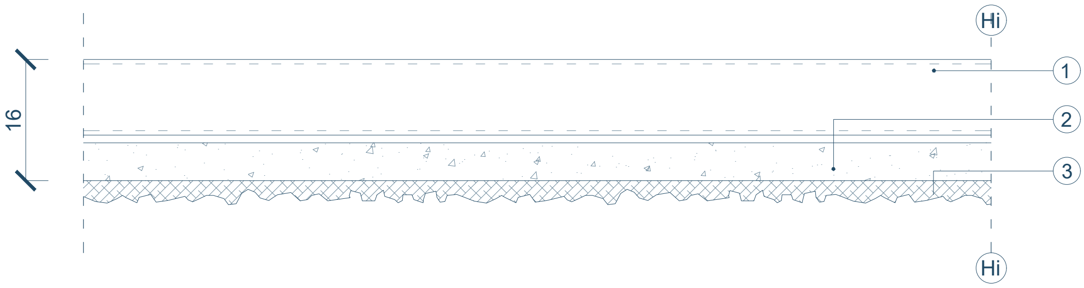
H.I.P. 06 - Vertical partition: main hall exterior finishing

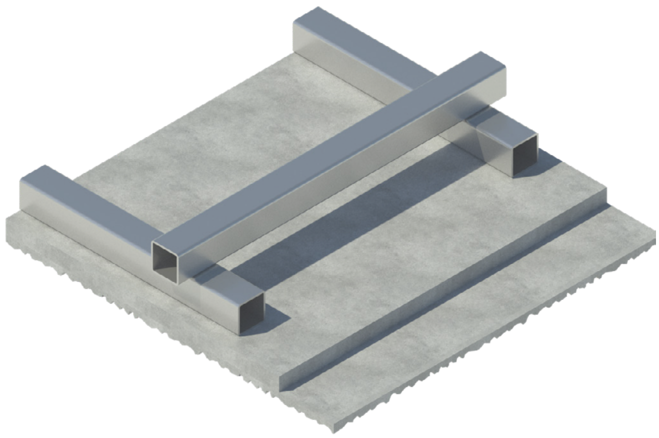




1. Finishing layer: double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing wooden layer
2. Support layer: vertical frame of C-shaped profiles, width 10 cm, th. 0.6 mm
3. Plasterboard sheet, dim. 20x30 cm, th. 1,25 cm

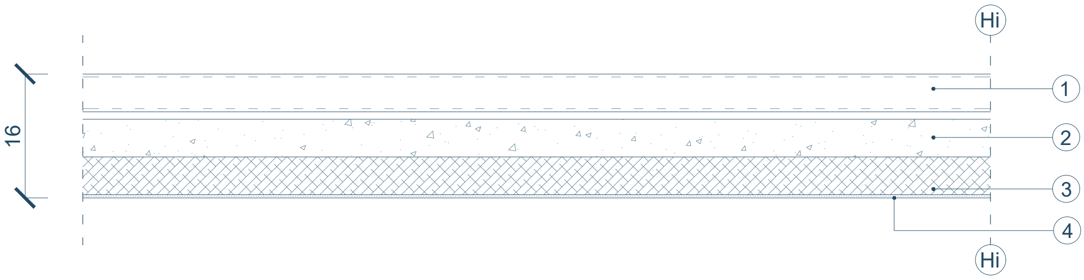
H.I.P. 07 - Auditorium acoustic ceiling

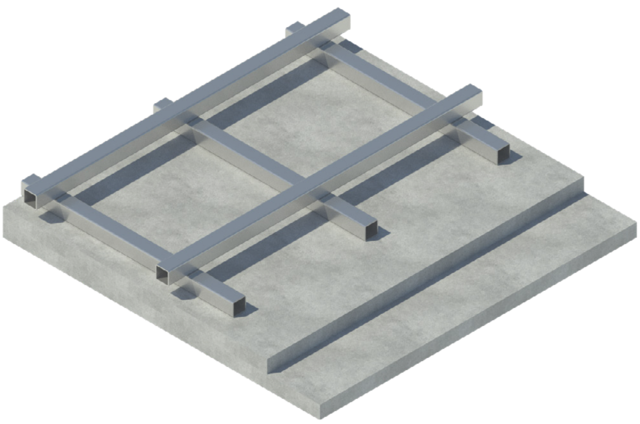




1. Supporting steel squared profile, dim. 100x100 mm, th. 6 mm
2. Concrete panel supports, th. 5 mm
3. Shaped fibre-reinforced polymer layer for acoustic dispersion

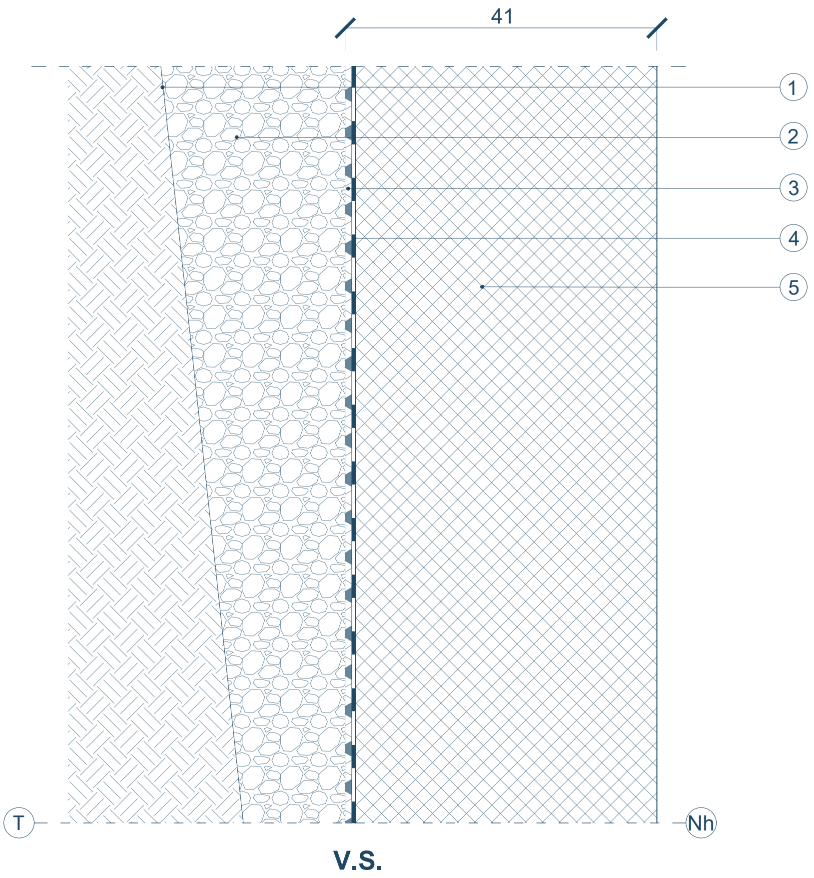
H.I.P. 08 - Auditorium acoustic baffle

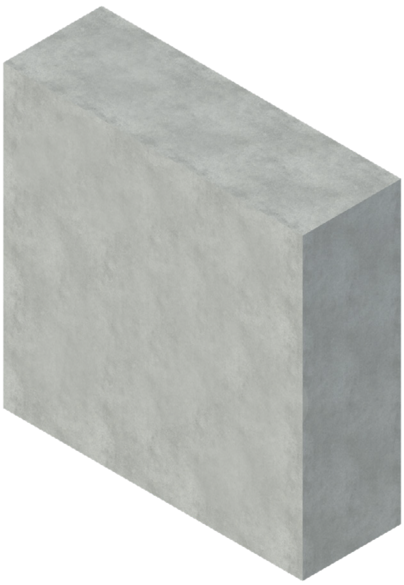




1. Supporting steel pipes, diameter 50 mm, th. 4 mm
2. Concrete panel supprts, th. 5 cm
3. Fibre-reinforced polymer panel, th. 5 cm
4. Sound insulating plaster finish

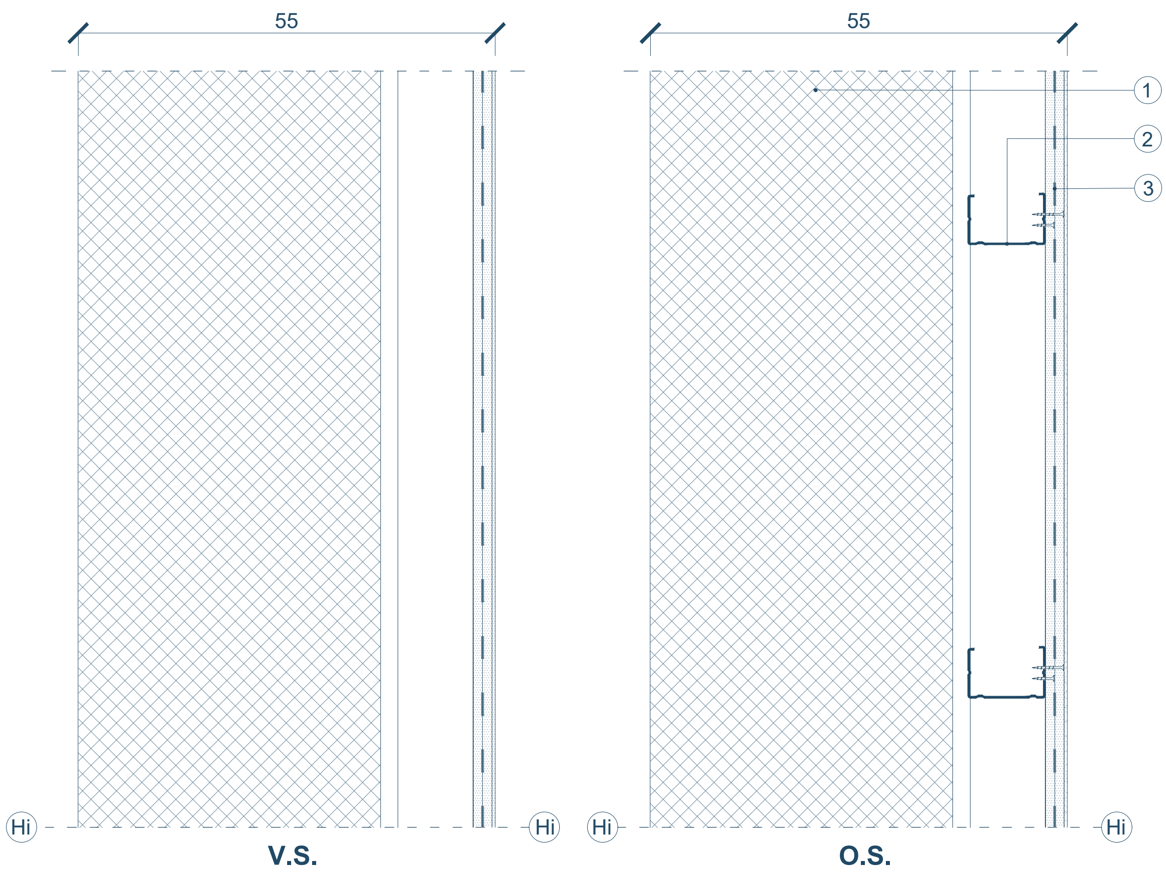
V.C.01 - Vertical closure: not insulated ground wall - U = 1,9 W/m^{2}K

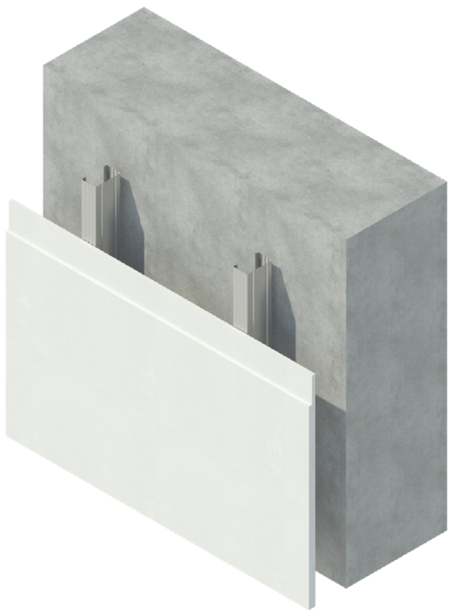




1. Protection layer of the drainage layer in non-woven fabric
2. Gravel draining layer for ventilated crawl space
3. Protection layer in alveolar membrane and integrated geotextile, sp. 0.9 cm
4. Water-tight layer in elastomeric bituminous waterproofing membrane, th. 0.45 cm
5. Load-bearing layer in reinforced concrete, th. 40 cm

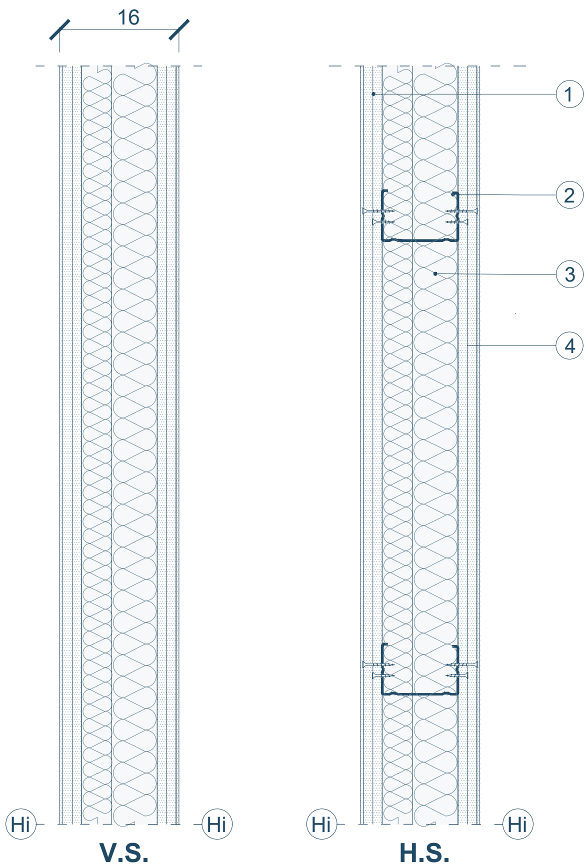
V.P.01 - Vertical partition: structural wall

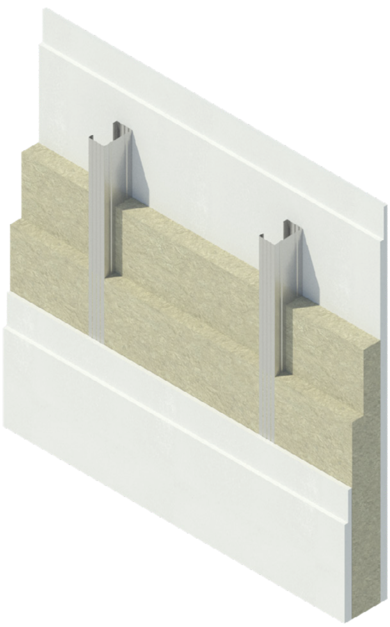




1. Load-bearing layer in reinforced concrete, th. 40 cm
2. Support layer: vertical frame of C-shaped profiles, width 10 cm, th. 0.6 mm
3. Cladding layer: double plasterboard sheet with interposed aluminum foil (vapor barrier), sp. 2x1.25 cm, width 120 cm, with a leveling and finishing layer

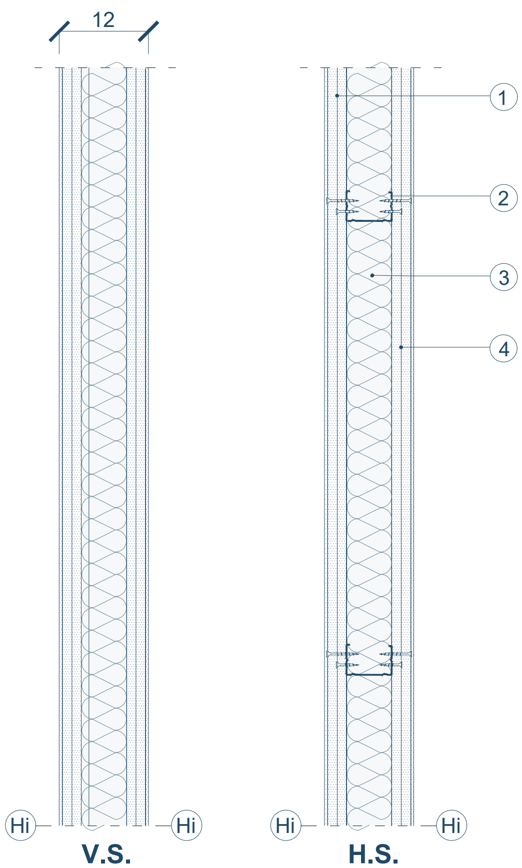
V.P.02 - Vertical partition: soundproof not equipped wall

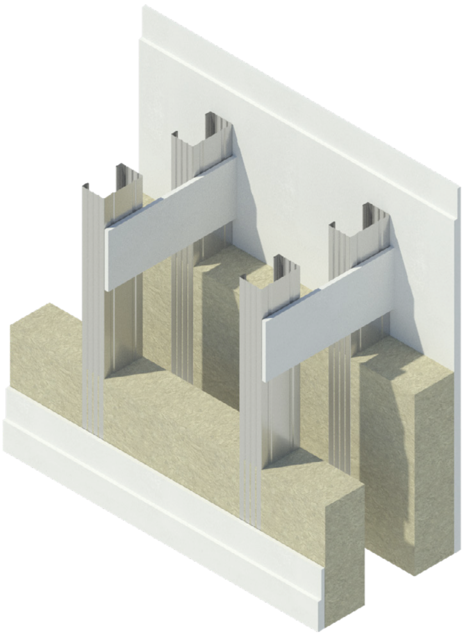




1. Finishing layer: double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing layer
2. Support layer: vertical frame of C-shaped profiles, width 10 cm, th. 0.6 mm
3. Sound-insulation layer: rock wool panels, th. 6+4 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
4. Finishing layer, double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing layer

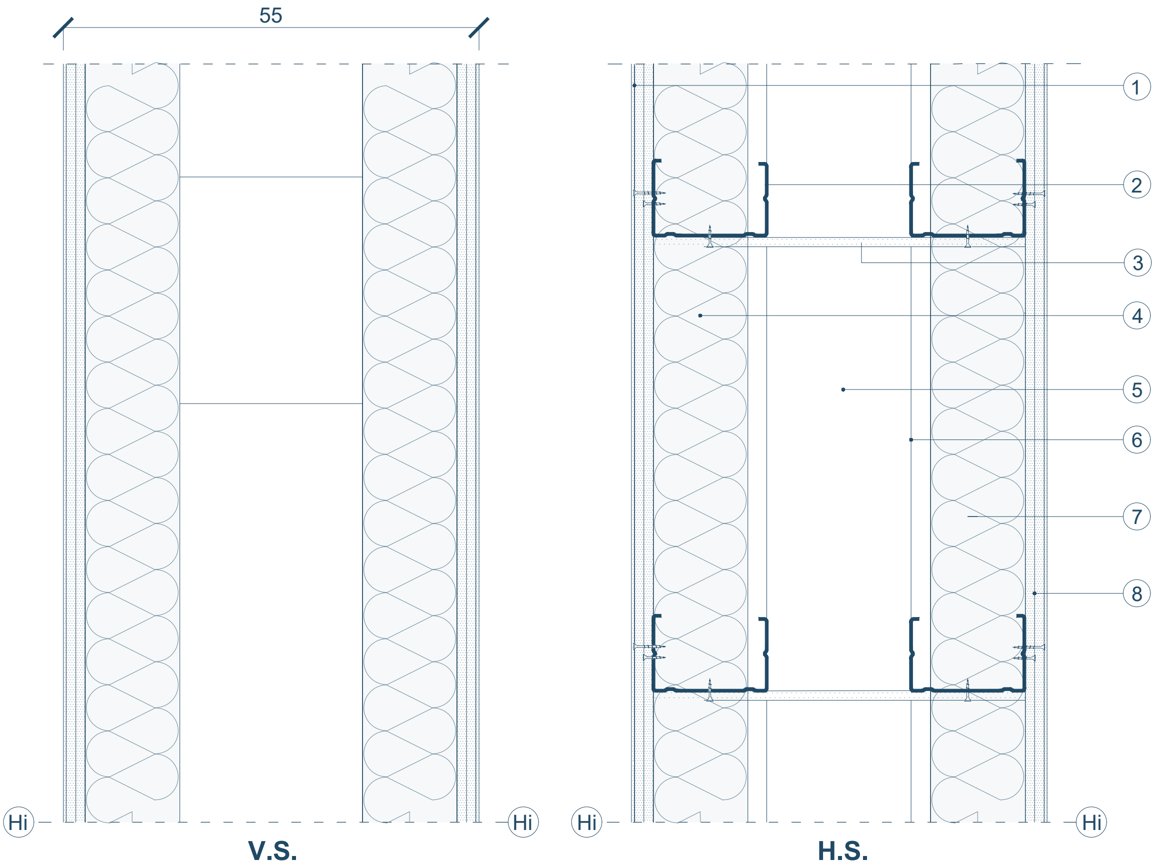
V.P.03 - Vertical partition: not equipped wall

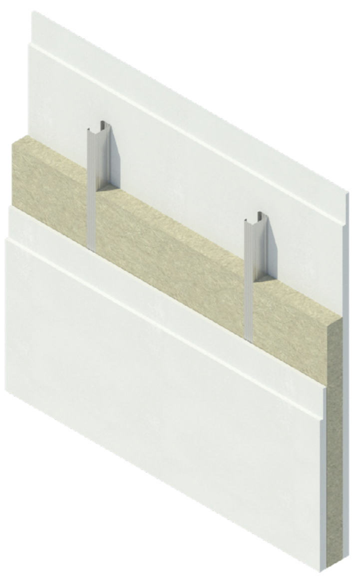




1. Finishing layer: double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing layer
2. Support layer: vertical frame of C-shaped profiles, width 10 cm, th. 0.6 mm
3. Sound-insulation layer: rock wool panels, th. 6 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
4. Finishing layer, double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing layer

V.P.04 - Vertical partition: equipped wall

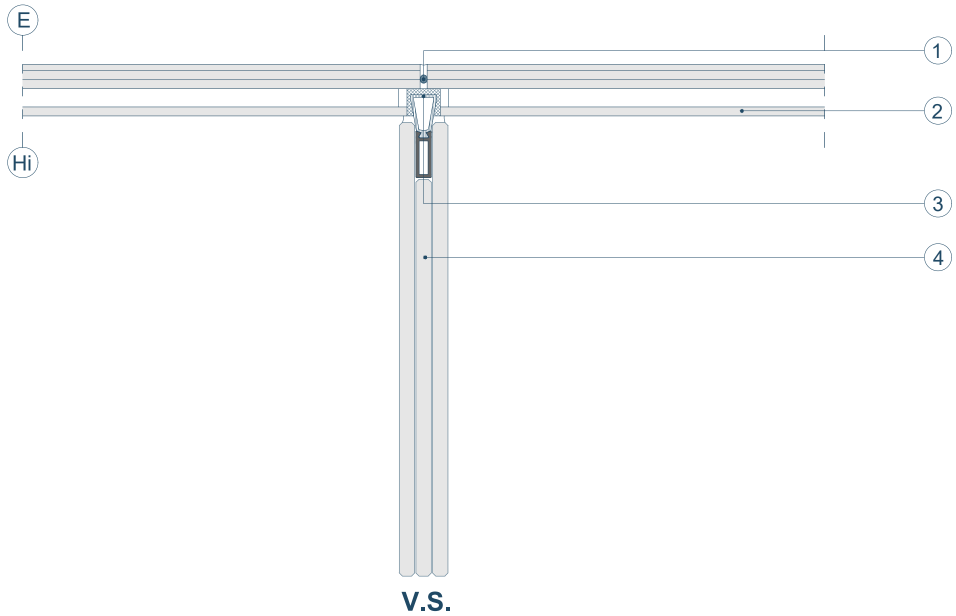


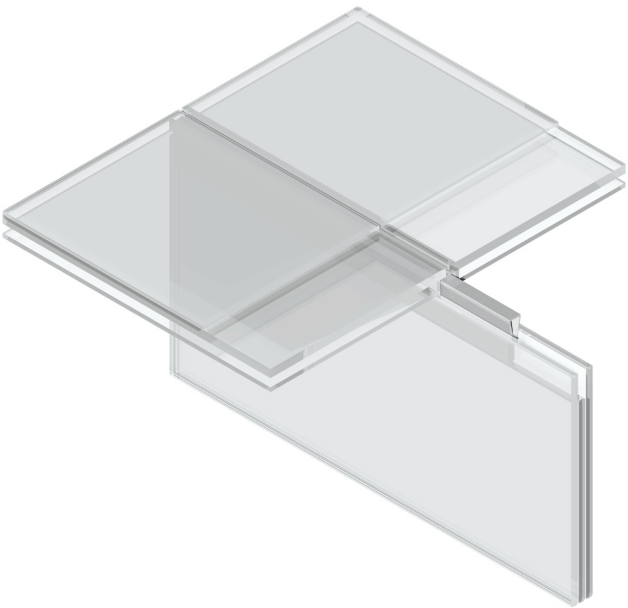


1. Finishing layer: double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing layer
2. Support layer: vertical frame of C-shaped profiles, width 10 cm, th. 0.6 mm

   Plasterboard sheet, dim. 20x30 cm, th. 1,25 cm
3. Sound-insulation layer: rock wool panels, th. 6 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
4. Equipped cavity, th. 25 cm
5. Support layer: vertical frame of C-shaped profiles, width 10 cm, th. 0.6 mm
6. Sound-insulation layer: rock wool panels, th. 6 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
7. Finishing layer: double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing layer

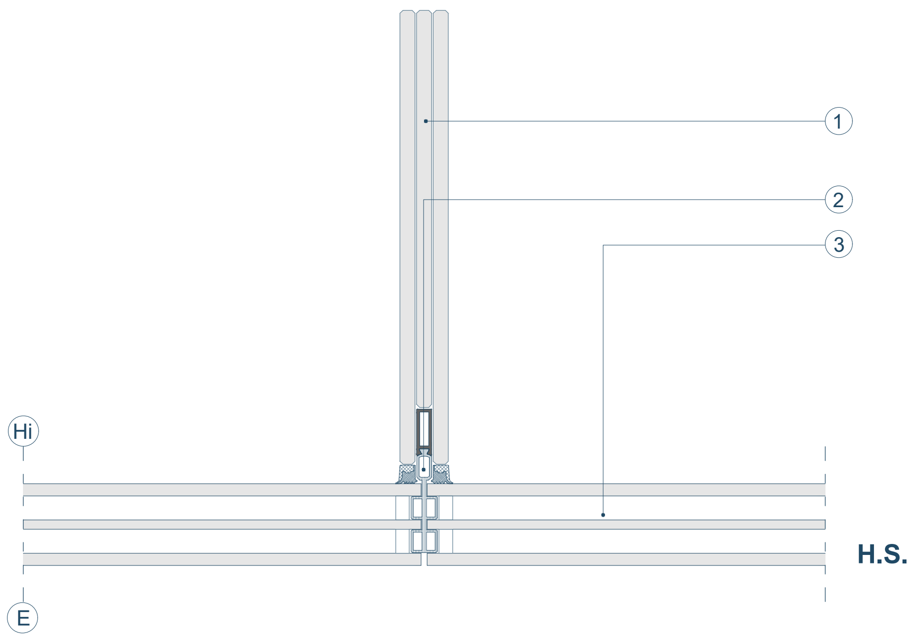
H.C. 08 - Glass floor

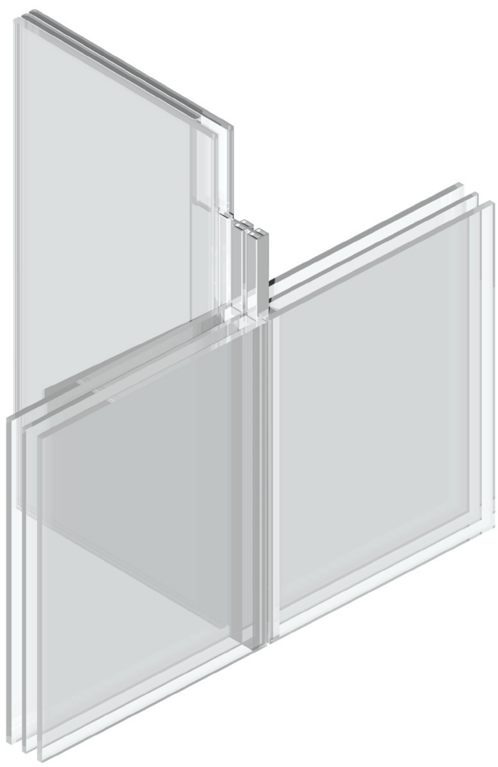




1. Silicone closing
2. Laminated glass floor: 4 mm sacrificial layer tempered glass; 6+6 mm tempered glass with PVB layer; 12 mm air filled cavity, 6 mm tempered glass
3. High resistance thermal cut and supporting element
4. Triple layered high resistance tempered glass with PVB layer, th. 1+1+1 cm, height 30 cm

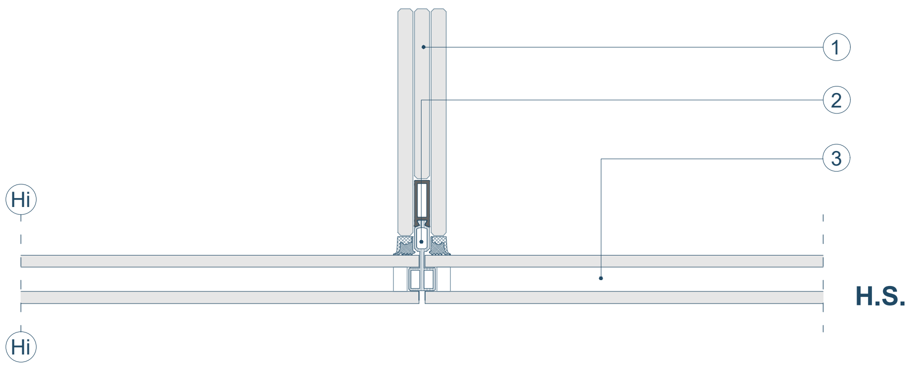
V.C. 02 - Ground floor glazed facade

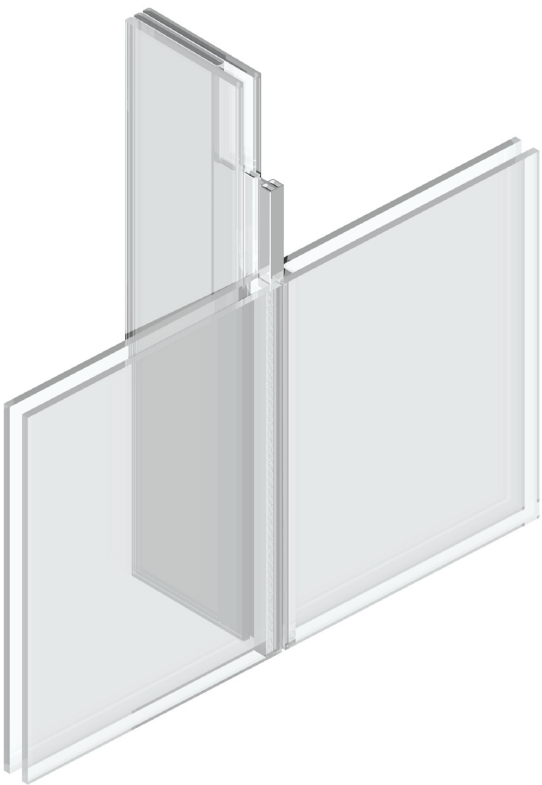




1. Triple layered high resistance tempered glass with PVB laye, th 1+1+1 cm, depth 30 cm
2. High resistance thermal cut
3. Triple layered glass with air fill, th. 8/16/6/16/8 mm

V.P. 05 - Reharsal rooms soundproof partition





1. Triple layered high resistance tempered glass with PVB laye, th 1+1+1 cm, depth 15 cm
2. High resistance acoustic cut
3. Double layered glass with air fill, th. 8/16/8 mm

Annex B
Energy simulations results

The energy simulations were carried out on an hourly basis, for the whole 365 days of the year. Then, in order to eliminate unusual peaks or downs, only the averages on the month days are considered for the calculus. The tables are divided per month, each containing the energy production and consumption. The production is then divided depending on the quantity of PV panels installed, each step is cumulating the ones before.

Here are presented the simulations relative to the SynEnergy Hall building, then the district and unit blocks simulations are introduced.

SynEnergy Hall

JANUARY				
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	0,00	0,00	0,00
07:00	13,87	0,00	0,00	0,00
08:00	25,73	0,10	0,15	0,17
09:00	21,16	6,07	8,79	10,10
10:00	263,80	16,16	23,09	26,43
11:00	198,12	26,63	37,82	42,82
12:00	199,14	34,33	48,43	54,45
13:00	179,73	36,81	51,59	57,93
14:00	168,75	33,06	46,03	51,97
15:00	166,11	24,65	34,16	39,06
16:00	174,54	14,19	19,94	23,09
17:00	207,47	4,59	6,61	7,70
18:00	219,58	0,08	0,13	0,15
19:00	204,52	0,00	0,00	0,00
20:00	209,19	0,00	0,00	0,00
21:00	211,96	0,00	0,00	0,00
22:00	211,66	0,00	0,00	0,00
23:00	226,53	0,00	0,00	0,00
24:00	65,10	0,00	0,00	0,00

FEBRUARY				
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	0,00	0,00	0,00
07:00	13,24	0,00	0,00	0,00
08:00	23,57	2,08	3,12	3,59
09:00	18,90	12,83	18,76	21,11
10:00	225,24	28,58	41,19	45,59
11:00	164,93	45,26	64,45	70,52
12:00	162,62	58,21	82,02	89,15
13:00	141,14	63,07	88,03	95,54
14:00	125,15	57,42	79,44	86,61
15:00	117,21	44,08	60,62	67,16
16:00	122,51	27,61	38,83	43,77
17:00	155,98	12,39	18,08	20,62
18:00	183,46	2,12	3,19	3,72
19:00	176,40	0,00	0,00	0,00
20:00	185,73	0,00	0,00	0,00
21:00	191,25	0,00	0,00	0,00
22:00	192,88	0,00	0,00	0,00
23:00	209,85	0,00	0,00	0,00
24:00	64,39	0,00	0,00	0,00

Hour	Consumption (kWh)	MARCH Production (kWh) Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,45	0,00	0,00	0,00
07:00	10,40	1,72	2,80	3,26
08:00	16,49	11,64	17,69	20,31
09:00	18,64	28,64	41,25	46,77
10:00	127,75	50,48	71,34	78,92
11:00	98,59	72,27	100,97	110,26
12:00	99,77	88,06	121,70	132,07
13:00	88,75	92,76	126,91	137,61
14:00	82,81	84,70	114,76	125,18
15:00	81,18	66,64	90,10	101,27
16:00	86,67	44,58	62,10	71,78
17:00	115,22	23,96	34,66	40,89
18:00	135,91	8,87	13,55	16,29
19:00	134,50	0,83	1,34	1,73
20:00	138,49	0,00	0,00	0,00
21:00	141,40	0,00	0,00	0,00
22:00	143,67	0,00	0,00	0,00
23:00	155,46	0,00	0,00	0,00
24:00	59,01	0,00	0,00	0,00

Hour	Consumption (kWh)	APRIL Production (kWh) Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	8,23	1,15	2,06	2,45
07:00	14,36	9,07	14,95	17,52
08:00	13,08	25,12	38,19	44,30
09:00	85,62	48,49	69,42	79,10
10:00	66,24	75,66	105,08	115,79
11:00	71,53	101,55	139,37	150,92
12:00	68,07	118,47	160,73	173,11
13:00	65,97	121,46	162,93	175,52
14:00	64,32	109,89	145,78	159,11
15:00	65,19	86,75	115,80	132,11
16:00	83,62	59,44	82,30	97,33
17:00	89,96	34,12	49,39	60,72
18:00	86,70	15,17	23,30	29,88
19:00	111,84	4,38	6,97	9,75
20:00	124,00	0,13	0,18	0,23
21:00	123,36	0,00	0,00	0,00
22:00	139,04	0,00	0,00	0,00
23:00	62,88	0,00	0,00	0,00
24:00	65,10	0,00	0,00	0,00

Hour	Consumption (kWh)	MAY Production (kWh) Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,36	0,57	0,74
06:00	6,67	5,39	9,14	11,26
07:00	11,81	16,42	26,68	32,19
08:00	11,19	35,53	53,58	63,81
09:00	51,17	61,38	87,27	101,17
10:00	47,98	90,44	123,70	138,23
11:00	57,75	116,70	157,65	171,21
12:00	56,99	132,85	177,39	191,53
13:00	57,32	134,75	177,86	192,17
14:00	57,13	122,01	159,17	176,22
15:00	58,55	98,00	129,69	150,69
16:00	86,79	68,78	94,42	114,41
17:00	85,76	41,91	60,15	76,53
18:00	74,08	21,04	31,89	42,96
19:00	80,64	9,12	14,00	20,09
20:00	114,64	1,91	2,76	4,13
21:00	116,14	0,00	0,00	0,00
22:00	129,62	0,00	0,00	0,00
23:00	62,87	0,00	0,00	0,00
24:00	65,10	0,00	0,00	0,00

Hour	Consumption (kWh)	JUNE Production (kWh) Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	1,01	1,71	2,29
06:00	6,43	7,01	12,10	15,37
07:00	11,46	17,73	29,37	36,45
08:00	11,03	37,28	56,68	68,60
09:00	50,39	63,40	90,36	105,94
10:00	47,74	92,57	125,80	142,50
11:00	63,58	118,56	158,67	172,81
12:00	68,61	135,52	179,26	193,53
13:00	74,31	138,35	180,84	195,28
14:00	78,02	126,36	163,19	181,29
15:00	82,82	102,99	134,95	157,78
16:00	147,56	74,27	100,96	123,43
17:00	135,32	46,43	66,02	85,29
18:00	116,43	24,26	36,65	50,85
19:00	115,16	11,39	17,61	26,33
20:00	133,22	4,28	6,16	9,99
21:00	132,45	0,00	0,00	0,00
22:00	132,07	0,00	0,00	0,00
23:00	62,87	0,00	0,00	0,00
24:00	65,10	0,00	0,00	0,00

		JULY		
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,38	0,68	0,93
06:00	2,49	5,28	9,41	11,92
07:00	3,67	15,42	26,38	32,37
08:00	2,08	35,53	54,93	66,05
09:00	10,55	63,70	91,56	106,67
10:00	21,71	96,08	131,11	147,45
11:00	32,08	125,97	169,11	182,77
12:00	38,26	146,03	193,70	207,61
13:00	38,29	150,58	197,29	211,39
14:00	32,20	138,51	179,13	196,25
15:00	22,06	113,00	147,59	170,69
16:00	11,11	81,06	110,00	133,12
17:00	2,40	49,88	71,04	91,00
18:00	156,67	25,16	38,34	52,93
19:00	155,27	10,96	17,39	26,15
20:00	169,91	3,82	5,60	9,10
21:00	133,22	0,00	0,00	0,00
22:00	132,45	0,00	0,00	0,00
23:00	132,07	0,00	0,00	0,00
24:00	63,26	0,00	0,00	0,00

		AUGUST		
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	6,73	1,83	3,36	4,06
07:00	12,39	10,56	17,99	21,29
08:00	11,47	28,53	44,02	51,66
09:00	53,44	54,71	78,67	90,23
10:00	53,61	85,81	118,29	130,89
11:00	80,93	114,95	156,34	168,54
12:00	87,62	134,90	181,29	194,21
13:00	96,92	139,30	184,99	198,13
14:00	103,14	127,09	166,70	181,28
15:00	107,79	101,85	134,40	153,63
16:00	198,95	71,01	97,36	115,91
17:00	175,12	41,55	59,76	74,70
18:00	148,24	19,26	29,62	39,29
19:00	143,58	6,66	10,75	15,60
20:00	163,08	0,84	1,28	2,03
21:00	140,64	0,00	0,00	0,00
22:00	143,66	0,00	0,00	0,00
23:00	63,67	0,00	0,00	0,00
24:00	63,26	0,00	0,00	0,00

		SEPTEMBER		
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ Top panels	+ Bottom
01:00	0,00	0,00	0,00	0,00
02:00	0,00	0,00	0,00	0,00
03:00	0,00	0,00	0,00	0,00
04:00	0,00	0,00	0,00	0,00
05:00	0,00	0,00	0,00	0,00
06:00	6,78	0,14	0,29	0,34
07:00	13,17	5,64	9,27	10,75
08:00	11,86	21,23	32,15	36,74
09:00	56,24	44,67	63,99	71,98
10:00	52,02	72,77	102,05	111,57
11:00	62,14	99,14	137,33	148,35
12:00	60,98	115,51	158,14	170,12
13:00	65,12	117,56	159,18	171,33
14:00	76,91	104,58	140,11	152,42
15:00	83,73	80,54	108,53	122,79
16:00	147,83	52,15	72,92	85,16
17:00	141,79	27,45	40,19	48,27
18:00	126,46	9,89	15,46	19,30
19:00	124,16	1,29	2,08	2,81
20:00	119,32	0,00	0,00	0,00
21:00	116,16	0,00	0,00	0,00
22:00	129,56	0,00	0,00	0,00
23:00	62,87	0,00	0,00	0,00
24:00	0,00	0,00	0,00	0,00

		OCTOBER		
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ Top panels	+ Bottom
01:00	0,00	0,00	0,00	0,00
02:00	0,00	0,00	0,00	0,00
03:00	0,00	0,00	0,00	0,00
04:00	0,00	0,00	0,00	0,00
05:00	0,00	0,00	0,00	0,00
06:00	7,38	0,00	0,00	0,00
07:00	14,76	1,36	2,13	2,47
08:00	13,66	10,87	16,03	18,44
09:00	88,27	27,36	39,16	44,27
10:00	73,50	47,05	66,65	73,98
11:00	77,37	65,28	91,57	100,52
12:00	71,65	76,23	105,88	115,69
13:00	67,22	76,23	104,92	114,79
14:00	65,40	65,40	89,26	98,58
15:00	68,72	47,39	65,01	73,88
16:00	98,27	27,94	39,50	45,75
17:00	120,77	11,77	17,22	20,18
18:00	118,16	1,78	2,72	3,26
19:00	121,03	0,00	0,00	0,00
20:00	122,79	0,00	0,00	0,00
21:00	121,70	0,00	0,00	0,00
22:00	135,91	0,00	0,00	0,00
23:00	65,03	0,00	0,00	0,00
24:00	2,03	0,00	0,00	0,00

NOVEMBER				
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	0,00	0,00	0,00
07:00	10,01	0,00	0,00	0,00
08:00	18,14	2,08	3,00	3,50
09:00	16,13	10,55	15,16	17,40
10:00	160,00	21,71	30,96	35,05
11:00	123,76	32,08	45,43	50,86
12:00	126,44	38,26	53,77	59,90
13:00	112,94	38,29	53,42	59,60
14:00	108,08	32,20	44,65	50,20
15:00	111,90	22,06	30,62	35,04
16:00	126,16	11,11	15,75	18,25
17:00	158,99	2,40	3,46	4,08
18:00	167,04	0,00	0,00	0,00
19:00	150,43	0,00	0,00	0,00
20:00	154,52	0,00	0,00	0,00
21:00	156,67	0,00	0,00	0,00
22:00	155,27	0,00	0,00	0,00
23:00	169,91	0,00	0,00	0,00
24:00	63,26	0,00	0,00	0,00

DECEMBER				
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ Top panels	+ Bottom
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	0,00	0,00	0,00
07:00	12,96	0,00	0,00	0,00
08:00	23,88	0,15	0,21	0,25
09:00	19,97	5,61	8,12	9,31
10:00	240,97	14,79	21,18	24,09
11:00	181,15	23,92	34,05	38,33
12:00	182,38	30,07	42,51	47,56
13:00	163,17	31,04	43,59	48,77
14:00	154,00	26,47	36,93	41,62
15:00	153,59	18,25	25,39	29,02
16:00	165,45	9,06	12,83	14,82
17:00	196,21	1,32	1,91	2,23
18:00	205,55	0,00	0,00	0,00
19:00	191,62	0,00	0,00	0,00
20:00	196,67	0,00	0,00	0,00
21:00	198,73	0,00	0,00	0,00
22:00	196,96	0,00	0,00	0,00
23:00	211,46	0,00	0,00	0,00
24:00	64,57	0,00	0,00	0,00

Multifunctional district

JANUARY

Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	0,00	0,00	0,00
07:00	3,18	0,00	0,00	0,00
08:00	56,00	0,83	0,97	1,31
09:00	157,15	22,43	26,28	34,05
10:00	58,25	56,40	66,51	84,24
11:00	49,61	89,51	106,26	129,72
12:00	52,62	113,21	135,15	160,48
13:00	44,78	119,71	143,49	167,13
14:00	41,35	106,16	127,40	148,95
15:00	50,19	77,57	92,83	111,31
16:00	53,50	42,66	50,90	62,70
17:00	58,27	10,42	12,36	15,58
18:00	43,53	0,00	0,00	0,00
19:00	103,69	0,00	0,00	0,00
20:00	215,85	0,00	0,00	0,00
21:00	184,51	0,00	0,00	0,00
22:00	104,91	0,00	0,00	0,00
23:00	104,34	0,00	0,00	0,00
24:00	103,95	0,00	0,00	0,00

FEBRUARY

Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,51	0,00	0,00	0,00
02:00	2,49	0,00	0,00	0,00
03:00	2,50	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	0,00	0,00	0,00
07:00	1,13	0,00	0,00	0,00
08:00	53,66	9,49	10,92	14,84
09:00	117,46	43,80	51,20	67,99
10:00	54,25	93,91	111,25	142,23
11:00	48,28	146,62	174,83	210,56
12:00	51,31	187,86	225,22	260,49
13:00	43,62	203,01	244,61	275,16
14:00	40,17	184,42	223,06	251,61
15:00	48,78	140,80	170,81	198,83
16:00	52,63	85,78	104,36	126,20
17:00	54,23	35,73	43,52	54,89
18:00	43,15	3,39	4,01	5,17
19:00	80,71	0,00	0,00	0,00
20:00	182,19	0,00	0,00	0,00
21:00	174,22	0,00	0,00	0,00
22:00	102,87	0,00	0,00	0,00
23:00	102,87	0,00	0,00	0,00
24:00	102,87	0,00	0,00	0,00

MARCH

Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,51	0,00	0,00	0,00
02:00	2,49	0,00	0,00	0,00
03:00	2,50	0,00	0,00	0,00
04:00	2,51	0,00	0,00	0,00
05:00	2,49	0,00	0,00	0,00
06:00	0,00	0,00	0,00	0,00
07:00	0,25	7,77	8,86	12,61
08:00	50,74	40,63	45,73	63,59
09:00	85,25	96,75	110,17	148,71
10:00	50,06	167,18	193,01	248,35
11:00	47,64	238,61	277,94	334,43
12:00	51,22	290,89	340,98	391,97
13:00	43,56	307,96	362,86	406,17
14:00	40,17	282,91	334,66	378,61
15:00	48,17	223,99	265,71	310,49
16:00	51,27	149,92	178,39	216,51
17:00	52,56	78,85	94,05	119,31
18:00	42,77	27,15	32,53	42,92
19:00	85,59	1,12	1,31	1,72
20:00	174,35	0,00	0,00	0,00
21:00	174,96	0,00	0,00	0,00
22:00	107,16	0,00	0,00	0,00
23:00	107,16	0,00	0,00	0,00
24:00	95,17	0,00	0,00	0,00

APRIL

Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	6,37	7,33	10,88
07:00	49,97	32,83	37,52	56,00
08:00	79,33	83,83	93,55	135,27
09:00	50,36	161,55	179,86	247,73
10:00	47,40	252,26	285,15	368,11
11:00	50,64	339,10	387,51	463,78
12:00	43,17	398,24	458,49	520,94
13:00	39,23	412,33	477,37	529,07
14:00	46,32	377,49	438,89	496,73
15:00	49,41	301,91	351,88	412,55
16:00	50,47	210,24	245,62	300,18
17:00	37,58	121,35	141,75	182,14
18:00	79,60	52,73	61,61	82,96
19:00	165,26	11,95	13,90	19,70
20:00	174,21	0,00	0,00	0,00
21:00	108,41	0,00	0,00	0,00
22:00	108,41	0,00	0,00	0,00
23:00	108,41	0,00	0,00	0,00
24:00	2,50	0,00	0,00	0,00

MAY

Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,51	0,00	0,00	0,00
02:00	2,49	0,00	0,00	0,00
03:00	2,50	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	2,81	3,23	4,52
06:00	2,49	22,99	26,51	39,77
07:00	50,50	58,73	67,11	102,23
08:00	78,74	120,28	133,74	195,62
09:00	48,91	208,25	228,52	315,99
10:00	47,56	307,16	340,73	441,75
11:00	50,90	397,55	446,24	536,55
12:00	43,58	456,44	516,48	586,15
13:00	40,66	468,32	533,04	592,09
14:00	48,47	429,78	491,18	559,69
15:00	52,07	351,02	402,12	474,79
16:00	54,35	251,39	288,01	354,83
17:00	36,82	156,87	179,13	232,02
18:00	81,71	78,84	89,92	123,32
19:00	155,27	29,51	33,81	49,04
20:00	173,08	3,23	3,71	5,19
21:00	107,16	0,00	0,00	0,00
22:00	107,16	0,00	0,00	0,00
23:00	107,16	0,00	0,00	0,00
24:00	2,51	0,00	0,00	0,00

JUNE

Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,49	0,00	0,00	0,00
02:00	2,50	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	5,75	6,63	10,11
06:00	2,49	28,49	33,01	51,93
07:00	47,43	63,80	73,09	115,43
08:00	74,51	127,26	141,54	210,73
09:00	49,47	217,33	236,92	331,04
10:00	47,92	317,68	347,71	455,15
11:00	54,01	409,22	453,92	551,70
12:00	49,89	471,59	527,79	599,89
13:00	51,76	487,08	548,57	608,89
14:00	64,78	451,04	510,06	580,84
15:00	69,63	374,79	424,88	501,25
16:00	69,98	276,42	313,21	385,53
17:00	40,26	179,40	202,22	261,95
18:00	118,91	95,87	108,06	149,68
19:00	236,53	40,10	45,88	68,25
20:00	220,47	11,15	12,87	20,00
21:00	122,86	0,00	0,00	0,00
22:00	113,17	0,00	0,00	0,00
23:00	112,28	0,00	0,00	0,00
24:00	2,50	0,00	0,00	0,00

JULY

Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	2,95	3,41	5,25
06:00	2,49	22,00	25,52	40,77
07:00	2,61	55,15	63,39	102,97
08:00	9,39	119,08	132,41	201,25
09:00	37,85	215,54	234,55	332,07
10:00	74,02	326,46	357,62	470,95
11:00	106,25	430,96	479,03	583,18
12:00	125,15	504,05	565,66	641,31
13:00	124,15	526,34	594,63	655,30
14:00	103,09	491,35	557,63	628,81
15:00	68,91	408,73	465,09	543,94
16:00	32,37	300,29	341,82	417,65
17:00	4,51	192,12	217,71	280,74
18:00	2,50	99,75	112,84	156,39
19:00	2,51	38,97	44,60	67,09
20:00	2,49	9,35	10,80	17,06
21:00	2,50	0,00	0,00	0,00
22:00	2,51	0,00	0,00	0,00
23:00	2,49	0,00	0,00	0,00
24:00	2,50	0,00	0,00	0,00

AUGUST

Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,49	0,00	0,00	0,00
02:00	2,50	0,00	0,00	0,00
03:00	2,51	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	9,28	10,72	16,76
07:00	52,88	38,10	43,68	68,40
08:00	85,12	94,44	105,07	157,17
09:00	49,25	182,74	200,81	281,47
10:00	57,52	287,12	320,02	417,69
11:00	67,32	387,15	437,18	526,95
12:00	60,97	457,87	521,51	590,95
13:00	61,97	478,07	547,90	603,50
14:00	74,78	441,67	508,36	572,21
15:00	76,89	360,38	415,97	485,24
16:00	76,39	256,27	296,29	360,81
17:00	40,72	153,45	177,06	227,53
18:00	138,25	71,32	82,14	112,24
19:00	294,41	21,32	24,61	36,35
20:00	269,32	1,13	1,30	1,93
21:00	110,98	0,00	0,00	0,00
22:00	103,41	0,00	0,00	0,00
23:00	103,41	0,00	0,00	0,00
24:00	2,50	0,00	0,00	0,00

SEPTEMBER				
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,50	0,00	0,00	0,00
02:00	2,51	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	1,38	1,59	2,51
07:00	52,36	21,23	24,19	35,21
08:00	83,61	71,31	79,84	113,42
09:00	50,28	147,73	167,05	227,14
10:00	46,74	239,53	274,83	350,73
11:00	50,33	326,53	378,18	448,57
12:00	43,60	383,35	446,86	506,29
13:00	46,82	393,46	461,03	510,22
14:00	63,43	353,45	415,93	470,60
15:00	67,11	274,47	323,98	379,64
16:00	67,14	178,87	211,74	258,93
17:00	39,31	93,20	110,58	142,07
18:00	95,49	31,73	37,78	50,59
19:00	189,80	2,18	2,57	3,49
20:00	174,23	0,00	0,00	0,00
21:00	104,53	0,00	0,00	0,00
22:00	104,53	0,00	0,00	0,00
23:00	104,53	0,00	0,00	0,00
24:00	2,51	0,00	0,00	0,00

OCTOBER				
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,49	0,00	0,00	0,00
02:00	2,50	0,00	0,00	0,00
03:00	2,51	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	0,00	0,00	0,00
07:00	53,01	6,58	7,44	10,29
08:00	90,57	39,15	44,62	60,10
09:00	53,38	93,15	107,72	141,81
10:00	47,44	156,36	182,87	228,91
11:00	50,67	215,15	253,42	300,59
12:00	42,96	250,42	296,48	339,81
13:00	38,87	251,02	298,46	336,07
14:00	46,70	215,68	257,24	295,97
15:00	50,38	156,07	186,46	221,62
16:00	52,27	89,85	107,54	132,77
17:00	38,79	35,10	42,06	53,98
18:00	77,04	2,85	3,36	4,39
19:00	171,22	0,00	0,00	0,00
20:00	174,20	0,00	0,00	0,00
21:00	103,03	0,00	0,00	0,00
22:00	99,66	0,00	0,00	0,00
23:00	99,66	0,00	0,00	0,00
24:00	2,25	0,00	0,00	0,00

NOVEMBER				
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,49	0,00	0,00	0,00
02:00	2,50	0,00	0,00	0,00
03:00	2,49	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,50	0,00	0,00	0,00
06:00	2,51	0,00	0,00	0,00
07:00	2,49	0,00	0,00	0,00
08:00	52,46	9,39	10,91	14,26
09:00	92,05	37,85	44,39	57,38
10:00	53,56	74,02	87,59	109,11
11:00	48,84	106,25	126,50	151,79
12:00	52,06	125,15	149,70	174,87
13:00	44,44	124,15	149,05	171,60
14:00	41,50	103,09	123,94	145,17
15:00	50,84	68,91	82,65	99,73
16:00	54,52	32,37	38,70	48,13
17:00	59,39	4,51	5,29	6,71
18:00	43,73	0,00	0,00	0,00
19:00	79,46	0,00	0,00	0,00
20:00	175,90	0,00	0,00	0,00
21:00	174,20	0,00	0,00	0,00
22:00	104,54	0,00	0,00	0,00
23:00	104,54	0,00	0,00	0,00
24:00	104,54	0,00	0,00	0,00

DECEMBER				
Hour	Consumption (kWh)	Production (kWh)		
		Roof	+ South	+ East / West
01:00	2,51	0,00	0,00	0,00
02:00	2,49	0,00	0,00	0,00
03:00	2,50	0,00	0,00	0,00
04:00	2,50	0,00	0,00	0,00
05:00	2,51	0,00	0,00	0,00
06:00	2,49	0,00	0,00	0,00
07:00	1,98	0,00	0,00	0,00
08:00	50,51	1,33	1,53	1,97
09:00	126,40	20,63	24,32	31,38
10:00	57,76	50,91	60,51	75,81
11:00	50,75	79,34	94,95	114,78
12:00	54,33	97,61	117,46	138,38
13:00	47,25	99,06	119,60	138,65
14:00	43,62	83,32	100,55	117,81
15:00	51,62	55,66	66,75	80,48
16:00	56,04	25,52	30,50	37,70
17:00	59,43	2,15	2,52	3,18
18:00	44,86	0,00	0,00	0,00
19:00	102,74	0,00	0,00	0,00
20:00	204,20	0,00	0,00	0,00
21:00	180,83	0,00	0,00	0,00
22:00	112,45	0,00	0,00	0,00
23:00	111,81	0,00	0,00	0,00
24:00	111,34	0,00	0,00	0,00

Base units

JANUARY		
Hour	Consumption (kWh)	Production (kWh)
01:00	26,50	0,00
02:00	26,89	0,00
03:00	26,67	0,00
04:00	27,85	0,00
05:00	29,73	0,00
06:00	293,91	0,00
07:00	290,27	0,00
08:00	287,70	8,91
09:00	267,97	37,21
10:00	247,43	74,99
11:00	92,52	108,82
12:00	85,09	126,03
13:00	78,84	127,01
14:00	75,12	112,10
15:00	72,84	80,48
16:00	73,24	41,94
17:00	75,60	12,26
18:00	264,56	0,00
19:00	226,12	0,00
20:00	231,70	0,00
21:00	224,60	0,00
22:00	217,32	0,00
23:00	211,50	0,00
24:00	73,10	0,00

FEBRUARY		
Hour	Consumption (kWh)	Production (kWh)
01:00	25,16	0,00
02:00	25,91	0,00
03:00	23,39	0,00
04:00	23,29	0,00
05:00	23,97	0,00
06:00	277,03	0,00
07:00	267,83	0,00
08:00	259,15	26,48
09:00	234,38	73,02
10:00	210,32	128,80
11:00	76,14	178,78
12:00	68,99	203,87
13:00	61,82	206,71
14:00	57,76	190,12
15:00	55,58	148,35
16:00	55,05	90,44
17:00	57,50	36,37
18:00	204,55	6,24
19:00	180,74	0,00
20:00	188,96	0,00
21:00	184,90	0,00
22:00	182,36	0,00
23:00	181,07	0,00
24:00	67,66	0,00

MARCH		
Hour	Consumption (kWh)	Production (kWh)
01:00	24,08	0,00
02:00	24,37	0,00
03:00	25,17	0,00
04:00	26,33	0,00
05:00	24,92	0,00
06:00	150,25	0,00
07:00	166,40	27,87
08:00	162,13	75,11
09:00	141,19	142,54
10:00	122,24	215,85
11:00	52,14	274,79
12:00	47,99	294,46
13:00	43,44	295,65
14:00	42,47	278,19
15:00	45,94	225,15
16:00	49,22	153,69
17:00	51,29	79,70
18:00	97,69	27,11
19:00	101,70	0,00
20:00	120,24	0,00
21:00	121,86	0,00
22:00	122,11	0,00
23:00	118,01	0,00
24:00	49,74	0,00

APRIL		
Hour	Consumption (kWh)	Production (kWh)
01:00	17,55	0,00
02:00	17,55	0,00
03:00	17,55	0,00
04:00	17,55	0,00
05:00	61,60	0,00
06:00	88,67	26,26
07:00	109,77	67,18
08:00	103,83	142,51
09:00	85,01	230,45
10:00	41,01	309,42
11:00	38,79	363,71
12:00	35,70	372,95
13:00	35,17	374,66
14:00	37,25	355,62
15:00	39,91	293,11
16:00	42,33	207,33
17:00	54,47	117,71
18:00	64,16	55,54
19:00	90,08	21,12
20:00	95,42	0,00
21:00	95,89	0,00
22:00	91,02	0,00
23:00	41,30	0,00
24:00	17,55	0,00

MAY		
Hour	Consumption (kWh)	Production (kWh)
01:00	17,55	0,00
02:00	17,55	0,00
03:00	17,55	0,00
04:00	17,55	0,00
05:00	16,91	14,54
06:00	18,38	51,59
07:00	70,91	105,66
08:00	77,88	178,90
09:00	60,84	278,03
10:00	33,26	357,09
11:00	33,96	402,63
12:00	31,40	404,73
13:00	31,95	408,99
14:00	34,65	391,24
15:00	35,97	327,84
16:00	38,26	228,24
17:00	41,15	142,61
18:00	49,27	88,59
19:00	83,62	34,40
20:00	93,24	0,00
21:00	93,48	0,00
22:00	86,10	0,00
23:00	34,89	0,00
24:00	17,55	0,00

JUNE		
Hour	Consumption (kWh)	Production (kWh)
01:00	17,55	0,00
02:00	17,55	0,00
03:00	17,55	0,00
04:00	17,55	0,00
05:00	15,55	21,58
06:00	15,05	63,48
07:00	73,22	119,57
08:00	80,61	178,46
09:00	64,59	281,87
10:00	38,60	360,60
11:00	40,07	405,00
12:00	38,78	407,93
13:00	41,95	411,06
14:00	47,36	397,94
15:00	49,02	337,08
16:00	51,58	237,60
17:00	57,64	161,11
18:00	60,42	108,84
19:00	92,56	49,72
20:00	102,03	13,95
21:00	101,99	0,00
22:00	93,18	0,00
23:00	39,47	0,00
24:00	17,55	0,00

JULY

Hour	Consumption (kWh)	Production (kWh)
01:00	17,55	0,00
02:00	17,55	0,00
03:00	17,55	0,00
04:00	17,55	0,00
05:00	15,46	17,35
06:00	14,99	54,97
07:00	75,15	112,93
08:00	85,26	176,78
09:00	67,39	290,32
10:00	45,44	379,51
11:00	48,58	434,02
12:00	45,15	440,48
13:00	48,23	441,56
14:00	53,11	432,13
15:00	53,40	369,81
16:00	55,06	262,28
17:00	68,31	166,54
18:00	65,77	112,72
19:00	101,35	49,78
20:00	111,54	15,55
21:00	111,06	0,00
22:00	100,63	0,00
23:00	37,62	0,00
24:00	17,55	0,00

AUGUST

Hour	Consumption (kWh)	Production (kWh)
01:00	17,55	0,00
02:00	17,55	0,00
03:00	17,55	0,00
04:00	17,55	0,00
05:00	15,46	0,00
06:00	14,94	31,02
07:00	77,33	80,05
08:00	87,83	156,88
09:00	68,74	260,46
10:00	41,41	346,54
11:00	42,21	405,69
12:00	42,25	416,58
13:00	44,78	417,73
14:00	49,64	401,65
15:00	50,95	339,72
16:00	53,72	239,91
17:00	67,87	140,16
18:00	66,07	77,53
19:00	101,08	25,98
20:00	109,07	0,00
21:00	108,17	0,00
22:00	98,66	0,00
23:00	37,91	0,00
24:00	17,55	0,00

SEPTEMBER

Hour	Consumption (kWh)	Production (kWh)
01:00	17,55	0,00
02:00	17,55	0,00
03:00	17,55	0,00
04:00	17,55	0,00
05:00	15,46	0,00
06:00	14,96	18,73
07:00	77,43	49,89
08:00	85,10	125,03
09:00	67,37	212,42
10:00	35,83	300,87
11:00	35,03	357,67
12:00	33,64	366,53
13:00	37,31	368,81
14:00	42,73	342,32
15:00	47,09	273,41
16:00	49,61	182,18
17:00	55,27	93,18
18:00	58,53	32,40
19:00	94,00	0,00
20:00	100,01	0,00
21:00	99,42	0,00
22:00	90,78	0,00
23:00	37,10	0,00
24:00	17,55	0,00

OCTOBER

Hour	Consumption (kWh)	Production (kWh)
01:00	17,55	0,00
02:00	17,55	0,00
03:00	17,55	0,00
04:00	17,55	0,00
05:00	52,29	0,00
06:00	73,13	0,00
07:00	104,57	23,25
08:00	104,23	67,00
09:00	89,20	133,82
10:00	39,33	198,13
11:00	34,50	243,36
12:00	30,70	251,73
13:00	31,08	250,38
14:00	35,29	218,14
15:00	39,48	159,31
16:00	41,10	91,43
17:00	58,80	32,85
18:00	64,89	12,91
19:00	91,36	0,00
20:00	96,15	0,00
21:00	96,84	0,00
22:00	92,15	0,00
23:00	37,17	0,00
24:00	17,75	0,00

NOVEMBER

Hour	Consumption (kWh)	Production (kWh)
01:00	21,83	0,00
02:00	20,40	0,00
03:00	21,10	0,00
04:00	20,47	0,00
05:00	19,56	0,00
06:00	169,94	0,00
07:00	190,91	0,00
08:00	188,14	21,06
09:00	169,10	55,33
10:00	152,49	95,25
11:00	58,36	124,23
12:00	52,75	133,14
13:00	47,92	130,20
14:00	47,09	108,32
15:00	49,43	70,81
16:00	52,25	30,68
17:00	55,44	5,60
18:00	152,20	0,00
19:00	136,58	0,00
20:00	141,61	0,00
21:00	138,64	0,00
22:00	136,17	0,00
23:00	134,20	0,00
24:00	52,31	0,00

DECEMBER

Hour	Consumption (kWh)	Production (kWh)
01:00	25,90	0,00
02:00	24,71	0,00
03:00	25,13	0,00
04:00	25,65	0,00
05:00	26,92	0,00
06:00	268,56	0,00
07:00	257,89	0,00
08:00	255,20	7,17
09:00	235,00	33,29
10:00	215,67	67,87
11:00	89,57	95,46
12:00	83,48	108,15
13:00	76,69	106,26
14:00	73,39	89,19
15:00	72,12	57,22
16:00	73,60	24,26
17:00	75,23	0,00
18:00	228,11	0,00
19:00	200,14	0,00
20:00	205,66	0,00
21:00	199,54	0,00
22:00	193,96	0,00
23:00	190,52	0,00
24:00	80,53	0,00

Annex B
Structural simulations results

Plates

Here it follows a table containing the forces and momentum of the plates of different levels, including the three foyers and the slab under the main hall. They are presented for each node, which is a point of the discretization of the 3D model where the values are calculated. Here all nodes of a plate are listed, considering that the nodes within the area of columns or walls are not considered for the dimensioning. The reason is that the FEM model considers all constraints as punctual, so that the values around the columns (usually with the highest values) are not real, being them counterbalanced by the stiffness of the structural elements. For this reason some higher values than the one considered may appear in the tables, but they are not considered in the calculations.
On the right, the displacement are presented for each node considering only the vertical direction (z), with negative values meaning that they are directing towards the ground.

	LEVEL 2			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1	-124,83	126,77	15,14	-0,3
2	-175,03	17,11	7,1	-0,6
3	-155,34	-20,52	22,16	-0,5
4	-1,22	-31,42	47,52	-0,3
5	-137,4	-60,37	9,93	-0,5
6	-34,65	-84,04	2,35	-0,3
7	-135,81	-56,04	7,11	-0,4
8	-108,33	16,5	-12,25	-0,2
9	-113,85	-41,04	29,66	-0,3
10	9,2	-1,73	61,71	-0,2
11	-60,61	-42,2	34,59	-0,2
12	-36,19	-54,32	47,84	-0,1
13	-11,63	26,57	22,8	-0,1
14	-9,12	8,02	39,49	-0,1
15	-196,35	-3,52	-2,08	-0,7
16	-183,83	-29,05	-0,32	-0,6
17	-165,9	-53,39	-1,66	-0,6
18	-151,78	-63,92	-2,33	-0,5
19	-125,42	-62,31	-2,63	-0,4
20	-75,61	-40,6	-2,8	-0,3
21	-13,45	37,77	-3,89	-0,1
22	-307,36	-17,83	3,49	-1,8
23	-329,76	-45,36	0,22	-2
24	-315,08	-60,57	24,36	-2,1
25	-315,96	-22,32	18,71	-1,9
26	-193,12	1,28	-6,38	-0,7
27	-126,81	11,94	10,51	-0,6
28	-140,93	16,63	-5,84	-0,5
29	-125,62	-12,1	-23,56	-0,5
30	-104,92	-50,01	-11,28	-0,5
31	-113,48	-46,05	-10,86	-0,4
32	-92,21	-44,81	-31,93	-0,3
33	-50,81	-35,5	-38,08	-0,2
34	-5,97	30,12	-27,05	-0,1
35	-272,33	-52,89	-24,18	-1,9
36	-254,72	-87,13	11,79	-1,9
37	52,05	31,25	35,11	-0,4
38	-56,31	137,39	-14,68	-0,3
39	64,52	-6,28	-49,46	-0,3
40	8,92	-73,4	-6,68	-0,3
41	22,62	27,16	5,39	-0,2
42	-26,33	-22,09	-83,32	-0,2
43	25,57	-48,28	-57,72	-0,1

	LEVEL 2			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
44	18,81	14,23	-26,91	-0,1
45	-145,82	-83,67	-50,98	-1,4
46	-114,96	-113,81	-7,97	-1,5
47	124,24	-58,35	18,33	-0,1
48	78,47	-75,36	-9,39	-0,1
49	179,22	20,74	-39,7	0
50	174,31	33,42	-0,42	0
51	58,87	-67,31	-41,45	-0,1
52	65,68	-49,56	-22,79	-0,1
53	95,68	-2,36	-84,83	-0,8
54	62,25	-167,69	-16,67	-1
55	62,68	-164,39	26,12	-1
56	-98,59	-110,14	40,46	-1,5
57	25,91	8,67	21,46	0
58	57,36	-30,94	-10,53	0
59	2,78	46,64	-22,52	0
60	-12,25	61,33	-17,27	0
61	22,63	-42,42	-34,2	-0,1
62	37,94	-48,83	-47,26	-0,1
63	358,64	-204,66	-3,74	-0,4
64	183,09	-203,18	-7,11	-0,6
65	272,73	-128,42	15,59	-0,5
66	72,49	-36,42	-53,93	-0,1
67	93,35	-59,02	-33,29	0
68	22,75	-16,79	-2,99	0
69	41,65	38,62	-52,7	-0,1
70	-13,51	-21,22	-47,04	-0,1
71	-26,73	-86,23	-42,79	-0,2
72	-22,05	-91,56	-17,74	-0,3
73	14,66	-10,91	2,16	-0,1
74	35,84	-75,04	21,41	-0,2
75	52,77	-0,74	53,61	-0,1
76	211,25	82,04	86,62	0
77	-1,84	8,32	48,34	0
78	122,37	23,67	86,08	-0,3
79	148,85	-150,84	22,98	-0,4
80	121,04	-140,55	-51,42	-0,4
81	61,73	-23,95	56,56	-0,1
82	15,91	-14,96	29,54	0
83	-32,81	-23,99	-36,93	-0,2
84	-61,37	-100,19	-38,13	-0,4
85	-62,33	-122,87	-34,67	-0,4
86	-20,58	-90,74	-40,21	-0,4

	LEVEL 2			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
87	48,76	35,08	-57,85	-0,3
88	-45,59	-68,05	41,15	-0,3
89	-17,17	-89,28	15,52	-0,4
90	-18,59	-75,86	-40,79	-0,4
91	-96,23	60,31	-55,28	-0,3
92	192,36	19,8	-149,03	-0,2
93	-56,63	-18,07	37,87	-0,2
94	-9,49	7,18	30,43	-0,1
95	-32,69	-15,51	-13,84	-0,2
96	-81,02	-103,65	-23,39	-0,4
97	-106,25	-122,24	-33,72	-0,5
98	-122,21	-83,28	-44,34	-0,6
99	-146,86	-32,84	-38,64	-0,5
100	-108,66	-40,86	28	-0,4
101	-104,79	-61,27	8,46	-0,4
102	-112,47	-45,28	-15,64	-0,4
103	-136,12	-14,83	-19,35	-0,4
104	-114,59	-5,89	20,13	-0,3
105	-120,82	-31,64	-12,3	-0,3
106	-82,87	-33,77	-1,03	-0,2
107	-26,06	14,05	3,35	-0,1
108	-40,95	-7,98	13,05	-0,2
109	-91,17	-86,48	1,88	-0,4
110	-126,25	-109,78	-13,09	-0,6
111	-156,93	-91,8	-17,69	-0,6
112	-180,48	-34,17	-13,87	-0,6
113	-98,25	-28,35	16,69	-0,3
114	-96,65	-37,37	8,04	-0,3
115	-100	-29,86	-2,51	-0,3
116	-108,69	-17,27	-3,02	-0,3
117	-104,52	-10,82	7,3	-0,3
118	-161,39	23,51	10,27	-0,4
119	-84,83	-42,25	-27,35	-0,3
120	-63,99	-36,34	-29,88	-0,2
121	-24,18	8,73	-26,17	-0,1
122	-38,86	12,73	44,46	-0,2
123	-77,2	-58,55	19,46	-0,3
124	-101,24	-97,92	5,77	-0,5
125	-115,57	-88,21	8,92	-0,5
126	-145,69	-44,48	23,04	-0,5
127	-1,4	-0,06	13,21	-0,1
128	2,99	-4,88	5,93	-0,2
129	5,53	-2,32	0,21	-0,2

LEVEL 2				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
130	6,12	1,54	-1,52	-0,2
131	9	4,12	0,82	-0,2
132	14,2	4,26	2,95	-0,2
133	-86,42	-9,39	19,05	-0,3
134	20,34	1,12	1,51	-0,2
135	-60,41	-27,93	6,75	-0,4
136	18,89	-5,16	-7,33	-0,2
137	-64,85	-38,63	-16,28	-0,4
138	9,51	-10,73	-19,23	-0,2
139	-85,1	-37,06	-28,15	-0,3
140	-2,33	-14,27	-30,08	-0,1
141	-8,38	-15,16	-40,17	-0,1
142	-4,6	4,98	-40,45	0
143	12,13	25,47	62,9	-0,1
144	-56,75	10,46	29,03	-0,2
145	7,84	-66,38	-7,1	-0,3
146	-9,69	-100,5	30,28	-0,4
147	-24,07	-18,82	48,17	-0,3
148	94,6	-149,11	10,52	-0,2
149	83,16	-130,71	12,82	-0,2
150	271,14	21,63	12,46	-0,1
151	26,93	-42,44	33,23	-0,1
152	55,21	-79,39	-16,73	-0,1
153	17,23	21,93	-42	-0,1
154	-58,53	-46,81	8,34	-0,1
155	-52,38	-40,22	-10,12	-0,1
156	-66,41	-26,65	-23,57	-0,1
157	-56,77	-24,16	7,61	-0,1
158	-57,9	-24,38	-7,1	-0,1
159	-60,48	-11,69	-13,58	-0,1
160	28,87	-3,85	-0,37	0
161	30,67	2,36	-9,23	0
162	24,69	1,52	-13,87	0
163	-79,08	3,79	50,82	-0,6
164	-653,58	-57,43	99,53	0
165	-163,47	19,48	15,3	-1,3
166	-132,04	3,64	-12,39	-1,2
167	249,16	2,13	-83,62	-0,5
168	-167,95	96,92	-81,91	-0,6
169	-217,09	51,2	-15,65	-1,4
170	-317,02	-5,18	8,58	-1,8
171	-352,5	1,51	-9,04	-2
172	-334,37	-13,4	56,14	-2,2
173	-296,03	-23,15	-39,24	-1,7
174	-222,97	-72,31	39,52	-1,9
175	-325,02	2,85	37,75	-1,9
176	-172,19	14,81	-14,31	-0,7
177	-453,36	11,78	82,56	-0,1
178	63,31	15,06	-21,55	-0,4
179	-186,83	3,04	-13,65	-0,8
180	-117,17	6,51	1,33	-0,8
181	-19,64	-20,97	-2,6	-0,6
182	-256,81	-45,68	100,46	-2,1
183	-150,1	-71,98	111,14	-1,7
184	-132,39	53,98	-85,1	-1,2
185	29,03	-50,01	125,35	-1,1
186	88,06	-317,89	-75,3	-0,4
187	129,21	-192,89	1,74	-0,4
188	56,05	-194,1	7,66	-0,1
189	47,2	-32,45	-56,99	-0,2
190	132,56	-10,12	-7,66	0
191	59,51	-45,5	-31,98	-0,2
192	40,85	-25,28	-47,5	-0,4
193	38,51	-14,65	-14,44	-0,4
194	146,98	-36,39	-46,44	-0,1
195	-94,85	-55,13	-45,39	-0,4
196	29,89	66,55	86,12	-0,1

LEVEL 2				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
197	-104,02	-44,69	-75,84	-0,5
198	-72,99	-72,66	-51,19	-0,5
199	-2,79	52,62	-2,96	0
200	14,03	52,56	-7,45	0
201	-60,27	-111,57	-126,79	-0,2
202	-145,86	-75,18	-29,51	0
203	-80,21	-56,43	15,28	0
204	-116,25	-94,31	40,49	0
205	20,8	-42,95	57,22	0
206	-16,35	5,92	41,53	0
207	8,62	43,11	21,5	0
208	31,33	156,64	15,59	0
209	43,48	217,42	7,54	0
210	39,25	196,26	-10,82	0
211	26,71	133,54	-8,88	0
212	46,48	232,4	-2,05	0
213	4,73	1,63	7,07	0
214	3,39	2,11	-0,02	0
215	48,13	152,61	5,22	0
216	15,05	48,8	-38,65	0
217	52,5	261,17	-3,94	0
218	207,33	154,45	19,34	0
219	45,67	7,54	23,34	0
220	155,06	31,41	19,6	0
221	-91,58	-11,19	36,25	0
222	63,79	-128,52	25,72	0
223	-129,35	-117,15	-56,97	-0,3
224	22,04	109,2	4,76	0
225	-74,5	54,55	76,36	-0,2
226	-176,44	80,26	69,3	-0,4
227	-138,57	-16,97	35,92	-0,3
228	-93,3	-1,06	15,58	-0,2
229	-109,69	-24,72	66,16	-0,5
230	-151,11	24,84	-33,75	-0,4
231	-121,4	0,05	46,22	-0,2
232	-0,7	-87,09	19,47	-0,5
233	32,37	160,52	6,42	0
234	37,13	-28,68	5,63	-0,1
235	264,55	53,19	3,19	0
236	269,35	54,14	1,96	0
237	267,44	53,75	2,81	0
238	268,93	54,06	1,9	0
239	249,6	50,15	4,58	0
240	219,55	44,09	9,65	0
241	268,64	53,98	4,28	0
242	271,84	54,63	4,61	0
243	272,24	54,7	3,03	0
244	22,85	66,77	13,42	0
245	32,34	25,64	47,61	0
246	166,64	32,64	-13,05	0
247	227,54	45,32	-5,88	0
248	260,57	52,24	-0,44	0
249	78,87	14,79	-18,47	0
250	1,14	0,4	-3,14	0
251	32,64	160,72	-13,09	0
252	38,09	188,3	-2,05	0
253	14,4	54,91	-15,27	0
254	60,13	296,24	2,84	0
255	56,91	278,31	13,63	0
256	0	0	0	0
257	0	0	0	0
258	0	0	0	0
259	108,99	44,76	30,72	0
260	42,23	207,1	24,85	0
261	1,23	-1,81	-0,39	0
262	-165,76	25,65	-54,65	-0,5
263	-210,59	-23,24	-13,09	-0,6

LEVEL 2				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
264	-137,98	38,23	26,51	-0,5
265	319,49	285,78	49,24	0
266	-33,88	-186,84	55,91	-0,2
267	0	0	0	0
268	-15,3	-8,27	1,48	0
269	-45,76	-48,35	27,41	-0,1
270	-71,58	0,4	23,99	-0,1
271	-20,2	13,16	-0,42	-0,1
272	134,86	30,81	-0,12	0
273	154,59	34,53	13,38	0
274	9,59	-142,73	8,91	0
275	-74,33	-14,79	-12,48	-0,1
276	-65,44	35,8	-32,22	-0,1
277	160,61	32,83	14,67	0
278	149,82	27,59	14,24	0
279	-2,56	-2,94	0,74	0
280	132,03	21,69	-6	0
281	433,16	398,92	-10,99	0
282	301,93	332,46	7,36	0
283	1481,24	139,84	-282,99	0
284	2063,06	502,63	102,11	0
285	784,62	1089,21	142,41	0
286	825,95	825,39	-9,6	0
287	406,54	258,07	19,7	0
288	878,78	299,93	46,19	0
289	598,54	248,99	88,72	0
290	434,96	592,39	67,89	0
291	440,56	651,11	-99,06	0

	LEVEL 4			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1	58,11	538,77	-37,96	0
2	102,33	567,85	-20,61	0
3	51,67	379,69	-41,09	-0,2
4	24,93	373,93	-40,13	-0,2
5	15,69	205,43	-46,31	-0,3
6	5,87	203,06	-37,67	-0,3
7	-10,5	50,1	-49,77	-0,5
8	-7,28	46,07	-39,16	-0,5
9	-31,1	-84,92	-56	-0,7
10	-17,32	-91,39	-45,51	-0,7
11	-48,03	-198,01	-65,27	-0,9
12	-25,45	-206,99	-55,95	-0,9
13	-62,31	-288,19	-77,67	-1,1
14	-32,21	-299,49	-69,96	-1
15	-74,41	-354,88	-92,96	-1,2
16	-37,81	-368,17	-86,98	-1,1
17	-84,46	-397,61	-110,78	-1,3
18	-42,25	-412,42	-106,43	-1,2
19	-92,22	-415,92	-130,61	-1,3
20	-45,24	-431,55	-127,6	-1,2
21	-97,03	-409,14	-151,76	-1,3
22	-46,25	-424,61	-149,39	-1,2
23	-97,64	-376,37	-173,11	-1,2
24	-43,6	-389,46	-170,27	-1,1
25	-90,84	-315	-193,48	-1,1
26	-36,09	-325,06	-186,3	-1
27	-74,9	-226,38	-208,15	-1
28	-8,24	-216,75	-195,58	-0,8
29	-25,69	-82,32	-222,34	-0,8
30	19,59	-102,76	-156,71	-0,6
31	-30,4	-7	-172,29	-0,7
32	302,13	210,74	-138,28	-0,4
33	116,56	599,01	-10,32	-0,1
34	66,26	394,04	-35,27	-0,2
35	23,4	213,09	-44,79	-0,3
36	-11,75	56,12	-50,78	-0,5
37	-40,8	-78,06	-57,36	-0,7
38	-65,43	-189,46	-65,64	-0,9
39	-86,71	-277,7	-76,27	-1,1
40	-105,27	-342,5	-89,37	-1,2
41	-121,42	-383,62	-104,86	-1,3
42	-135,23	-400,82	-122,49	-1,4
43	-146,5	-393,73	-141,84	-1,4
44	-154,83	-361,71	-162,25	-1,4
45	-160,06	-304,12	-182,63	-1,3
46	-161,78	-218,79	-200,26	-1,2
47	-172,02	-122,33	-208,64	-1,1
48	-171,2	-35,66	-200,36	-0,9
49	122,42	622,24	-6	-0,1
50	72,96	409,48	-28,79	-0,2
51	27,09	223,04	-39,12	-0,4
52	-13,32	63,54	-46,12	-0,6
53	-48,57	-71,07	-52,92	-0,8
54	-79,51	-181,65	-60,56	-1
55	-106,97	-268,49	-69,87	-1,1
56	-131,62	-331,72	-81,21	-1,3
57	-153,94	-371,36	-94,68	-1,4
58	-174,3	-387,44	-110,13	-1,5
59	-193,05	-379,95	-127,22	-1,5
60	-210,71	-348,93	-145,16	-1,5
61	-228,25	-294,85	-162,52	-1,4
62	-248,03	-221,53	-175,67	-1,4
63	-269,54	-138,61	-184,29	-1,3
64	-290,53	-61,15	-178,35	-1,1
65	125,83	639,94	-2,68	-0,1
66	75,77	422,54	-22,18	-0,2
67	28,2	232,69	-31,18	-0,4

	LEVEL 4			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
68	-15,46	71,03	-37,69	-0,6
69	-54,98	-64,3	-43,91	-0,8
70	-90,72	-174,53	-50,58	-1
71	-123,24	-260,39	-58,42	-1,2
72	-153,15	-322,34	-67,84	-1,3
73	-181,04	-360,74	-79	-1,5
74	-207,47	-375,95	-91,79	-1,6
75	-233,08	-368,41	-105,78	-1,6
76	-258,69	-338,95	-120,08	-1,6
77	-285,31	-289,43	-133,22	-1,6
78	-313,46	-223,84	-142,79	-1,5
79	-342,96	-149,26	-149,93	-1,4
80	-370,05	-70,64	-147,61	-1,4
81	128,11	652,87	0,62	-0,1
82	77,03	432,32	-15,16	-0,2
83	28,15	240,46	-21,87	-0,4
84	-17,62	77,41	-26,85	-0,6
85	-59,99	-58,48	-31,75	-0,8
86	-99,13	-168,51	-36,96	-1
87	-135,45	-253,65	-43,03	-1,2
88	-169,46	-314,6	-50,3	-1,4
89	-201,78	-352,04	-58,88	-1,5
90	-233,03	-366,66	-68,67	-1,6
91	-263,88	-359,39	-79,24	-1,7
92	-295,02	-331,65	-89,76	-1,7
93	-326,99	-285,79	-99,12	-1,7
94	-359,74	-225,26	-105,89	-1,6
95	-393,02	-154,66	-111,47	-1,6
96	-424,48	-76,03	-110,18	-1,5
97	129,53	661,09	4,18	-0,1
98	77,6	438,47	-7,64	-0,2
99	27,83	245,61	-11,61	-0,4
100	-19,19	81,87	-14,47	-0,6
101	-63,27	-54,24	-17,5	-0,8
102	-104,53	-164,04	-20,82	-1
103	-143,29	-248,56	-24,79	-1,2
104	-180,02	-308,72	-29,63	-1,4
105	-215,3	-345,39	-35,43	-1,6
106	-249,73	-359,58	-42,08	-1,7
107	-283,87	-352,59	-49,24	-1,7
108	-318,2	-326,18	-56,28	-1,8
109	-352,95	-282,8	-62,46	-1,8
110	-387,93	-225,34	-66,95	-1,7
111	-423,19	-157,1	-70,66	-1,7
112	-456,62	-78,45	-69,87	-1,6
113	130,1	664,43	7,91	-0,1
114	77,78	440,8	0,19	-0,2
115	27,72	247,78	-0,84	-0,4
116	-19,76	83,97	-1,28	-0,6
117	-64,49	-52,02	-2,11	-0,8
118	-106,63	-161,45	-3,25	-1
119	-146,46	-245,39	-4,88	-1,2
120	-184,43	-304,84	-7,13	-1,4
121	-221,06	-340,82	-10,03	-1,6
122	-256,88	-354,55	-13,55	-1,7
123	-292,38	-347,56	-17,46	-1,7
124	-327,86	-321,84	-21,38	-1,8
125	-363,45	-279,84	-24,84	-1,8
126	-398,97	-224,13	-27,28	-1,8
127	-434,8	-157,42	-28,92	-1,7
128	-468,95	-79,27	-28,2	-1,7
129	129,83	662,8	11,62	-0,1
130	77,68	439,26	8,03	-0,2
131	28	246,82	9,97	-0,4
132	-19,09	83,49	12,02	-0,6
133	-63,47	-52,04	13,52	-0,8
134	-105,28	-160,96	14,69	-1

	LEVEL 4			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
135	-144,82	-244,29	15,49	-1,2
136	-182,5	-303,04	15,91	-1,4
137	-218,8	-338,3	15,89	-1,6
138	-254,23	-351,38	15,44	-1,7
139	-289,21	-343,95	14,59	-1,7
140	-323,99	-318,15	13,5	-1,8
141	-358,64	-276,55	12,46	-1,8
142	-393,03	-221,73	11,93	-1,8
143	-427,8	-156,07	12,75	-1,7
144	-462,43	-79,13	14,02	-1,7
145	128,73	656,31	15,09	-0,1
146	77,36	433,97	15,5	-0,2
147	28,74	242,8	20,29	-0,4
148	-17,14	80,42	24,75	-0,6
149	-60,18	-54,36	28,52	-0,8
150	-100,52	-162,61	31,95	-1
151	-138,43	-245,28	35,15	-1,2
152	-174,31	-303,31	38,14	-1,4
153	-208,61	-337,76	40,92	-1,5
154	-241,85	-349,93	43,4	-1,6
155	-274,43	-341,51	45,45	-1,7
156	-306,65	-314,78	46,97	-1,7
157	-338,54	-272,61	48,07	-1,7
158	-369,89	-218,12	49,17	-1,7
159	-401,05	-154,02	52,47	-1,7
160	-433,75	-79,17	57,51	-1,6
161	126,85	645,28	18,13	-0,1
162	76,83	425,19	22,23	-0,2
163	29,91	235,92	29,6	-0,4
164	-14	74,9	36,24	-0,6
165	-54,79	-58,87	42,08	-0,8
166	-92,6	-166,31	47,57	-1
167	-127,64	-248,27	52,93	-1,2
168	-160,27	-305,56	58,29	-1,4
169	-190,93	-339,1	63,64	-1,5
170	-220,13	-350,08	68,85	-1,6
171	-248,36	-340,11	73,63	-1,6
172	-275,99	-311,52	77,59	-1,7
173	-303,07	-267,57	80,51	-1,7
174	-329,29	-212,43	82,51	-1,6
175	-354,24	-151,28	86,7	-1,6
176	-376,89	-86,66	96,67	-1,5
177	124,27	630,26	20,54	-0,1
178	76,09	413,36	27,89	-0,2
179	31,42	226,53	37,44	-0,4
180	-9,87	67,25	45,91	-0,6
181	-47,66	-65,28	53,46	-0,8
182	-82,02	-171,82	60,65	-1
183	-113,11	-253,02	67,8	-1,2
184	-141,18	-309,56	75,1	-1,3
185	-166,62	-342,16	82,63	-1,4
186	-189,94	-351,76	90,23	-1,5
187	-211,71	-339,72	97,52	-1,6
188	-232,48	-308,24	103,75	-1,6
189	-252,41	-260,88	108,12	-1,6
190	-270,97	-203,06	110,13	-1,5
191	-286,77	-141,92	112,42	-1,4
192	-300,56	-94,76	119,26	-1,4
193	121,12	612	22,2	0
194	75,13	399,05	32,2	-0,2
195	33,12	215,11	43,44	-0,3
196	-5,07	57,87	53,28	-0,5
197	-39,29	-73,21	62,1	-0,7
198	-69,53	-178,72	70,49	-0,9
199	-95,81	-259,13	78,85	-1,1
200	-118,26	-314,95	87,48	-1,3
201	-137,11	-346,65	96,53	-1,4

NODE	LEVEL 4 Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
202	-152,76	-354,83	105,94	-1,4
203	-165,84	-340,38	115,31	-1,5
204	-177,14	-304,98	123,62	-1,5
205	-187,24	-252,02	129,21	-1,4
206	-195,68	-188,28	130,09	-1,3
207	-198,63	-124,12	126,83	-1,3
208	-194,47	-81,73	121,85	-1,2
209	117,54	591,4	23,02	0
210	73,96	382,95	35,02	-0,2
211	34,84	202,22	47,38	-0,3
212	0,01	47,29	58,08	-0,5
213	-30,33	-82,16	67,61	-0,7
214	-56,06	-186,49	76,59	-0,9
215	-77,06	-266,04	85,45	-1,1
216	-93,22	-321,11	94,56	-1,2
217	-104,5	-352	104,17	-1,3
218	-111,02	-358,92	114,39	-1,3
219	-113,23	-342,1	125	-1,4
220	-112,05	-302,14	135,03	-1,3
221	-108,93	-241,09	142,02	-1,3
222	-104,67	-165,44	141,54	-1,2
223	-95,52	-89,65	128,15	-1,1
224	-69,29	-35,94	101,38	-1
225	113,67	569,4	22,98	0
226	72,58	365,78	36,28	-0,2
227	36,39	188,49	49,18	-0,3
228	4,97	36,07	60,19	-0,5
229	-21,47	-91,54	69,88	-0,7
230	-42,7	-194,5	78,8	-0,9
231	-58,4	-273	87,37	-1
232	-68,18	-327,23	95,94	-1,1
233	-71,61	-357,31	104,83	-1,2
234	-68,3	-363,2	114,33	-1,2
235	-58,07	-344,52	124,56	-1,2
236	-41,38	-300,45	135,13	-1,2
237	-20,05	-230,01	143,98	-1,1
238	1,68	-135,29	144,66	-1
239	21,17	-30,72	124,46	-0,9
240	50,63	51,93	69,29	-0,7
241	113,63	61,24	-8,86	-0,6
242	-2,94	-3,33	67,36	-0,8
243	109,68	546,98	22,12	0
244	71	348,29	36,02	-0,2
245	37,62	174,52	48,9	-0,3
246	9,41	24,76	59,74	-0,5
247	-13,41	-100,8	69,08	-0,7
248	-30,52	-202,12	77,35	-0,8
249	-41,43	-279,25	84,86	-1
250	-45,46	-332,29	91,85	-1,1
251	-41,73	-361,32	98,58	-1,1
252	-29,19	-366,17	105,39	-1,1
253	-6,65	-346,21	112,67	-1,1
254	26,93	-299,7	120,8	-1,1
255	71,61	-222,74	129,64	-1
256	123,75	-106,88	135,9	-0,8
257	164,08	46,25	121,58	-0,7
258	182,25	189,49	52,63	-0,5
259	228,88	248,65	-80,2	-0,4
260	105,73	525,07	20,51	0
261	69,28	331,17	34,38	-0,1
262	38,45	160,87	46,76	-0,3
263	13,08	13,82	57,04	-0,5
264	-6,67	-109,48	65,66	-0,6
265	-20,43	-208,8	72,86	-0,8
266	-27,58	-284,06	78,72	-0,9
267	-27,21	-335,31	83,28	-1
268	-18,1	-362,6	86,6	-1

NODE	LEVEL 4 Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
269	1,4	-365,83	88,79	-1,1
270	33,48	-344,39	90,12	-1
271	81,07	-296,61	91,11	-0,9
272	148,1	-218,14	92,96	-0,8
273	239,02	-98,23	97,82	-0,7
274	357,64	111,62	107,26	-0,5
275	402,41	384,79	55,21	-0,3
276	357,92	488,73	-113,1	-0,2
277	476,22	361,68	-252,92	-0,1
278	312,73	217,7	-204,53	-0,3
279	-15,62	14,78	-3,19	0
280	-0,25	33,53	-11,25	0
281	3,8	16,99	-11,99	0
282	-2,69	19,75	-7,56	0
283	101,99	504,51	18,25	0
284	67,54	315,04	31,54	-0,1
285	38,92	147,97	43,06	-0,3
286	15,87	3,58	52,56	-0,4
287	-1,56	-117,32	60,33	-0,6
288	-13,01	-214,24	66,28	-0,7
289	-17,8	-287	70,24	-0,9
290	-14,94	-335,59	71,97	-0,9
291	-3,07	-360,07	71,2	-1
292	19,65	-360,36	67,64	-1
293	55,8	-335,98	60,99	-0,9
294	109,32	-285,46	51	-0,8
295	186,08	-205,71	37,49	-0,7
296	298,31	-88,17	21,83	-0,5
297	466,23	72,37	6,54	-0,4
298	865,26	575,56	31,9	-0,2
299	1079,21	1055,42	-274,16	-0,1
300	655,44	306,74	-153,86	0
301	369,35	148,66	-139,22	0
302	393,65	197,15	-253,84	-0,1
303	-2,3	43,98	15,84	0
304	52,17	108,08	25,85	0
305	43,51	35,33	-20,5	0
306	14,85	8,21	-8	0
307	98,63	486,06	15,39	0
308	65,98	300,41	27,63	-0,1
309	39,26	136,08	38,1	-0,3
310	17,94	-5,91	46,88	-0,4
311	1,94	-124,32	53,93	-0,6
312	-8,43	-218,45	58,8	-0,7
313	-12,46	-288,02	61,01	-0,8
314	-9,18	-333,03	60,04	-0,9
315	2,56	-353,48	55,38	-0,9
316	24,27	-349,21	46,34	-0,9
317	57,93	-319,66	32,04	-0,8
318	106,49	-263,31	11,08	-0,7
319	174,3	-176,72	-17,55	-0,6
320	268,99	-49,54	-60,54	-0,5
321	395	141,59	-103,46	-0,3
322	287,54	419,19	-271,28	-0,1
323	359,7	274,42	87,2	0
324	286,92	176,46	-24,37	0
325	168,58	92,36	-32,79	0
326	218,7	117,09	-124,1	0
327	24,59	14,42	14,25	0
328	17,04	-11,31	-15,12	0
329	63,82	105,47	-12,84	0
330	57,04	36,88	33,52	0
331	15,73	8,87	15,7	0
332	95,89	470,46	11,91	0
333	65,03	287,66	22,71	-0,1
334	39,97	125,2	32,19	-0,3
335	19,73	-14,89	40,62	-0,4

NODE	LEVEL 4 Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
336	4,11	-130,82	47,43	-0,5
337	-6,48	-221,76	51,68	-0,7
338	-11,25	-287,51	52,59	-0,8
339	-9,4	-328,12	49,57	-0,8
340	-0,17	-343,58	42,03	-0,9
341	17,12	-333,58	29,19	-0,8
342	43,11	-297,31	9,99	-0,8
343	78,3	-233,2	-16,98	-0,7
344	123,08	-137,25	-53,1	-0,5
345	173,07	-4,01	-98,18	-0,4
346	226,81	192,49	-145,15	-0,2
347	182,92	421,89	-144,22	-0,1
348	124,14	420,78	-9,32	0
349	199,48	729,59	179,03	0
350	179,29	320,39	40,67	0
351	156,78	182,47	29,22	0
352	103,21	87,63	15,25	0
353	56,68	18,9	10,03	0
354	94,8	27,47	-28,26	0
355	20,73	-32,23	5,77	0
356	36,98	-30,84	-17,23	0
357	-4,01	-66,48	0,34	0
358	4,43	-71,7	-11,92	-0,1
359	-19,81	-82,03	-8,04	-0,1
360	-9,67	-88,43	-15,26	-0,1
361	-26,54	-77,28	-16,49	-0,1
362	-13,28	-81,26	-18,65	-0,1
363	-24,7	-54,54	-21,86	0
364	-9,24	-55,35	-19,73	0
365	-16,3	-10,48	-23,12	0
366	-26,35	29,69	-5,61	0
367	-7,79	36,07	22,33	0
368	4,51	28,01	20,51	0
369	94,17	458,62	7,52	0
370	65,49	277,03	16,55	-0,1
371	41,94	114,9	25,56	-0,3
372	21,91	-24,06	34,55	-0,4
373	5,37	-137,48	41,92	-0,5
374	-6,77	-224,75	46,12	-0,6
375	-13,54	-286,09	46,31	-0,7
376	-14,28	-321,8	42,05	-0,8
377	-8,81	-331,9	33,01	-0,8
378	2,59	-315,97	18,74	-0,8
379	19,04	-273,15	-1,38	-0,7
380	38,71	-202,15	-27,99	-0,6
381	58,14	-101,68	-60,68	-0,5
382	70,98	29,12	-94,98	-0,4
383	62,76	179,42	-113,88	-0,2
384	26,47	288,02	-85,63	-0,1
385	28,33	315,83	-32,45	0
386	44,24	260,56	14,36	0
387	52,07	169,48	29,54	0
388	39,68	84,73	30,41	0
389	18,27	18,83	26,46	0
390	-2,98	-28,2	20,26	0
391	-20,18	-57,99	11,04	0
392	-32,34	-71,13	-0,15	-0,1
393	-39,77	-68,62	-11,09	-0,1
394	-42,82	-51,69	-18,78	0
395	-44,36	-25,53	-18,43	0
396	-41,46	-2,02	-6,5	0
397	-25,61	15,01	7,31	0
398	-2,94	34,86	11,94	0
399	94,39	451,98	1,28	0
400	69,1	268,36	8,58	-0,1
401	46,68	103,94	18,66	-0,3
402	25,1	-34,69	29,83	-0,4

LEVEL 4

NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
403	5,83	-145,12	38,65	-0,5
404	-9,16	-227,94	43,19	-0,6
405	-18,67	-284,32	42,95	-0,7
406	-22,33	-314,98	38,03	-0,8
407	-20,47	-320,06	28,67	-0,8
408	-14,19	-299,1	15,07	-0,7
409	-5,45	-251,37	-2,63	-0,7
410	2,58	-176,4	-24,07	-0,6
411	5,31	-75,74	-47,79	-0,5
412	-2,56	42,76	-69,2	-0,3
413	-22,36	156,45	-78,42	-0,2
414	-38,16	233,54	-67,33	-0,1
415	-36,84	250,01	-38,98	0
416	-20,9	210,61	-8,84	0
417	-6,28	142,78	14,59	0
418	-3,76	73,24	27,07	0
419	-10,63	17,28	30,48	0
420	-21,25	-22,31	26,72	0
421	-31,61	-46,69	17,83	0
422	-40,08	-57,63	6,08	0
423	-46,14	-56,86	-5,71	0
424	-49,72	-46,86	-14,26	0
425	-49,77	-31,85	-16,57	0
426	-42,79	-15,52	-12,18	0
427	-26,75	3,21	-4,85	0
428	-3,17	35,05	-0,72	0
429	99,2	453,14	-9,04	0
430	79,91	260,16	-1,99	-0,1
431	55,74	89,37	13,08	-0,2
432	28,95	-48,51	28,54	-0,4
433	4,66	-154,29	39,13	-0,5
434	-14,13	-231,41	43,65	-0,6
435	-26,44	-282,31	42,66	-0,7
436	-32,38	-308,14	37,1	-0,7
437	-32,8	-309,07	27,91	-0,7
438	-29,2	-284,69	15,98	-0,7
439	-23,88	-234,41	2,24	-0,6
440	-20,11	-158,28	-12,23	-0,5
441	-22,13	-58,99	-26,13	-0,4
442	-33,92	53,25	-38,57	-0,3
443	-52,69	155,62	-49,35	-0,2
444	-64,87	216,42	-56,86	-0,1
445	-57,07	219,11	-51,87	0
446	-37,08	174,79	-31,18	0
447	-23,28	111,91	-3,15	0
448	-19,73	55,12	18,6	0
449	-22,15	12,42	28,71	0
450	-26,66	-16,46	28,47	0
451	-31,4	-33,77	21,07	0
452	-35,65	-41,6	9,9	0
453	-39,15	-41,83	-1,91	0
454	-41,44	-36,68	-11,64	0
455	-40,79	-28,54	-17,33	0
456	-34,44	-18,3	-18,51	0
457	-21,08	-2,47	-15,82	0
458	-1,35	30	-11,31	0
459	118,82	466,35	-30,64	0
460	104,47	245,06	-13	-0,1
461	67,73	66,04	13,41	-0,3
462	30,23	-66,56	33,73	-0,4
463	-0,57	-164,4	44,58	-0,5
464	-22,98	-234,34	47,61	-0,6
465	-37,17	-279,5	44,83	-0,7
466	-43,98	-301,01	38,01	-0,7
467	-44,63	-298,98	28,65	-0,7
468	-40,66	-272,96	18,13	-0,7
469	-33,98	-222,42	7,88	-0,6

LEVEL 4

NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
470	-26,91	-147,37	-0,66	-0,5
471	-22,19	-49,33	-6,41	-0,4
472	-23,54	66,32	-10,76	-0,3
473	-37,47	178,03	-22,8	-0,2
474	-54,13	239,76	-49,9	-0,1
475	-32,46	219,67	-74,13	0
476	-7,12	144,91	-53	0
477	-8,88	75,61	-15,02	0
478	-14,4	32,53	12,73	0
479	-16,19	6,24	25,6	0
480	-15,51	-9,86	27,04	0
481	-14,08	-18,89	21,07	0
482	-13,24	-22,79	11,18	0
483	-13,56	-23,02	0,25	0
484	-14,72	-20,48	-9,49	0
485	-16,04	-16,71	-17,33	0
486	-15,92	-12,89	-22,09	0
487	-9,58	-3,96	-22,86	0
488	1,41	20,08	-17,57	0
489	192,58	484,58	-68,71	0
490	135,55	202	-11,16	-0,1
491	71,18	31,46	27,44	-0,3
492	22,18	-86,42	47,42	-0,4
493	-13,36	-173,13	54,82	-0,5
494	-37,29	-235,07	54,08	-0,6
495	-51,38	-274,71	48,12	-0,7
496	-57,15	-292,74	39,07	-0,7
497	-55,95	-288,95	28,64	-0,7
498	-49,05	-262,77	18,36	-0,6
499	-37,55	-213,58	9,68	-0,6
500	-22,26	-141,05	3,94	-0,5
501	-3,49	-45,38	2,04	-0,4
502	19,42	74	3,23	-0,3
503	42,36	221,34	0,2	-0,1
504	26,95	335,34	-47,64	-0,1
505	46,78	228,72	-104,31	0
506	38,8	86,16	-52,43	0
507	8,33	31,96	-9,18	0
508	0,72	12,03	13,29	0
509	6,3	3,64	23,08	0
510	16,81	0,21	24,17	0
511	26,9	-0,86	19,87	0
512	33,48	-0,91	12,59	0
513	35,34	-0,75	4,23	0
514	32,88	-0,45	-4,03	0
515	26,98	-0,82	-10,29	0
516	16,83	-1,06	-20,28	0
517	9,38	-4,66	-23,21	0
518	5,5	7,01	-17,02	0
519	266,72	345,98	-82,29	-0,1
520	123,56	127,71	25,38	-0,2
521	49,39	-2,69	55,52	-0,3
522	-2,05	-102,31	66,91	-0,4
523	-36,21	-177,24	67,15	-0,5
524	-57,8	-231,69	60,85	-0,6
525	-69,18	-266,67	50,66	-0,6
526	-71,97	-282,2	38,55	-0,7
527	-67,35	-277,71	26,12	-0,7
528	-56,13	-252,35	14,7	-0,6
529	-38,67	-205,18	5,39	-0,5
530	-14,52	-135,28	-1,15	-0,4
531	18,18	-41,53	-4,95	-0,3
532	64,18	78,49	-8,76	-0,2
533	135,33	228,18	-18,6	-0,1
534	308,73	580,2	-81,02	0
535	26,73	-2,17	-4,12	0
536	6,2	-4,52	-8,87	0

LEVEL 4

NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
537	115,61	199,34	23,78	-0,1
538	52,24	81,54	65,6	-0,2
539	-4,4	-26,54	84,47	-0,3
540	-42,5	-109,52	84,26	-0,4
541	-68,05	-174,76	77,09	-0,5
542	-83,23	-223,04	65,1	-0,6
543	-89,52	-254,46	50,56	-0,6
544	-87,91	-268,49	35,12	-0,6
545	-79,11	-264,15	20,16	-0,6
546	-63,53	-240,16	6,73	-0,6
547	-41,15	-195	-4,54	-0,5
548	-11,19	-126,77	-13,76	-0,4
549	28,3	-32,39	-22,28	-0,3
550	80,97	94,99	-34,47	-0,2
551	155,57	288,2	-57,02	-0,1
552	214,56	602,54	-64,65	0
553	6,21	2,88	-0,71	0
554	2,42	-4,84	-1,15	0
555	-52,9	46,33	45,85	-0,1
556	-53,07	36,63	86,91	-0,2
557	-72,63	-40,2	96,77	-0,3
558	-90,37	-109,31	92,69	-0,4
559	-103,35	-166,09	80,71	-0,5
560	-109,97	-209,16	64,64	-0,6
561	-110,01	-237,89	46,53	-0,6
562	-103,52	-251,23	28,1	-0,6
563	-90,67	-247,75	10,69	-0,6
564	-71,66	-225,6	-4,76	-0,5
565	-46,49	-182,52	-17,91	-0,5
566	-14,95	-115,52	-29,11	-0,4
567	23,14	-19,84	-39,58	-0,3
568	66,43	114,16	-50,85	-0,2
569	104,23	300,89	-56,67	-0,1
570	105,22	499,2	-30,61	0
571	-1,21	-1,18	-0,62	0
572	-1,7	-6,44	0,05	0
573	-115,92	16,02	71,79	-0,2
574	-129,2	-7,79	87,33	-0,3
575	-129,66	-51,82	95,29	-0,3
576	-132,36	-105,29	90,62	-0,4
577	-134,17	-152,89	77,22	-0,5
578	-132,91	-190,79	58,93	-0,5
579	-127,2	-217,19	38,36	-0,6
580	-116,42	-230,45	17,62	-0,6
581	-100,42	-228,55	-1,69	-0,6
582	-79,35	-209	-18,52	-0,5
583	-53,49	-168,8	-32,41	-0,4
584	-23,37	-104,35	-43,41	-0,4
585	9,7	-11,01	-51,46	-0,3
586	42,16	116,31	-54,74	-0,2
587	67,65	275,7	-45,53	-0,1
588	90,41	447,48	-17,24	0
589	-0,42	-0,92	-0,48	0
590	-1,96	-7,41	-0,09	0
591	-162,51	-4,64	75,09	-0,2
592	-163,86	-26,51	85,03	-0,3
593	-161,78	-59,24	87,69	-0,3
594	-157,78	-98,17	82,46	-0,4
595	-153,23	-136,13	68,63	-0,5
596	-146,85	-168,44	49,16	-0,5
597	-137,29	-192,59	26,91	-0,5
598	-123,72	-206,34	4,46	-0,5
599	-105,97	-206,97	-16,09	-0,5
600	-84,31	-191,19	-33,37	-0,5
601	-59,32	-155,4	-46,67	-0,4
602	-31,85	-95,89	-55,63	-0,3
603	-3,2	-9,25	-59,37	-0,2

	LEVEL 4			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
604	24,84	106,24	-55,81	-0,1
605	52,07	248,35	-40,81	-0,1
606	81,65	407,78	-13,56	0
607	-0,2	-0,87	-0,24	0
608	-1,58	-7,49	-0,15	0
609	-173,26	-12,55	72,39	-0,2
610	-171,49	-33,84	79,42	-0,3
611	-167,34	-58,3	79,27	-0,3
612	-161,95	-86,55	72,68	-0,4
613	-155,51	-115,3	58,16	-0,4
614	-147,46	-141,83	37,59	-0,5
615	-136,68	-163,9	13,78	-0,5
616	-122,41	-178,92	-10,13	-0,5
617	-104,62	-183,37	-31,43	-0,5
618	-83,92	-172,98	-48,33	-0,4
619	-61,08	-143,4	-60,03	-0,4
620	-36,76	-90,91	-66,15	-0,3
621	-11,45	-12,99	-65,93	-0,2
622	14,78	91,25	-58,15	-0,1
623	42,94	221,08	-40,65	-0,1
624	73,84	370,5	-13,12	0
625	-0,18	-0,86	-0,16	0
626	-1,48	-7,43	-0,13	0
627	-156,29	-15,49	66,66	-0,2
628	-152,59	-32,98	72,98	-0,3
629	-148,12	-50,33	71,67	-0,3
630	-143,21	-69,27	64,07	-0,3
631	-137,78	-89,33	48,68	-0,4
632	-131,19	-110	26,73	-0,4
633	-122,11	-130,29	0,98	-0,4
634	-109,59	-147,76	-24,65	-0,4
635	-93,8	-157,91	-46,52	-0,4
636	-75,84	-154,93	-62,43	-0,4
637	-56,7	-133,27	-71,85	-0,3
638	-36,57	-89,03	-75,02	-0,3
639	-14,97	-20,17	-71,74	-0,2
640	8,9	73,86	-61,45	-0,1
641	36,05	193,08	-42,43	0
642	66,09	332,26	-13,92	0
643	-0,11	-0,82	-0,1	0
644	-1,46	-7,39	-0,07	0
645	-113,26	-15,01	60,47	-0,2
646	-108,84	-26,71	66,84	-0,2
647	-104,18	-36,56	65,56	-0,2
648	-100	-46,41	57,88	-0,3
649	-96,88	-57,5	42,3	-0,3
650	-94,4	-71,65	19,09	-0,3
651	-90,3	-90,28	-9,18	-0,3
652	-82,46	-111,89	-37,32	-0,3
653	-71,17	-130,56	-59,91	-0,3
654	-58,43	-137,59	-74,25	-0,3
655	-45,4	-125,32	-80,87	-0,3
656	-31,44	-89,62	-81,3	-0,2
657	-14,99	-29,42	-76,01	-0,2
658	5,25	55,18	-64,45	-0,1
659	29,84	164,19	-44,65	0
660	57,97	291,67	-15,46	0
661	0,3	-0,95	-0,18	0
662	-1,4	-7,35	0	0
663	-47,02	-12,13	55,03	-0,1
664	-41,66	-16,21	61,12	-0,2
665	-35,4	-18,19	60,27	-0,2
666	-29,77	-19,05	53,74	-0,2
667	-27,91	-20,22	40,13	-0,2
668	-31,48	-25,59	17,42	-0,2
669	-36,81	-41,48	-13,75	-0,2
670	-38,08	-69,64	-45,93	-0,3

	LEVEL 4			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
671	-34,89	-101,4	-69,52	-0,3
672	-31,23	-121,94	-81,48	-0,2
673	-28,26	-119,96	-84,91	-0,2
674	-22,96	-91,94	-83,39	-0,2
675	-13,21	-39,35	-77,49	-0,1
676	2,1	36,07	-66,2	-0,1
677	24,2	135,1	-46,44	0
678	47,06	248,47	-17,84	0
679	38,33	-6,25	50,17	-0,1
680	46,06	-1,45	54,6	-0,1
681	58,23	4,43	53,08	-0,1
682	70,27	10,53	48,79	-0,1
683	76,82	19,31	41	-0,1
684	69,37	28,02	24,75	-0,1
685	46,48	19,96	-6,72	-0,2
686	27,75	-17,58	-45,73	-0,2
687	16,49	-71,04	-71,68	-0,2
688	1,95	-110,42	-79,79	-0,2
689	-10,05	-117,15	-81,46	-0,2
690	-13,94	-94,6	-80,02	-0,1
691	-11,23	-48,18	-75,2	-0,1
692	-1,74	18,78	-65,82	-0,1
693	16,11	104,86	-48,87	0
694	35,12	211,54	-23,48	0
695	135,4	5,29	45,31	0
696	152,46	21,44	42,47	0
697	177,2	32,07	39,04	0
698	200,66	40,36	36,82	-0,1
699	221,01	52,85	36,55	-0,1
700	231,9	80,95	37,36	-0,1
701	194,93	104,64	20,88	-0,1
702	117,16	50,51	-24,9	-0,1
703	76,89	-46,61	-54,87	-0,1
704	20,56	-104,81	-64,56	-0,1
705	2,11	-113,15	-71,52	-0,1
706	-7,08	-96,01	-72,39	-0,1
707	-9,07	-54,38	-69,21	-0,1
708	-5,62	5,8	-62,63	-0,1
709	5,19	78,62	-50,19	0
710	23,04	162,95	-28,12	0
711	234,4	35,32	29,83	0
712	282,67	55,18	20,32	0
713	320,26	63,61	16,35	0
714	354,88	71,14	14,63	0
715	389,03	79,38	15,9	0
716	431,36	97,05	23,43	0
717	486,88	184,13	46,76	0
718	430,81	208,35	43,92	0
719	35,02	-42,73	-0,01	0
720	17,66	-77,86	-46,89	-0,1
721	2,11	-105,66	-56,42	-0,1
722	-2,74	-94,93	-58,66	-0,1
723	-4,67	-58,12	-55,73	-0,1
724	-4,3	-1,58	-50,38	0
725	-1,68	63,47	-43,89	0
726	8,11	116,9	-34,92	0
727	-10,08	556,33	-55,35	0
728	7,29	387,04	-28,75	-0,1
729	163,53	814,65	-32,93	0
730	-0,17	204,29	-22,71	-0,3
731	-1,76	40,79	-24,41	-0,5
732	-5,42	-222,08	-43,69	-0,8
733	-3,88	-102,13	-31,84	-0,6
734	-6,74	-318,21	-59,16	-1
735	170,12	851,86	-29,09	0
736	174,94	876,86	-26,59	0
737	-7,82	-389,82	-77,61	-1,1

	LEVEL 4			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
738	-8,61	-436,19	-98,39	-1,1
739	-8,72	-448,61	-143,52	-1,1
740	-9,14	-456,41	-120,7	-1,1
741	-9,25	-410,57	-164,47	-1
742	1,33	-331,33	-182,15	-0,8
743	171,33	79,03	-180,27	-0,4
744	-27,69	-217,05	-176,01	-0,6
745	-611,53	282,65	225,51	-0,2
746	107,16	126,45	-198,39	-0,5
747	-182,61	-25,09	-185,18	-0,8
748	178,89	896,63	-24,39	0
749	181,85	911,59	-22,02	0
750	183,72	921,13	-19,41	0
751	184,39	924,66	-16,6	0
752	183,79	921,86	-13,66	0
753	181,96	912,8	-10,7	0
754	178,96	897,89	-7,82	0
755	174,95	877,86	-5,11	0
756	170,13	853,71	-2,67	0
757	164,74	826,63	-0,55	0
758	159,03	797,93	1,22	0
759	153,25	768,89	2,63	0
760	147,64	740,71	3,71	0
761	142,42	714,46	4,49	0
762	137,76	691,02	5,02	0
763	-408,12	-14,84	-144,24	-1,3
764	-502,38	-16,39	-68,03	-1,6
765	-509,94	-16,56	14,91	-1,6
766	-485,67	-20,33	63,83	-1,6
767	-515,84	-16,72	-26,91	-1,6
768	-467,45	-15,37	-107,83	-1,4
769	133,81	671,2	5,32	0
770	-313,85	-5,89	-175,79	-1
771	426,52	-446,01	132,36	-0,2
772	-393,87	-13,49	103,4	-1,4
773	-258,34	-76,76	140,28	-1,2
774	-129,66	-65,87	121,43	-1
775	-26,35	-32,72	81,71	-0,9
776	206,4	37,51	-99,56	-0,6
777	-5,38	8,35	6,49	0
778	-13,8	8,96	0,53	0
779	-5,89	14,78	-0,65	0
780	-2	22,61	4,79	0
781	-0,56	14,51	10,43	0
782	1,47	7,36	1,87	0
783	3,56	10,21	9,71	0
784	3,32	17,3	2,74	0
785	10,82	41,82	3,76	0
786	291	178,75	-229,33	-0,3
787	380,03	209,91	-267,43	-0,2
788	-4,7	41,85	19,02	0
789	-8,96	13,17	4,3	0
790	9,76	49,26	-1,05	0
791	13,59	52,9	0,76	0
792	5,05	27,98	-4,7	0
793	112,08	81,35	-112,67	0
794	279,77	204,4	-218,6	-0,1
795	16,34	20,79	-45,99	0
796	4,8	-54,28	-14,63	-0,1
797	-5,87	-88,97	-18,56	-0,1
798	-8,2	-88,43	-22,07	-0,1
799	14,28	10,56	14,08	0
800	-15,58	-53,11	-16,23	-0,1
801	0,22	2,93	-1,96	0
802	1,5	6,6	3,96	0
803	8,82	41,28	10,09	0
804	130,77	655,98	5,32	0

LEVEL 4				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
805	128,99	647,1	4,77	0
806	129,22	648,93	2,73	0
807	133,96	676,03	-3,82	0
808	149,99	781,49	-30,91	0
809	508,3	1287,36	-211,36	0
810	127,02	-144,06	-142,38	0
811	8,6	56,78	46,89	-0,1
812	-169,65	-3,01	70,46	-0,2
813	-125,73	-8,06	61,94	-0,1
814	-178,11	-5,76	65,77	-0,2
815	-152,07	-4,38	57,8	-0,2
816	-97,74	-2,52	48,63	-0,1
817	516,28	804,93	-228,77	0
818	124,63	342,04	-146,61	0
819	143,59	699,81	-53,52	0
820	119	596,56	-18,56	0
821	108,23	542,26	-17,83	0
822	91,83	459,49	-18,73	0
823	83,45	417,29	-19,36	0
824	99,83	499,85	-18,06	0
825	74,5	372,29	-19,67	0
826	-19,11	-0,01	39,98	-0,1
827	77,79	0,33	33,84	0
828	171,08	-2,48	41,95	0
829	360,65	72,49	11,3	0
830	444,15	89,24	14,07	0
831	483,63	97,12	16,95	0
832	404,78	81,34	12,15	0
833	185,87	37,05	26,73	0
834	297,4	59,86	13,81	0
835	623,34	132,75	65,33	0
836	534,91	107,98	23,21	0
837	887,09	280,05	274,56	0
838	-250,23	12,61	21,87	0
839	0,52	-97,66	-42,75	-0,1
840	-2,2	-104,5	-48,43	-0,1
841	15,31	-32,94	-23,04	0
842	75,37	309,6	-8,76	0
843	-3,73	-33,11	-43,67	0
844	-2,87	29,36	-38,7	0
845	-3,6	-80,51	-47,61	-0,1
846	-0,28	89,08	-35,72	0
847	7,49	90,85	-27,37	0
848	60,59	253,95	-9,84	0
849	41,4	181,33	-15,72	0
850	110,77	20,3	-68,6	0
851	1,39	-1,08	0,17	0
852	24,2	3,3	4,24	0
853	16,44	3,18	-16,15	0
854	94,33	18,01	0,87	0
855	138,32	27,55	-6,34	0
856	141,7	28,6	-9,49	0
857	122,02	23,92	-2,71	0
858	59,24	10,62	3,61	0
859	132,09	26,91	-11,67	0
860	16,84	81,59	8,59	0
861	18,85	95,15	-0,88	0
862	13,84	70,82	-4,5	0
863	20,3	100,76	4,05	0
864	7,46	38,83	-5,15	0
865	111,54	35,42	-6,65	0
866	60,88	24,82	3,41	0
867	33,53	9,44	-17,74	0
868	2,8	14,92	-2,54	0
869	1,41	7,27	0,08	0
870	1,59	6,62	0,11	0
871	1,94	9,98	0,08	0

LEVEL 4				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
872	2,32	11,53	0,66	0
873	2,35	11,61	0,61	0
874	2,34	11,56	0,46	0
875	2,32	11,49	0,31	0
876	2,37	11,66	-0,03	0
877	2,29	11,32	-0,32	0
878	1,76	8,8	0,83	0
879	2,02	10,19	0,5	0
880	2,06	10,41	0,29	0
881	2,04	10,35	0,2	0
882	-0,61	-5,48	-0,69	0
883	2,03	10,29	0,13	0
884	2,03	10,24	0,13	0
885	-0,68	-5,85	0,26	0
886	2,28	11,56	0,23	0
887	1535,61	1252,83	79,53	0
888	194,77	212,23	7,53	0
889	112,4	583,28	-69,91	0
890	151,13	729,89	-47,73	0
891	4265,09	3644,41	1433,34	0

	LEVEL 5			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1	52,8	478,91	46,69	0
2	93,73	517,44	34,5	0
3	43,15	329,94	50,11	-0,1
4	18,67	320,63	48,8	-0,1
5	9,15	166,67	57,16	-0,3
6	2,74	162,42	48,53	-0,3
7	-15,42	21,49	62,72	-0,5
8	-9,4	15,98	52,43	-0,4
9	-34,61	-103,57	70,23	-0,6
10	-18,59	-110,9	60,37	-0,6
11	-50,13	-206,46	80,29	-0,8
12	-26,17	-215,82	71,86	-0,7
13	-62,82	-285,94	92,91	-0,9
14	-32,47	-297,1	86,3	-0,9
15	-72,94	-341,09	107,75	-1
16	-37,59	-353,61	103,03	-0,9
17	-80,36	-371,06	124,27	-1,1
18	-41,3	-384,22	121,2	-1
19	-84,49	-374,84	141,63	-1,1
20	-43,13	-387,55	139,63	-1
21	-84,15	-350,99	158,6	-1,1
22	-41,61	-361,2	156,49	-0,9
23	-76,96	-296,9	173,51	-1
24	-35,87	-302,95	168,68	-0,8
25	-59,74	-210,29	183,12	-0,9
26	-13,13	-201,59	171,25	-0,7
27	-20,28	-71,25	188,1	-0,8
28	3,43	-77,48	144,17	-0,5
29	10,18	104,6	156,12	-0,6
30	257,45	169,27	122,78	-0,4
31	-19,02	213,57	78,62	-0,5
32	368,21	659,64	-12,2	-0,2
33	142,68	182,84	-22,54	-0,4
34	462,23	136,46	-54,61	-0,1
35	106,95	550,63	25,61	0
36	57,42	348,46	43,81	-0,2
37	15,79	176,65	55,21	-0,3
38	-17,95	29,07	63,19	-0,5
39	-45,6	-95,74	70,98	-0,7
40	-68,75	-197,5	80,09	-0,8
41	-88,33	-275,65	91,07	-1
42	-104,81	-329,68	103,99	-1,1
43	-118,3	-359,08	118,61	-1,2
44	-128,6	-363,23	134,4	-1,2
45	-135,25	-341,2	150,5	-1,2
46	-137,75	-291,6	165,44	-1,1
47	-135,71	-211,46	176,6	-1,1
48	-136,21	-104,03	175,35	-1
49	-140,51	13,02	149,85	-0,9
50	-134,39	83,34	85,08	-0,8
51	-99,12	77,48	34,53	-0,7
52	113,1	576,9	20,98	0
53	64	367,55	37,03	-0,2
54	19,11	189,12	49,08	-0,3
55	-20,29	38,11	58,07	-0,5
56	-54,45	-87,72	66,11	-0,7
57	-84,18	-189,19	74,64	-0,9
58	-110,25	-266,51	84,44	-1
59	-133,21	-319,68	95,83	-1,2
60	-153,45	-348,58	108,74	-1,3
61	-171,23	-353,07	122,77	-1,3
62	-186,88	-332,98	137	-1,3
63	-201,02	-288,27	149,66	-1,3
64	-215,36	-220,73	157,03	-1,2
65	-230,8	-137,26	153,02	-1,2
66	-245,43	-56,8	130,42	-1,1
67	-246,66	0,19	96,53	-1

	LEVEL 5			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
68	-232,5	20,03	63,04	-0,9
69	117,21	598,04	16,78	0
70	67,1	383,98	29,9	-0,2
71	20,11	201,24	40,51	-0,3
72	-22,94	47,31	48,94	-0,5
73	-61,81	-79,84	56,42	-0,7
74	-96,82	-181,48	64,01	-0,9
75	-128,5	-258,36	72,42	-1,1
76	-157,4	-310,94	82,02	-1,2
77	-184,09	-339,57	92,81	-1,3
78	-209,12	-344,7	104,37	-1,4
79	-233,14	-327,03	115,74	-1,4
80	-256,98	-288,15	125,05	-1,4
81	-281,24	-231,76	129,37	-1,4
82	-305,26	-165,74	125,25	-1,3
83	-324,67	-102,15	111,34	-1,3
84	-332,42	-52,62	91,32	-1,2
85	-325,57	-18	70,59	-1,1
86	120,15	614,29	12,41	0
87	68,81	396,96	22,17	-0,2
88	20,1	211,39	30,37	-0,3
89	-25,47	55,38	37,16	-0,5
90	-67,67	-72,88	43,28	-0,7
91	-106,62	-174,83	49,39	-0,9
92	-142,71	-251,5	56,04	-1,1
93	-176,47	-303,74	63,52	-1,3
94	-208,5	-332,36	71,81	-1,4
95	-239,41	-338,35	80,51	-1,5
96	-269,84	-323,22	88,74	-1,5
97	-300,26	-289,47	95,02	-1,5
98	-330,67	-241,34	97,47	-1,5
99	-359,94	-185,32	94,72	-1,5
100	-385,4	-129,41	87,26	-1,4
101	-405,07	-84,89	80,96	-1,4
102	-402,85	-56,21	74,04	-1,3
103	122,14	625,46	7,67	-0,1
104	69,84	406,04	13,8	-0,2
105	19,93	218,74	19,08	-0,3
106	-27,29	61,46	23,59	-0,6
107	-71,61	-67,54	27,72	-0,8
108	-113,17	-169,72	31,87	-1
109	-152,29	-246,28	36,35	-1,1
110	-189,46	-298,32	41,38	-1,3
111	-225,22	-327,02	46,92	-1,4
112	-260,14	-333,82	52,66	-1,5
113	-294,67	-320,77	57,92	-1,6
114	-328,99	-290,79	61,72	-1,6
115	-362,85	-247,97	62,97	-1,6
116	-395,5	-197,38	61,04	-1,6
117	-426,26	-144,37	57,21	-1,5
118	-455,55	-91,22	53,22	-1,5
119	-498,62	-49,05	70,12	-1,4
120	123,2	631,31	2,68	-0,1
121	70,46	410,95	5	-0,2
122	20,01	222,88	7,12	-0,4
123	-27,93	65,01	9	-0,6
124	-73,24	-64,32	10,77	-0,8
125	-116,07	-166,55	12,58	-1
126	-156,72	-242,96	14,61	-1,2
127	-195,65	-294,81	16,97	-1,3
128	-233,34	-323,48	19,66	-1,5
129	-270,25	-330,75	22,49	-1,6
130	-306,66	-318,96	25,1	-1,6
131	-342,55	-291,22	26,91	-1,6
132	-377,58	-251,44	27,28	-1,6
133	-411,18	-203,95	25,81	-1,6
134	-443,51	-152,91	22,02	-1,6

	LEVEL 5			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
135	-475,84	-100,19	17,72	-1,6
136	-518,46	-54,6	3,17	-1,5
137	123,33	631,71	-2,34	-0,1
138	70,79	411,59	-3,84	-0,2
139	20,58	223,61	-4,96	-0,4
140	-27,14	65,77	-5,83	-0,6
141	-72,3	-63,5	-6,61	-0,8
142	-115,05	-165,58	-7,29	-1
143	-155,7	-241,74	-7,87	-1,2
144	-194,66	-293,26	-8,26	-1,3
145	-232,41	-321,65	-8,43	-1,5
146	-269,31	-328,8	-8,37	-1,6
147	-305,54	-317,22	-8,13	-1,6
148	-340,96	-290,16	-7,88	-1,7
149	-375,05	-251,56	-7,93	-1,7
150	-407,1	-205,83	-8,74	-1,6
151	-436,35	-156,95	-11,25	-1,6
152	-463,43	-109,71	-16,4	-1,6
153	-482,07	-58,52	-25,34	-1,5
154	122,55	626,77	-7,14	-0,1
155	70,87	408,03	-12,31	-0,2
156	21,69	220,94	-16,54	-0,3
157	-24,85	63,68	-20,12	-0,6
158	-68,72	-65,18	-23,41	-0,8
159	-110,06	-166,9	-26,59	-1
160	-149,18	-242,65	-29,75	-1,2
161	-186,48	-293,67	-32,86	-1,3
162	-222,41	-321,41	-35,82	-1,4
163	-257,34	-327,74	-38,41	-1,5
164	-291,47	-315,19	-40,35	-1,6
165	-324,57	-287,12	-41,34	-1,6
166	-355,96	-247,74	-41,25	-1,6
167	-384,47	-201,83	-40,35	-1,6
168	-408,7	-154,25	-39,62	-1,6
169	-426,68	-107,86	-40,37	-1,5
170	-438,51	-62,02	-46,06	-1,5
171	120,93	616,87	-11,48	0
172	70,73	400,55	-19,97	-0,2
173	23,34	215,08	-27,04	-0,3
174	-21,14	58,89	-33,09	-0,5
175	-62,66	-69,25	-38,69	-0,7
176	-101,35	-170,43	-44,18	-0,9
177	-137,49	-245,65	-49,73	-1,1
178	-171,46	-296	-55,39	-1,3
179	-203,72	-322,74	-61	-1,4
180	-234,73	-327,53	-66,17	-1,5
181	-264,8	-312,76	-70,25	-1,5
182	-293,85	-281,8	-72,38	-1,6
183	-321,11	-239,21	-71,76	-1,6
184	-345,04	-190,56	-68,14	-1,5
185	-363,48	-141,48	-62,54	-1,5
186	-375,06	-96,64	-56,91	-1,4
187	-378,74	-57,55	-56,95	-1,4
188	118,56	602,61	-15,13	0
189	70,38	389,61	-26,43	-0,2
190	25,4	206,38	-35,91	-0,3
191	-16,25	51,68	-44,05	-0,5
192	-54,51	-75,47	-51,61	-0,7
193	-89,47	-175,94	-59,02	-0,9
194	-121,31	-250,56	-66,6	-1,1
195	-150,39	-300,14	-74,45	-1,2
196	-177,15	-325,63	-82,46	-1,3
197	-202,2	-328,33	-90,12	-1,4
198	-226,09	-310,17	-96,49	-1,5
199	-249,16	-274,27	-100,04	-1,5
200	-270,94	-225,52	-98,99	-1,4
201	-289,65	-170,7	-92,12	-1,4

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
202	-302,25	-117,6	-80,05	-1,4
203	-305,9	-73,3	-66,64	-1,3
204	-298,75	-41,43	-56,47	-1,2
205	-88,93	-220,17	154,34	-1,2
206	-123,14	-248,44	129,28	-1,2
207	-139,83	-159,71	118,03	-1
208	-116,91	-138,62	138,35	-1
209	-157,68	-62,19	96,35	-0,8
210	-116,41	-21,73	118,27	-0,7
211	-176,83	15,96	54,49	-0,5
212	-106,78	116,86	68,61	-0,5
213	-161,99	42,18	6,45	-0,3
214	-151,66	111,94	-35,67	-0,3
215	115,58	584,82	-17,92	0
216	69,79	375,84	-31,39	-0,2
217	27,7	195,36	-42,73	-0,3
218	-10,56	42,52	-52,46	-0,5
219	-44,89	-83,4	-61,45	-0,7
220	-75,26	-183,05	-70,25	-0,9
221	-101,76	-257,01	-79,26	-1
222	-124,59	-305,82	-88,72	-1,2
223	-144,14	-330,07	-98,62	-1,3
224	-161,05	-330,44	-108,53	-1,3
225	-176,24	-308,1	-117,38	-1,4
226	-190,76	-265,36	-123,12	-1,4
227	-205,15	-206,93	-122,6	-1,3
228	-217,99	-141,16	-112,63	-1,3
229	-224,96	-79,64	-92,5	-1,2
230	-219,95	-33,63	-66,35	-1,1
231	-198,66	-7,42	-44,1	-1
232	-167,43	-3,41	-34,52	-1
233	-279,29	-12,33	-60,1	-1,2
234	-54,3	-409,36	131,49	-1,7
235	-62,61	-405,95	120,26	-1,6
236	-80,28	-401,45	121,2	-1,6
237	-72,38	-400,2	136,13	-1,7
238	-98,7	-374,94	117,63	-1,5
239	-88,05	-367,83	138,35	-1,6
240	-116,99	-328,04	110,5	-1,4
241	-108,06	-320,01	135,46	-1,4
242	-137,19	-262,07	100,29	-1,2
243	-159,1	-182,26	85,87	-1
244	-181,66	-100,37	65,9	-0,8
245	-198,12	-35,2	39,9	-0,6
246	-200,27	-2,79	16,52	-0,4
247	112,13	564,47	-19,74	0
248	68,95	360	-34,67	-0,2
249	30	182,66	-47,23	-0,3
250	-4,57	31,98	-57,95	-0,5
251	-34,58	-92,49	-67,75	-0,7
252	-59,87	-191,17	-77,23	-0,8
253	-80,35	-264,43	-86,88	-1
254	-95,98	-312,57	-97,06	-1,1
255	-106,92	-335,77	-107,94	-1,2
256	-113,62	-334,09	-119,39	-1,2
257	-117,11	-307,59	-130,6	-1,3
258	-119,22	-256,9	-139,49	-1,2
259	-122,44	-185,06	-141,7	-1,2
260	-127,88	-101,34	-130,58	-1,1
261	-130,54	-23,09	-101,21	-1
262	-119,41	29,6	-57,81	-0,9
263	-85,96	45,25	-14,47	-0,8
264	-29,89	25,63	7,89	-0,8
265	-29,62	-281,95	86,26	-1,5
266	-11,02	-252,43	93,75	-1,3
267	-26,36	-329,72	103,29	-1,5
268	-34,37	-341,35	104,55	-1,6

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
269	-42,21	-379,49	107,1	-1,5
270	-47,82	-386,39	115,01	-1,6
271	-60,64	-404,9	107,04	-1,6
272	-79,71	-405,9	103,28	-1,5
273	-98,39	-383,93	95,87	-1,5
274	-116,74	-340,59	85,17	-1,3
275	-135,94	-278,28	71,39	-1,2
276	-156,73	-202,28	55,03	-1
277	-178,07	-123,54	37,81	-0,8
278	-194,77	-57,81	23,06	-0,6
279	-200,64	-18,15	12,74	-0,4
280	108,37	542,6	-20,56	0
281	67,81	342,9	-36,21	-0,2
282	32,02	168,96	-49,35	-0,3
283	1,17	20,7	-60,43	-0,5
284	-24,49	-102,08	-70,35	-0,6
285	-44,66	-199,59	-79,71	-0,8
286	-58,98	-272,04	-89,02	-0,9
287	-67,1	-319,53	-98,74	-1
288	-68,72	-341,98	-109,21	-1,1
289	-63,78	-338,95	-120,68	-1,1
290	-52,72	-309,42	-133,02	-1,1
291	-37,23	-251,71	-145,12	-1,1
292	-21,55	-164,46	-153,03	-1
293	-13,25	-53,14	-146,6	-0,9
294	-13,47	56,92	-110,34	-0,8
295	-1,94	126,56	-42,88	-0,7
296	40,8	129,01	29,45	-0,6
297	117,65	81,98	83,05	-0,5
298	3,03	151,43	-37,94	-0,7
299	22,76	217,12	-37,09	-0,6
300	26,23	132,71	23,27	-0,7
301	-1,38	67,17	9,66	-0,9
302	35,15	7,48	67,04	-0,9
303	-4,59	-41,86	48,55	-1
304	32,89	-123,58	88,6	-1,1
305	-4,16	-153,01	75,92	-1,2
306	17,91	-236,67	96,33	-1,2
307	-4,06	-321,8	98,37	-1,3
308	-27,75	-378,02	96,89	-1,4
309	-50,29	-407,76	92,84	-1,5
310	-70,72	-412,91	86,13	-1,5
311	-88,53	-394,88	76,27	-1,4
312	-103,9	-355,08	62,84	-1,3
313	-117,77	-295,27	45,88	-1,2
314	-131,91	-219,03	26,84	-1
315	-147,87	-134,24	10,3	-0,8
316	-164,76	-58,7	4,02	-0,6
317	-170,14	-12,39	9,81	-0,3
318	104,44	520,25	-20,45	0
319	66,35	325,34	-36,11	-0,1
320	33,49	154,95	-49,2	-0,3
321	6,08	9,34	-60,04	-0,5
322	-15,58	-111,45	-69,43	-0,6
323	-31,03	-207,49	-77,87	-0,8
324	-39,7	-278,85	-85,85	-0,9
325	-40,86	-325,53	-93,76	-1
326	-33,65	-347,31	-102,04	-1
327	-17,14	-343,56	-111,16	-1
328	9,56	-312,72	-121,64	-1
329	46,71	-251,58	-133,94	-0,9
330	92,43	-153,43	-147,51	-0,8
331	136,72	-7,44	-155,08	-0,7
332	146,4	164,76	-126,9	-0,6
333	142,33	274,5	-29,59	-0,5
334	192,79	261,59	86,54	-0,4
335	264,15	157,8	149,09	-0,3

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
336	79,36	98,08	-87,98	-0,2
337	169,97	58,51	-125,19	-0,1
338	154,5	205,22	-142,52	-0,2
339	61,75	190,23	-106,17	-0,3
340	119,44	306,36	-115,46	-0,3
341	39,14	228,42	-86,77	-0,4
342	90,62	321,44	-33,1	-0,4
343	107,27	224,61	52,04	-0,6
344	118,08	55,96	89,71	-0,7
345	95,05	-105,56	94,76	-0,9
346	60,28	-229,9	91,15	-1,1
347	24,65	-319,72	86,72	-1,2
348	-7,79	-379,48	82,24	-1,3
349	-35,2	-412,42	76,81	-1,4
350	-56,97	-420,9	69,51	-1,4
351	-72,9	-406,53	59,43	-1,4
352	-82,93	-370,43	45,72	-1,3
353	-87,41	-313,38	27,85	-1,1
354	-87,54	-235,42	6,47	-0,9
355	-88,8	-138,89	-13,38	-0,7
356	-97,47	-35,68	-18,62	-0,5
357	-118,16	3,1	16,16	-0,3
358	100,49	498,33	-19,54	0
359	64,53	308,04	-34,62	-0,1
360	34,2	141,26	-47,13	-0,3
361	9,68	-1,49	-57,22	-0,4
362	-8,66	-119,98	-65,52	-0,6
363	-20,27	-214,13	-72,4	-0,7
364	-24,42	-283,91	-78,18	-0,8
365	-20,1	-329,25	-83,1	-0,9
366	-5,99	-349,93	-87,44	-1
367	19,71	-345,33	-91,53	-1
368	59,44	-314,01	-95,94	-0,9
369	116,53	-252,76	-101,78	-0,8
370	195,29	-154,39	-111,03	-0,7
371	300,67	1,22	-128,14	-0,5
372	425,51	290,23	-143,82	-0,4
373	348,89	521,55	-30,23	-0,3
374	431,2	449,51	157,42	-0,2
375	448,92	202,32	179,74	-0,2
376	363,95	54,28	157,24	-0,2
377	312,83	62,83	165,02	-0,3
378	308,76	104,4	-172,29	0
379	301,74	214	-173,63	-0,1
380	291,24	423,11	-165,14	-0,1
381	211,2	510,46	-23,04	-0,3
382	302,1	343,1	89,54	-0,4
383	242,24	76,43	91,46	-0,6
384	168,2	-103,62	78,41	-0,8
385	104,17	-230,27	70,21	-1
386	52,08	-320,61	65,63	-1,1
387	10,79	-381,51	62,45	-1,3
388	-20,81	-416,46	58,96	-1,3
389	-43,3	-427,63	53,94	-1,3
390	-56,74	-416,51	46,49	-1,3
391	-60,62	-384,08	35,83	-1,2
392	-53,89	-330,56	21,06	-1,1
393	-35,29	-254,32	1,99	-0,9
394	-5,01	-149,49	-22,97	-0,7
395	28,5	3,48	-36,34	-0,5
396	-29,97	232,34	14,25	-0,3
397	96,64	477,6	-18,04	0
398	62,37	291,6	-32,07	-0,1
399	33,98	128,39	-43,62	-0,3
400	11,65	-11,33	-52,6	-0,4
401	-4,28	-127,18	-59,46	-0,6
402	-13,26	-218,94	-64,38	-0,7

	LEVEL 5			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
403	-14,5	-286,48	-67,46	-0,8
404	-6,94	-329,67	-68,7	-0,9
405	10,92	-348,22	-68,03	-0,9
406	41,21	-341,56	-65,29	-0,9
407	87,14	-308,45	-60,32	-0,8
408	153,79	-246,34	-53,1	-0,7
409	250,05	-149,36	-44,11	-0,6
410	391,82	-6,97	-35,26	-0,4
411	629,88	210,91	-34,84	-0,3
412	1118,49	1000,5	-57,08	-0,1
413	1038,11	442,6	183,65	0
414	538,13	112,26	93,03	0
415	369,03	42,08	81,69	-0,1
416	262,78	1,98	89,96	-0,1
417	276,6	1,89	151,62	-0,1
418	254,79	138,44	-136,02	0
419	414,24	169,31	-141,67	0
420	672,01	307,91	-235,54	0
421	690,95	988,22	50,92	-0,1
422	536,74	341,45	49,7	-0,3
423	340,06	63	35,22	-0,5
424	217,35	-106,14	31,22	-0,7
425	130,84	-229,35	33,02	-0,9
426	67,9	-318,93	36,09	-1,1
427	21,4	-380,66	38,76	-1,2
428	-12,13	-417,33	40,12	-1,3
429	-34,31	-430,75	39,73	-1,3
430	-45,39	-422,19	37,33	-1,2
431	-44,5	-392,62	32,77	-1,2
432	-29,29	-342,13	25,94	-1
433	4,13	-269,73	16,38	-0,9
434	66,02	-165,79	4,28	-0,7
435	156,72	-35,09	-7,43	-0,4
436	445,97	317,81	-101,3	-0,2
437	92,98	458,58	-16,17	0
438	59,9	276,43	-28,89	-0,1
439	32,82	116,66	-39,23	-0,3
440	11,86	-19,91	-46,94	-0,4
441	-2,67	-132,81	-52,24	-0,5
442	-10,33	-221,7	-55,12	-0,7
443	-10,44	-286,33	-55,49	-0,7
444	-2,12	-326,43	-53,11	-0,8
445	15,84	-341,59	-47,55	-0,8
446	45,15	-331,07	-38,09	-0,8
447	88,33	-293,53	-23,69	-0,7
448	149,24	-226,2	-2,93	-0,6
449	233,98	-123,15	27,08	-0,5
450	353,58	31,93	68,6	-0,3
451	521,98	297,25	137,98	-0,2
452	480,37	916,36	176,89	0
453	394,58	356,19	-170,52	0
454	412,09	190,76	-67,31	0
455	302,61	64,79	3,82	0
456	218,94	1,06	26,15	0
457	157,95	-33,16	39,49	0
458	180,95	-29,37	82,18	-0,1
459	114,72	-43,81	43,49	0
460	93,79	-50,62	70,67	0
461	209,76	144,52	-33,02	0
462	320,34	198,97	19,39	0
463	423,61	298,51	168,03	0
464	652,82	1153,69	-126,16	-0,1
465	523,97	323,79	-109,86	-0,2
466	332,6	77,37	-57,69	-0,4
467	210,61	-93,38	-30,67	-0,6
468	126,16	-218,39	-10,23	-0,8
469	64,77	-310,38	4,08	-1

	LEVEL 5			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
470	19,74	-374,46	14,49	-1,1
471	-12,34	-413,36	21,92	-1,2
472	-32,96	-428,77	27,1	-1,2
473	-42,36	-421,88	30,7	-1,2
474	-39,72	-393,45	33,48	-1,1
475	-22,89	-343,59	36,62	-1
476	12,62	-270,39	41,18	-0,8
477	74,17	-168,76	52,72	-0,6
478	191,74	16,44	64,45	-0,4
479	330,46	419,58	73,26	-0,2
480	89,57	441,55	-14,17	0
481	57,17	262,74	-25,47	-0,1
482	30,77	106,23	-34,55	-0,2
483	10,43	-27,15	-41	-0,4
484	-3,67	-136,88	-44,84	-0,5
485	-11,2	-222,54	-45,92	-0,6
486	-11,76	-283,76	-44,05	-0,7
487	-4,83	-320,09	-38,85	-0,8
488	10,15	-330,92	-29,69	-0,8
489	33,87	-315,27	-15,69	-0,7
490	67,04	-271,5	4,45	-0,7
491	110,19	-196,55	32,35	-0,6
492	162,44	-84,27	69,17	-0,4
493	218,16	80,63	113,42	-0,3
494	240,01	307,24	135,75	-0,2
495	139,52	446,39	64,53	0
496	203,49	368,32	-78	0
497	208	198,32	-59,87	0
498	194,22	93,66	-36,97	0
499	153,91	15,53	-9,75	0
500	118,32	-26,76	7,47	0
501	91,7	-42,25	18,57	0
502	77,66	-30,26	24,6	0
503	84,34	-28,4	38,77	0
504	77,63	10,61	25,73	0
505	82,89	31,49	25,57	0
506	92,24	68,24	20,71	0
507	117,34	95,85	-6,81	0
508	136,02	144,33	24,41	0
509	177,08	225,94	43,47	0
510	217,98	428,96	100,24	0
511	122,84	559,87	-45,66	-0,1
512	271,03	406,38	-143,9	-0,2
513	218,08	121,55	-114,09	-0,4
514	149,09	-64,46	-73,71	-0,6
515	90,55	-197,56	-44,02	-0,8
516	42,9	-295,05	-22,25	-1
517	5,69	-362,96	-6,14	-1,1
518	-21,75	-404,56	6,22	-1,2
519	-39,7	-421,75	16,17	-1,2
520	-48,13	-415,68	24,88	-1,2
521	-46,71	-386,87	33,65	-1,1
522	-34,8	-335,01	44,15	-1
523	-11,35	-257,63	58,6	-0,8
524	22,52	-146,34	76,94	-0,6
525	54,96	24,09	86,19	-0,4
526	-20,06	60,02	10,51	-0,2
527	86,43	426,53	-12,28	0
528	54,28	250,57	-22,21	-0,1
529	28	97,08	-30,12	-0,2
530	7,61	-33,16	-35,45	-0,4
531	-6,81	-139,64	-38,08	-0,5
532	-15,12	-221,91	-37,84	-0,6
533	-17,2	-279,52	-34,48	-0,7
534	-13	-311,89	-27,69	-0,7
535	-2,65	-318,25	-16,95	-0,7
536	13,35	-297,5	-1,63	-0,7

	LEVEL 5			
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
537	33,86	-248,06	18,99	-0,6
538	56,36	-167,89	45,15	-0,5
539	75,7	-54,72	74,87	-0,4
540	80,43	87,62	97,92	-0,3
541	58,32	228,77	91,56	-0,2
542	35,13	299,01	36,34	-0,1
543	56,87	276,8	-16,06	0
544	87,66	191,12	-41,56	0
545	91,59	96,07	-34,04	0
546	85,04	26,45	-20,38	0
547	71,17	-18,11	-5,76	0
548	58,85	-35,56	6,49	0
549	51,59	-26,65	15,71	0
550	50,06	7,59	21,13	0
551	55,58	65,5	24,64	0
552	63,42	142,23	30,5	0
553	72,62	247,66	44,11	0
554	45,63	352,44	29,9	0
555	18,19	385,24	-23,79	-0,1
556	48,64	303,85	-89,14	-0,2
557	77,84	132,67	-101,6	-0,4
558	66,35	-39,67	-82,47	-0,6
559	39,33	-175,95	-58,42	-0,8
560	9,85	-277,48	-37,55	-0,9
561	-16,78	-348,66	-20,22	-1
562	-37,99	-392,54	-5,64	-1,1
563	-52,6	-411,11	7,05	-1,1
564	-60,21	-405,47	18,73	-1,1
565	-61,09	-375,91	30,39	-1,1
566	-56,38	-321,99	43,17	-0,9
567	-48,91	-242,96	57,55	-0,8
568	-44,62	-139,69	69,64	-0,6
569	-57,22	-43,01	63,52	-0,4
570	-42,81	16,5	41,63	-0,2
571	83,57	413,35	-10,65	0
572	51,29	239,76	-19,42	-0,1
573	24,71	89,06	-26,34	-0,2
574	3,8	-38,15	-30,77	-0,4
575	-11,45	-141,44	-32,54	-0,5
576	-21,05	-220,38	-31,48	-0,6
577	-25,11	-274,53	-27,44	-0,7
578	-23,95	-303,28	-20,3	-0,7
579	-18,26	-305,86	-9,9	-0,7
580	-9,3	-281,3	3,84	-0,7
581	0,7	-228,6	20,71	-0,6
582	8,12	-147,53	39,67	-0,5
583	7,67	-41,34	57,44	-0,4
584	-4,93	77,19	67,1	-0,3
585	-25,28	178,73	59,52	-0,2
586	-32,75	231,53	35,85	-0,1
587	-18,71	220,45	6,89	0
588	6,19	162,17	-11,14	0
589	24,69	89,91	-17,7	0
590	29,86	28,02	-15,21	0
591	27,78	-12,29	-7,77	0
592	23,6	-29,51	1,71	0
593	20,95	-23,39	9,97	0
594	20,51	6,73	14,44	0
595	19,6	61,83	14,84	0
596	12,89	140,99	14,54	0
597	-7,06	231,77	13,72	0
598	-34,61	302,77	6,4	0
599	-47,54	312,88	-19,03	-0,1
600	-34,4	242,37	-48,35	-0,3
601	-10,29	112,7	-66,1	-0,4
602	-0,59	-33,58	-66,01	-0,6
603	-8,01	-162,57	-55,83	-0,7

		LEVEL 5		
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
604	-24,03	-263,12	-42	-0,9
605	-41,76	-334,83	-27,51	-1
606	-57,25	-379,54	-13,42	-1,1
607	-68,46	-398,87	-0,09	-1,1
608	-74,71	-393,74	12,4	-1,1
609	-76,55	-364,36	24,04	-1
610	-76,04	-310,66	34,75	-0,9
611	-77,09	-234,05	43,9	-0,8
612	-84,67	-144,19	49,27	-0,6
613	-93,48	-62,13	49,1	-0,4
614	-96,03	-13,23	42,91	-0,2
615	80,94	401,66	-9,44	0
616	48,29	230,08	-17,33	-0,1
617	21,1	81,94	-23,49	-0,2
618	-0,63	-42,39	-27,27	-0,3
619	-16,95	-142,62	-28,48	-0,5
620	-27,96	-218,46	-27,01	-0,6
621	-33,9	-269,55	-22,9	-0,6
622	-35,27	-295,4	-16,27	-0,7
623	-32,96	-295,39	-7,4	-0,7
624	-28,45	-268,88	3,2	-0,6
625	-23,98	-215,57	14,58	-0,6
626	-22,72	-136,51	25,16	-0,5
627	-28,25	-36,54	32,79	-0,4
628	-42,54	71	36,12	-0,3
629	-59,83	161,6	36,49	-0,2
630	-66,17	205,9	35,93	-0,1
631	-51,38	192,98	30,05	0
632	-26,35	139,14	16,9	0
633	-9,66	74,42	2,07	0
634	-4,18	22,26	-5,87	0
635	-4,46	-10,79	-5,13	0
636	-5,71	-25,19	0,96	0
637	-5,38	-21,61	7,3	0
638	-2,72	1,95	8,69	0
639	-0,66	50,83	1,58	0
640	-7,8	129,69	-12,21	0
641	-35,11	221,93	-20,7	0
642	-63,9	290,67	-20,13	0
643	-71,67	292,29	-11,44	-0,1
644	-57,81	215,52	-16,96	-0,3
645	-39,69	91,76	-31,95	-0,4
646	-34,13	-41,66	-43,86	-0,6
647	-39,47	-160,07	-46,01	-0,7
648	-51,04	-254,67	-40,35	-0,9
649	-64,3	-323,54	-30,17	-1
650	-76,01	-367,16	-17,89	-1
651	-84,29	-386,49	-5,08	-1,1
652	-88,34	-382,18	7,1	-1,1
653	-88,47	-354,47	17,53	-1
654	-86,25	-303,45	24,95	-0,9
655	-84,79	-230,53	28,29	-0,7
656	-88,06	-141,81	28,61	-0,6
657	-99,23	-60,65	34,21	-0,4
658	-94,47	-5,87	41,59	-0,2
659	78,47	390,99	-8,73	0
660	45,28	221,19	-16,07	-0,1
661	17,33	75,48	-21,74	-0,2
662	-5,36	-46,08	-25,08	-0,3
663	-22,8	-143,42	-25,93	-0,4
664	-35,08	-216,45	-24,27	-0,5
665	-42,45	-264,98	-20,33	-0,6
666	-45,38	-288,74	-14,49	-0,6
667	-44,66	-287,36	-7,39	-0,6
668	-41,45	-260,57	0,06	-0,6
669	-37,31	-208,55	6,56	-0,5
670	-34,09	-132,59	10,51	-0,5

		LEVEL 5		
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
671	-33,68	-36,2	10,71	-0,4
672	-38,24	72,95	8,88	-0,2
673	-51,98	172,68	14,47	-0,1
674	-64,68	221,15	35,5	-0,1
675	-40,63	193,29	56,61	0
676	-14,86	117,79	41,37	0
677	-14,42	50,87	15,03	0
678	-19,51	10,76	-0,44	0
679	-22,96	-11,16	-3,25	0
680	-24,5	-20,73	1,33	0
681	-23,63	-19,71	7,3	0
682	-18,62	-6,65	8,08	0
683	-6,6	27,66	-4,42	0
684	4,35	101,4	-33,52	0
685	-4,43	228,74	-62,89	0
686	-49,69	323,03	-30,63	0
687	-53,04	316,19	2,82	-0,1
688	-18,4	213,54	13,81	-0,2
689	-24,91	68,53	-9,55	-0,4
690	-39,17	-58,05	-29,83	-0,6
691	-54,33	-165,16	-38,95	-0,7
692	-69,01	-251,14	-38,34	-0,8
693	-82,08	-314,71	-31,23	-0,9
694	-92,24	-355,62	-20,38	-1
695	-98,37	-374,19	-7,96	-1
696	-99,72	-370,84	4,22	-1
697	-95,97	-345,88	14,35	-1
698	-87,26	-299,45	20,4	-0,9
699	-74,15	-231,2	20,37	-0,7
700	-59,67	-140,19	14,92	-0,6
701	-53,1	-28,2	15,28	-0,4
702	-86,82	1,72	56,19	-0,2
703	76,08	380,81	-8,56	0
704	42,27	212,73	-15,73	-0,1
705	13,48	69,42	-21,17	-0,2
706	-10,19	-49,38	-24,21	-0,3
707	-28,67	-143,92	-24,76	-0,4
708	-41,96	-214,35	-22,91	-0,5
709	-50,2	-260,75	-19,03	-0,6
710	-53,71	-283,07	-13,72	-0,6
711	-52,97	-281,21	-7,81	-0,6
712	-48,59	-255,17	-2,36	-0,6
713	-41,19	-205,32	1,35	-0,5
714	-31,05	-132,66	2,04	-0,4
715	-17,95	-39,06	-1	-0,3
716	-0,77	74,11	-6,49	-0,2
717	16,87	208,11	-6,4	-0,1
718	2,46	305,27	37,14	-0,1
719	20,25	201,31	88,4	0
720	16,08	70,3	44,57	0
721	-11,99	19,11	11,02	0
722	-23,29	-0,34	-2,16	0
723	-26,6	-9,06	-3,82	0
724	-27,99	-12,88	0,88	0
725	-29,73	-13,63	7,35	0
726	-30,05	-11,35	11,07	0
727	-21,04	-4,28	5,37	0
728	26,14	43,67	-29,8	0
729	80,76	196,37	-86,31	0
730	-0,99	430,03	-111,12	0
731	130,14	442,15	47,52	-0,1
732	68,74	188,16	19,27	-0,2
733	8,49	38,41	-11,99	-0,4
734	-31,58	-76,41	-31,68	-0,5
735	-59,72	-172,11	-40,03	-0,7
736	-80,26	-249,14	-39,73	-0,8
737	-95,34	-306,58	-33,04	-0,9

		LEVEL 5		
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
738	-105,47	-343,88	-22,18	-1
739	-110,35	-361,03	-9,1	-1
740	-109,33	-358,34	4,35	-1
741	-101,45	-336,19	16,32	-0,9
742	-85,32	-294,79	24,73	-0,8
743	-58,54	-233,38	27,76	-0,7
744	-17,77	-148,49	21,36	-0,5
745	45,28	-8,52	13,94	-0,3
746	61,4	220,61	28,04	-0,2
747	73,64	370,52	-8,98	0
748	39,2	204,3	-16,35	-0,1
749	9,55	63,57	-21,79	-0,2
750	-15,06	-52,34	-24,63	-0,3
751	-34,45	-144,02	-24,81	-0,4
752	-48,49	-211,94	-22,57	-0,5
753	-57,15	-256,43	-18,38	-0,6
754	-60,54	-277,67	-12,97	-0,6
755	-58,8	-275,75	-7,24	-0,6
756	-52,04	-250,78	-2,19	-0,6
757	-40,11	-202,99	1,19	-0,5
758	-22,19	-132,8	2,31	-0,4
759	3,82	-40,58	1,34	-0,3
760	42,49	74,51	1,1	-0,2
761	104,38	214,84	7,98	-0,1
762	254,72	529,38	62,5	0
763	305,57	337,41	-21,64	-0,1
764	110,74	143,45	-31,89	-0,2
765	25,2	18,41	-41,26	-0,4
766	-28,82	-87,82	-47,37	-0,5
767	-64,12	-175,17	-48,77	-0,7
768	-88,51	-245,08	-45,02	-0,8
769	-105,37	-296,94	-36,51	-0,9
770	-116,02	-330,42	-24,18	-0,9
771	-120,52	-345,59	-9,29	-1
772	-118,28	-342,78	6,75	-0,9
773	-108,13	-322,4	22,49	-0,9
774	-87,96	-284,51	36,63	-0,8
775	-54,35	-228,69	48,21	-0,7
776	1,45	-149	56,48	-0,5
777	85,16	-52,02	62,65	-0,3
778	352,72	269,17	61,34	-0,1
779	71,04	359,5	-10,02	0
780	35,98	195,54	-17,99	-0,1
781	5,52	57,77	-23,63	-0,2
782	-19,98	-54,92	-26,28	-0,3
783	-40,16	-143,51	-25,96	-0,4
784	-54,76	-208,79	-23	-0,5
785	-63,58	-251,36	-17,99	-0,5
786	-66,52	-271,61	-11,73	-0,6
787	-63,5	-269,69	-5,14	-0,6
788	-54,35	-245,6	0,89	-0,5
789	-38,64	-199,15	5,75	-0,5
790	-15,41	-129,82	9,49	-0,4
791	17,42	-36,02	13,47	-0,3
792	63,52	87,26	21,92	-0,2
793	131,47	268,22	41,7	-0,1
794	192,16	562,5	53,43	0
795	134,65	418,93	-90,64	-0,1
796	70,48	163,12	-84,7	-0,2
797	5,81	18,04	-73,06	-0,4
798	-39,17	-87,53	-65,88	-0,5
799	-71,78	-171,69	-60,11	-0,6
800	-95,72	-237,04	-52,37	-0,7
801	-112,92	-284,33	-41,37	-0,8
802	-124,02	-314,02	-26,87	-0,9
803	-128,86	-326,67	-9,5	-0,9
804	-126,91	-322,81	9,75	-0,9

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
805	-117,25	-302,71	29,84	-0,8
806	-98,58	-266,09	50,17	-0,7
807	-68,72	-211,28	70,53	-0,6
808	-24,67	-133,57	93,66	-0,5
809	41,88	0,23	112,65	-0,3
810	59,98	219,22	99,81	-0,1
811	68,13	347,11	-11,72	0
812	32,52	186,06	-20,69	-0,1
813	1,31	51,89	-26,72	-0,2
814	-24,99	-57,02	-29,15	-0,3
815	-45,86	-142,06	-28,14	-0,4
816	-60,9	-204,39	-24,09	-0,5
817	-69,8	-244,85	-17,72	-0,5
818	-72,31	-263,97	-9,91	-0,6
819	-68,21	-261,94	-1,63	-0,5
820	-57,32	-238,51	6,23	-0,5
821	-39,43	-192,88	13,17	-0,5
822	-14,32	-123,43	19,38	-0,4
823	18,15	-26,77	26,16	-0,3
824	56,99	104,87	35,48	-0,2
825	93,66	284,51	42,81	-0,1
826	101,12	481,39	25,23	0
827	78,57	196,15	71,02	0
828	15,01	226,14	53,93	0
829	-35,4	287,15	8,3	0
830	2,23	414,54	87,18	0
831	-44,75	264,38	-47,91	-0,1
832	-17,23	160,12	-84,58	-0,2
833	-32,72	25,9	-83,22	-0,3
834	-56,69	-80,75	-76,18	-0,5
835	-80,26	-163,6	-68,78	-0,6
836	-100,85	-225,55	-59,59	-0,7
837	-117,32	-268,54	-47,02	-0,8
838	-128,78	-294,17	-30,56	-0,8
839	-134,51	-303,73	-10,67	-0,8
840	-133,96	-298,11	11,65	-0,8
841	-126,86	-277,46	35,27	-0,8
842	-113,38	-241,05	59,35	-0,7
843	-94,4	-186,65	83,54	-0,6
844	-73,8	-110,5	105,46	-0,4
845	-62,14	-10,97	116,04	-0,3
846	-94,47	6,81	74,04	-0,2
847	64,77	332,66	-14,11	0
848	28,74	175,5	-24,49	-0,1
849	-3,1	45,85	-31,08	-0,2
850	-30,06	-58,47	-33,28	-0,3
851	-51,51	-139,32	-31,35	-0,4
852	-66,95	-198,19	-25,86	-0,5
853	-75,96	-236,19	-17,63	-0,5
854	-78,21	-254	-7,7	-0,5
855	-73,46	-251,8	2,84	-0,5
856	-61,61	-229,12	12,94	-0,5
857	-42,8	-184,67	21,75	-0,4
858	-17,78	-116,01	28,9	-0,3
859	11,56	-19,28	34,43	-0,2
860	41,17	109,67	37,65	-0,1
861	65,48	268,5	33	-0,1
862	89,1	441,62	14,29	0
863	-0,56	211,78	10,35	0
864	-49,21	227,8	-4,76	-0,1
865	-66,64	206,69	-38,7	-0,1
866	-62,59	128,13	-63,16	-0,2
867	-58,07	23,21	-74,06	-0,3
868	-66,87	-76,51	-76,06	-0,5
869	-82,97	-155,5	-73,41	-0,6
870	-100,77	-212,66	-66,07	-0,7
871	-116,76	-250,24	-53,42	-0,7

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
872	-128,85	-270,85	-35,54	-0,8
873	-135,76	-276,66	-13,35	-0,8
874	-136,94	-269,02	11,62	-0,8
875	-132,64	-248,18	37,53	-0,7
876	-124,23	-213,26	62,56	-0,6
877	-114,81	-162,99	84,74	-0,5
878	-109,56	-98,89	100,43	-0,4
879	-113,73	-39,06	103,12	-0,3
880	-105	0,89	92,61	-0,2
881	60,81	315,47	-17,26	0
882	24,58	163,52	-29,43	-0,1
883	-7,64	39,61	-36,74	-0,2
884	-35,04	-59,09	-38,65	-0,3
885	-56,91	-134,9	-35,62	-0,4
886	-72,67	-189,66	-28,37	-0,4
887	-81,86	-224,76	-17,91	-0,5
888	-84,11	-241,03	-5,39	-0,5
889	-79,16	-238,72	7,85	-0,5
890	-66,92	-217,32	20,44	-0,5
891	-47,7	-175,33	30,95	-0,4
892	-22,59	-110,04	37,97	-0,3
893	5,82	-17,63	40,11	-0,2
894	33,1	104,41	36,39	-0,1
895	56,6	252	26,34	-0,1
896	82,62	414,03	10,72	0
897	-0,17	199,72	-28,73	0
898	-42,9	212,17	-33,85	-0,1
899	-57,54	186,87	-34,55	-0,1
900	-53,51	111,02	-44,47	-0,2
901	-49,84	12,33	-59,79	-0,3
902	-58,26	-79,82	-72,29	-0,4
903	-74,3	-151,04	-77,03	-0,5
904	-92,52	-200,16	-73,24	-0,6
905	-109,36	-229,99	-61,3	-0,7
906	-122,53	-244	-42,21	-0,7
907	-130,6	-245,22	-17,64	-0,7
908	-132,99	-235,65	9,98	-0,7
909	-130,14	-215,85	37,74	-0,6
910	-123,72	-185,09	62,55	-0,6
911	-116,79	-142,47	81,45	-0,5
912	-113,24	-90,25	91,85	-0,4
913	-114,49	-40,63	96,88	-0,3
914	-110,94	-7,78	92,4	-0,2
915	56,15	294,82	-21,16	0
916	20,1	149,84	-35,49	-0,1
917	-12,11	33,17	-43,65	-0,2
918	-39,57	-58,65	-45,2	-0,3
919	-61,53	-128,42	-40,92	-0,3
920	-77,43	-178,32	-31,71	-0,4
921	-86,84	-209,98	-18,72	-0,4
922	-89,36	-224,44	-3,3	-0,5
923	-84,67	-222,12	13,03	-0,5
924	-72,57	-202,67	28,54	-0,4
925	-53,12	-164,79	41,2	-0,4
926	-26,95	-105,97	48,64	-0,3
927	4,4	-22,15	48	-0,2
928	37,22	92,14	37,31	-0,1
929	62,87	237,79	19,73	-0,1
930	78,06	395,04	5,61	0
931	10,99	191,78	-63,26	0
932	-11,32	237,69	-41,61	0
933	-15,92	201,86	-23,84	-0,1
934	5,07	106,65	-25,95	-0,2
935	-8,37	-5,85	-52,24	-0,3
936	-30,67	-91,04	-74,13	-0,4
937	-53,76	-150,65	-84,47	-0,5
938	-75,32	-188,25	-83,28	-0,5

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
939	-93,96	-207,6	-71,58	-0,6
940	-108,3	-212,99	-50,79	-0,6
941	-117,1	-208,52	-23,19	-0,6
942	-119,66	-197,12	7,84	-0,6
943	-116,34	-179,81	38,22	-0,6
944	-108,49	-155,77	63,84	-0,5
945	-97,84	-123,1	81,2	-0,4
946	-86,49	-80,29	88,55	-0,3
947	-77,12	-26,07	90,43	-0,2
948	-86,56	-4,88	100,17	-0,1
949	50,69	270,11	-25,79	0
950	15,42	134,25	-42,55	-0,1
951	-16,1	26,63	-51,6	-0,2
952	-42,96	-56,9	-52,75	-0,2
953	-64,47	-119,52	-47,12	-0,3
954	-80,17	-163,72	-35,85	-0,4
955	-89,71	-191,32	-20,24	-0,4
956	-92,73	-203,61	-1,76	-0,4
957	-88,85	-201,25	17,95	-0,4
958	-77,63	-184,23	36,92	-0,4
959	-58,7	-151,69	52,79	-0,3
960	-31,72	-101,69	62,62	-0,3
961	3,61	-30,89	62,71	-0,2
962	48,05	67,89	47,99	-0,1
963	98,24	216	15,4	-0,1
964	107,48	404,19	-11,98	0
965	105,01	184,26	-62,77	0
966	44,71	306	-88,05	0
967	154,07	288,18	11,51	-0,1
968	104,21	79,25	-26,18	-0,2
969	46,01	-35,12	-64,15	-0,3
970	4,89	-106,26	-87,76	-0,3
971	-26,28	-151,73	-98,37	-0,4
972	-50,7	-175,56	-97,15	-0,5
973	-70,2	-182,03	-84,48	-0,5
974	-84,8	-176,52	-61,09	-0,5
975	-93,31	-164,88	-29,33	-0,5
976	-94,78	-151,54	6,5	-0,5
977	-89,52	-137,95	40,98	-0,5
978	-78,75	-122,48	69,28	-0,4
979	-63,21	-101,77	88,39	-0,3
980	-41,32	-71,01	95,66	-0,3
981	-9,57	-17,53	97,22	-0,2
982	17,54	81,06	93,54	-0,1
983	44,43	240,84	-30,99	0
984	10,86	116,74	-50,29	-0,1
985	-18,93	20,19	-60,17	-0,1
986	-44,17	-53,52	-60,85	-0,2
987	-64,33	-107,88	-53,88	-0,3
988	-79,18	-145,53	-40,64	-0,3
989	-88,56	-168,43	-22,57	-0,4
990	-92,25	-178,04	-1,15	-0,4
991	-89,83	-175,35	21,96	-0,4
992	-80,66	-160,78	44,79	-0,4
993	-63,93	-133,99	64,84	-0,3
994	-38,63	-93,66	79,18	-0,3
995	-3,06	-37,28	84,2	-0,2
996	46,16	38,74	76,08	-0,1
997	120,48	141,02	43,36	-0,1
998	275,54	406,31	-56,83	0
999	332,13	175,83	-37,99	-0,1
1000	162,31	27,32	-79,16	-0,1
1001	82,39	-59,81	-97,27	-0,2
1002	32,7	-118,2	-111,01	-0,3
1003	0,93	-150,55	-116,32	-0,4
1004	-21,01	-160,53	-112,9	-0,4
1005	-37,65	-152,27	-98,7	-0,4

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1006	-50,07	-132,94	-72,28	-0,4
1007	-56,61	-111,88	-35,02	-0,4
1008	-55,41	-96,35	7,18	-0,4
1009	-47,2	-87,93	46,88	-0,4
1010	-34,7	-82,73	78,61	-0,3
1011	-18,81	-74,44	100,65	-0,3
1012	4,55	-55,35	114,62	-0,2
1013	39,44	-24,53	119,72	-0,1
1014	154,87	111,53	136,92	-0,1
1015	37,46	206,89	-36,42	0
1016	6,99	97,57	-58,09	-0,1
1017	-19,55	14,23	-68,59	-0,1
1018	-41,64	-48,2	-68,71	-0,2
1019	-59,11	-93,27	-60,52	-0,2
1020	-72,06	-123,61	-45,65	-0,3
1021	-80,68	-141,17	-25,64	-0,3
1022	-85,01	-147,49	-1,87	-0,3
1023	-84,74	-143,88	24,19	-0,3
1024	-79,09	-131,31	50,72	-0,3
1025	-66,94	-110,01	75,23	-0,3
1026	-47,16	-79,04	94,75	-0,2
1027	-18,4	-35,99	106,42	-0,2
1028	21,59	23,06	107,36	-0,1
1029	77,77	109,35	96,15	-0,1
1030	115,42	218,78	46,91	0
1031	224,07	235,92	-133,67	-0,1
1032	138,31	25,35	-133,81	-0,2
1033	78,61	-68,87	-132,56	-0,2
1034	42,32	-121,52	-132,32	-0,3
1035	22,34	-145,33	-131	-0,3
1036	11,97	-143,36	-125,32	-0,3
1037	5,48	-118,55	-111,08	-0,3
1038	-0,74	-81	-82,43	-0,3
1039	-2,57	-46,46	-39,03	-0,3
1040	4,37	-28,55	11,56	-0,3
1041	16,78	-28,81	55,82	-0,3
1042	27,56	-36,8	88,02	-0,2
1043	34,7	-40,48	110,41	-0,2
1044	42,66	-31,79	127,44	-0,1
1045	60,13	10,72	139,21	-0,1
1046	39,63	85,89	124,83	0
1047	30,1	168,67	-41,49	0
1048	4,73	77,41	-64,93	-0,1
1049	-16,4	9,32	-75,64	-0,1
1050	-33,28	-40,54	-75,12	-0,1
1051	-46,19	-75,55	-65,95	-0,2
1052	-55,65	-98,07	-50,06	-0,2
1053	-62,35	-109,81	-29,08	-0,3
1054	-66,89	-112,19	-4,19	-0,3
1055	-69,32	-106,78	23,64	-0,3
1056	-68,75	-95,37	53,01	-0,3
1057	-63,61	-79,09	81,37	-0,2
1058	-52,84	-57,35	105,24	-0,2
1059	-36,56	-27,34	121	-0,2
1060	-15,98	15,53	125,83	-0,1
1061	3,09	69,48	113,57	-0,1
1062	14,74	106,39	77,84	-0,1
1063	60,33	100,31	32,24	-0,1
1064	233,98	170,69	-2,14	0
1065	96,75	60,03	19,26	-0,1
1066	228	70,32	6,49	0
1067	109,76	30,76	20,17	-0,1
1068	232,57	49,37	16,28	0
1069	116,68	19,54	19,56	-0,1
1070	242,81	47,13	16,5	0
1071	122,72	16,64	15,48	-0,1
1072	253,33	48,36	13,29	0

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1073	127,43	17,19	9,85	-0,1
1074	261,35	50,02	8,94	0
1075	130,27	20,35	4,44	-0,1
1076	266,4	51,88	5,05	0
1077	130,42	27,02	0,49	-0,1
1078	269,53	55,64	3,48	0
1079	126,16	37,23	-1,58	-0,1
1080	270,98	66,88	5,74	0
1081	120,36	57,96	-0,34	-0,1
1082	255,25	70,41	12,21	0
1083	101,5	108,63	-2,01	-0,1
1084	272,91	129,02	35,31	0
1085	48,18	135,11	-54,36	-0,1
1086	138,52	274,25	18,35	0
1087	36,85	101,77	-111,63	-0,1
1088	53,71	17,58	-144,48	-0,2
1089	41,78	-68,84	-144,64	-0,2
1090	33,72	-118,18	-139,29	-0,3
1091	35,27	-137,35	-133,32	-0,3
1092	46,28	-126,71	-126,61	-0,3
1093	60,98	-85,06	-115,19	-0,3
1094	70,99	-19,43	-89,64	-0,2
1095	77,37	36,78	-36,56	-0,2
1096	95,52	54,56	23,47	-0,2
1097	117,17	36,95	67,34	-0,2
1098	116,98	9,68	90,68	-0,1
1099	102,61	-5,16	107,11	-0,1
1100	83,89	-4,88	120,39	-0,1
1101	60,55	9,07	125,61	0
1102	26,48	-0,21	101,5	0
1103	23,03	127,51	-45,12	0
1104	5,55	57,43	-69,18	0
1105	-7,34	6,25	-79,51	-0,1
1106	-16,34	-30,17	-78,3	-0,1
1107	-22,24	-54,67	-68,55	-0,1
1108	-26,04	-69,28	-52,5	-0,2
1109	-28,94	-75,18	-31,96	-0,2
1110	-32,41	-73,12	-7,99	-0,2
1111	-37,6	-64,67	19,35	-0,2
1112	-43,61	-52,85	49,86	-0,2
1113	-47,84	-41,08	81,24	-0,2
1114	-48,27	-29,73	107,98	-0,2
1115	-46,03	-15,14	124,93	-0,2
1116	-44,68	6,44	128,19	-0,1
1117	-45,25	32,2	115,85	-0,1
1118	-41,93	48,54	88,66	-0,1
1119	-27,57	45,75	59,81	-0,1
1120	-7,31	27,92	40,33	-0,1
1121	6,47	7,57	31,48	-0,1
1122	13,75	-5,72	25,74	-0,1
1123	17,85	-11,79	19,17	-0,1
1124	20,09	-12,62	11,45	-0,1
1125	20,34	-9,18	3,57	-0,1
1126	18	-1,52	-3,54	-0,1
1127	12,74	11,17	-9,58	-0,1
1128	2,85	31,37	-16,1	-0,1
1129	-17,81	52,11	-31,95	-0,1
1130	-35,39	58,99	-61,55	-0,2
1131	-36,53	35,02	-100,74	-0,2
1132	-22,5	-17,12	-125,56	-0,2
1133	-4,08	-73,24	-131,78	-0,2
1134	13,91	-113,22	-126,79	-0,2
1135	38,17	-127,67	-118,06	-0,2
1136	73,23	-113,59	-108,31	-0,2
1137	123,84	-59,16	-100,04	-0,2
1138	177,69	44,68	-80,59	-0,1
1139	191,98	147,43	-28,25	-0,1

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1140	261,14	163,89	51,91	-0,1
1141	276,31	93,27	72,04	-0,1
1142	238,14	46,09	74,22	-0,1
1143	192,34	27,83	81,58	0
1144	142,25	17,95	90,61	0
1145	90,56	6,68	95,08	0
1146	55,14	0,03	91,21	0
1147	17,48	86,02	-45,61	0
1148	11,6	39,3	-68,55	0
1149	10,44	5,87	-77,86	-0,1
1150	12,61	-16,67	-76,01	-0,1
1151	16,72	-30,65	-66,22	-0,1
1152	21,32	-37,79	-50,99	-0,1
1153	24,82	-38,64	-32,51	-0,1
1154	25,09	-32,57	-12,18	-0,1
1155	18,93	-19,27	10,6	-0,1
1156	4,14	-4,13	39,18	-0,1
1157	-12,09	5,02	72,25	-0,1
1158	-24,99	3,88	102,6	-0,1
1159	-36,93	-1,53	118,74	-0,1
1160	-51,92	-1,41	119,58	-0,1
1161	-68,29	4,86	108,25	-0,1
1162	-79,02	10,2	89,68	-0,1
1163	-80,89	7,51	69,29	-0,2
1164	-76,09	-3,63	52,6	-0,2
1165	-69,58	-18,13	40,71	-0,2
1166	-64,82	-30,57	31,32	-0,2
1167	-62,26	-38,09	21,89	-0,2
1168	-61,72	-40,13	11,65	-0,2
1169	-63,28	-36,82	1,11	-0,2
1170	-67,2	-28,45	-9,02	-0,2
1171	-73,76	-15,52	-18,62	-0,2
1172	-83,47	-0,31	-29,43	-0,2
1173	-93,78	11,46	-44,62	-0,2
1174	-98,88	10,58	-65,56	-0,2
1175	-91,83	-8,51	-86,58	-0,2
1176	-71,56	-42,42	-101,13	-0,2
1177	-43,21	-80,11	-104,8	-0,2
1178	-9,77	-107,71	-99,19	-0,2
1179	29,82	-115,25	-87,52	-0,2
1180	80,52	-96,19	-71,31	-0,2
1181	149,61	-50,69	-50,49	-0,1
1182	280,56	74,94	-34,29	-0,1
1183	521,86	382,91	28,68	0
1184	574,8	256,88	62,65	0
1185	447,84	95,81	40,35	0
1186	375,29	73,72	32,83	0
1187	303,71	59,03	36,97	0
1188	224,6	43,41	42,53	0
1189	136,7	22,05	51,18	0
1190	49,12	8,21	50,16	0
1191	15,79	48,52	-40,13	0
1192	25,55	24,89	-59,72	0
1193	40,2	9,02	-67,28	0
1194	57,73	0,29	-65	0
1195	75,61	-3,56	-56,06	-0,1
1196	91,59	-4,09	-42,97	-0,1
1197	103,99	-1,6	-28,08	-0,1
1198	111,59	5,92	-13,76	-0,1
1199	110,97	23,94	-0,77	-0,1
1200	90,6	52,46	17,12	-0,1
1201	51,07	62,3	55,05	-0,1
1202	24,01	43,98	87,59	-0,1
1203	-2,92	12,51	101,86	-0,1
1204	-41,29	-8,36	98,8	-0,1
1205	-74,6	-13	90,27	-0,1
1206	-99,27	-13,96	78,91	-0,2

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1207	-113,75	-18,22	66,94	-0,2
1208	-119,53	-27,92	55,73	-0,2
1209	-120,07	-41,03	45,43	-0,2
1210	-118,86	-53,72	34,98	-0,2
1211	-118,12	-62,65	23,43	-0,3
1212	-118,88	-65,88	10,67	-0,3
1213	-121,61	-62,78	-2,61	-0,3
1214	-126,47	-53,76	-15,44	-0,3
1215	-133,24	-40,48	-27,27	-0,3
1216	-140,63	-26,43	-38,36	-0,3
1217	-145,6	-17,06	-49,43	-0,3
1218	-143,44	-17,95	-60,29	-0,3
1219	-130,47	-31,87	-69,37	-0,2
1220	-106,2	-56,06	-73,89	-0,2
1221	-72,9	-82,31	-72,24	-0,2
1222	-33,32	-100,11	-64,21	-0,2
1223	11,84	-99,45	-50,52	-0,2
1224	64,26	-70,52	-28,78	-0,2
1225	122,54	-4,78	-2,97	-0,1
1226	128,14	119,37	75,87	0
1227	19,28	19,33	-26,31	0
1228	48,36	15,61	-39,97	0
1229	85,17	16,62	-44,68	0
1230	124,58	21	-42,44	0
1231	161,28	26,38	-35,94	0
1232	191,76	31,52	-27,01	0
1233	214,23	36	-17,34	0
1234	228,94	40,79	-8,92	0
1235	238,98	52,05	-6,85	0
1236	246,79	101,8	-13,91	0
1237	158,14	150,41	0,18	0
1238	125,02	98,53	61,96	-0,1
1239	37,35	14,26	63,65	-0,1
1240	-23,93	-11,77	63,63	-0,1
1241	-72,62	-21,21	61,44	-0,1
1242	-108,22	-24,87	59,21	-0,2
1243	-131,44	-31	56,69	-0,2
1244	-143,83	-42,48	52,99	-0,2
1245	-148,76	-57,98	46,71	-0,3
1246	-150,07	-73,58	37,05	-0,3
1247	-150,75	-85,23	24,15	-0,3
1248	-152,43	-90,16	8,99	-0,3
1249	-155,8	-87,24	-7,03	-0,3
1250	-161	-76,92	-22,32	-0,3
1251	-167,54	-61,3	-35,41	-0,3
1252	-173,74	-44,47	-45,04	-0,3
1253	-176,32	-32,08	-50,54	-0,3
1254	-171,14	-29,5	-51,99	-0,3
1255	-155,24	-39,03	-49,96	-0,3
1256	-128,55	-57,84	-45,3	-0,2
1257	-93,6	-78,24	-38,26	-0,2
1258	-53,6	-90,11	-28,44	-0,2
1259	-10,57	-83	-14,94	-0,2
1260	33,19	-48,37	3,38	-0,1
1261	80,13	29,53	27,5	-0,1
1262	97,43	165,73	43,05	0
1263	158,52	97,14	-29,31	0
1264	55,68	23,46	10,91	-0,1
1265	-13,9	-6,87	17,23	-0,1
1266	-68,6	-17,31	25,29	-0,1
1267	-109,84	-21,37	33,51	-0,2
1268	-137,38	-29,46	42,31	-0,2
1269	-152,21	-45,59	47,84	-0,2
1270	-158,18	-67,5	46,93	-0,3
1271	-160,27	-89,48	38,67	-0,3
1272	-161,74	-105,88	24,58	-0,3
1273	-163,99	-113,31	7,03	-0,3

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1274	-167,48	-110,54	-11,74	-0,4
1275	-172,39	-97,91	-29,53	-0,3
1276	-178,53	-77,46	-43,85	-0,3
1277	-184,74	-53,65	-51,89	-0,3
1278	-187,68	-33,47	-51,51	-0,3
1279	-182,56	-24,49	-42,85	-0,3
1280	-165,8	-30,56	-29,58	-0,3
1281	-137,94	-48,44	-16,19	-0,2
1282	-103,37	-68,7	-5,13	-0,2
1283	-66,57	-79,52	4,33	-0,2
1284	-30,22	-70,43	14,2	-0,2
1285	3,92	-32,75	25,4	-0,1
1286	30,87	41,26	34,03	-0,1
1287	38,86	133,33	22,7	0
1288	83,93	152,4	-48,97	0
1289	41,49	46,73	-38,81	0
1290	-14,3	6,52	-25,92	-0,1
1291	-63,26	-1,14	-12,66	-0,1
1292	-104,85	-2,01	5,95	-0,2
1293	-132,52	-11,34	27,42	-0,2
1294	-145,15	-35,56	44,3	-0,2
1295	-148,99	-69,51	48,78	-0,3
1296	-150,79	-102,06	41	-0,3
1297	-153,17	-125,24	25,14	-0,3
1298	-155,95	-135,84	5,13	-0,4
1299	-159,06	-133,22	-16,31	-0,4
1300	-162,71	-117,56	-36,77	-0,4
1301	-167,5	-90,06	-53,19	-0,3
1302	-173,57	-54,49	-61,1	-0,3
1303	-179,22	-20,59	-55,2	-0,3
1304	-176,99	-1,24	-35,45	-0,3
1305	-160,15	-5,13	-8,6	-0,2
1306	-131,23	-28,59	13,52	-0,2
1307	-98,57	-56,04	25,92	-0,2
1308	-68,33	-71,14	31,95	-0,2
1309	-40,94	-63,78	36,02	-0,1
1310	-16,61	-29,62	38,81	-0,1
1311	2,94	30,71	36,22	-0,1
1312	20,88	110,31	22	0
1313	23,71	105,88	-42,58	0
1314	11,77	47,43	-57,75	0
1315	-14,93	19,45	-57,38	-0,1
1316	-50,7	22,2	-47,21	-0,1
1317	-87,65	35,72	-22,92	-0,1
1318	-114,48	28,01	16,63	-0,2
1319	-119,84	-11,26	46	-0,2
1320	-119,28	-65,94	53,61	-0,3
1321	-123,78	-113,64	43,77	-0,3
1322	-128,14	-144,17	25,65	-0,3
1323	-131,6	-158,02	3,53	-0,4
1324	-133,91	-155,65	-20,03	-0,4
1325	-135,21	-137,08	-42,9	-0,4
1326	-136,06	-101,56	-62,34	-0,3
1327	-139,39	-50,34	-72,79	-0,3
1328	-146,68	8,14	-65,37	-0,3
1329	-150,83	45,98	-29,64	-0,2
1330	-135,44	40,12	14,96	-0,2
1331	-100,99	-0,01	44,12	-0,2
1332	-75,63	-44,88	52,28	-0,2
1333	-57,89	-67,56	52,14	-0,1
1334	-41,05	-63,31	50,46	-0,1
1335	-24,91	-34,1	47,43	-0,1
1336	-8,21	17,84	40,48	-0,1
1337	11,95	89,02	25,41	0
1338	5,26	62,06	-43,71	0
1339	-3,7	30,79	-64,03	0
1340	-7,09	19,82	-72,57	0

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1341	-12,72	48,04	-74,57	-0,1
1342	-50,63	90,79	-45,12	-0,1
1343	-75,31	100,13	8,95	-0,1
1344	-57,95	28,88	56,95	-0,2
1345	-75,1	-66,14	58,64	-0,2
1346	-84,61	-126,08	46,29	-0,3
1347	-91,34	-163,32	26,14	-0,3
1348	-95,15	-180,06	2,3	-0,4
1349	-96,46	-178,02	-22,94	-0,4
1350	-95,21	-157,15	-47,63	-0,3
1351	-90,89	-115,89	-69,45	-0,3
1352	-82,28	-46,86	-85,7	-0,3
1353	-80,18	48,6	-81,11	-0,2
1354	-106,67	125,85	-35,05	-0,2
1355	-62,86	123,25	45,39	-0,1
1356	-34,7	26,99	71,57	-0,1
1357	-43,15	-43,66	67,95	-0,1
1358	-39,04	-68,42	63,84	-0,1
1359	-32,54	-66,93	58,42	-0,1
1360	-23,86	-40,93	52,33	-0,1
1361	-12,55	5,49	44,42	0
1362	4,76	68,17	31,45	0
1363	-8,98	25,54	-46,63	0
1364	-7,16	17,99	-60,88	0
1365	-7,18	8,05	-65,61	0
1366	52,43	24,04	-72,8	0
1367	40,88	190,07	-127,79	0
1368	91,26	257,07	25,12	-0,1
1369	-0,08	38,57	46,11	-0,1
1370	-23,28	-63,59	55,68	-0,2
1371	-37,49	-138,14	42,09	-0,3
1372	-45,28	-181,08	21,67	-0,3
1373	-50,06	-200,85	-2,4	-0,3
1374	-52,35	-199,42	-27,5	-0,3
1375	-52,36	-177,03	-51,61	-0,3
1376	-46,96	-130,32	-71,62	-0,3
1377	-43,68	-59,54	-81,87	-0,2
1378	41,05	66,29	-87,25	-0,1
1379	3,6	321,59	-46	-0,1
1380	131,76	221,87	76,04	-0,1
1381	-1,6	4,44	60,74	-0,1
1382	-7,67	-36,77	68,38	-0,1
1383	-16,06	-71,41	63,73	-0,1
1384	-16,54	-71,42	57,27	-0,1
1385	-14,98	-47,47	50,1	-0,1
1386	-11,07	-3,11	42,85	0
1387	-2,98	52,07	35,07	0
1388	-19,78	486,61	59,17	0
1389	7,56	323,93	35,71	-0,1
1390	137,3	686,49	24,08	0
1391	149,94	749,68	10,35	0
1392	-2,68	150,23	33,78	-0,3
1393	-3,41	-2,99	37,27	-0,4
1394	-5,13	-135,24	46,05	-0,6
1395	-5,82	-325,3	74,29	-0,8
1396	-5,77	-243,12	58,63	-0,7
1397	-5,15	-380,44	92,28	-0,9
1398	157,77	788,84	7,68	0
1399	163,91	819,57	6,33	0
1400	169,01	845,07	5,15	0
1401	173,01	865,03	3,83	0
1402	-3,79	-407,04	111,72	-0,9
1403	-1,13	-402,64	131,5	-0,9
1404	0,56	-364,39	149,59	-0,8
1405	14,2	-280,08	163,94	-0,6
1406	211,89	156,5	159,15	-0,3
1407	-21,89	-158,54	161,3	-0,5

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1408	-663,31	-129,86	490,89	0,1
1409	-909,69	243,78	-123,73	-0,1
1410	68,54	-96,66	78,91	0
1411	467,65	127,88	-1,74	0,2
1412	164,36	16,46	-11,43	-0,3
1413	-195,9	7,97	54,89	-0,8
1414	-23,49	16,72	26,51	-0,5
1415	-316,29	-5,41	64,63	-1
1416	-358,01	8,07	48,19	-1,2
1417	-457,04	-73,77	128,47	-1,4
1418	-126,66	-91,01	162,62	-1,4
1419	175,76	878,79	2,36	0
1420	177,16	885,79	0,79	0
1421	177,15	885,77	-0,79	0
1422	175,77	878,83	-2,3	0
1423	173,09	865,45	-3,67	0
1424	169,29	846,46	-4,82	0
1425	164,6	822,99	-5,69	0
1426	159,27	796,35	-6,24	0
1427	153,59	767,97	-6,48	0
1428	147,85	739,25	-6,41	0
1429	142,29	711,43	-6,09	0
1430	137,1	685,51	-5,58	0
1431	132,43	662,17	-4,95	0
1432	128,34	641,72	-4,29	0
1433	124,83	624,17	-3,67	0
1434	121,84	609,2	-3,14	0
1435	119,26	596,29	-2,75	0
1436	116,95	584,76	-2,52	0
1437	114,77	573,86	-2,47	0
1438	-553,72	18,66	-9,57	-1,5
1439	-457,55	-18,19	-57,75	-1,4
1440	-515,02	-16,44	-42,74	-1,5
1441	-377,06	-27,43	-64,46	-1,3
1442	-273,14	-3,32	-61,83	-1,1
1443	55,04	-6,85	28,57	-0,7
1444	-135,33	-7,4	-39,28	-0,9
1445	233,12	82,41	94,96	-0,4
1446	74,49	14,07	60,26	0
1447	84,02	306,15	127,09	0
1448	-17,71	-230,58	73,87	-1,5
1449	-6,51	-134,14	37,01	-1,3
1450	-13,52	-27,7	-0,73	-1,1
1451	-42,31	-410,12	126,21	-1,8
1452	-30,01	-377,77	106	-1,7
1453	-31,7	-325,23	83,24	-1,6
1454	-2,51	74,22	-36,47	-0,9
1455	28,51	155,25	-87,05	-0,4
1456	20,08	80,97	-66,82	-0,3
1457	132,69	-6,85	-26,47	-0,1
1458	55,95	7,42	-27,76	-0,2
1459	15,04	182,48	-78,2	-0,6
1460	19,63	170,37	-53,95	-0,7
1461	-64,84	-101,94	154,66	-0,9
1462	-45,66	-226,15	152,85	-1,2
1463	-83,7	-308,8	159,92	-1,4
1464	-60,03	-364,23	152,53	-1,6
1465	-83,48	44,03	123,86	-0,7
1466	-143,91	700,62	-292,62	-0,1
1467	48,63	467,78	8,77	-0,3
1468	428,68	734,41	658,87	0
1469	-94,03	248,82	52,32	-0,4
1470	38,1	-239,86	-457,48	0
1471	-15,19	88,03	-46,87	-0,1
1472	-46,27	-401,38	146,43	-1,7
1473	-37,32	-421,87	132,93	-1,8
1474	-167,27	0,22	-10,18	-0,1

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1475	-198,36	4,31	8,83	-0,1
1476	-185,61	4,5	7,17	-0,1
1477	301,73	19,03	132,9	-0,4
1478	296,49	40,12	169,72	-0,2
1479	186,17	32,06	78,65	-0,5
1480	185,62	-11,04	142,64	-0,1
1481	63,91	-28,79	91,08	-0,1
1482	253,47	-83,16	-42,34	0
1483	313,58	193,96	-232,86	0
1484	74,34	-14,39	72,07	0
1485	65,04	158,54	-31,18	0
1486	157,94	174,13	-57,17	0
1487	36,05	35,63	50,97	0
1488	-22,83	-5,08	0,57	0
1489	-1,63	-0,5	-1,19	0
1490	-13,29	-3,15	-2,26	0
1491	-6,49	-1,11	4,28	0
1492	-28,06	-5,42	6,75	0
1493	2,18	0,5	1,37	0
1494	52,28	149,34	15,08	-0,1
1495	-133,7	-24,5	6,63	-0,1
1496	-99,17	-858,63	199,85	0
1497	46,99	-311,07	-424	0
1498	-75,43	-66,24	9,39	0
1499	45,15	78,37	-8,91	0
1500	-56,23	-13,86	24,5	0
1501	132,19	132	7,73	0
1502	-87,07	7,52	41,14	0
1503	-90,19	-27,82	48,88	0
1504	48	137,71	45,31	0
1505	-59,89	-11,98	8,29	0
1506	-6,94	-0,78	14,1	0
1507	110,12	550,61	-2,95	0
1508	107,29	536,46	-3,51	0
1509	103,86	519,31	-4,3	0
1510	99,61	498,07	-5,34	0
1511	433,23	719,06	196,71	0
1512	115,77	578,21	14,66	0
1513	137,19	665,81	46,43	0
1514	94,31	471,55	-6,66	0
1515	87,7	438,49	-8,26	0
1516	69,64	348,21	-12,1	0
1517	57,92	289,6	-14,09	0
1518	44,5	222,52	-15,72	0
1519	29,94	149,7	-16,38	0
1520	100,54	501,93	10,36	0
1521	106,93	534,1	11,94	0
1522	95	473,86	9,51	0
1523	93,25	469,73	-1,04	0
1524	442,19	506,44	-132,01	0
1525	351,05	82,62	-46,45	0
1526	337,68	67,98	-10,72	0
1527	357,17	71,57	-5,99	0
1528	379,8	76,28	-5,59	0
1529	408,59	82,31	-5,41	0
1530	397,48	80	-5,61	0
1531	413,48	83,33	-4,79	0
1532	15,56	77,8	-14,9	0
1533	4,01	20,06	-9,2	0
1534	20,06	4,01	-9,22	0
1535	149,53	29,91	-16,18	0
1536	77,91	15,58	-14,91	0
1537	282,31	56,46	-12,38	0
1538	330,51	66,1	-9,04	0
1539	385,46	77,09	-1,27	0
1540	404,91	80,98	-14,98	0
1541	379,45	75,89	-2,23	0

LEVEL 5				
NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1542	220,46	44,09	-14,98	0
1543	0	0	0,34	0
1544	362,89	72,58	-5,43	0
1545	447,55	394,98	-78,84	0
1546	49,52	247,58	-26,19	0
1547	35,61	178,05	-12,99	0
1548	23,43	117,14	-14,81	0
1549	8,03	40,16	-21,45	0
1550	-14,86	-74,28	-25,59	0
1551	-8,71	5,64	-54,44	0
1552	-221,05	-25,06	-13,59	0
1553	45,35	41,43	-60,48	0
1554	-35,51	149,96	-36,18	-0,1
1555	-15,86	-119,67	63,69	-0,2
1556	9,02	11,21	69,91	-0,1
1557	-4,64	8,07	-46,16	0
1558	-11,3	-219,83	26,2	-0,3
1559	-8,22	-230,06	0,77	-0,3
1560	-12,77	-184,23	48,87	-0,3
1561	-5,24	-217,46	-25,59	-0,3
1562	0,62	10,17	39,13	0
1563	30,37	159,14	28,96	0
1564	47,65	241,21	7,28	0
1565	45,21	223,24	-14,14	0
1566	23,82	113,58	-28,76	0
1567	414,87	83,61	-3,14	0
1568	421,98	85,12	2,48	0
1569	-9,04	-44,41	-21,77	0
1570	307,59	70,97	45,94	0
1571	207,24	30,75	5,98	0
1572	31,92	134,92	83,64	0
1573	-33,01	-527,49	-175,69	0
1574	-34,25	-546,71	296,56	0
1575	-106,62	-3,8	90,3	0
1576	-105,03	-20,71	76,98	0
1577	-37,28	51,43	85,19	0
1578	-6,75	-205,41	190,87	0
1579	-2,07	-205,95	-6,11	0
1580	62,26	42,26	97,7	0
1581	23,42	-9,41	80,25	0
1582	1,46	-178,77	-51,1	-0,3
1583	-8,31	-114,42	-72,15	-0,2
1584	-357,01	103,22	-25,97	0
1585	-193,93	42,31	-78,59	0
1586	77,91	31,92	-90,17	-0,1
1587	63,84	314,01	24,97	0
1588	76,82	379,87	68,17	0
1589	-15,86	-65,95	66,02	0
1590	-6,5	-82,91	62,56	0
1591	56,7	277,45	14,82	0
1592	41,47	31,56	76	0
1593	-4,21	-40,96	42,55	0
1594	-6,37	-74,68	52,41	0
1595	-0,64	12,02	33,76	0
1596	749,15	553,11	221,11	0
1597	645,16	141,03	63,92	0
1598	536,12	107,02	20,9	0
1599	459,77	92,25	20,37	0
1600	377,72	75,96	19,91	0
1601	282,9	56,99	19,51	0
1602	177,44	35,76	20,49	0
1603	-77,89	-38,35	32,64	0
1604	47,38	232,91	12,68	0
1605	40,59	199,18	13,98	0
1606	-9,94	67,21	30,86	0
1607	52,26	257,98	12,24	0
1608	31,41	155,07	16,87	0

LEVEL 5

NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1609	28,53	5,67	26,35	0
1610	15,62	76,78	25,41	0
1611	1650,74	1571,74	34,14	0
1612	1458,11	1497,16	64,61	0
1613	674,47	912,49	-14,68	0
1614	703,64	722,54	-28,59	0
1615	99,48	497,41	59,48	0
1616	3970,75	953,53	-639,22	0
1617	112,55	562,77	-2,61	0
1618	562,91	2592,25	-91,54	0
1619	874,25	3467,63	412,2	0
1620	79,54	397,7	-10,1	0
1621	967,07	617,28	-98,79	0
1622	582,4	2676,79	71,05	0
1623	250,71	1077,41	166,28	0
1624	1492,91	773,37	202,21	0

MAIN HALL

NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
1	-726,15	-263,6	230,72	0
2	-48,75	-269,99	54,66	0
3	-161,77	-574,83	61,67	0
4	-127,58	-502,33	20,26	0
5	121,67	-80,09	90,14	-0,1
6	-803,89	-385,22	-250,84	-0,1
7	-563,14	-260,27	-324,72	0
8	1920,78	128,16	-1002,17	0
9	-113,48	-1173,44	238,52	0,1
10	-238,51	-1643,78	70,82	0
11	-195,12	-1332,95	-268,94	-0,7
12	290,94	-844,06	-55,11	-1,1
13	949,43	247,58	351,8	-0,9
14	3905,08	1940,53	933,07	-0,4
15	3649,33	1953,06	-684,65	0,1
16	71,03	-21,11	159,28	0
17	183,55	56,21	290,24	0
18	368,68	21,35	273,28	0
19	299,91	43,87	143,34	0
20	512,31	-8,37	200,87	0
21	493,79	69	107,8	0
22	597,65	-23,45	96,8	0
23	616,78	87,51	51,12	0
24	618,43	-22,43	-23,12	0
25	631,25	91,29	-13,99	0
26	575,83	-5,71	-134,73	0
27	574,48	86,35	-76,21	0
28	464,44	25,09	-225,73	0
29	443,38	79,39	-110,52	0
30	292,25	71,04	-291,77	0
31	240,16	62,1	-119,87	0
32	9,38	-41,6	-324,3	0
33	21,48	184,16	-85,55	0
34	-26,73	127,86	197,99	0
35	59,69	-58,71	477,51	0
36	379,59	96,78	486,88	0
37	556,42	-23,44	410,06	0
38	658,67	-123,02	285,47	0
39	699,6	-176,55	129,04	0
40	702,49	-183,13	-35,2	0
41	670,53	-148,64	-196,4	-0,1
42	592,81	-72,65	-341,15	-0,1
43	443,44	15,5	-445,8	-0,1
44	267,81	59,83	-446,49	0
45	539,76	55,96	566,22	0
46	723,59	84,9	657,71	0
47	873,99	-118,68	521,81	0
48	873,18	-295,09	329,58	0
49	854,85	-367,61	137,81	-0,1
50	840,14	-377,15	-49,03	-0,1
51	830,88	-333,41	-236,19	-0,1
52	814,03	-224,05	-425,04	-0,1
53	753,45	-15,67	-595	-0,1
54	533,94	209,38	-653,37	-0,1
55	138,49	315,07	-584,96	0
56	133,43	-18,52	-304,37	0
57	927,94	581,36	720,49	0
58	1484,16	160,8	805,78	0
59	1222,57	-361,61	519,79	0
60	1073,28	-512,32	296,63	-0,1
61	989,28	-572,88	114,11	-0,1
62	961,09	-580,48	-58	-0,2
63	983,84	-541,72	-234,95	-0,2
64	1054,59	-438,6	-432,76	-0,2
65	1166,27	-205,67	-674,83	-0,2
66	1138,16	295,8	-930,05	-0,2
67	1845,82	-595,77	538,33	-0,1

MAIN HALL

NODE	Mxx (kN/m)	Myy (kN/m)	Mxy (kN/m)	Uz (cm)
68	1390,24	-616,81	323,02	0
69	1150,1	-706,76	186,99	-0,1
70	1031,58	-750,82	64,34	-0,2
71	998,84	-758,59	-57,79	-0,3
72	1048,34	-732,67	-184,98	-0,3
73	1193,15	-663,19	-329,54	-0,3
74	1462,99	-526,82	-536,93	-0,3
75	1991,39	-73,78	-783,22	-0,3
76	1638,98	-249,7	1,01	-0,2
77	1236,66	-710,5	65,03	-0,1
78	1048,22	-820,65	66,93	-0,3
79	939,31	-875,1	8,65	-0,4
80	914,77	-883,83	-49,87	-0,4
81	966,12	-864,95	-110,4	-0,5
82	1123,87	-815,79	-165,16	-0,5
83	1429,69	-669,39	-236,15	-0,4
84	1606,37	-197,62	-303,61	-0,4
85	855,3	-607,68	50,38	-0,3
86	820,26	-889,46	-29,69	-0,2
87	678,73	-963,55	-31,97	-0,5
88	723,06	-961,31	-24,5	-0,6
89	761,59	-916,45	-56,16	-0,7
90	706,94	-887,97	13,71	-0,7
91	1086,09	-729,33	20,09	-0,6
92	268,82	-907,56	-83,16	-0,6
93	298,9	-1083,38	12,1	-0,5
94	504,51	-948,2	-79,37	-0,9
95	645,29	151,12	-21,9	-0,9
96	388,87	-13,74	-206,19	-0,8
97	315,75	393,3	-211,73	0
98	215,91	135,35	258,03	0
99	236,49	57,26	20,74	0
100	598,6	1,49	-43,61	0
101	58,2	168,81	-17,16	0
102	792,41	191,99	2,37	0
103	360,1	68,15	32,19	0
104	780,93	157,4	-15,84	0
105	-85,99	-57,1	141,16	0
106	-10,53	36,12	38,87	0
107	405,33	216,53	524,94	0
108	431,48	-6,04	48,59	0
109	618,25	98,77	13,88	0,1
110	218,63	-5,12	204,78	0
111	364,3	53,44	104,03	0
112	616,19	130,11	-30,53	0
113	457,08	121,56	-18,32	0
114	87,9	27,06	-82,35	0
115	231,6	39,94	116,57	0
116	186,03	44,78	-19,89	0
117	107,84	119,42	53,55	0
118	139,59	132,6	161,44	0
119	832,08	182,75	0,63	0
120	3,7	8,7	-103,23	0
121	30,02	-135,56	-312,49	0
122	198,49	-28,79	-122,62	0
123	887,18	130,97	433,7	0
124	3044,39	1065,93	1442,92	0
125	1446,86	-146,67	573,39	0,1
126	386,48	-465,65	57,58	0
127	538,23	-714,9	35,02	-0,2
128	515,67	-989,07	-182,26	-0,6
129	125,44	-667,77	-34,45	-0,8
130	240,57	-770,16	125,92	-0,8
131	838,47	447,7	-752,3	-1
132	2227,98	284,26	-681,8	-1
133	1313,64	360,9	-547,87	0,1
134	293,65	-731,46	-64,9	0,1

Main hall structure

Here it follows a table containing the forces and momentum of the main hall structure, which had to be verified by the chosen profiles. They are presented for each bar, which is then divided in two nodes. The forces in each bar are the same for both nodes, except for the ones with any type of constraints to the ground. This is due to the absence of any variable loads, which would have created a difference between the two sides of the same bar. The difference between two same nodes of different bars is due to the presence of concentrated loads applied to the nodes, which has to be counterbalanced by the difference of the two bar loads.

On the right, the displacement (linear and rotation ones) are presented for each node, divided in the different direction of the displacement: x, y and z. The higher displacement are in z direction, because all the loads are directed in that direction, negative because they are heading towards the ground. The maximum value for the displacement is reached by node 59, with a value of 5,4 cm.

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
1	1	-504,36	1,8	-5,21	0,06	11,24	2,61
1	2	-504,36	1,8	-10,79	0,06	-5,42	-1,13
2	3	-345,52	-0,15	38,08	0	-64,89	-0,35
2	4	-345,52	-0,15	32,6	0	7,45	-0,05
3	5	-284,95	0,74	-48,82	-0,01	14,52	0,64
3	6	-284,95	0,74	-54,27	-0,01	-90,33	-0,87
4	7	-599,1	6,13	29,06	0,14	-7,36	3,95
4	8	-599,1	6,13	23,43	0,14	47,8	-8,94
5	9	-361,35	11,36	-13,77	0,24	25,26	17,4
5	10	-361,35	11,36	-19,35	0,24	-9,2	-6,24
6	11	-385,9	13,38	230,02	-0,37	-355,05	20,8
6	12	-385,9	13,38	224,54	-0,37	110,17	-6,59
7	13	-172,6	-4,29	51,19	0,08	-108,51	-6,95
7	14	-172,6	-4,29	45,74	0,08	-9,92	1,78
8	15	-3103,18	-22,24	-58,92	0,55	-105,74	-23,1
8	16	-2592,36	-0,76	-191,14	-0,17	-630,07	11,87
9	16	-2967,75	-61,03	-111,56	-0,23	409,12	-84,74
9	17	-2977,02	31,03	-69,15	0,15	-16,08	-36,74
10	17	-2839,94	-38,35	41,93	-0,05	-39,42	-48,91
10	18	-2742,55	40,34	-21,25	-0,02	-12,75	-51,8
11	18	-2884,45	-28,53	11,13	-0,05	7,67	-32,07
11	19	-2859,32	47,56	-12,96	-0,14	-61,23	-62,19
12	19	-3099,6	-24,54	-6,12	0,02	-21,82	-24,57
12	20	-3079,19	47,01	12,93	-0,23	-66,46	-58,6
13	20	-3215,13	-29,47	-25,94	0,14	-36,25	-31,06
13	21	-3208,66	41,73	18,1	-0,2	-72,02	-48,9
14	21	-3135,28	-36,02	-26,44	0,22	-49,35	-41,42
14	22	-3160,76	34,8	7,35	-0,08	-53,41	-39,17
15	22	-2924,56	-39,25	-7,05	0,17	-45,58	-48,59
15	23	-2996,49	34,22	-13,07	0	-39,4	-40,35
16	23	-2750,55	-34,65	22,99	0,03	-28,64	-43,33
16	24	-2925,2	41,74	-28,76	0,05	-7,16	-54,34
17	24	-2892,29	-27,15	31,8	-0,12	32,84	-31,64
17	25	-2816,34	55,76	-34,71	0,01	-5,23	-76,87
18	25	-2973,61	-11,32	-33,84	-0,04	110,19	-5,83
18	26	-2916,18	70,29	68,64	-0,01	100,82	-97,14
19	26	-2027,17	13,97	221,69	0,35	-833,69	31,76
19	27	-2737,69	16,25	198,97	-0,51	179,23	-12,48
20	27	-2052,35	-55,82	-7,47	-0,01	150,89	-71,02
20	15	-1928,04	44,7	52,62	0,17	294,43	-55,29
21	28	-2783,43	-12,35	14,39	0,41	-130,51	-17,64
21	29	-2991,3	7,32	-3,78	0	-167,65	-10,59
22	29	-3113,61	-6,31	12,91	-0,21	66,72	-7,37
22	30	-3120,61	7,21	-8,95	0,05	74,61	-10,4
23	30	-3150,12	-7,81	3,87	0,02	37,26	-10,39

NODE	Ux (cm)	Uy (cm)	Uz (cm)
1	0,4	-0,4	-5
2	0,3	-0,4	-5,3
3	0,5	-0,7	-5
4	0,4	-0,7	-5,3
5	0,4	-1	-5,2
6	0,5	-1	-4,9
7	0,2	-0,3	-4,7
8	0,2	-0,3	-4,4
9	0,1	-0,2	-3
10	0,1	-0,2	-3,2
11	0,1	0	-0,9
12	0,1	-0,1	-1,3
13	0	-0,2	-1,2
14	0,1	-0,2	-1,3
15	-0,1	0,1	-1,7
16	-0,3	0	-2,2
17	-0,5	-0,2	-3,7
18	-0,5	-0,5	-4,4
19	-0,4	-0,8	-4,6
20	-0,2	-0,9	-4,5
21	0,1	-1	-4,6
22	0,4	-0,9	-4,8
23	0,5	-0,7	-4,9
24	0,6	-0,4	-4,5
25	0,5	-0,2	-3
26	0,2	0	-0,9
27	0,1	0,1	-1,3
28	-0,1	0,1	-1,8
29	-0,3	-0,1	-2,4
30	-0,4	-0,3	-3,6
31	-0,4	-0,5	-4,1
32	-0,3	-0,7	-4,2
33	-0,1	-0,9	-4,1
34	0,1	-0,9	-4,1
35	0,3	-0,8	-4,3
36	0,5	-0,7	-4,5
37	0,5	-0,4	-4,1
38	0,4	-0,2	-2,9
39	0,2	-0,1	-1,2
40	0,1	0	-1,4
41	0	-0,5	-1,5
42	0	-0,7	-1,9
43	0,1	-0,9	-3,3
44	0,2	-1	-4,2
45	0,2	-1	-4,6

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
23	31	-3189,24	6,49	-19,86	-0,06	2,62	-8
24	31	-3253,14	-7,55	-17,28	-0,08	45,24	-9,98
24	32	-3254,88	8,28	-36,71	-0,08	-78,06	-10,55
25	32	-3299,23	-9,56	-17,83	-0,13	-15	-13,35
25	33	-3298,36	9,77	-33,28	-0,06	-125,2	-12,91
26	33	-3327,82	-10,75	-1,26	-0,08	-83,4	-14,95
26	34	-3326,04	10,41	-14,85	0,03	-119,2	-13,95
27	34	-3323,86	-10,46	23,66	0,01	-125,63	-14,3
27	35	-3315,26	9,84	9,07	0,1	-55,34	-13,28
28	35	-3270,52	-8,96	31,09	0,06	-95,97	-12,01
28	36	-3245,45	8,19	13,1	0,08	2,33	-10,83
29	36	-3143,87	-6,91	24,72	0,02	-20,37	-9,19
29	37	-3071,1	8,05	1,98	-0,03	50,5	-10,96
30	37	-3046,69	-8,04	0,43	-0,03	79,35	-11,83
30	38	-3067,29	6,37	-23,27	-0,09	33,6	-7,76
31	38	-3173,21	-8,71	-39,77	0,01	78,22	-13,15
31	39	-3176,41	5,34	-56,95	0,33	-203,42	-4,64
32	39	-3018,05	-6,65	57,35	-0,17	-403,17	-8,39
32	40	-2730,44	14,52	44,4	-0,34	-59,76	-19,98
33	40	-2444,69	-8,09	20,96	-0,06	73,47	-10,15
33	28	-2496,9	6,88	10,53	0,25	135,99	-8,64
34	9	-626,79	5,48	7,49	-0,17	110,39	11,25
34	11	-1361,03	26,06	68,86	-0,19	100,28	-39,04
35	11	-878,29	5,27	115,71	0,36	-506,02	8,95
35	13	-555,52	-0,79	96,53	-0,3	134,61	2,45
36	13	-629,47	-13,62	-7,32	0,07	85,75	-17,13
36	41	-456,4	6,31	-3,27	0,05	74,13	-6,22
37	41	-849,97	-9,59	24,91	0,22	-113,55	-11,75
37	42	-824,12	1,27	11,41	-0,11	-7,45	1,1
38	42	-714,78	-16,84	28,25	0,24	-120,74	-23,41
38	43	-607,3	3,43	-10,37	0,1	84,19	-1,55
39	43	-567,15	-14,13	39,57	0,03	-8,26	-18,88
39	44	-605,55	7,54	-43,06	0,09	12,82	-8,38
40	44	-694,5	-10,83	38,29	0,03	-22,78	-13,49
40	45	-747,56	9,83	-31,45	0,01	3,3	-12,61
41	45	-876,65	-8,24	23,46	0,04	0,12	-9,55
41	46	-950,85	11,52	-24,39	-0,05	-12,71	-14,85
42	46	-1023,55	-8,53	14,91	0,08	-3,83	-9,96
42	6	-996,66	10,57	-18,49	-0,06	-9,52	-12,83
43	6	-984,19	-10,05	16,12	0,08	-6,23	-12,17
43	3	-891,54	9,58	-23,92	-0,04	-9,09	-11,08
44	3	-805,84	-9,78	28,44	0,03	-5,73	-12,08
44	1	-754,99	11,66	-38,43	0,01	-7,23	-14,26
45	1	-649,92	-8,05	42,74	-0,09	16,84	-9,1
45	8	-592,52	14,73	-50,74	0	-26,43	-19,34
46	8	-586,1	-5,19	43,24	-0,17	51,19	-3,73
46	9	-552,34	18,51	-52,08	-0,09	-62,85	-25,86
47	10	-861,15	0,56	-37,26	-0,19	148,48	0,75
47	12	-428,18	6,13	-63,87	0,11	-171,13	-10,49
48	12	-345,67	-6,9	31,83	-0,1	-272,09	-11,75
48	14	-527,08	1,09	11,11	-0,2	-5,67	-2,12
49	14	-650,28	-2,85	13,96	-0,02	52,19	-3,33
49	47	-748,52	2,11	-9,79	0,15	38,75	-2,33
50	47	-802,08	-2,75	23,41	0,14	-66,63	-3,68
50	48	-819,28	3,36	-1,38	0,14	-37,16	-4,92
51	48	-838,12	-2,91	51,84	0,09	-116,02	-3,54
51	49	-906,63	1,75	22,28	0,08	122,12	-1,74
52	49	-913,3	-1,37	32,85	0,16	36,52	-0,7
52	50	-892,98	2,39	-2,98	0,08	87,92	-2,57
53	50	-861,99	-1,66	23,16	0,09	28,7	-1,77
53	51	-830,49	3,18	-9,9	0,04	51,82	-4,31
54	51	-796,18	-2,65	13,41	0,03	32,6	-3,97
54	52	-752,15	4,01	-15,16	0,02	15,23	-6,12
55	52	-742,35	-4,06	14,61	0,01	8,71	-6,34
55	5	-756,49	3,69	-11,76	0,02	11,59	-5,73
56	5	-790,57	-4,32	18,22	0,01	3,5	-6,42
56	4	-843,18	2,86	-9,1	0,01	27,76	-4,12
57	4	-883,08	-3,53	18,57	-0,01	26,38	-4,76
57	2	-912,47	2,09	-13,5	-0,05	53,82	-2,4

NODE	Ux (cm)	Uy (cm)	Uz (cm)
46	0,3	-1,1	-4,8
47	0	-0,4	-1,7
48	0	-0,7	-2,1
49	0,1	-0,9	-3,5
50	0,2	-1	-4,5
51	0,2	-1	-4,9
52	0,3	-1,1	-5
53	0,5	-0,9	-4,9
54	0,4	-0,9	-5,3
55	0,5	-0,8	-5
56	0,4	-0,8	-5,3
57	0,5	-0,7	-5
58	0,4	-0,6	-5,1
59	0,4	-0,6	-5,4
60	0,4	-0,5	-5,1
61	0,3	-0,5	-5,4
62	0,4	-0,4	-5,1
63	0,3	-0,3	-5
64	0,2	-0,4	-5,3
65	0,2	-0,3	-4,9
66	0,2	-0,3	-5
67	0,2	-0,3	-4,7
68	0,1	-0,3	-4,2
69	0,1	-0,3	-4,4
70	0,1	-0,2	-3,9
71	0,1	-0,2	-3,9
72	0,1	-0,2	-3,5
73	0,1	-0,2	-2,6
74	0,1	-0,1	-2,6
75	0,1	-0,1	-2,1
76	0,1	-0,1	-1,9
77	0,1	-0,1	-1,5
78	0,1	-0,1	-0,7
79	0,1	-0,1	-1,1
80	0,1	-0,1	-0,7
81	0,1	-0,2	-1,1
82	0	-0,2	-1
83	0	-0,3	-1,4
84	0	-0,3	-1,5
85	0	-0,4	-1,5
86	0	-0,4	-1,6
87	0	-0,4	-1,5
88	0	-0,5	-1,5
89	0	-0,5	-1,8
90	0	-0,6	-1,6
91	0	-0,6	-1,9
92	0	-0,7	-1,7
93	0	-0,8	-2,2
94	0,1	-0,7	-2,6
95	0,1	-0,8	-2,6
96	0,1	-0,8	-3,1
97	0,1	-0,9	-3
98	0,2	-0,9	-3,7
99	0,2	-0,9	-4
100	0,2	-0,9	-4
101	0,2	-0,9	-4,3
102	0,2	-0,9	-4,1
103	0,2	-1	-4,4
104	0,2	-1	-4,7
105	0,2	-1	-4,6
106	0,2	-1	-4,9
107	0,2	-1	-4,6
108	0,3	-1	-4,7
109	0,3	-1	-5
110	0,3	-1	-4,8
111	0,3	-1,1	-5,1
112	0,3	-1,1	-4,8
113	0,4	-1	-4,8
114	0,3	-1	-5,1

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
58	2	-948,06	-2,89	6,7	-0,05	87,79	-3,3
58	7	-979,73	1,36	-30,84	-0,14	41,53	-0,57
59	7	-1018,86	-2,43	-11,08	-0,12	136,6	-2,23
59	10	-1033,7	1,02	-48,44	-0,23	-3,09	0,49
60	5	11,23	-5,09	8,98	-0,04	-3,67	-8,29
60	53	11,23	-5,09	2,05	-0,04	10,58	4,85
61	53	-27,9	10,09	3,97	0,03	-8,82	11,51
61	54	-27,9	10,09	-1,78	0,03	-6,47	-10,11
62	54	27,73	-5,11	2,39	-0,06	7,14	-5,9
62	55	27,73	-5,11	-3,91	-0,06	5,37	6,11
63	55	-31,45	6,07	4,35	0,06	-5,21	7,22
63	56	-31,45	6,07	-1,87	0,06	-2,33	-6,84
64	56	25,97	-8,86	1,94	-0,06	2,24	-8,8
64	57	25,97	-8,86	-3,87	-0,06	0,14	10,41
65	57	-53,24	5,09	4,5	0,05	-0,17	5,15
65	4	-53,24	5,09	-2,32	0,05	2,59	-7,8
66	4	-3,14	-4,61	2,6	-0,07	4,19	-7,21
66	58	-3,14	-4,61	-4,45	-0,07	1,76	4,92
67	58	-15,98	9,79	2,45	0,08	-1,42	11,6
67	59	-15,98	9,79	-3,34	0,08	-2,38	-9,54
68	59	13,82	-5,15	1,22	-0,1	2,76	-5,8
68	60	13,82	-5,15	-5,22	-0,1	-2,05	6,57
69	60	-17,22	6,24	5,63	0,11	2,16	7,68
69	61	-17,22	6,24	-0,61	0,11	7,99	-6,85
70	61	11,23	-8,93	6,64	-0,09	-7,45	-8,61
70	62	11,23	-8,93	0,7	-0,09	0,68	11,17
71	62	-38,45	4,16	26,84	0,08	-0,66	4,4
71	2	-38,45	4,16	20,03	0,08	58,89	-6,17
72	2	1,25	-4,43	-10,97	-0,13	18,28	-6,41
72	63	1,25	-4,43	-17,96	-0,13	-19,42	5,13
73	63	-18,13	9,02	1,12	0,17	16,56	11,19
73	64	-18,13	9,02	-4,77	0,17	12,54	-8,64
74	64	15,24	-5,16	1,04	-0,15	-13,49	-5,55
74	65	15,24	-5,16	-5,4	-0,15	-18,73	6,83
75	65	-18,43	6,14	7,82	0,18	18,7	7,91
75	66	-18,43	6,14	1,48	0,18	29,68	-6,6
76	66	10,91	-9,01	12,38	-0,09	-27,78	-8,23
76	67	10,91	-9,01	6,4	-0,09	-6,84	11,88
77	67	-41,79	2,83	43,49	0,08	8,01	3,23
77	7	-41,79	2,83	36,62	0,08	110,63	-4,02
78	7	-3,67	-4,75	-12,21	-0,17	2,46	-6,31
78	68	-3,67	-4,75	-19,06	-0,17	-37,49	5,84
79	68	-11	8,24	3,08	0,23	32,97	10,5
79	69	-11	8,24	-2,89	0,23	33,18	-7,87
80	69	7,1	-5,5	2,35	-0,13	-34,88	-5,69
80	70	7,1	-5,5	-3,97	-0,13	-36,78	7,28
81	70	-10,89	5,95	9,43	0,18	37,66	7,92
81	71	-10,89	5,95	3	0,18	52,57	-6,35
82	71	2,85	-9,54	14,4	-0,02	-47,96	-8,41
82	72	2,85	-9,54	8,51	-0,02	-22,78	12,55
83	72	-36,89	1,76	44,31	0,03	27	2,33
83	10	-36,89	1,76	37,33	0,03	133,17	-2,26
84	10	-252,08	-6,86	6,81	-0,16	-43,62	-8,76
84	73	-252,08	-6,86	0	-0,16	-34,97	8,68
85	73	215,48	4,15	9,02	0,2	30,72	4,69
85	74	215,48	4,15	3,09	0,2	44,13	-4,51
86	74	-229,96	-7,5	6,94	-0,03	-46,33	-8,72
86	75	-229,96	-7,5	0,7	-0,03	-37,43	8,74
87	75	232,85	3,84	-2,83	0,06	38,7	4,07
87	76	232,85	3,84	-9,27	0,06	24,16	-5,15
88	76	-214,41	-14,57	-6,8	0,05	-21,98	-14,67
88	77	-214,41	-14,57	-12,59	0,05	-42,91	16,8
89	77	218,74	2,33	-102,43	-0,03	52,09	-0,47
89	12	218,74	2,33	-109,48	-0,03	-226,52	-6,59
90	12	107,89	-7,15	19,36	0,43	-106,19	-11,92
90	78	107,89	-7,15	12,54	0,43	-65,64	6,26
91	78	-91,85	7,26	1,38	-0,21	54,95	7,35
91	79	-91,85	7,26	-4,43	-0,21	51,64	-8,38
92	79	100,72	-2,02	-10,05	0,33	-55,4	-2,41

NODE	Ux (cm)	Uy (cm)	Uz (cm)
115	0,4	-1	-4,9
116	0,4	-1	-5,2
117	0,4	-1	-4,9
118	0,4	-0,6	-4,8
119	0,5	-0,5	-4,4
120	0,5	-0,5	-4,6
121	0,4	-0,7	-4,8
122	0,4	-0,7	-4,4
123	0,3	-0,7	-4,8
124	0,2	-0,8	-4,7
125	0,2	-0,9	-4,2
126	0,2	-0,9	-4,6
127	0	-0,9	-4,5
128	0	-0,9	-4
129	-0,1	-0,9	-4,5
130	-0,2	-0,8	-4,5
131	-0,2	-0,8	-4,1
132	-0,3	-0,7	-4,5
133	-0,3	-0,6	-4,5
134	-0,3	-0,6	-4,2
135	-0,4	-0,5	-4,4
136	-0,4	-0,4	-4,2
137	-0,4	-0,4	-3,9
138	-0,4	-0,3	-3,9
139	0,4	-0,3	-3,6
140	0,5	-0,3	-3,6
141	0,5	-0,4	-4,1
142	0,3	-0,2	-2,3
143	0,3	-0,2	-2
144	0,3	-0,2	-1,6
145	0,2	-0,1	-0,7
146	0,1	0	-1,1
147	0,1	0	-0,9
148	0	0	-1,6
149	0	0	-1,7
150	0	0	-1,8
151	-0,1	0	-1,6
152	-0,2	0	-2
153	-0,2	-0,1	-1,8
154	-0,3	-0,2	-2,9
155	-0,3	-0,2	-3,1
156	-0,3	-0,2	-3,3
157	0	0	0
158	-0,1	-0,3	-3,2
159	-0,1	-1,2	-4,7
160	0,4	-0,8	-4,5
161	0	0	-4,7
162	0	0	0
163	0,1	-0,4	-3,1
164	0,1	-1,3	-4,8
165	0,4	-0,8	-4,7
166	0	0	-4,9
167	0	0	-5
168	0,5	-0,6	-4,8
169	0,4	-1,3	-4,9
170	0	-0,3	-3,1
171	0	0	0
172	0	0	0
173	0,1	-0,3	-3,3
174	0,6	-1	-5,1
175	0,4	-0,4	-4,9
176	0	0	-5,1
177	0	0	0
178	0,2	-0,3	-3,4
179	0,7	-0,6	-5,1
180	0,2	-0,2	-4,9
181	0	0	-5
182	0	0	0
183	0,2	-0,3	-3,2

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
92	80	100,72	-2,02	-16,26	0,33	-85,89	2,27
93	80	-106,73	4,3	-9,74	-0,07	86,75	5,1
93	81	-106,73	4,3	-16,04	-0,07	56,45	-5,01
94	81	95,46	-4,15	-9,05	0,21	-51,59	-4,45
94	82	95,46	-4,15	-14,8	0,21	-77,15	4,45
95	82	-121,48	4,54	-12,48	0,05	92,92	5,1
95	14	-121,48	4,54	-19,4	0,05	51,75	-6,61
96	14	40,82	-2,18	23,48	-0,14	-22,92	-3,62
96	83	40,82	-2,18	16,63	-0,14	28,35	1,96
97	83	-53,96	7,96	8,36	0,08	-23,7	9,57
97	84	-53,96	7,96	2,61	0,08	-11,93	-7,51
98	84	55,27	-3,53	5,34	-0,14	12,96	-3,8
98	85	55,27	-3,53	-0,89	-0,14	18,13	4,41
99	85	-57,15	4,49	2,52	0,09	-17,96	5,73
99	86	-57,15	4,49	-3,71	0,09	-19,33	-4,7
100	86	51,33	-5,9	-1,71	-0,14	17,87	-5,46
100	87	51,33	-5,9	-7,47	-0,14	8,01	7,22
101	87	-77,35	4,02	-27,72	0,09	-9,41	4,53
101	47	-77,35	4,02	-34,55	0,09	-88,78	-5,71
102	47	-245,35	0,96	-61,64	-0,23	23,3	1,69
102	41	-245,35	0,96	-67,1	-0,23	-107,78	-0,26
103	47	-9,19	-3,92	-6,1	0,08	46,74	-6,05
103	88	-9,19	-3,92	-13,1	0,08	21,7	4,18
104	88	-9,48	9,11	1,16	-0,11	-18,1	10,56
104	89	-9,48	9,11	-4,59	-0,11	-21,78	-8,98
105	89	5,98	-5,12	1,29	0,03	24,1	-5,85
105	90	5,98	-5,12	-5,07	0,03	19,62	6,3
106	90	-11,07	5,41	0,54	-0,07	-19,25	6,59
106	91	-11,07	5,41	-5,67	-0,07	-25,2	-5,96
107	91	8,18	-7,87	-6,48	0	23,66	-8,17
107	92	8,18	-7,87	-12,35	0	3,07	9,03
108	92	-20,61	6,14	-40,76	-0,02	-3,79	6,66
108	48	-20,61	6,14	-47,57	-0,02	-116,01	-8,95
109	48	-400,19	-9,06	-120,64	-0,14	45,98	-5,51
109	42	-400,19	-9,06	-126,16	-0,14	-208,07	13,14
110	43	-514,9	-6,37	-19,29	-0,13	33,08	-9,42
110	49	-514,9	-6,37	-24,92	-0,13	-13,33	3,95
111	44	-519,82	-1,79	6,87	-0,08	-7,81	-2,66
111	50	-519,82	-1,79	1,24	-0,08	0,7	1,11
112	45	-370,32	1,23	23,61	-0,03	-42,05	1,8
112	51	-370,32	1,23	18,09	-0,03	0,87	-0,73
113	46	-291,12	1,89	51,07	-0,01	-85,54	2,69
113	52	-291,12	1,89	45,62	-0,01	12,9	-1,15
114	48	11,23	-2,82	19,85	0,09	-18,17	-4,83
114	93	11,23	-2,82	12,8	0,09	24,76	2,58
115	93	-35,31	10,21	0,98	-0,08	-20,75	12,64
115	94	-35,31	10,21	-4,84	-0,08	-24,93	-9,53
116	94	33,68	-5	-1,06	-0,04	27,69	-5,56
116	95	33,68	-5	-7,53	-0,04	17,33	6,49
117	95	-36,04	5,69	0,25	0,05	-16,7	7,14
117	96	-36,04	5,69	-6,01	0,05	-23,41	-6,13
118	96	30,52	-7,1	-0,74	-0,14	22,53	-6,97
118	97	30,52	-7,1	-6,73	-0,14	14,19	8,87
119	97	-48,68	4,96	12,39	0,14	-15,86	5,94
119	49	-48,68	4,96	5,59	0,14	6,94	-6,62
120	49	-34,39	-2,59	-29,9	-0,08	104,48	-3,71
120	98	-34,39	-2,59	-36,78	-0,08	18,85	2,93
121	98	5,83	8,6	-5,09	0,07	-16,16	11,22
121	99	5,83	8,6	-11,04	0,07	-34,05	-7,85
122	99	-12,69	-5,59	-0,57	-0,18	36,71	-6,05
122	100	-12,69	-5,59	-6,95	-0,18	27,77	7,23
123	100	9,54	5,05	5,16	0,13	-27,52	6,58
123	101	9,54	5,05	-1,22	0,13	-22,83	-5,42
124	101	-13,17	-8,18	3,46	-0,18	21,48	-7,86
124	102	-13,17	-8,18	-2,49	-0,18	22,56	10,3
125	102	-3,66	4,12	12,24	0,12	-25,94	4,73
125	50	-3,66	4,12	5,36	0,12	-3,34	-5,84
126	50	-37,23	-3,78	-19,54	-0,06	64,89	-5,53
126	103	-37,23	-3,78	-26,34	-0,06	6,74	4,05

NODE	Ux (cm)	Uy (cm)	Uz (cm)
184	0,6	-0,1	-4,6
185	0	-0,4	-4,3
186	0	0	-4,3
187	0	0	-4,1
188	0,4	-0,9	-4,1
189	-0,3	-0,9	-4,3
190	-0,2	-0,2	-3,2
191	0	0	0
192	0	0	0
193	-0,1	0,2	-1,8
194	-0,2	-0,4	-2
195	-0,1	-0,9	-1,9
196	0	0	-1,6
197	0	0	0
198	0	0,1	-1,4
199	-0,1	-0,2	-1,5
200	0	-0,5	-1,5
201	0	0	-1,3
202	0	0	-1,1
203	-0,3	-0,2	-1,2
204	0,2	-0,1	-1,2
205	0,1	0,1	-1,1
206	0	0	0
207	0	0	0
208	0	0,1	-0,8
209	-0,1	0,2	-1
210	0,5	-0,4	-0,9
211	0	0	-0,9
212	0	0	0
213	0,2	0	-2,2
214	0,3	0,2	-3,1
215	0,2	-0,6	-2,9
216	0	0	-2,9
217	0	0	-3
218	0,2	-1,2	-3,2
219	-0,2	-0,4	-3,4
220	-0,2	-0,1	-2,8
221	0	0	0
222	0	0	0
223	0	0	0
224	0	0	0
225	0	0	0
226	0	0	0
227	-0,1	-0,7	-1,3
228	0	0	0
229	0	0	0
230	-0,1	0,1	-1,7
231	0	0	0
232	0	0	0
233	0	0	0

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
127	103	11,75	8,28	-1,96	0,06	-5,86	10,5
127	104	11,75	8,28	-7,95	0,06	-16,92	-8
128	104	-17,82	-5,96	0,1	-0,12	17,83	-6,57
128	105	-17,82	-5,96	-6,16	-0,12	10,76	7,33
129	105	14,76	4,9	4,9	0,1	-10,95	6,27
129	106	14,76	4,9	-1,56	0,1	-6,92	-5,55
130	106	-17,06	-9,3	2,93	-0,11	6,35	-9,05
130	107	-17,06	-9,3	-2,9	-0,11	6,38	11,14
131	107	-1,66	4,24	7,87	0,09	-7,65	4,47
131	51	-1,66	4,24	0,82	0,09	3,78	-6,67
132	51	-44,68	-5,06	-4,39	-0,06	27,6	-7,74
132	108	-44,68	-5,06	-11,2	-0,06	7,79	5,13
133	108	20,52	8,47	2,48	0,05	-6,67	9,97
133	109	20,52	8,47	-3,38	0,05	-7,66	-8,55
134	109	-25,62	-5,92	1,92	-0,08	8,21	-6,74
134	110	-25,62	-5,92	-4,29	-0,08	5,46	6,99
135	110	22,18	5,04	4,77	0,07	-5,48	6,04
135	111	22,18	5,04	-1,59	0,07	-1,71	-5,92
136	111	-23,05	-10,05	1,96	-0,06	1,61	-10
136	112	-23,05	-10,05	-3,79	-0,06	-0,36	11,57
137	112	3,45	4,67	-0,74	0,05	0,41	4,32
137	52	3,45	4,67	-7,73	0,05	-10,64	-7,86
138	52	-10,91	-5,46	8,11	-0,04	-2,43	-8,79
138	113	-10,91	-5,46	1,27	-0,04	9,52	5,12
139	113	-8,15	9,41	4,35	0,03	-8,05	10,6
139	114	-8,15	9,41	-1,41	0,03	-4,89	-9,61
140	114	6,28	-5,35	2,65	-0,06	5,32	-6,24
140	115	6,28	-5,35	-3,58	-0,06	4,24	6,18
141	115	-10,4	5,58	3,98	0,04	-4,18	6,49
141	116	-10,4	5,58	-2,26	0,04	-2,18	-6,49
142	116	6,93	-9,42	1,03	-0,04	2,04	-9,47
142	117	6,93	-9,42	-4,72	-0,04	-1,92	10,74
143	117	-31,78	5,13	-3,02	0,04	2,24	4,77
143	5	-31,78	5,13	-9,87	0,04	-14,23	-8,35
144	24	-1760,56	7,53	-31,11	0,06	61,07	11,35
144	37	-1760,56	7,53	-36,7	0,06	-9,62	-4,35
145	23	-1624,26	-3,74	30,84	-0,01	-42,6	-4,72
145	36	-1624,26	-3,74	25,28	-0,01	15,58	3,04
146	36	-151,66	-16,28	6,15	0	-3,66	-24,85
146	118	-151,66	-16,28	-0,81	0	3,26	17,38
147	118	64,9	31,71	3,39	0,03	-2,86	40,6
147	119	64,9	31,71	-2,71	0,03	-2,09	-31,49
148	119	-84,06	-32,95	5,38	-0,05	2,21	-32,84
148	120	-84,06	-32,95	-0,76	-0,05	7,51	42,71
149	120	7,29	15,2	29,1	0,04	-8,28	15,15
149	37	7,29	15,2	22,21	0,04	57,6	-23,88
150	25	-1608,5	27,43	-28,59	0,08	45,34	39,79
150	38	-1608,5	27,43	-34,15	0,08	-19,72	-17,1
151	17	-1753,25	-4,55	-16,33	-0,07	41,47	-6,75
151	30	-1753,25	-4,55	-21,91	-0,07	1,62	2,74
152	31	-1753,56	8,58	2,86	0,05	1,73	5,66
152	18	-1753,56	8,58	-2,72	0,05	1,88	-12,21
153	19	-1523,83	15,18	64,27	0,09	-99,18	21,74
153	32	-1523,83	15,18	58,75	0,09	27,5	-9,52
154	20	-1312,33	10,65	114,77	0,06	-179,88	15,21
154	33	-1312,33	10,65	109,29	0,06	49,08	-6,57
155	34	-1269,93	2,15	-126,02	0	57,44	1,18
155	21	-1269,93	2,15	-131,49	0	-205,36	-3,2
156	35	-1410,55	-5,22	-79,09	-0,05	37,3	-3,57
156	22	-1410,55	-5,22	-84,59	-0,05	-130,61	7,14
157	36	-36,23	17,52	7,51	-0,03	-30,79	26,26
157	121	-36,23	17,52	0,67	-0,03	-20,36	-18,45
158	121	-36,58	-32,07	4,87	0,02	18,16	-41,3
158	122	-36,58	-32,07	-1,27	0,02	22,27	32,1
159	122	20,43	33,71	2,26	-0,09	-21,94	33,01
159	123	20,43	33,71	-3,76	-0,09	-23,61	-42,7
160	123	-109,33	-16,8	-19,1	0,08	27,19	-17,83
160	35	-109,33	-16,8	-26,09	0,08	-31,77	26,01
161	35	-60,69	18,79	30,98	-0,09	-83,07	28,31

NODE	Rx (rad)	Ry (rad)	Rz (rad)
1	-0,001	-0,001	0,000
2	-0,001	-0,001	0,000
3	-0,001	-0,000	0,000
4	-0,001	-0,001	0,000
5	-0,002	0,000	0,000
6	-0,001	0,000	0,000
7	0,001	-0,001	0,000
8	0,001	-0,001	0,000
9	0,002	0,000	0,000
10	0,003	0,000	-0,000
11	0,002	0,002	0,000
12	0,002	0,001	0,000
13	0,000	-0,001	0,000
14	0,001	-0,001	0,000
15	0,000	0,001	0,000
16	0,003	-0,002	-0,001
17	0,001	-0,001	-0,000
18	0,001	-0,001	0,000
19	0,001	-0,001	0,000
20	0,002	-0,001	0,000
21	0,003	0,001	0,000
22	0,002	0,001	-0,000
23	0,001	0,002	-0,000
24	0,001	0,001	0,000
25	0,002	0,002	0,001
26	0,002	0,002	0,001
27	-0,000	-0,002	-0,001
28	0,001	-0,000	-0,000
29	0,002	-0,001	0,000
30	0,001	-0,001	0,000
31	0,001	-0,001	-0,000
32	0,001	-0,001	-0,000
33	0,002	-0,001	-0,000
34	0,002	0,000	0,000
35	0,002	0,001	0,000
36	0,001	0,002	0,000
37	0,001	0,002	0,000
38	0,002	0,002	0,000
39	0,002	0,001	-0,000
40	0,000	-0,001	-0,000
41	0,001	0,000	0,000
42	0,002	-0,000	0,000
43	0,002	0,001	0,000
44	0,000	0,001	-0,000
45	-0,001	0,001	0,000
46	-0,001	0,000	0,000
47	0,001	0,000	0,000
48	0,002	-0,000	0,000
49	0,002	0,001	0,000
50	0,000	0,001	0,000
51	-0,001	0,001	-0,000
52	-0,001	0,001	0,000
53	-0,001	-0,000	0,000
54	-0,002	-0,000	0,000
55	-0,001	-0,000	0,000
56	-0,001	-0,000	0,000
57	-0,001	-0,000	0,000
58	-0,001	-0,001	0,000
59	-0,001	-0,001	0,000
60	-0,001	-0,001	0,000
61	-0,001	-0,001	0,000
62	-0,001	-0,001	0,000
63	-0,000	-0,001	0,000
64	0,000	-0,001	0,000
65	0,000	-0,001	0,000
66	0,001	-0,001	0,000
67	0,001	-0,001	0,000
68	0,001	-0,001	0,000
69	0,002	-0,001	0,000

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
161	124	-60,69	18,79	24,14	-0,09	-12,71	-19,66
162	124	-16,14	-32,78	5,88	0,08	10,98	-41,5
162	125	-16,14	-32,78	-0,17	0,08	17,42	32,5
163	125	4,96	33,68	0,29	-0,14	-17,46	33,13
163	126	4,96	33,68	-5,7	-0,14	-23,5	-42,15
164	126	-86,72	-18,61	-37,66	0,12	26,79	-19,62
164	34	-86,72	-18,61	-44,59	0,12	-79,5	28,48
165	34	-82,13	17,99	42,91	-0,13	-88,2	27,64
165	127	-82,13	17,99	36,03	-0,13	13,13	-18,54
166	127	-6,14	-33,78	5,13	0,14	-11,81	-42,58
166	128	-6,14	-33,78	-0,86	0,14	-7,03	32,97
167	128	-3,93	32,96	-1,27	-0,11	6,8	32,87
167	129	-3,93	32,96	-7,29	-0,11	-2,8	-41,05
168	129	-66,62	-20,08	-36,65	0,1	2,85	-21,18
168	33	-66,62	-20,08	-43,51	0,1	-99,71	30,2
169	33	-91,95	16,36	33,75	-0,11	-46,1	25,66
169	130	-91,95	16,36	26,79	-0,11	32,52	-16,81
170	130	-4,58	-34,47	3,29	0,14	-28,33	-43,79
170	131	-4,58	-34,47	-2,71	0,14	-27,68	33,33
171	131	-8,15	31,95	-1,52	-0,03	27,93	32,32
171	132	-8,15	31,95	-7,6	-0,03	17,58	-40,21
172	132	-54,9	-20,25	-19,86	0,05	-19,94	-21,65
172	32	-54,9	-20,25	-26,7	0,05	-79,34	30,01
173	32	-92,49	14,77	13,17	-0,06	-2	23,29
173	133	-92,49	14,77	6,17	-0,06	23,23	-15,25
174	133	-3,99	-34,36	1,34	0,05	-20,22	-44,18
174	134	-3,99	-34,36	-4,7	0,05	-24	33,23
175	134	-13,53	31,49	0,19	0,04	24,47	31,82
175	135	-13,53	31,49	-5,97	0,04	17,82	-40,52
176	135	-53,44	-18,06	5,52	-0,03	-19,74	-19,38
176	31	-53,44	-18,06	-1,32	-0,03	-14,39	26,68
177	31	-118,94	15,07	-6,76	0,02	35,35	23,01
177	136	-118,94	15,07	-13,66	0,02	9,07	-15,79
178	136	29,95	-32,15	2,56	-0,03	-7,99	-41,78
178	137	29,95	-32,15	-3,56	-0,03	-9,14	31,65
179	137	-49,54	32,99	5,57	0,06	9,27	32,84
179	138	-49,54	32,99	-0,55	0,06	15	-42,51
180	138	-25,62	-15,67	28,67	-0,03	-16,83	-16,12
180	30	-25,62	-15,67	21,77	-0,03	48,07	24,2
181	38	-122,13	12,17	-18,84	0,07	68,79	19,87
181	139	-122,13	12,17	-25,8	0,07	10,89	-11,7
182	139	13,07	-33,46	-0,33	-0,08	-9,39	-43,83
182	140	13,07	-33,46	-6,43	-0,08	-17,07	32,24
183	140	-32,73	31,91	2,63	0,14	17,41	32,71
183	141	-32,73	31,91	-3,52	0,14	16,39	-40,44
184	141	-28,48	-17,91	19,82	-0,11	-18,09	-18,64
184	37	-28,48	-17,91	12,94	-0,11	23,98	27,35
185	16	-1272,77	-30,89	40,91	0,73	-43,31	-46,55
185	29	-1272,77	-30,89	35,39	0,73	35,27	17,09
186	15	-1161,9	21,94	55,51	-0,56	-111,25	27,63
186	28	-1161,9	21,94	50,03	-0,56	-3,39	-17,21
187	40	-1252,19	-28,64	-37,08	0,24	-21,17	-20,15
187	27	-1252,19	-28,64	-42,55	0,24	-102,44	38,32
188	39	-1116,03	38,7	-254,95	-0,63	159,36	20,45
188	26	-1116,03	38,7	-260,45	-0,63	-369,35	-58,93
189	38	-24,87	-21,62	1,19	-0,08	16,56	-31,59
189	142	-24,87	-21,62	-5,65	-0,08	10,87	23,58
190	142	-16,37	30,97	-2,56	-0,01	-9,6	38,26
190	143	-16,37	30,97	-8,69	-0,01	-22,47	-32,62
191	143	-2,61	-34,39	-5,97	-0,01	21,68	-32,04
191	144	-2,61	-34,39	-11,99	-0,01	1,51	45,18
192	144	-124,24	8,9	-134,72	-0,09	-1,91	8,62
192	39	-124,24	8,9	-141,72	-0,09	-362,59	-14,61
193	39	-362,76	-23,39	-1,07	0,7	-121,11	-31,31
193	145	-362,76	-23,39	-7,92	0,7	-132,58	28,39
194	145	307,77	18,76	-11,42	-0,33	115,62	23,26
194	146	307,77	18,76	-17,47	-0,33	83,01	-19,1
195	146	-304,96	-28,39	-18,64	0,48	-82,4	-28,22
195	147	-304,96	-28,39	-24,63	0,48	-130,76	35,23

NODE	Rx (rad)	Ry (rad)	Rz (rad)
70	0,002	-0,000	0,000
71	0,002	-0,000	-0,000
72	0,002	-0,000	-0,000
73	0,002	0,001	-0,000
74	0,003	0,001	-0,000
75	0,002	0,001	-0,000
76	0,003	0,002	-0,000
77	0,002	0,001	-0,000
78	0,002	-0,000	0,000
79	0,002	-0,000	0,000
80	0,002	-0,001	0,000
81	0,001	-0,001	0,000
82	0,001	-0,001	0,000
83	0,000	-0,001	0,000
84	0,001	-0,001	0,000
85	0,001	-0,000	0,000
86	0,001	-0,000	0,000
87	0,001	0,000	0,000
88	0,001	0,000	0,000
89	0,001	0,000	0,000
90	0,001	0,000	0,000
91	0,002	-0,000	0,000
92	0,002	0,000	0,000
93	0,002	-0,000	0,000
94	0,002	-0,000	0,000
95	0,002	0,000	0,000
96	0,002	0,000	0,000
97	0,002	0,000	0,000
98	0,002	0,001	0,000
99	0,002	0,001	0,000
100	0,001	0,001	0,000
101	0,001	0,001	0,000
102	0,001	0,001	-0,000
103	0,000	0,001	0,000
104	-0,000	0,001	0,000
105	-0,000	0,001	-0,000
106	-0,001	0,001	-0,000
107	-0,001	0,001	-0,000
108	-0,001	0,001	0,000
109	-0,001	0,001	0,000
110	-0,001	0,001	0,000
111	-0,001	0,001	0,000
112	-0,001	0,001	-0,000
113	-0,001	0,000	0,000
114	-0,001	0,000	0,000
115	-0,001	0,000	0,000
116	-0,001	0,000	0,000
117	-0,001	0,000	0,000
118	0,001	0,002	0,000
119	0,001	0,002	0,000
120	0,001	0,002	-0,000
121	0,001	0,002	-0,000
122	0,001	0,002	0,000
123	0,001	0,001	0,000
124	0,002	0,001	-0,000
125	0,002	0,001	0,000
126	0,002	0,001	0,000
127	0,002	0,000	-0,000
128	0,002	-0,000	-0,000
129	0,002	-0,000	0,000
130	0,002	-0,001	-0,000
131	0,002	-0,001	-0,000
132	0,001	-0,001	0,000
133	0,001	-0,001	-0,000
134	0,001	-0,001	-0,000
135	0,001	-0,001	0,000
136	0,001	-0,001	-0,000
137	0,001	-0,001	0,000
138	0,001	-0,001	0,000

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
196	147	304	17,29	-14,86	-0,08	150,8	18,42
196	40	304	17,29	-21,78	-0,08	103,46	-26,25
197	40	-25,53	-9,03	38,74	-0,22	-65,25	-15,94
197	148	-25,53	-9,03	31,86	-0,22	25,38	7,25
198	148	-61,03	28,23	2,99	0,19	-21,81	37,04
198	149	-61,03	28,23	-3,01	0,19	-21,83	-26,11
199	149	50,66	-26,11	-6,58	-0,28	21,77	-24,45
199	150	50,66	-26,11	-12,6	-0,28	0,26	34,12
200	150	-138,57	11,13	-60,03	0,29	0,26	10,35
200	28	-138,57	11,13	-66,89	0,29	-162,14	-18,13
201	28	196,78	-17,13	-20,72	0,2	172,92	-26,34
201	151	196,78	-17,13	-27,68	0,2	110,07	18,13
202	151	-219,66	30,28	14,29	-0,42	-95,41	37,2
202	152	-219,66	30,28	8,29	-0,42	-70,15	-30,56
203	152	217,38	-23,29	12,21	0,24	71,32	-24,21
203	153	217,38	-23,29	6,12	0,24	92,13	28,66
204	153	-278,01	22,93	79,67	-0,46	-104,7	26,38
204	29	-278,01	22,93	72,83	-0,46	89,87	-32,14
205	29	-95,86	-11,08	91,52	-0,27	-193,61	-18,28
205	154	-95,86	-11,08	84,53	-0,27	36,05	10,63
206	154	-14,95	35,07	15,19	0,22	-30,45	45,37
206	155	-14,95	35,07	9,15	0,22	-3,04	-33,64
207	155	-5,97	-32,25	16,47	-0,19	3,02	-33,05
207	156	-5,97	-32,25	10,31	-0,19	33,78	41,06
208	156	-64,23	17,77	19,8	0,11	-37,21	18,39
208	30	-64,23	17,77	12,97	0,11	4,57	-26,93
209	157	3911,23	-5,36	966,93	0,28	-301,72	-21,2
209	158	3908,99	-5,36	948,95	0,28	3327,06	-0,91
210	158	3908,89	-5,27	-501,93	-0,07	3327,06	-0,92
210	19	3901,24	-5,27	-518,61	-0,07	1369,22	19,32
211	19	995,38	-12,85	-36,12	-0,71	1253,78	-58,14
211	159	978,87	-12,85	-52,81	-0,71	1035,48	4,95
212	159	603,16	-12,85	-578,12	1,68	1035,48	4,71
212	160	266,69	12,08	136,81	-2,28	-243,91	3,24
213	160	61,44	-12,08	-28,36	0,37	243,91	-3,93
213	161	31,02	-12,08	-41,24	0,37	3,57	79,47
214	162	3512,08	13,45	1009,44	-4,63	-307,84	-16,91
214	163	3509,85	13,45	992,45	-4,63	3278,25	-65,11
215	163	3526,38	-21,94	-458,26	4,77	3278,03	-75,55
215	20	3518,73	-21,94	-473,29	4,77	1635,58	1,81
216	20	955,65	-13,72	-44,8	-0,67	1436,01	-58,34
216	164	939,14	-13,72	-59,28	-0,67	1197	4,69
217	164	584,63	-13,7	-522,23	1,38	1197	4,57
217	165	282,35	8,25	103,42	-1,64	-56,86	2,86
218	165	54,19	-8,25	-2,09	0,4	56,86	-3,27
218	166	23,77	-8,25	-13,58	0,4	3,61	52,82
219	167	21,91	-5,58	6,59	0,38	6,57	-35,28
219	168	52,33	-5,58	-4,65	0,38	13,15	2,59
220	168	286,2	5,58	-93,28	-1,2	-13,15	-2,32
220	169	575,04	-6,19	519,35	0,29	1262,63	-1,03
221	169	931,39	-6,19	58,95	-0,18	1262,63	-1,05
221	21	947,9	-6,19	44,67	-0,18	1499,07	27,2
222	21	3446,01	2,02	456,79	-0,17	1729,54	8,08
222	170	3453,66	2,02	442,08	-0,17	3287,89	1,08
223	170	3430,94	1,96	-1007,55	0,26	3287,89	1,08
223	171	3433,17	1,96	-1024,33	0,26	-309,01	-5,87
224	172	3707,79	6,12	993,77	0,19	-314,61	21,72
224	173	3705,56	6,12	976,25	0,19	3323,32	-0,89
225	173	3715,67	6,21	-471,08	-0,18	3323,32	-0,87
225	22	3708,02	6,21	-486,98	-0,18	1556,23	-23,79
226	22	984,14	-1,24	-34,68	0,2	1403,19	-7,39
226	174	967,63	-1,24	-50,38	0,2	1200,55	-1,49
227	174	600,82	-1,21	-554,16	-0,51	1200,55	-1,37
227	175	278,92	2,09	112,13	-0,62	-101,81	1,25
228	175	56,01	-2,09	-7,03	0,29	101,81	-1,36
228	176	25,6	-2,09	-19,23	0,29	11,84	12,99
229	177	4225,17	7,03	941,09	-0,05	-310,05	26,89
229	178	4222,93	7,03	922,46	-0,05	3345,18	-0,67
230	178	4213,3	6,99	-534,1	-0,21	3345,18	-0,64

NODE	Rx (rad)	Ry (rad)	Rz (rad)
139	0,002	0,002	-0,000
140	0,002	0,002	0,000
141	0,002	0,002	0,000
142	0,002	0,002	0,000
143	0,002	0,002	0,000
144	0,002	0,002	-0,000
145	0,002	-0,001	0,000
146	0,001	-0,001	-0,000
147	0,001	-0,002	-0,000
148	-0,000	-0,001	0,000
149	0,000	-0,001	-0,000
150	-0,000	-0,000	-0,000
151	0,001	0,001	0,000
152	0,002	-0,000	-0,000
153	0,003	-0,000	-0,000
154	0,002	-0,002	0,000
155	0,002	-0,001	-0,000
156	0,001	-0,001	-0,000
157	0,006	-0,007	0,000
158	0,005	-0,005	0,000
159	-0,001	0,001	0,002
160	-0,001	-0,000	0,002
161	0,000	0,000	0,001
162	0,009	-0,003	0,000
163	0,004	-0,008	0,002
164	-0,001	0,000	0,002
165	-0,001	-0,000	0,002
166	-0,001	0,000	0,000
167	-0,001	0,000	0,000
168	-0,001	-0,000	0,001
169	-0,001	0,000	0,001
170	0,007	0,001	-0,000
171	0,010	0,001	-0,000
172	0,008	0,006	-0,000
173	0,006	0,004	-0,000
174	-0,001	0,000	-0,000
175	-0,001	-0,000	0,001
176	-0,001	-0,000	0,000
177	0,004	0,009	-0,000
178	0,003	0,006	-0,001
179	-0,001	-0,001	0,000
180	-0,001	-0,000	-0,000
181	0,000	-0,000	-0,000
182	-0,000	0,009	-0,000
183	-0,006	0,006	-0,002
184	0,000	-0,001	0,001
185	-0,000	-0,000	-0,002
186	0,001	0,000	-0,000
187	0,001	-0,000	0,001
188	-0,001	0,000	0,003
189	0,000	0,001	0,001
190	0,002	-0,005	0,000
191	0,002	-0,009	0,000
192	-0,004	-0,004	-0,000
193	0,000	-0,004	-0,001
194	0,001	0,000	-0,002
195	-0,001	0,000	0,004
196	0,000	-0,001	0,001
197	-0,004	-0,002	0,000
198	-0,001	-0,005	-0,001
199	0,001	0,000	0,001
200	-0,000	0,000	0,000
201	-0,001	-0,000	-0,000
202	-0,001	-0,000	0,001
203	-0,000	-0,000	0,002
204	0,001	-0,001	-0,002
205	-0,002	-0,001	-0,001
206	-0,004	0,001	-0,000
207	-0,002	0,001	0,000

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
230	23	4205,65	6,99	-551,96	-0,21	1139,58	-29,02
231	23	1198,11	-4,98	38,96	0,01	1078,37	-25,71
231	179	1181,6	-4,98	20,7	0,01	1231,93	-0,07
232	179	656,01	-5	-686,94	-0,02	1231,93	-0,09
232	180	261,29	-3,98	147,11	0,59	-283,16	-0,46
233	180	63,5	3,98	-30,78	0,11	283,16	0,74
233	181	33,08	3,98	-44,74	0,11	18,92	-27,08
234	182	4509,86	-11,85	895,38	4,18	-289,53	19,76
234	183	4507,63	-11,85	876,25	4,18	3277,58	67,5
235	183	4483,83	26,97	-589,11	-4,91	3277,42	74,9
235	24	4476,18	26,97	-607,93	-4,91	735,2	-39,67
236	24	1234,5	-22,89	63,46	0,12	802,99	-95,05
236	184	1217,99	-22,89	43,84	0,12	1090,66	27,65
237	184	693,91	9,26	-708,36	0,51	1089,34	60,34
237	185	264,95	-12,14	178,24	2,39	-363,5	-7,94
238	185	87,63	10,31	-42,23	-0,24	363,59	-0,61
238	186	57,21	10,31	-57,14	-0,24	11,66	-73,61
239	187	61,48	-15,59	73,41	0,38	-9,74	-105,26
239	188	91,89	-15,59	58,84	0,38	456,59	4,66
240	188	258,26	15,58	-190,89	-3,03	-456,59	-3,53
240	189	681,87	-4,2	650,77	0,8	862,97	-2,11
241	189	1077,35	-4,19	41,11	-0,35	862,97	-2,24
241	18	1093,87	-4,19	21,98	-0,35	1029,66	19,89
242	18	4361,63	-4,71	569	0,01	1028,33	-18,02
242	190	4369,29	-4,71	550,52	0,01	3368,95	1,66
243	190	4383,66	-4,75	-906,28	0,5	3368,95	1,6
243	191	4385,9	-4,75	-925,24	0,5	-285,68	20,56
244	192	2972,84	2,9	777,54	2,05	-167,1	6,83
244	193	2970,6	2,9	759,56	2,05	2744,25	-4,15
245	193	2957,09	2,9	-399,34	0,7	2744,25	-4,58
245	16	2949,44	2,9	-416,02	0,7	1180,01	-15,7
246	16	1038,17	30,23	96,58	-0,85	11,13	147,04
246	194	1021,65	30,23	79,89	-0,85	444,33	-1,35
247	194	702,85	30,22	-480,64	-1,38	444,33	-0,8
247	195	292,7	14,54	219,98	-3,52	-496,78	5,35
248	195	135,22	-14,53	-74,72	0,79	496,78	-6,35
248	196	104,81	-14,53	-87,6	0,79	-63,78	94,03
249	197	3378,24	-18,71	794,11	2,94	-155,2	-10,71
249	198	3376,01	-18,71	777,12	2,94	2659,42	56,32
250	198	3328,42	15,58	-616,62	-3,47	2659,23	64,86
250	15	3320,77	15,58	-631,65	-3,47	458,35	9,93
251	15	859,93	-13,03	37,89	0,07	234,59	-58,92
251	199	843,42	-13,03	23,4	0,07	375,34	0,91
252	199	533,14	-13,04	-406,7	0,45	375,34	0,78
252	200	263,8	2,66	169,11	-0,02	-470,8	0,14
253	200	78,67	-2,66	-65,8	0,08	470,8	-0,15
253	201	48,25	-2,66	-77,29	0,08	-15,61	17,94
254	202	-15,6	-6	44,61	0,58	11,01	-36,32
254	203	14,82	-6	33,36	0,58	275,34	4,33
255	203	233,54	6	-102,26	-2,06	-275,34	-3,87
255	204	317,79	24,9	285,58	-2,04	309,84	5,01
256	204	598,72	24,89	-41,87	0,31	309,84	5,4
256	27	615,24	24,89	-56,14	0,31	86,2	-108,21
257	27	2760,72	5,1	596,67	0,3	132,91	20,28
257	205	2768,37	5,1	581,95	0,3	2176,32	2,58
258	205	2834,16	5,16	-642,75	1,12	2176,32	2,32
258	206	2836,4	5,16	-659,54	1,12	-129,03	-15,95
259	207	862,83	0,88	402,12	-1,41	-39,18	3,89
259	208	860,59	0,88	384,6	-1,41	1413,58	0,64
260	208	829,62	0,85	-132,58	-1,09	1413,58	1,02
260	26	821,97	0,85	-148,48	-1,09	895,17	-2,1
261	26	207,76	-47,99	346,75	-1,51	-1186,64	-215,61
261	209	191,25	-47,99	331,05	-1,51	428,05	13,02
262	209	80,78	-47,99	137,07	4,53	428,05	12,31
262	210	364,04	-15,91	213,94	5,61	-154,41	-9,34
263	210	186,02	15,91	-33,63	-1,44	154,41	10,8
263	211	155,6	15,91	-45,83	-1,44	-117,84	-98,23
264	212	4008,64	3,58	788,69	-1,19	-232,11	14,95
264	213	4006,4	3,58	770,06	-1,19	2825,3	0,91

NODE	Rx (rad)	Ry (rad)	Rz (rad)
208	-0,000	0,002	0,000
209	0,001	0,002	0,006
210	0,000	0,000	-0,005
211	0,001	0,001	-0,001
212	-0,003	0,006	-0,000
213	-0,000	0,004	-0,000
214	0,002	0,000	0,004
215	-0,000	-0,000	-0,004
216	0,002	0,002	-0,001
217	0,001	-0,001	0,001
218	-0,001	0,000	0,004
219	0,002	0,001	-0,001
220	-0,000	-0,005	0,000
221	-0,002	-0,008	0,000
222	0,0	0,0	0,0
223	0,0	0,0	0,0
224	0,001	0,003	-0,001
225	0,0	0,0	0,0
226	0,0	0,0	0,0
227	0,001	-0,000	0,000
228	0,0	0,0	0,0
229	0,006	-0,002	0,001
230	0,000	0,001	0,000
231	0,009	0,004	-0,001
232	0,0	0,0	0,0
233	0,007	-0,002	0,001

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
265	213	3962,61	3,62	-619,34	-0,92	2825,3	1,22
265	25	3954,96	3,62	-637,2	-0,92	273,5	-13,48
266	25	1003,97	-34,03	103,32	-1,03	354,39	-165,68
266	214	987,46	-34,03	85,05	-1,03	839,24	9,5
267	214	517,31	-34,02	-536,63	3,7	839,23	8,83
267	215	219,99	-21,15	106,24	4,49	-321,41	-5,62
268	215	5,4	21,15	-29,63	-0,62	321,41	7,16
268	216	-25,01	21,15	-43,59	-0,62	65,21	-140,85
269	217	43,36	-19,64	89,27	0,73	9,14	-131,52
269	218	73,78	-19,64	74,71	0,73	587,31	6,98
270	218	234,25	19,64	-189,18	-4,44	-587,31	-5,41
270	219	588,15	8,26	628,58	-1,31	599,08	3,53
271	219	984,86	8,33	67,97	0,56	599,08	3,68
271	17	1001,38	8,33	48,84	0,56	907,69	-40,36
272	17	4354,15	-3,35	588,75	0,28	880,68	-12,87
272	220	4361,8	-3,35	570,27	0,28	3303,9	1,15
273	220	4381,83	-3,52	-885,23	0,71	3303,9	1,04
273	221	4384,07	-3,52	-904,18	0,71	-266,68	15,08
274	187	0	6,8	-2,01	0,15	43,04	25,55
274	217	0	6,8	-23,43	0,15	-58,57	-28,8
275	196	0	6,81	43,84	0,09	-195	24,55
275	217	0	6,81	22,88	0,09	65,74	-28,66
276	196	0	2,28	18,52	0,06	-114,44	12,84
276	201	0	2,28	-1,24	0,06	-50,76	-3,99
277	201	0	1,74	16,58	-0,04	-34,82	2,42
277	202	0	1,74	-2,39	-0,04	15,39	-9,91
278	202	0	-1,02	-32,49	-0,13	49,47	3,23
278	211	0	-1,02	-51,81	-0,13	-254,41	10,61
279	211	0	-7,7	75,53	-0,09	-333,69	-27,3
279	216	0	-7,7	55,02	-0,09	165,6	31,56
280	216	0	-6,13	14,11	-0,13	26,77	-27,75
280	186	0	-6,13	-7,26	-0,13	54,05	21,11
281	186	0	-2,51	18,95	-0,12	-15,2	-11,51
281	181	0	-2,51	-2,41	-0,12	50,72	8,54
282	181	0	-0,29	8,99	-0,11	27,06	-2,66
282	176	0	-0,29	-11,52	-0,11	17,4	-0,48
283	176	0	1,39	5,08	-0,04	30,84	4,63
283	167	0	1,39	-14,25	-0,04	-2,21	-5,42
284	167	0	2,14	4,02	0,04	31,52	7,17
284	166	0	2,14	-14,95	0,04	-7,13	-8
285	166	0	3,34	2,49	0,12	42,75	11,04
285	161	0	3,34	-17,27	0,12	-11,74	-13,58
286	191	0	7,05	-7,53	-0,16	-594,87	9,98
286	157	0	7,05	-15,23	-0,16	-627,56	-10,26
287	157	0	7,5	-1,12	-0,1	-624,99	10,74
287	162	0	7,5	-8,92	-0,1	-639,59	-11,07
288	162	0	2,53	2,82	-0,05	-646,35	6,29
288	171	0	2,53	-4,78	-0,05	-649,12	-0,89
289	171	0	-5,49	1,85	-0,02	-650,13	-6,74
289	172	0	-5,49	-5,85	-0,02	-655,86	9,03
290	172	0	-9,15	8,36	0,07	-658,51	-12,54
290	177	0	-9,15	0,66	0,07	-645,55	13,75
291	177	0	-8,31	19,09	0,29	-648,99	-12,94
291	182	0	-8,31	11,39	0,29	-605,22	10,93
292	182	0	-6,5	45,73	0,87	-602,28	-9,19
292	212	0	-6,5	38,03	0,87	-482,02	9,47
293	212	0	-2,07	143,58	1,41	-485,64	-5,23
293	207	0	-2,07	135,89	1,41	-84,34	0,7
294	207	0	-4,44	-60,41	-0,36	-86,55	-2,97
294	206	0	-4,44	-68,11	-0,36	-271,1	9,77
295	206	0	-0,63	-15,81	-0,4	-271,73	-6,19
295	197	0	-0,63	-23,41	-0,4	-327,33	-4,41
296	197	0	0,98	-5,84	-0,33	-320,52	5,83
296	192	0	0,98	-13,64	-0,33	-348,85	2,98
297	192	0	-0,07	-69,47	-0,84	-347,07	-4,05
297	221	0	-0,07	-77,17	-0,84	-557,64	-3,84
298	221	0	7,46	-11,2	-0,38	-554,79	11,06
298	191	0	7,46	-18,9	-0,38	-598	-10,38
299	187	0	4,86	25,74	0,16	-56,73	20,27

BAR	NODE	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kN)	My (kN)	Mz (kN)
299	161	0	4,86	4,79	0,16	62,57	-17,74
301	228	0	0	0	0	0	0
301	42	0,01	0	-10,08	0	-18,94	0
303	230	-1016,85	-8,44	601,69	1,81	-0,72	-5,65
303	11	-1016,84	-8,44	595,95	1,81	1280,04	12,41
305	16	-680,34	16,46	-477,49	-2,22	1483,81	25,24
305	232	-680,34	16,46	-485,76	-2,22	-1,72	-25,54
307	234	-1593,74	-39,23	995,13	2,81	-1,21	-30,48
307	26	-1593,74	-39,23	990,27	2,81	1795,68	40,53
308	230	-71,09	0,91	16,55	-0,72	-1,81	5,65
308	13	-71,08	0,91	-4,17	-0,72	46,05	-1,38
309	41	436,07	1,92	-22,88	0	236,21	13,93
309	225	436,06	1,92	-42,31	0	0	0
310	232	1415,19	-7,05	96,11	1,72	-2,22	-25,54
310	15	1395,57	-234,99	81,59	78,8	472,36	13,74
311	234	786,94	6,57	19,45	-1,21	-2,81	30,48
311	27	786,94	6,57	3,75	-1,21	65,13	-8,01

Roof structure - axial forces

Here it follows a table containing the axial forces, which had to be verified by the chosen profiles. They are presented for each bar, which is then divided in two nodes. The forces in each bar are the same for both nodes, except for the ones with any type of constraints to the ground. This is due to the absence of any variable loads, which would have created a difference between the two sides of the same bar. The difference between two same nodes of different bars is due to the presence of concentrated loads applied to the nodes, which has to be counterbalanced by the difference of the two bar loads.

BAR	NODE	Fx (kN)
1	1	1806,77
1	2	2221,99
2	3	0
2	2	3209,58
3	3	0
3	4	0
4	4	0
4	1	2236,9
5	5	-596,18
5	6	-369,73
6	7	-638,19
6	8	-230,69
7	10	-215,18
7	9	0
8	11	-581,77
8	12	-214,87
9	13	-288,06
9	14	-126,67
10	15	259,12
10	16	494,7
11	17	3237,01
11	18	5411,23
12	20	-62,89
12	19	123,56
13	21	0
13	22	0
14	23	-411,85
14	24	-37
15	25	1075,81
15	26	5531,41
16	27	0
16	28	556,18
17	29	-850,71
17	30	-44,42
18	31	-741,41
18	32	-103,4
19	33	-584,77
19	34	-76,23
20	35	-426,87
20	36	-73,84
21	37	-304,36
21	38	-232,83
22	39	-408,78
22	40	-338,87
23	41	-218,47
23	42	-95,83
24	43	-149,58
24	44	-11,62
25	45	-119,42
25	46	10,08
26	47	-85,71
26	48	-0,16
27	50	-30,24
27	49	30,61
28	52	-55,8
28	51	665,55
29	54	75,23
29	53	5542,33
30	55	0
30	56	0
31	57	-281,01
31	58	4553,63
32	59	-448,56
32	60	-45,22
33	62	-653,27
33	61	-621,62
34	63	2313,36
34	64	2727,81
35	65	-394,74
35	66	-228,24
36	68	-572,13
36	67	0
37	69	-561,64
37	70	0
38	71	-503,57
38	72	-378,84
39	1	1720,46
39	73	1720,46
40	6	522,87
40	74	522,87
41	8	326,24
41	75	326,24
42	10	304,32
42	76	304,32
43	12	303,87
43	77	303,87
44	14	179,14
44	78	179,14
45	16	-699,61
45	79	-699,61
46	18	1899,76
46	80	1899,76
47	20	88,94
47	81	88,94
48	81	52,32
48	24	52,32
49	82	1895,79
49	26	1895,79
50	83	-786,55
50	28	-786,55
51	84	62,82
51	30	62,82
52	85	146,23
52	32	146,23
53	86	107,81
53	34	107,81
54	87	104,42
54	36	104,42
55	88	329,28
55	38	329,28
56	89	1905,81
56	2	1905,81
57	39	578,1
57	90	578,1
58	73	626,5
58	91	626,5
59	74	451,74
59	92	451,74
60	75	390,91
60	93	390,91
61	76	351,32
61	94	351,32
62	77	225,54
62	95	225,54
63	78	-276,98
63	96	-276,98
64	79	835,93
64	97	835,93
65	80	447,21
65	98	447,21
66	98	369,55
66	82	369,55
67	99	729,53
67	83	729,53
68	100	-414,76

BAR	NODE	Fx (kN)
68	84	-414,76
69	101	67,32
69	85	67,32
70	102	161,08
70	86	161,08
71	103	172,76
71	87	172,76
72	104	225,9
72	88	225,9
73	105	453,4
73	89	453,4
74	106	479,23
74	40	479,23
75	41	308,97
75	107	308,97
76	90	423,22
76	108	423,22
77	91	379,5
77	109	379,5
78	92	307,3
78	110	307,3
79	93	217,76
79	111	217,76
80	94	43,89
80	112	43,89
81	95	-313,12
81	113	-313,12
82	96	140,95
82	114	140,95
83	97	123,45
83	115	123,45
84	115	23,3
84	99	23,3
85	116	23,2
85	100	23,2
86	117	-450,49
86	101	-450,49
87	118	-111,44
87	102	-111,44
88	119	35,95
88	103	35,95
89	120	100,94
89	104	100,94
90	121	162,59
90	105	162,59
91	122	217,7
91	106	217,7
92	123	135,52
92	42	135,52
93	43	211,53
93	124	211,53
94	107	292,87
94	125	292,87
95	108	251,23
95	126	251,23
96	109	159,59
96	127	159,59
97	110	31,21
97	128	31,21
98	111	-164,47
98	129	-164,47
99	112	-441,78
99	130	-441,78
100	113	-286,85
100	131	-286,85
101	114	-181,66
101	132	-181,66
102	132	-274,5
102	116	-274,5

BAR	NODE	Fx (kN)
103	133	-387,05
103	117	-387,05
104	134	-557,14
104	118	-557,14
105	135	-298,42
105	119	-298,42
106	136	-129,06
106	120	-129,06
107	137	-28,66
107	121	-28,66
108	138	40,43
108	122	40,43
109	139	72,67
109	123	72,67
110	140	16,44
110	44	16,44
111	45	168,89
111	141	168,89
112	124	194,44
112	142	194,44
113	125	116,84
113	143	116,84
114	126	-8,33
114	144	-8,33
115	127	-163,58
115	145	-163,58
116	128	-362,17
116	146	-362,17
117	129	-595,46
117	147	-595,46
118	130	-586,94
118	148	-586,94
119	131	-429,55
119	149	-429,55
120	149	-496,33
120	133	-496,33
121	150	-653,87
121	134	-653,87
122	151	-675,24
122	135	-675,24
123	152	-461,32
123	136	-461,32
124	153	-289,1
124	137	-289,1
125	154	-165,83
125	138	-165,83
126	155	-75,44
126	139	-75,44
127	156	-22,65
127	140	-22,65
128	157	-14,25
128	46	-14,25
129	47	121,21
129	158	121,21
130	141	93,36
130	159	93,36
131	142	-39,68
131	160	-39,68
132	143	-200,03
132	161	-200,03
133	144	-368,5
133	162	-368,5
134	145	-555,09
134	163	-555,09
135	146	-755,79
135	164	-755,79
136	147	-819,31
136	165	-819,31
137	148	-636,53

BAR	NODE	Fx (kN)
137	166	-636,53
138	166	-666,95
138	150	-666,95
139	167	-844,98
139	151	-844,98
140	168	-788,6
140	152	-788,6
141	169	-607,77
141	153	-607,77
142	170	-438,79
142	154	-438,79
143	171	-298,66
143	155	-298,66
144	172	-180,29
144	156	-180,29
145	173	-86,26
145	157	-86,26
146	174	0,23
146	48	0,23
147	49	-43,29
147	175	-43,29
148	158	-96,16
148	176	-96,16
149	159	-272,87
149	177	-272,87
150	160	-441,5
150	178	-441,5
151	161	-596,35
151	179	-596,35
152	162	-753,87
152	180	-753,87
153	163	-918,54
153	181	-918,54
154	164	-1010,15
154	182	-1010,15
155	165	-818,46
155	183	-818,46
156	183	-816,13
156	167	-816,13
157	184	-1004,49
157	168	-1004,49
158	185	-910,2
158	169	-910,2
159	186	-742,75
159	170	-742,75
160	187	-584,9
160	171	-584,9
161	188	-428,41
161	172	-428,41
162	189	-276,39
162	173	-276,39
163	190	-132,31
163	174	-132,31
164	191	42,76
164	50	42,76
165	51	-941,22
165	192	-941,22
166	175	-661,4
166	193	-661,4
167	176	-665,98
167	194	-665,98
168	177	-718,28
168	195	-718,28
169	178	-800,88
169	196	-800,88
170	179	-913,46
170	197	-913,46
171	180	-1048,18
171	198	-1048,18

BAR	NODE	Fx (kN)
172	181	-1171,46
172	199	-1171,46
173	182	-1008,63
173	200	-1008,63
174	200	-961,02
174	184	-961,02
175	201	-1128,35
175	185	-1128,35
176	202	-1016,39
176	186	-1016,39
177	203	-861,97
177	187	-861,97
178	204	-707,51
178	188	-707,51
179	205	-542,49
179	189	-542,49
180	206	-368,79
180	190	-368,79
181	207	-189,97
181	191	-189,97
182	208	78,92
182	52	78,92
183	53	1565,78
183	209	1565,78
184	192	347,57
184	210	347,57
185	193	-206,97
185	211	-206,97
186	194	-454,42
186	212	-454,42
187	195	-601,51
187	213	-601,51
188	196	-731,71
188	214	-731,71
189	197	-875,69
189	215	-875,69
190	198	-1047,48
190	216	-1047,48
191	199	-1278,51
191	217	-1278,51
192	217	-1165,18
192	201	-1165,18
193	218	-1000,97
193	202	-1000,97
194	219	-880,53
194	203	-880,53
195	220	-772,87
195	204	-772,87
196	221	-675,78
196	205	-675,78
197	222	-583,73
197	206	-583,73
198	223	-500,09
198	207	-500,09
199	224	-425,71
199	208	-425,71
200	225	-106,39
200	54	-106,39
201	57	397,4
201	209	397,4
202	226	150,1
202	210	150,1
203	227	15,46
203	211	15,46
204	228	-145,6
204	212	-145,6
205	229	-281,54
205	213	-281,54
206	230	-399,08

BAR	NODE	Fx (kN)
206	214	-399,08
207	231	-514,42
207	215	-514,42
208	232	-662,72
208	216	-662,72
209	233	-973,7
209	217	-973,7
210	217	-1157,17
210	234	-1157,17
211	218	-795,47
211	235	-795,47
212	219	-608,21
212	236	-608,21
213	220	-452,74
213	237	-452,74
214	221	-295,18
214	238	-295,18
215	222	-110,14
215	239	-110,14
216	223	165,51
216	240	165,51
217	224	723,52
217	241	723,52
218	225	2566,16
218	58	2566,16
219	59	634,35
219	226	634,35
220	242	561,96
220	227	561,96
221	243	333,95
221	228	333,95
222	244	39,5
222	229	39,5
223	245	-180,41
223	230	-180,41
224	246	-365,42
224	231	-365,42
225	247	-527,39
225	232	-527,39
226	248	-662,93
226	233	-662,93
227	249	-595,84
227	250	-595,84
228	250	-799,59
228	251	-799,59
229	234	-850,93
229	252	-850,93
230	235	-688,75
230	253	-688,75
231	236	-504,71
231	254	-504,71
232	237	-326,64
232	255	-326,64
233	238	-159,73
233	256	-159,73
234	239	-4,24
234	257	-4,24
235	240	93,46
235	258	93,46
236	241	63,95
236	60	63,95
237	61	879,1
237	242	879,1
238	259	1052,13
238	243	1052,13
239	260	741,69
239	244	741,69
240	261	381,18
240	245	381,18

BAR	NODE	Fx (kN)
241	262	145,5
241	246	145,5
242	263	-84,03
242	247	-84,03
243	264	-293,13
243	248	-293,13
244	265	-413,24
244	249	-413,24
245	266	-355,05
245	267	-355,05
246	267	-528,38
246	268	-528,38
247	251	-562,9
247	269	-562,9
248	252	-404,71
248	270	-404,71
249	253	-151,04
249	271	-151,04
250	254	104,58
250	272	104,58
251	255	372,95
251	273	372,95
252	256	691,86
252	274	691,86
253	257	1037,24
253	275	1037,24
254	258	923,86
254	62	923,86
255	63	2144,01
255	259	2144,01
256	276	1536,45
256	260	1536,45
257	277	1115
257	261	1115
258	278	718,05
258	262	718,05
259	279	487,46
259	263	487,46
260	280	171,37
260	264	171,37
261	281	-115,36
261	265	-115,36
262	282	-229,18
262	266	-229,18
263	283	-194,31
263	284	-194,31
264	284	-283,26
264	285	-283,26
265	268	-255,33
265	286	-255,33
266	269	-94,57
266	287	-94,57
267	270	218,61
267	288	218,61
268	271	496,09
268	289	496,09
269	272	746,95
269	290	746,95
270	273	1061,15
270	291	1061,15
271	274	1535,3
271	292	1535,3
272	275	2237,23
272	64	2237,23
273	65	558,25
273	276	558,25
274	293	1091,43
274	277	1091,43
275	294	1258,56

BAR	NODE	Fx (kN)
275	278	1258,56
276	295	1114,91
276	279	1114,91
277	296	863,4
277	280	863,4
278	297	328,58
278	281	328,58
279	298	-33,99
279	282	-33,99
280	299	-100,51
280	283	-100,51
281	300	-86,29
281	301	-86,29
282	301	-49,04
282	302	-49,04
283	285	110,69
283	303	110,69
284	286	267,01
284	304	267,01
285	287	620,84
285	305	620,84
286	288	835,38
286	306	835,38
287	289	895,08
287	307	895,08
288	290	869,69
288	308	869,69
289	291	747
289	309	747
290	292	322,78
290	66	322,78
291	67	1074,95
291	293	1074,95
292	310	1527,14
292	294	1527,14
293	311	1997,31
293	295	1997,31
294	312	2502,45
294	296	2502,45
295	313	1033,83
295	297	1033,83
296	314	390,94
296	298	390,94
297	315	-4,68
297	299	-4,68
298	316	31,79
298	300	31,79
299	317	3,64
299	318	3,64
300	318	127,04
300	319	127,04
301	302	581,47
301	320	581,47
302	303	833,54
302	321	833,54
303	304	1217,38
303	322	1217,38
304	305	1344,72
304	323	1344,72
305	306	1291,72
305	324	1291,72
306	307	1190,77
306	325	1190,77
307	308	1059,42
307	326	1059,42
308	309	809,11
308	68	809,11
309	69	0
309	310	0

BAR	NODE	Fx (kN)
310	327	317,51
310	311	317,51
311	328	388,35
311	312	388,35
312	329	2030,07
312	313	2030,07
313	330	1254,77
313	314	1254,77
314	331	588,83
314	315	588,83
315	332	71,53
315	316	71,53
316	333	240,82
316	317	240,82
317	334	60,01
317	335	60,01
318	335	217,21
318	336	217,21
319	319	767,08
319	337	767,08
320	320	2035,98
320	338	2035,98
321	321	1902,03
321	339	1902,03
322	322	1679,67
322	340	1679,67
323	323	1451,72
323	341	1451,72
324	324	1268,23
324	342	1268,23
325	325	1086,25
325	343	1086,25
326	326	864,69
326	70	864,69
327	71	-317,51
327	327	-317,51
328	344	-73,99
328	328	-73,99
329	345	310,35
329	329	310,35
330	346	1519,3
330	330	1519,3
331	347	1144,61
331	331	1144,61
332	348	587,47
332	332	587,47
333	349	-39,06
333	333	-39,06
334	350	500,75
334	334	500,75
335	351	-34,58
335	352	-34,58
336	352	612,31
336	353	612,31
337	336	1333,64
337	354	1333,64
338	337	1567,52
338	355	1567,52
339	338	312,43
339	356	312,43
340	339	322
340	357	322
341	340	304,23
341	358	304,23
342	341	265,99
342	359	265,99
343	342	195,29
343	360	195,29
344	343	0

BAR	NODE	Fx (kN)
344	72	0
345	4	-314,36
345	344	-314,36
346	5	-310,35
346	345	-310,35
347	7	0
347	346	0
348	9	1127,76
348	347	1127,76
349	11	822,75
349	348	822,75
350	13	407,38
350	349	407,38
351	15	-366,45
351	350	-366,45
352	17	1220,68
352	351	1220,68
353	19	-174,74
353	361	-174,74
354	361	582,44
354	23	582,44
355	353	1575,46
355	25	1575,46
356	354	779,29
356	27	779,29
357	355	0
357	29	0
358	356	-312,43
358	31	-312,43
359	357	-322
359	33	-322
360	358	-304,23
360	35	-304,23
361	359	-265,99
361	37	-265,99
362	360	-195,29
362	3	-195,29
363	362	1249,63
363	363	1313,74
364	364	-298
364	363	1599,91
365	364	-210,4
365	365	-98,3
366	365	-222,41
366	362	1379,05
367	366	-161,58
367	367	717,55
368	368	-324,97
368	369	683,76
369	370	23,63
369	371	850,1
370	372	392,52
370	373	1126,61
371	374	477,67
371	375	1539,92
372	376	569,04
372	377	2151,61
373	378	580,22
373	379	2422,35
374	380	-48,32
374	381	998,22
375	382	-182,3
375	383	650,99
376	384	-104,74
376	385	976,81
377	386	-256,1
377	387	2428,08
378	388	-961,89
378	389	2138,62

BAR	NODE	Fx (kN)
379	390	-1374,23
379	391	1501,16
380	392	-1101,54
380	393	1061,82
381	394	-859,58
381	395	752,83
382	396	-578,6
382	397	550,6
383	398	-317,42
383	399	600,4
384	401	344,33
384	400	595,75
385	403	166,09
385	402	494,34
386	405	196,46
386	404	567,7
387	407	291
387	406	724,6
388	409	424,49
388	408	968,78
389	411	591,55
389	410	1342,1
390	413	795,86
390	412	1917,2
391	415	1047,01
391	414	2159,04
392	416	842,36
392	417	919,57
393	418	894,36
393	419	2164,14
394	420	698,76
394	421	1830,04
395	422	666,58
395	423	1377,05
396	424	1061,42
396	425	1592,84
397	426	854,46
397	427	1348,2
398	428	284,95
398	429	1070,33
399	430	-176,12
399	431	545,71
400	432	-42,42
400	433	40,33
401	362	542,6
401	434	542,6
402	367	114,77
402	435	114,77
403	369	-255,88
403	436	-255,88
404	371	-582,57
404	437	-582,57
405	373	-925,85
405	438	-925,85
406	375	-1267,4
406	439	-1267,4
407	377	-1164,63
407	440	-1164,63
408	379	453,71
408	441	453,71
409	381	37,1
409	442	37,1
410	442	109,27
410	385	109,27
411	443	557,03
411	387	557,03
412	444	-1086,61
412	389	-1086,61
413	445	-1165,28

BAR	NODE	Fx (kN)
413	391	-1165,28
414	446	-776,04
414	393	-776,04
415	447	-364,9
415	395	-364,9
416	448	59,74
416	397	59,74
417	449	570,19
417	399	570,19
418	450	1132,01
418	363	1132,01
419	400	190,51
419	451	190,51
420	434	111,89
420	452	111,89
421	435	-168,34
421	453	-168,34
422	436	-449,41
422	454	-449,41
423	437	-704,67
423	455	-704,67
424	438	-860,01
424	456	-860,01
425	439	-664,4
425	457	-664,4
426	440	57,09
426	458	57,09
427	441	157,26
427	459	157,26
428	459	264,26
428	443	264,26
429	460	175
429	444	175
430	461	-541,81
430	445	-541,81
431	462	-701,03
431	446	-701,03
432	463	-478,39
432	447	-478,39
433	464	-125,16
433	448	-125,16
434	465	284,99
434	449	284,99
435	466	698,55
435	450	698,55
436	467	735,25
436	401	735,25
437	402	-88,66
437	468	-88,66
438	451	-58,14
438	469	-58,14
439	452	-109,21
439	470	-109,21
440	453	-209,49
440	471	-209,49
441	454	-298,87
441	472	-298,87
442	455	-319,22
442	473	-319,22
443	456	-173,15
443	474	-173,15
444	457	188,71
444	475	188,71
445	458	236,36
445	476	236,36
446	476	350,52
446	460	350,52
447	477	311,09
447	461	311,09

BAR	NODE	Fx (kN)
448	478	-33,42
448	462	-33,42
449	479	-134,33
449	463	-134,33
450	480	-40,57
450	464	-40,57
451	481	152,92
451	465	152,92
452	482	377,8
452	466	377,8
453	483	519,69
453	467	519,69
454	484	414,74
454	403	414,74
455	404	-313,26
455	485	-313,26
456	468	-231,62
456	486	-231,62
457	469	-105,5
457	487	-105,5
458	470	-12,49
458	488	-12,49
459	471	62,11
459	489	62,11
460	472	149,2
460	490	149,2
461	473	282,31
461	491	282,31
462	474	469,31
462	492	469,31
463	475	401,89
463	493	401,89
464	493	512,44
464	477	512,44
465	494	584,29
465	478	584,29
466	495	416,21
466	479	416,21
467	496	329,1
467	480	329,1
468	497	311,53
468	481	311,53
469	498	338
469	482	338
470	499	364,57
470	483	364,57
471	500	328,03
471	484	328,03
472	501	190,23
472	405	190,23
473	406	-545,15
473	502	-545,15
474	485	-405,31
474	503	-405,31
475	486	-125,14
475	504	-125,14
476	487	133,68
476	505	133,68
477	488	352,95
477	506	352,95
478	489	543,89
478	507	543,89
479	490	706,01
479	508	706,01
480	491	801,47
480	509	801,47
481	492	588,75
481	510	588,75
482	510	685,66

BAR	NODE	Fx (kN)
482	494	685,66
483	511	894,45
483	495	894,45
484	512	810,91
484	496	810,91
485	513	687,58
485	497	687,58
486	514	554,48
486	498	554,48
487	515	431,83
487	499	431,83
488	516	296,9
488	500	296,9
489	517	136,92
489	501	136,92
490	518	-3,88
490	407	-3,88
491	408	-818,83
491	519	-818,83
492	502	-571,05
492	520	-571,05
493	503	-141,97
493	521	-141,97
494	504	246,89
494	522	246,89
495	505	579,26
495	523	579,26
496	506	875,9
496	524	875,9
497	507	1112,15
497	525	1112,15
498	508	1179,03
498	526	1179,03
499	509	799,67
499	527	799,67
500	527	870,17
500	511	870,17
501	528	1235,14
501	512	1235,14
502	529	1167,57
502	513	1167,57
503	530	946,85
503	514	946,85
504	531	703,71
504	515	703,71
505	532	446,76
505	516	446,76
506	533	179,81
506	517	179,81
507	534	-76,02
507	518	-76,02
508	535	-205,76
508	409	-205,76
509	410	-1100,51
509	536	-1100,51
510	519	-639,52
510	537	-639,52
511	520	-98,64
511	538	-98,64
512	521	346,72
512	539	346,72
513	522	729,53
513	540	729,53
514	523	1103,59
514	541	1103,59
515	524	1487,46
515	542	1487,46
516	525	1642,36
516	543	1642,36

BAR	NODE	Fx (kN)
517	526	1096,01
517	544	1096,01
518	544	1116,67
518	528	1116,67
519	545	1643,14
519	529	1643,14
520	546	1491,34
520	530	1491,34
521	547	1096,52
521	531	1096,52
522	548	733,94
522	532	733,94
523	549	380,59
523	533	380,59
524	550	16,58
524	534	16,58
525	551	-320,53
525	535	-320,53
526	552	-434,13
526	411	-434,13
527	412	-926,64
527	553	-926,64
528	536	-337,33
528	554	-337,33
529	537	110,04
529	555	110,04
530	538	461,05
530	556	461,05
531	539	775,95
531	557	775,95
532	540	1124,3
532	558	1124,3
533	541	1588,97
533	559	1588,97
534	542	2211,49
534	560	2211,49
535	543	1675,39
535	561	1675,39
536	561	1600,63
536	545	1600,63
537	562	2113,51
537	546	2113,51
538	563	1502,37
538	547	1502,37
539	564	1018,75
539	548	1018,75
540	565	629,92
540	549	629,92
541	566	252,69
541	550	252,69
542	567	-159,01
542	551	-159,01
543	568	-568,19
543	552	-568,19
544	569	-683,89
544	413	-683,89
545	414	754,36
545	570	754,36
546	553	494,59
546	571	494,59
547	554	522,34
547	572	522,34
548	555	587,82
548	573	587,82
549	556	672,26
549	574	672,26
550	557	805,06
550	575	805,06
551	558	1061,32

BAR	NODE	Fx (kN)
551	576	1061,32
552	559	1639,48
552	577	1639,48
553	560	3221,01
553	578	3221,01
554	578	2916,81
554	562	2916,81
555	579	1442,95
555	563	1442,95
556	580	875,25
556	564	875,25
557	581	579,22
557	565	579,22
558	582	339,9
558	566	339,9
559	583	64,39
559	567	64,39
560	584	-287,56
560	568	-287,56
561	585	-692,28
561	569	-692,28
562	586	-800,45
562	415	-800,45
563	418	-706,84
563	570	-706,84
564	587	-645,85
564	571	-645,85
565	588	-305,56
565	572	-305,56
566	589	24,55
566	573	24,55
567	590	318,75
567	574	318,75
568	591	592,56
568	575	592,56
569	592	913,91
569	576	913,91
570	593	1496,84
570	577	1496,84
571	594	3003,1
571	578	3003,1
572	578	3384,06
572	595	3384,06
573	579	1773,37
573	596	1773,37
574	580	1167,5
574	597	1167,5
575	581	868,98
575	598	868,98
576	582	686,13
576	599	686,13
577	583	570,98
577	600	570,98
578	584	514,75
578	601	514,75
579	585	543,16
579	602	543,16
580	586	880,48
580	419	880,48
581	420	-633,83
581	587	-633,83
582	603	-609,52
582	588	-609,52
583	604	-267,54
583	589	-267,54
584	605	141,01
584	590	141,01
585	606	554,99
585	591	554,99

BAR	NODE	Fx (kN)
586	607	968,55
586	592	968,55
587	608	1429,98
587	593	1429,98
588	609	1973,64
588	594	1973,64
589	610	1367,27
589	611	1367,27
590	611	1680,92
590	612	1680,92
591	595	2259,33
591	613	2259,33
592	596	1641,27
592	614	1641,27
593	597	1122,02
593	615	1122,02
594	598	695,7
594	616	695,7
595	599	331,72
595	617	331,72
596	600	-5,13
596	618	-5,13
597	601	-380,48
597	619	-380,48
598	602	-863,49
598	421	-863,49
599	422	-540,2
599	603	-540,2
600	620	-606,96
600	604	-606,96
601	621	-344,83
601	605	-344,83
602	622	70,58
602	606	70,58
603	623	507,39
603	607	507,39
604	624	905
604	608	905
605	625	1235,72
605	609	1235,72
606	626	1271,29
606	610	1271,29
607	627	689,77
607	628	689,77
608	628	1011,97
608	629	1011,97
609	612	1546,32
609	630	1546,32
610	613	1395,91
610	631	1395,91
611	614	928,42
611	632	928,42
612	615	427,31
612	633	427,31
613	616	-36,38
613	634	-36,38
614	617	-455,93
614	635	-455,93
615	618	-834,69
615	636	-834,69
616	619	-1082,09
616	423	-1082,09
617	424	-608,45
617	620	-608,45
618	637	-938,84
618	621	-938,84
619	638	-646,84
619	622	-646,84
620	639	-165,13

BAR	NODE	Fx (kN)
620	623	-165,13
621	640	283,25
621	624	283,25
622	641	611,19
622	625	611,19
623	642	778,13
623	626	778,13
624	643	716,2
624	627	716,2
625	644	335,6
625	645	335,6
626	645	659,88
626	646	659,88
627	629	985,35
627	647	985,35
628	630	884,56
628	648	884,56
629	631	495,8
629	649	495,8
630	632	-26,57
630	650	-26,57
631	633	-519,27
631	651	-519,27
632	634	-924,15
632	652	-924,15
633	635	-1157,92
633	653	-1157,92
634	636	-918,85
634	425	-918,85
635	426	-1537,6
635	637	-1537,6
636	654	-1702,54
636	638	-1702,54
637	655	-1169,21
637	639	-1169,21
638	656	-491,27
638	640	-491,27
639	657	-16,4
639	641	-16,4
640	658	218,41
640	642	218,41
641	659	340,69
641	643	340,69
642	660	321,89
642	644	321,89
643	661	135,89
643	662	135,89
644	662	402,5
644	663	402,5
645	646	551,97
645	664	551,97
646	647	386,47
646	665	386,47
647	648	-29,83
647	666	-29,83
648	649	-591,72
648	667	-591,72
649	650	-1083,42
649	668	-1083,42
650	651	-1472,47
650	669	-1472,47
651	652	-1699,09
651	670	-1699,09
652	653	-1526,63
652	427	-1526,63
653	428	-1994,15
653	654	-1994,15
654	671	-2196,47
654	655	-2196,47

BAR	NODE	Fx (kN)
655	672	-1765,69
655	656	-1765,69
656	673	-659,57
656	657	-659,57
657	674	-460
657	658	-460
658	675	-209,15
658	659	-209,15
659	676	-33,81
659	660	-33,81
660	677	72,73
660	661	72,73
661	678	64,61
661	679	64,61
662	679	137,97
662	680	137,97
663	663	189,02
663	681	189,02
664	664	-65,31
664	682	-65,31
665	665	-594,62
665	683	-594,62
666	666	-1196,72
666	684	-1196,72
667	667	-1580,92
667	685	-1580,92
668	668	-1839,86
668	686	-1839,86
669	669	-1978,09
669	687	-1978,09
670	670	-1687,76
670	429	-1687,76
671	430	-1078,65
671	671	-1078,65
672	688	-1699,51
672	672	-1699,51
673	689	-2122,16
673	673	-2122,16
674	690	-1649,27
674	674	-1649,27
675	691	-1041,04
675	675	-1041,04
676	692	-644,06
676	676	-644,06
677	693	-339,17
677	677	-339,17
678	694	-39,38
678	678	-39,38
679	695	112,25
679	696	112,25
680	696	-151,08
680	697	-151,08
681	680	-285,85
681	698	-285,85
682	681	-378,42
682	699	-378,42
683	682	-1303,78
683	700	-1303,78
684	683	-1771,33
684	701	-1771,33
685	684	-1889,54
685	702	-1889,54
686	685	-1940,21
686	703	-1940,21
687	686	-1932,31
687	704	-1932,31
688	687	-1712,31
688	431	-1712,31
689	432	-971,8

BAR	NODE	Fx (kN)
689	688	-971,8
690	705	-1558,74
690	689	-1558,74
691	706	-1598,61
691	690	-1598,61
692	707	-1951,85
692	691	-1951,85
693	708	-1487,54
693	692	-1487,54
694	709	-983,66
694	693	-983,66
695	710	-558,43
695	694	-558,43
696	711	-23,94
696	695	-23,94
697	712	223,09
697	713	223,09
698	713	-355,49
698	714	-355,49
699	697	-795,03
699	715	-795,03
700	698	-1524,97
700	716	-1524,97
701	699	-1808,48
701	717	-1808,48
702	700	-1512,59
702	718	-1512,59
703	701	-1370,61
703	719	-1370,61
704	702	-1283
704	720	-1283
705	703	-1155,64
705	721	-1155,64
706	704	-806,88
706	433	-806,88
707	365	-782,82
707	705	-782,82
708	366	-921,55
708	706	-921,55
709	368	-940,7
709	707	-940,7
710	370	-1672,29
710	708	-1672,29
711	372	-1261,14
711	709	-1261,14
712	374	-889,14
712	710	-889,14
713	376	-560,57
713	711	-560,57
714	378	201,13
714	712	201,13
715	380	257,73
715	722	257,73
716	722	-319,55
716	384	-319,55
717	714	-861,55
717	386	-861,55
718	715	-1769,42
718	388	-1769,42
719	716	-1087,57
719	390	-1087,57
720	717	-1183,2
720	392	-1183,2
721	718	-1046,81
721	394	-1046,81
722	719	-921,09
722	396	-921,09
723	720	-802,54
723	398	-802,54
724	721	-588,7
724	364	-588,7
725	1	3458,7
725	362	3458,7
726	39	1743,32
726	400	1743,32
727	41	881,7
727	402	881,7
728	43	318,89
728	404	318,89
729	45	-158,46
729	406	-158,46
730	47	-628,75
730	408	-628,75
731	49	-1149,68
731	410	-1149,68
732	51	-1844,76
732	412	-1844,76
733	53	4910,12
733	414	4910,12
734	55	948,27
734	416	948,27
735	57	-631,93
735	418	-631,93
736	59	-250,19
736	420	-250,19
737	61	165,57
737	422	165,57
738	63	927,91
738	424	927,91
739	65	-1147,33
739	426	-1147,33
740	67	-2141,3
740	428	-2141,3
741	69	-1714,46
741	430	-1714,46
742	71	-1448,87
742	432	-1448,87
743	4	-1365,13
743	365	-1365,13
744	6	1613,91
744	367	1613,91
745	73	1500,3
745	434	1500,3
746	90	1113,38
746	451	1113,38
747	107	753,54
747	468	753,54
748	124	433,77
748	485	433,77
749	141	152,71
749	502	152,71
750	158	-20,7
750	519	-20,7
751	175	358,14
751	536	358,14
752	192	1917,29
752	553	1917,29
753	209	807,24
753	570	807,24
754	226	170,16
754	587	170,16
755	242	451,23
755	603	451,23
756	259	840,94
756	620	840,94
757	276	1085,3
757	637	1085,3
758	293	301,64
758	654	301,64
759	310	-653,54
759	671	-653,54
760	327	-1918,78
760	688	-1918,78
761	344	-1571,67
761	705	-1571,67
762	5	-1382,85
762	366	-1382,85
763	8	684,04
763	369	684,04
764	74	1053,9
764	435	1053,9
765	91	1021,74
765	452	1021,74
766	108	867,99
766	469	867,99
767	125	681,43
767	486	681,43
768	142	510,98
768	503	510,98
769	159	423,03
769	520	423,03
770	176	515,83
770	537	515,83
771	193	821,08
771	554	821,08
772	210	474,23
772	571	474,23
773	227	619,04
773	588	619,04
774	243	891,51
774	604	891,51
775	260	1256
775	621	1256
776	277	1610,04
776	638	1610,04
777	294	1674,91
777	655	1674,91
778	311	456,28
778	672	456,28
779	328	-2200,09
779	689	-2200,09
780	345	-1849,38
780	706	-1849,38
781	7	-1557,44
781	368	-1557,44
782	10	50,06
782	371	50,06
783	75	670,22
783	436	670,22
784	92	856,47
784	453	856,47
785	109	867,76
785	470	867,76
786	126	790,44
786	487	790,44
787	143	679,59
787	504	679,59
788	160	568,88
788	521	568,88
789	177	468,69
789	538	468,69
790	194	388,67
790	555	388,67
791	211	186,42
791	572	186,42
792	228	817,69
792	589	817,69

BAR	NODE	Fx (kN)
793	244	1188,86
793	605	1188,86
794	261	1633,03
794	622	1633,03
795	278	2293,48
795	639	2293,48
796	295	3608,34
796	656	3608,34
797	312	7320,37
797	673	7320,37
798	329	350,05
798	690	350,05
799	346	-555,29
799	707	-555,29
800	9	-1803,94
800	370	-1803,94
801	12	-519,26
801	373	-519,26
802	76	353,56
802	437	353,56
803	93	703,23
803	454	703,23
804	110	823,23
804	471	823,23
805	127	817,48
805	488	817,48
806	144	743,49
806	505	743,49
807	161	620,5
807	522	620,5
808	178	443,04
808	539	443,04
809	195	202,94
809	556	202,94
810	212	-39,61
810	573	-39,61
811	229	919,52
811	590	919,52
812	245	1373,71
812	606	1373,71
813	262	1815,94
813	623	1815,94
814	279	2361,84
814	640	2361,84
815	296	3038,07
815	657	3038,07
816	313	3484,2
816	674	3484,2
817	330	1491,24
817	691	1491,24
818	347	193,96
818	708	193,96
819	11	-776,24
819	372	-776,24
820	14	-1122,36
820	375	-1122,36
821	77	156,77
821	438	156,77
822	94	636,53
822	455	636,53
823	111	781,76
823	472	781,76
824	128	799,15
824	489	799,15
825	145	752,24
825	506	752,24
826	162	646,89
826	523	646,89
827	179	460,4
827	540	460,4
828	196	144,32
828	557	144,32
829	213	-202,33
829	574	-202,33
830	230	978,1
830	591	978,1
831	246	1446,23
831	607	1446,23
832	263	1777,88
832	624	1777,88
833	280	2057,19
833	641	2057,19
834	297	2215,01
834	658	2215,01
835	314	2023,64
835	675	2023,64
836	331	1220,09
836	692	1220,09
837	348	416,96
837	709	416,96
838	13	-408,16
838	374	-408,16
839	16	-1897,25
839	377	-1897,25
840	78	491,4
840	439	491,4
841	95	757,75
841	456	757,75
842	112	771,43
842	473	771,43
843	129	755,62
843	490	755,62
844	146	724,67
844	507	724,67
845	163	661,13
845	524	661,13
846	180	518,35
846	541	518,35
847	197	185,08
847	558	185,08
848	214	-280,06
848	575	-280,06
849	231	1035,04
849	592	1035,04
850	247	1441,81
850	608	1441,81
851	264	1599,75
851	625	1599,75
852	281	1634,94
852	642	1634,94
853	298	1539,72
853	659	1539,72
854	315	1276,99
854	676	1276,99
855	332	886,53
855	693	886,53
856	349	460,4
856	710	460,4
857	15	-388,27
857	376	-388,27
858	18	4344,68
858	379	4344,68
859	79	1958,57
859	440	1958,57
860	96	1129,77
860	457	1129,77
861	113	832,07
861	474	832,07
862	130	710,36
862	491	710,36
863	147	655,35
863	508	655,35
864	164	627,29
864	525	627,29
865	181	576,76
865	542	576,76
866	198	324,02
866	559	324,02
867	215	-198,2
867	576	-198,2
868	232	1140,05
868	593	1140,05
869	248	1381,4
869	609	1381,4
870	265	1336,24
870	626	1336,24
871	282	1199,4
871	643	1199,4
872	299	1005,94
872	660	1005,94
873	316	801,28
873	677	801,28
874	333	693,45
874	694	693,45
875	350	787,4
875	711	787,4
876	17	1208,11
876	378	1208,11
877	20	1470,36
877	381	1470,36
878	80	1348,06
878	441	1348,06
879	97	988,56
879	458	988,56
880	114	712,86
880	475	712,86
881	131	526,22
881	492	526,22
882	148	412,1
882	509	412,1
883	165	370,9
883	526	370,9
884	182	411,2
884	543	411,2
885	199	421,91
885	560	421,91
886	216	238,66
886	577	238,66
887	233	1218,58
887	594	1218,58
888	249	1140,24
888	610	1140,24
889	266	938,38
889	627	938,38
890	283	730,88
890	644	730,88
891	300	510,71
891	661	510,71
892	317	324,76
892	678	324,76
893	334	269,09
893	695	269,09
894	351	323,53
894	712	323,53
895	19	354,5
895	380	354,5
896	22	756,9

BAR	NODE	Fx (kN)
896	383	756,9
897	81	910,32
897	442	910,32
898	98	656,29
898	459	656,29
899	115	295,24
899	476	295,24
900	132	-58,62
900	493	-58,62
901	149	-350,23
901	510	-350,23
902	166	-537,59
902	527	-537,59
903	183	-546,9
903	544	-546,9
904	200	-183,96
904	561	-183,96
905	217	209,77
905	578	209,77
906	250	791,85
906	611	791,85
907	267	480,93
907	628	480,93
908	284	459,06
908	645	459,06
909	301	526,97
909	662	526,97
910	318	574,39
910	679	574,39
911	335	530,72
911	696	530,72
912	352	363,88
912	713	363,88
913	361	118,04
913	722	118,04
914	21	-76,39
914	382	-76,39
915	24	1607,98
915	385	1607,98
916	82	1416,29
916	443	1416,29
917	99	1025,34
917	460	1025,34
918	116	741,26
918	477	741,26
919	133	557,01
919	494	557,01
920	150	451,72
920	511	451,72
921	167	421,46
921	528	421,46
922	184	457,44
922	545	457,44
923	201	441,61
923	562	441,61
924	218	231,18
924	579	231,18
925	234	1277,04
925	595	1277,04
926	251	1328,55
926	612	1328,55
927	268	1363,99
927	629	1363,99
928	285	1509,6
928	646	1509,6
929	302	1703,51
929	663	1703,51
930	319	1776,33
930	680	1776,33

BAR	NODE	Fx (kN)
931	336	1443,86
931	697	1443,86
932	353	517,84
932	714	517,84
933	23	-384,75
933	384	-384,75
934	26	4561,1
934	387	4561,1
935	83	2035,25
935	444	2035,25
936	100	1166,64
936	461	1166,64
937	117	860,18
937	478	860,18
938	134	738,65
938	495	738,65
939	151	690,59
939	512	690,59
940	168	703,95
940	529	703,95
941	185	643,12
941	546	643,12
942	202	354,81
942	563	354,81
943	219	-223,62
943	580	-223,62
944	235	1158,83
944	596	1158,83
945	252	1519,47
945	613	1519,47
946	269	1716,03
946	630	1716,03
947	286	1994,48
947	647	1994,48
948	303	2426,03
948	664	2426,03
949	320	2955,76
949	681	2955,76
950	337	3094,14
950	698	3094,14
951	354	610,79
951	715	610,79
952	25	-1118,89
952	386	-1118,89
953	28	-1842,52
953	389	-1842,52
954	84	528,55
954	445	528,55
955	101	787,78
955	462	787,78
956	118	798,06
956	479	798,06
957	135	776,45
957	496	776,45
958	152	730,02
958	513	730,02
959	169	616,21
959	530	616,21
960	186	588,56
960	547	588,56
961	203	206,62
961	564	206,62
962	220	-337,01
962	581	-337,01
963	236	989,45
963	597	989,45
964	253	1449,08
964	614	1449,08
965	270	1754,94

BAR	NODE	Fx (kN)
965	631	1754,94
966	287	2120,61
966	648	2120,61
967	304	2733,19
967	665	2733,19
968	321	4004,37
968	682	4004,37
969	338	7412,51
969	699	7412,51
970	355	-1239,21
970	716	-1239,21
971	27	-2741,84
971	388	-2741,84
972	30	-1034,17
972	391	-1034,17
973	85	196,55
973	446	196,55
974	102	671,68
974	463	671,68
975	119	812,72
975	480	812,72
976	136	817,26
976	497	817,26
977	153	750,89
977	514	750,89
978	170	630,86
978	531	630,86
979	187	462,31
979	548	462,31
980	204	117,96
980	565	117,96
981	221	-283,81
981	582	-283,81
982	237	902,95
982	598	902,95
983	254	1330,68
983	615	1330,68
984	271	1636,95
984	632	1636,95
985	288	1944,94
985	649	1944,94
986	305	2327,67
986	666	2327,67
987	322	2687,53
987	683	2687,53
988	339	1742,5
988	700	1742,5
989	356	-2713,49
989	717	-2713,49
990	29	-2690,68
990	390	-2690,68
991	32	-389,93
991	393	-389,93
992	86	419,37
992	447	419,37
993	103	759,2
993	464	759,2
994	120	868,83
994	481	868,83
995	137	838,8
995	498	838,8
996	154	729,47
996	515	729,47
997	171	570,74
997	532	570,74
998	188	364,75
998	549	364,75
999	205	69,89
999	566	69,89

BAR	NODE	Fx (kN)
1000	222	-125,6
1000	583	-125,6
1001	238	913,75
1001	599	913,75
1002	255	1237,28
1002	616	1237,28
1003	272	1470,93
1003	633	1470,93
1004	289	1656,61
1004	650	1656,61
1005	306	1792,94
1005	667	1792,94
1006	323	1788,05
1006	684	1788,05
1007	340	1291,68
1007	701	1291,68
1008	357	-2470,69
1008	718	-2470,69
1009	31	-2502,75
1009	392	-2502,75
1010	34	236,04
1010	395	236,04
1011	87	780,94
1011	448	780,94
1012	104	951,99
1012	465	951,99
1013	121	943,64
1013	482	943,64
1014	138	828,06
1014	499	828,06
1015	155	655,28
1015	516	655,28
1016	172	453,88
1016	533	453,88
1017	189	239,24
1017	550	239,24
1018	206	18,51
1018	567	18,51
1019	223	116,91
1019	584	116,91
1020	239	1054,44
1020	600	1054,44
1021	256	1193,18
1021	617	1193,18
1022	273	1298,51
1022	634	1298,51
1023	290	1353,93
1023	651	1353,93
1024	307	1314,17
1024	668	1314,17
1025	324	1244,63
1025	685	1244,63
1026	341	893,32
1026	702	893,32
1027	358	-2129,27
1027	719	-2129,27
1028	33	-2165,69
1028	394	-2165,69
1029	36	960,05
1029	397	960,05
1030	88	1242,71
1030	449	1242,71
1031	105	1181,71
1031	466	1181,71
1032	122	996,8
1032	483	996,8
1033	139	765,99
1033	500	765,99
1034	156	518,68

BAR	NODE	Fx (kN)
1034	517	518,68
1035	173	267,98
1035	534	267,98
1036	190	35,42
1036	551	35,42
1037	207	-109,96
1037	568	-109,96
1038	224	439,17
1038	585	439,17
1039	240	1446,69
1039	601	1446,69
1040	257	1181,45
1040	618	1181,45
1041	274	1093,67
1041	635	1093,67
1042	291	1079,35
1042	652	1079,35
1043	308	862,47
1043	669	862,47
1044	325	724,39
1044	686	724,39
1045	342	387,94
1045	703	387,94
1046	359	-1783,86
1046	720	-1783,86
1047	35	-1786,64
1047	396	-1786,64
1048	38	2094,79
1048	399	2094,79
1049	89	1838,95
1049	450	1838,95
1050	106	1380,95
1050	467	1380,95
1051	123	980,66
1051	484	980,66
1052	140	631,72
1052	501	631,72
1053	157	307,26
1053	518	307,26
1054	174	-10,36
1054	535	-10,36
1055	191	-318,81
1055	552	-318,81
1056	208	-502,23
1056	569	-502,23
1057	225	824,65
1057	586	824,65
1058	241	2554,19
1058	602	2554,19
1059	258	926,68
1059	619	926,68
1060	275	644,12
1060	636	644,12
1061	292	858,9
1061	653	858,9
1062	309	326,9
1062	670	326,9
1063	326	95,47
1063	687	95,47
1064	343	-323,4
1064	704	-323,4
1065	360	-1443,98
1065	721	-1443,98
1066	37	-1431,89
1066	398	-1431,89
1067	2	4577,22
1067	363	4577,22
1068	40	2380,96
1068	401	2380,96

BAR	NODE	Fx (kN)
1069	42	1385,57
1069	403	1385,57
1070	44	795,05
1070	405	795,05
1071	46	332,92
1071	407	332,92
1072	48	-86,5
1072	409	-86,5
1073	50	-496,66
1073	411	-496,66
1074	52	-912,39
1074	413	-912,39
1075	54	-1355,83
1075	415	-1355,83
1076	56	1025,49
1076	417	1025,49
1077	58	5891,97
1077	419	5891,97
1078	60	-1212,17
1078	421	-1212,17
1079	62	-469,11
1079	423	-469,11
1080	64	605,17
1080	425	605,17
1081	66	-933,19
1081	427	-933,19
1082	68	-925,13
1082	429	-925,13
1083	70	-1459,04
1083	431	-1459,04
1084	72	-1245,6
1084	433	-1245,6
1085	3	-1278,28
1085	364	-1278,28
1086	365	1097,36
1086	71	1097,36
1087	432	1175,28
1087	69	1175,28
1088	430	1254,93
1088	67	1254,93
1089	428	1595,14
1089	65	1595,14
1090	426	1451,41
1090	63	1451,41
1091	424	-261,59
1091	61	-261,59
1092	422	326,39
1092	59	326,39
1093	420	866,24
1093	57	866,24
1094	418	1609,71
1094	55	1609,71
1095	55	-2978,2
1095	414	-2978,2
1096	53	4551,62
1096	412	4551,62
1097	51	2581,45
1097	410	2581,45
1098	49	1598,46
1098	408	1598,46
1099	47	861,75
1099	406	861,75
1100	45	196,66
1100	404	196,66
1101	43	-478,42
1101	402	-478,42
1102	41	-1274,35
1102	400	-1274,35
1103	39	-2492,87

BAR	NODE	Fx (kN)
1103	362	-2492,87
1104	366	1150,07
1104	344	1150,07
1105	705	1345,02
1105	327	1345,02
1106	688	1550,43
1106	310	1550,43
1107	671	-796,61
1107	293	-796,61
1108	654	-683,04
1108	276	-683,04
1109	637	-827,59
1109	259	-827,59
1110	620	-324,59
1110	242	-324,59
1111	603	276,52
1111	226	276,52
1112	587	785,6
1112	209	785,6
1113	209	-780,88
1113	553	-780,88
1114	192	1055,42
1114	536	1055,42
1115	175	1237,38
1115	519	1237,38
1116	158	785,95
1116	502	785,95
1117	141	294,45
1117	485	294,45
1118	124	-174,67
1118	468	-174,67
1119	107	-616,89
1119	451	-616,89
1120	90	-1004,93
1120	434	-1004,93
1121	73	-1129,54
1121	367	-1129,54
1122	368	1400,28
1122	345	1400,28
1123	706	1610,78
1123	328	1610,78
1124	689	1840,7
1124	311	1840,7
1125	672	-2962,62
1125	294	-2962,62
1126	655	-1907,17
1126	277	-1907,17
1127	638	-1249,06
1127	260	-1249,06
1128	621	-683,61
1128	243	-683,61
1129	604	-186,69
1129	227	-186,69
1130	588	119,64
1130	210	119,64
1131	210	13,82
1131	554	13,82
1132	193	431,91
1132	537	431,91
1133	176	494,94
1133	520	494,94
1134	159	272,37
1134	503	272,37
1135	142	-58,2
1135	486	-58,2
1136	125	-393,27
1136	469	-393,27
1137	108	-674,01
1137	452	-674,01
1138	91	-824,78
1138	435	-824,78
1139	74	-711,1
1139	369	-711,1
1140	370	1638,86
1140	346	1638,86
1141	707	2103,12
1141	329	2103,12
1142	690	2817,85
1142	312	2817,85
1143	673	-4978,93
1143	295	-4978,93
1144	656	-2553,06
1144	278	-2553,06
1145	639	-1554,3
1145	261	-1554,3
1146	622	-944,69
1146	244	-944,69
1147	605	-498,79
1147	228	-498,79
1148	589	-227,51
1148	211	-227,51
1149	211	297,05
1149	555	297,05
1150	194	287,86
1150	538	287,86
1151	177	161,08
1151	521	161,08
1152	160	-48,8
1152	504	-48,8
1153	143	-303,56
1153	487	-303,56
1154	126	-549,84
1154	470	-549,84
1155	109	-730,43
1155	453	-730,43
1156	92	-777,76
1156	436	-777,76
1157	75	-619,66
1157	371	-619,66
1158	372	706,04
1158	347	706,04
1159	708	866,47
1159	330	866,47
1160	691	108,75
1160	313	108,75
1161	674	-2084,07
1161	296	-2084,07
1162	657	-1988,46
1162	279	-1988,46
1163	640	-1540,84
1163	262	-1540,84
1164	623	-1097,69
1164	245	-1097,69
1165	606	-708,99
1165	229	-708,99
1166	590	-424,74
1166	212	-424,74
1167	212	406,92
1167	556	406,92
1168	195	222,23
1168	539	222,23
1169	178	-13,33
1169	522	-13,33
1170	161	-249,41
1170	505	-249,41
1171	144	-476,65
1171	488	-476,65
1172	127	-679,29
1172	471	-679,29
1173	110	-824,35
1173	454	-824,35
1174	93	-851,2
1174	437	-851,2
1175	76	-667,42
1175	373	-667,42
1176	374	213,62
1176	348	213,62
1177	709	154,73
1177	331	154,73
1178	692	-356
1178	314	-356
1179	675	-1161,95
1179	297	-1161,95
1180	658	-1447,48
1180	280	-1447,48
1181	641	-1381,34
1181	263	-1381,34
1182	624	-1149,04
1182	246	-1149,04
1183	607	-845,07
1183	230	-845,07
1184	591	-546,36
1184	213	-546,36
1185	213	438,99
1185	557	438,99
1186	196	152,34
1186	540	152,34
1187	179	-139,81
1187	523	-139,81
1188	162	-388,13
1188	506	-388,13
1189	145	-599,27
1189	489	-599,27
1190	128	-788,22
1190	472	-788,22
1191	111	-958,12
1191	455	-958,12
1192	94	-1067,5
1192	438	-1067,5
1193	77	-910,37
1193	375	-910,37
1194	376	-244,17
1194	349	-244,17
1195	710	-221,76
1195	332	-221,76
1196	693	-443,51
1196	315	-443,51
1197	676	-829,95
1197	298	-829,95
1198	659	-1121,69
1198	281	-1121,69
1199	642	-1234,61
1199	264	-1234,61
1200	625	-1176,29
1200	247	-1176,29
1201	608	-964,35
1201	231	-964,35
1202	592	-643,02
1202	214	-643,02
1203	214	415,47
1203	558	415,47
1204	197	43,87
1204	541	43,87
1205	180	-267,1
1205	524	-267,1
1206	163	-497,42
1206	507	-497,42

BAR	NODE	Fx (kN)
1207	146	-686,61
1207	490	-686,61
1208	129	-875,17
1208	473	-875,17
1209	112	-1111,1
1209	456	-1111,1
1210	95	-1467,04
1210	439	-1467,04
1211	78	-1878,22
1211	377	-1878,22
1212	378	-1021,69
1212	350	-1021,69
1213	711	-507,93
1213	333	-507,93
1214	694	-494,68
1214	316	-494,68
1215	677	-704,3
1215	299	-704,3
1216	660	-956,14
1216	282	-956,14
1217	643	-1141,11
1217	265	-1141,11
1218	626	-1216,41
1218	248	-1216,41
1219	609	-1129,02
1219	232	-1129,02
1220	593	-780,12
1220	215	-780,12
1221	215	326,87
1221	559	326,87
1222	198	-118,5
1222	542	-118,5
1223	181	-376,22
1223	525	-376,22
1224	164	-556,74
1224	508	-556,74
1225	147	-736,87
1225	491	-736,87
1226	130	-960,1
1226	474	-960,1
1227	113	-1298,41
1227	457	-1298,41
1228	96	-1974,7
1228	440	-1974,7
1229	79	-3879,42
1229	379	-3879,42
1230	380	-189,4
1230	351	-189,4
1231	712	-232,03
1231	334	-232,03
1232	695	-367,88
1232	317	-367,88
1233	678	-593,25
1233	300	-593,25
1234	661	-816
1234	283	-816
1235	644	-991,23
1235	266	-991,23
1236	627	-1125,44
1236	249	-1125,44
1237	610	-1228,66
1237	233	-1228,66
1238	594	-1069,82
1238	216	-1069,82
1239	216	114,53
1239	560	114,53
1240	199	-149,06
1240	543	-149,06
1241	182	-221,84

BAR	NODE	Fx (kN)
1241	526	-221,84
1242	165	-351,1
1242	509	-351,1
1243	148	-550,21
1243	492	-550,21
1244	131	-813,94
1244	475	-813,94
1245	114	-1128,98
1245	458	-1128,98
1246	97	-1436,19
1246	441	-1436,19
1247	80	-1448,79
1247	381	-1448,79
1248	382	257,82
1248	361	257,82
1249	722	125,6
1249	352	125,6
1250	713	-222,07
1250	335	-222,07
1251	696	-458,03
1251	318	-458,03
1252	679	-519,78
1252	301	-519,78
1253	662	-452,71
1253	284	-452,71
1254	645	-356,68
1254	267	-356,68
1255	628	-387,61
1255	250	-387,61
1256	611	-827,31
1256	217	-827,31
1257	217	552,68
1257	561	552,68
1258	200	1065,97
1258	544	1065,97
1259	183	1052,8
1259	527	1052,8
1260	166	787,83
1260	510	787,83
1261	149	375,43
1261	493	375,43
1262	132	-125,01
1262	476	-125,01
1263	115	-635,6
1263	459	-635,6
1264	98	-994,86
1264	442	-994,86
1265	81	-920,63
1265	383	-920,63
1266	384	467,67
1266	353	467,67
1267	714	105,19
1267	336	105,19
1268	697	-776,11
1268	319	-776,11
1269	680	-1211,38
1269	302	-1211,38
1270	663	-1322,81
1270	285	-1322,81
1271	646	-1313,54
1271	268	-1313,54
1272	629	-1295,82
1272	251	-1295,82
1273	612	-1300,99
1273	234	-1300,99
1274	595	-1089,01
1274	218	-1089,01
1275	218	108,36
1275	562	108,36

BAR	NODE	Fx (kN)
1276	201	-161,75
1276	545	-161,75
1277	184	-232,88
1277	528	-232,88
1278	167	-352,11
1278	511	-352,11
1279	150	-551,35
1279	494	-551,35
1280	133	-822,26
1280	477	-822,26
1281	116	-1147,55
1281	460	-1147,55
1282	99	-1468,16
1282	443	-1468,16
1283	82	-1490,69
1283	385	-1490,69
1284	386	1223,73
1284	354	1223,73
1285	715	673,7
1285	337	673,7
1286	698	-1891,19
1286	320	-1891,19
1287	681	-2106,59
1287	303	-2106,59
1288	664	-1895,71
1288	286	-1895,71
1289	647	-1671,05
1289	269	-1671,05
1290	630	-1473,93
1290	252	-1473,93
1291	613	-1228,34
1291	235	-1228,34
1292	596	-796,33
1292	219	-796,33
1293	219	298,49
1293	563	298,49
1294	202	-157,99
1294	546	-157,99
1295	185	-414,13
1295	529	-414,13
1296	168	-551,68
1296	512	-551,68
1297	151	-741,66
1297	495	-741,66
1298	134	-978,26
1298	478	-978,26
1299	117	-1330,5
1299	461	-1330,5
1300	100	-2028,56
1300	444	-2028,56
1301	83	-3990,85
1301	387	-3990,85
1302	388	3129,74
1302	355	3129,74
1303	716	4177,5
1303	338	4177,5
1304	699	-5095,91
1304	321	-5095,91
1305	682	-3036,67
1305	304	-3036,67
1306	665	-2203,5
1306	287	-2203,5
1307	648	-1736,59
1307	270	-1736,59
1308	631	-1388,59
1308	253	-1388,59
1309	614	-1036,91
1309	236	-1036,91
1310	597	-651,31

BAR	NODE	Fx (kN)
1310	220	-651,31
1311	220	389,07
1311	564	389,07
1312	203	0,51
1312	547	0,51
1313	186	-354,57
1313	530	-354,57
1314	169	-459,94
1314	513	-459,94
1315	152	-694,23
1315	496	-694,23
1316	135	-905,16
1316	479	-905,16
1317	118	-1155,3
1317	462	-1155,3
1318	101	-1522,57
1318	445	-1522,57
1319	84	-1937,85
1319	389	-1937,85
1320	390	3031,03
1320	356	3031,03
1321	717	3388,31
1321	339	3388,31
1322	700	-3949,92
1322	322	-3949,92
1323	683	-2896,13
1323	305	-2896,13
1324	666	-2125,69
1324	288	-2125,69
1325	649	-1617,6
1325	271	-1617,6
1326	632	-1232,24
1326	254	-1232,24
1327	615	-883,66
1327	237	-883,66
1328	598	-577,11
1328	221	-577,11
1329	221	463,37
1329	565	463,37
1330	204	161,46
1330	548	161,46
1331	187	-143,17
1331	531	-143,17
1332	170	-386,26
1332	514	-386,26
1333	153	-625,39
1333	497	-625,39
1334	136	-838,56
1334	480	-838,56
1335	119	-1020,9
1335	463	-1020,9
1336	102	-1130,85
1336	446	-1130,85
1337	85	-957,69
1337	391	-957,69
1338	392	2741,01
1338	357	2741,01
1339	718	3025,14
1339	340	3025,14
1340	701	-2817,89
1340	323	-2817,89
1341	684	-2340,38
1341	306	-2340,38
1342	667	-1802,43
1342	289	-1802,43
1343	650	-1380,44
1343	272	-1380,44
1344	633	-1045,33
1344	255	-1045,33

BAR	NODE	Fx (kN)
1345	616	-762,68
1345	238	-762,68
1346	599	-561,45
1346	222	-561,45
1347	222	566,93
1347	566	566,93
1348	205	332,28
1348	549	332,28
1349	188	36,24
1349	532	36,24
1350	171	-257,61
1350	515	-257,61
1351	154	-531,54
1351	498	-531,54
1352	137	-762,77
1352	481	-762,77
1353	120	-917,15
1353	464	-917,15
1354	103	-935,32
1354	447	-935,32
1355	86	-725,6
1355	393	-725,6
1356	394	2262,44
1356	358	2262,44
1357	719	2595,65
1357	341	2595,65
1358	702	-2089,83
1358	324	-2089,83
1359	685	-1711,9
1359	307	-1711,9
1360	668	-1325,82
1360	290	-1325,82
1361	651	-1036,89
1361	273	-1036,89
1362	634	-799,12
1362	256	-799,12
1363	617	-645,48
1363	239	-645,48
1364	600	-624,16
1364	223	-624,16
1365	223	742,42
1365	567	742,42
1366	206	551,22
1366	550	551,22
1367	189	245,13
1367	533	245,13
1368	172	-89,14
1368	516	-89,14
1369	155	-410,1
1369	499	-410,1
1370	138	-685,45
1370	482	-685,45
1371	121	-870,48
1371	465	-870,48
1372	104	-899,45
1372	448	-899,45
1373	87	-699,77
1373	395	-699,77
1374	396	1739,36
1374	359	1739,36
1375	720	2111,44
1375	342	2111,44
1376	703	-1350,01
1376	325	-1350,01
1377	686	-1016,61
1377	308	-1016,61
1378	669	-735,62
1378	291	-735,62
1379	652	-600,02

BAR	NODE	Fx (kN)
1379	274	-600,02
1380	635	-409,73
1380	257	-409,73
1381	618	-445,04
1381	240	-445,04
1382	601	-862,73
1382	224	-862,73
1383	224	1070,39
1383	568	1070,39
1384	207	870,85
1384	551	870,85
1385	190	511,25
1385	534	511,25
1386	173	120,56
1386	517	120,56
1387	156	-260,2
1387	500	-260,2
1388	139	-608,17
1388	483	-608,17
1389	122	-886,84
1389	466	-886,84
1390	105	-1015,33
1390	449	-1015,33
1391	88	-838,41
1391	397	-838,41
1392	398	1251,44
1392	360	1251,44
1393	721	1596,17
1393	343	1596,17
1394	704	-349,91
1394	326	-349,91
1395	687	-123,11
1395	309	-123,11
1396	670	78,28
1396	292	78,28
1397	653	-86,38
1397	275	-86,38
1398	636	373,23
1398	258	373,23
1399	619	288,04
1399	241	288,04
1400	602	-1673,8
1400	225	-1673,8
1401	225	1763,09
1401	569	1763,09
1402	208	1349,68
1402	552	1349,68
1403	191	851,68
1403	535	851,68
1404	174	376,27
1404	518	376,27
1405	157	-80,79
1405	501	-80,79
1406	140	-526,54
1406	484	-526,54
1407	123	-959,61
1407	467	-959,61
1408	106	-1344,15
1408	450	-1344,15
1409	89	-1419,28
1409	399	-1419,28
1410	364	1010,13
1410	72	1010,13
1411	433	1169,75
1411	70	1169,75
1412	431	1280,89
1412	68	1280,89
1413	429	1292,3
1413	66	1292,3

BAR	NODE	Fx (kN)
1414	427	1857,8
1414	64	1857,8
1415	425	635,98
1415	62	635,98
1416	423	1686,83
1416	60	1686,83
1417	421	3596,89
1417	58	3596,89
1418	419	-4233,42
1418	56	-4233,42
1419	56	2755,72
1419	415	2755,72
1420	54	1889,99
1420	413	1889,99
1421	52	1262,87
1421	411	1262,87
1422	50	674,94
1422	409	674,94
1423	48	94,89
1423	407	94,89
1424	46	-498,25
1424	405	-498,25
1425	44	-1151,81
1425	403	-1151,81
1426	42	-1986,93
1426	401	-1986,93
1427	40	-3394,63
1427	363	-3394,63
1428	362	-2309,85
1428	6	-2309,85
1429	367	-994,82
1429	8	-994,82
1430	369	-98,23
1430	10	-98,23
1431	371	706,91
1431	12	706,91
1432	373	1559,82
1432	14	1559,82
1433	375	2655,67
1433	16	2655,67
1434	377	4719,38
1434	18	4719,38
1435	379	-2106,84
1435	20	-2106,84
1436	381	-472,56
1436	22	-472,56
1437	22	-625,29
1437	385	-625,29
1438	24	-2301,47
1438	387	-2301,47
1439	26	4701,61
1439	389	4701,61
1440	28	2578,27
1440	391	2578,27
1441	30	1435,1
1441	393	1435,1
1442	32	524,01
1442	395	524,01
1443	34	-361,25
1443	397	-361,25
1444	36	-1385,15
1444	399	-1385,15
1445	38	-2989,92
1445	363	-2989,92
1446	400	-1033,03
1446	73	-1033,03
1447	434	-820,16
1447	74	-820,16
1448	435	-369

BAR	NODE	Fx (kN)
1448	75	-369
1449	436	126,59
1449	76	126,59
1450	437	647,85
1450	77	647,85
1451	438	1142,46
1451	78	1142,46
1452	439	1068,76
1452	79	1068,76
1453	440	-498,48
1453	80	-498,48
1454	441	-173,6
1454	81	-173,6
1455	81	-238,11
1455	443	-238,11
1456	82	-553,06
1456	444	-553,06
1457	83	1071,75
1457	445	1071,75
1458	84	1149,55
1458	446	1149,55
1459	85	638,9
1459	447	638,9
1460	86	91,7
1460	448	91,7
1461	87	-445,46
1461	449	-445,46
1462	88	-959,86
1462	450	-959,86
1463	89	-1222,21
1463	401	-1222,21
1464	402	-610,44
1464	90	-610,44
1465	451	-661
1465	91	-661
1466	452	-474,28
1466	92	-474,28
1467	453	-184,14
1467	93	-184,14
1468	454	126,5
1468	94	126,5
1469	455	354,6
1469	95	354,6
1470	456	336,14
1470	96	336,14
1471	457	-2,67
1471	97	-2,67
1472	458	27,61
1472	98	27,61
1473	98	-5,83
1473	460	-5,83
1474	99	-22,71
1474	461	-22,71
1475	100	337,86
1475	462	337,86
1476	101	367,66
1476	463	367,66
1477	102	140,13
1477	464	140,13
1478	103	-179,17
1478	465	-179,17
1479	104	-487,68
1479	466	-487,68
1480	105	-696,68
1480	467	-696,68
1481	106	-649,63
1481	403	-649,63
1482	404	-489,59
1482	107	-489,59

BAR	NODE	Fx (kN)
1483	468	-594,33
1483	108	-594,33
1484	469	-537,59
1484	109	-537,59
1485	470	-380,7
1485	110	-380,7
1486	471	-188,27
1486	111	-188,27
1487	472	-20,69
1487	112	-20,69
1488	473	80,86
1488	113	80,86
1489	474	80,04
1489	114	80,04
1490	475	102,48
1490	115	102,48
1491	115	70,63
1491	477	70,63
1492	116	58,44
1492	478	58,44
1493	117	73,2
1493	479	73,2
1494	118	-14,14
1494	480	-14,14
1495	119	-169,29
1495	481	-169,29
1496	120	-352,39
1496	482	-352,39
1497	121	-504,85
1497	483	-504,85
1498	122	-563,66
1498	484	-563,66
1499	123	-468,07
1499	405	-468,07
1500	406	-479,6
1500	124	-479,6
1501	485	-611,24
1501	125	-611,24
1502	486	-608,83
1502	126	-608,83
1503	487	-517,62
1503	127	-517,62
1504	488	-382,78
1504	128	-382,78
1505	489	-234,25
1505	129	-234,25
1506	490	-85,32
1506	130	-85,32
1507	491	28,93
1507	131	28,93
1508	492	102,68
1508	132	102,68
1509	132	60,28
1509	494	60,28
1510	133	-6,29
1510	495	-6,29
1511	134	-107,17
1511	496	-107,17
1512	135	-233,72
1512	497	-233,72
1513	136	-358,04
1513	498	-358,04
1514	137	-464,29
1514	499	-464,29
1515	138	-526,42
1515	500	-526,42
1516	139	-515,92
1516	501	-515,92
1517	140	-407,66

BAR	NODE	Fx (kN)
1517	407	-407,66
1518	408	-551,23
1518	141	-551,23
1519	502	-705,25
1519	142	-705,25
1520	503	-698,34
1520	143	-698,34
1521	504	-615,62
1521	144	-615,62
1522	505	-505,38
1522	145	-505,38
1523	506	-379,04
1523	146	-379,04
1524	507	-230,75
1524	147	-230,75
1525	508	-73,4
1525	148	-73,4
1526	509	64,97
1526	149	64,97
1527	149	9,94
1527	511	9,94
1528	150	-128,3
1528	512	-128,3
1529	151	-275,8
1529	513	-275,8
1530	152	-379
1530	514	-379
1531	153	-477,35
1531	515	-477,35
1532	154	-540,91
1532	516	-540,91
1533	155	-557,43
1533	517	-557,43
1534	156	-514,14
1534	518	-514,14
1535	157	-394,56
1535	409	-394,56
1536	410	-797,5
1536	158	-797,5
1537	519	-911,45
1537	159	-911,45
1538	520	-796,54
1538	160	-796,54
1539	521	-668,94
1539	161	-668,94
1540	522	-567,53
1540	162	-567,53
1541	523	-478,37
1541	163	-478,37
1542	524	-371,21
1542	164	-371,21
1543	525	-214,24
1543	165	-214,24
1544	526	-6,02
1544	166	-6,02
1545	166	-66,49
1545	528	-66,49
1546	167	-284,75
1546	529	-284,75
1547	168	-484,68
1547	530	-484,68
1548	169	-452,33
1548	531	-452,33
1549	170	-546,73
1549	532	-546,73
1550	171	-590,36
1550	533	-590,36
1551	172	-593,57
1551	534	-593,57
1552	173	-540,36
1552	535	-540,36
1553	174	-402,44
1553	411	-402,44
1554	412	-1784,69
1554	175	-1784,69
1555	536	-1265,25
1555	176	-1265,25
1556	537	-864,73
1556	177	-864,73
1557	538	-654,03
1557	178	-654,03
1558	539	-552,11
1558	179	-552,11
1559	540	-506,78
1559	180	-506,78
1560	541	-480,27
1560	181	-480,27
1561	542	-400,5
1561	182	-400,5
1562	543	-135,8
1562	183	-135,8
1563	183	-188,51
1563	545	-188,51
1564	184	-454,86
1564	546	-454,86
1565	185	-536,2
1565	547	-536,2
1566	186	-518,6
1566	548	-518,6
1567	187	-551,45
1567	549	-551,45
1568	188	-592,89
1568	550	-592,89
1569	189	-624,28
1569	551	-624,28
1570	190	-602,16
1570	552	-602,16
1571	191	-441,63
1571	413	-441,63
1572	414	-3807,71
1572	192	-3807,71
1573	553	-1633,91
1573	193	-1633,91
1574	554	-878,34
1574	194	-878,34
1575	555	-550,05
1575	195	-550,05
1576	556	-397,26
1576	196	-397,26
1577	557	-346,42
1577	197	-346,42
1578	558	-380,55
1578	198	-380,55
1579	559	-488,44
1579	199	-488,44
1580	560	-414,54
1580	200	-414,54
1581	200	-436,23
1581	562	-436,23
1582	201	-503,61
1582	563	-503,61
1583	202	-384,61
1583	564	-384,61
1584	203	-333,53
1584	565	-333,53
1585	204	-369,1
1585	566	-369,1
1586	205	-471,94
1586	567	-471,94
1587	206	-618,22
1587	568	-618,22
1588	207	-756,17
1588	569	-756,17
1589	208	-680,24
1589	415	-680,24
1590	416	-1191,27
1590	209	-1191,27
1591	570	-849,07
1591	210	-849,07
1592	571	-378,13
1592	211	-378,13
1593	572	28,89
1593	212	28,89
1594	573	348,55
1594	213	348,55
1595	574	578,66
1595	214	578,66
1596	575	688,59
1596	215	688,59
1597	576	572,83
1597	216	572,83
1598	577	-44,98
1598	217	-44,98
1599	217	-34,41
1599	579	-34,41
1600	218	608,77
1600	580	608,77
1601	219	769,13
1601	581	769,13
1602	220	693,89
1602	582	693,89
1603	221	470,15
1603	583	470,15
1604	222	127,19
1604	584	127,19
1605	223	-328,55
1605	585	-328,55
1606	224	-873,7
1606	586	-873,7
1607	225	-1300,47
1607	417	-1300,47
1608	418	-557,98
1608	226	-557,98
1609	587	-729,57
1609	227	-729,57
1610	588	-698,43
1610	228	-698,43
1611	589	-632,22
1611	229	-632,22
1612	590	-578,99
1612	230	-578,99
1613	591	-540,23
1613	231	-540,23
1614	592	-524,08
1614	232	-524,08
1615	593	-535,49
1615	233	-535,49
1616	594	-356,86
1616	250	-356,86
1617	250	-420,33
1617	595	-420,33
1618	234	-545,84
1618	596	-545,84
1619	235	-451,32
1619	597	-451,32
1620	236	-403,2
1620	598	-403,2

BAR	NODE	Fx (kN)
1621	237	-434,13
1621	599	-434,13
1622	238	-570,38
1622	600	-570,38
1623	239	-886,54
1623	601	-886,54
1624	240	-1641,71
1624	602	-1641,71
1625	241	-3941,04
1625	419	-3941,04
1626	420	-354,37
1626	242	-354,37
1627	603	-618
1627	243	-618
1628	604	-777,43
1628	244	-777,43
1629	605	-885,85
1629	245	-885,85
1630	606	-937,07
1630	246	-937,07
1631	607	-903,55
1631	247	-903,55
1632	608	-778
1632	248	-778
1633	609	-527,91
1633	249	-527,91
1634	610	-87,21
1634	267	-87,21
1635	267	-281,2
1635	612	-281,2
1636	251	-623,85
1636	613	-623,85
1637	252	-715,73
1637	614	-715,73
1638	253	-701,54
1638	615	-701,54
1639	254	-690,44
1639	616	-690,44
1640	255	-745,27
1640	617	-745,27
1641	256	-929,11
1641	618	-929,11
1642	257	-1301,91
1642	619	-1301,91
1643	258	-1724,58
1643	421	-1724,58
1644	422	-402,49
1644	259	-402,49
1645	620	-568,01
1645	260	-568,01
1646	621	-795,97
1646	261	-795,97
1647	622	-1068,11
1647	262	-1068,11
1648	623	-1173,78
1648	263	-1173,78
1649	624	-1068,6
1649	264	-1068,6
1650	625	-789,43
1650	265	-789,43
1651	626	-376,66
1651	266	-376,66
1652	627	95,04
1652	284	95,04
1653	284	-336,48
1653	629	-336,48
1654	268	-656,24
1654	630	-656,24
1655	269	-796,61

BAR	NODE	Fx (kN)
1655	631	-796,61
1656	270	-786,09
1656	632	-786,09
1657	271	-738,22
1657	633	-738,22
1658	272	-740,59
1658	634	-740,59
1659	273	-840,3
1659	635	-840,3
1660	274	-987,49
1660	636	-987,49
1661	275	-865,36
1661	423	-865,36
1662	424	-892,62
1662	276	-892,62
1663	637	-410,59
1663	277	-410,59
1664	638	-731,22
1664	278	-731,22
1665	639	-1392,5
1665	279	-1392,5
1666	640	-1502,64
1666	280	-1502,64
1667	641	-1231,29
1667	281	-1231,29
1668	642	-780,89
1668	282	-780,89
1669	643	-258,43
1669	283	-258,43
1670	644	254,28
1670	301	254,28
1671	301	-524,69
1671	646	-524,69
1672	285	-852,91
1672	647	-852,91
1673	286	-965,74
1673	648	-965,74
1674	287	-836,31
1674	649	-836,31
1675	288	-665,7
1675	650	-665,7
1676	289	-581,19
1676	651	-581,19
1677	290	-629,75
1677	652	-629,75
1678	291	-831,62
1678	653	-831,62
1679	292	-1333,77
1679	425	-1333,77
1680	426	329,21
1680	293	329,21
1681	654	553,12
1681	294	553,12
1682	655	-164,85
1682	295	-164,85
1683	656	-2253,24
1683	296	-2253,24
1684	657	-2011,37
1684	297	-2011,37
1685	658	-1388,35
1685	298	-1388,35
1686	659	-759,14
1686	299	-759,14
1687	660	-169,82
1687	300	-169,82
1688	661	390,42
1688	318	390,42
1689	318	-789,65
1689	663	-789,65

BAR	NODE	Fx (kN)
1690	302	-1238,56
1690	664	-1238,56
1691	303	-1365,16
1691	665	-1365,16
1692	304	-869,47
1692	666	-869,47
1693	305	-436,5
1693	667	-436,5
1694	306	-236,03
1694	668	-236,03
1695	307	-187,43
1695	669	-187,43
1696	308	-243,92
1696	670	-243,92
1697	309	-380,02
1697	427	-380,02
1698	428	1591,17
1698	310	1591,17
1699	671	2017,53
1699	311	2017,53
1700	672	2614
1700	312	2614
1701	673	-5076,97
1701	313	-5076,97
1702	674	-2546,68
1702	314	-2546,68
1703	675	-1403,24
1703	315	-1403,24
1704	676	-679,32
1704	316	-679,32
1705	677	-132,22
1705	317	-132,22
1706	678	430,63
1706	335	430,63
1707	335	-1004,07
1707	680	-1004,07
1708	319	-1776,82
1708	681	-1776,82
1709	320	-2329,7
1709	682	-2329,7
1710	321	-607,95
1710	683	-607,95
1711	322	108,36
1711	684	108,36
1712	323	248,39
1712	685	248,39
1713	324	288,84
1713	686	288,84
1714	325	284,76
1714	687	284,76
1715	326	174,08
1715	429	174,08
1716	430	1327,72
1716	327	1327,72
1717	688	1459,79
1717	328	1459,79
1718	689	1567,36
1718	329	1567,36
1719	690	-3016,23
1719	330	-3016,23
1720	691	-1921,02
1720	331	-1921,02
1721	692	-1072,8
1721	332	-1072,8
1722	693	-513,57
1722	333	-513,57
1723	694	-189,34
1723	334	-189,34
1724	695	283,99

BAR	NODE	Fx (kN)
1724	352	283,99
1725	352	-969,14
1725	697	-969,14
1726	336	-2187,93
1726	698	-2187,93
1727	337	-5090,29
1727	699	-5090,29
1728	338	1782,33
1728	700	1782,33
1729	339	1287,85
1729	701	1287,85
1730	340	1123,15
1730	702	1123,15
1731	341	1098,05
1731	703	1098,05
1732	342	1103,92
1732	704	1103,92
1733	343	940,55
1733	431	940,55
1734	365	921,84
1734	5	921,84
1735	366	963,63
1735	7	963,63
1736	368	960,32
1736	9	960,32
1737	370	1070,34
1737	11	1070,34
1738	372	549,79
1738	13	549,79
1739	374	521,65
1739	15	521,65
1740	376	951,31
1740	17	951,31
1741	378	-528,78
1741	19	-528,78
1742	380	-153,89
1742	21	-153,89
1743	21	234,49
1743	384	234,49
1744	23	516,67
1744	386	516,67
1745	25	905,85
1745	388	905,85
1746	27	932,21
1746	390	932,21
1747	29	956,45
1747	392	956,45
1748	31	958,36
1748	394	958,36
1749	33	945,38
1749	396	945,38
1750	35	931,61
1750	398	931,61
1751	37	886,26
1751	364	886,26
1752	432	1031,79
1752	344	1031,79
1753	705	1174,32
1753	345	1174,32
1754	706	1301,3
1754	346	1301,3
1755	707	-1021,16
1755	347	-1021,16
1756	708	-844,11
1756	348	-844,11
1757	709	-447,75
1757	349	-447,75
1758	710	-132,68
1758	350	-132,68

BAR	NODE	Fx (kN)
1759	711	-308,96
1759	351	-308,96
1760	712	71,16
1760	361	71,16
1761	361	-540,86
1761	714	-540,86
1762	353	-1240,82
1762	715	-1240,82
1763	354	-2128,34
1763	716	-2128,34
1764	355	745,8
1764	717	745,8
1765	356	765,61
1765	718	765,61
1766	357	712,26
1766	719	712,26
1767	358	707,98
1767	720	707,98
1768	359	742,59
1768	721	742,59
1769	360	749,84
1769	433	749,84

Roof structure - displacement

Here it follows a table containing the displacements, which were verified for the whole structure. They are presented for each node, divided in the different direction of the displacement: x, y and z. The higher displacement are in z direction, because all the loads are directed in that direction, negative because they are heading towards the ground.

The maximum value for the displacement is reached by node 200, with a value of 8 cm, which is acceptable being less than 9cm.

NODE	Ux (cm)	Uy (cm)	Uz (cm)
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	-0,1	-0,1	-0,7
7	0	0	0
8	-0,1	-0,2	-1,1
9	0	0	0
10	0	-0,3	-1,4
11	0	0,1	0
12	0	-0,3	-1,3
13	0	0,2	0
14	0,1	-0,3	-1,1
15	0	0,2	-0,1
16	0,1	-0,3	-0,7
17	0	0	0
18	0	0	0
19	0	0,2	-0,1
20	0	-0,3	-0,4
21	0	0,2	-0,1
22	0	-0,3	-0,5
23	0	0,1	-0,1
24	0	-0,3	-0,4
25	0	0	0
26	0	0	0
27	0	0	0
28	-0,1	-0,3	-0,7
29	0	0	0
30	-0,1	-0,4	-1,2
31	0	0	0
32	0	-0,3	-1,4
33	0	0	0
34	0	-0,3	-1,5
35	0	0	0
36	0,1	-0,2	-1,3
37	0	0	0
38	0,1	-0,2	-0,8
39	-0,1	-0,1	-0,8
40	0,1	-0,1	-1,1
41	-0,1	-0,1	-1,4
42	0,1	-0,1	-2
43	-0,2	-0,1	-1,7
44	0,1	-0,1	-2,6
45	-0,3	0	-1,8

NODE	Ux (cm)	Uy (cm)	Uz (cm)
46	0,2	-0,1	-3
47	-0,3	0	-1,7
48	0,2	0	-3,1
49	-0,3	0,1	-1,3
50	0,3	0,1	-2,9
51	-0,3	0,1	-0,8
52	0,3	0,1	-2,5
53	0	0	0
54	0,3	0,2	-1,9
55	-0,3	-0,1	-0,4
56	0,2	0,2	-1,1
57	-0,3	0	-0,5
58	0	0	0
59	-0,3	0	-0,5
60	0,3	0	-0,2
61	-0,2	0	-0,3
62	0,2	0	-0,2
63	0	0	0
64	0	0	0
65	-0,1	0	0
66	0,1	0	0
67	0	0	0
68	0,1	0	0
69	0	0	0
70	0	0	0
71	0	0	0
72	0	0	0
73	-0,1	-0,1	-1,3
74	-0,1	-0,2	-1,8
75	0	-0,2	-2,1
76	0	-0,3	-2,2
77	0	-0,3	-2,2
78	0	-0,4	-2
79	0	-0,2	-1,8
80	0	-0,3	-1,9
81	0	-0,3	-1,9
82	0	-0,3	-1,9
83	0	-0,2	-1,8
84	-0,1	-0,4	-2,1
85	0	-0,4	-2,3
86	0	-0,3	-2,4
87	0	-0,3	-2,3
88	0,1	-0,2	-2
89	0,1	-0,2	-1,6
90	-0,1	-0,1	-1,9

NODE	Ux (cm)	Uy (cm)	Uz (cm)
91	-0,1	-0,2	-2,4
92	-0,1	-0,2	-2,8
93	-0,1	-0,3	-3
94	0	-0,3	-3,2
95	0	-0,3	-3,2
96	0	-0,3	-3,2
97	0	-0,3	-3,3
98	0	-0,3	-3,3
99	0	-0,3	-3,3
100	0	-0,3	-3,3
101	0	-0,4	-3,4
102	0	-0,3	-3,4
103	0	-0,3	-3,3
104	0,1	-0,3	-3,1
105	0,1	-0,2	-2,8
106	0,1	-0,2	-2,4
107	-0,2	-0,1	-2,3
108	-0,2	-0,1	-2,9
109	-0,1	-0,2	-3,4
110	-0,1	-0,2	-3,8
111	-0,1	-0,3	-4,1
112	-0,1	-0,3	-4,3
113	0	-0,3	-4,5
114	0	-0,3	-4,6
115	0	-0,3	-4,6
116	0	-0,3	-4,6
117	0	-0,3	-4,6
118	0	-0,3	-4,5
119	0,1	-0,3	-4,4
120	0,1	-0,3	-4,2
121	0,1	-0,2	-3,9
122	0,1	-0,2	-3,5
123	0,1	-0,1	-3,1
124	-0,2	0	-2,5
125	-0,2	-0,1	-3,2
126	-0,2	-0,1	-3,9
127	-0,2	-0,2	-4,5
128	-0,1	-0,2	-4,9
129	-0,1	-0,3	-5,3
130	-0,1	-0,2	-5,5
131	0	-0,2	-5,7
132	0	-0,3	-5,7
133	0	-0,3	-5,7
134	0	-0,2	-5,6
135	0,1	-0,3	-5,5

NODE	Ux (cm)	Uy (cm)	Uz (cm)
136	0,1	-0,2	-5,2
137	0,1	-0,2	-4,9
138	0,1	-0,2	-4,5
139	0,2	-0,1	-4
140	0,2	-0,1	-3,5
141	-0,3	0	-2,5
142	-0,3	0	-3,4
143	-0,3	-0,1	-4,2
144	-0,2	-0,1	-4,9
145	-0,2	-0,2	-5,5
146	-0,1	-0,2	-6
147	-0,1	-0,2	-6,3
148	-0,1	-0,2	-6,5
149	0	-0,2	-6,6
150	0	-0,2	-6,6
151	0,1	-0,2	-6,5
152	0,1	-0,2	-6,2
153	0,1	-0,2	-5,9
154	0,2	-0,1	-5,4
155	0,2	-0,1	-4,9
156	0,2	-0,1	-4,3
157	0,2	0	-3,7
158	-0,3	0,1	-2,4
159	-0,3	0	-3,4
160	-0,3	0	-4,4
161	-0,3	-0,1	-5,2
162	-0,2	-0,1	-5,9
163	-0,2	-0,1	-6,5
164	-0,1	-0,1	-6,9
165	-0,1	-0,1	-7,2
166	0	-0,2	-7,3
167	0	-0,1	-7,3
168	0,1	-0,1	-7,1
169	0,1	-0,1	-6,7
170	0,2	-0,1	-6,3
171	0,2	-0,1	-5,7
172	0,2	0	-5,1
173	0,2	0	-4,4
174	0,3	0	-3,6
175	-0,3	0,1	-2
176	-0,3	0,1	-3,3
177	-0,3	0	-4,4
178	-0,3	0	-5,3
179	-0,2	0	-6,1
180	-0,2	0	-6,8
181	-0,1	-0,1	-7,3
182	-0,1	-0,1	-7,6
183	0	-0,1	-7,8
184	0,1	-0,1	-7,7
185	0,1	0	-7,4
186	0,1	0	-7
187	0,2	0	-6,5
188	0,2	0	-5,8
189	0,3	0	-5,1
190	0,3	0,1	-4,3
191	0,3	0,1	-3,4
192	-0,2	0,1	-1,7
193	-0,3	0,1	-3,1
194	-0,3	0,1	-4,3
195	-0,3	0	-5,3
196	-0,2	0	-6,1
197	-0,2	0	-6,8
198	-0,1	0	-7,4
199	-0,1	0	-7,8
200	0	0	-8
201	0,1	0	-7,9
202	0,1	0	-7,5
203	0,2	0	-7,1
204	0,2	0,1	-6,5

NODE	Ux (cm)	Uy (cm)	Uz (cm)
205	0,2	0,1	-5,7
206	0,3	0,1	-4,9
207	0,3	0,1	-3,9
208	0,3	0,1	-2,9
209	-0,3	0	-1,7
210	-0,3	0,1	-2,9
211	-0,3	0,1	-4,1
212	-0,3	0,1	-5,1
213	-0,3	0,1	-6
214	-0,2	0,1	-6,7
215	-0,2	0,1	-7,3
216	-0,1	0,1	-7,7
217	0	0,1	-7,9
218	0,1	0,1	-7,8
219	0,1	0,1	-7,4
220	0,2	0,1	-6,9
221	0,2	0,1	-6,2
222	0,2	0,1	-5,4
223	0,2	0,1	-4,5
224	0,2	0,1	-3,5
225	0,2	0,1	-2,3
226	-0,3	0	-1,6
227	-0,3	0,1	-2,7
228	-0,3	0,1	-3,8
229	-0,3	0,1	-4,7
230	-0,2	0,1	-5,6
231	-0,2	0,2	-6,3
232	-0,1	0,2	-6,8
233	-0,1	0,2	-7,2
234	0	0,2	-7,2
235	0,1	0,2	-6,9
236	0,1	0,2	-6,4
237	0,2	0,2	-5,8
238	0,2	0,2	-5
239	0,2	0,2	-4,1
240	0,2	0,1	-3
241	0,2	0,1	-1,7
242	-0,3	0	-1,4
243	-0,3	0,1	-2,4
244	-0,2	0,1	-3,3
245	-0,2	0,2	-4,2
246	-0,2	0,2	-5
247	-0,2	0,2	-5,7
248	-0,1	0,2	-6,2
249	-0,1	0,2	-6,5
250	0	0,2	-7,4
251	0	0,2	-6,5
252	0,1	0,2	-6,2
253	0,1	0,2	-5,7
254	0,2	0,2	-5,1
255	0,2	0,2	-4,4
256	0,2	0,2	-3,5
257	0,3	0,1	-2,5
258	0,3	0,1	-1,4
259	-0,2	0,1	-1,1
260	-0,2	0,1	-1,9
261	-0,2	0,2	-2,8
262	-0,2	0,2	-3,6
263	-0,2	0,2	-4,3
264	-0,1	0,2	-5
265	-0,1	0,2	-5,4
266	-0,1	0,2	-5,7
267	0	0,2	-6,7
268	0	0,3	-5,6
269	0,1	0,3	-5,3
270	0,1	0,3	-4,9
271	0,1	0,2	-4,3
272	0,2	0,2	-3,7
273	0,2	0,2	-2,9

NODE	Ux (cm)	Uy (cm)	Uz (cm)
274	0,2	0,1	-2,1
275	0,2	0	-1,1
276	-0,1	0,1	-0,7
277	-0,1	0,1	-1,4
278	-0,1	0,2	-2,1
279	-0,1	0,2	-2,8
280	-0,1	0,2	-3,5
281	-0,1	0,2	-4,1
282	-0,1	0,2	-4,6
283	0	0,2	-4,8
284	0	0,3	-5,8
285	0	0,3	-4,6
286	0,1	0,3	-4,3
287	0,1	0,3	-3,8
288	0,1	0,2	-3,4
289	0,1	0,2	-2,8
290	0,1	0,2	-2,2
291	0,1	0,1	-1,6
292	0,1	0,1	-0,8
293	-0,1	0	-0,3
294	-0,1	0,1	-0,7
295	-0,1	0,1	-1,2
296	-0,1	0,1	-2
297	-0,1	0,2	-2,7
298	-0,1	0,2	-3,3
299	-0,1	0,2	-3,7
300	0	0,2	-3,8
301	0	0,3	-4,8
302	0	0,2	-3,6
303	0,1	0,2	-3,2
304	0,1	0,2	-2,7
305	0,1	0,2	-2,3
306	0,1	0,2	-1,9
307	0,1	0,2	-1,5
308	0,1	0,1	-1,1
309	0,1	0	-0,6
310	0	0	0
311	0	0	0
312	0	0	0
313	-0,1	0,1	-1,1
314	-0,1	0,2	-1,9
315	-0,1	0,2	-2,4
316	-0,1	0,2	-2,7
317	0	0,2	-2,9
318	0	0,2	-3,8
319	0,1	0,2	-2,5
320	0,1	0,2	-2,1
321	0	0,2	-1,5
322	0	0,1	-1,1
323	0	0,1	-0,9
324	0	0,1	-0,7
325	0,1	0,1	-0,5
326	0,1	0	-0,3
327	0	0	0
328	0	0	0
329	0	0	0
330	-0,1	0,1	-0,7
331	-0,1	0,2	-1,2
332	-0,1	0,2	-1,6
333	0	0,2	-1,8
334	0	0,2	-1,9
335	0	0,2	-2,8
336	0,1	0,2	-1,6
337	0,1	0,1	-1
338	0	0	0
339	0	0	0
340	0	0	0
341	0	0	0
342	0	0	0

NODE	Ux (cm)	Uy (cm)	Uz (cm)
343	0	0	0
344	0	0	0
345	0	0	0
346	0	0	0
347	0	0,1	-0,3
348	0	0,2	-0,6
349	0	0,2	-0,8
350	0	0,1	-0,9
351	0	0,2	-1
352	0	0,2	-1,9
353	0	0,1	-0,8
354	0,1	0	-0,4
355	0	0	0
356	0	0	0
357	0	0	0
358	0	0	0
359	0	0	0
360	0	0	0
361	0	0,2	-1
362	0,3	0,3	-0,1
363	-0,2	0,5	-0,2
364	-0,1	-0,1	0
365	0,1	-0,1	0
366	0,1	-0,2	0
367	0,2	0,3	-0,8
368	0,1	-0,2	0
369	0,1	0,3	-1,2
370	0,1	-0,2	0
371	0,1	0,4	-1,4
372	0,1	-0,3	0
373	0	0,5	-1,3
374	0,1	-0,4	0
375	-0,1	0,6	-1,1
376	0	-0,6	-0,1
377	-0,1	0,8	-0,6
378	0	-0,7	0
379	0	1	-0,2
380	0	-0,7	-0,2
381	0	0,9	-0,5
382	-0,1	-0,7	-0,1
383	0	0,9	-0,6
384	-0,1	-0,6	-0,1
385	0	0,9	-0,5
386	-0,1	-0,5	0
387	0	1	-0,2
388	-0,1	-0,4	0,1
389	0,1	0,8	-0,6
390	-0,1	-0,4	0,1
391	0,1	0,7	-1,2
392	-0,1	-0,3	0,1
393	0	0,5	-1,4
394	-0,1	-0,3	0,1
395	0	0,5	-1,5
396	-0,1	-0,2	0
397	-0,1	0,4	-1,3
398	-0,1	-0,2	0
399	-0,2	0,4	-0,9
400	0,2	0,2	-0,9
401	-0,2	0,4	-1,2
402	0,3	0,2	-1,4
403	-0,2	0,3	-2
404	0,3	0,1	-1,7
405	-0,2	0,2	-2,6
406	0,4	0	-1,8
407	-0,3	0,1	-3
408	0,5	-0,1	-1,6
409	-0,4	0	-3,1
410	0,7	-0,2	-1,3
411	-0,5	-0,1	-2,9

NODE	Ux (cm)	Uy (cm)	Uz (cm)
412	0,8	-0,2	-0,7
413	-0,6	-0,2	-2,5
414	0,9	-0,1	-0,2
415	-0,7	-0,2	-1,9
416	0,9	-0,1	-0,5
417	-0,8	-0,3	-1,2
418	0,7	-0,1	-0,5
419	-0,9	-0,3	-0,2
420	0,6	-0,2	-0,5
421	-0,7	-0,2	-0,2
422	0,5	-0,2	-0,3
423	-0,6	-0,2	-0,2
424	0,5	-0,2	0
425	-0,5	-0,2	0
426	0,3	-0,2	0,1
427	-0,4	-0,2	0
428	0,2	-0,2	0,1
429	-0,2	-0,2	0
430	0,2	-0,2	0
431	-0,1	-0,2	0
432	0,1	-0,1	0
433	-0,1	-0,1	0
434	0,2	0,3	-1,4
435	0,2	0,3	-1,8
436	0,1	0,4	-2,1
437	0	0,5	-2,2
438	0	0,6	-2,2
439	0	0,7	-2
440	0	0,9	-1,9
441	0	0,9	-1,9
442	0	0,9	-2
443	0	0,9	-1,9
444	0,1	0,9	-1,9
445	0,1	0,8	-2,1
446	0	0,6	-2,3
447	0	0,5	-2,4
448	-0,1	0,4	-2,3
449	-0,1	0,4	-2,1
450	-0,2	0,4	-1,7
451	0,3	0,2	-1,9
452	0,2	0,3	-2,4
453	0,2	0,3	-2,8
454	0,1	0,4	-3,1
455	0,1	0,5	-3,2
456	0	0,6	-3,3
457	0	0,8	-3,3
458	0	0,8	-3,3
459	0	0,9	-3,4
460	0	0,8	-3,4
461	0	0,8	-3,4
462	0	0,7	-3,4
463	0	0,6	-3,4
464	-0,1	0,5	-3,4
465	-0,1	0,4	-3,2
466	-0,2	0,4	-2,9
467	-0,2	0,3	-2,5
468	0,3	0,1	-2,3
469	0,3	0,2	-2,9
470	0,2	0,3	-3,4
471	0,2	0,3	-3,8
472	0,1	0,4	-4,2
473	0,1	0,5	-4,4
474	0,1	0,6	-4,5
475	0	0,7	-4,6
476	0	0,8	-4,6
477	0	0,7	-4,6
478	0	0,7	-4,6
479	0	0,6	-4,6
480	-0,1	0,5	-4,4

NODE	Ux (cm)	Uy (cm)	Uz (cm)
481	-0,1	0,4	-4,2
482	-0,2	0,3	-3,9
483	-0,2	0,3	-3,5
484	-0,2	0,2	-3,1
485	0,4	0	-2,5
486	0,4	0,1	-3,2
487	0,3	0,2	-3,9
488	0,3	0,3	-4,5
489	0,2	0,3	-4,9
490	0,1	0,4	-5,3
491	0,1	0,5	-5,5
492	0,1	0,6	-5,7
493	0	0,7	-5,7
494	0	0,6	-5,7
495	0	0,5	-5,7
496	-0,1	0,4	-5,5
497	-0,1	0,4	-5,3
498	-0,2	0,3	-4,9
499	-0,2	0,2	-4,5
500	-0,3	0,2	-4
501	-0,3	0,1	-3,5
502	0,5	0	-2,5
503	0,5	0	-3,4
504	0,4	0,1	-4,2
505	0,3	0,2	-4,9
506	0,3	0,2	-5,5
507	0,2	0,3	-6
508	0,1	0,4	-6,3
509	0,1	0,5	-6,6
510	0	0,6	-6,6
511	0	0,5	-6,6
512	-0,1	0,4	-6,5
513	-0,1	0,3	-6,3
514	-0,2	0,2	-5,9
515	-0,2	0,2	-5,5
516	-0,3	0,1	-4,9
517	-0,3	0,1	-4,3
518	-0,3	0	-3,7
519	0,6	-0,1	-2,4
520	0,6	0	-3,4
521	0,5	0	-4,4
522	0,4	0,1	-5,2
523	0,3	0,1	-5,9
524	0,3	0,2	-6,5
525	0,2	0,3	-6,9
526	0,1	0,3	-7,2
527	0	0,4	-7,3
528	0	0,3	-7,3
529	-0,1	0,3	-7,1
530	-0,2	0,2	-6,8
531	-0,2	0,1	-6,3
532	-0,3	0,1	-5,8
533	-0,4	0	-5,1
534	-0,4	0	-4,4
535	-0,4	-0,1	-3,6
536	0,7	-0,1	-2
537	0,7	-0,1	-3,3
538	0,6	0	-4,4
539	0,5	0	-5,3
540	0,4	0	-6,1
541	0,3	0,1	-6,8
542	0,2	0,1	-7,3
543	0,1	0,2	-7,6
544	0	0,3	-7,8
545	-0,1	0,2	-7,7
546	-0,1	0,1	-7,5
547	-0,2	0,1	-7,1
548	-0,3	0	-6,5
549	-0,4	0	-5,9

NODE	Ux (cm)	Uy (cm)	Uz (cm)
550	-0,4	-0,1	-5,1
551	-0,5	-0,1	-4,3
552	-0,5	-0,2	-3,4
553	0,8	-0,1	-1,8
554	0,8	-0,1	-3,1
555	0,7	-0,1	-4,3
556	0,6	-0,1	-5,3
557	0,5	0	-6,1
558	0,4	0	-6,8
559	0,3	0	-7,4
560	0,1	0	-7,8
561	0	0,1	-8
562	-0,1	0	-7,9
563	-0,2	0	-7,6
564	-0,3	-0,1	-7,1
565	-0,4	-0,1	-6,5
566	-0,5	-0,1	-5,7
567	-0,6	-0,1	-4,9
568	-0,6	-0,2	-3,9
569	-0,7	-0,2	-2,9
570	0,8	-0,1	-1,7
571	0,8	-0,1	-3
572	0,7	-0,1	-4,1
573	0,6	-0,1	-5,1
574	0,6	-0,1	-6
575	0,5	-0,1	-6,7
576	0,4	-0,1	-7,3
577	0,2	-0,1	-7,7
578	0	-0,1	-7,9
579	-0,2	-0,1	-7,8
580	-0,3	-0,1	-7,4
581	-0,4	-0,2	-6,9
582	-0,5	-0,2	-6,2
583	-0,6	-0,2	-5,4
584	-0,7	-0,2	-4,5
585	-0,7	-0,2	-3,5
586	-0,8	-0,3	-2,4
587	0,7	-0,1	-1,6
588	0,7	-0,1	-2,7
589	0,6	-0,2	-3,8
590	0,5	-0,2	-4,7
591	0,4	-0,2	-5,6
592	0,3	-0,2	-6,3
593	0,2	-0,2	-6,9
594	0,1	-0,2	-7,3
595	-0,1	-0,3	-7,3
596	-0,2	-0,3	-6,9
597	-0,3	-0,3	-6,4
598	-0,4	-0,3	-5,8
599	-0,5	-0,3	-5
600	-0,6	-0,2	-4,1
601	-0,7	-0,2	-3
602	-0,8	-0,2	-1,8
603	0,6	-0,2	-1,4
604	0,6	-0,2	-2,4
605	0,5	-0,2	-3,4
606	0,4	-0,3	-4,3
607	0,4	-0,3	-5,1
608	0,3	-0,3	-5,7
609	0,2	-0,3	-6,2
610	0,1	-0,4	-6,6
611	0	-0,3	-7,4
612	-0,1	-0,4	-6,6
613	-0,2	-0,4	-6,2
614	-0,3	-0,4	-5,8
615	-0,4	-0,3	-5,1
616	-0,5	-0,3	-4,4
617	-0,5	-0,3	-3,6
618	-0,6	-0,2	-2,6
619	-0,7	-0,2	-1,4
620	0,5	-0,2	-1,2
621	0,5	-0,2	-2
622	0,4	-0,3	-2,8
623	0,4	-0,3	-3,6
624	0,3	-0,3	-4,4
625	0,2	-0,4	-5
626	0,2	-0,4	-5,5
627	0,1	-0,5	-5,7
628	0	-0,5	-6,7
629	-0,1	-0,5	-5,7
630	-0,2	-0,5	-5,4
631	-0,2	-0,4	-4,9
632	-0,3	-0,4	-4,3
633	-0,4	-0,4	-3,7
634	-0,5	-0,3	-3
635	-0,5	-0,3	-2,1
636	-0,6	-0,2	-1,2
637	0,4	-0,2	-0,8
638	0,4	-0,3	-1,4
639	0,4	-0,3	-2,1
640	0,3	-0,4	-2,9
641	0,3	-0,4	-3,6
642	0,2	-0,4	-4,2
643	0,1	-0,5	-4,6
644	0	-0,5	-4,8
645	0	-0,6	-5,8
646	-0,1	-0,6	-4,7
647	-0,2	-0,5	-4,3
648	-0,2	-0,5	-3,9
649	-0,3	-0,5	-3,4
650	-0,3	-0,4	-2,9
651	-0,4	-0,4	-2,3
652	-0,4	-0,3	-1,6
653	-0,5	-0,2	-0,9
654	0,3	-0,2	-0,4
655	0,3	-0,3	-0,8
656	0,3	-0,3	-1,3
657	0,3	-0,4	-2,1
658	0,2	-0,4	-2,8
659	0,2	-0,5	-3,3
660	0,1	-0,5	-3,7
661	0	-0,6	-3,9
662	0	-0,6	-4,9
663	-0,1	-0,6	-3,6
664	-0,1	-0,6	-3,3
665	-0,2	-0,6	-2,8
666	-0,2	-0,5	-2,4
667	-0,2	-0,5	-2
668	-0,3	-0,4	-1,5
669	-0,3	-0,3	-1,1
670	-0,3	-0,2	-0,6
671	0,2	-0,2	0
672	0,2	-0,3	0
673	0,3	-0,3	-0,2
674	0,3	-0,4	-1,2
675	0,2	-0,4	-2
676	0,1	-0,5	-2,5
677	0,1	-0,6	-2,8
678	0	-0,6	-2,9
679	0	-0,7	-3,8
680	-0,1	-0,6	-2,6
681	-0,1	-0,6	-2,1
682	-0,2	-0,6	-1,6
683	-0,1	-0,5	-1,2
684	-0,1	-0,5	-1
685	-0,2	-0,4	-0,8
686	-0,2	-0,3	-0,5
687	-0,2	-0,2	-0,3
688	0,2	-0,2	0
689	0,2	-0,2	0,1
690	0,2	-0,3	0
691	0,2	-0,3	-0,7
692	0,2	-0,4	-1,3
693	0,1	-0,5	-1,6
694	0	-0,6	-1,9
695	0	-0,7	-1,9
696	0	-0,7	-2,8
697	-0,1	-0,6	-1,6
698	-0,1	-0,6	-1,1
699	-0,2	-0,5	-0,2
700	-0,1	-0,5	-0,1
701	-0,1	-0,5	0
702	-0,1	-0,4	0
703	-0,1	-0,3	0
704	-0,1	-0,2	0
705	0,1	-0,2	0
706	0,2	-0,2	0
707	0,2	-0,2	0
708	0,1	-0,3	-0,3
709	0,1	-0,4	-0,6
710	0,1	-0,5	-0,8
711	0	-0,6	-1
712	0	-0,7	-1
713	0	-0,7	-1,9
714	-0,1	-0,6	-0,8
715	-0,1	-0,5	-0,5
716	-0,2	-0,4	0
717	-0,1	-0,4	0,1
718	-0,1	-0,4	0,1
719	-0,1	-0,3	0,1
720	-0,1	-0,2	0
721	-0,1	-0,2	0
722	0	-0,7	-1