Antiseismic GreenRinG

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Architectural application of seismic control through tuned mass damping. Roof garden project on the Ex Ceat complex in Turin.

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ABSTRACT

Negli ultimi anni il tema delle sopraelevazioni come strumento di recupero è risultato essere tra i più diffusi grazie agli innumerevoli vantaggi che offre. Per far fronte ad un contesto progettuale sempre più attento all'aspetto sostenibile, la tipologia di sopraelevazione preferita è la copertura verde, sia estensiva nel caso di un intervento minore che intensiva per far fronte a richieste specifiche. Il metodo acquisisce un valore ulteriore quando si fonde ad aspetti tecnologico-strutturali e anzi li sottolinea andando a realizzare un sistema complesso e funzionale.

Questa fusione può concretizzarsi nel sistema di mitigazione sismica TMD, un accorgimento che permette di ridurre gli spostamenti di un edificio in seguito a delle sollecitazioni provocate da sismi e quindi rende l'edificio più stabile accorciando i suoi tempi di oscillazione. Per verificare l'effettivo funzionamento di questa tecnologia si è scelto un caso studio, conforme ai requisiti, al quale poterla applicare. L'esperimento ha permesso quindi di adottare un approccio alla progettazione misto che ha unito l'aspetto compositivo, andando a soddisfare le esigenze del caso studio prescelto e degli stakeholders che ne usufruiscono oggi e ne potrebbero usufruire in futuro e, quello strutturale che ha comportato uno studio preliminare della teoria di funzionamento del sistema e una simulazione tramite software idoneo per confermare la riuscita dell'applicazione. In questa ultima fase, ancora più che durante tutto il processo evolutivo di ricerca, si evince come i due approcci non possano riuscire al completo se non coesistendo. Pertanto, risulta fondamentale un continuo confronto tra le due discipline per poter affrontare gli eventuali ostacoli e trovar loro la soluzione più congeniale.

ABSTRACT

In recent years, the issue of elevations as a recovery tool has proved to be among the most widespread thanks to the many advantages it offers. In order to cope with a design context that is increasingly attentive to the sustainable aspect, the preferred type of elevation is green roofing, whether extensive in the case of minor or intensive intervention to meet specific requests. The method acquires a further value when it merges with technological-structural aspects and even underlines them by creating a complex and functional system. This fusion can take the form of the TMD seismic mitigation system, a device that makes it possible to reduce the movement of a building as a result of the stresses caused by earthquakes and therefore makes the building more stable by shortening its oscillation times. In order to verify the effective functioning of this technology, a case study was chosen, in accordance with the requirements, to which it could be applied.

The experiment allowed to adopt a mixed approach to design that combined the compositional aspect, meeting the needs of the selected case study and stakeholders who use it today and could use it in the future, and the structural one that involved a preliminary study of the theory of system operation and a simulation by suitable software to confirm the success of the application. In this last phase, even more than during the whole evolutionary process of research, it is clear that the two approaches cannot succeed in full if they do not coexist. Therefore, a continuous comparison between the two disciplines is fundamental in order to face possible obstacles and find the most suitable solution for them.

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INTRODUCTION

INTRODUCTION

Earthquakes are among the major causes of destruction of buildings, and more generally, of entire cities. Over the years they have taken on different interpretations, but today, thanks to scientific development, we are able to recognize the cause and consequently, we can try to prevent them. In fact, often afterwards we recognize "premonitory signals", better known as seismic precursors that, although not with a scientific value, can be considered in this operation of prevention. This does not allow to have an effective and irrefutable data that would generate possible evacuations before the disaster. What it can do is to prevent damage by meeting certain requirements. One of these is the adoption of a suitable design, or rather anti-seismic, and in the event that the building in question does not have this characteristic, try to remedy it by adapting it. The systems to do this are varied, but in this thesis we have chosen to deepen one that although widely studied at the theoretical level, is innovative because it is not made on a large number of models. The objective of this thesis is primarily to provide a clear definition is understandable of this system known as TMD and to evaluate its efficiency by applying it to a real case study. Up to now, in fact, this mitigation system has been mostly realized on simulation models obtaining only a series of experimental studies. The turning point then becomes its application to a real case study. This study follows a philosophy of dualistic thinking that therefore acts on two fronts, the seismic, structural adjustment, and the architectural enhancement of the existing through the insertion of a new block characterizing. This experiment will allow you to get in touch with the advantages, previously studied and final, but especially with unforeseen complications and discoveries step by step during the application and design itself. This intervention can be incorporated within the family of the elevations, more specifically the garden roofs and consequently, as will be explained below, we expect to respect the advantages provided in this type of intervention of a social, environmental and soil conservation. The TMD study aims to understand how efficient this solution is for mitigating modest earthquakes and whether its application can be repeated, especially on existing buildings. In fact, on new buildings, especially if located in areas with a high seismic risk, it is preferable to follow the road that provides the insulation at the base. The exhibition of this long research hopes to be an updated collector on the theory of TMD, an example of the realization of green roof in respect of society and the environment that is repeatable and inspirational in a city context and a demonstration of a successful fusion between compositional aspect and technical aspect supported in the structural field through software simulation.

1

TMD

TMD

1.1 WHAT IS IT?

TMD can be defined as a vibration control and mitigation system. If we consider buildings and infrastructures of different types, such as skyscrapers, towers or bridges, we can say that during seismic events or even simple gusts of wind, they move horizontally up to reach even 1 meter of displacement. Clearly one of the factors for which the size of the oscillation varies is the height of the building, in fact, the greater the height, the greater the displacement of the oscillatory movement. This system is therefore able to reduce the structural response of buildings to external dynamic excitations. This technique consists in the insertion of a mass on the main structure by means of elements with elastic, visco-elastic or elasto-plastic behaviour. In essence, the auxiliary mass absorbs most of the energy produced by the vibration, avoiding the direct and total impact on the main structure. The goal is to find an agreement between the two masses, a parallel vibration rhythm. The most recent and unconventional philosophy of TMD sees as protagonists elements with a large mass, such as garden roofs, which are not only an element of mitigation, but also have other roles. These masses must be integrated into the existing or new structure to which this technology comes, but at the same time, in order to have an active and functioning TMD system they must be isolated from the part below (E. Matta and A. De Stefano, 2008).

There are many reasons why this system is preferred to others:

- simpler design and final realisation
- less impact on the structure on which it is applied, and
- lower initial construction and periodic maintenance costs.

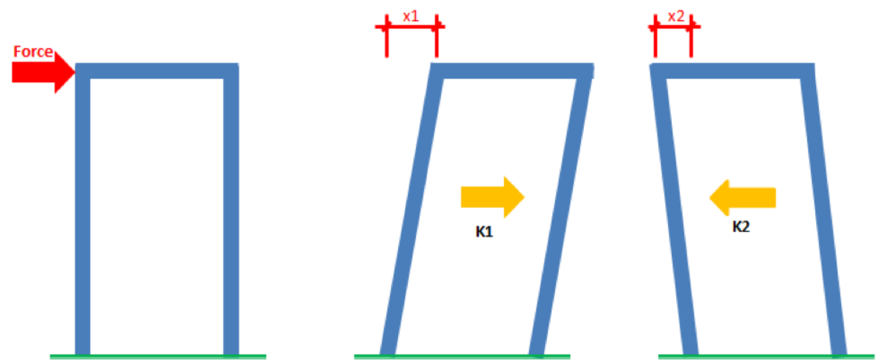
In the past, since the 1970s, the main use of this system has certainly been to control the vibrations induced by the action of the wind, improving the functionality of the building and the comfort of its occupants, reducing discomfort, nausea and even possible shocks caused by oscillations (https://bsbgroup.com/blog/the-mechanism-and-applications-of-tuned-mass-damper-tmd/).

In this thesis the intention is to explore a branch of application almost not at all widespread. The TMD in fact, as defined, controls the vibrations of a building induced by external agents, so even the movement resulting from earthquakes falls within these causes. However, the use of TMD as an anti-seismic system is rare due to the unpredictable characteristics of seismic excitation.

1.2 THE BASIC THEORY

As mentioned above, the TMD system works on a certain structure to mitigate the vibrations that can be generated by different entities. But how can the work done by TMD be described in concrete terms?
If we consider a situation of oscillation of a structure, the TMD system creates simultaneously with the movement of the building equal and opposite thrusts that lead to the achievement, after a short time, of a horizontal displacement equal to or close to zero. To better understand the difference between the reaction of a structure with and without TMD you can analyse in detail the two cases (https://bsbgroup.com/blog/the-mechanism-and-applications-of-tuned-mass-damper-tmd/).

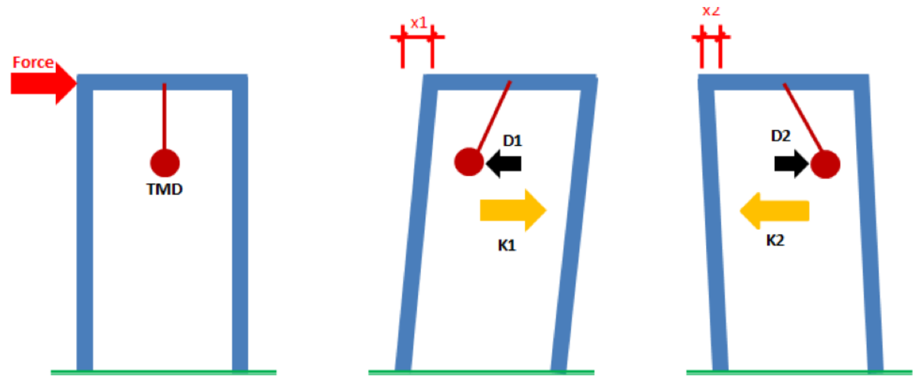
• **Case 1 - Without TMD**
The lateral force of an earthquake or wind strikes the structure generating a displacement x. During the oscillation the building will go back of x1 which will be a movement lower than x, but higher than that of the following oscillation x2. After a series of backwards and forwards movements, the structure will stop. The time of reaching a zero displacement depends on the damping ratio, a dimensional value that describes how a structure in oscillation comes to rest after being stressed (https://bsbgroup.com/blog/the-mechanism-and-applications-of-tuned-mass-damper-tmd/).



Schematic A - Building Without TMD

Building without TMD. Source: (https://bsbgroup.com/blog/the-mechanism-and-applications-of-tuned-mass-damper-tmd/).

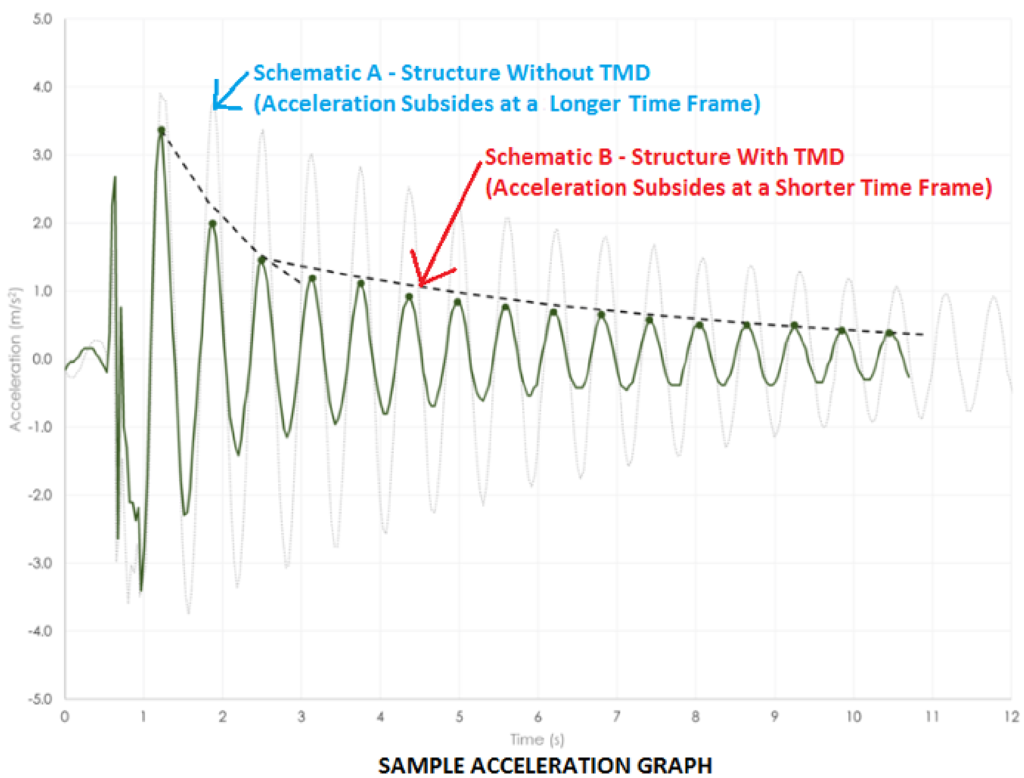
• **Case 2 - With TMD**
Considered a building and an horizontal force acting on it (as in case 1), the structure begins to oscillate with horizontal displacements. At the same time, it also generates a quantity of kinetic energy which, in the previous case, pushed the building to continue to oscillate for a certain amount of time. In this case, however, with the installation of the TMD system in the structure, during the oscillation, through the springs, the TMD is activated by creating contrast forces both during the oscillation from right to left and during the oscillation from left to right. This however generates some horizontal displacements of the structure, during the oscillation, that however will turn out inferior to those seen in the case 1. These forces of contrast generated by the TMD generate a time of inferior oscillation and a more rapid stability of the structure (https://bsbgroup.com/blog/the-mechanism-and-applications-of-tuned-mass-damper-tmd/).



Schematic B - Building With TMD

Building with TMD. Source: (https://bsbgroup.com/blog/the-mechanism-and-applications-of-tuned-mass-damper-tmd/).

The time it takes for the building to oscillate from left to right and then from right to left is called the "time period" and helps technicians to understand how long it takes for the structure to return to its initial position: the longer the period, the longer it will take for the structure to return to the zero position. When designing a building, it is necessary to evaluate the period of the building in order to avoid long periods of oscillation that would cause inconvenience to the users present inside in the event of stress from the outside. The TMD system thus becomes effective when the frequency (measured in Hz) of the structure and that of the mitigation system correspond or are very close. The image below shows the accelerations of the two structures analysed in the previous cases, the first describing the situation without TMD and the second with the application of this system. Case 1 has higher oscillations than case 2. In the second case, there is a downhill peak that demonstrates the readiness of the damping created by the TMD that reduces the time of oscillation and the amplitude of each oscillation (https://bsbgroup.com/blog/the-mechanism-and-applications-of-tuned-mass-damper-tmd/).



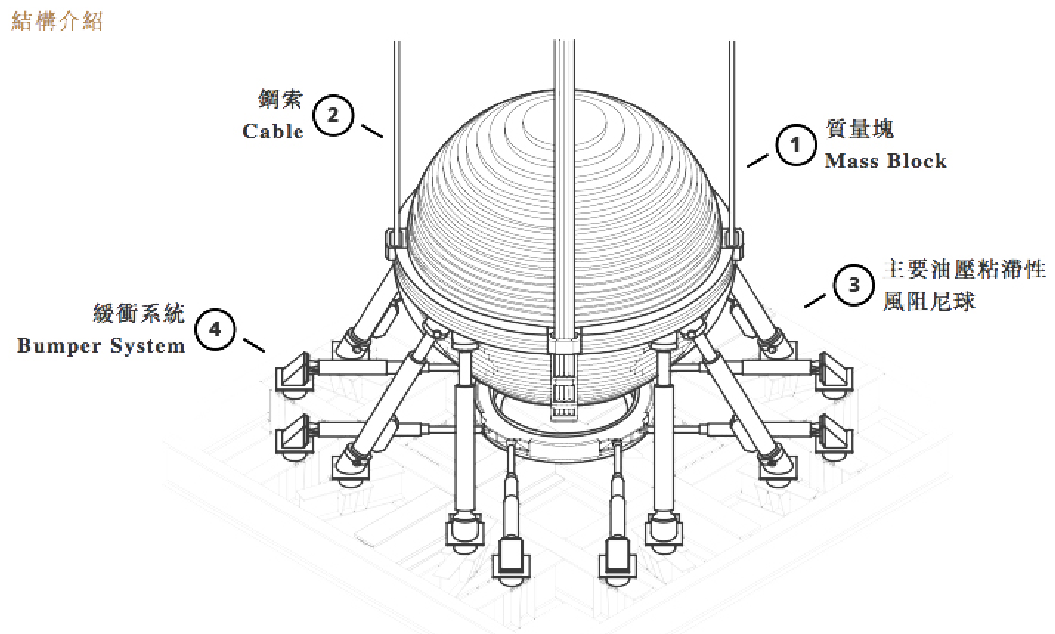
Acceleration graph. Source: (https://bsbgroup.com/blog/the-mechanism-and-applications-of-tuned-mass-damper-tmd/).

1.3 DETAILS OF TMD DIFFERENT TYPOLOGIES

In recent years we have tried to study different strategies to control vibrations from wind or earthquake to improve the functionality and safety of the structures. Among these, the tuned mass damper (TMD), characterized by its efficiency in proportion to maintenance costs and ease of installation, is part of the family of passive heat sinks. Passive systems are the most widespread and familiar in the Civil Engineering market, mainly due to their great reliability. In fact, although they can be considered less performing, they are preferred over active systems that require an external energy source or control devices. (E. Matta & A. De Stefano, 2008)

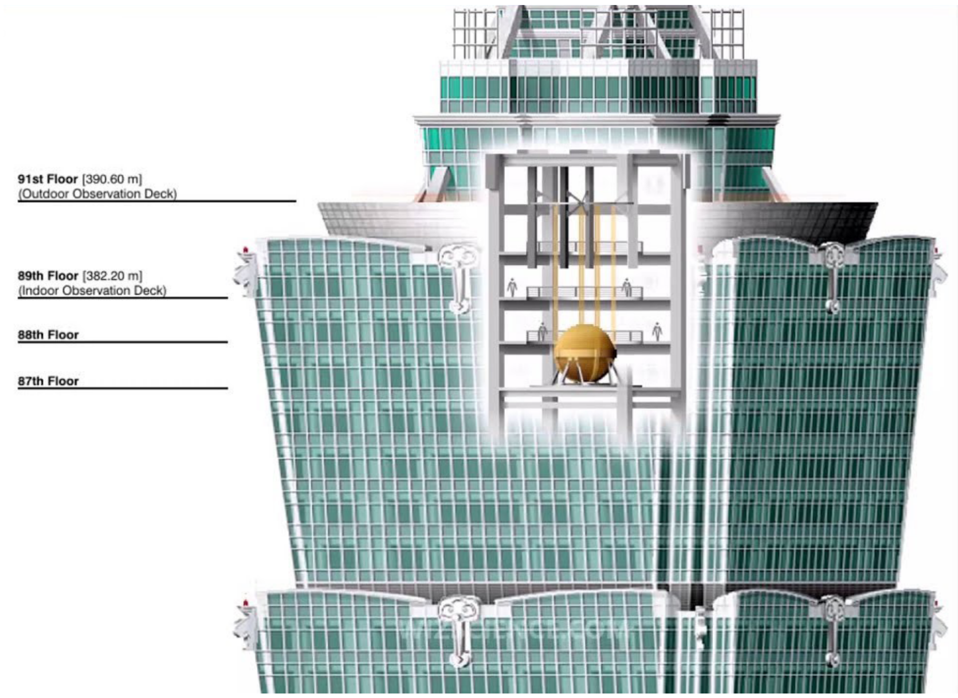
This system can be divided into two macro-categories:
- Tuned mass damper - TMD
- Tuned liquid damper - TLD

In the first case the tuned mass is a solid element of any nature: a sphere, a mass of ground, one or more planes built at the top. . . In the second case, the mass is represented by tanks or columns containing liquid inside them. Both have been studied for almost a century and have been applied since the seventies to mitigate the movements due to the wind on flexible structures such as skyscrapers or bridges.

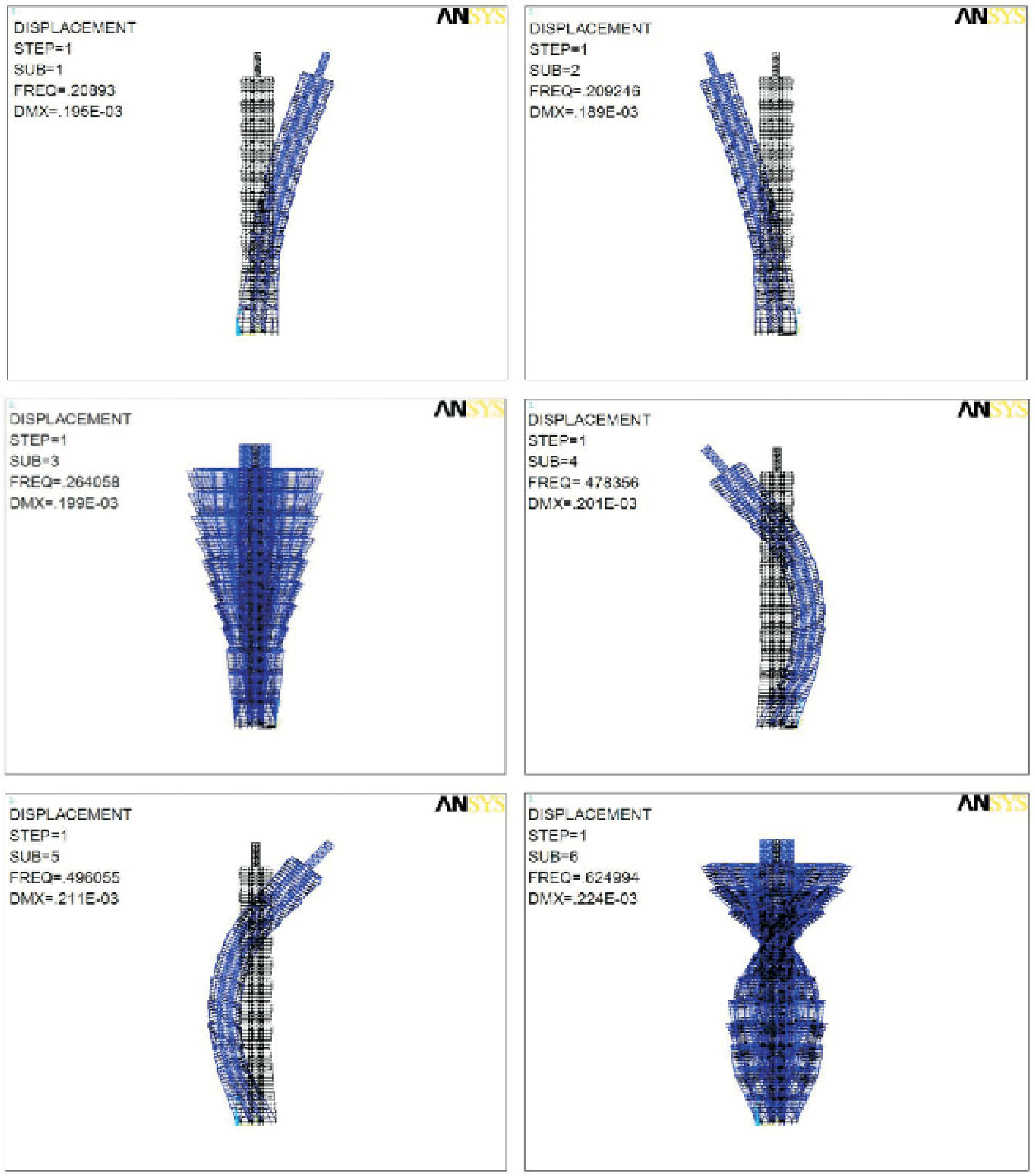


Mass damper of the TaiPei 101.

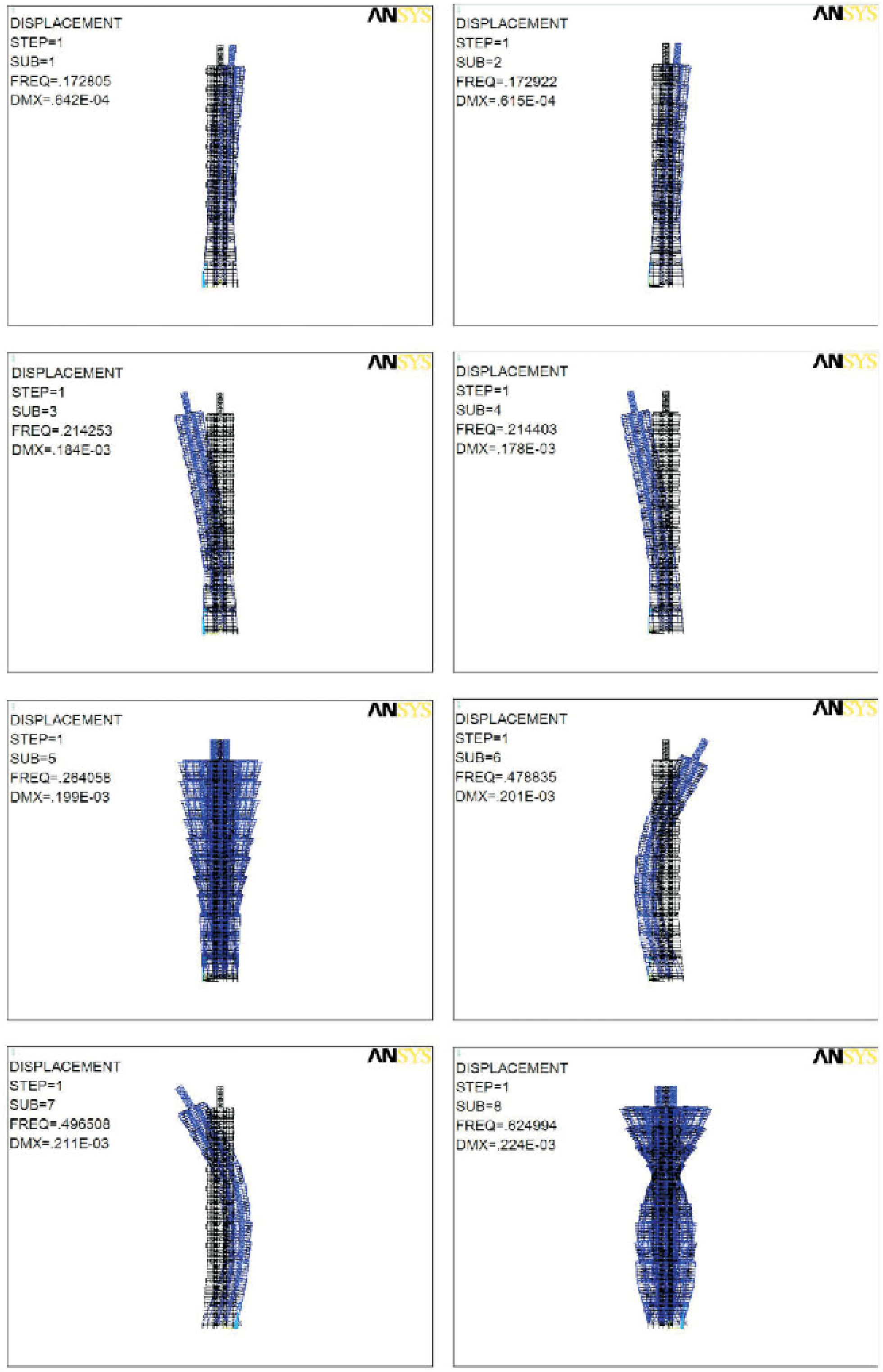
One of the most famous cases of application of tuned mass damper is that of Taipei 101. The skyscraper located in Taiwain reproduces the shape of a “bamboo”; because it seems to consist of 8 trocs stacked and is spread over 101 floors for 508 meters high. Between the 87th and the 92nd floor there is the largest tuned mass damper in the world: a giant steel ball, composed of 41 overlapping discs that create a mass of 660 tons for a diameter of 5. 5 meters. The solid mass is suspended, attached to the structure by means of cables and therefore wants to counter the effect of strong earthquakes in that geographical area and the effect of the wind that reaches speeds of 200 km/h. The principle of operation that may seem complicated is actually simple. The enormous spherical mass of steel, thanks to its inertia, opposes the movements of the top of the ephibium, contrasting the movement of the structure through hydraulic pistons. The energy input from the earthquake and wind is dissipated through the hydraulic pistons that connect the ball to the structure of the Taipei 101. The task of absorbing the displacements is then carried out by the pistons at the base. If the Taipei 101, for example, moves to the right, the mass of the solid opposes this movement, a person present inside the skyscraper will have the feeling that it is the sphere that moves to the right, or in the opposite direction to that in which this high skyscraper oscillates. Hydraulic pistons play an important role because they compress and stretch, depending on the direction of movement, dissipate input energy and reduce the amplitude of oscillations as also shown in the explanation at point 1. 2 (De Pisapia, 2015).



Tuned mass damper of the TaiPei 101.



The illustrations show the displacements of the tower, without the TMD and using the TMD. (Tuan & Shang, 2014).



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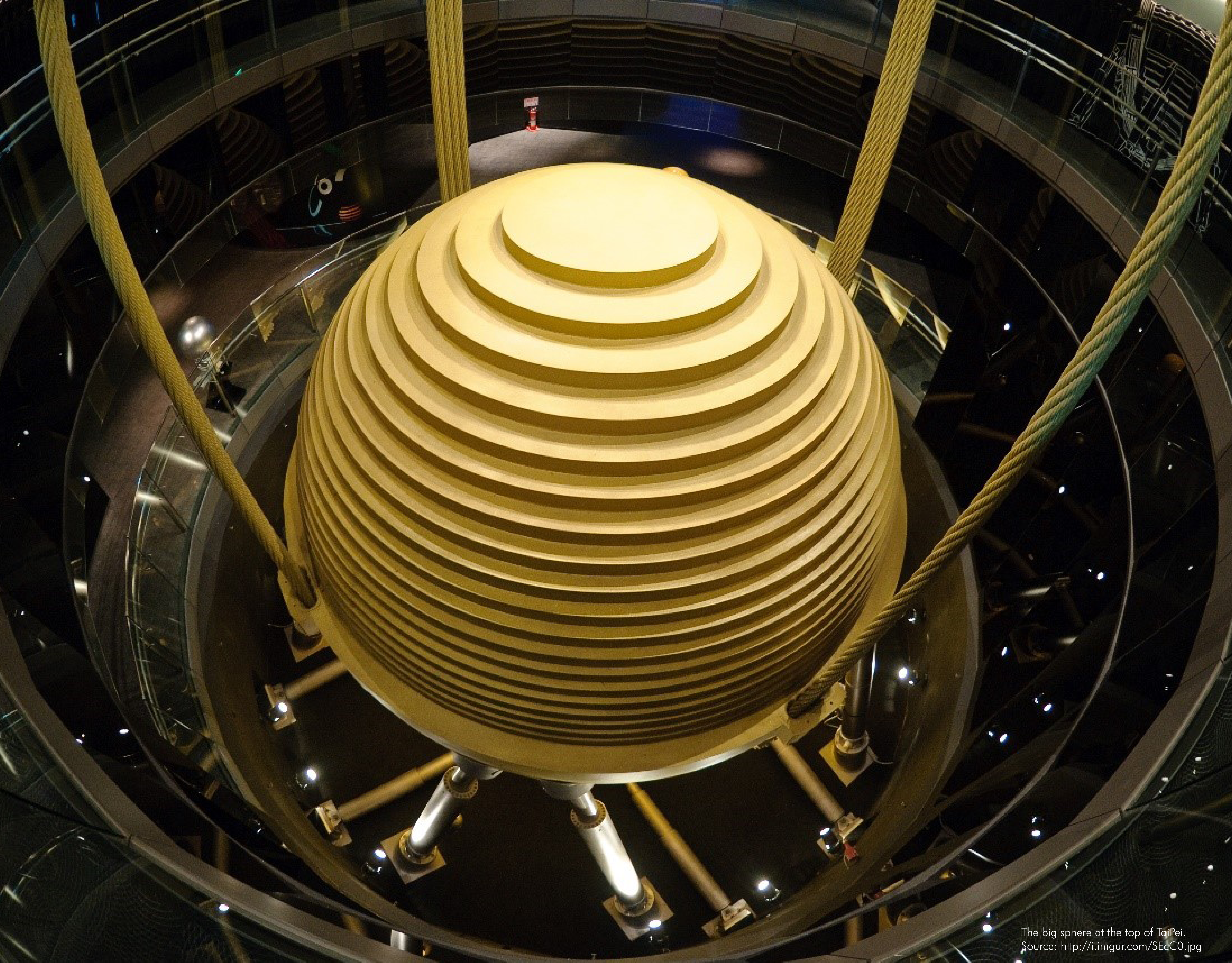
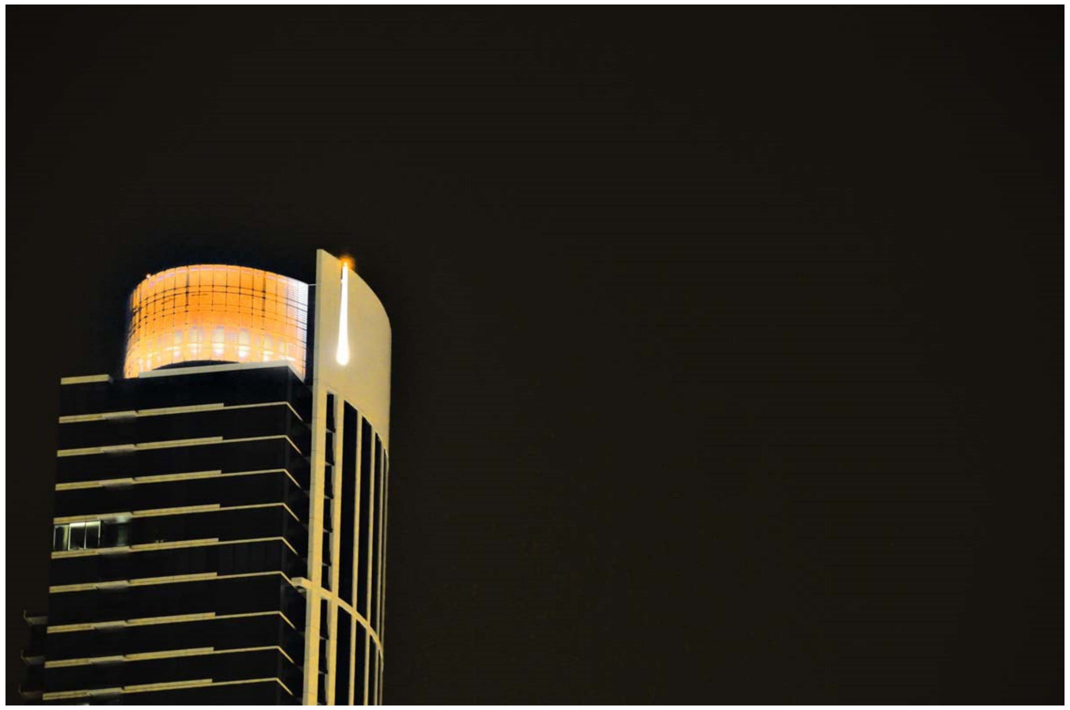


The big sphere at the top of TaiPei.
Source: http://i.imgur.com/SEcC0.jpg

The Tuned Liquid Damper (TLD), on the other hand, contrasts the forces acting on the structure by virtue of the movement of water inside a tubular container. This system dissipates structural vibrations thanks to the movement of the liquid mass in the pipe, where the recovery force is due to gravity acting on the liquid and the damping effect due to the loss of hydraulic pressure due to the holes installed inside the container. In case you decide to use tubular elements the damping capacity depends on the opening of control orifices and their opening varies depending on the intensity of the oscillation, this makes the system semi-active. In fact, the possibility to adjust the liquid content in the water columns allows to respond even to dampen low frequencies. The TLD can also be simply a passive system, in this case the liquid is not contained within adjustable water columns, but within simple rectangular or cylindrical tanks, attached to the top of buildings. The energy is then dissipated by the wave motion of the liquid that must be tuned with the natural frequency of the structure (Nanda & Bisval, 2014).

An example of a TLD is the application of a tank of about 190000 liters, on the roof of the One Rincon Hill skyscraper, located in San Francisco.



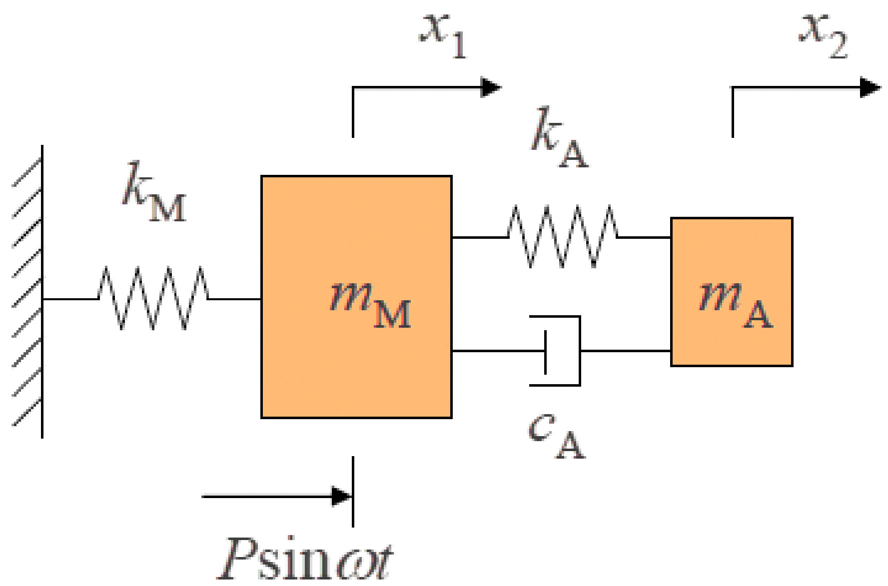
Water tanks of the tower. Source: http://i.imgur.com/SEcC0.jpg

One Rincon Hill skyscraper. Source: http://i.imgur.com/SEcC0.jpg

1.4 TMD OPTIMAL DESIGN

The TMD system can theoretically be considered as a mass mA, attached to the main mass of the building through a spring, with stiffness kA and damping coefficient cA. The main mass to which it is connected is an SDOF structure with stiffness kM, mass mM. The resulting overall structure will have two degrees of freedom (Abdulsalam, M. Al-Janabi & M.G. Al-Taweel, 2009).

Il sistema TMD è schematizzato come segue (Den Hartog, 1956):



The equation that describes the system is:

$$\begin{cases} m_M\ddot{x}_1 + k_M x_1 + k_A(x_1 - x_2) + c_A(\dot{x}_1 - \dot{x}_2) = P\sin\omega t \\ m_A\ddot{x}_2 + k_A(x_2 - x_1) + c_A(\dot{x}_2 - \dot{x}_1) = 0 \end{cases} \qquad (01)$$

The vibration forced solution is:

$$\begin{cases} x_1 = a_1\sin(\omega t + \varphi_1) \\ x_2 = a_2\sin(\omega t + \varphi_2) \end{cases} \qquad (02)$$

Replacing equation 02 in 01 and introducing the following symbols:

$f = \omega_A/\omega_M$ (tuning)

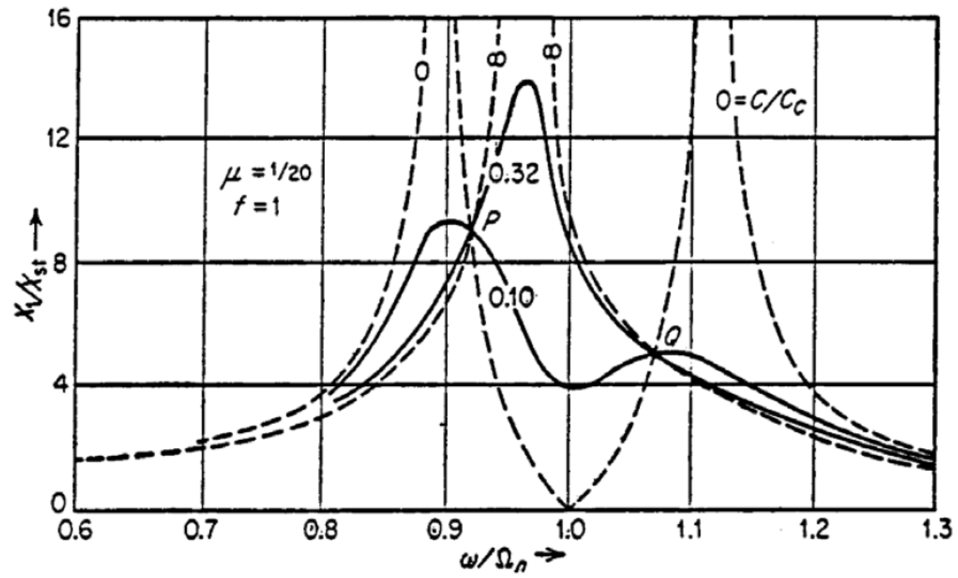
$r = \omega/\omega_M$ (excitation frequency ratio)

$c_c = 2m_A\omega_M$ (crictical damping)

The amplitude ratio of the main mass, obtained after solved a_1 and a_2 is:

$$\frac{a_1}{x_{st}} = \sqrt{\frac{\left(2\frac{c_A}{c_C}r\right)^2 + \left(r^2 - f^2\right)^2}{\left(2\frac{c_A}{c_C}r\right)^2\left(r^2 - 1 + \mu r^2\right)^2 + \left[\mu f^2 r^2 - \left(r^2 - 1\right)\left(r^2 - f^2\right)\right]^2}} \qquad (03)$$

Assuming $f = 1$ and $\mu = \frac{m_A}{m_M} = \frac{1}{20}$, the next image shows the amplitude ratio for various values of c_A/c_C:



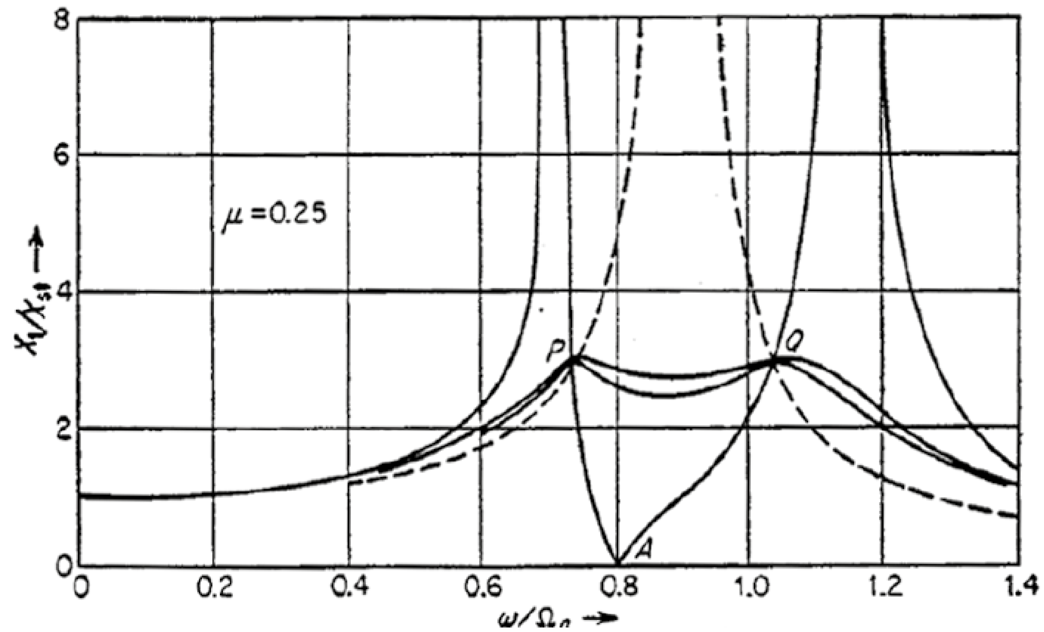
FRF graph. Den Hartog, 1956, pag 97.

It's possible to observe what happens increasing the damping.
Con $c_A = 0$ the dynamic vibration absorber is obtained, it is a simple mass-spring oscillator with virtually no damping, studied by Frahm in 1909.

"When the damping becomes infinite, the masses are virtually clamped together and an undamped SDOF system is obtained with a mass 21/20 m_M. Two other curves are drawn for intermediate value of damping ratios (0.10 and 0.32). All four curves pass through the fixed points P and Q independent of the damping.

Once μ and f are assigned, the most favourable damping is the one making the curve passing with a horizontal tangent through the highest of the two fixed points P or Q. While this criterion will provide the optimal damping, much can still be done in terms of frequency ratio. By changing the "tuning" f, the fixed points P *and Q are shifted along the curve for $c_A = 0$ (one goes up and the other down). Clearly the optimal case is such that:*

- *by a proper choice of f the two fixed points are adjusted to equal heights (optimum tuning);*
- *by a proper choice of c_A/c_C the curve is adjusted to pass with a horizontal tangent through "one" of them (optimum damping)."*



FRF graph. Den Hartog, 1956, pag. 100.

The starting equation is than satisfied by three equations:

$f = \frac{1}{1+\mu}$ (Optimum tuning) (04)

$\frac{a_1}{x_{st}} = \sqrt{1+\frac{2}{\mu}}$ (Nearly-optimum response amplitude) (05)

$\frac{c_A}{c_C} = \sqrt{\frac{3\mu}{8(1+\mu)^3}}$ (Optimum damping) (06)

These are the basic formulas to design in an optimal way a TMD with the objectives to minimize the worst-case displacement response of an undamped SDOF system subject to an harmonic excitation of unknown frequency.

The steps to follow when designing a TMD in this case are therefore:

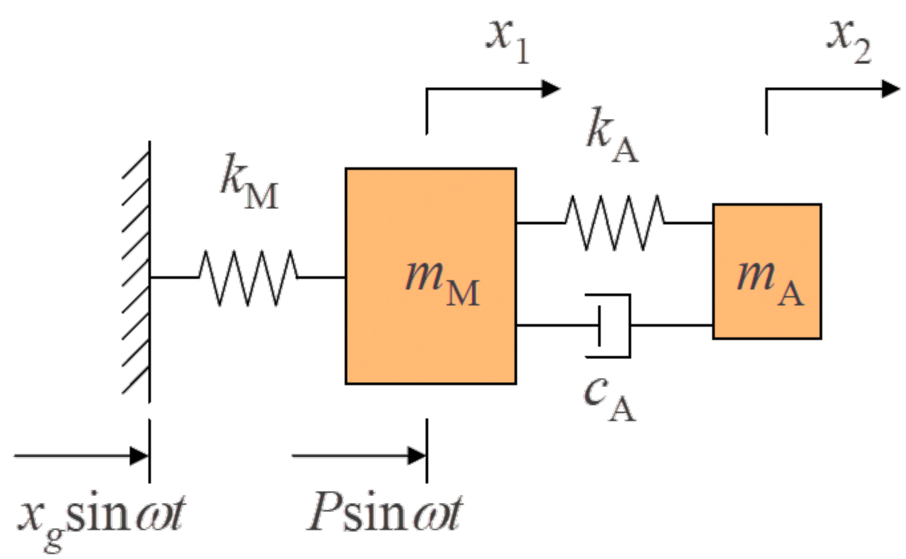
- choose a μ that can tune the equation (05)

-compare f and c_A/c_C with equations (04) and (06)

- obtain the TMD parameters m_A, c_A, k_A, i. e. mass, damping and stiffness of the anti-seismic system.

The previous study was aimed at minimizing the relative displacements of the main structure subjected to a sinusoidal input force $P \sin \omega t$.

However, another design scenario was imagined, later, which adds an input such as the force or movement of the ground resulting from the earthquake. And other output types can be calculated, such as relative displacement, absolute acceleration.



The formulas to have an optimal design of a TMD system like this one are (Warburton, 1982):

$\zeta_A = c_A/(2\omega_A m_A)$ (Damping ratio)

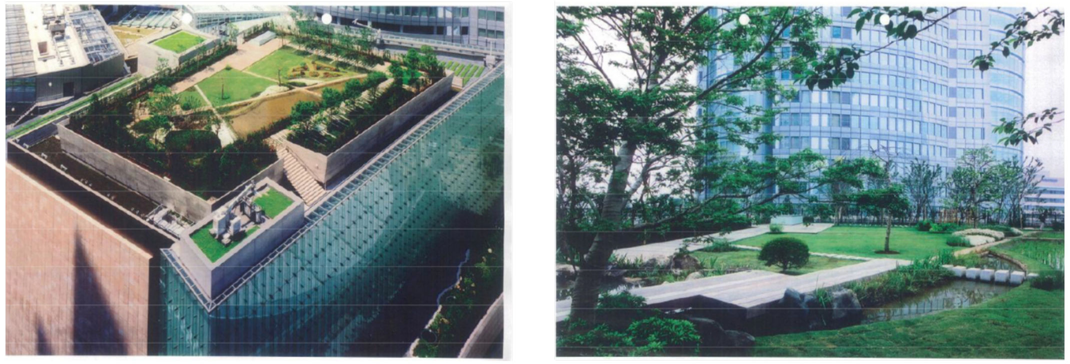
$f = \frac{\sqrt{1-\mu/2}}{1+\mu}$ (Optimum tuning)

$\zeta_A = \sqrt{\frac{3\mu}{8(1+\mu)(1-\frac{\mu}{2})}}$ (Optimum damping)

1.5 REAL APPLICATIONS TO MITIGATE EARTHQUAKES

It is very rare to find real applications of this system with regard to seismic mitigation. Although TMD applications are very common to dampen wind vibration and there are many skyscrapers that have chosen to adopt this system. Earthquake mitigation is in fact carried out with better known systems, recognized by law or systems capable of counteracting violent earthquakes more effectively than would be able to do the tuned mass damper.

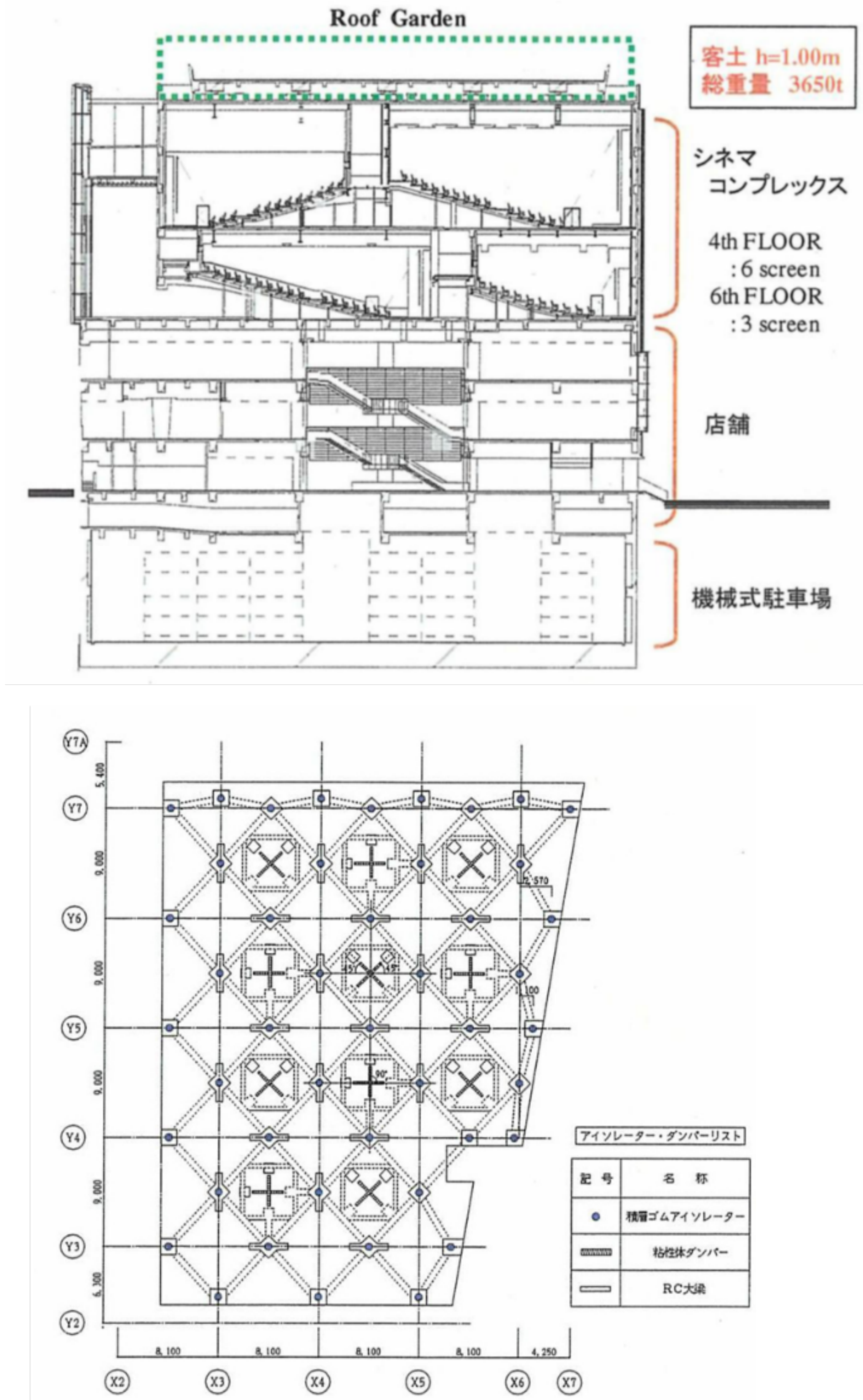
KEYAKI-ZAKA COMPLEX IN ROPPONGI HILLS, TOKYO



Views of Keyaki-Zaka complex. (T. Kamada and T. Fujita, 2007).

Japan, however, a very advanced country in terms of earthquake mitigation, has adopted this solution in the construction of a multifunctional complex that houses a large basement car park, shops, services and a big theater. This building, built in 2003 after a disastrous earthquake, houses a large roof garden, with an area of 1300 m2, which in addition to having a social and environmental function, also has an anti-seismic function. This garden, that offers to the surrounding buildings a panoramic view, was designed with the theme of the Japanese garden and is visited by many tourists who can admire the environmental sensitivity in the city of Tokyo (A. Martelli and M. Forni, 2010). The green roof layer is one meter thick, for a mass of 3650 tons, about 8% of the mass of the entire building (total mass ratio). This is supported by 46 rubber bearings 60 cm in diameter (elastomeric insulators) and 22 hydraulic pistons (viscoelastic heat sinks). The maximum force developed by a damper is 362. 8 kN and leads to an 80% reduction in symmetrical cuts for level 2 earthquakes. The fluctuation in mass due to changes in soil moisture is between -7% and +10% (T. Kamada and T. Fujita, 2007).

The reduction of the heat island, the vegetation and the anti-seismic project combined lead to consider this as a great environmental friendly project.



Above a section and below a structural plan showing the base on which the roof garden rests (T. Kamada and T. Fujita, 2007).

2

GREEN ROOFS

GREEN ROOFS

A roof garden can be defined as a roof covered with greenery. The green that grows above the roof can be of different types and can cover both entirely or partially the surface. Between the green layer and the building below, there must be an impermeable layer to prevent the passage of water and the consequent creation of damage.

Over the years, the use of this technology has become increasingly widespread to the point that, in some cities, the presence of green roofs in the case of flat roofs has been mandatory for years (E. Zalata, D.Melnikov, 2017).

In Tokyo since 2001 at least 20% of roofs larger than 250 m2 must be green and at least 10% if the area is larger than 1000 m2, in Basel since 2002, in Copenhagen since 2010 and in Toronto 2009 if the roof area is larger than 2000 m2 (E. Zalata, D.Melnikov, 2017). In Germany, the construction of green roofs has grown exponentially for over 10 years, so much so that 14% of the roofs built are green. This has been achieved through the use of subsidies and tax reductions for companies that build buildings with roof gardens. Italy, on the other hand, despite arriving a little late to this type of innovation, was the first European country to issue an specific sector normative that provided guidelines on the design and principles of green roofs, thanks to the UNI 11235 standard in 2007 (F. Cumo, F. Rosa, L. Calcagnini, B. Vivio, 2012).In Italy D.P.R. no. 59 of 2009, repealed by the Decree of 26 June 2015, introduced the definition of green coverage (P. Stefanizzi, 2015):

"Green roofs are continuous roofs equipped with a system that uses plant species able to adapt and develop in the environmental conditions characteristic of the roof of a building. These coverings are realized through a structural system that foresees in particular a suitable cultural layer on which radiate associations of vegetable species, with minimum maintenance interventions, extensive green coverings, or with medium and high maintenance interventions, intensive green coverings."

2.1 SPACES SUITABLE FOR ROOF GARDENS

There are several different buildings that can have roof gardens, thus demonstrating a wide range of possibilities to act positively on the environment, on the urban landscape and on the image of a city. These being very heavy can obviously be built on buildings with very solid structures, so that it is not always possible to insert these systems on existing buildings.

Underground buildings

Top view of Standford University roble field parking structure. Source: (https://watrydesign.com/project/stanford-university-roble-field-parking-structure-10)

The construction of underground car parks has often been an ideal solution to limit the consumption of land and often the squares and public parks prove to be an excellent idea to cover these buildings. Other times the green roof was built over schools, libraries, underground prisons, thus becoming an open space directly functional to the buildings below (T. H. Osmundson, 1999).

Stanford University, for example, is growing exponentially as it has to accommodate more and more students and preserving common spaces in the open air becomes fundamental to any place of study. The need to create a large car park has been combined with that of the green, it has been created an expanse of greenery to bring together students in recreational and sporting moments.

The structure of the car park is developed for 5 floors underground providing charging stations for electric vehicles. The structure holds a minimum weight of land and the slopes lie on the natural level of the site trying to camouflage the parking below.
(https://watrydesign.com/project/stanford-university-roble-field-parking-structure-10).

Offices

The garden roofs located above public or private offices become spaces for events, socialization and relaxation, making workplaces more comfortable (T. H. Osmundson, 1999). This category includes all those types of buildings suitable for public and private offices, work and study environments that could use a roof garden as a place to relax and socialize.

Nanyang technological Unversity green roof. Source: (https://www.greenroofs.com/projects/nanyang-technological-university-ntu-school-of-art-design-and-media-adm/)

One example is Nanyang Technological University (NTU), a 200-hectare university campus on the suburbs of Singapore, which has become one of the world's leading scientific and technological research universities. This is the first art university on the island and also houses an art gallery. The building develops around an almond-shaped courtyard and is composed of two arches that intersect, rising from 2 to 5 floors above ground. The reinforced concrete roof is covered by a green roof that, following the rounded shape of the building, creates a gentle hill that not only has an aesthetic function, but is also a common outdoor space for students and visitors. The surface on the roof is made up of a combination of two herbs and remains green all year round thanks to an irrigation system capable to alternate automatically with rainwater. This green roof favours both indoor and outdoor climatic conditions, reducing consumption and giving students a cooler outdoor climate. Its energy and water efficiency has also led to an award and recognitions (https://www.greenroofs.com/projects/nanyang-technological-university-ntu-school-of-art-design-and-media-adm/).

Residences

These can belong to small apartments becoming private places, such as small terraces, as well as productive places, but it often happens that large, but they can also arise on large residential blocks and have the function of common spaces (T. H. Osmundson, 1999).

Connected roofs

An advanced idea can also be to connect several roofs and consequently create a macro surface through the use of bridges and stairs. These connections allow a better usability of urban spaces. This also significantly improves the overall view of some building blocks (T. H. Osmundson, 1999).

Bridges

Even when not exactly positioned on top of a roof, a garden placed over a bridge needs the same attention. In this case, too, it is necessary to check the structural resistance and decide on the size and thickness of the garden roof. These kinds of interventions become very interesting because they allow to give value to connections from one part of the city to the other (T. H. Osmundson, 1999).

Among this typology, the most famous example is certainly represented by the High Line, an example of industrial restoration able to give a new face to New York. An elevated railway between 1930 and 1980 has become a walk that allows you to overlook the chaos of the metropolis. This is now a large consolidated urban area around which commercial activities, exhibitions and shops develop. Architects Diller, Scofidio and Renfro wanted to recreate the image of old factories invaded by weeds using specially tall herbivorous species. The thickness of this roof garden, which is therefore developed in length and crosses the city, as you can imagine, has a variable thickness but falls into the category of intensive greenery and in some places exceeds even one meter in height. The plant species are very varied, grasses have been used, shrubs that emerge between the floor. The High Line hides the city's traffic and has also encouraged real estate sales in the area, demonstrating that the green roof has environmental benefits, but also brings benefits to the image, so as to make people reflect around the world about the retrofit of old industrial structures of this type. (A. Musacchio, 2014)

High Line. Source: (https://patricetodisco.files.wordpress.com/2012/05/img_5914.jpg).

2.2 ADVANTAGES OF USE

If the roof garden system is designed, planned and implemented correctly, it can create a series of advantages in terms of the environment, sustainability and economy. The first category of benefits also brings about air improvements that have positive consequences for the inhabitants and their health. Combining these concrete effects on well-being and the idea of a sustainable investment in terms of economic feasibility results in a high percentage of spread of this system.

In Italy, the Law of 14/01/2013 n. 10 "Norme per lo sviluppo degli spazi verdi urbani" reiterates the potential of the system of vegetation envelope (P. Stefanizzi, 2015).

Art. 6, comma 1 (P. Stefanizzi, 2015):
"- promoting energy saving and efficiency
- absorption of fine dust
- reduce the summer heat island effect
- while promoting regular rainwater harvesting".

• Improved microclimate
The cooling and humidifying effect of the air generated by green roofs improves the performance of air conditioning systems and reduces carbon emissions. In recent years the ambient temperature is higher than expected due to elements that improve our lives on a daily basis, but which also have negative repercussions (cars, air conditioners, …). This overheating creates inconvenience not only for the environment, but also directly for the population. According to some studies, overheating is greater in more urbanized areas because of the presence of many absorbent surfaces such as the endless expanses of asphalt. This also generates a higher percentage of smog with the relative presence of polluting particles. The use of green roofs, which reflect heat, would reduce the heat island effect. In one case study it was shown that the perceived temperature difference on a green roof and on a simple roof can be as much as 35°. According to other studies, also the quantity of vegetation present is directly connected to the recorded temperature, in fact, the thicker the vegetation, the lower the perceived

temperature will be (E. Zalata, D.Melnikov, 2017).

• Particle filtration
The green of the garden roofs allows the filtering of air and the consequent cleaning of particles and dust due to the smog and any harmful emissions (E. Zalata, D.Melnikov, 2017).

• Rainwater retention
The presence of a green roof reduces the flow of water by up to 50-90%. This indirectly reduces construction costs thanks to the possibility of using pipes and drains with lower flow rates. The temporary "storage" of rainwater through the use of green roofs is one of the aspects most explored and studied in recent years. This capacity reduces the possibility of flooding due to incorrect operation of the manholes, which are clogged by the amount of water that reaches them and by the speed with which it flows when there are no green covers. After an investigation, it is possible to summarize the percentages of entertainment of water by the extensive green roofs based on the different thicknesses, which can have the ground, and if you consider a slope of the roofing equal to 2% (E. Zalata, D.Melnikov, 2017).

Soil thicknesses	Percentage of retention
20-40 mm	40-45%
60-80 mm	50-55%
100-120 mm	55-60%

These percentages refer to a model study, but vary according to factors such as location, soil moisture, amount and intensity of precipitation (E. Zalata, D.Melnikov, 2017).

• Greater sound absorption
The vegetation on the roofs has a high power of absorption even compared to solid surfaces. In buildings adjacent to noisy structures such as rooms or factories, the green roof is able to perform the task of acoustic insulation (E. Zalata, D.Melnikov, 2017).

• Energy improvement with cost reduction

Thanks to the presence of a green roof you have the opportunity to reduce emissions by increasing the energy performance of the building.

The layer that is created, joining earth and plants, plays the role of an additional insulating layer and allows a lower demand for heating and cooling systems (E. Zalata, D.Melnikov, 2017).

• Natural habitat creation

The green roofs allow wildlife to find its own space within the inhabited city. The presence of vegetation on the roof attracts different types of birds and allows them to settle and maintain biodiversity in the built cities (E. Zalata, D.Melnikov, 2017).

• More usable space

Green roofs allow you to use a space that would otherwise be unused to place parks, green areas for rest, sports fields or gardens. The space at the top of buildings can be very impressive and become a reason for attraction following the implementation of this type of projects. These areas are first of all easily reachable by the occupants of the lower floors and therefore more usable and usable and, in addition, also improve the appearance of the structure within the city (E. Zalata, D.Melnikov, 2017).

• Bringing environmental benefits

The creation of a green roof in a specific building gives back to the lot the natural space lost through the construction of the structure in question. It allows the flora and fauna to regain space within the city. There are, by the way, studies that define the typology and the quantity of fauna present on the roofs (birds, spiders, cockroaches, etc.) also in relation to the typology of vegetation present. Other research also states that there are not many differences between the fauna present in natural places and those in nature recreated on roofs thanks to man (E. Zalata, D.Melnikov, 2017).

• Costs and maintenance

The cost of a green roof compared to a traditional roof is clearly higher, but

can be considered an investment that will generate an economic return over the years. Green roofs have many advantages that smooth out the initial costs of the roof over time, such as a reduction in emissions from the building and a consequent saving in terms of heating and cooling (less energy use). The maintenance of green roofs in some cases involves artificial irrigation. In extensive roofs it is often not necessary or is reduced to the presence of a pipe to be used in drought conditions, while in intensive roofs it is usually planned to design a more elaborate irrigation system. Another factor to consider in the first years of life of green roofs is the fertilization waiting to accumulate natural organic matter over the months. Regular checks on the health of the plants present and the correct functioning of the various layers that make up the roof are also provided for (E. Zalata, D.Melnikov, 2017).

2.3 HOW ARE GREEN ROOFS MADE?

The structure of green roofs involves the overlapping of several layers with different functions from each other. Some of the main layers are the insulating layer to prevent water from reaching the underside of the roof and the draining layer for rainwater.

The construction of a roof garden requires a well-defined technological project and should not be underestimated, this to promote the long life of the system and the reduction of maintenance costs. It also depends a lot on the needs and type of green roof that you want to build, extensive or intensive.

The main layers that generally make up the green roof are (K. Vijayaraghavan 2016):

- vegetation
- substrate
- filter fabric
- drainage element
- protection layer
- root barrier

Vegetation

The green roof is a system aimed at the production of plants, trees, however it does not seem to be the most suitable place for plant production mainly because of a fundamental factor such as water. This element is not always available on roofs, it may depend on climatic conditions, but also on the willingness of users to take the systems to the top of a building. However, it is important to underline that the life of a garden roof depends on the life of the plants. This factor can be remedied in the case of extensive green roofs by the use of succulents that do not suffer from sun exposure and drought, otherwise irrigation systems become necessary. However, vegetation is a component of this system that is independent of location, climate and other environmental factors (K. Vijayaraghavan 2016).

Substrate

The soil or substrate is the component that directly feeds the plants and, depending on its composition and thickness, can have a strong effect on the growth of vegetation and on the performance of the green roof. A successful green roof is a matter of choosing the substrate. The advantages of green roofs, water drainage, thermal improvement of buildings and sound insulation depend by the amount of groung you choose to use. This is also what drives the two different categories of green roofs, extensive and intensive. The properties of the soil are then the chemical component that favors the growth of some species rather than others. Commercial substrates are generally used, but very natural products can be used (especially for vegetable gardens) or mixes of low and organic waste materials. The choice of substrate also affects the porosity, weight and ability to drain water (K. Vijayaraghavan 2016).

Filter layer

This layer has the main function of separating the soil from the drainage layer, thus preventing small plant components from coming into contact with the layer below and preventing the proper functioning of the drainage. The choice of material is therefore of particular importance because it could unconsciously limit the flow of water. In common practice, geotextile fabrics are preferred to polymeric fabrics. This type of fabric has a high mechanical resistance capable of withstanding large weights without cracking. They also have small pores that

allow water to pass through and also works well as protection from the roots.. The thickness also has a great impact, in fact, high thicknesses encourage the retention of rainfall (K. Vijayaraghavan 2016).

Unlike these, the polymeric fabric only absorbs 1,5 L di acqua/m2, causing the water retention of green roofs. (Wong e Jim, 2014).

Drainage layer

This is the component of the roof garden that serves to give balance between water and air. This layer is in fact fundamental for realizing a good garden, the vegetal species need a substratum rich of nutrients, of water, but also of an aerated component which can be guaranteed only with a working drainage. This also protects the underlying layers and together with the substrate improves the thermal conditions of the underlying building. Green roofs mainly use two types of drainage layer. There are modular plastic panels (polyethylene or polystyrene) that can store water and have great mechanical strength and there are also those made of granular materials such as gravel, crushed stone, expanded clay (LECA), crushed brick, splinters. Choosing one drainage system rather than another depends very much on the construction costs, in fact the panels are more expensive both for the supply and for the installation. Granular ones are used more, they are in common use especially for small interventions on residential buildings, they still work very well and have much lower costs, because often waste materials are used. The critical points of the granular layers are that they can only be applied to flat roofs or roofs with low inclinations, unlike the others which, in addition to being able to store water, are lighter and can be applied to sloping green roofs (K. Vijayaraghavan 2016).

Waterproofing layer and Root barrier

The waterproof layer is of particular importance for the good realization of a green roof, one could say that it is the part that must be more resistant and that must last longer. Although this, on a physical level, is not part of the green roof is a fundamental requirement before installing the whole package because it serves to prevent leakage and infiltration. The mass that is added above the roof is in fact damp and water can be very harmful to the floor below, in case there is a leak, maintenance also becomes very difficult because it is necessary to remove all the layers described so far. The types of waterproofing layers are single-layer membranes, bitumen sheets and thermoplastic membranes. Here too, the choice of this component depends on the cost, the requirements and the prospects for its durability. If this layer serves to protect the floor from water, there is another accompanying layer that serves to protect the floor from the roots of plants that come that can penetrate deep into it and also damage the sheath. It is not mandatory for extensive green, but it is mandatory for intensive green. On the market, the root barrier is presented as hard plastic sheets or copper metal sheets (K. Vijayaraghavan 2016).

2.4 INTENSIVE AND EXTENSIVE GREEN ROOFS

Based on the depth of the substrate, two types of green roofs are identified: extensive and intensive. The deeper the substrate, the greater the amount of different vegetation tolerated. Rainwater runoff retention on an aged intensive green roof (A.F. Speak, J.J. Rothwell, S.J. Lindley, C.L. Smith, 2013).

The two types of green roofs include different technological characteristics.

Extensive green roofs are designed to be self-contained, so they are not expected to have maintenance costs. Artificial irrigation is not foreseen for these roofs, but natural precipitation should be sufficient to meet the necessary water demand. The thickness of the soil in these cases varies between 3 and 5 cm. In the case of the intensive typology, on the other hand, the planting of many types of vegetation is foreseen, which require a layer of soil with a thickness that varies between 15 cm and 1 meter (E. Zalata, D.Melnikov, 2017).

The Italian standard UNI 11235 of 2007 provides the following definitions for green roofs:

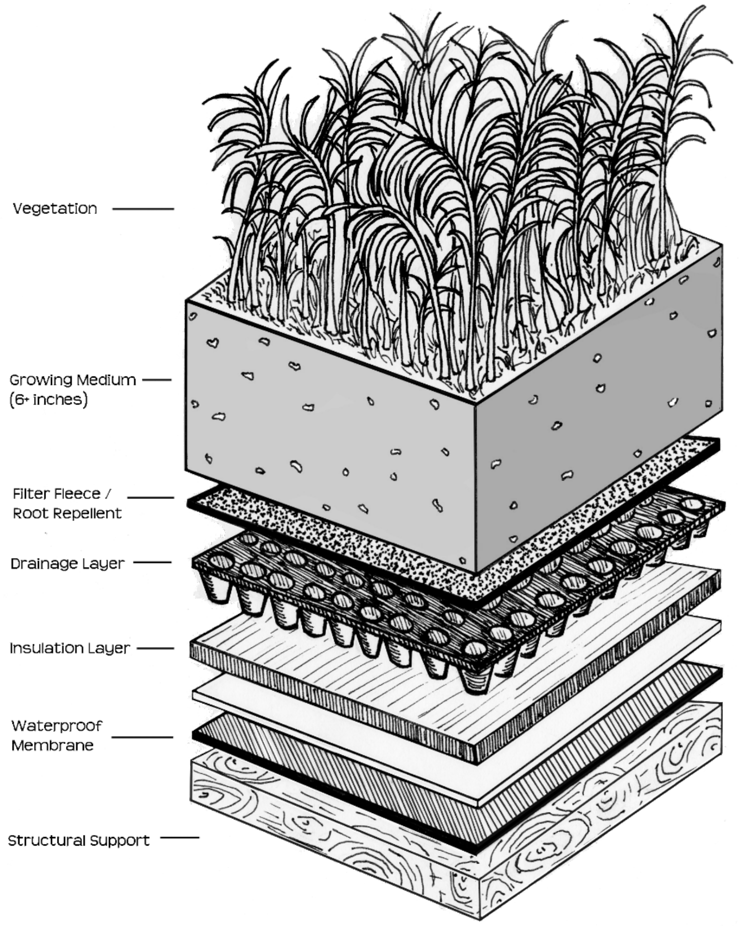
"Extensive green roofing: a system that uses plant species that can adapt and develop in the environmental conditions in which they are placed, requiring minimal maintenance. The species are characterized by a high settlement capacity,

through reproductive efficiency, frugality, resistance to water and thermal stress, both winter and summer.
Main features:
- Substrate thicknesses varying between 10 and 15 cm
- flat and inclined surfaces
- plant species with low nutritional requirements
- 1-2 maintenance operations per year
- average package weight 80-120 kg/m2."

(F. Cumo, F. Rosa, L. Calcagnini, B. Vivio, 2012)

"Intensive green coverage: System that uses plant species able to adapt and develop in the environmental conditions in which they are placed, even with the necessary help of a maintenance of medium and high intensity, depending on the associations of plant species.
Main features:
- substrate thickness varying between 15 and 50 cm
- any surface (roofs, terraces, garages)
- plant species with different nutritional needs
- dedicated irrigation system
- more than 2 maintenance operations per year
- average package weight greater than 150-250 kg/m2 and bonded any shrub species and floorings present."

(F. Cumo, F. Rosa, L. Calcagnini, B. Vivio, 2012)

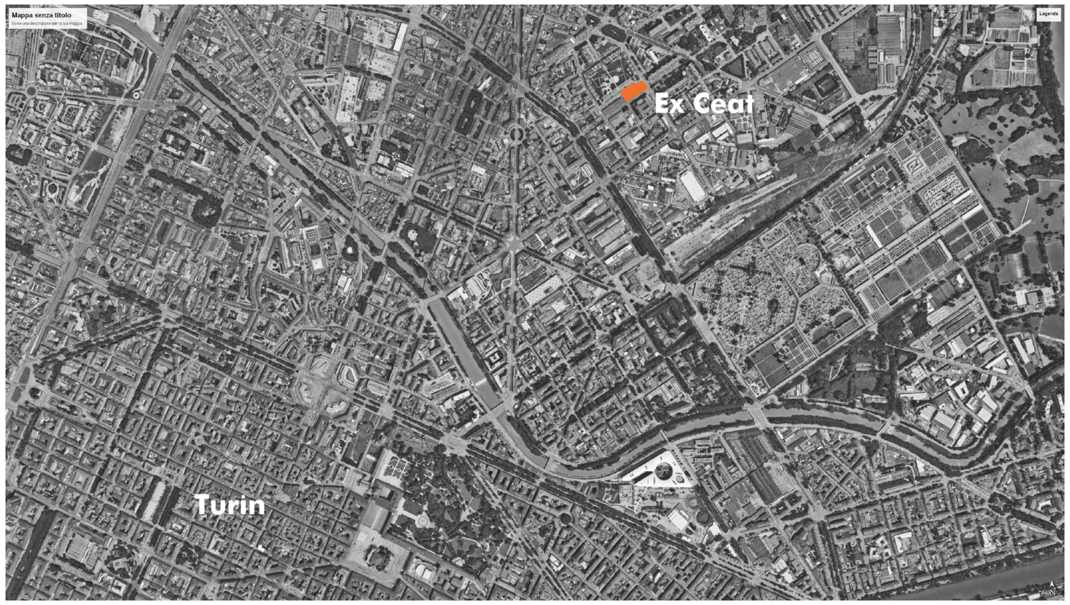


Example of intensive roof (https://www.greenroofplan.com/intensive-vs-extensive-green-roofs/).

3

CASE STUDY: EX CEAT, TURIN

3 CASE STUDY: EX CEAT, TURIN



Project area localization. Source: Google Maps.

3.1 THE CHOICE OF BUILDING

After a multicriteria discussion, the decision was made to take Turin as the research location for the case study. This decision stems from the desire to study this solution within a better known city and within daily reach for any inspections and field tests. Clearly choosing a building within this city has also allowed a greater knowledge of the dynamics of life and relationships of the place, something that is difficult to see in a city not lived for long, but also of city and municipal policies. In the national seismic classification, Turin is considered to belong to seismic zone 4.

Earthquake Zone 4	Zone with very low seismic hazard. It is the least dangerous area where the chances of seismic damage are low.

Each zone then corresponds to the relevant technical standards with specific indications useful for the construction of buildings and infrastructure. The national territory is divided, according to the Ordinance of the PCM n. 3519/2006, into four seismic zones according to the maximum horizontal acceleration variation (pga). This value has a 10% probability of being exceeded in 50 years.

Zona sismica	*Descrizione*	*accelerazione con probabilità di superamento del 10% in 50 anni [a_g]*	*accelerazione orizzontale massima convenzionale (Norme Tecniche) [a_g]*	*nu co co ter ric ne zo*
1	Indica la zona più pericolosa, dove possono verificarsi fortissimi terremoti.	$a_g > 0,25$ g	0,35 g	70
2	Zona dove possono verificarsi forti terremoti.	$0,15 < a_g \leq 0,25$ g	0,25 g	2.
3	Zona che può essere soggetta a forti terremoti ma rari.	$0,05 < a_g \leq 0,15$ g	0,15 g	2.
4	E' la zona meno pericolosa, dove i terremoti sono rari ed è facoltà delle Regioni prescrivere l'obbligo della progettazione antisismica.	$a_g \leq 0,05$ g	0,05 g	2.

Source: (https://www.tuttitalia.it/)

The ideal way to best verify the answers of the TMD system applied to the building would have coincided with the choice of a city with a high seismic risk, but the objective of this thesis is mainly to apply the system, enhance its advantages and application, but above all the creation of a model, of application on a building with regular forms and not particularly strange, which is then easily repeatable in most cities, even those with a high seismic risk.
After several bibliographic researches and analyses of the buildings found that at first glance seemed to meet the necessary requirements for this work, the final choice falls on the former CEAT factory, located in Via Leoncavallo 17. The building in question is located in the area of Barriera di Milano (Circoscrizione 6) in the heart of a large former industrial area. The district of location, which can be considered almost peripheral, is characterized by the presence of both residential buildings and, many, industrial structures or dedicated to production. This mixture in the years following the construction of neighborhoods like this has always worked perfectly because usually the residential centers were created to accommodate the workers of industries located around it and their families. Clearly, over the years, many of these industries have gone bankrupt or have been moved elsewhere, thus leaving an infinite amount of space occupied and often unusable for bureaucratic reasons that prevent any kind of functional transformation or requalification.

3.2 HISTORY OF THE EX FACTORY

The factory was founded in 1924 by Augusto and Virginio Tedeschi as a company producing telephone and electrical cables. Then, in the 1940s, the production of rubber products began, with the coincidence of the design of a plant entirely dedicated to the production of tyres (currently via Leoncavallo, formerly via Como). This extension is called CEAT GOMMA and its construction began in 1939. During the war it was used, at a time of crisis, for the production of gas masks. Also in the same years, precisely in the summer months of 1943, it suffered damage caused by aerial bombardments that damaged it for 50% of its extension. In 1946, after some work on yet another conversion into a building for the production of tires, resumed operation.

Post aerial bombardments situation. Source: (https://www.tuttitalia.it/)

In the years between 1947 and 1960, this building underwent various changes that are documented in the building practices deposited in the archives of the city of Turin. Below is a table containing all the practices consulted for the definition of the steps that have followed in the life of this building (M. Rolfo, 1997).

1942 1 33	01/01/1942	Via COMO 31	SOC. AN. CEAT	FABBR. INDUSTR.	PERMESSO DI COSTRUIRE
1947 2 30011	04/06/1947	Via COMO 31	S.A. CEAT	OCCUPAZIONE	AUT. ABITABILITA'-AGIBILITA'
1948 2 30058	18/10/1948	Via COMO 31	SOC. AN. CEAT	OCCUPAZIONE	LICENZA OCCUPAZIONE
1950 1 10001	01/01/1950	Via COMO 31	SOC. AN. CEAT	AMPLIAM. SOPRAEL. FABBR.	PERMESSO DI COSTRUIRE
1950 1 10527	01/01/1950	Via LEONCAVALLO RUGGERO 29	SOC. CEAT	AMPLIAM. SOPRAELEV. FABBR.	PERMESSO DI COSTRUIRE
1951 1 11467	11/12/1951	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	SOPRAEL. SULLA VIA PRIV. PARUZZARO	PERMESSO DI COSTRUIRE
1951 1 30390	06/04/1951	Via LEONCAVALLO RUGGERO 25	SOC.P.AZ . CEAT	VARIANTE A PROG. AMPLIAMENTO	PERMESSO DI COSTRUIRE
1951 18 20150	18805	Via LEONCAVALLO RUGGERO 25	SOC CEAT	DENUNCIA E COLLAUDO CEMENTO ARMATO	DEPOSITATA - ISTRUTTORIA NON PREVISTA
1951 2 40034	09/05/1951	Via LEONCAVALLO RUGGERO 25	SOC.TA' P. AZNI CEAT GOMMA	OCCUPAZIONE	LICENZA OCCUPAZIONE
1951 2 50033	09/05/1951	Via LEONCAVALLO RUGGERO 25	SOCTA' P. AZNI CEAT GOMMA	OCCUPAZIONE	LICENZA OCCUPAZIONE
1952 1 30338	07/03/1952	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	6 SERBATOI FERRO	PERMESSO DI COSTRUIRE
1952 1 40337	07/03/1952	Via LEONCAVALLO RUGGERO 25	SOC CEAT GOMMA	SERBATOIO IN FERRO	PERMESSO DI COSTRUIRE
1953 1 11723	23/11/1953	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	AMPLIAMENTO	NON DEFINITO
1954 1 10360	01/01/1954	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	AMPL.TO EDIFICIO IND.	PERMESSO DI COSTRUIRE
1954 1 10569	01/01/1954	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	FAB.TO IND.LE	PERMESSO DI COSTRUIRE
1954 1 10970	01/01/1954	Via LEONCAVALLO RUGGERO 25	SOC. CEAT	AMPL.TO FAB.TO IND.LE	PERMESSO DI COSTRUIRE
1954 1 70147	05/02/1954	Via LEONCAVALLO	SOC CEAT	AMPLIAMENTO	NON DEFINITO

1954 1 70427	06/04/1954	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	SOPRAELEV 1 PIANO	NON DEFINITO
1954 2 20089	12/10/1954	Via LEONCAVALLO RUGGERO 25	S.P.A. CEAT GOMMA	OCCUPAZIONE	LICENZA OCCUPAZIONE
1955 1 10280	01/01/1955	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	FABBR.TO IND.	PERMESSO DI COSTRUIRE
1955 1 10767	01/01/1955	Via LEONCAVALLO RUGGERO 25	SOC. CEAT	AMPL.TO FABBR.TO	PERMESSO DI COSTRUIRE
1955 1 10930	01/01/1955	Via LEONCAVALLO RUGGERO 25	CEAT GOMMA	AMPLIAM. FABBR. INDUSTRIALE	PERMESSO DI COSTRUIRE
1955 1 11195	01/01/1955	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	FABBR. 5 P.F.T.	PERMESSO DI COSTRUIRE
1955 1 30736	27/05/1955	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	TETTOIA APERTA	PERMESSO DI COSTRUIRE
1955 2 10105	31/12/1955	Via LEONCAVALLO RUGGERO 25	S.P.A. CEAT GOMMA	OCCUPAZIONE	LICENZA OCCUPAZIONE
1955 2 10106	31/12/1955	Via LEONCAVALLO RUGGERO 25	S.P.A. CEAT GOMMA	OCCUPAZIONE	LICENZA OCCUPAZIONE
1955 2 60038	20/05/1955	Via LEONCAVALLO RUGGERO 25	S.P.A. CEAT GOMMA	OCCUPAZIONE	LICENZA OCCUPAZIONE
1956 1 10108	01/01/1956	Via LEONCAVALLO RUGGERO 25	SOC. CEAT	FABBR.TO 2 P.F.T.	PERMESSO DI COSTRUIRE
1956 1 10448	01/01/1956	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	FABBRICATO INDUSTRIALE	PERMESSO DI COSTRUIRE
1958 1 10599	01/01/1958	Via LEONCAVALLO RUGGERO 25	CEAT GOMMA	LOCALE PROVV. 4 P.F.T.	PERMESSO DI COSTRUIRE
1958 1 11229	17/09/1958	Via LEONCAVALLO RUGGERO 25	SOC CEAT GOMME	SOPRAELEVAZIONE 1 PIANO	LICENZA
1958 1 11321	01/01/1958	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMMA	AMPLIAM. SOPRAELEV. FABBR. INDUST.	PERMESSO DI COSTRUIRE
1967 2 10401	25/08/1967	Via LEONCAVALLO RUGGERO 25	SOC CEAT GOMME	OCCUPAZIONE	LICENZA OCCUPAZIONE
1967 2 10402	25/08/1967	Via LEONCAVALLO RUGGERO 25	SOC. CEAT GOMME	OCCUPAZIONE	LICENZA OCCUPAZIONE

1974 1 10851	09/10/1974	Via TERNENGO 24	SOC. C.E.A.T.	APERTURA PORTONE	LICENZA
1976 1 10788	13/09/1976	Via TERNENGO 34	SOC. CEAT	APERTURA PORTONE	LICENZA
1989 1 3660	24/07/1989	Via LEONCAVALLO RUGGERO 25	ASSOCIAZ IONE GRUPPO ABELE	RISTRUTTURAZIONE	CONCESSIONE EDILIZIA
1990 1 4136	19/09/1990	Via LEONCAVALLO RUGGERO 25	A.E.M.	POSA CAVI ELETTRICI	APPROVAZIONE
1991 2 304	23/12/1991	Via LEONCAVALLO RUGGERO 25	ASSOCIAZ IONE GRUPPO ABELE	AGIBILITA'	AUTORIZZAZIONE EDILIZIA
1993 1 4360	23/12/1993	Via LEONCAVALLO RUGGERO 25	ASSOCIAZ IONE GRUPPO ABELE (CITTA' DI TORINO)	MODIFICHE INTERNE CON CAMBIO DI DESTINAZIONE D'USO	CONCESSIONE EDILIZIA
2001 9 16143	14/11/2001	Via LEONCAVALLO RUGGERO 25	ASSOCIAZ IONE GRUPPO ABELE	ART. 26 L. 47/85	VERIFICATA POSITIVA
2002 9 7873	31/05/2002	Via LEONCAVALLO RUGGERO 25	GRUPPO ABELE (CITTA' DI TORINO)	DENUNCIA INIZIO ATTIVITA L.662/96 (VARIANTE A CONC. 509/94)	VERIFICATA POSITIVA
2004 2 15560	03/11/2004	Via LEONCAVALLO RUGGERO 25	ASSOCIAZ IONE GRUPPO ABELE	AGIBILITA'	AUTORIZZAZIONE AGIBILITA'
2006 2 9191	10/07/2006	Via LEONCAVALLO RUGGERO 25	CITTA' DI TORINO (SETT. RISTRUTT UR. NUOVI EDIFICI)	AGIBILITA'	ANNULLAMENTO
2007 9 1053	25/01/2007	Via LEONCAVALLO RUGGERO 25 piano 1	SOC. GRUPPO ABELE	SANATORIA OPERE SOGGETTE A DIA ART. 37 DPR 380/01	DIA CONVENZIONATE
2007 9 14867	29/10/2007	Via LEONCAVALLO RUGGERO 25	SOC. GRUPPO ABELE	TUE37-4 DIA IN SANATORIA: LIEVI MOD. INT.	PRESA D'ATTO

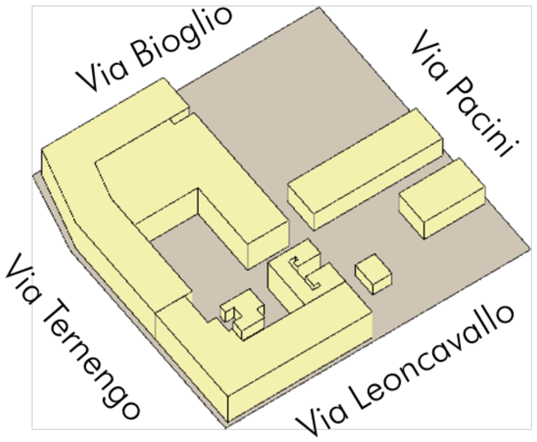
(M. Rolfo, 1997)


Vintage internal illustration of Ex-Ceat complex. Source: (http://www.museotorino.it/view/s/c44b2497c6e8fe93914291).

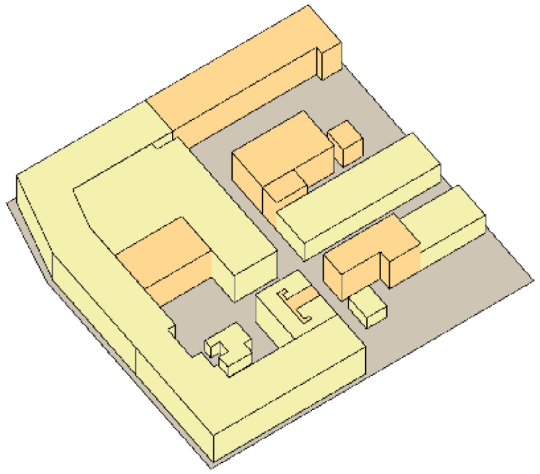
In 1950 the structure includes, as it's possible to see in the picture below, the main sleeve on Via Ternengo and the lateral developments of its Via Bioglio and Via Leoncavallo (S. Boi, G. Castellano, 2014).

Vintage top illustration of Ex-Ceat complex. Source: (http://www.museotorino.it/view/s/7773d7a0f2c44b2497c6e8fe93914291).

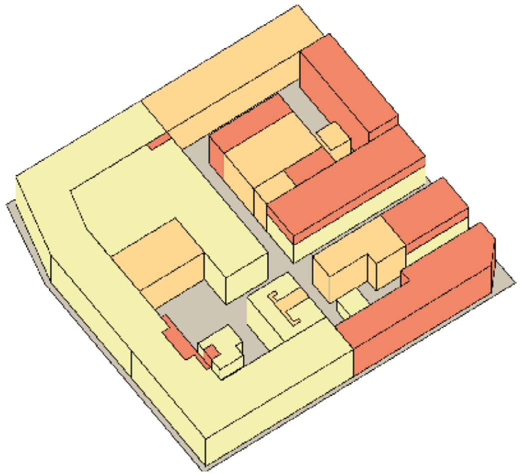
• 1951



• 1956



• 1960



It's possible to see thank the figures, the development of the complex Ex Ceat in the first years (S. Boi, G. Castellano, 2014).

In 1961, however, the complex was subject to a large fire that struck the part between Via Ternengo and Via Bioglio (S. Boi, G. Castellano, 2014).


Pagina 4 Gazzetta del Popolo

CRONACHE TORINESI

CENTO VIGILI DEL FUOCO LOTTANO PER SEDICI ORE CONTRO UNA MURAGLIA DI FIAMME

Due miliardi di danni nel rogo della CEAT

L'allarme nella notte alle 3,30 è dato dal custode che si salva gettandosi da una finestra - Centinaia di operai collaborano con i pompieri - Ventimila litri d'acqua al minuto sull'immane braciere - Quattro feriti - Distrutti alcuni dei più importanti reparti sotto l'edificio crollato - Le cause: forse un corto circuito - Una intervista con il vice presidente della Società, che elogia le maestranze e assicura che non mancherà il lavoro - Possibile ripresa della produzione alla fine di gennaio

"Two billion damage at the stake of the CEAT, one hundred firefighters fight for sixteen hours against a wall of flames".

(G. Beraudo, A. Castrovilli, C. Seminara, 2006)

This is how it is described on 8 January 1961 in the article on the Cronache Torinesi of the Gazzetta del Popolo, a fatal night and day for the plant according to the words of lawyer Ugo Ricciardi in an immediate interview by journalists. According to him, the cause of this disaster could be a short circuit, one of the major dangers that actually led to the effects on both the plant and the staff employed.

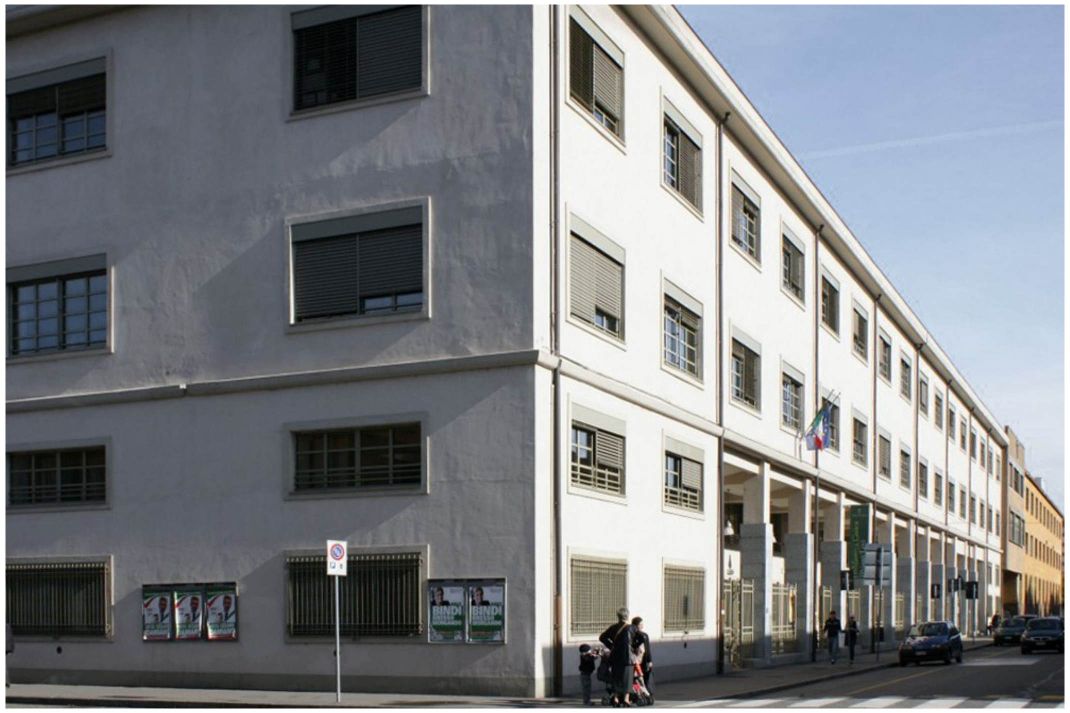
Post fire building situation. Source: (G. Beraudo, A. Castrovilli, C. Seminara, 2006).

In a few months, however, the plant is put back into operation and work is resumed immediately (G. Beraudo, A. Castrovilli, C. Seminara, 2006).

The part of the whole complex, still present today, is the sleeve on Via Leoncavallo, at that time destined for office use and definitively abandoned in 1982 after all the workings were moved to the new plant in Settimo Torinese a few years earlier (M. Rolfo, 1997) (S. Boi, G. Castellano, 2014).

Photography from Via Pacini (Giuseppe Beraudo, 1973)

Photography of Ex-Ceat building. (Giuseppe Beraudo, 1973)



Above the facade on via Leoncavallo, before and after the renovation of 2000.

A period photo of the facade on Via Bioglio (Giuseppe Giraudo, 1973).

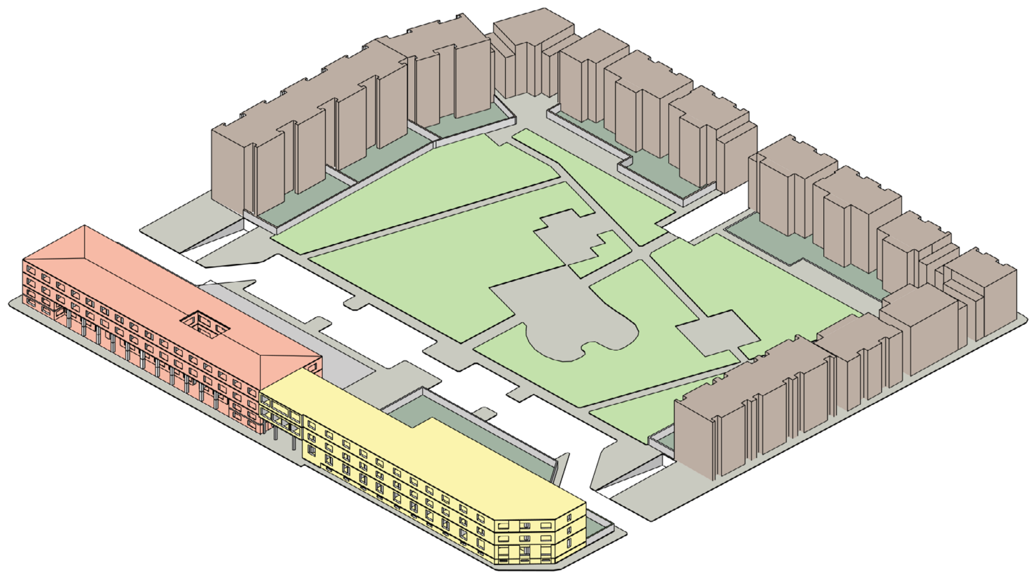
Historical picture taken from Via Ternengo (ASCT, Gazzetta del Popolo, I-1559).

3.3 STATE OF THE BUILDING

To date, by consulting the practices found in the archive, you can define the sizes available in the buildings. In practice 30/42 relating to the ground floor subsequently raised the sleeve to the post in via Ternengo, and currently preserved, the declared meters are 1520 square meters S. C. In one of the last instead, the 1386/57, relating to the sleeve placed in via Pacini the meters are 2038 square meters S. C.

The two parts considered are very similar and share the following characteristics:
- RC load-bearing structure
- no 3 floors above ground
- T beams in reinforced concrete

The complex belongs to the urban transformation zone 9. 7 and currently the intended uses are defined as in the figure below.



LEGENDA

Residenze

Servizi pubblici

Gruppo Abele

Parco pubblico

Giardini privati

(S. Boi, G. Castellano, 2014).

The indices defined by Z.U.T. 9.7 are listed below.
Gross floor area for use:
- Minimum residence 19,570 sqm
- Service activities for individuals and businesses maximum 1,800 sqm
- TOTAL AREAS TO SERVICES (minimum): 25,380 sqm
Estimated Territorial Area of the area (ST): 38,988 square metres

Going to work on a building that in its time had a great historical importance characterizing the city in a phase of exploits of mass processing indirectly allows to give again a decisive importance to spaces like this. As at the time, even today, given their strategic position, with their effective functioning and effective communication with the surrounding area, the effects on the context would be not insignificant. Analysing our national territory, there are many examples of buildings like this one, characterized by a large surface area and by having played a decisive productive role in the past, and most of them are obsolete or abandoned. The goal is usually to give them a new life by proposing a different use. In some of these buildings, as in our case, the industrial complex is dedicated to different end uses, sometimes conflicting or without a common thread.

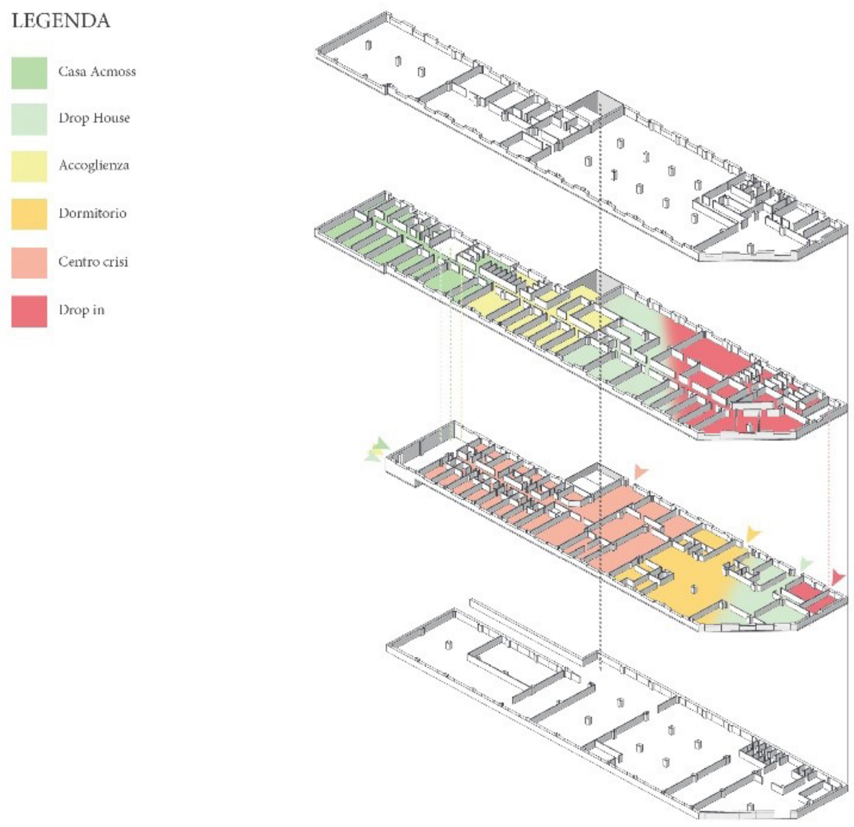
In 1981, after the transfer of the company to Settimo Torinese, as mentioned before, the City of Turin purchased the entire area including the historical sleeve on Via Leoncavallo (S. Boi, G. Castellano, 2014).
Currently, the destinations present within the building under consideration can be divided between those present on the left of the central subway (block A) and that on its right (block B).

Block A:
- Registry
- Civic Library
- Social services
- Traffic police
- Multipurpose hall

This first block was recently renovated in 2005, in fact, the library inside was opened to the public in 2007 and occupies two floors of the former factory.

Block B:
- ACMOS Group
- Abele Group (reception, crisis centre, drop in, drop house and dormitory)

Bloc A functions. 7



Bloc B functions.

The context in which this building is located is very varied. The area is inhabited by citizens of colorful origin who contribute to have a very lively environment between local markets, parks and common spaces in the immediate vicinity. Already in the past, the expansion of the Barriera district was born from the movement of Italians from all over Italy, some for one reason and some for another, who found themselves taking their few things and migrating to the north. The move did not only take place from south to north, but also trivially from the surrounding Piedmont countryside to the productive city, where in industrial areas such as the one under consideration, the possibility of working was greater and moving to the city allowed to have new opportunities of different types and an improvement in their living conditions. Today, this same philosophy is attributed to foreign citizens, who do not enjoy the period of great expansion of construction, production and industrial district, but who still find in it different opportunities and sometimes better than those that have left miles away.

The building in question, with its current functions, plays a great role of involvement and welcome on several fronts. In block A there are in fact different destinations, as explained above, which contribute to different types of well-being of the citizen. Spaces such as the registry office, the social services or the library become essential in the daily life of the citizens of the neighborhood and allow the meeting of more people who use it. In block B, however, less reasoned and not at all restructured, there is the will of a group of people who have imposed themselves as an objective to help people with various social problems.
Block B will be the object of the intervention of this work, for this reason knowing in depth who works there and the philosophy of thought adopted was fundamental for a better success of the project.

Actual state plans

3.4 GRUPPO ABELE

After several cognitive visits to better understand the surrounding context, the second step was to get in direct contact with those who work within the Abele group and then consequently know the type of users with whom they have to deal. In the first meeting a guided tour was made to discover well the spaces, the different uses intended for the various environments, the accesses and routes. Later there was a long chat with those responsible to discover the different services they offer as a Gruppo Abele.

GruppoAbele

Logo. Source: https://www.gruppoabele.org/

This group was founded in 1965 in Turin thanks to Don Luigi Ciotti and is composed of 207 members. Their aim is to work in the social field by reducing everything that could create a feeling of loss or inequality between people, so they are committed to supporting people in need by helping them out of these moments through a reintegration into society and a recovery of the person and his security. They define their mission as the sum of four main points (https://www.gruppoabele.org/):

- Reduce bias
- Sharing Hope
- Multiplying opportunities
- Add rights

In order to implement these guidelines, each space within block B has a specific function which we can define and describe by means of the inspections.
On the first floor there are the crisis centre, the dormitory and the drop house, spaces with different functions defined below.

Crisis centre

This section welcomes all people who have serious problems related to addiction to psychoactive substances and/or behaviour and who, as a result, need urgent intervention. The first step by volunteers is to try to give an initial response to these addictions through drug support and a subsequent rehabilitation program. Together with each person we try to analyze the case, to understand the seriousness of the addiction and we decide how to overcome the problem and slowly reintegrate into everyday life (https://www.gruppoabele.org/).

Gruppo Abele guest. Source: https://www.gruppoabele.org/

Dormitory

The Gruppo Abele also has a space dedicated to night hospitality for 25 people per night. Volunteers provide basic need to the guests, most of them women, and then they try to dedicate time to guide them in the recovery of autonomy (https://www.gruppoabele.org/).

Drop house

This space is open to women of different origins, at predetermined times and days, who populate it by creating a sort of large family. These women embrace these spaces in the hope of abandoning the isolation in which they find themselves. If mothers leave their children in the internal kindergarten and join together in this path of activities of various kinds that allow them to have new opportunities. One of the main activities within this section is the teaching of the Italian language, for these women a foreign language, which opens new horizons and allows a simpler daily life. The activities planned in this space are divided into lessons, such as those described so far and workshops in cooking, art or personal care. The requests for registration in these programs are greater every year and this confirms the real contribution that it generates among the citizens of the neighbourhood (https://www.gruppoabele.org/).

On the second floor there is the drop-in, the reception and, not part of the Gruppo Abele, the ACMOS group.

Drop in

This section, open from 9 to 12, welcomes homeless people and often victims of substances. The majority of those received are foreign men to whom basic services are offered and then more specific and individual support, dialogue and other services "affiliated" with the Gruppo Abele. Here we also try to create a dialogue between those who use this service and the neighborhood not yet accustomed to this situation of discomfort now present and established in the neighborhood, trying to create moments of confrontation and encounter between the various parties (https://www.gruppoabele.org/).

Gruppo Abele volunteer. Source: https://www.gruppoabele.org/

After having come into live contact with these spaces and with the volunteers who manage these realities every day, the design process for this building began. As previously mentioned, the building is spread over three floors above ground and the Gruppo Abele has been selling it since 1989, but only using the first two floors. The third floor is now the subject of work by architect Carla Barovetti, who works with the group and has the task of expanding the workspace of volunteers. It was therefore a must to have more meetings with the architect and understand his design intentions and consequently compare and address the ideas and possible solutions.

3.5 DESIGN REQUIREMENTS

As explained in Chapter 1, the application of the TMD system takes place on roofs, which are necessarily flat and only if they have certain basic structural requirements in the building under consideration.

Block B, which is the subject of this thesis, is presented, as mentioned above, on three floors above ground and closes with a flat roof. The supporting structure is a rectangular mesh of pillars almost precisely regular even if the values of the wheelbases are not always the same. The floors are supported by double row lowered beams, except for the covering floor, which is supported by pignatas and armed beams. The structure is in a good state of preservation and this allows to act on it for the application of the seismic mitigation system.

Various aspects were therefore taken into account in the choice of the building. First of all, the location within the city of Turin, which even if it is not an area with a high seismic risk, allows a more direct contextual and social evaluation as well as a better conception of the spaces and the structure of the building thanks to the possible tests from life.

Secondly, it is important to choose a building that needs to be renovated in order to start a new dialogue with the city. A building degraded not only aesthetically, but also because of its location and having been somewhat isolated in recent years. With an intervention on this structure, the objective is also to create social benefits for the neighborhood by making the block of the former CEAT factory a starting point for a redevelopment of the neighborhood. The roof thus becomes a new landscape over the city without consuming soil. This building is part of an area of project that has been destined to the transformation and recovery of industrial buildings abandoned since 1995 in the Gregotti-Cagnardi floor, for this reason choosing this building is still the most appropriate solution, the one that best reflects the philosophy of design and redevelopment adopted. Over the years, referring to this transformation plan, there have been several interventions that have enriched the neighbourhood: introduction of social housing, remediation works for parks and the redesign of Block A. Working on this building is not possible if not considering the whole context both environmental and social. Whatever the project idea, it must have great communicative power and bring together the needs of all closer stakeholders.

The third important point that led to the choice of this block was the correspondence of the structure to the requirements for the construction of a TMD system: without a frame structure in reinforced concrete and steel, it would not be possible to prepare the isolators to support the entire seismic mitigation system. In order to carry out research based on these requirements, the approach was to address the presence of possible industrial buildings in Turin. This category of buildings usually has the characteristics sought after for this study:

- Frame structure
- Concrete or steel structure
- Flat roof
- Large surface area
- Simple block shape

The last step that was necessary to climb to confirm that the building chosen was the right one was to understand if the realization of a green roof, the most advantageous solution according to research related to the area previously made, would have brought some advantages in this project of seismic adjustment, but also of consequent territorial redevelopment. In order to verify this last point, the repeated meetings with the leaders of the Abel group were fundamental. The

willingness of the association to renew the building permit also corresponds to a great spirit of initiative that is bringing new ideas. In fact, the design of a roof garden could go hand in hand with the renovation of the top floor where you want to set up the new Drop House and the managers were very enthusiastic about the design proposal, which could also be useful in terms of image.

4

THE DESIGN

THE DESIGN

The design approach began with the confirmation of the choice of the building, a structure that would allow the insertion of the functions assumed, but that could do so by hosting a large mass where to place them responding to the need to create a roof garden. The intention, however, is to create a roof garden ad hoc in relation to those who live on the floors below and that as a result could take advantage of this new view of the city.

This roofing project must meet the following requirements:
- Social utility
- Improving and spreading the image of the Abel group
- Dialogue with the surrounding area
- Comply with the requirements necessary to implement a TMD system

As has been said in the second chapter. The roof garden exists when a roof houses species of plants able to relate to the environmental conditions present, which require different types of maintenance depending on the type and that bring benefits of various kinds (environmental, energy, economic in the long run, ...).

4.1 *BONUS VERDE* INCENTIVE

Recently, in Delibera n. 1/2014 the realization of green roofs was recognized as a possible intervention subject to tax incentives. In 2019 we talk about the Green Bonus, a tool included in the Budget Law that allows you to deduct some work done on a structure. This is how the requirements and guidelines of the Bonus are defined (L. 145/2018):

The maximum limit of the amount deductible is set at 5,000 euros, so they can be recovered in the tax return up to 1,800 euros (or 36% of 5,000 euros).

"It is important to clarify which jobs fall within the scope of tax relief. As this is a confirmation of the previous budget rule, the works and interventions that can be reported in the tax return are:
- green areas of private outdoor areas of existing buildings, building units, appurtenances or fences;
- irrigation systems and the construction of wells;
- upgrading of lawns;
- large prunings;
- supply of plants and shrubs;
- realization of green roofs and hanging gardens."
Reading these lines we can see that if you carry out work related to green, and in relation to this project should refer to the last specific item dedicated to green roofs, you are entitled to tax benefits post tax return covering up to 36% of a maximum amount of work 5000 euros.
This is because this type of intervention is recognised as having a series of consequent advantages, which are discussed in chapter 2, including:
- increased energy efficiency
- absorption of fine dust
- the reduction of the "heat island" effect in the summer period
- better rainwater harvesting.

4.2 THE VEGETABLE GARDEN, A PRODUCTIVE ROOF GARDEN SOLUTION

The project solution for a roofing with the needs mentioned above is the creation of gardens with different destinations and then a public space with commercial purposes that serves as a further link with the city.
The urban garden solution has already been applied in the city, proving useful in completing unresolved urban spaces, but especially on a social level. Two examples follow.

OURSECRET GARDEN, TURIN, 2010.

It's a vegetable garden realised on the roof of Studio999 Offices. It shows a new way of designing and using unused areas of the courtyards in high-density neighborhoods, Oursecretgarden also provides a different way of living and creating opportunities for socializing among the inhabitants (http://www.studio999.it/buildings-2/).

Top photo of Oursecret garden space.
Source: (http://www.studio999.it/buildings-2/).

ORTOALTO, FONDERIE OZANAM, 2016.

Ortoalto Le Fonderie Ozanam is OrtiAlti's pilot project and demonstrates how the rooftop garden can function as an urban regeneration device. OrtiAlti creates community hanging gardens through a collaborative methodology that allows the recovery and transformation of flat roofs in green roofs, encourages the participation of communities of inhabitants in the care and management of gardens, creates opportunities for work insertion and animation of new spaces, triggers new micro-economies at the scale of the district, thanks to the enhancement of fresh vegetables to "cm 0" (http://www.ozanam.ortialti.com/il-progetto/).
There are three different types of vegetable gardens identified in the project:
- public;
- for the activities of the Gruppo Abele;
- for therapeutic purposes.

Orti Alti, Fonderie Ozanam project.
Source: http://www.ozanam.ortialti.com/il-progetto/.

Public gardens

This first typology includes plots of land dedicated to people outside the structure who can use this service through the registration and payment of a monthly sum. Clearly, the extension of the usability of the space on the roof also to external users considerably increases the attempt of contact with the outside by the building in question.

Gardens for activities of the Gruppo Abele

As explained above, the group works with users of various kinds. A part of this audience remains constant and is often enriched with new elements every day. These people who are engaged in the search for themselves and a door to freedom and integration are supported by the staff of the group. The proposed activities change according to the people and their difficulties, but why not devote part of the gardens on the roof and the few closed structures planned among the gardens to the implementation of workshops and group activities? The idea of creating this type of space was born precisely to allow the group to complement the activities already carried out in the lower floors (language courses, personal care, teaching small activities, . . .) also others that involve women, children and why not, the whole family in agricultural activities. Putting these people in contact with the ground, using agriculture to teach a trade, related vocabulary, basic safety standards and even allow the realization of a product at zero km. Like the vegetable gardens, the two closed structures, designed with guidelines for an educational classroom. Free spaces at the service of the imagination of the group staff, but also spaces ready to welcome proposals from users themselves to create workshops or group activities. Spaces that allow interaction between several people, the meeting of ideas and the creation of products or marketable materials to raise funds.

Therapeutic gardens

This section is very important and its realization in the project has objectives that combine the compositional and social aspects with final curative effects.
Since the times of the Sumerians, one can find evidence of man's preference for natural rather than built environments. Many studies try in particular to understand how nature can have positive effects on the psychophysical well-being of a

person. Somehow man feels at ease in a green, natural environment and when he regains his position in this society he feels in the right place and therefore able to best face his life, in all its facets.
It seems that when you see living natural elements (plants, animals, . . .) stress, anxiety and similar human symptoms are reduced considerably.

4.3 HISTORY OF GARDEN THERAPY

Since the times of ancient Egypt there were the first uses of horticulture for therapeutic purposes in subjects with psychological disorders with the aim of relaxing them. So, from then on, the years passed, but the habit of inserting green spaces was not lost, for example in convents and monasteries, making them available to residents, sick or not, in an attempt to offer spaces of natural generation of sensations of quietness and tranquillity.

The date on which the actual birth of orthotherapy is inserted, however, is the beginning of the 19th century when the book "Medical inquirers and observation upon diseas of the mind" was published in 1812 by Benjamin Rush. This volume expresses the improvement of the conditions of patients with psychiatric disorders when they are engaged in natural activities. At that time, both in America and in Europe, the idea of developing gardens, green spaces and farms was considered a new and effective alternative to asylums for the management of patients with psychiatric problems and mental disorders. During the period of the First World War, these agricultural activities were widely exploited for the rehabilitation of wounded soldiers and civilians. These practices were also present in the Second World War, reducing in most cases the time of hospitalization. Over the years, the spread of horticulture used as a therapy continued, there were further studies to deepen the subject, but also numerous applications. Towards the end of the 20th century, in New York, through the publication of the volume "Horticulture as a therapeutic aid", the importance and effective effectiveness of horticulture was recognised at the medical level. (C. Righetto, 2005).

4.4 HORTICULTURE TODAY IN ITALY AND ABROAD

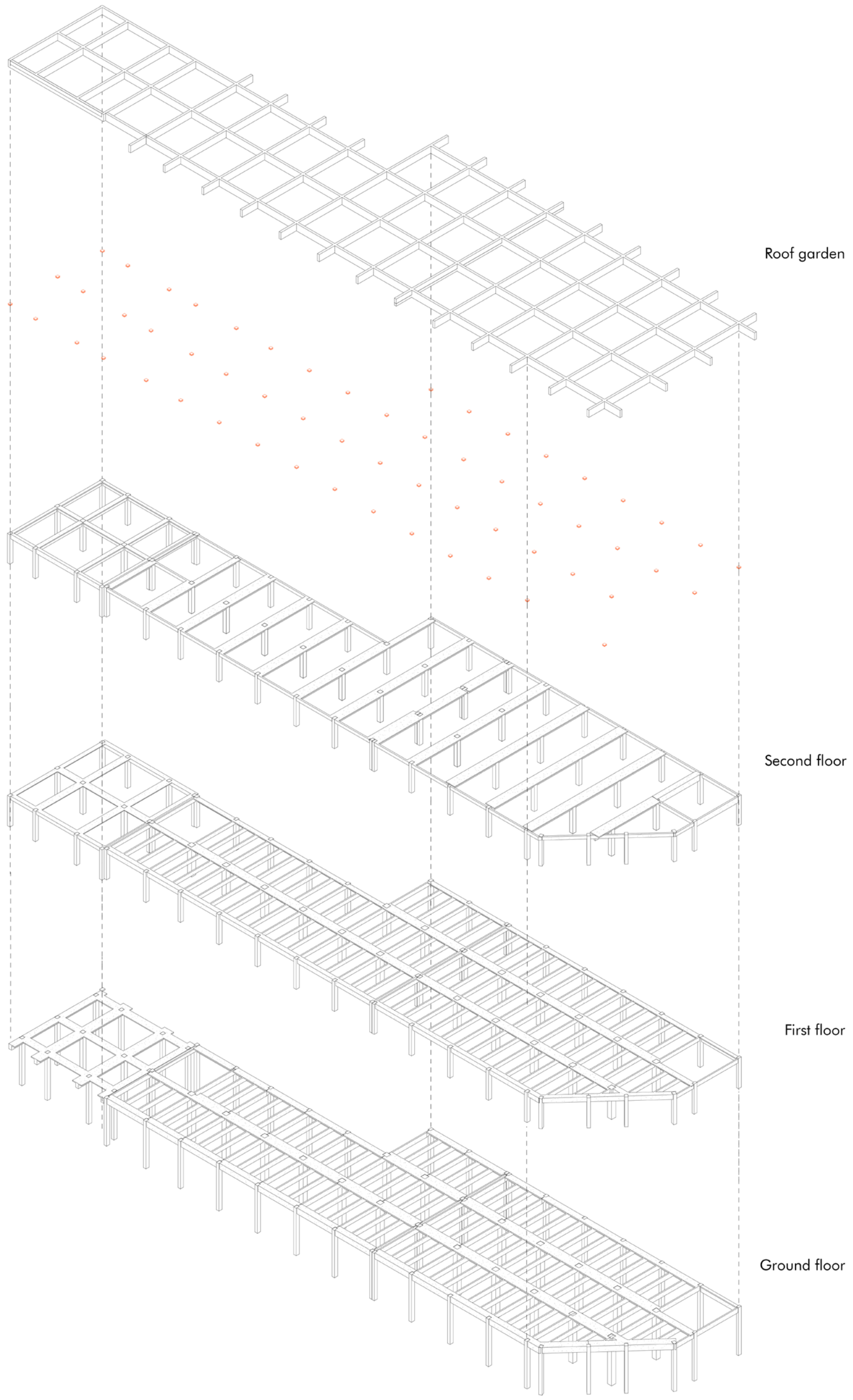
Abroad, particularly in England and America, orthotherapy is often used in medical settings. There are two types of approach, one in which green is associated

with an improvement in user well-being in the broadest sense and a second in which green has a more specific role and medical results and improvements are expected after the man-plant encounter. The "healing garden";, that is the first type, provides for a relaxation of the person, but without curative effects, while the "therapeutic garden";, however, is aimed at concrete collaboration in the therapy provided for the patient. In Italy, on the other hand, it is more social bodies that use horticulture for therapeutic purposes, while, unfortunately, this practice is not yet very widespread in medical-hospital facilities (C. Righetto, 2005).

Of course we do not consider the Abele group as a hospital, but as we have said before it also provides some of its users with initial health support in serious cases. For this reason, the idea of including vegetable gardens that allow people in difficulty related to addictions to use these spaces to find their way back seems to be a good option.

4.5 DESIGN PROPOSAL

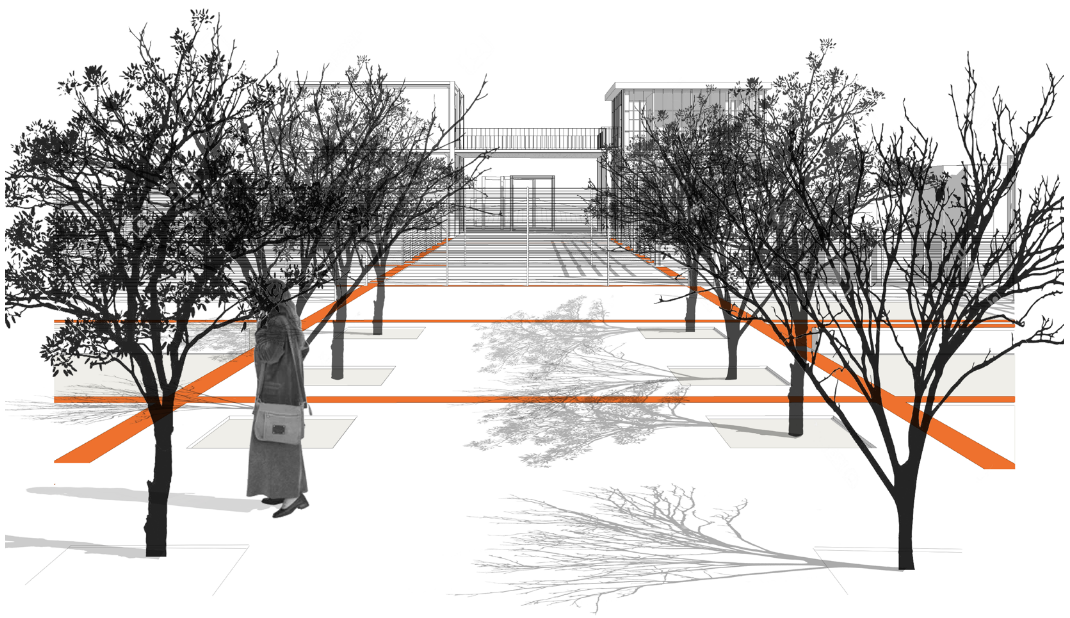
The design idea must therefore include all the ingredients described above, taking into account the context and creating a language that can communicate with the existing but is at the same time innovative, that brings a wave of freshness to the neighborhood.
The division of spaces is the result of the study of the building and its structure. As previously mentioned, the block has a structure with almost regular frame typical of industrial buildings. This has given rise to a partition of the spaces on the roof that recalls this regular rhythm dictated by the position of the pillars. Then, as a first step, a regular division of the space into rectangles has been reproduced.



Axonometric structural exploded view of the building.

Through meetings with the architect who collaborates with the Abele group, the subdivision of the third floor was defined. The proposed project involves the creation of rooms arranged around the entire perimeter that embrace a large central corridor. Hence the idea of dedicating the entire central strip to a large space, which not only takes spatially and functionally the floor below, but allows the placement of rows of trees and the insertion of self-locking on the ground going to simulate a large central tree-lined square. This central distribution space allows to reach from the inside the therapeutic gardens and the gardens for the activity of the Gruppo Abele, acts as a manoeuvring space for the transport of tools and materials for agriculture, houses the future flows of users of the roof and allows access to the greenhouse and other enclosed spaces present (tool shed, changing room and workshop rooms).

Perspective section of the building.



View of the central axis of the green roof.

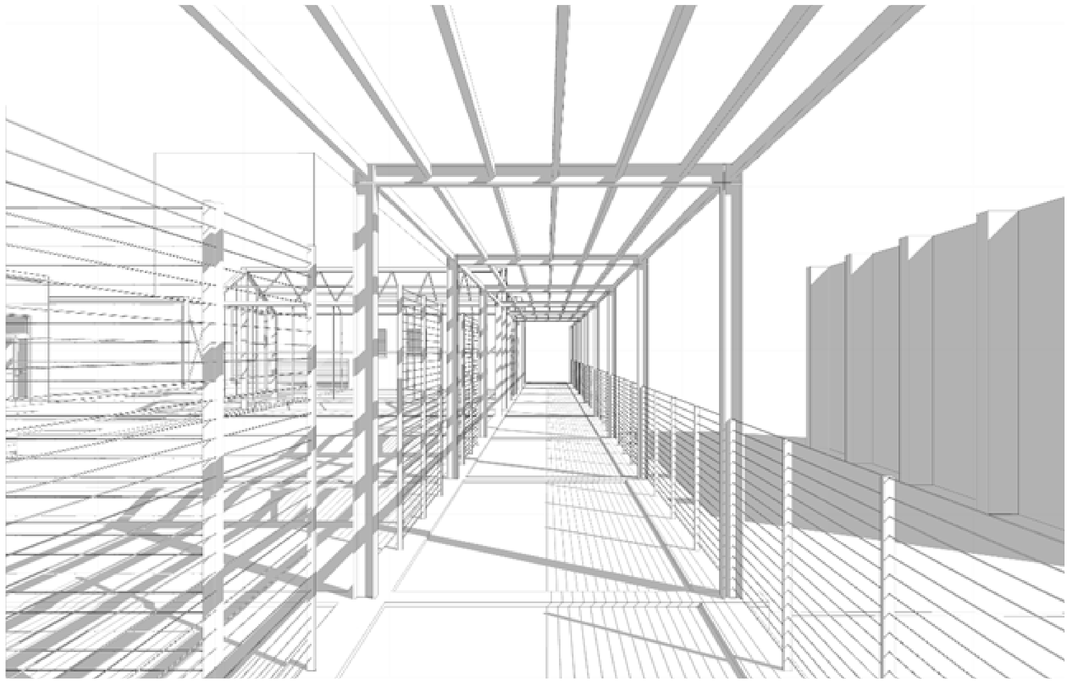
As in the floor below, also here the perimeter is composed by rectangular spaces derived from the position of the pillars, These rectangular spaces on the roof became large concrete tanks that will accommodate several centimeters of land dedicated to the construction of the gardens. The largest vegetable gardens are those intended for the activities of the Abel Group. Having more space would in fact allow more women or people participating in these activities to use this land. The smaller ones, but almost similar to the first ones, are the public gardens. For this type of plant, in fact, it has been decided to maintain a large size to allow at least every user to be able to plant more specialties of vegetables and be able to ensure a supply at least family. The third dimension used corresponds to about half of those mentioned above and is dedicated to horticultural therapy. This division stems from the desire to guarantee each "patient", who turns to the Abele group for support during the exit from the prison of addiction, to have a personal space of land in which to put into practice the techniques learned, in which to find their natural essence and where to see personal improvements through the care of a living element that needs to be taken care of. According to some studies, in fact, therapy promotes the reintegration into daily life of people with disorders of various kinds thanks to their awareness. Patients find their own position when they realize that they are able to look after a third element whose life must be preserved.

4.6 GREEN RING

The use of the grid as a design concept is an idea that wants to go beyond the perimeter limits of the building with the desire to create that illusory image of "infinite"; grid. Taking into consideration this first consideration and the desire to create an intervention communicating with the context, but still distinguishable, comes the idea of overcoming the contour, of coming out of the edge of the roof. From this comes a long tunnel that runs along the entire perimeter of block B, a "green ring"; key to this project. In fact, this element want to respond to different needs:
- create an external distribution space that allows access to all the gardens
- create an additional green space that simulates a gallery, a balcony over the city
- make the intervention visible at a distance and therefore distinguishable

This perimeter element consists of a paved base resting on beams. More specifically, this ring is entirely cantilevered for a value of about 2. 5 meters and is supported by cantilevered beams resting on the perimeter pillars. This structural imprint makes it possible to bring to the façade the system of beams that delimits the tanks and supports the roof. Also in this case there are smaller tanks delimited by regular beams for each perimeter pillar, by the external perimeter of the block in the internal part and by a 2.5 metre overhang in the external part. The entire walking surface is composed of a layer of grass on the ground that fills the

tanks and the arrangement of the self-locking that facilitate the walk by users. This green tunnel is evoked by the creation of a steel grid resting on a structure of steel pillars positioned at regular intervals following the warping of the beams. This grid creates a railing on the outside to make it possible for people to see the city, while on the inside it acts as a separator between the path and the gardens. The internal part of this grid is however interrupted near the accesses to the gardens, in fact this green ring wants to be an alternative distribution route able to allow users access to all the gardens of the Abele group from the outside following a circular trajectory. This route also has a pergola in the upper part which, together with the lateral grid, allows the diffusion of a hypothetical climbing ivy with a double function:
- shading the space
- visually increase the presence of green.



View of the Green rinG.

4.7 DISTRIBUTION AND ACCESS ROUTES

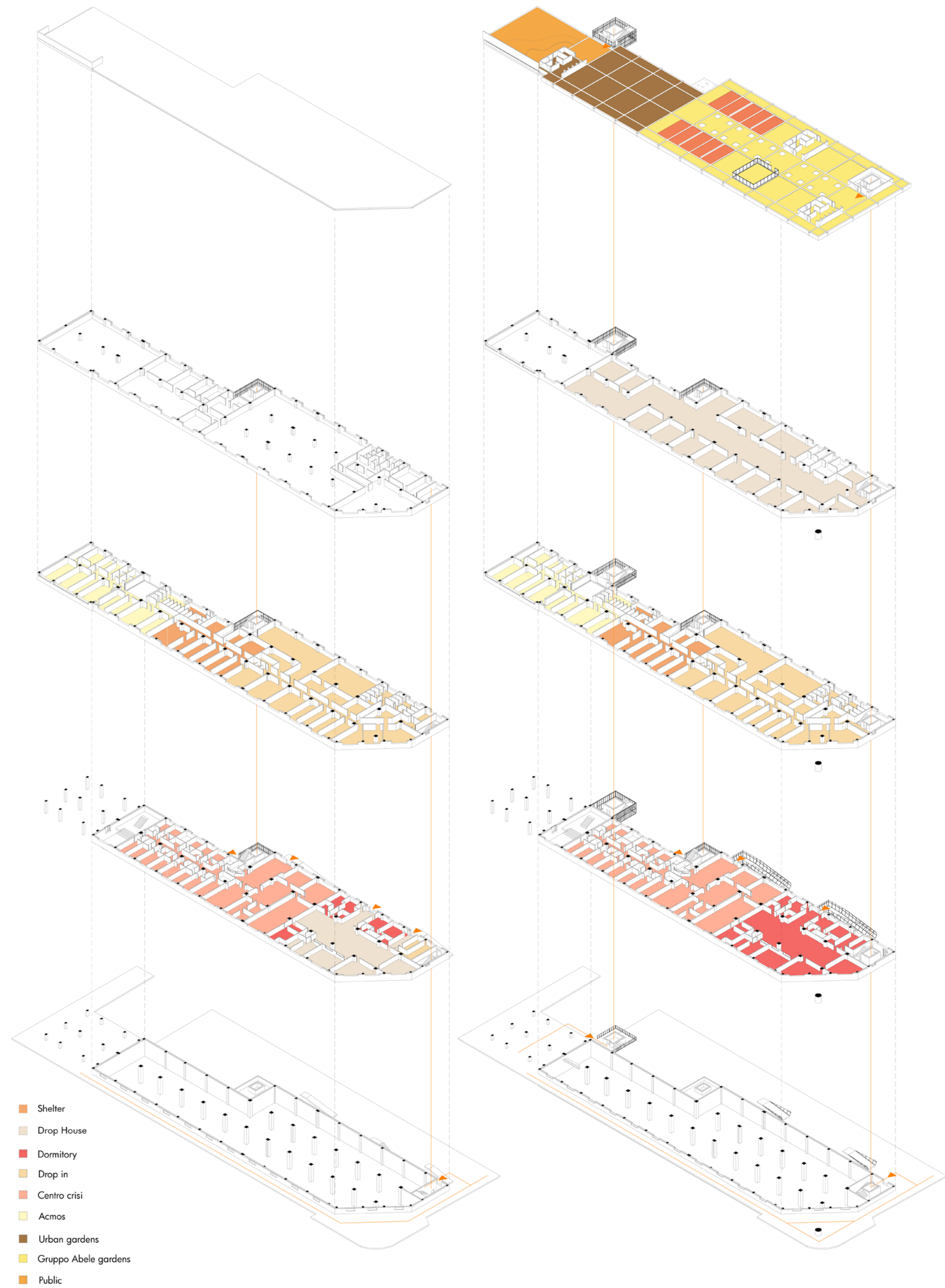
The accesses to the structure have a strong change. Considering the situation to date we find a small external entrance on Via Pacini divided into two parts, on the one hand you can access directly to the upper floors through a small stairwell, on the other hand you can access the ground floor (raised) by means of a ramp and the courtyard. In the inner courtyard there is another ramp that allows access to the crisis center and an outer glass block located in the middle of the sleeve (see image X) that serves to access from the outside to the first, second and third floor).

This design of the roof garden has also made it possible to create order and give hierarchy to the accesses to the floors below. At the same time, the choices were also induced by the regulations on escape routes (Ministerial Decree of 19 March 2015).

The small existing stairwell on Via Pacini has been demolished together with part of the attic to create a more comfortable stairwell, supported by the walls of the elevator shaft. This allows access to all levels by connecting all the activities managed by the Gruppo Abele An external staircase was built at the opposite end of the block to access the public spaces of the roof garden.

By using both the stairwell and the stairwell you can reach an open space from which you can then use the various spaces. Through these openings you can have access to the green ring, described above, and then enjoy every garden passing from the outside. The angular staircase allows the ascent to the roof and the direct contact with the gardens intended for the activities of the Abele group, the greenhouse, the changing room and tools area and finally the classrooms for activities. The other stairwell, on the other hand, designed to resume a spatial symmetry of the accesses, connects with the more "public" area of the roof. Through this access you can access both the part of the gardens dedicated to the public with its area tools, and the most alternative part of this distribution, the non-conformist, located above the underpass that divides the two blocks of this large building.

The external glazed staircase also served to create a volume that gives value to the underpass, restoring a symmetry with respect to the central axis of Via Gaetano Pugnani.



Exploded axonometric representaion of the new building functions.

4.8 THE EXCEPTION TO THE RULE

As has been said a few lines before, the building is somehow interrupted by an underpass that characterizes it today, but that has always distinguished it from the golden times of CEAT. This portion of the building, in fact, located in the center of the building, housed the company's offices at the time and was characterized by a large triumphal staircase to access it, a symbol of the bureaucratic part of the company. In addition, at the top of this portion stood the large CEAT sign that made the building recognizable by meters. From this distinction over the years comes the desire to maintain, even in this project, this characteristic distinction.

The "nonconformist" part of the design is born, with spatial rules that almost oppose those used until now.
In this part, as in the adjacent one, the main user is the public outside the building and, more specifically, outside the realities of the Abele group. This will be the greatest connection with the neighborhood and the city through the creation of a bar accessible to all and a large green area to relax and enjoy a bit of peace just a few meters higher than the chaos of the city.
The compositional idea followed in the realization of this space does not follow the regular scan dictated by the position of the pillars as in the rest of the project, but wants to be the reproduction of a fluid natural space, with soft lines. This green forest is crossed by a path with curved lines, a large space created by the positioning of porticos that are growing as you approach the facade. Despite the fact that the latter, close to this space, has been raised and lowered, it allows us to see this green world hidden even from the outside and to arouse curiosity in the hypothetical external user who sees at the sign CEAT of the time a large mass of vegetation peeping out.
What an outside public or simple neighborhood can see from this central element is not only the protruding and irregular vegetation, but also the bar that rises on another additional floor that marks the beginning of this slice of the building. To access both the bar and the "forest"; one of the two new entrances must be used, more precisely the stairwell adjacent to the underpass which, thanks to its position, also allows the creation of a symmetry with block A. The positioning of this new entrance to the building and the roof manages to create a new flow

and much greater than today that could have excellent consequences such as the reduction of stops in the underpass by the clochard. Today, in fact, this space is populated by homeless people who degrade the area and make the passage difficult for people who live in the area. This also means additional insulation of the building and in particular of block B.

Photo of the building overpass.

Representation of the overpass new project.

4.9 THE FLOOR AND THE CHOICE OF THE GROUND MASS

As has been said several times before, the application of a TMD system offers the possibility of adding a large mass. We must imagine that the addition of a foreign body, of a not insignificant weight, above a building is the right key to obtain a valid seismic mitigation system. This is the reason for the choice of creating vegetable gardens on the roof.

The idea of choosing the vegetable garden as a hanging garden represents a sustainable and different tool compared to other possible solutions. The waterproofing, drainage and root barrier layers must not be damaged during soil working. The substrate can be composed of different types of soil depending on the needs, temperatures and thickness varies depending on the types of plants that you want to plant. The thickness of the substrate varies mainly according to the type of vegetables to be grown. There are not many other differences compared to the classic typology of green gardens, in fact the volcanic soils (from which you get the substrates for the hanging green) have a positive impact on the success of cultivation because they are very fertile. The most important recommendation is to use exclusively natural materials for the substrate so as not to contaminate vegetables and cause damage to human health. The "Matrix of system properties for the most common types of green roofs"; shows that in Italy, on average, 25-35 cm of substrate are required to create a roof garden, thus excluding the load-bearing structure of the system and the various layers of waterproofing (http://www.isprambiente.gov.it/files/pubblicazioni/manuali-lineeguida/mlg-78.3-2012-verde-pensile.pdf).

This is enough to show that the garden can be considered among the category of intensive green roofs, i.e. those with a depth of soil greater than 15 cm. However, these data are not absolute and the value of the substrate can vary significantly if you decide, for example, to plant trees or some vegetables such as tomatoes or asparagus that require much greater depth. The roots of a tomato plant can vary between 0. 7 and 1. 5 metres (http://www.agraria.org/coltivazionierbacee/pomodoro.html).

Caratteristiche	Tipo sistema (espresso in base alla vegetazione prevista)						
	Prato fruibile	Tappeto di sedum	Prato - pascolo	Tappeto di perenni	Arbusti e suffrutici	Orto	Siepi ed alberi
Spessore substrato (cm)	15-25	8-10	12-15	10-15	15-35	25-35	35-100
Peso (kg/m^2)	220 – 400	120-160	160 – 300	120-300	220-550	300/550	450/1500
Coefficiente deflusso	0,35-0,25	0,50-0,40	0,40-0,30	0,40-0,35	0,35-0,15	0,25-0,20	<0,20
Manutenzione	Medio alta	Medio-Bassa	Bassa	Medio-bassa	Medio-bassa	Alta	Medio-alta
Fabbisogno idrico	Alto	Basso	Basso	Medio-basso	Medio-basso	Alto	Alto
Fruibilità	Alta	Nulla	Bassa	Bassa	Media	Media	Alta
Isolamento termico	Alto	Basso	Medio	Medio-basso	Alto	Alto	Alto
Abbattimento inquinanti (PM10, O_3, NOx, CO_2, SO_2)	Medio	Basso	Medio	Medio-basso	Medio	Basso	Alto
Tasso di concimazione	Alto	Basso	Basso	Medio-basso	Medio	Medio-alto	Alto

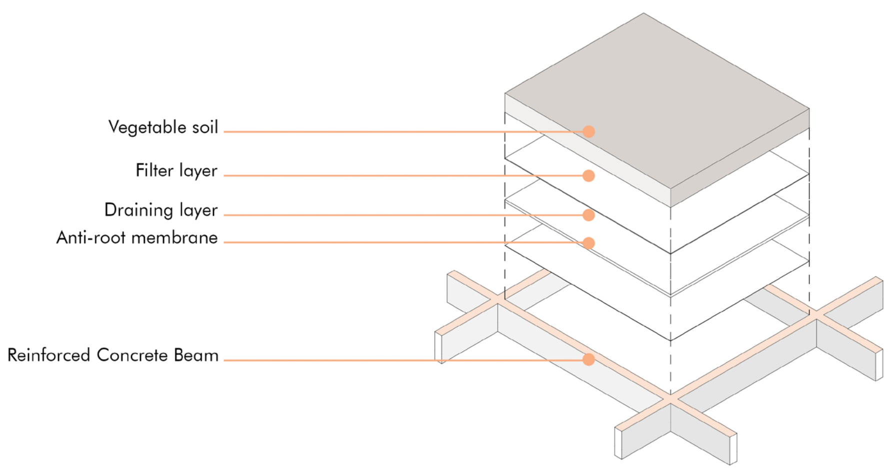
Source: (http://www.isprambiente.gov.it/files/pubblicazioni/manuali-lineeguida/mlg-78.3-2012-verde-pensile.pdf).

From this research it was considered appropriate to choose a depth of land ranging between 30 cm and 1 meter to offer freedom to users and to give the opportunity to cultivate more plant species without too many limits, but especially to take up the initial challenge.

Add a large mass on the roof and isolate it from the rest of the building to ensure anti-seismic benefits to what extent?

This choice therefore becomes of fundamental importance for the tuning of the masses and for the efficiency of the TMD. At the same time, the calculation simulations had to demonstrate which weight the existing structure was able to support and which total mass ratio was more efficient. As shown below, the substrate value of 55 cm could only be defined very precisely afterwards. This, combined with the other layers (slab, sheath, drainage layer and filter layer), results in a total weight of 1679 kg/sqm.

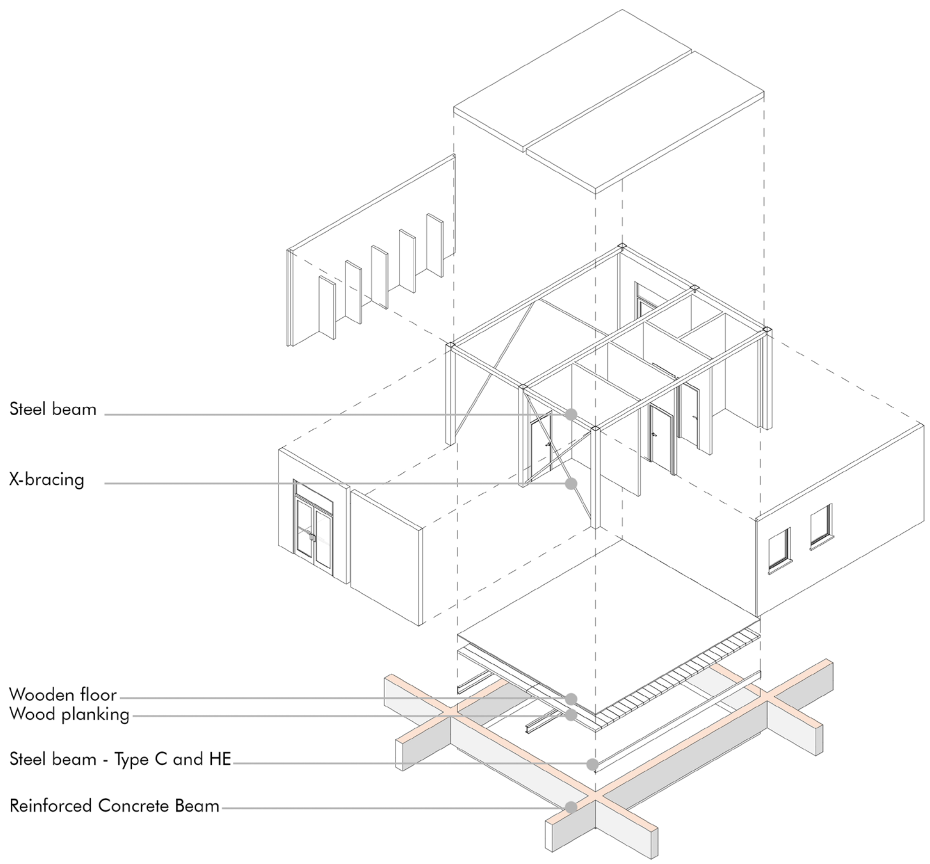
This layer of soil is hosted by all the reinforced concrete tanks that arise from the intersection of the beams that support the roof garden. It will therefore be present everywhere, clearly near the gardens, in the central section and in the green tunnel with an additional layer of lawn and self-locking devices that facilitate the passage. The parts of the roof that do not have the tanks full of soil are those in correspondence of the changing rooms, the laboratory classrooms dedicated to the activities of the Abele group and the sheds for the tools. In these spaces, a different technological solution has been devised. Thanks to steel beams (type C and type HE), bolted to the internal faces of the pools, it was possible to rest on a board and then on a wooden floor. The construction of this dry pavement makes the process reversible by offering users to change the intended use later. It is enough to dismantle this system to be able to fill these empty tanks with earth as well.



Hortus block exploded

4.10 DOUBLE MODULE

The reinforced concrete beams that support the roof garden are located at the mesh of pillars below, in fact, the rule is that all structural elements always lie on this imaginary grid, while the functional spaces are closed within it. This rule was also useful for thinking about premises that house laboratory activities, bathrooms and tool rooms. These are in fact modules with structure, in view, that encloses the respective functions, as if it were a shell. As can be seen from the pillars and the beam in the middle, these blocks become double modules. The bracings, also visible, are necessary to ensure that all the objects in the roof are rigidly connected to the structure of the TMD in order to create a single mass, with a single oscillation.

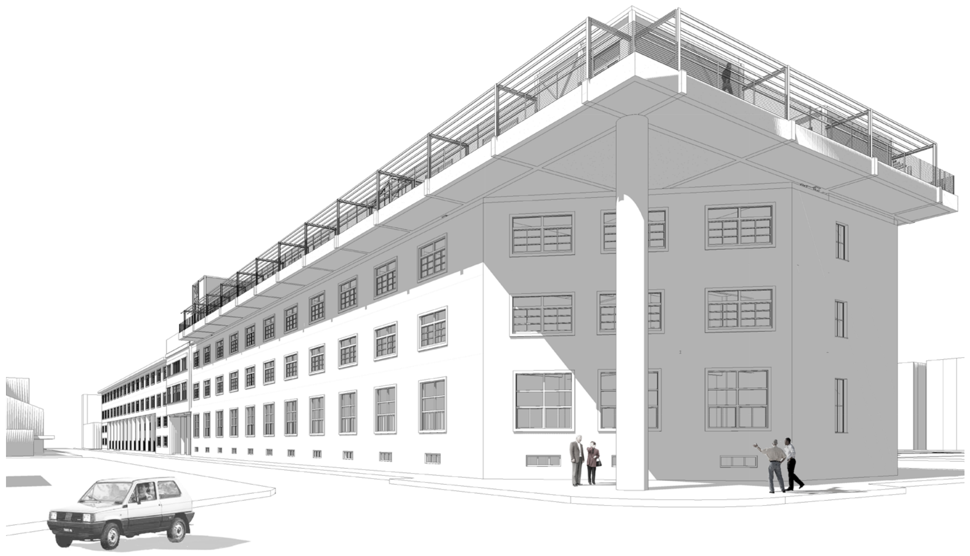


Facility room exploded

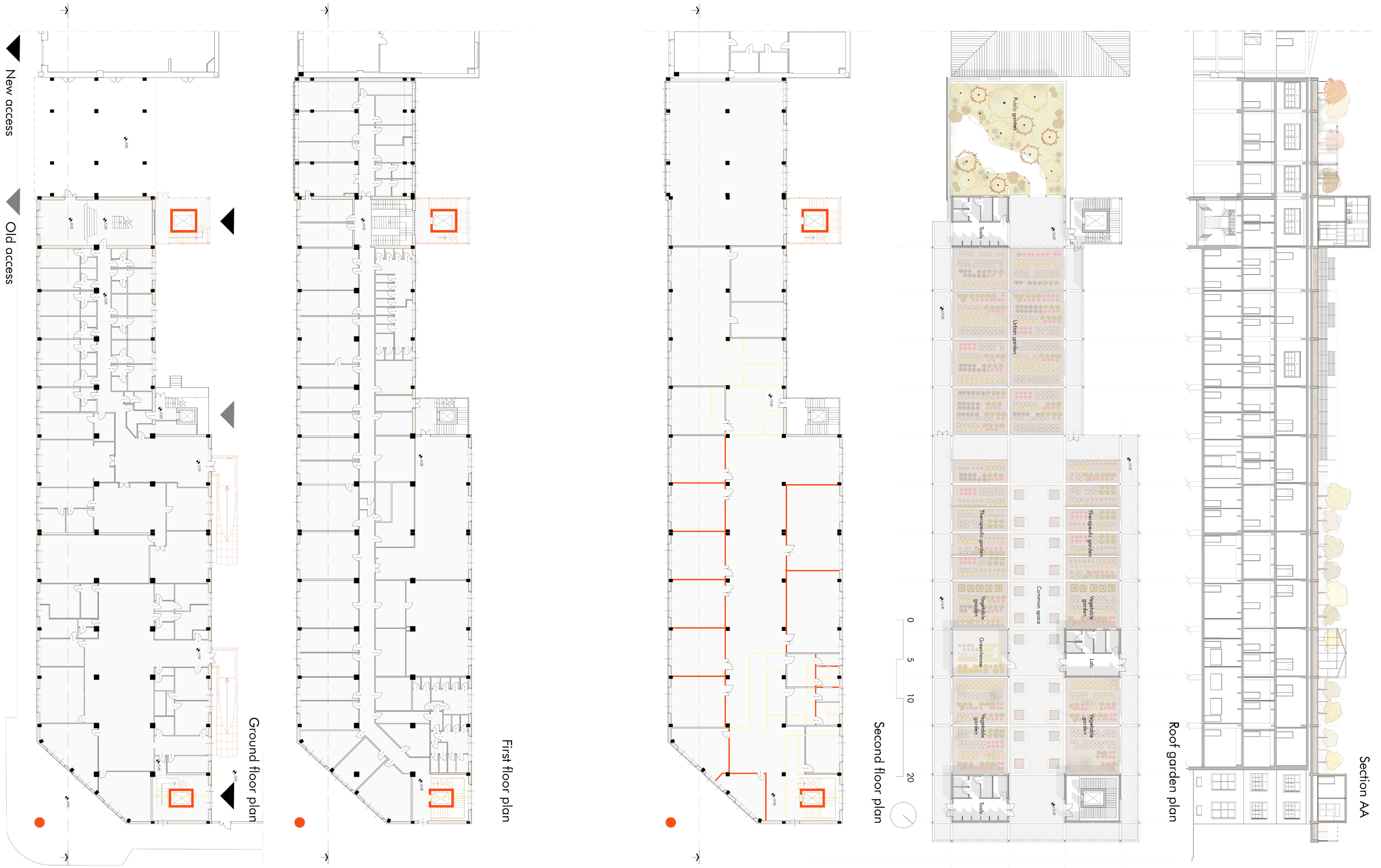
4.11 THE COLUMN

The building, as has been said, is located in Via Leoncavallo, more precisely in a block surrounded by other buildings with different conformations as well as a park within a residential complex with a closely adjacent courtyard.
The structure under study, i. e. block B, has an interesting particularity in its form, however simple it may be. In fact, the basic shape is a rectangle widely developed longitudinally but has the edge cut at the intersection of Via Pacini and Via Leoncavallo. However, the work carried out takes up the rectangular shape of the block, so a part of the roof is protruding. Hence the idea, for different reasons, to think about this corner. In fact, the projecting roof can give the idea of instability if you look at the intervention from below, and also, always if you consider a spectator, a user who studies the structure from the ground floor, it is necessary to create a clear call to the intervention.
After some research and careful observation of "similar" projects located in the same city, a solution arises spontaneously that would solve the above issues and at the same time would give a characteristic imprint is recognizable to the project.
The goal is also to leave a strong trace within the neighborhood taking advantage of a space that would otherwise remain empty (see drawing) and the key element becomes a column placed exactly in that space.
The angular column immediately recalls some of the works of the Milanese architect Aldo Rossi, in particular the Friedrichstadt Block 10. This symbol represents the building's bond with the land on which it is built, becoming part of the city. For this reason, the column is defined as an "element of urban recognition"; that therefore outlines, even from a distance, the corner of a building that would otherwise lose its civic character. (T. Monestiroli, 2006)
The column that has been inserted falls exactly at the point corresponding to the intersection of the extensions of the two sides, almost as if to ideally reform the missing angle. It is made of steel, with a diameter of 60 cm. Inside it is hollow, so it does not require an excessive amount of material, and could be useful for the passage of implants. This column takes on a symbolic key therefore, but above all has a structural value, because it provides a support to the beams of the roof garden that otherwise would have an excessive overhang.

Source: Aldo Rossi, Friedrichstadt Block 10 (S. Banti, 2017).



View of the building angle.

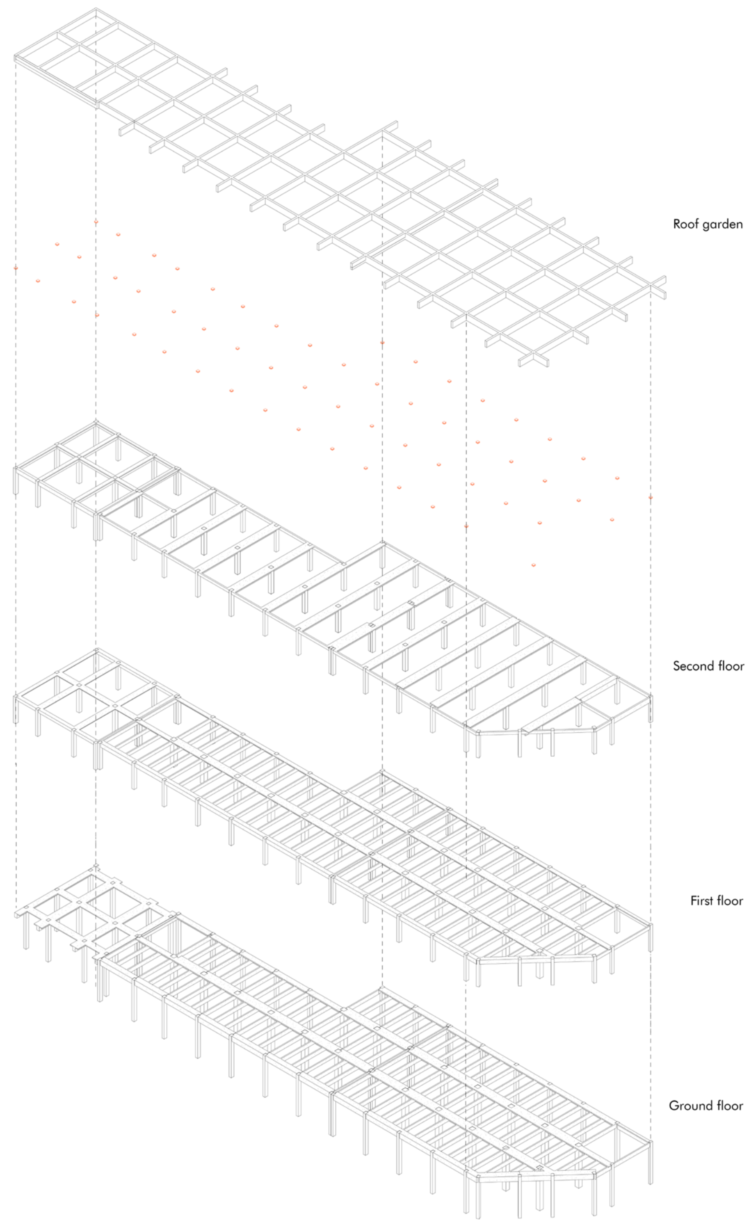


Project plans and section.

5

STRUCTURAL SIZE OF THE EXISTING BUILDING

STRUCTURAL SIZE OF THE EXISTING BUILDING



Structural exploded view.

5.1 BUILDING LAYOUT

The building under consideration obviously meets all the requirements described in chapter 1, necessary for the application of this anti-seismic system. The structure must necessarily be framed and must not be rigid (masonry buildings or prefabricated panels) so as to be able to absorb the movements due to the effect of the earthquake.
In order to simulate the TMD system it is therefore necessary to know the physical and geometric characteristics of the building on which the garden roof is to be applied. The level of knowledge may vary depending on the information held, therefore the accuracy of the surveys, the verification of possible upgrades of the building over time and the inspections are essential to carry out some checks.

Thanks to the vision of some surveys represented on a scale of 1:200 it was possible to learn much of the information, but due to the lack of reliability it was necessary to view some building practices in the municipality of Turin that were essential to reconstruct the missing parts and to verify the size of the building system. These were used to reconstruct the structural plants and a reliable model with which it was possible to carry out the dynamic analysis at a later date.
The part of the building analyzed, chosen to realize the TMD roof garden was made of reinforced concrete and consists of 3 floors above ground plus a basement respectively at 1. 39 m - 6. 66 m -10, 86 m. The extrados of the cover, on the other hand, reach 14. 94 m.
The surface examined is about 1742 m2 and since the building is about 95 m long, there are two expansion joints (necessary to divide the building into several parts when you exceed tens of meters). A joint divides the porticoed part of the building, managed by the Acmos group, from the rest of the building. The remaining part is in turn divided into two equal parts by another expansion joint.

The plant as a whole can be considered irregular because it is not symmetrical with respect to the two axes x and y, but also as a result of the irregularity of the size of the bays.
A bidirectional reinforced concrete frame forms the load-bearing structure of the building.

garden that otherwise would have an excessive overhang.
The apparently regular rectangular mesh of pillars therefore shows slight differences for each span, but is maintained at about 7. 10 m x 5. 10 m. (see Annex).

5.2 PILLARS

The dimensions of the pillars were measured and verified on site because of the difference between the different sources owned. Between ground floor and second floor the section remains constant 66 x 66 cm, while from the second floor to the roof the section changes to 50 x 50. The pillars on the top floor support a much lower weight, as shown in the load analyses carried out (see annex).

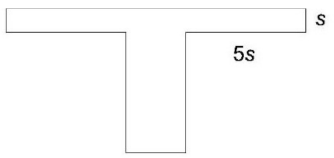
5.3 FLOOR SLABS AND LOAD ANALYSIS

The concrete floors are supported by double row lowered beams with the exception of the roofing floor, which has a beamed and brick floor resting on a single frame of lowered beams. On-site checks were also used to observe the directions of the warping of each inter-storey and the actual presence of expansion joints.

5.4 THE BEAMS

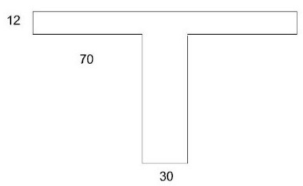
The main frame of the beams follows the longitudinal direction x, while the secondary frame is always arranged in the direction y, on the short side, except for the part of the building where the overpass is present. In this last in fact the sense of the two warps changes, the main beams are arranged on the short side and have a cantilevered part that also serves to support the presence of the pillars with different axis than those below ("pilastri in falso").
The reinforced concrete files, which could have provided details about the geometric sections of the structural elements, have never been deposited at the offices of the City of Turin and not even the historical archives in the city have useful documentation for this detailed reconstruction. The section drawings owned and recovered are all on a scale of 1:200, so this has led to a lack of technical

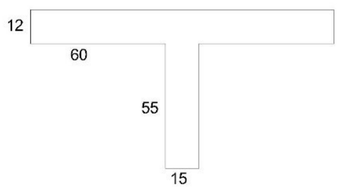
details and a low level of detail of the representations that has generated a reconstruction of the size of the geometric sections of the beams with due approximations. The measurable part, thanks to the drawings, is exclusively the lowered part of each beam element. The remaining part of the geometric section, i. e. the wings of the T-beams, has been deduced by means of an approximation.
Consequently, knowing the height of the lowered beams, the thickness of the armed slab s, and setting the width of the wings equal to 5s, the dimensions of all the elements have been reconstructed. This simplification has been particularly useful in the reconstruction of the finite element model.



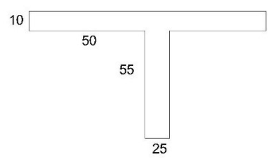
Part of a building that develops in longitude

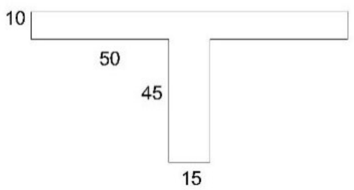
First floor



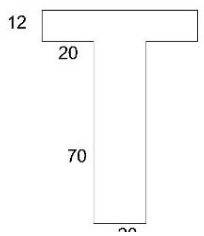


Second floor



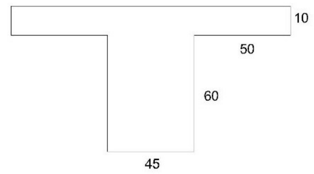


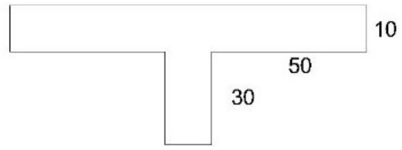
Third floor



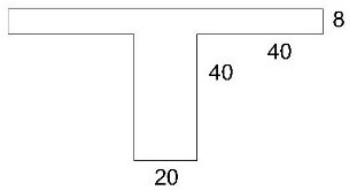
Part of the building with overpass

First floor

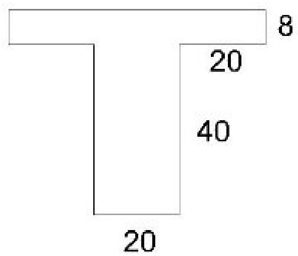


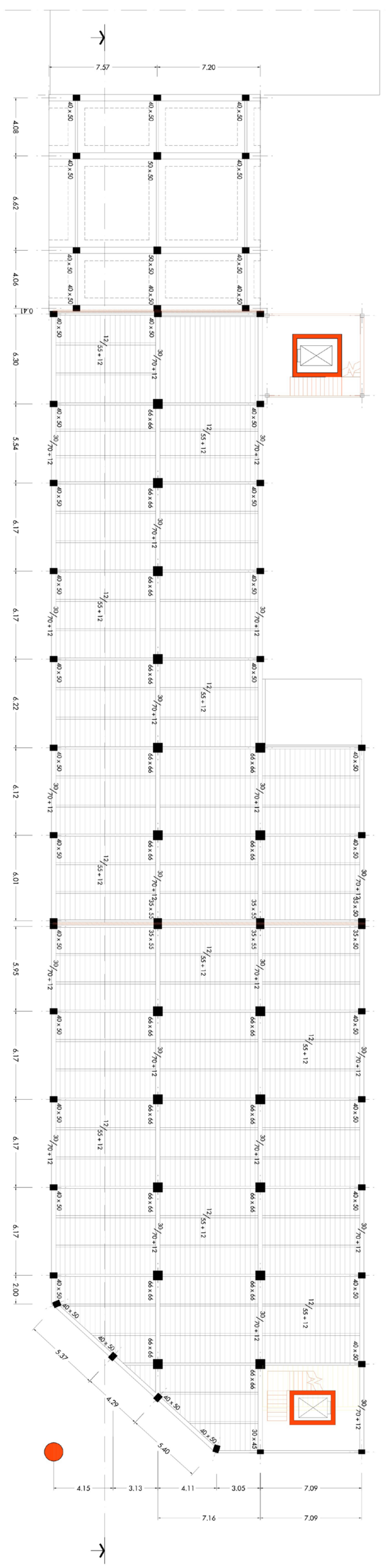


Second floor

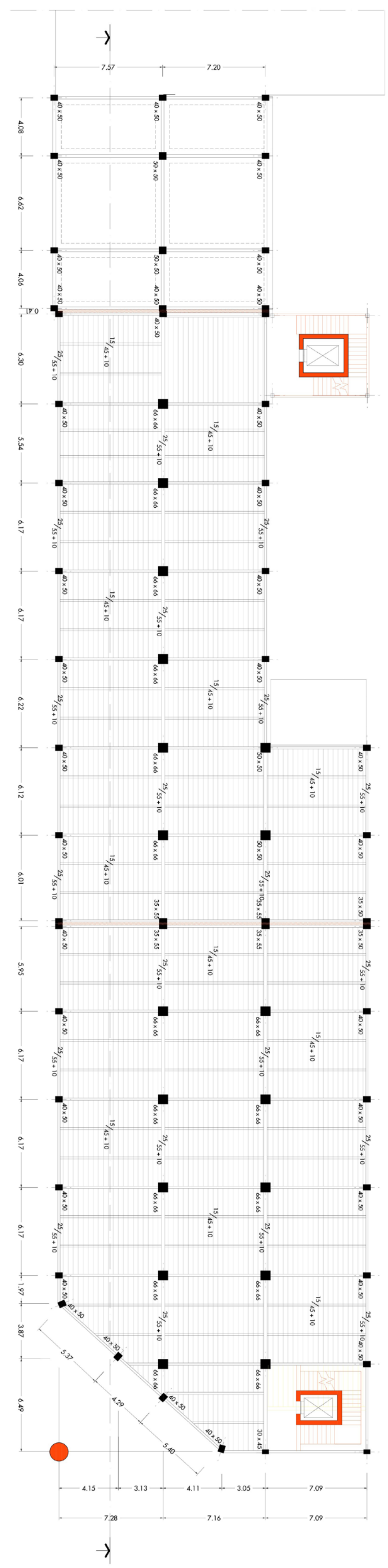


Third floor



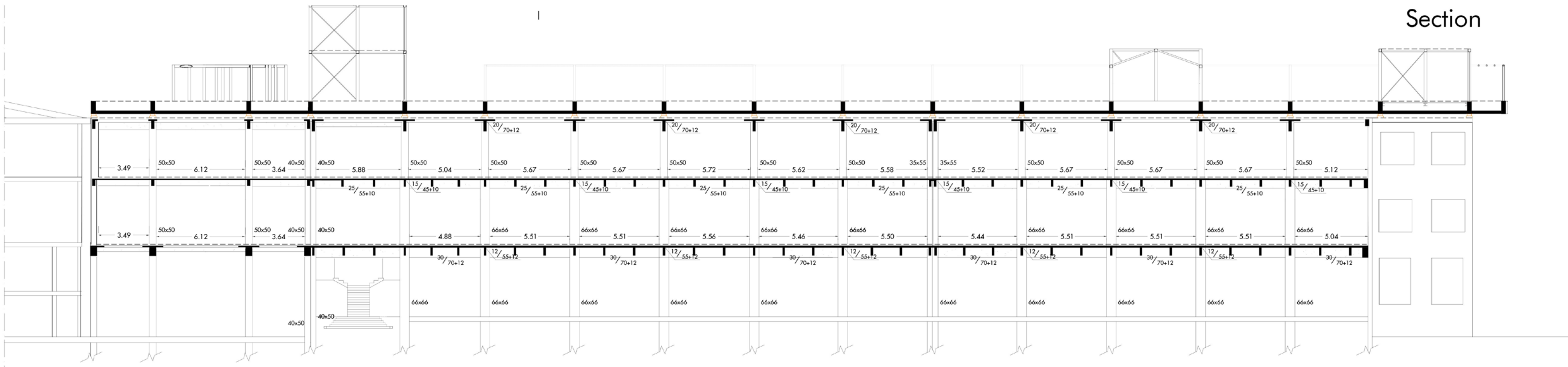


Ground floor plan

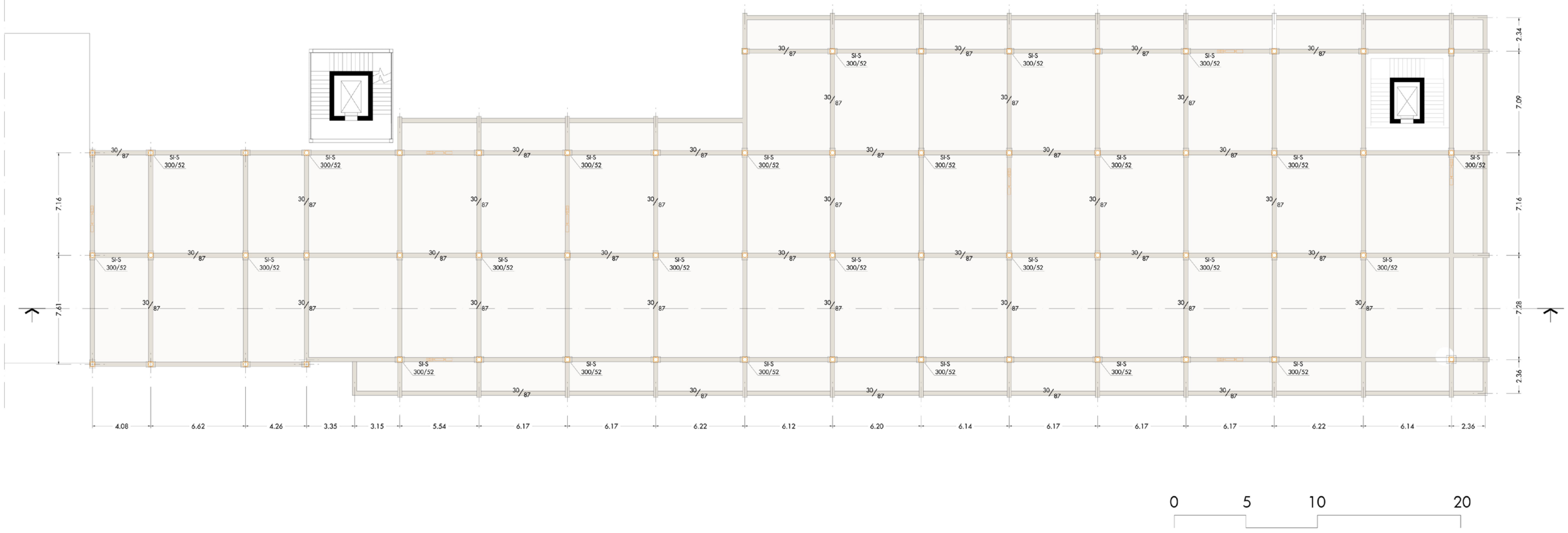


First floor plan

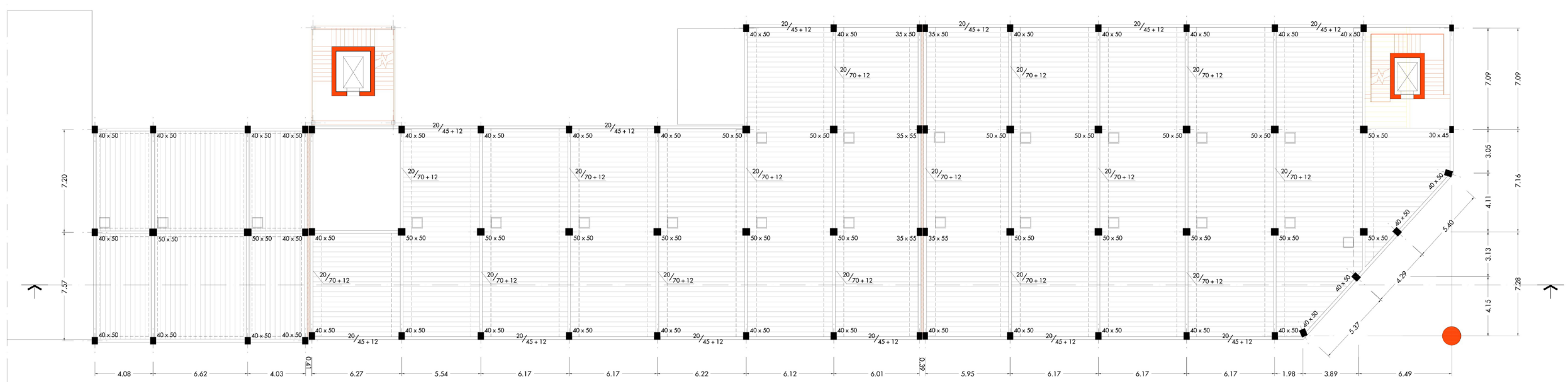
Section



Roof garden plan



Second floor plan



5.5 DYNAMIC FINITE ELEMENT ANALYSIS IN NÒLIAN ALL IN ONE

Knowledge of the structure is of fundamental importance so that a correct overall dynamic analysis of the building can be carried out. This type of analysis, carried out using the Nòlian software, is used to restore the dynamic behaviour of the building subjected to the vibrations caused by an earthquake. However, for the purposes of the simulation that must be done later in the Matlab environment it is necessary to grasp a global and generic behavior that may be affected by some inaccuracies and assumptions.

The objective of this analysis is to derive:
- modal forms
- modal frequencies and periods
- the matrix of indirect stiffness.

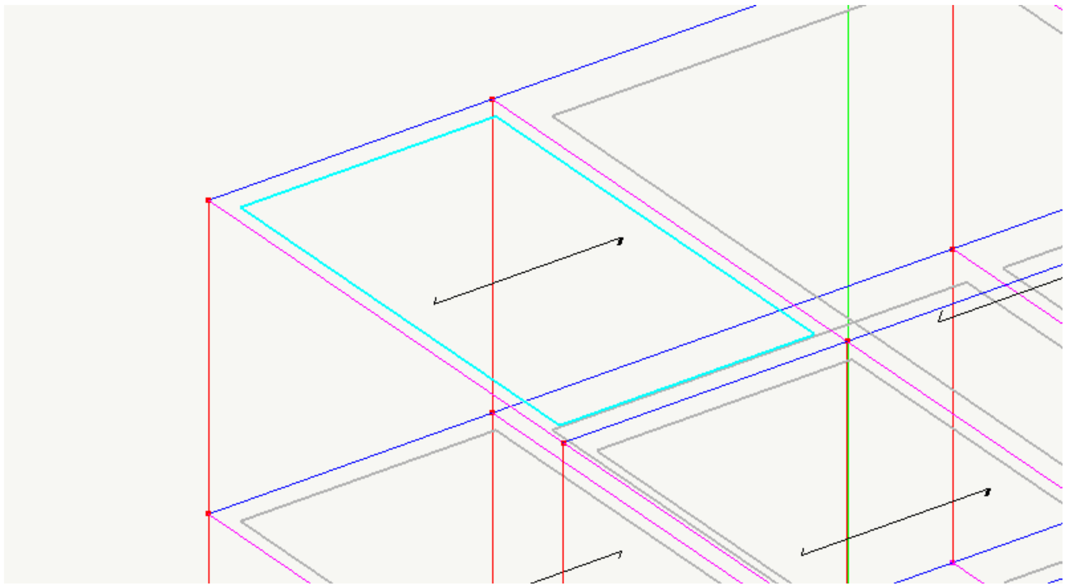
The preliminary assumptions, which precede the creation of the model, have made it possible to exclude the presence of the basement and simplify the model at the expansion joints.
The perimeter walls continue below a height equal to a basement and, being in direct contact with the ground, are considered as retaining walls. Therefore it was decided to make an approximation whereby the pillars of the model start from the level 0. 00 m instead of the level 1. 39 m.

The expansion joints are solidified to prevent the respective parts of the building from moving separately, i.e. with different periods of oscillation. In this way the whole building moves uniformly and the structure that will support the garden roof to TMD in turn can be considered as a single slab without joints. The insertion of an expansion joint in the TMD structure would have complicated the good execution of the seismic intervention. The built-up parts that make up the roof garden to TMD and everything that is above must move rigidly and must have a free space along the perimeter that allows the oscillations of this. This preliminary assumption has made it possible to link the different structures together and the split pillar is shaped as if it were a single pillar.
The building was modelled in the Cad environment defining the axes of pillars

and the main beams. The secondary beams have been modelled only when they converge in the node, in order to guarantee the right stiffness of the building and to avoid an overload of nodes that would have complicated the dynamic analysis in Nolian.
Subsequently, thanks to the .dxf extension, the model was imported into Nolian. Here the size of the geometrical section and the physical characteristics of the concrete material were assigned.
Since the frame structure is made of reinforced concrete, the only constraints inserted were the joints at the base of each pillar.
To conclude the model is necessary:
- assign loads for each structural element
- define seismic masses
- create the rigid planes.

Loads

The edge beams were loaded with a uniformly distributed weight of 11. 7 kN equal to the weight of the perimeter walls.
Subsequently, by means of the “floor loads” function, the weights were generated, taking care to define the direction of the warping and the beams that take the respective loads.



Floor loads function in Nolian.

The loads taken on are:
- partition weight = 2 kN/m2
Applied to the first and second floor attics.
- own weight due to unmodelled beams = 5. 3 kN/m2
Applied to the floor of the first floor
- own weight due to unmodelled beams = 4. 57 kN/m2
- floor weight = 2,1 kN/m2
Applied respectively to all intermediate floors

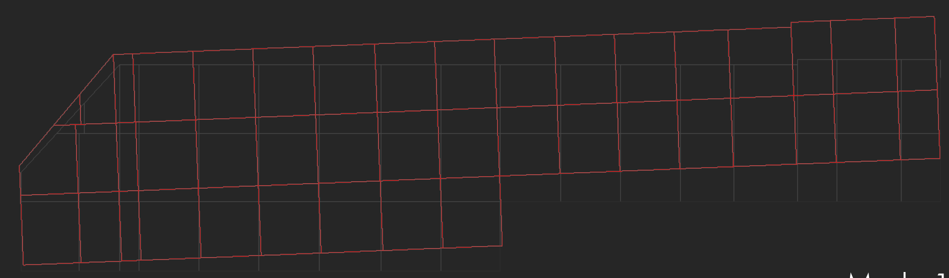
Assignment of masses

This procedure is also carried out automatically thanks to the “convert loads into masses” function and it is possible to verify that each element has been converted into mass. In fact, thanks to the physical characteristics assigned to the elements, the software recognizes the mass of each element by automatically dividing the weight by the acceleration of gravity.

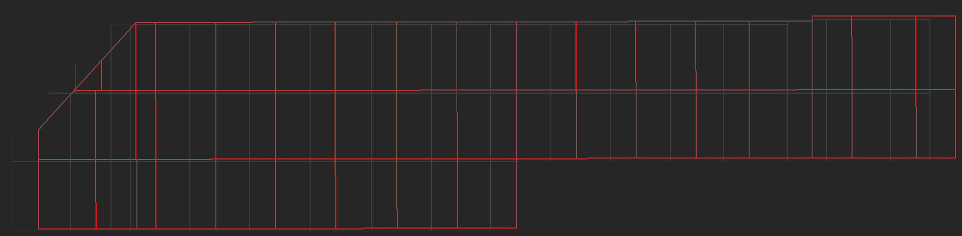
Thanks to an automatic function, it is also possible to generate “rigid decks”, i. e. to allow the decks to be rigid on the plane in which they lie.
Nolian has an archive of response spectra that are used to perform a dynamic analysis, in fact just enter the coordinates of the site, choose the type of soil and generate the spectra. In our project we assume a type C soil.

The dynamic analysis carried out shows the following modal forms of the respective frames that make up the building and the modal parameters, which were then also verified in Matlab (http://www.softing.it/files/tutorial_base.pdf).

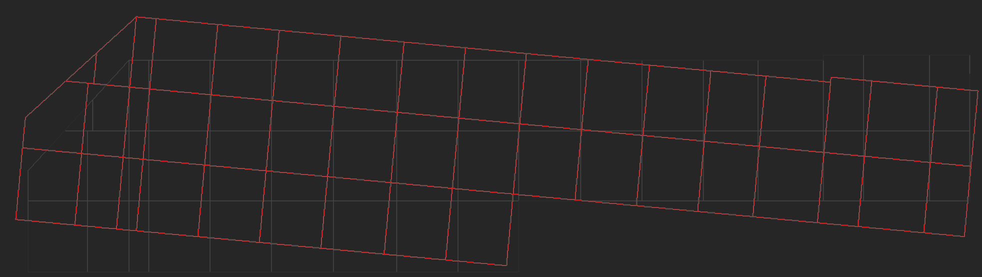
Modal shape plans



Mode 1

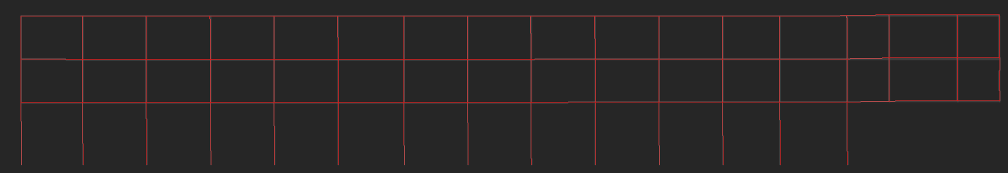


Mode 2

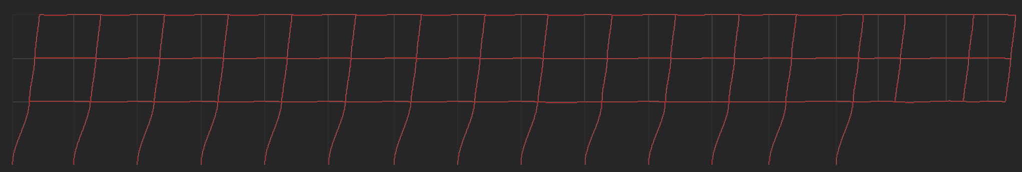


Mode 3

Modal shape A



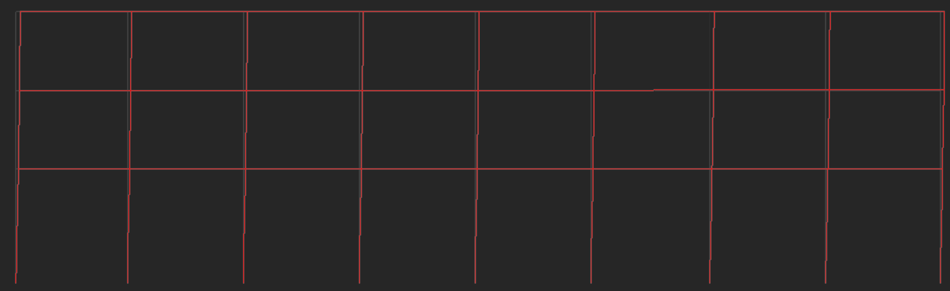
Mode 1



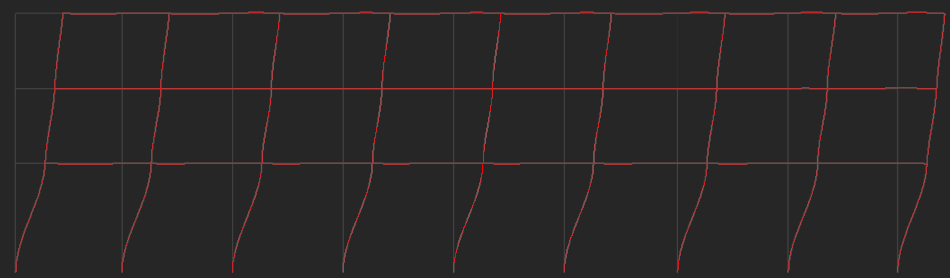
Mode 2

Mode 3

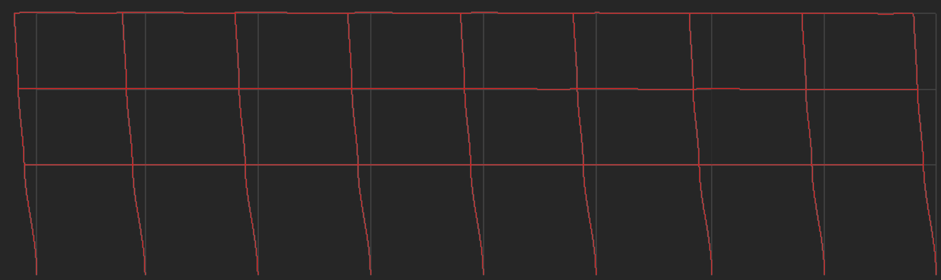
Modal shape B



Mode 1

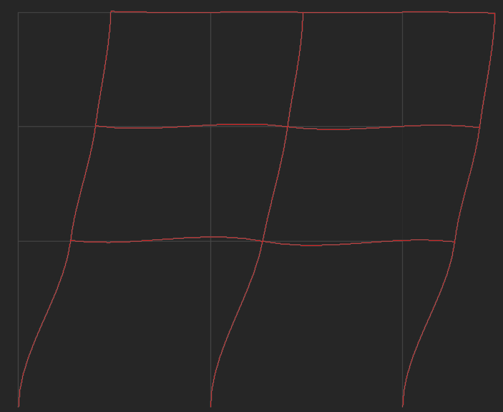


Mode 2

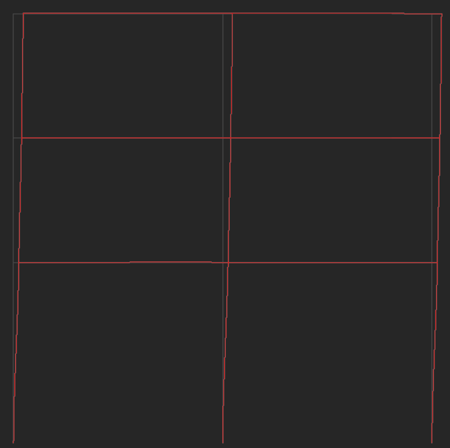


Mode 3

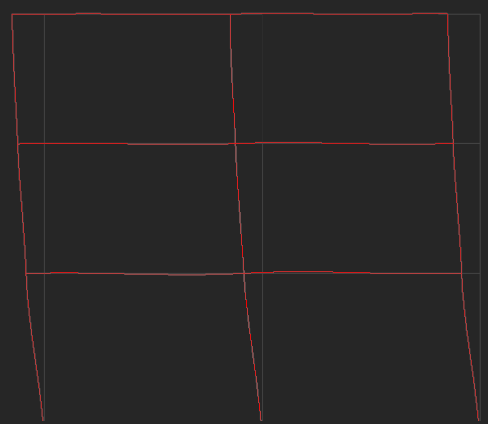
Modal shape C



Mode 1



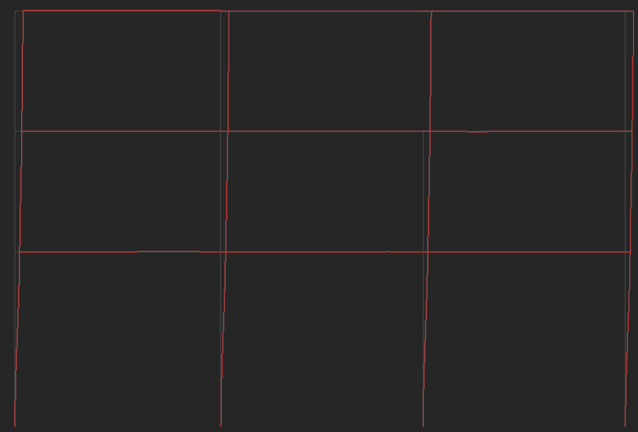
Mode 2



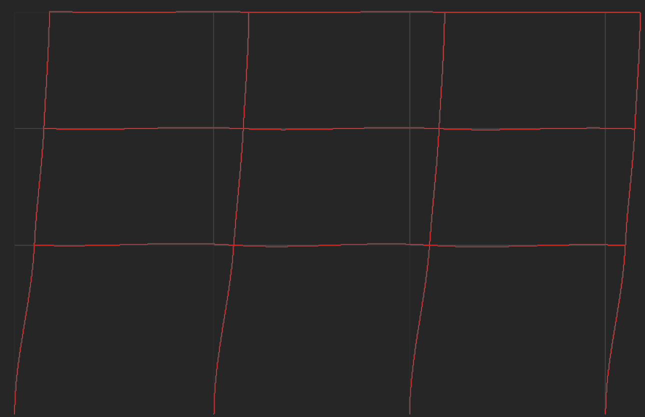
Mode 3

Modal shape D

Mode 1



Mode 2



Mode 3

Indirectly, thanks to the Nolian model, the matrix of the stiffnesses [K] was calculated using the following procedure:
1) an additional constraint to each plane has been introduced in such a way as to prevent the rotation of the plane around the vertical axis z
2) a large force (1*10^10 N) was added to the first floor long x, and the displacements long x were read to the three floors
3) proceed as in point 2 by applying the force to the second and then to the third floor,
4) finally, the 9 read displacements were collected, realizing the beta flexibility matrix

The same procedure was carried out in direction y. By obtaining the following results.

$$[\beta]_{x} = \begin{bmatrix} 1.72 & 1.82 & 1.84 \\ 1.82 & 2.67 & 2.83 \\ 1.84 & 2.83 & 4.67 \end{bmatrix} \text{*10e-9}$$

$$[\beta]_{Y} = \begin{bmatrix} 1.61 & 1.83 & 1.88 \\ 1.83 & 2.95 & 3.27 \\ 1.88 & 3.27 & 4.78 \end{bmatrix} \text{*10e-9}$$

Thanks to the "inverse matrix" function of the β function, the stiffness matrix has been calculated as follows.
The reconstruction of the building using the Nolian 3D model has made it possible to derive the matrix of the masses and the matrix of rigidity, which is of fundamental importance in order to carry out the subsequent analysis.

6

SEISMIC CONTROL

SEISMIC CONTROL

Thenextstepistoevaluatetheanti-seismiceffectthattheroofgardencouldhaveatTMD. The seismic control of the building is evaluated first in the x-direction and then in the y-direction, thanks to the Matlab calculation software.

Specifically, the objectives were:
1. Simulate the seismic response of 2D structural frames first in the x and y directions.
2. Define the mass of the passive TMD to be installed over the existing building to mitigate the seismic response
3. Simulate the seismic response of structural frames before and after the installation of the TMD.

6.1 SEISMIC RESPONSE OF 2D STRUCTURE USING MATLAB

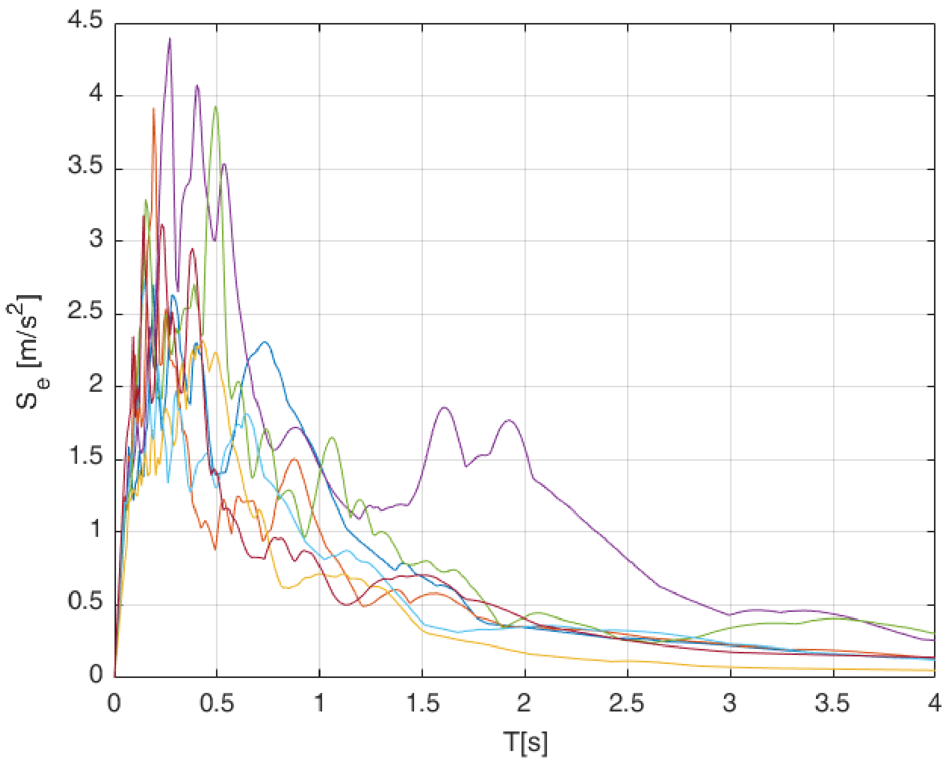
The seismic response to be carried out accurately needs a seismic input or an earthquake. Consequently, the first step was to identify a group of accelerograms compatible with the project site and its sysmic hazard with reference to the standards, in this case NTC2008.

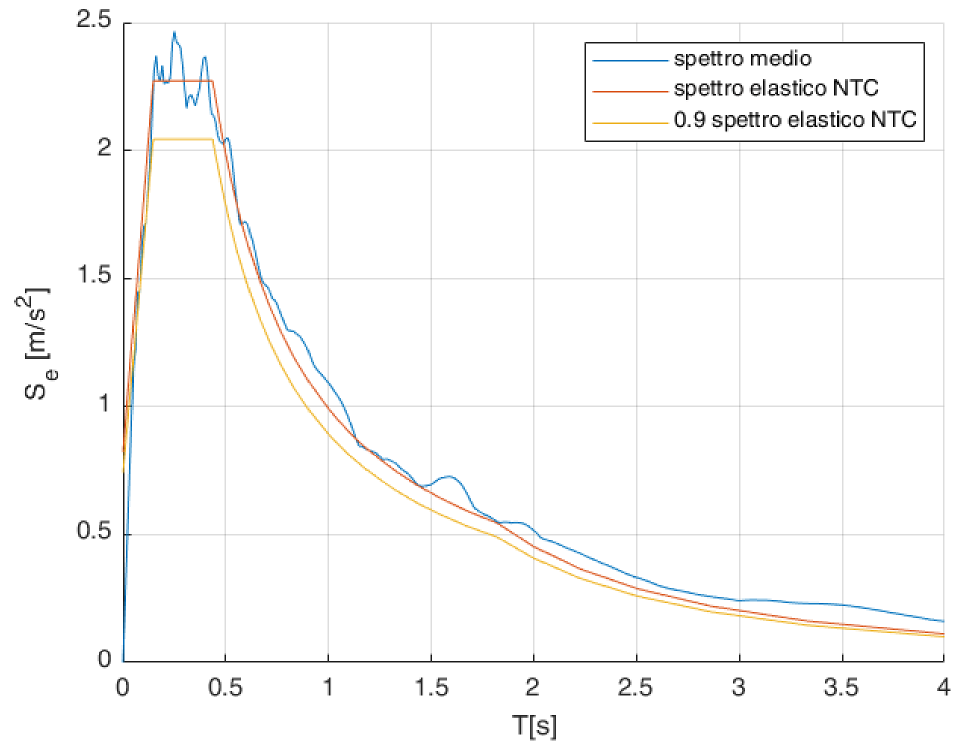
Thanks to the use of the Rexel-Reluis software, 7 spectrum-compatible accelerograms were identified for 7 different seismic activities. The information given to the program has been:
- Lon. [°]: 7.6667
- Lat. [°]: 45.05
- Site class: C
- Top. cat.: T1

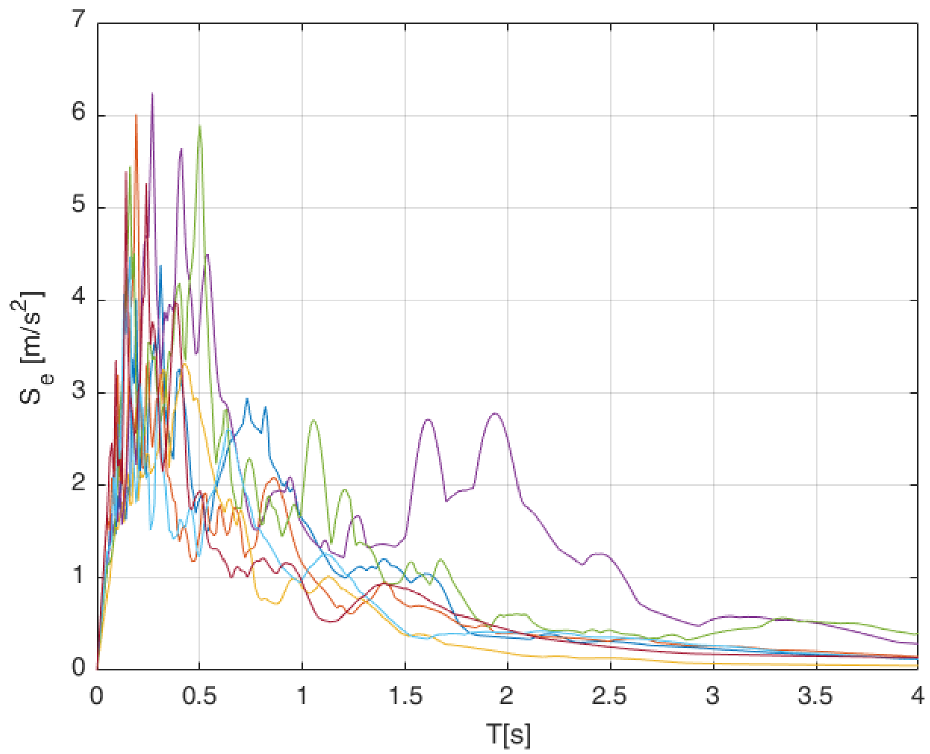
- Vn: 50 years
- CU: II
- SL: SLV

The procedure followed therefore consists in applying the seven seismic data to the chosen structure. The input vector is the vector ui (with i = 1, . . . , 7) which represents the acceleration of the support in m/s_2. The mean peak response will be used to assign the mass of the TMD. It is important to specify the sampling time of the signal of the 7 earthquakes supplied expressed in second. In this case it is equal to 0.01

The graphs of the spectra with a damping ratio of 5% and 2% are reported, so that the differences between the two cases can be compared. It should be noted that the regulatory spectrum cannot be calculated with values of $\zeta < 5\%$, therefore the comparison between the average spectrum (with $\zeta = 2\%$) and the regulatory ones is not significant. As you can see from Figure X, the average spectrum is never less than 90% of the regulatory spectrum, you can never go below this for the average spectrum to be compatible.







After having inserted the earthquakes in the spreadsheet and therefore the impulses that act on the structure, it is necessary to introduce the physical and geometric characteristics of the building that reacts, through the matrices of mass and stiffness. The mass matrix was obtained from the Nolian model and verified by hand calculation. The stiffness matrix has been calculated as the inverse of the flexibility matrix.

$$[K]=\begin{bmatrix} 2.1068e+09 & -1.5552e+09 & 1.1233e+08 \\ -1.5552e+09 & 2.1950e+09 & -7.1745e+08 \\ 1.1233e+08 & -7.1745e+08 & 6.0464e+08 \end{bmatrix}$$

$$[M]=\begin{bmatrix} 2706756 & 0 & 0 \\ 0 & 1714362 & 0 \\ 0 & 0 & 1033200 \end{bmatrix}$$

Once the matrices are defined, it is possible to write down the equation that governs the problem:

$$[M]\{\ddot{u}\}+[c]\{\dot{u}\}+[K]\{u\}=\{F(t)\}$$

In order to determine the eigenvalues ω and the corresponding cars $\{\phi\}$ it is necessary to solve the homogeneity associated with this equation:

$$([K]-\omega^2[M]\{\phi\}=\{0\}$$

At this point it is imposed, in order not to get the trivial equation:

$$det([K]-\omega k^2[M])=0$$

From this equation we obtain the natural pulsations, ω, which represent the eigenvalues of the system. Using the command of Matlab [F, E]=eig (K,M) it is possible to obtain the matrix of the eigenvalues and the matrix of the car headers, respectively [E] and [F].

$$[E]=\begin{bmatrix} 84.22 & 0 & 0 \\ 0 & 595.31 & 0 \\ 0 & 0 & 1964.38 \end{bmatrix}$$

$$[F]=\begin{bmatrix} 3.44e-04 & 3.96e-04 & -3.06e-04 \\ 4.56e-04 & 7.28e-05 & 6.07e-04 \\ 5.57e-04 & -7.39e-04 & -3.30e-04 \end{bmatrix}$$

The normalised eigenvalue matrix is now calculated using the following expression:

$$\{U\}=\{\phi\}/(\sqrt{\{\phi\}T[m]\{\phi\}})$$

The matrix of normalized eigenvectors is as follows:

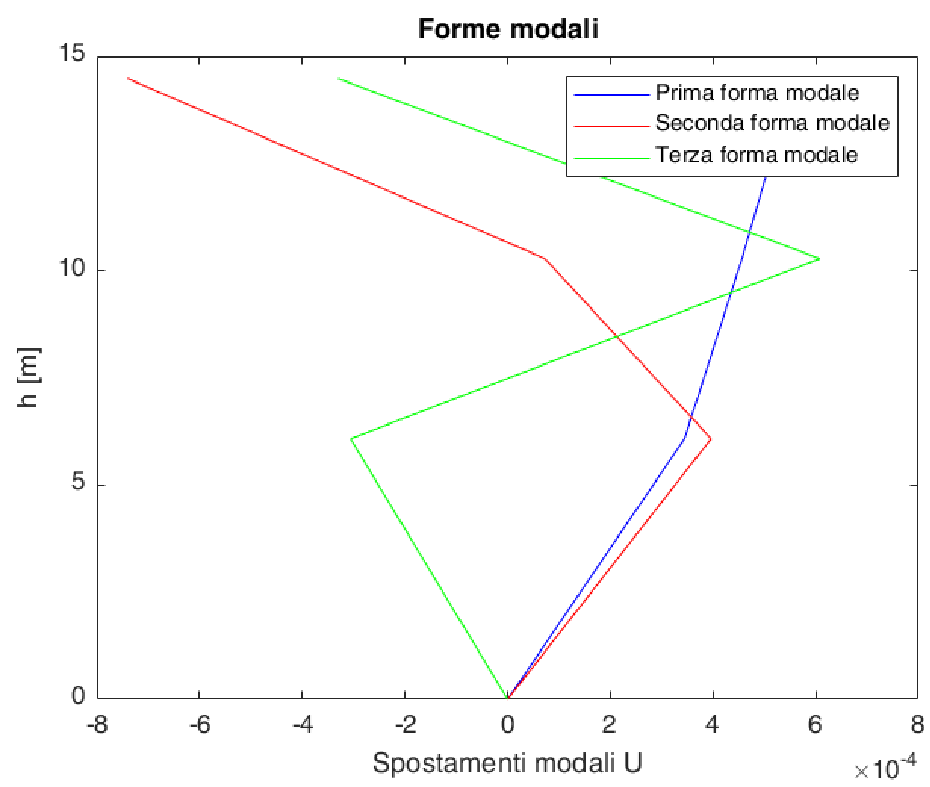
$$[U]=\begin{bmatrix} 34.4e-05 & 39.6e-05 & -30.6e-05 \\ 45.6e-05 & 72.8e-06 & 60.7e-05 \\ 55.7e-05 & -73.9e-05 & -33.0e-05 \end{bmatrix}$$

The frequencies are calculated as the inverse of the period:

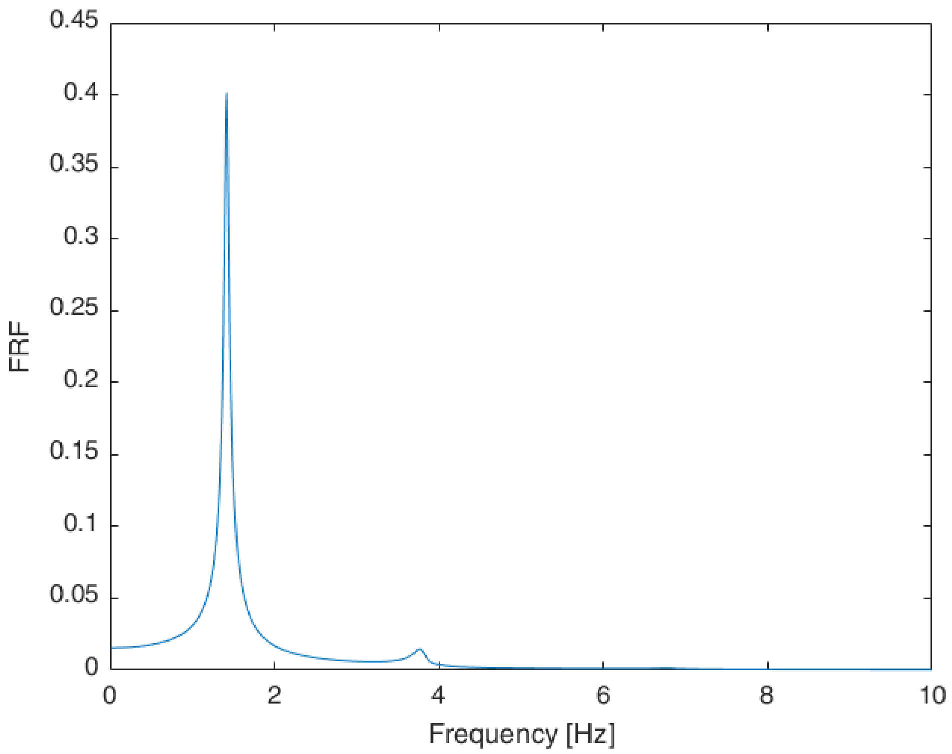
$$T=2\pi/\omega i$$

$$fi=1/T$$

	ω_n [1/s]	f [1/s]	T [s]
Mode 1	9.17	1.46	0.68
Mode 2	24.39	3.88	0.25
Mode 3	44.32	7.05	0.14



The mode shapes obtained from the simulation in Nolian correspond to those obtained in Matlab as well as the T periods correspond. The mode masses show that the building under consideration moves a lot in the initial moments of the earthquake and at the height of the first floor, while it remains rigid on the upper floors. While graph X shows that the first modal form has no reversal, the second has only one reversal and the third modal form has two reversals.



Thanks to the relative mass value with respect to x, equal to 0. 947, it is possible to demonstrate that 95% of the mass is explained by the first way of vibrating. The results obtained show that the first modes are those with the lowest frequency.

At this point the damping matrix [C] is obtained by forcing the diagonalisation, i.e. by placing:

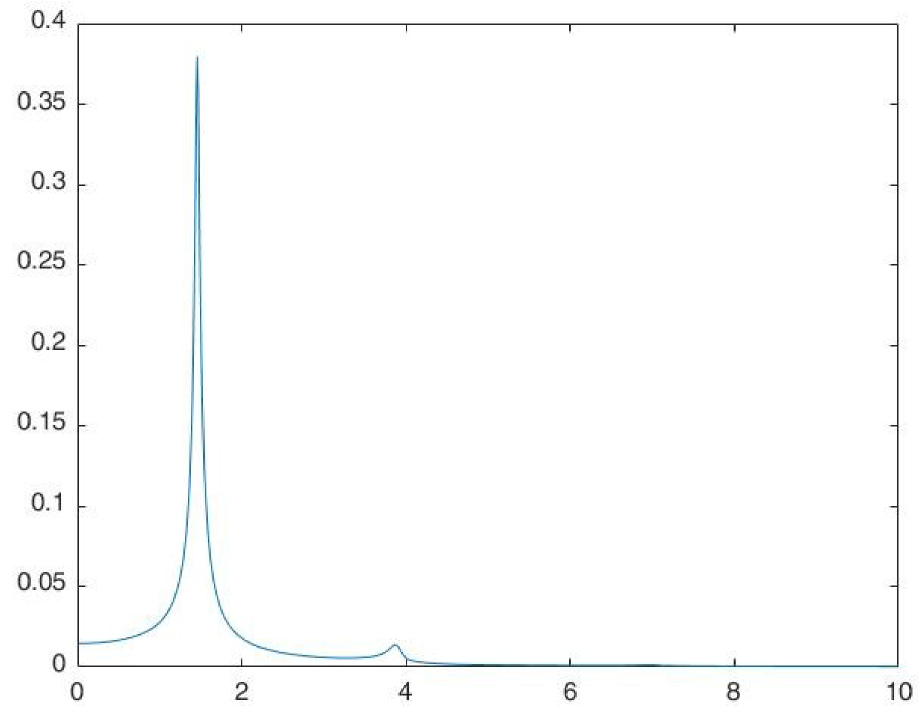
$$[U]^T[c][U] = [2\ \zeta\ \omega\ ]$$

$$[c] = ([U]^T)^{-1}[2\ \zeta\ \omega][U]^{-1}$$

This method assumes that the damping is low, to obtain acceptable results, that all the relative dampings ζk are known and, in the case under consideration, we assume a damping of 2% for each mode of vibration obtaining:

$$[C]= 1.0e{+}6* \begin{bmatrix} 2.6594 & -1.1324 & -0.1020 \\ -1.1324 & 2.1661 & -0.5581 \\ -0.1020 & -0.5581 & 0.8988 \end{bmatrix}$$

After analysing the behaviour of the structure, the FRF (frequency response function) graph can be used to represent the amplification due to the first two modes: the highest peak represents the first mode and the lowest peak the second. This is the function that shows how the acceleration of the ground is transformed into the maximum structural displacement (relative to the ground).

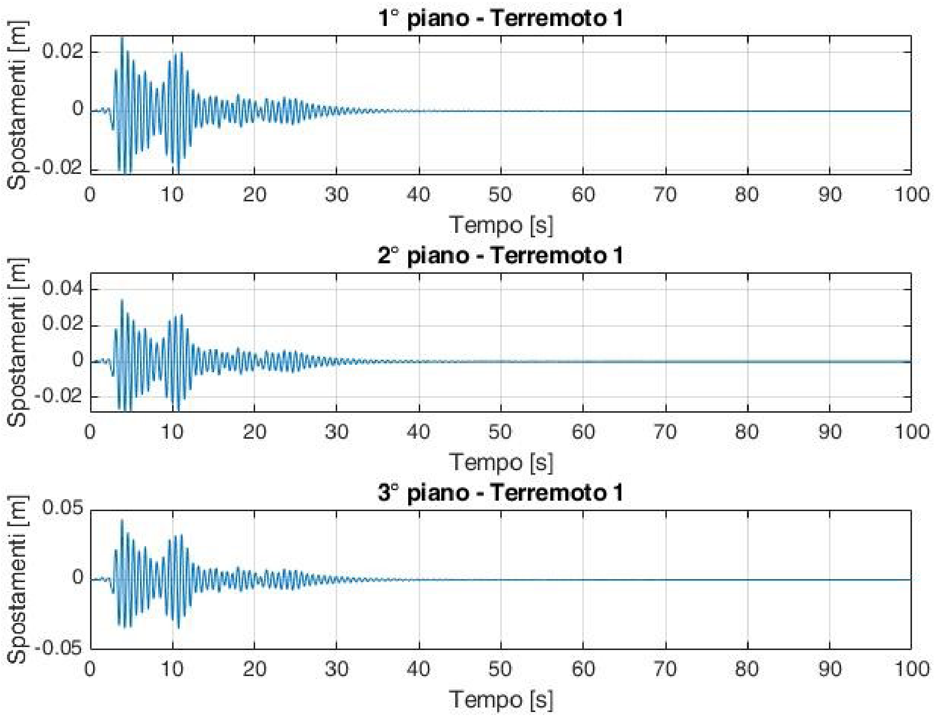


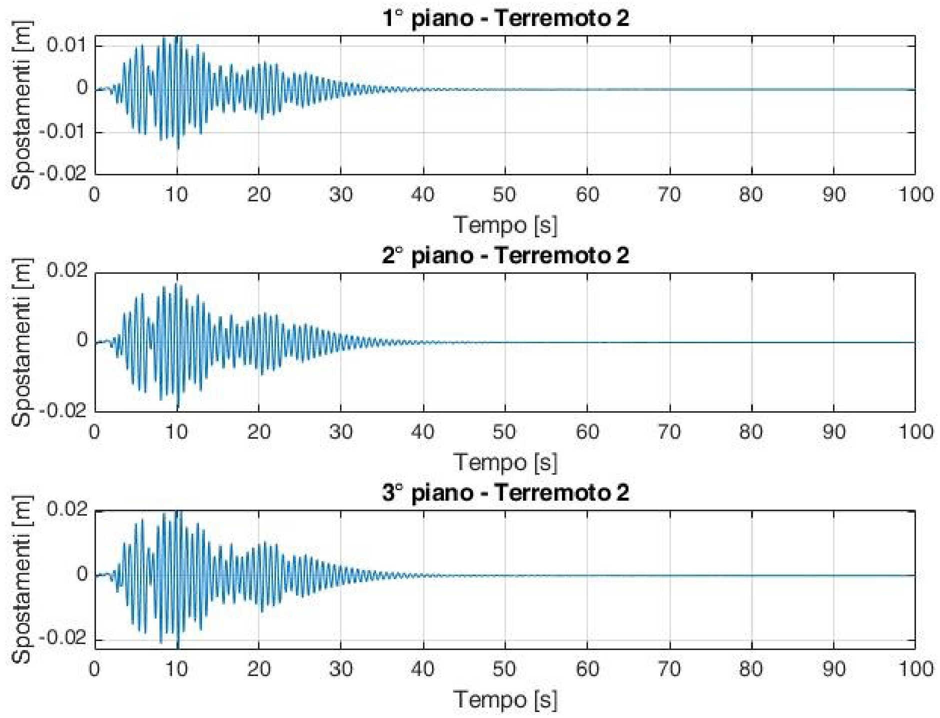
6.2 STRUCTURE STRESS AND DISPLACEMENTS OF THE UNCONTROLLED STRUCTURE

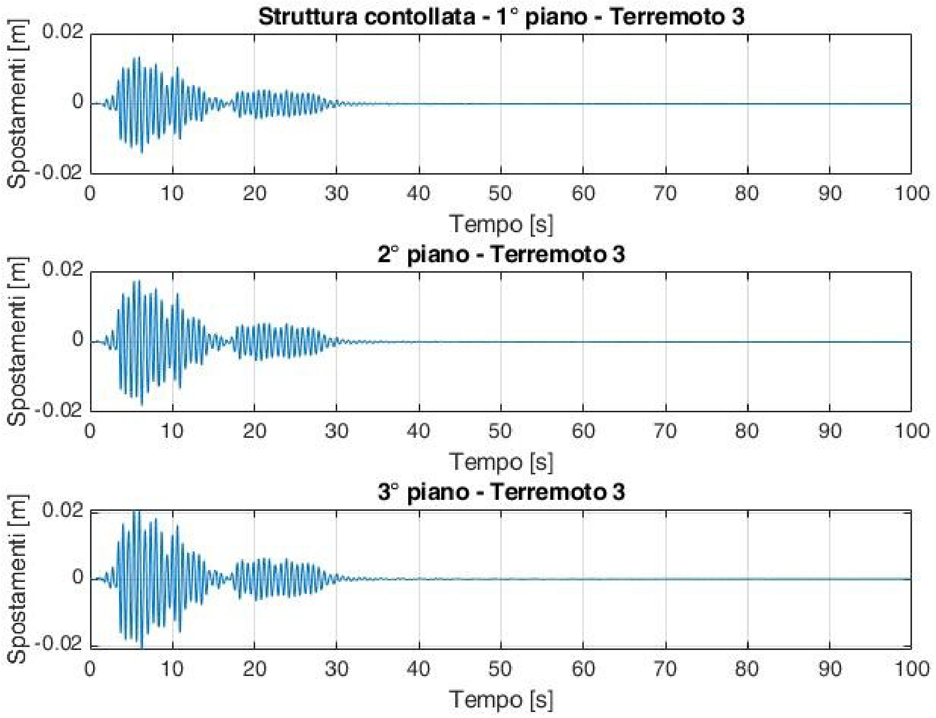
Through the classical time-history analysis and through the spate space analysis it is possible to show the cutting edges at the base and the movements of the

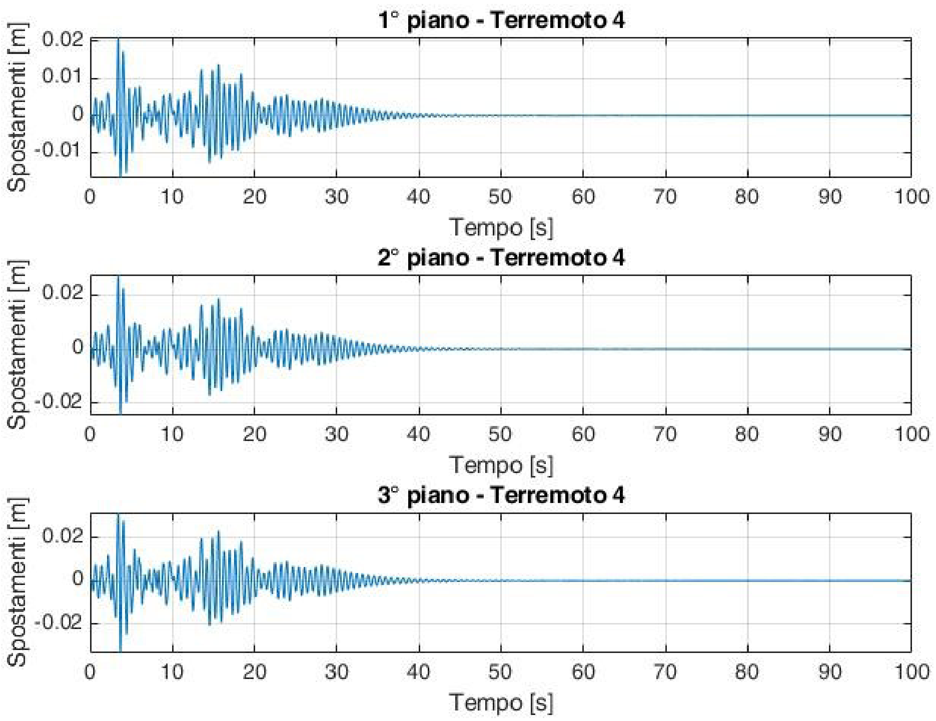
structure, for each earthquake, and see how these vary over time. The earthquake signal is then translated into static forces (shear forces at the base) and displacements.
The maximum displacement and the shear force are then evaluated against the seven accelerograms of the seven earthquakes considered. This type of analysis allows to make a comparison and evaluate how the TMD will dampen the forces and reduce the movements of the building.

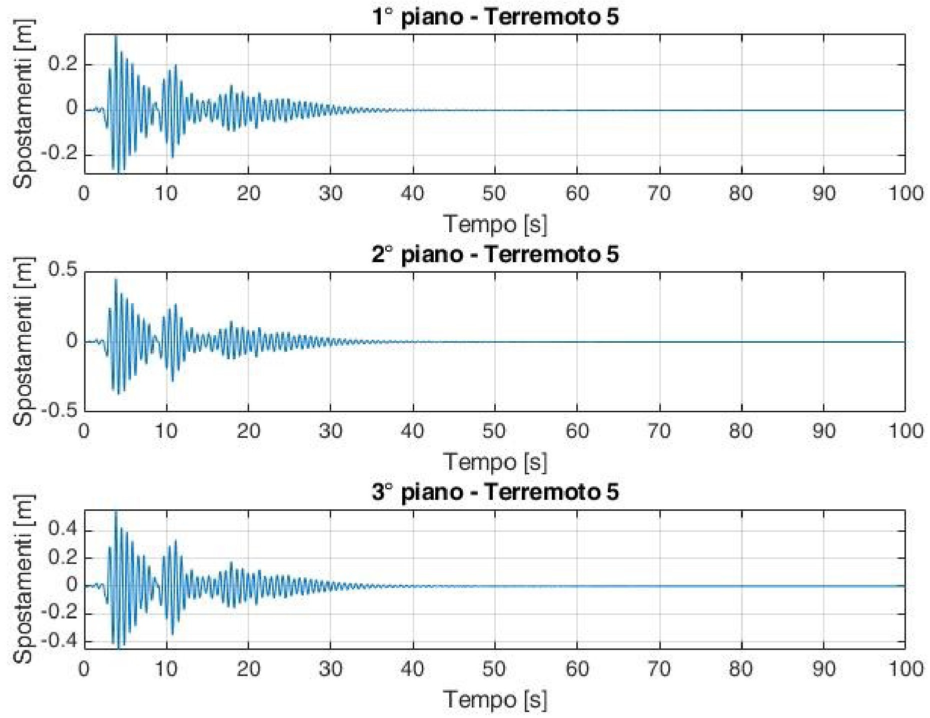
The time-history and state space analyses provide the same results.

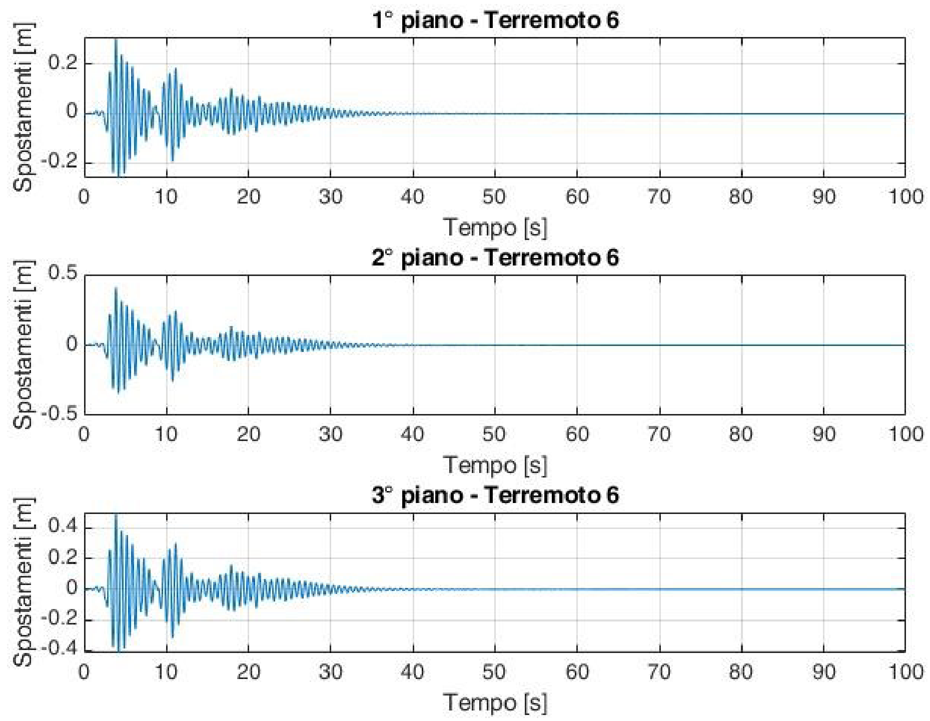


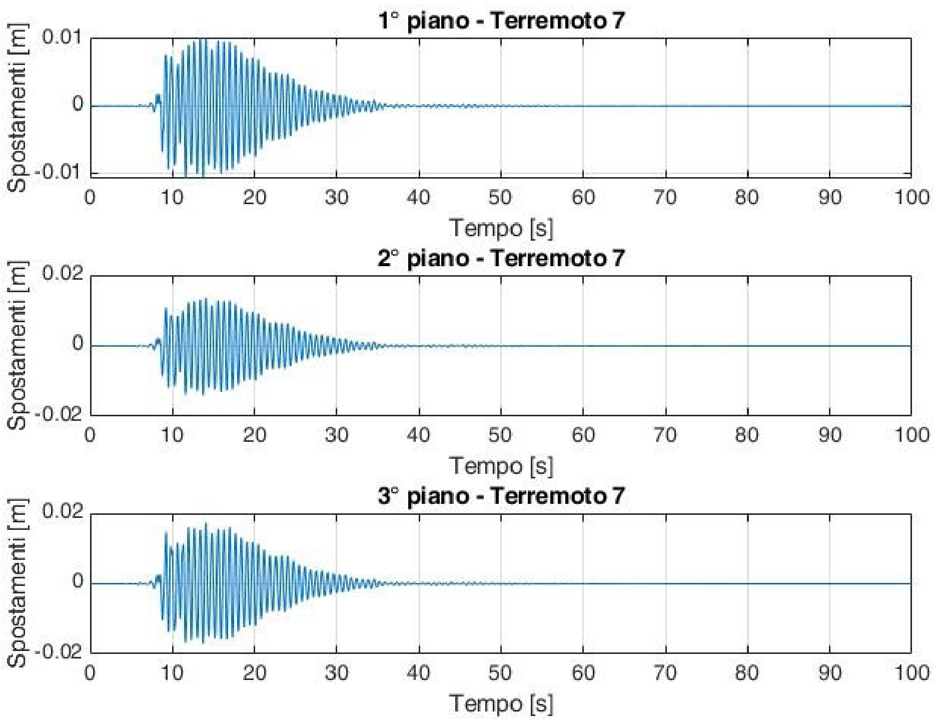



Struttura contollata - 1° piano - Terremoto 3
2° piano - Terremoto 3
3° piano - Terremoto 3
Spostamenti [m]
Tempo [s]


1° piano - Terremoto 4
2° piano - Terremoto 4
3° piano - Terremoto 4
Spostamenti [m]
Tempo [s]


1° piano - Terremoto 5
2° piano - Terremoto 5
3° piano - Terremoto 5
Spostamenti [m]
Tempo [s]

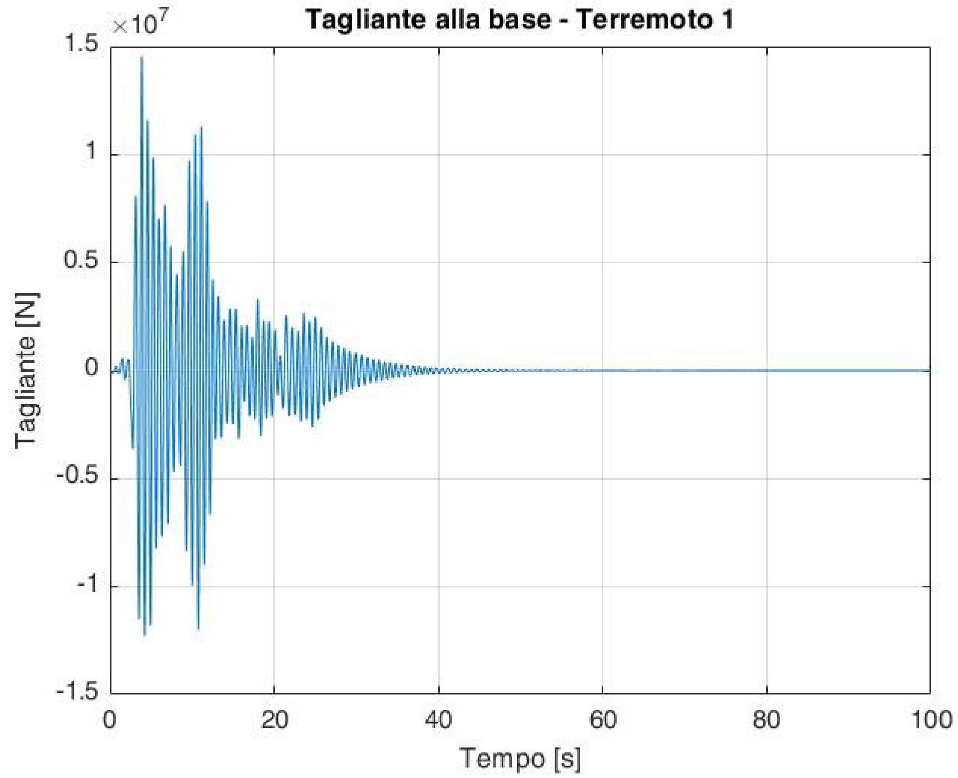

1° piano - Terremoto 6
2° piano - Terremoto 6
3° piano - Terremoto 6
Spostamenti [m]
Tempo [s]

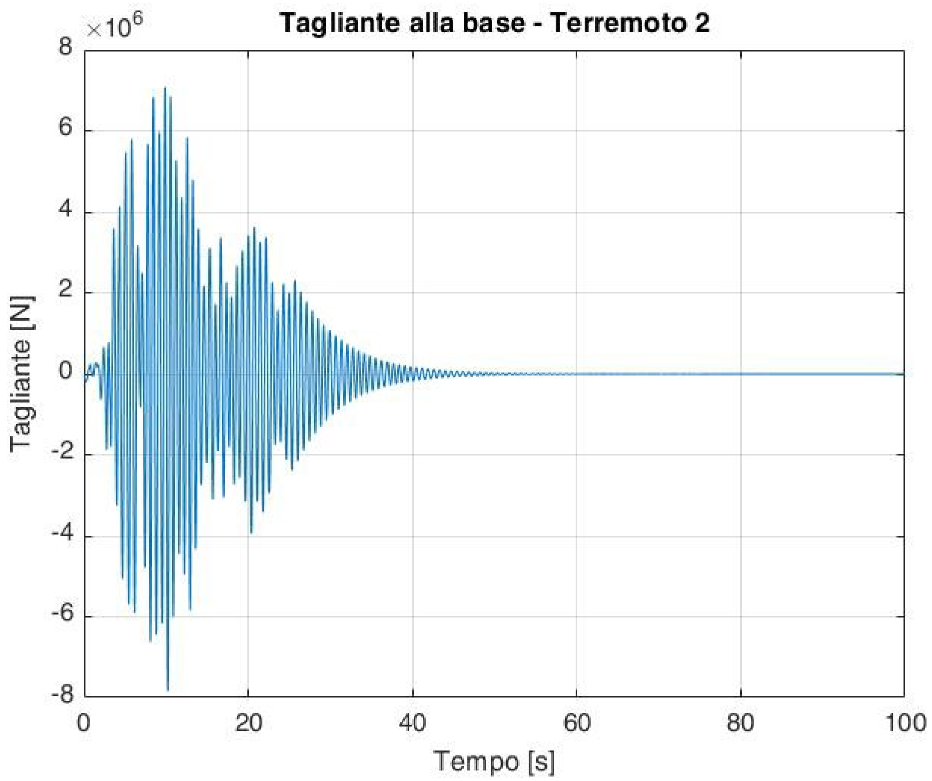


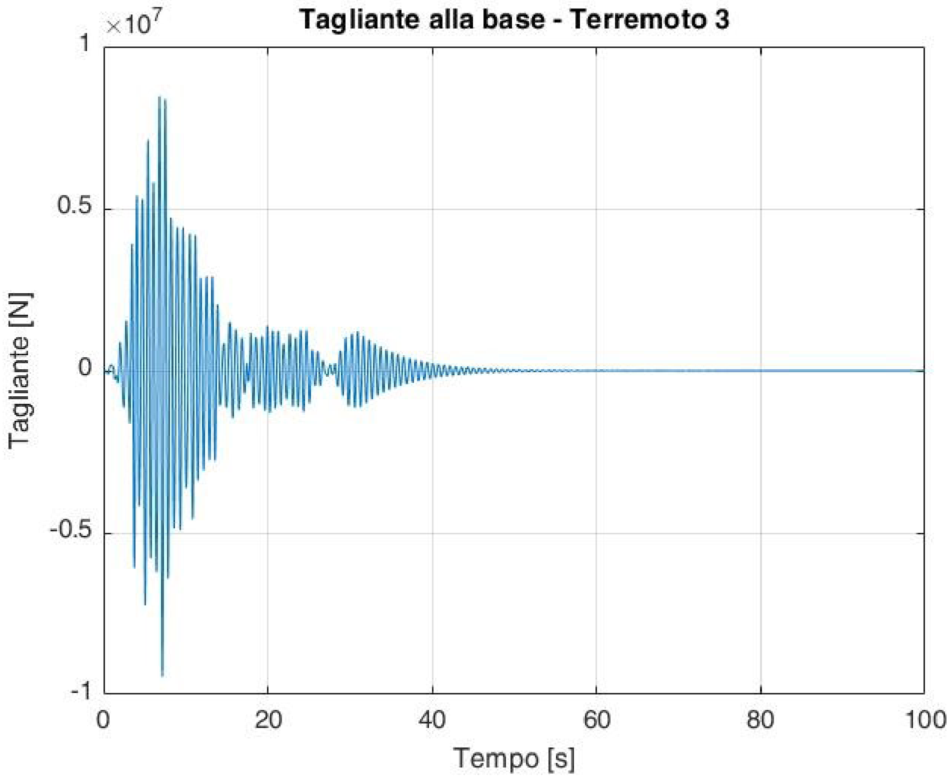
From the graphs you can see that the movements are growing for the higher floors. By enveloping earthquakes, we can see that the maximum displacements for each floor are:

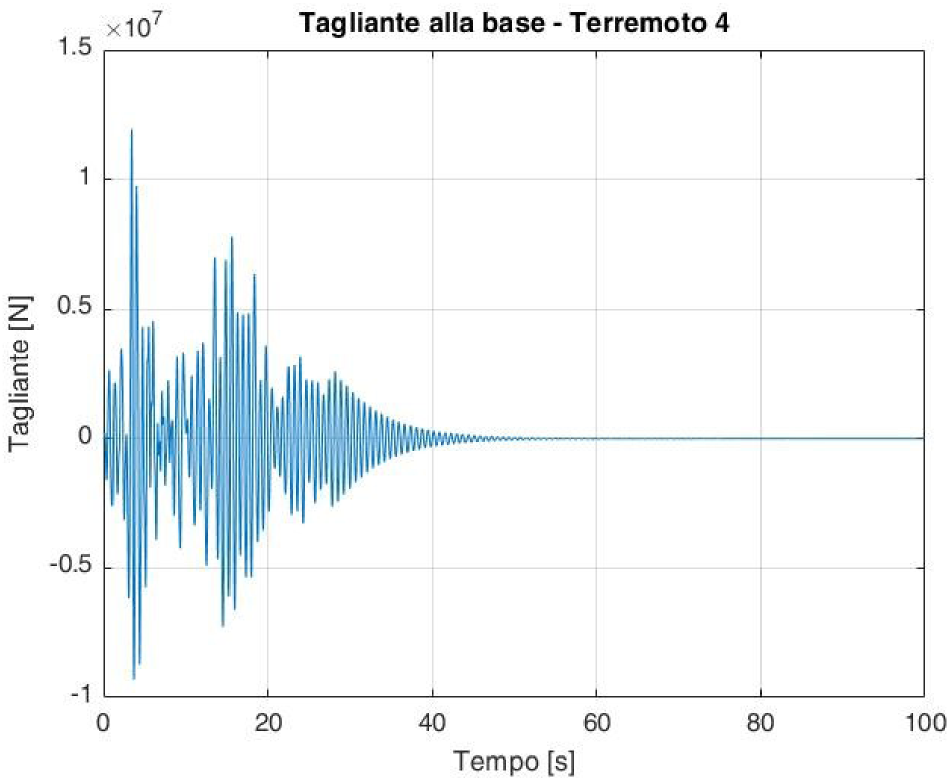
	Spostamenti [m]
Piano 1	0.0182
Piano 2	0.0240
Piano 3	0.0296

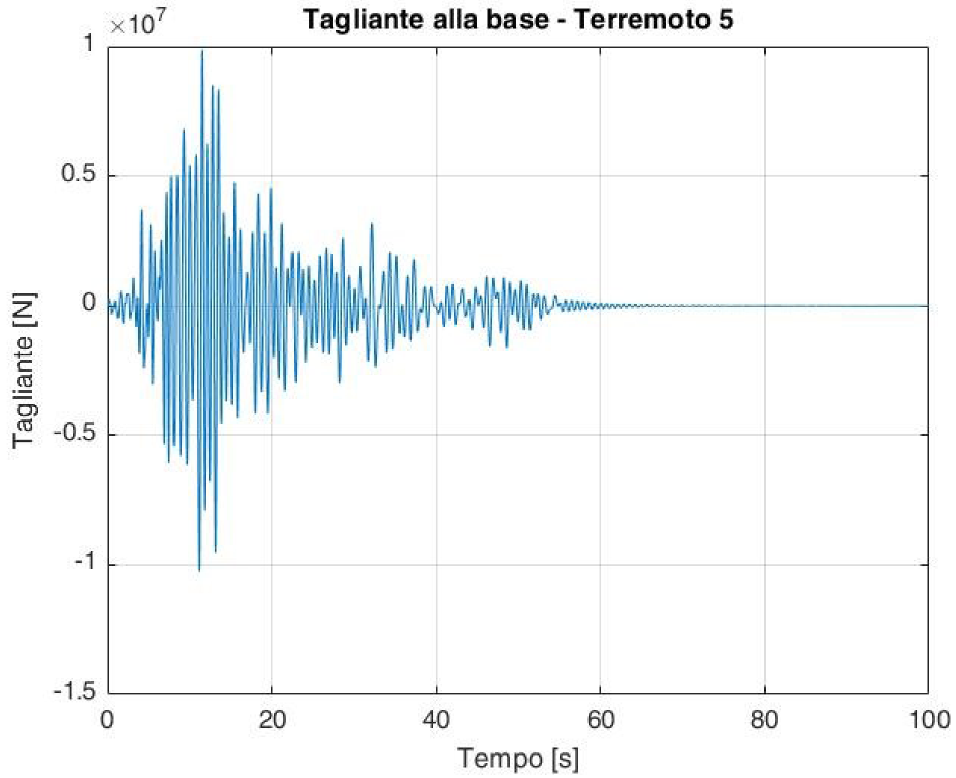
Through a time history you can reconstruct the trend of the cutting edge at the base for each hearthquake.

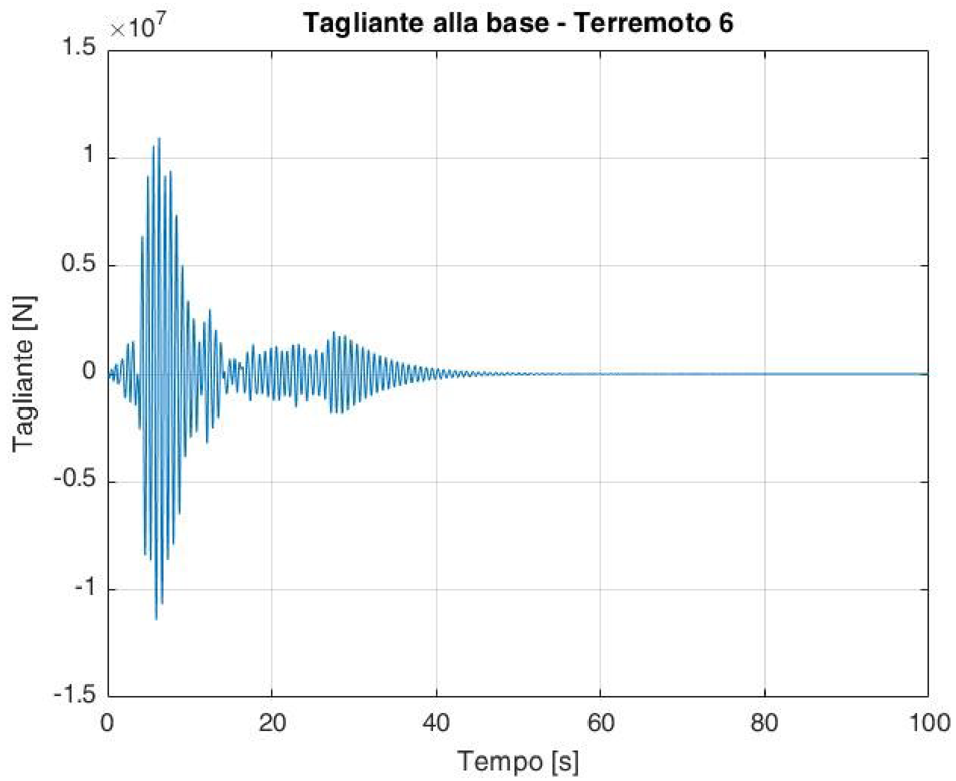


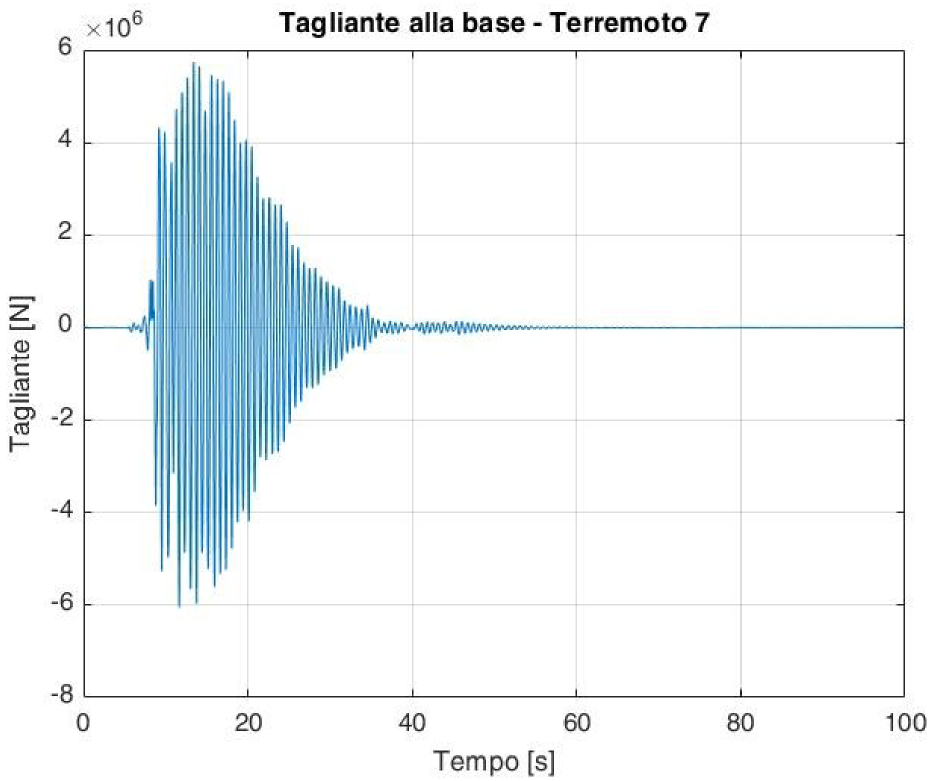



Tagliante alla base - Terremoto 3
×10^7
1
0.5
0
-0.5
-1
Tagliante [N]
0
20
40
60
80
100
Tempo [s]


Tagliante alla base - Terremoto 4
×10^7
1.5
1
0.5
0
-0.5
-1
Tagliante [N]
0
20
40
60
80
100
Tempo [s]


Tagliante alla base - Terremoto 5
×10^7
1
0.5
0
-0.5
-1
-1.5
Tagliante [N]
0
20
40
60
80
100
Tempo [s]


Tagliante alla base - Terremoto 6
×10^7
1.5
1
0.5
0
-0.5
-1
-1.5
Tagliante [N]
0
20
40
60
80
100
Tempo [s]



At this point the equivalent static forces of each plane are calculated:

$$\begin{Bmatrix} f_1(t) \\ f_2(t) \\ f_3(t) \end{Bmatrix} = [K] \begin{Bmatrix} u_1(t) \\ u_2(t) \\ u_3(t) \end{Bmatrix}$$

The sum of the three forces returns the shear force to the base of the structure:

$$V_b(t)=f_1(t)+f_2(t)+f_3(t)$$

The value obtained is of 10209 kN.

6.3 THE EFFICIENCY OF THE TMD: WICH MASS TO APPLY?

This phase is of crucial importance consists in entering the parameters of the TMD and evaluating how the behavior of the structure changes. Specifically, it is possible to evaluate how the displacement and cutting values change from the uncontrolled to the controlled structure. It is then possible to evaluate the damping values of the entire anti-seismic system, its rigidity thanks to which the right isolators will be chosen.

The choice of the mass is strongly conditioned by the type of architectural project to be carried out, by the choice of the technological package of the attic, but it depends above all on the structural capacity of the building that I must be able to support even the considerable masses.
Several simulations are therefore carried out to observe the behaviour and efficiency of the TMD in relation to its total mass ratio (e. g. : 10%, 20%, 30%, 40%. . .).

The following parameters have been calculated several times and related to different mass ratios from 0% to 100% to observe how the system efficiency varies:
- Total mass ratio, ratio between the mass of the roof garden and the mass of the existing frame:

$$\mu = MTMD/M\text{telaio}$$

- The optimal frequency ratio results from the formula of (Warburton, 1982):

$$f_{opt} = \frac{\sqrt{1-\mu/2}}{1+\mu}$$

- The optimal damping (Warburton, 1982):

$$\zeta_{opt} = \sqrt{\frac{3\mu}{8(1+\mu)(1-\frac{\mu}{2})}}$$

- The stiffness of TMD:

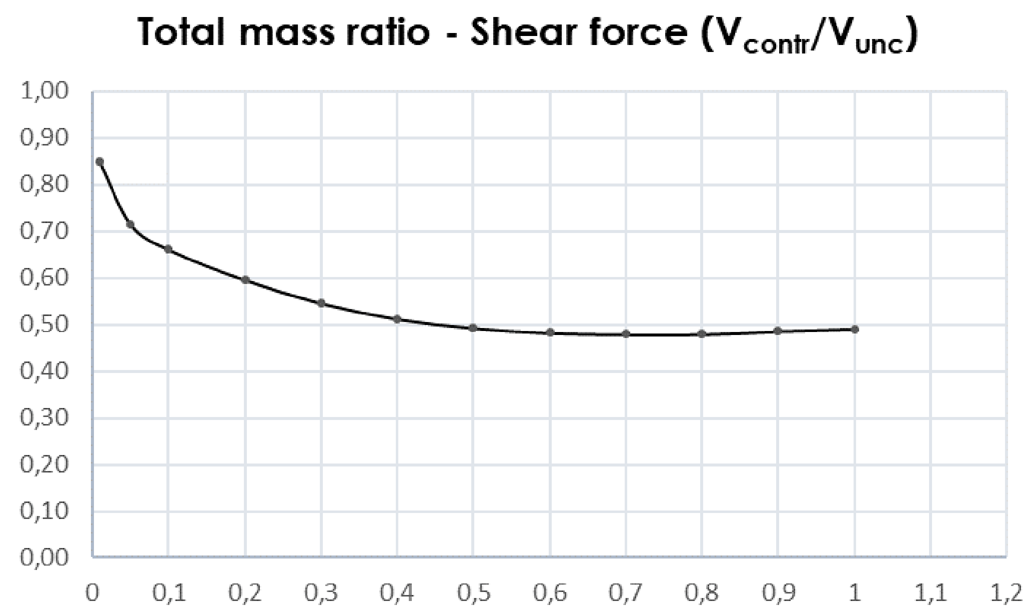
$$ktmd$$

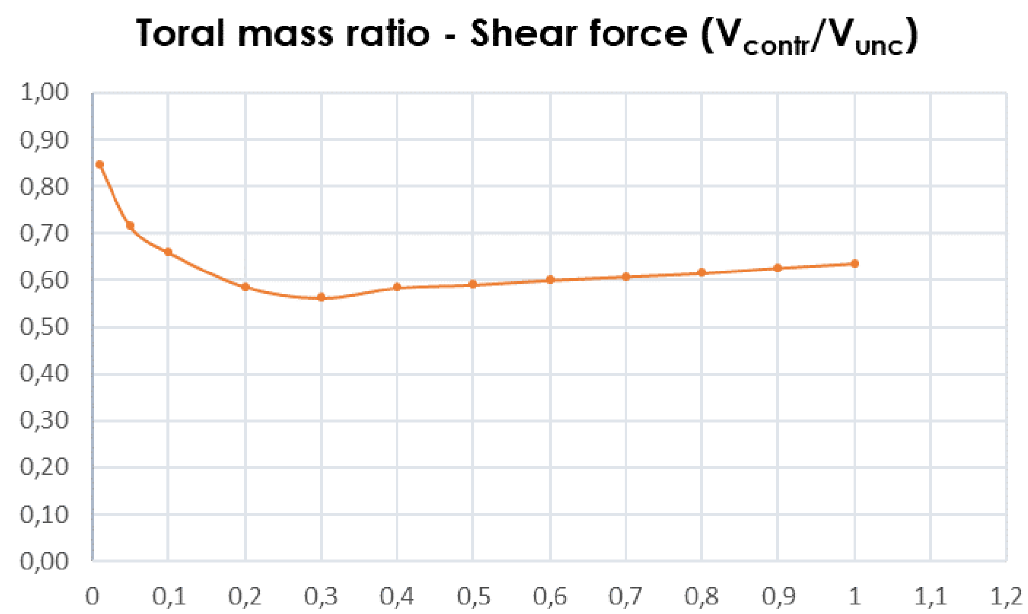
- The damping coefficient

$$Ctmd$$

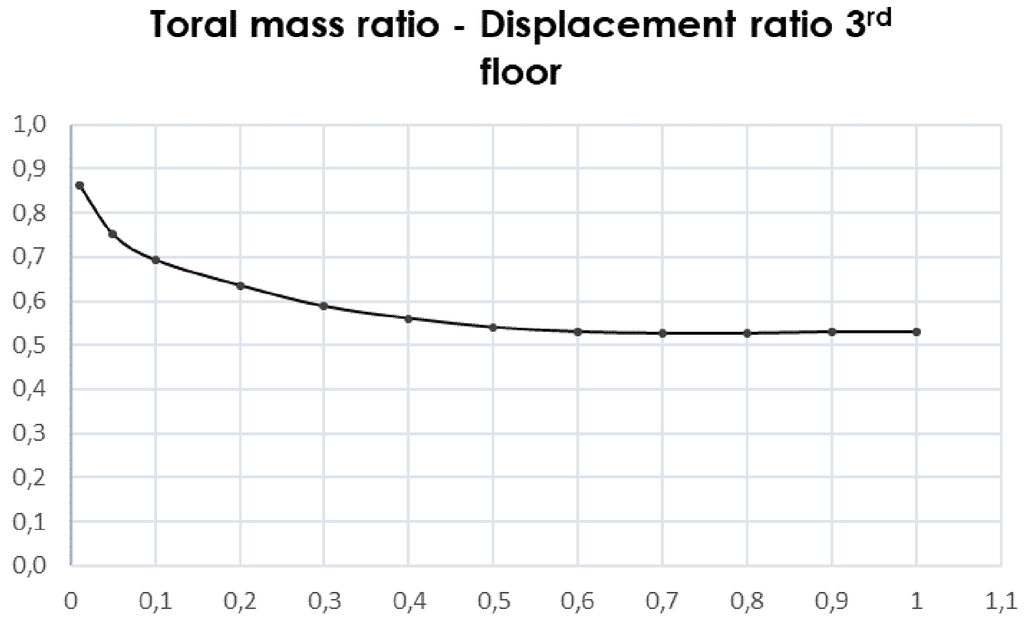
However, two approaches were followed to carry out this analysis:
- the first approach is to use the optimal damping from the Warburton formula seen above.
- the second approach ("ottimiazzazione vincolata") is useful in choosing the isolators on which to place the roof garden. It is assumed that the damping can not be higher than 20%, so for mass ratios with which □_opt is higher than this threshold the value is imposed equal to 0. 2. This is because most of the isolators on the market (HDRB) are able to develop at most a 20% damping. Once this value has been exceeded, the isolators work as if they were constraints, compromising the operation of the TMD.

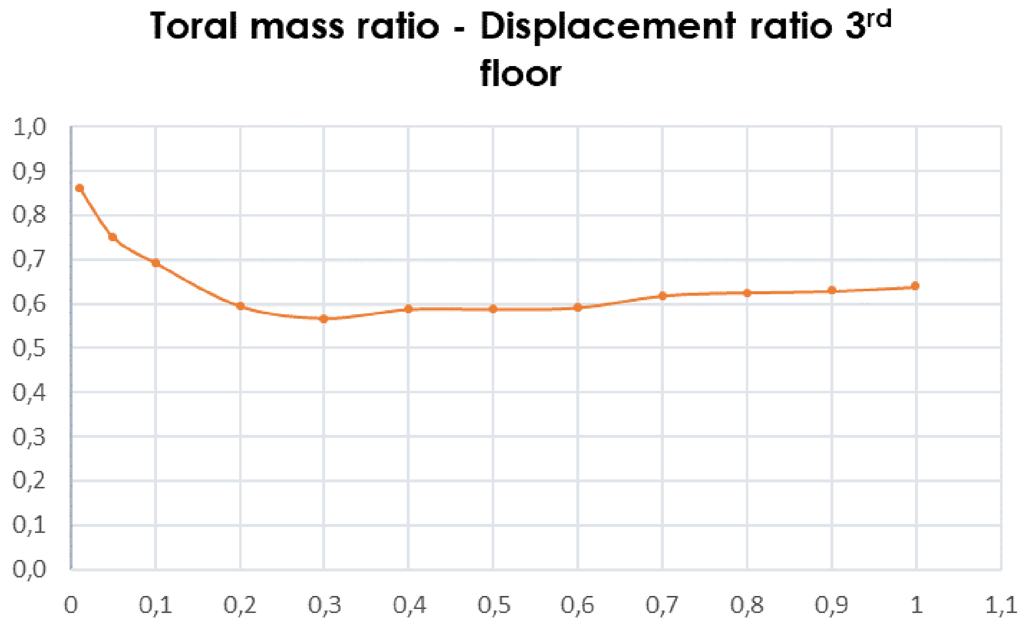
For each attempt made, therefore for each total mass ratio, it was necessary to observe the graph of the frequency response function and verify the optimal frequency of Warburton. The frequency response function for the controlled structure has a different form than the FRF of the uncontrolled structure; in fact, if the structure is controlled, the function is characterized by two peaks placed at the same level and not by just one, as in the other case. The FRF of the controlled structure is determined manually until the two peaks reach the same level.
The following is a comparison of the results obtained by the two approaches (over optimal damping and under constrained optimization).
Through the graph that relates the total mass ratio to the cutting ratio at the base, it is possible to notice that using only insulators capable of developing small dampings, the system would stop being efficient already around the total mass ratio value of 30%.



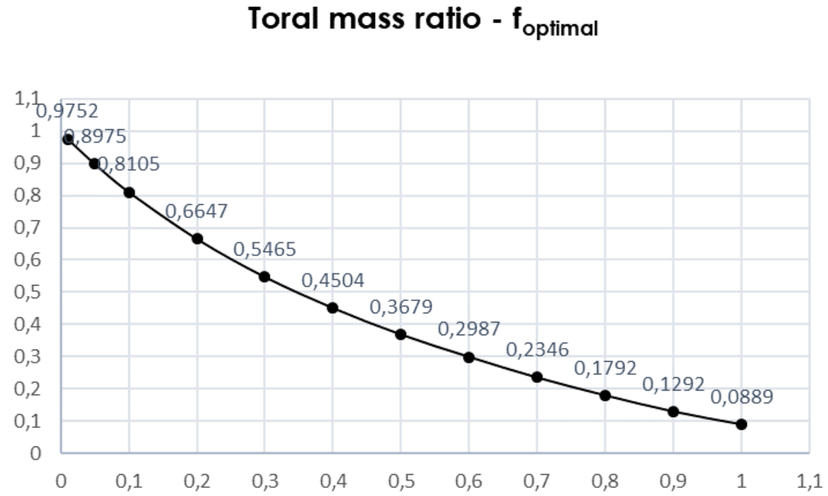


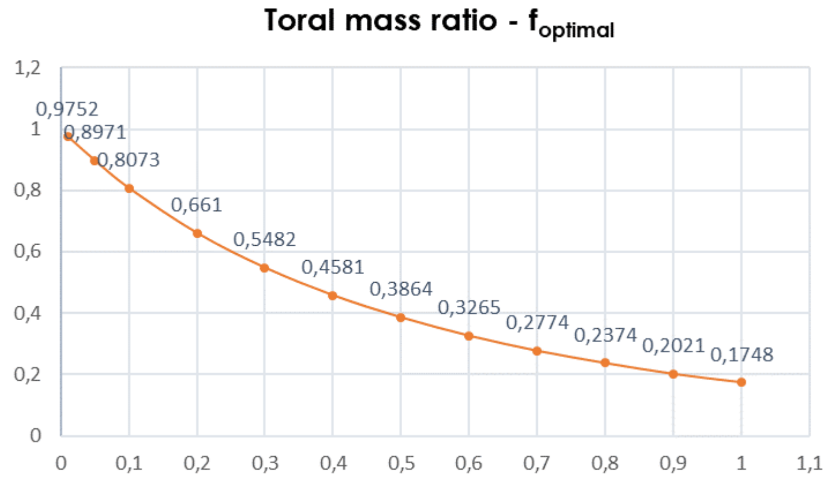
The antismic system is efficient for small mass ratios, little by little it becomes less efficient and for large mass ratios it starts to be even worse.





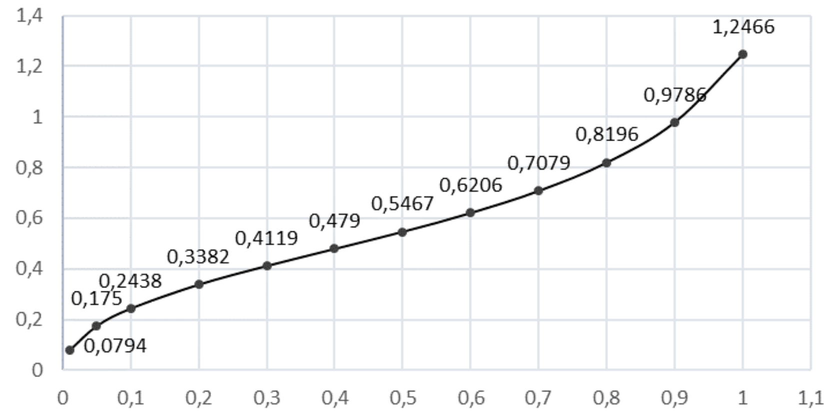
Optimum frequency values decrease as mass ratios increase as shown in the graphs below.



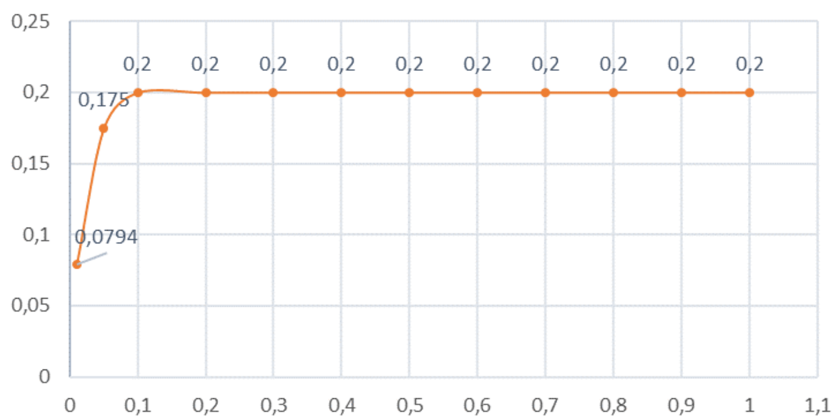


The graph linking the total mass ratio to the optimal damping shows that as the mass of the TMD increases, more and more damping is needed from the isolators, which is difficult to achieve thanks to those on the market.
The graph drawn up with the second approach shows that already from the total mass ratio of 10% the damping is higher than 0.2. Following this graph the choice of the mass to be applied could stop, setting the maximum threshold $\mu =$ 10%. One way to make a heavier garden roof feasible is to use additional isolators (hydraulic pistons) to compensate for this negativity and develop a greater damping, suitable for the project that provides a mass ratio ranging from 50 % to 70%.

Toral mass ratio - $\zeta_{optimal}$

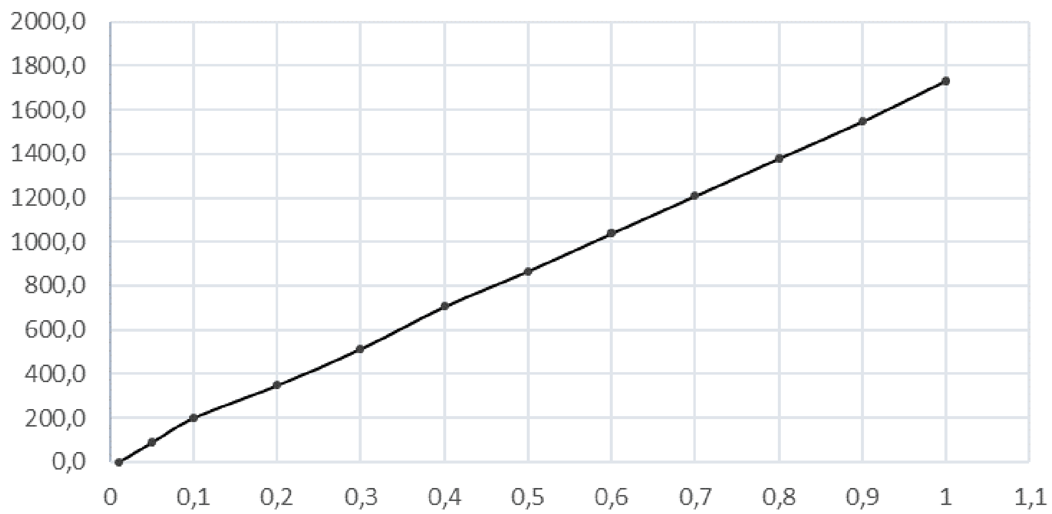


Toral mass ratio - ζ=0,2



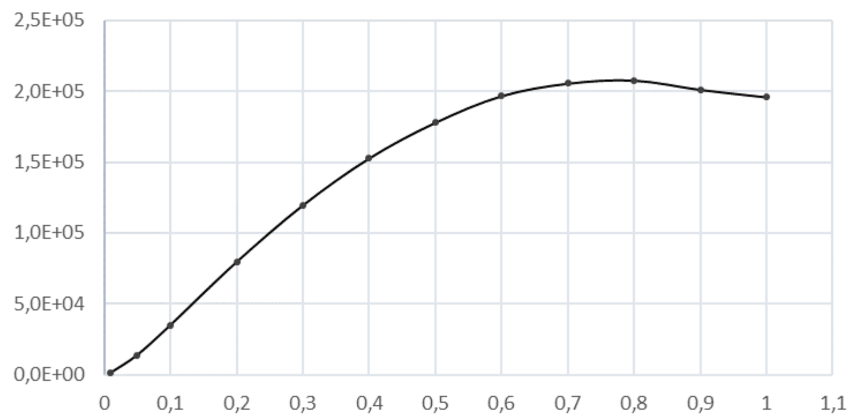
As the mass ratio increases, it goes without saying that the normal stress acting on the individual isolator also increases. To calculate the normal stress acting on the isolator, several "packages" (stratigraphies of garden roofs) with mass ratios ranging from 0. 1% to 100% were designed. Each stratigraphy returned a corresponding Nsd. To this is due the direct proportionality between Nsd and Mass Ratio, with consequent right trend, as shown in the graph below. Once the number of insulators generally positioned at the pillars of the structure has been chosen, it is possible to calculate the stiffness and damping of the individual insulator.

Toral mass ratio - N_{sd} on isolator

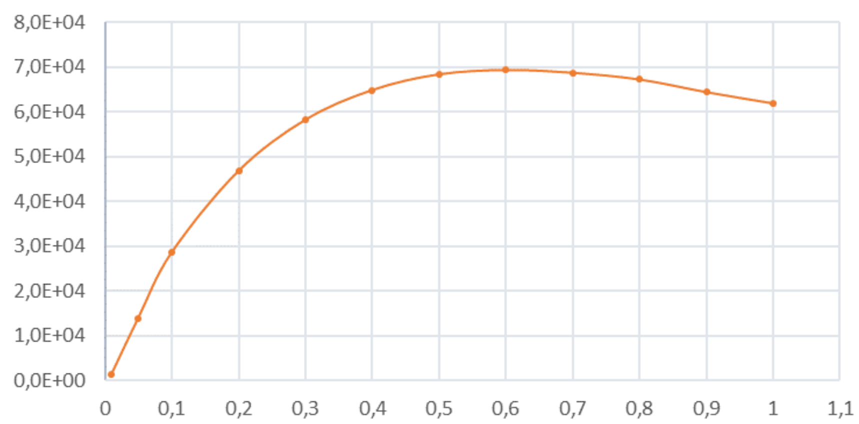


It is also possible to relate these to the total mass ratio to observe the efficiency of the isolators and their response.
The damping effect of the individual isolator increases by up to 80% in the first approach and up to 60% in the second approach, before decreasing.

Toral mass ratio - Isolator Damping

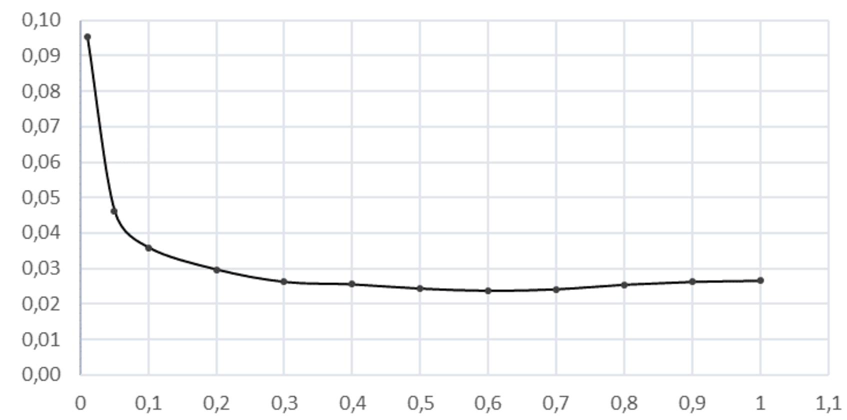


Toral mass ratio - Isolator Damping

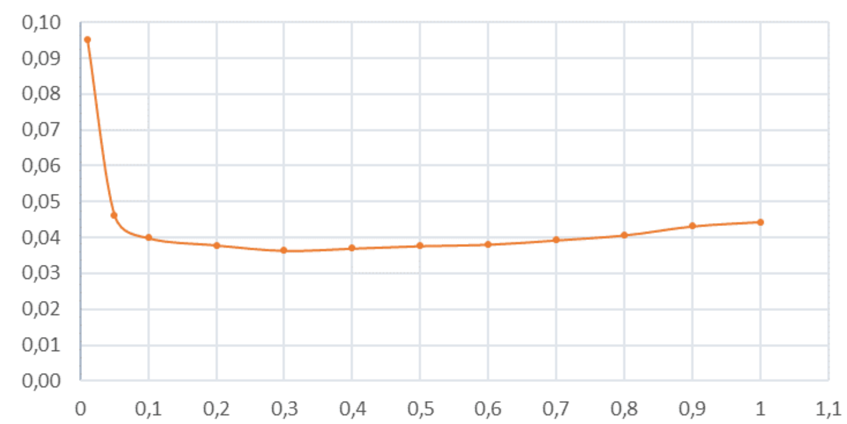


The graphs below that relate the total mass ratio and the displacement of the roof garden relative to the top of the building show that for very small mass ratios the displacements are large, but decrease dramatically already applying on the roof a mass equal to 10% of the total mass. Displacements are reduced by up to 60% using optimal damping. Using a damping $\zeta = 0.2$ instead there is a change of trend already for ratios equal to 30%, it means that the relative shifts at the top increase already exceeded this threshold. Using only HDRB insulators would not be convenient to design a very heavy garden roof.

Toral mass ratio - Displacement TMD



Toral mass ratio - Displacement TMD



After verifying the effectiveness of the TMD when the mass varies, it was concluded that in order to add a large mass of soil, between 50% and 70% of the entire building, it is not possible to place the garden roof only on HDRB insulators. These isolators have the advantage of working in all directions and can have very small dimensions, but as already mentioned they develop a damping of only 0.2 (https://www.fipindustriale.it/index.php?area=106&menu=67&page=167).

For a chosen mass ratio of 60%, a damping would be needed:

$$c_{TMD} = 2^{*}\,\zeta_{TMD}{}^{*}\omega_{TMD}{}^{*}massa_{TMD} = 1.14E+07$$

But using HDRB isolators you can only have:

$$c_{TMD,is} = 2^{*}0.2^{*}\omega_{TMD}{}^{*}massa_{TMD} = 4.02E+06$$

This damping is developed through the use of 58 elastomeric insulators placed at almost all pillars.
Elastomeric insulators work as if they were springs because of their construction. They are small cylinders made up of alternating layers of elastomer and steel, they are vertically rigid and horizontally flexible. These characteristics make it possible to react well to vertical forces and to increase the period of oscillation.

Elastomeric isolator model. https://www.fipindustriale.it/public/S02_SI-ita.pdf

The isolators chosen are the SI-S 300/52 elastomeric insulators.

SI-S	V kN	F_{zd} kN	K_e kN/mm	K_v kN/mm	D_g mm	t_e mm	h mm	H mm	Z mm	W kg
SI-S 300/52	490	1860	0.54	584	300	52	116	166	350	84
SI-S 350/50	700	3010	0.77	779	350	50	108	158	400	109
SI-S 400/50	1150	4680	1.01	1246	400	50	108	158	450	140
SI-S 450/54	1540	5770	1.18	1369	450	54	118	168	500	183
SI-S 500/54	2230	8050	1.45	1962	500	54	118	168	550	224
SI-S 550/56	2720	9310	1.70	2153	550	56	117	167	600	265
SI-S 600/56	3200	10310	2.02	2438	600	56	114	164	650	307
SI-S 650/54	3650	10830	2.46	2848	650	54	109	159	700	351
SI-S 700/60	4460	11370	2.57	2871	700	60	125	185	750	481
SI-S 800/60	6930	14990	3.35	4519	800	60	125	185	850	624
SI-S 900/60	8480	21220	4.24	5317	900	60	126	186	950	790
SI-S 1000/70	10940	22590	4.49	5316	1000	70	146	226	1050	1214
SI-S 1100/70	14840	27460	5.43	7324	1100	70	146	226	1150	1463
SI-S 1200/80	17990	28700	5.66	7224	1200	80	156	236	1250	1750

Legenda

V	Carico verticale massimo agente sull'isolatore in presenza di sisma corrispondente allo SLC
F_{zd}	Carico verticale massimo agente sull'isolatore in assenza di sisma (SLU), concomitante con rotazione 0 e spostamento orizzontale 10 mm
K_e	Rigidezza orizzontale equivalente
K_v	Rigidezza verticale
D_g	Diametro elastomero
t_e	Spessore totale gomma
h	Altezza escluse piastre di ancoraggio
H	Altezza totale incluse piastre di ancoraggio
Z	Lato piastre di ancoraggio
W	Peso isolatore escluse zanche

https://www.fipindustriale.it/public/S02_SI-ita.pdf

The Fzd force acting on the single insulator that sizes the isolator is equal to 1038 kN. The chosen isolator is designed to support 100 mm displacements accordingly, it is assumed to be largely sufficient to withstand the displacements of the designed TMD which should not exceed 38 mm.
The difference ΔcTMD = 9. 24E+05 is the damping part that should be compensated for differently. It was decided to distribute this quantity over 8 viscous isolators (pistons), 4 in the x direction and 4 in the y direction. With an average input speed of 0. 13 m/s and a delta_c_tmd of 7. 39E+06, spread over 4 pistons in each direction, a force of 296 kN was obtained. The viscous isolators chosen corresponds to the type MC 500/200 of the productor "Somma International".

6.4 VERIFICATION OF THE EXISTING PILLARS AT THE SLV

The choice of such a large mass of land was also possible thanks to the supporting structure of the building, which being of an industrial nature was designed to support large loads. This was verified by the verification of the pillars at the SLV which have a section of 66x66 cm2 for the first two floors above ground and become 50x50 cm2 at the top floor.

	g1 [kN/mq]	g2 [kN/mq]	Q [kN/mq]	Tot [kN/mq]
Level 1	2.81095	5.345	3	11.15595
Level 2	1.932041	5.345	3	10.27704
Level 3	1.4154	3.345	-	4.7604
Level TMD	6.158391			

After carrying out the analysis of loads related to the areas of competence acting on the pillars, the verification was carried out by comparing the stress acting with the resistant one.
Only the cross-section and height of the pillars are known, but not the amount of iron and the characteristics of the materials that were chosen. For this reason it was decided to assume poor characteristics and be sure that those pillars held the added weight in any case.
Normal stress resistant:

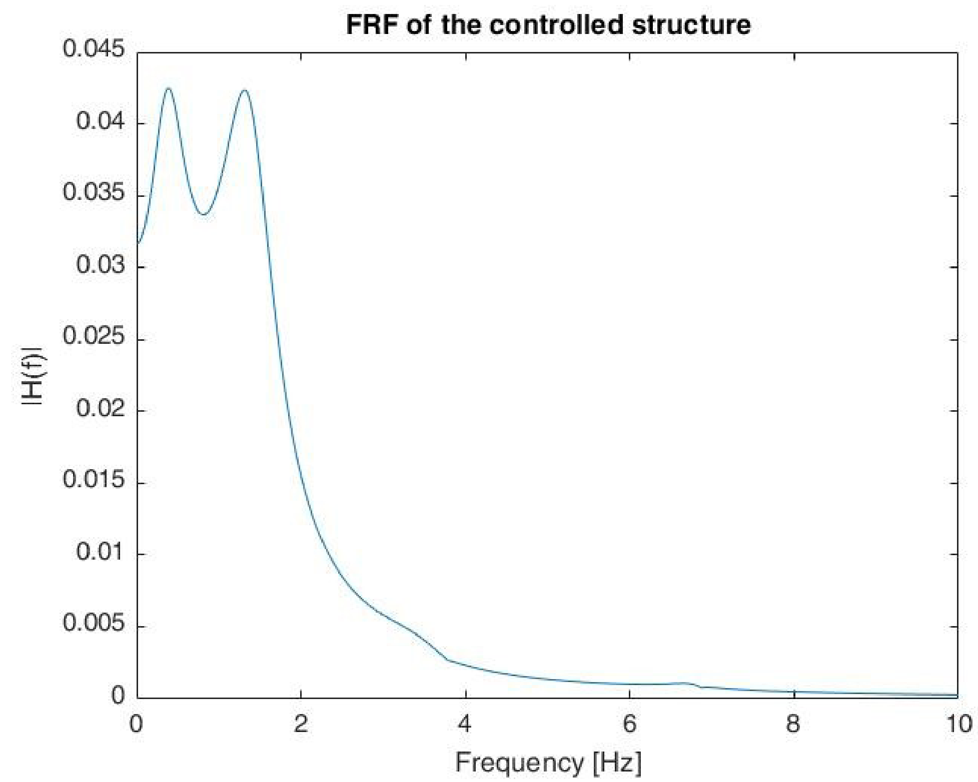
$$Nrd = fcd\left(Ac + \frac{fyd}{fck}As\right)$$

calculated with:
- amount of reinforcement As = 0.03 Ac
- concrete resistance Rck = 20 Mpa (calcestruzzio C16/20)
- steel fyk = 315 Mpa

has, however, led to positive verifications as follows:

	Nsd [kN]	Nrd [kN]
Column 1	2953.555	5979.922
Column 2	2117.435	5979.922
Column 3	1331.588	3432.003

6.4 VERIFICATION OF THE EXISTING PILLARS AT THE SLV



Following the previous analysis, the mass ratio of 60% was chosen and, thanks to the combination of elastomeric isolators and hydraulic pistons, the optimal damping of 60% was chosen:

$$\zeta_{opt} = \sqrt{\frac{3\mu}{8(1+\mu)(1-\frac{\mu}{2})}} = 0.6206$$

The response of the structure to a seismic event is obtained by using the same procedure as for the uncontrolled situation, obviously considering the benefits that are obtained from the use of a passive control system.

To analyse the new system, the TMD is inserted into the structure, therefore the stiffness and mass matrices of the frame must be modified.

$$[K] = \begin{bmatrix} [K] + K_{TMD} & -K_{TMD} \\ -K_{TMD} & K_{TMD} \end{bmatrix}$$

$$[m] = \begin{bmatrix} [m] & 0 \\ 0 & m_{TMD} \end{bmatrix}$$

$$[C] = \begin{bmatrix} [C] + C_{TMD} & -C_{TMD} \\ -C_{TMD} & C_{TMD} \end{bmatrix}$$

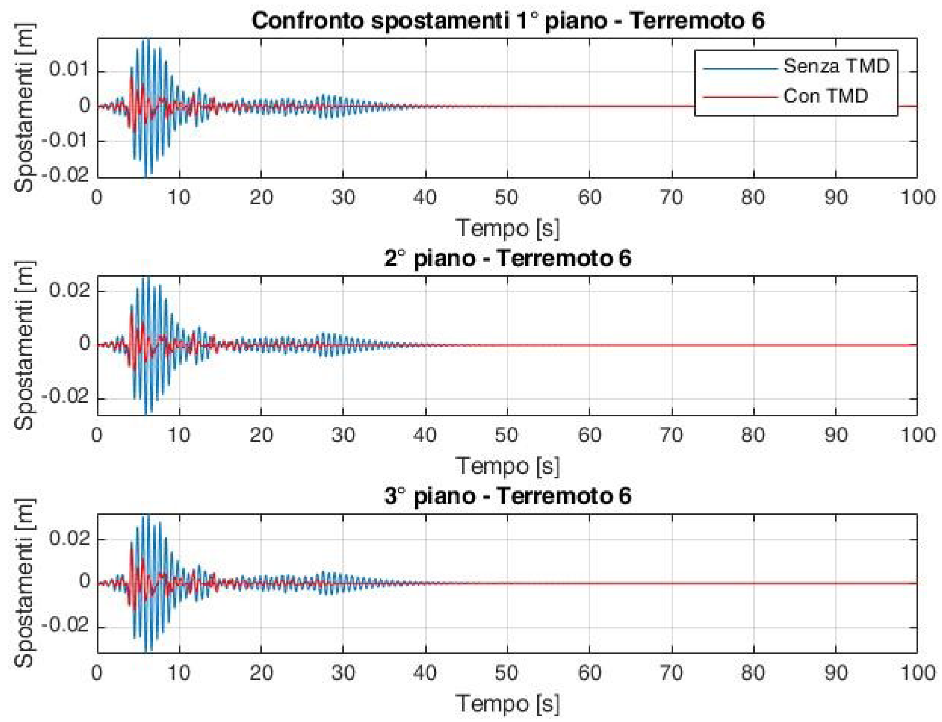
As can be seen from the tables above, the introduction of the passive control system adds a degree of freedom to the structure, so you have matrices with 4x4 size. At this point the analysis is performed as in the previous case with the uncontrolled structure, with the method "state-space".

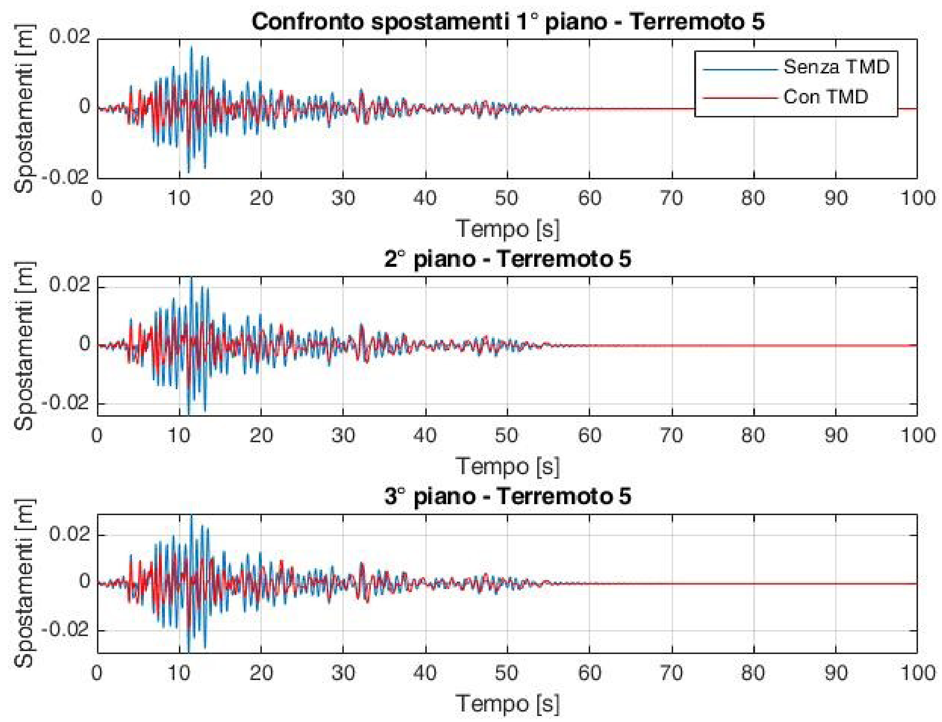
The movements to the various planes of the frame related to the controlled structure are:

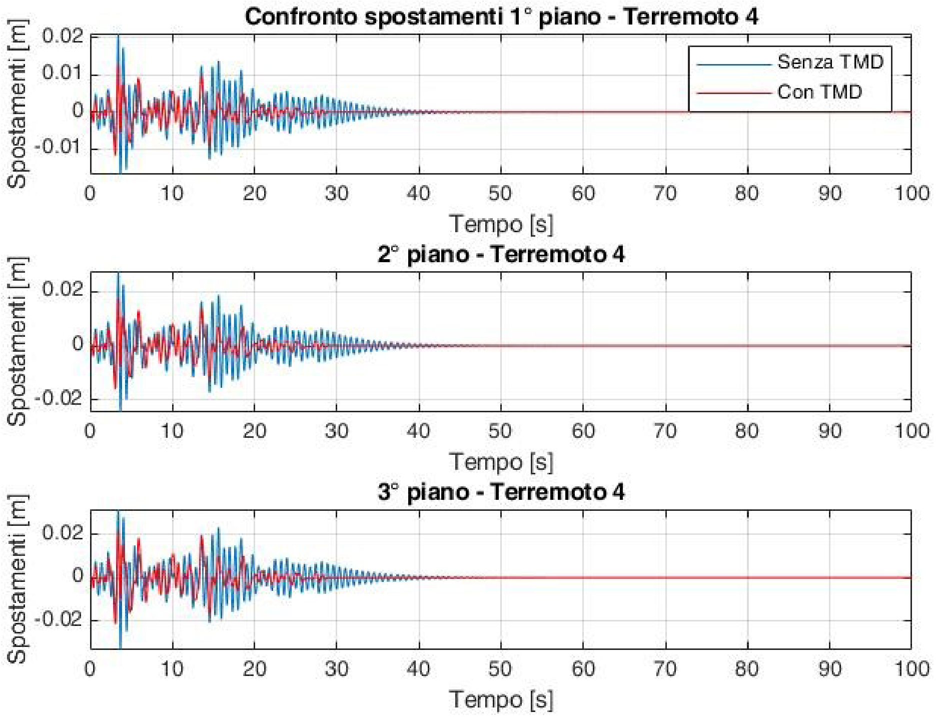
Displacements [m]	
Level 1	0.0182
Level 2	0.0240
Level 3	0.0296

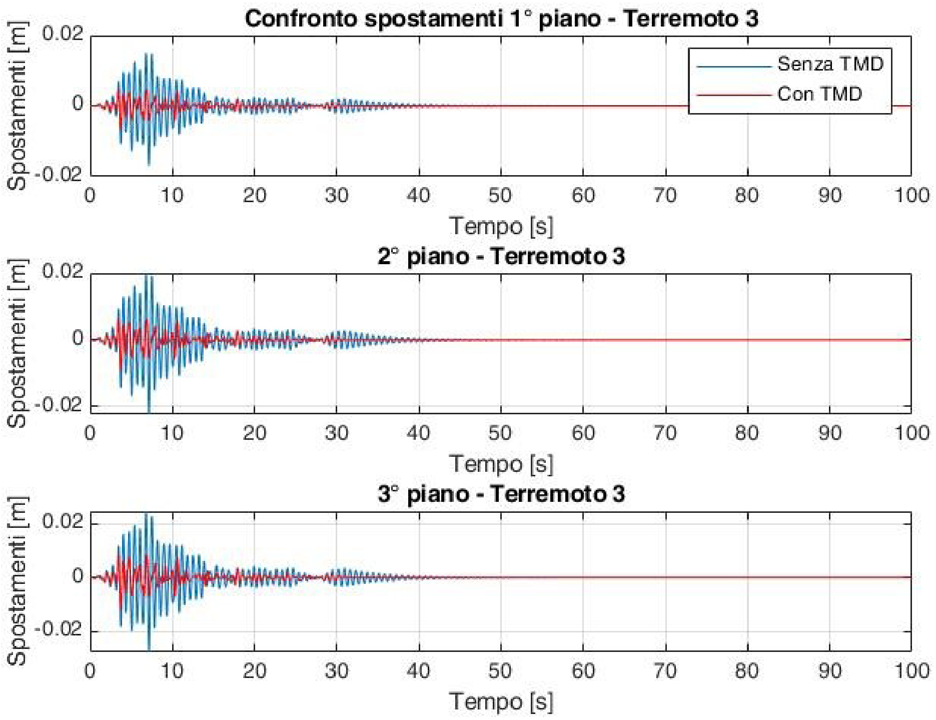
Displacements with TMD [m]	
Level 1	0.0109
Level 2	0.0143
Level 3	0.0175

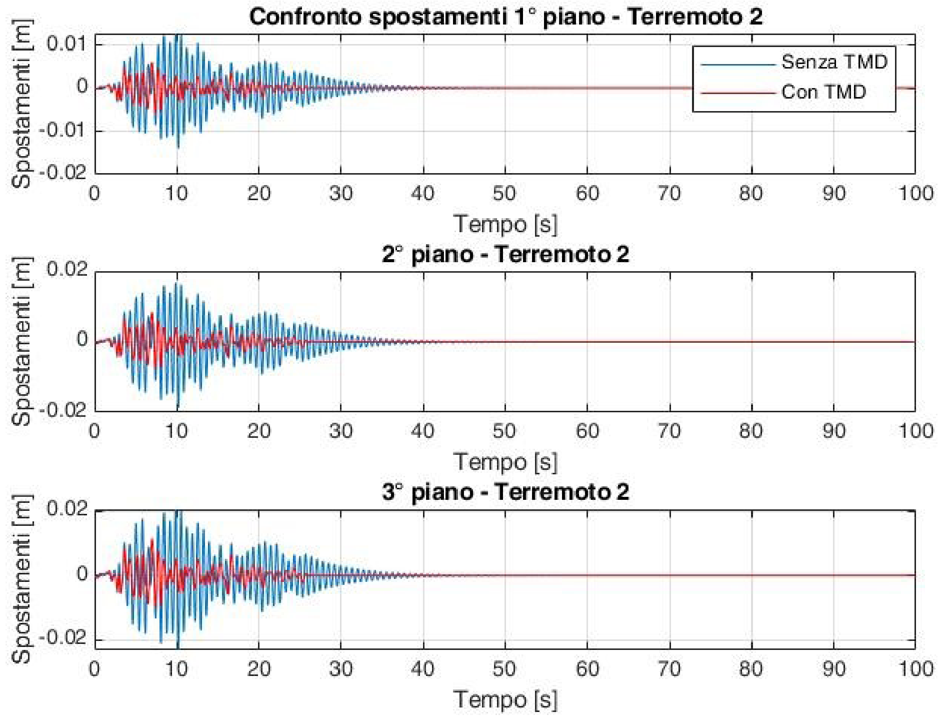
By superimposing the graphs obtained with the control mechanism and without, the following graphs are obtained.

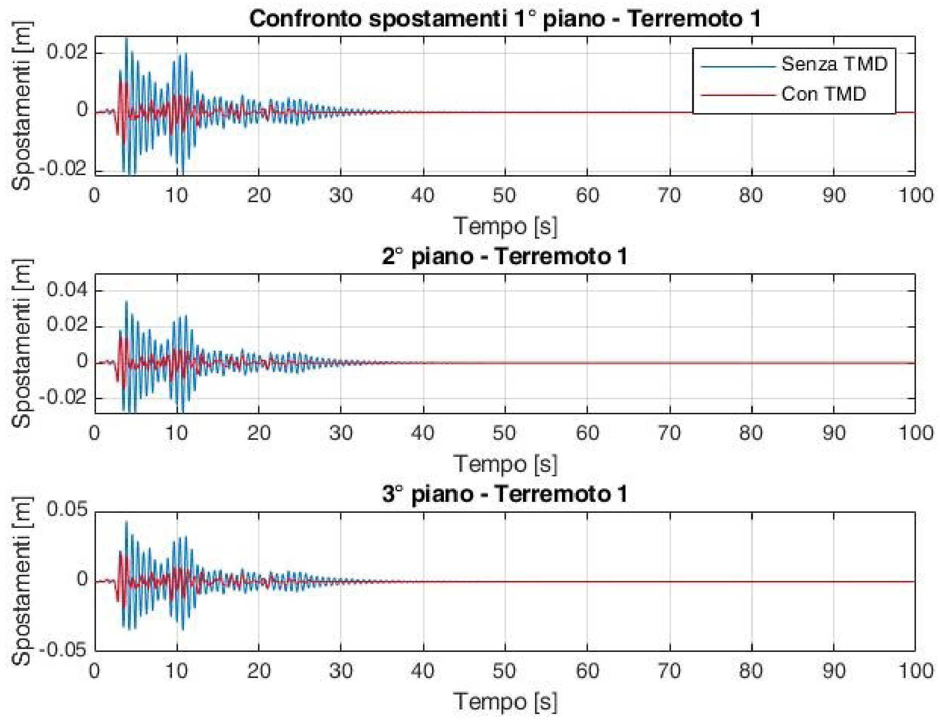


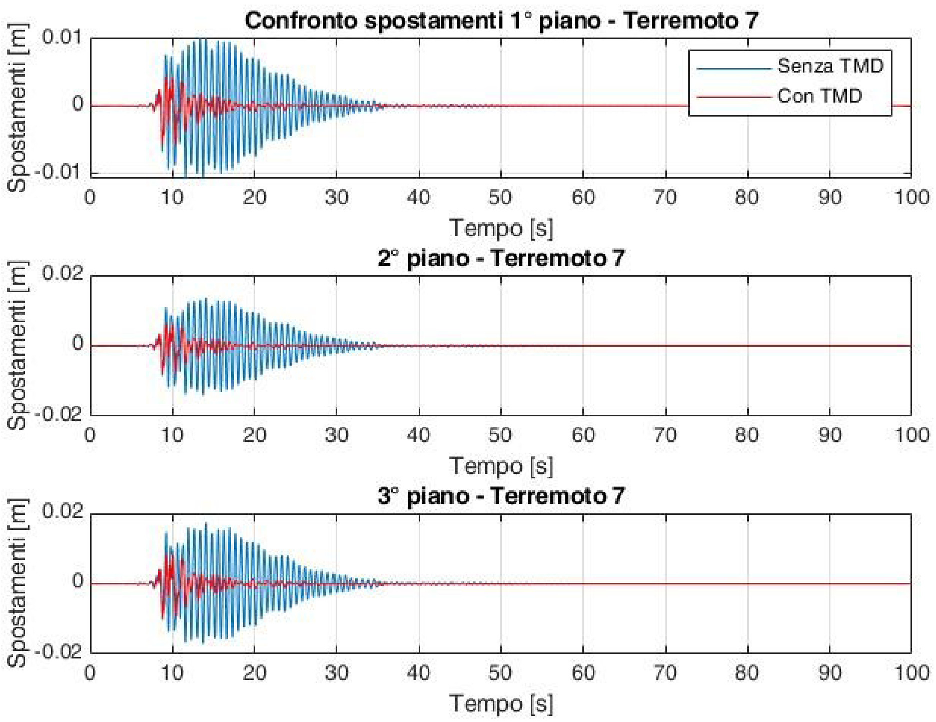



Confronto spostamenti 1° piano - Terremoto 4
Senza TMD
Con TMD
Spostamenti [m]
Tempo [s]
2° piano - Terremoto 4
Spostamenti [m]
Tempo [s]
3° piano - Terremoto 4
Spostamenti [m]
Tempo [s]


Confronto spostamenti 1° piano - Terremoto 3
Senza TMD
Con TMD
Spostamenti [m]
Tempo [s]
2° piano - Terremoto 3
Spostamenti [m]
Tempo [s]
3° piano - Terremoto 3
Spostamenti [m]
Tempo [s]


Confronto spostamenti 1° piano - Terremoto 2
Senza TMD
Con TMD
Spostamenti [m]
Tempo [s]
2° piano - Terremoto 2
Spostamenti [m]
Tempo [s]
3° piano - Terremoto 2
Spostamenti [m]
Tempo [s]


Confronto spostamenti 1° piano - Terremoto 1
Senza TMD
Con TMD
Spostamenti [m]
Tempo [s]
2° piano - Terremoto 1
Spostamenti [m]
Tempo [s]
3° piano - Terremoto 1
Spostamenti [m]
Tempo [s]



Confronto spostamenti 1° piano - Terremoto 7
Senza TMD
Con TMD
Spostamenti [m]
Tempo [s]
2° piano - Terremoto 7
Spostamenti [m]
Tempo [s]
3° piano - Terremoto 7
Spostamenti [m]
Tempo [s]

7

DETAILS AND CRITICAL ASPECTS

DETAILS AND CRITICAL ASPECTS

The realization of a roof garden already requires special attention to technological aspects, the use of materials, layers. In general, much attention must be paid to drainage, water drainage and the ability to give the soil the ideal characteristics for the growth of various types of plant species. The organisation of maintenance, the choice of materials to be used and the quality of the workforce are fundamental aspects, especially in intensive greenery. As already mentioned in the second chapter, the roof garden offers many advantages but requires special attention and the choice of the technological package is important. The realization of a TMD garden roof must take into account, not only the basic considerations that are needed to be able to realize a simple roof, but a whole series of complications of an architectural and technological nature are added. The entire mass of the roof garden and all the elements that are placed on it must create a rigid body that moves independently of the existing building. Existing body and garden roof are connected only by means of elastomeric isolators and viscous isolators (hydraulic pistons) that have the task of absorbing the displacements and tuning the oscillation frequency of the two rigid bodies.

The displacements of the building in question are very small in the order of 3 cm and thanks to the TMD are reduced to 1.75 cm, but if you decide to make a similar retrofit in a different context from the seismic point of view, the displacements at the top of the building could be much higher. The aim of the thesis was precisely to evaluate the possible application of this system from the architectural point of view, to demonstrate its effectiveness and its repeatability, for this very reason the detailed drawings take into account the possibility that the displacements are about 20 cm. This consideration is aimed to emphasize the difficulties that can go against realizing a roof garden of this type. Care must be taken to create joints between the existing building and what is part of the roof.

The points identified within the project that can be considered as common problems in the construction of a roof garden of this type concern:
- the positioning of the isolators
- the inspection of isolators
- the joints
- the joints in the facade

The positioning of the isolators

The elastomeric isolators that represent the only point of contact between the existing building and the garden roof must be positioned in axis with the vertical supports and must necessarily be positioned on a clean and solid surface that allows the creation of concrete elements of support. For this specific case study the existing roof was covered with a bituminous sheath, not perfectly adherent to the surface, which should preferably be removed.

Only after dimensioning the isolators is it possible to understand how much space is needed for each one of them to be positioned. In the case of large isolators, it can be more difficult to position them on the axis of the edge pillars. On the perimeter of the building there is not always a kerb that comes out of the facade wire and that can accommodate these heat sinks. The isolators chosen in the case study illustrated have base plates of 30x30 cm and there were no problems in their positioning. The concrete blocks on which the isolator plate is fixed must still be larger, in this case 40x65 cm, and attention must be paid to their positioning, especially on the perimeter of the building.

The inspection of isolators

This system requires maintenance and testing, approximately every 10 years. For this very reason, it is necessary to create inspection hatches and guarantee each isolator a point from which it can be checked. It was decided that all the isolators on the perimeter of the building could be viewed from the outside, trivially climbing with a staircase resting from the ground floor to the top floor and dismantling the metal profile that serves to cover the space between the building and the new roof garden. This solution is more effective because it provides more room for manoeuvre and is less expensive. In fact, all the isolators in the

central positions require the construction of an inspection hatch, with consequent demolition of parts of the floor. The hatches are positioned close to the concrete beams. Thanks to these hatches it is possible to view each isolator and replace it if necessary. In fact, in this case it is necessary to slightly lift the existing floor thanks to the small jacks resting on the “baggioli” and remove the isolators. The designed inspection hole is 70x70cm.

The concrete block at the base is used to add centimetres of height to the isolator, creating a cavity that is 30 cm high overall and facilitating inspection. This block also serves as a base for the jacks that may be used to lift the upper floor.

The joints

As mentioned above, the existing structure must not come into contact with the new garden roof, because the two systems must move independently. A possible contact in addition to not operating the TMD, could create damage to the structure or at the junctions, doors, landings, walls, railings . . . Problems of this type have been encountered at the new stairwells designed that are structures independent of the roof garden. The construction of the landings that would allow you to go from the staircase to the floor of the roof had to suffer a lot of attention. The distance between the stairwells and the walls of the existing structure has been highlighted and emphasized also for architectural reasons, giving importance to the nature of these joints.

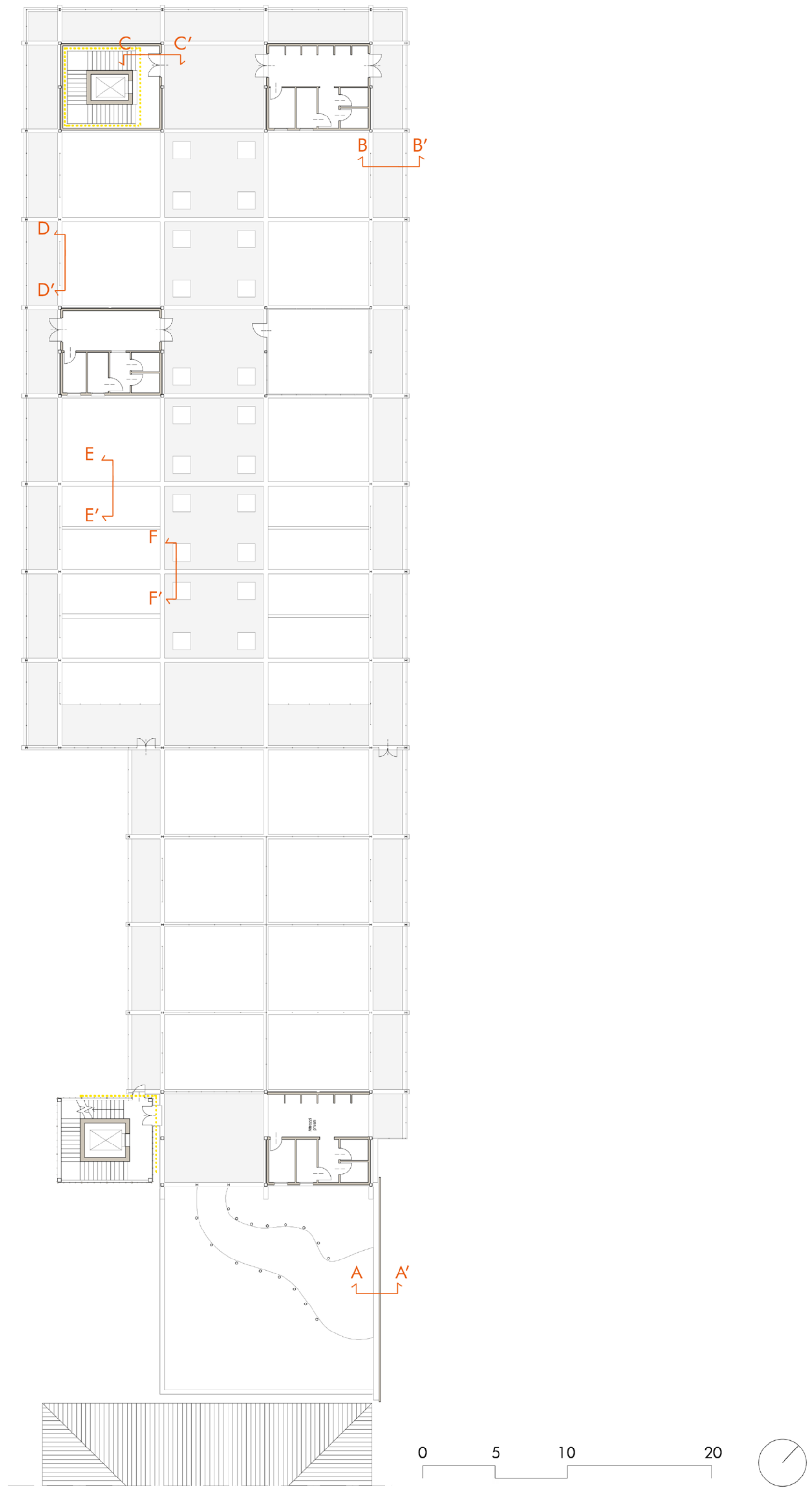
The staircase added to the existing structure, on the side of Via Pacini, is supported by the external walls of the lift shaft and is 45 cm away from the walls that surround it. When you get to the top floor, at the level of the roof garden, the solution adopted was not to make the last rise of the staircase by creating a joint with the landing instead attached to the structure of the roof garden. The landing must also have a joint to the elevator walls. A steel C-profile connected to the walls of the lift shaft, slightly raised and detached from the landing, allows you to land on the roof exiting the lift car.

The joints in the facade

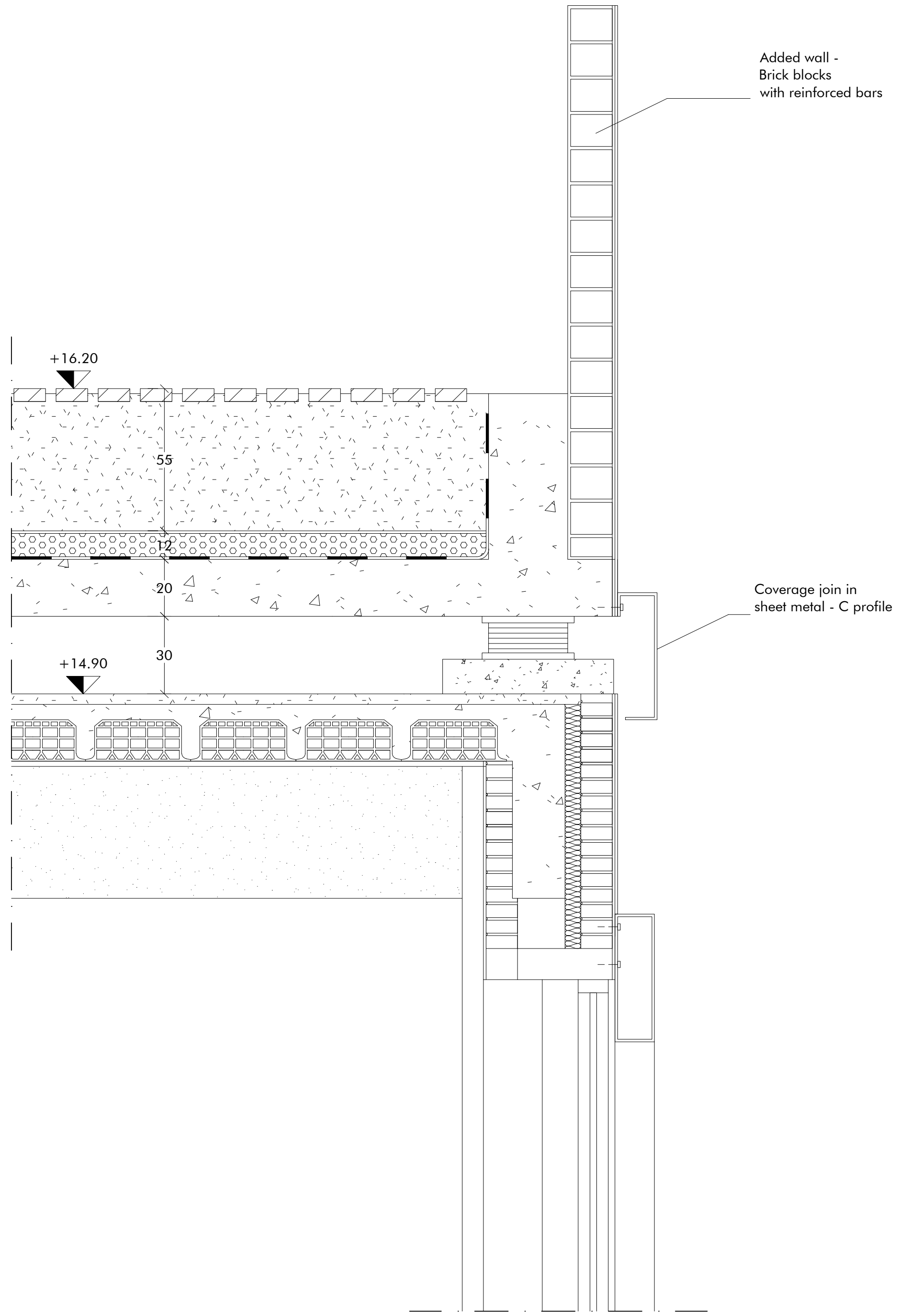
The most difficult joint to hide or show off is the one on the facade, i. e. the horizontal gap that separates the existing roof from the roof garden and serves precisely to arrange the isolators. This gap must be large enough for inspections to be carried out, as mentioned above, and requires protection. In fact, it is necessary to create a system that covers this joint in the facade, preventing water infiltration and the creation of dirt of various kinds. The choice of how to cover this cut is mainly of an architectural nature and depends on the choices of the designer. In the case study of the Ex Ceat the problem was of a lesser nature because the garden roof slab, cantilevered on all sides, hides this detail. However, an L-shaped sheet metal was designed which was only connected to the lower surface of the garden roof slab. The fact that it is connected only to the upper slab guarantees a certain flexibility to the sheet and in case of horizontal movements there would be a minimum of play that would prevent damage to the joint cover.

The facade located at the underpass, on which the old logo of the factory is placed, has been cut at the isolator, making the retrofitting visible and giving importance to the project. It was then decided to cover this joint with a C-shaped sheet, imitating the metal boxes already present in the facade, which frame the existing windows.

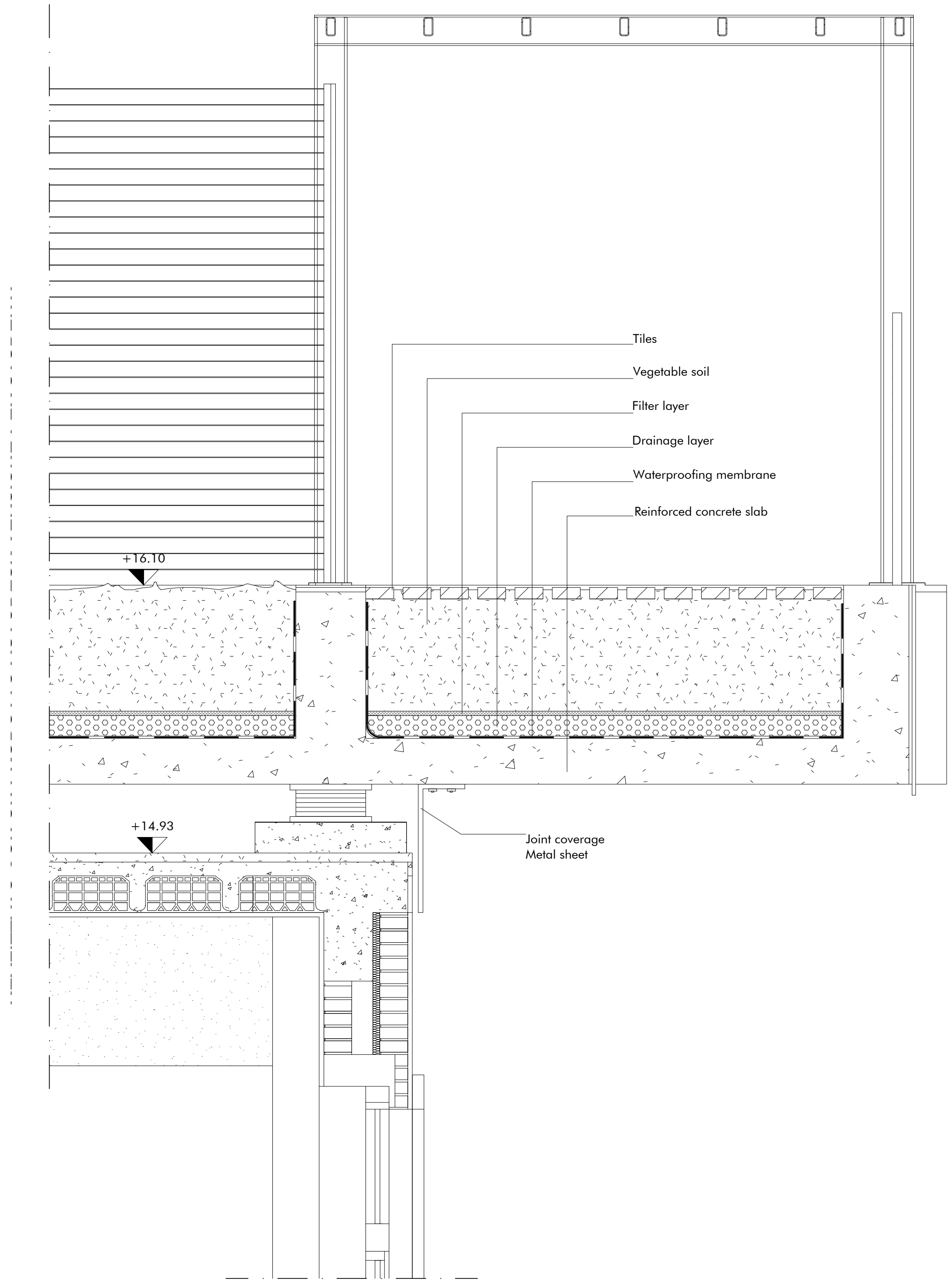
Joints and detail sections position



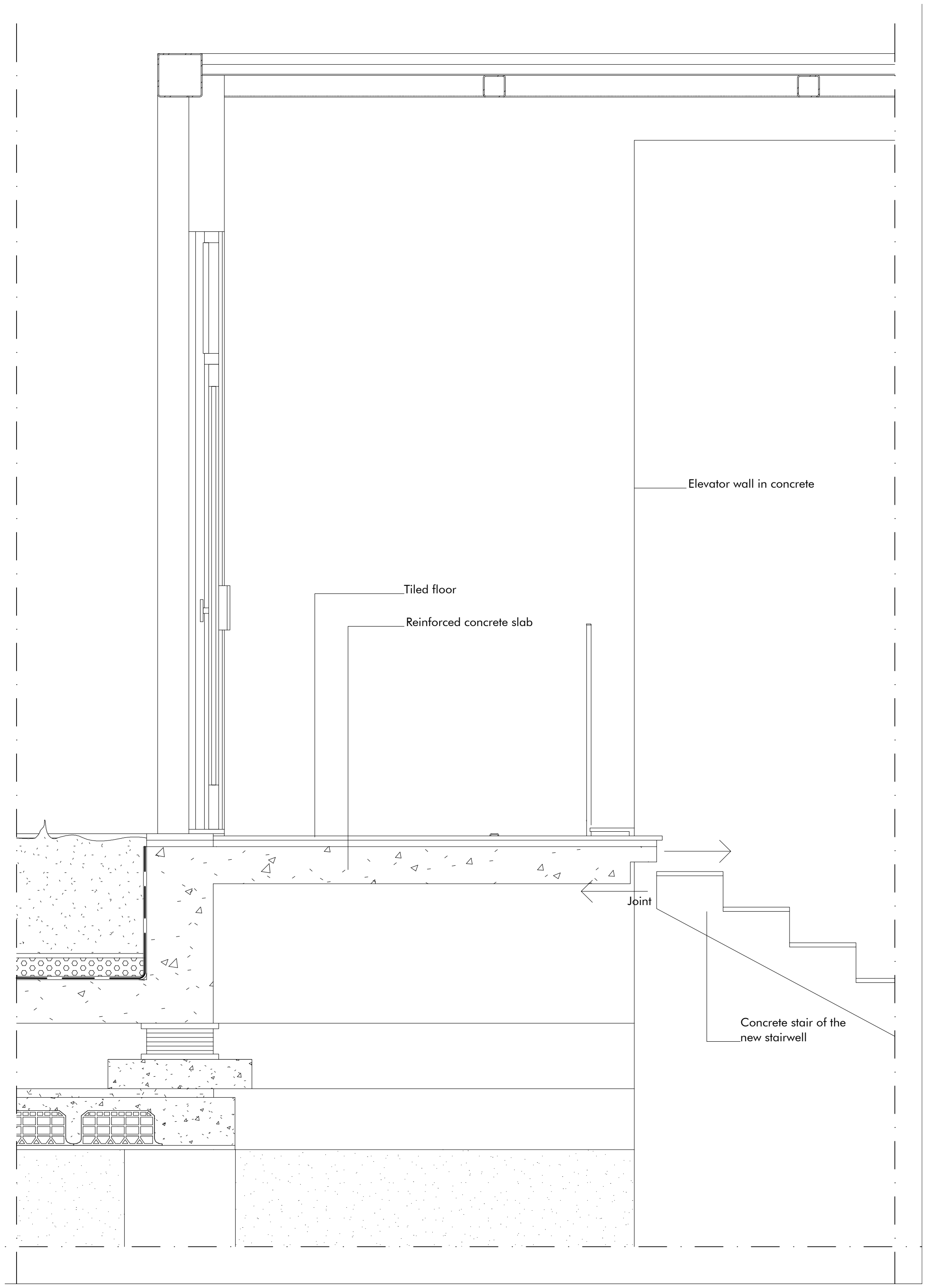
Section AA - facade



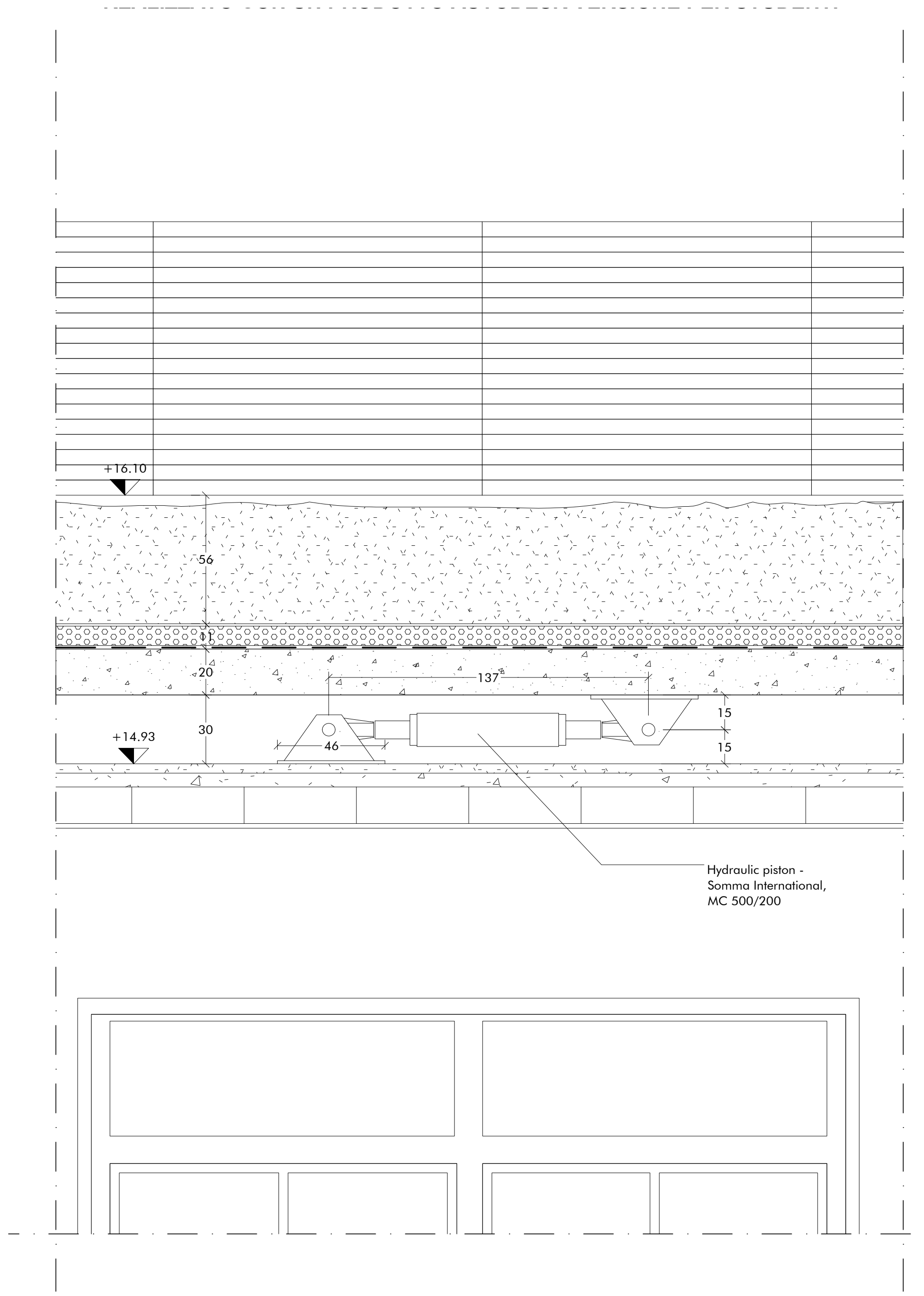
Section BB - green ring



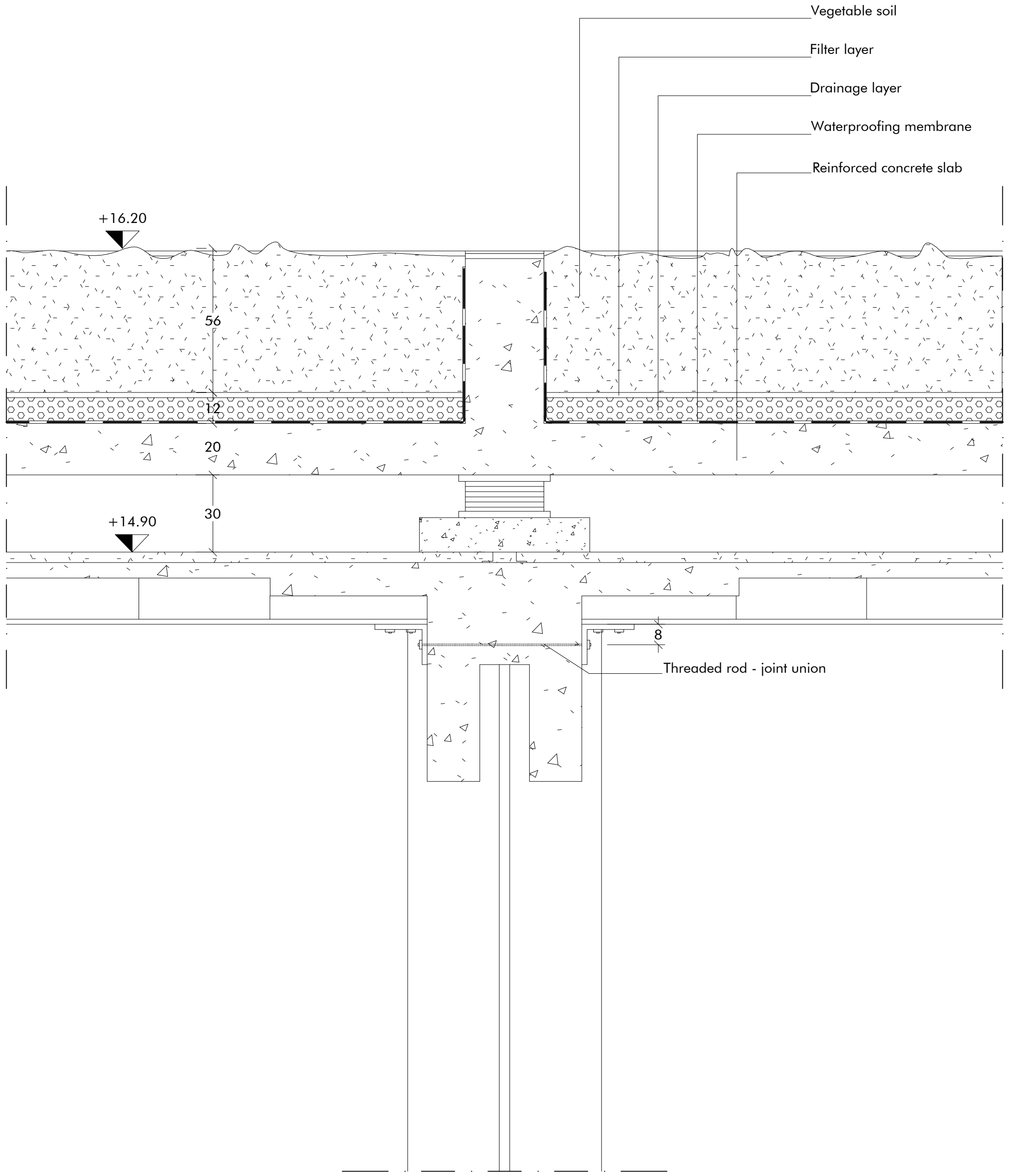
Section CC - joint between stairs and slab



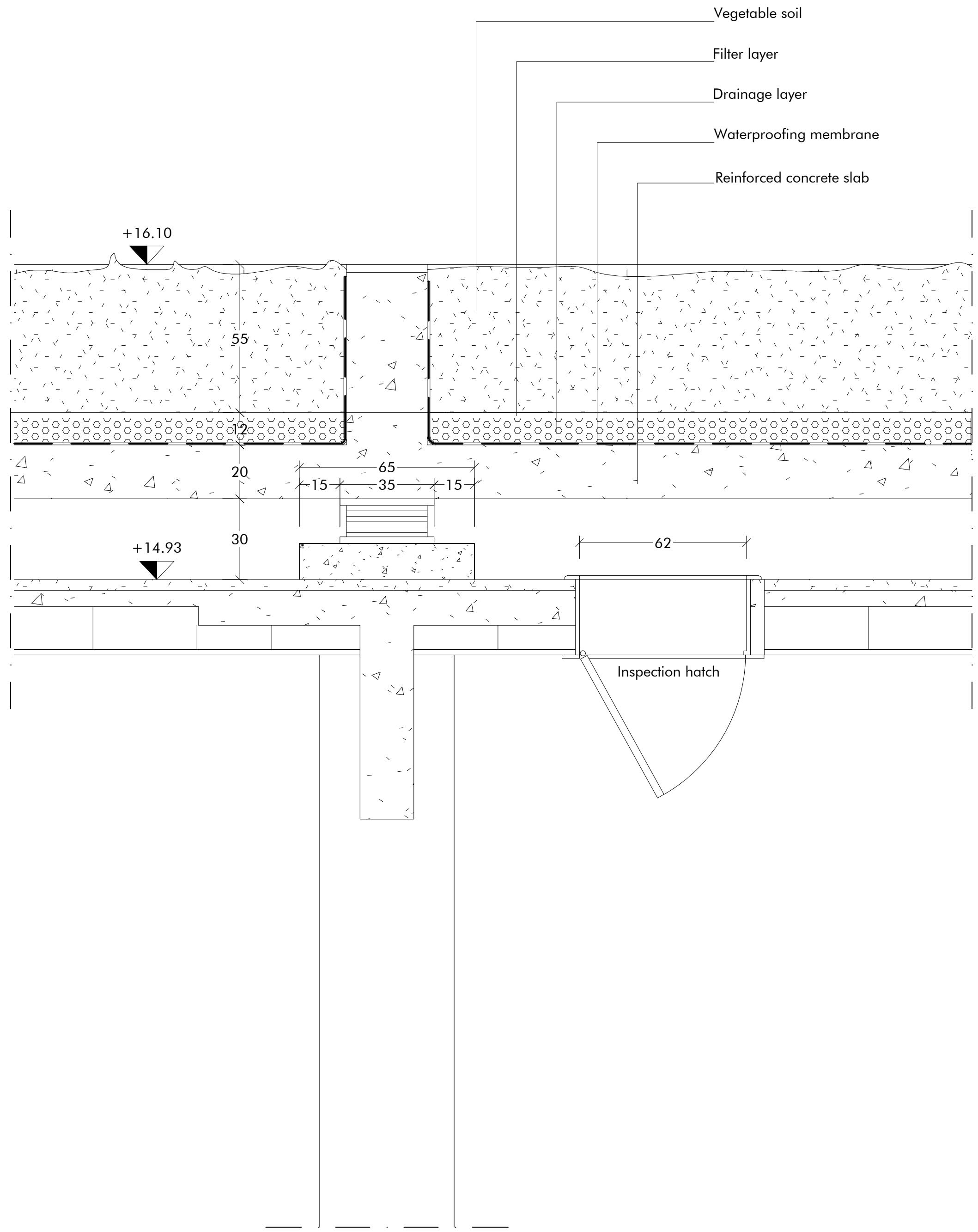
Section DD - hydraulic piston



Section EE - joint remob



Section FF - hatch



CONCLUSIONS

It is important to specify the actual value that comes with this work. This research was, in fact, the result of the union of several different disciplines, the most important, the structural and compositional, and secondary, technological, energy-environmental and social.
Facing such a requalification has allowed to obtain a scientific-experimental advancement and application through the study and verification of the seismic mitigation system TMD, but also to deepen aspects of distribution, study and planning of spaces and their functions and to come into contact with social realities, unknown to many, discovering advantages, activities, results, but above all deficiencies and weaknesses that we have tried to fill.
Secondly, working to apply a technical system and, at the same time, trying to carry out a functional and important intervention, we had to face various problems such as technological aspects, distribution and visual recognition.
For each of these obstacles, an ad hoc solution has been studied to meet the needs and maintain a dialogue with existence.
This thesis, however, stems primarily from an interest in a little-known seismic mitigation system and aims to study and apply it in order to extrapolate its advantages and any critical issues.
In retrospect of this work, as one might expect after a brief research on the subject, having chosen a case study located in Turin, a city with a low seismic risk level, the results obtained show minimum displacements that do not exceed the limits set by law. Intervening in a building of this type might therefore seem like a job with negligible value, but in reality the main objective was to demonstrate how much this system could work.

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